Coral reef fish and the aquarium trade: ecological impacts and socio-cultural influences in southern Sri Lanka

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Abstract

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James Alexander Edward Howard

The chronic degradation of coral reefs globally and its negative impact on coastal communities such as those in southern Sri Lanka dependent on the marine ornamental trade for their livelihood forms the focus of this study. Attempts to improve the conservation status of Sri Lanka's coral reefs and their associated fauna have failed because they omit to address the social circumstances of local people. Such social-ecological systems require an integrated approach, which provides holistic reasons for the degradation of natural ecosystems and livelihoods of coastal people. The aim of this study was therefore to ascertain the current sustainability of the marine ornamental trade in southern Sri Lanka through an interdisciplinary study employing a participatory bottom-up approach, and derive from findings alternative pathways to restore and maintain the health of the reef and thus provide better livelihoods for the fishing communities.

Findings confirm both the fragile state of nearshore coral reefs, their fish populations and the precarious nature of local communities' livelihoods. Historical and recent environmental and anthropogenic impacts reduced resilience in all trade sectors and current fishing practices and the unjust supply chain compound these effects. Therefore, a holistic co-management framework is recommended that recognises local ecological knowledge and involves fishing communities as citizen scientists to improve monitoring and also provides communication channels to facilitate interaction within and across all groups of the ornamental trade. In this way, all actors are involved in making decisions and taking responsibility for the management of the supply chain at their particular level. This single, coherent framework would thus employ diverse groups and ways of doing as a resilience strategy to halt the degradation and reinvigorate the reef for more sustainable utilisation whilst simultaneously developing highly acceptable alternative income generating livelihoods such as the community-based aquaculture experiment undertaken during this study.

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List of Acronyms

AIG	Alternative Income Generation
ANOVA	Analysis of Variance
BA	Basins of Attraction
BCD	Buoyancy Control Device
BD	Bandaramulla
BOBLME	Bay of Bengal Large Marine Ecosystem Project
BPU	Biodiversity Protection Unit
CCD	Coast Conservation Department
CEA	Central Environmental Authority
CENARA	Capacity Enhancement of NARA project
C.I.	Confidence Intervals
CIDA	Canadian International Development Agency
CITES	Convention on International Trade in Endangered Species
CMT	Customary Marine Tenure
CO	Corallivore
COTS	Crown-Of-Thorns Starfish
CPUE	Catch Per Unit Effort
CRTF	Coral Reef Task Force
DC	Dead Coral
DFAR	Department of Fisheries and Aquatic Resources
DWC	Department of Wildlife and Conservation
Ei	Electivity indice
EBFM	Ecosystem-Based Fisheries Management
EDB	Export Development Board
ENSO	El Niño Southern Oscillation
ESRC	Economic and Social Research Council
EU	European Union
FAO	Food and Agriculture Organisation
FOB	Free-On-Board value
GATT	General Agreement on Trade and Tariffs
GBBO	Glass Bottom Boat Operator
GDP	Gross Domestic Product
GEE	Generalised Estimating Equation
GIS	Geographical Information Systems

GLM	Generalised Linear Model
GLMM	Generalised Linear Mixed Model
GPS	Global Positioning System
GSP	Generalised Scheme of Preferences
HB	Herbivore
HK	Hikkaduwa
HSAM	Hikkaduwa Special Area Management Plan
ICM	Integrated Coastal Management
IFAD	International Fund for Agricultural Development
IN/INV	Invertivore
IPCC	International Panel on Climate Change
ITQ	Individual Transferable Quota
IUCN	International Union for the Conservation of Nature
JICA	Japanese International Cooperation Agency
KP	Kapparathota
Linf	Ultimate Length of an individual
Lm	Length at maturity
Lmax	Maximum Length
LC	Live Coral
LEK	Local Ecological Knowledge
LK	Local Knowledge
LKR	Sri Lankan Rupees
LMM	Linearised Mixed Effect Model
LTTE	Liberation Tigers of Tamil Eelam
MAC	Marine Aquarium Council
MAC[b]	Marine Advisory Committee
MANOVA	Multivariate Analysis of Variance
MFAR	Ministry of Fisheries and Aquatic Resources
MPA	Marine Protected Area
NAQDA	National Aquaculture Development Authority
NARA	National Aquatic Resources Agency
NERC	Natural Environment Research Council
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
NT	Not Targeted
NTZ	No Take Zone

OF	Ornamental Fishery
OM	Omnivore
PADI	Professional Association of Diving Instructors
PI	Piscivore
PL	Planktivore
PO	Polhena
QQ	Quantile-quantile
R	Rubble
S	Sand
SAM	Special Area Management Plan
SC	Structural Complexity
SCUBA	Self-Contained Underwater Breathing Apparatus
SCD	Substrate Composition Diversity
SD	Standard Deviation
SE	Standard Error
SES	Social-Ecological System
SSI	Semi-Structured Interview
SST	Sea Surface Temperature
TCRC	Transforming Coral Reef Conservation
ToC	Tragedy of the Commons
TL	Thalaramba
TMC	Tropical Marine Centre
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UVC	Underwater Visual Census
UW	Unawatuna
VHT	Vertical Height (substrate)
WTO	World Trade Organisation

Declaration

The work contained in this thesis has not been submitted elsewhere for any other degree or qualification and unless otherwise referenced is the author's own work.

James Alexander Edward Howard

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Dedication

In loving memory

of

Beryl Jane Lakey

(1922 – 2012)

Chapter 1

Introduction

1.1 Preface

My interest in tropical coral reefs goes back to when I was growing up in several developing countries in Africa. I became increasingly aware of the struggle between the local villagers' need to utilise their environment for a livelihood and the conservation of the local habitat. Through marine studies at Cape Town for my Masters and the acquisition of diving qualifications my interest shifted to marine environments where ornamental fish were under threat. My interest was still firmly located in what was actually happening on the reefs and how much were the local fishers and villagers contributing to their current status and what more could be done towards sustainability. Thus on securing the opportunity for research in Sri Lanka, through Durham University, I had the opportunity to explore this issue. Therefore, the aim of my thesis is to discover how sustainable the marine ornamental fishery in southern Sri Lanka is, from the perspective of the local fishers and divers of this area. If there are signs that it is not sustainable, as the literature maintained, then to ask what alternative procedures and management approaches that perhaps involve these divers could be adopted to move the fishery into a path of greater sustainability both in terms of the coral reefs and the local divers' livelihoods. This overarching aim is researched through seven key objectives, which reflect the interdisciplinary nature of the research (Section 1.4).

This chapter has four sections; an overview of the main themes, the rationale and unique focus, the objectives and a chapter summary of the study. First it provides an overview of the main themes that permeate the entire thesis. They embrace the complexity and dynamism of social and ecological systems and the interdisciplinarity of approaches, epistemologies and methods to uncover the problematic relationships between humans and their environment. The rationale and unique focus of the thesis precedes the delineation of the study's seven objectives developed to explore the overall research question from the divers' perspective. Finally, a summary of each chapter is provided in relation to each of the seven specific objectives to guide the reader along the path of discovery to the findings, recommendations and concluding remarks.

1.2 Major themes of the thesis

The global failure of policies aimed at preserving biodiversity, halting the effects of climate change, reducing poverty and ensuring social justice, particularly in poor nations, is now widely accepted (Ludwig, 2001; Mehta, 2007; Ehrlich & Pringle, 2008). Conserving marine resources and the ecosystem services associated with the biomes involved therefore remains a challenge. Although the reasons for this failure differ depending on the narratives and the groups involved, one uniting factor is the need for a change in direction and practices. Research in many fields from biology, environmental sciences, economics, sociology, anthropology and development is finding conclusive proof that humans and nature co-exist in complex and dynamic systems (Levin, 1999). This seemingly obvious reality has been bypassed, at the policy level for decades, in favour of simpler outlooks and solutions to human natural resource requirements. Complex systems were stripped down and their main components identified in order to attempt to control the fluxes of these systems. Coupled to this was the belief of many academics and practitioners that these systems remain predominantly in equilibrium and/or optimal states (Zimmerer, 2000; Kuhn et al., 2009; Scoones, 1999). By impeding excessive outside stressors or by manipulating the core elements of these systems it was hoped that these “equilibrium” positions could be maintained through management (Maarleveld & Dabgbégnon, 1999) and technology (Ludwig, 2001). With hindsight there is realisation that this model has failed and studies show that in avoiding the complexity and unpredictability of these systems, disastrous consequences can result for natural and human capital (Ludwig et al., 1993).

There is a pressing need to shift from these generalised, simple models of systems in states of equilibrium and move towards the growing acceptance of viewing natural systems as complex and dynamic and thus in need of appropriately aligned management methods (Hilborn & Gunderson, 1996; Keeley & Scoones, 2003; Ludwig et al., 1993). The transition to this approach is gathering pace as alternative strategies are sought to address resource management issues to suit the environmental and social changes that appear to be accelerating. Furthermore, researchers and practitioners across a wide scope of disciplines are simultaneously embracing the complex, adaptive systems approach, including ecologists and environmental anthropologists. Its core framework and methods can be applied to extremely disparate issues: from the unpredictability and complexity of economic markets to the non-linear relationships between gene structure and function (Leach et al., 2010). I therefore chose to apply this approach to the marine ornamental trade in Sri Lanka in an attempt to portray its current state and uncover the potential for sustainability of this fishery in relation to the social and economic institutions surrounding it. My intention is to explore, from the integrated approach of an environmental anthropologist and a marine ecologist, the multiple and interconnected influences on this fishery; hence managing complexity is a major theme of this thesis.

Complexity was explored via systems ecology theory several decades ago (Holling, 1973), yet it gained little currency at the time and was largely ignored by policy-makers. However, complexity theories gained popularity over time and my approach has drawn on established scientific theory centred on non-linear stability to address problems of development, poverty and sustainability (Walker et al., 2004). The complex, dynamic version of natural systems is extremely relevant to social-ecological systems (discussed in Chapter 2.13.2) in the marine context. Humans have utilised and exploited the oceans for millennia and anthropogenic impacts are experienced in even the most isolated of marine areas. In the field of marine ecology and conservation there is growing appreciation of the need to embrace complexity in such systems, which is also needed within coral reef ecological studies, that have focused mainly on documenting the degradation of the world's coral reefs but not on researching the processes causing such decline and degradation (Hughes et al., 2010). Some coral reef systems have degraded and shifted in state whereas others have not, which has led many to believe coral reefs have properties that allow for multiple stable states to exist (Knowlton, 1992). However, understanding how these states alternate remains unclear, although much evidence indicates these shifts in state are linked with reductions in ecosystem resilience (see Chapter 2.13.2.1) as a result of human actions (Folke et al., 2004). Furthermore, a broader scope of research into such systems, away from viewing ecological and biological elements in isolation and including social, economic and cultural drivers, is long overdue. In ecological experiments, humans are usually excluded from the equation, cited as being too "complex", their effects too wide ranging or not part of the natural ecosystem (Alberti et al., 2003). However, the direct effects of fishing on natural populations has meant that some fisheries research incorporates humans into its analysis. For example, some marine ecologists include humans as a trophic level in food chain studies to understand the ecological role of humans in coastal communities and thus assess their impact in relation to current problems of alternate stable states and trophic cascades (see Chapter 2.6.2 and 2.8) in marine ecosystems (Pinnegar et al., 2000). Greater interdisciplinarity is needed in fisheries studies with a growing need to draw on people's cultural capital and include humans as "ecological actors" to derive improved and more adaptive management strategies (Castilla, 1998: 282). Inclusion of humans within study systems is standard practice for environmental anthropologists and so interdisciplinary research between anthropologists and ecologists is valuable in order to re-evaluate how anthropology can support ecologists to address environmental degradation.

This integration of two disciplines in order to understand to a greater degree complex, natural systems is the second major theme of this thesis. Most natural systems need to be viewed as social-ecological systems (Berkes & Folke, 2002) since they are not only inherently connected with human actions but also therefore complex, dynamic, unstable with non-linear properties operating at various scales in time and space. The complexity of these systems is examined in Chapter 2 together with the conceptual framework for utilising this approach. In addition to the shift in understanding natural systems, is a coincidental burgeoning of interdisciplinary research (Rhoten, 2005). The academic community is attempting to bridge disciplinary divides in order to solve complex, chronic problems. For over 30 years, environmental anthropologists and some biologists have had a remit to work alongside local communities rather than distance themselves from them. And although many authors during the 1990s began to call for greater interdisciplinarity in conservation biology work, whether marine or terrestrial (Arrow et al., 1995; Meffe & Viederman, 1995), it is only recently that the mainstream of marine conservation is working to incorporate social sciences alongside ecological work. From a few individuals navigating the divide between disciplines, there is now a multitude of research seeking "...to understand the source and role of change in systems..." and "...gradual change and episodic change, local and global changes" (Holling et al., 2002:11). This interdisciplinary approach covers a wide range of global biomes, societies and contexts and spans research on tropical forests and Amazonian indigenous peoples (Posey et al., 1984), Sahel drylands and pastoralists (Sendzimir et al., 2011), the Arctic and native Americans (Krupnik et al., 2010) and marine conservation with close proximity to my own area of research via tropical coral reefs and Pacific island communities (Cinner et al., 2009a).

Interdisciplinary studies often involve the participation of researchers from several different disciplines with widely divergent world-views, opinions and methods which cannot always be readily accommodated, making this approach difficult to put into practice. Many researchers have spent their academic career with only one theoretical perspective and find it difficult to adapt to other ways of thinking or working collaboratively with researchers from alternative fields. In this project, by working across two disciplines, I have endeavoured to avoid the potential problems associated with collaborating among diverse disciplines by learning the skills of both an environmental anthropologist and enhancing my skills as an ecologist. My desire to work in this way, prevented me from being closed-minded to the new discipline. I consider the nature of my project to be a clear example of the necessity to conduct some broad scale research at a regional scale, while focusing on individual fishers and local groups or fish species to provide the necessary detail. Eriksen (2001) provides a metaphor for these contrasting strategies of macro-ecologists and anthropologists when he compares the broad, often global scale work of evolutionary biologists and macro-ecologists to that of circling the earth taking photographs from a helicopter, whereas the social anthropologist is in a specific location examining every grain of sand. In this thesis I have sought a middle ground, whereby I am able to present results concerning one of the three ornamental fish collecting regions in Sri Lanka while retaining an appreciation of the concerns and priorities of different local people, that is, not just the divers, but all those along the market chain.

In tandem with this idea of bridging disciplines is the implication of bridging methods and forms of data, and being aware and inclusive of different knowledge forms. By doing this, I intend to show the complementarity of quantitative and qualitative data as well as diverse knowledge systems. With varying forms of knowledge and data, which are often complementary or congruent, it is possible to obtain more robust results. The results of this study exhibit this standpoint and furthermore, illustrate how such an approach opens these results to a wider audience than a single discipline study.

1.3 Rationale and unique focus of the thesis

This thesis focuses on the marine ornamental fishery and trade based around coral reefs in southern Sri Lanka. Earlier studies on the topic exposed the unsustainable nature of the industry but did not bring about any noticeable change, with each subsequent study reaffirming the results of previous studies and an underlying negative image of ornamental fish collectors (Wood, 1985, 1996, 2001a; Pyle, 1993; Ekaratne, 2000; Wijesekara & Yakupitiyage, 2001). All these studies of the Sri Lankan ornamental fishery were apolitical ecological studies conducted from a top-down, power-heavy approach, which focused on presenting the perceived unsustainability in terms of volumes of fish exported and their value, the indirect effects of ornamental fish collection, such as trophic cascades and direct habitat damage alongside the multiple stressors affecting and contributing to the steady deterioration of coral reefs in Sri Lanka. Although these problems cannot be denied, these studies did not empirically measure any of the stated effects of the ornamental trade on reef ecology or investigate socio-cultural factors behind participant behaviours and therefore the full complexity of the situation has remained unknown. Furthermore, it means that any recommended actions for sustainable fishery management would be flawed as they were not situated within this wider context.

This top-down approach used by researchers in development, environmental studies and conservation in the past has however, been moving towards the more widely used bottom-up approach now promoted in these same disciplines (Sillitoe, 1998). This is the first study on the ornamental fishery in Sri Lanka conducted from a bottom-up perspective, that is, reporting the situation predominantly from the view of the divers and at the level of their everyday lives, rather than the often constrained view provided by government officials or NGOs as offered in prior studies on the trade (Wood, 1985, 1996, 2001a; Pyle, 1993; Ekaratne, 2000; Wijesekara & Yakupitiyage, 2001).

First, since the last study was over 10 years ago, an up-to-date assessment of the ornamental trade in Sri Lanka was required; however, I decided to take a more holistic approach in an attempt to disentangle the current status of the ornamental fishery and identify reasons for the current impasse between sustaining the fishery as a form of livelihood for divers in these villages whilst also maintaining the health of the local reefs and their fish populations.

The application of an interdisciplinary study to this fishery in Sri Lanka is unique. This is beneficial as many scientific researchers remain strongly wedded to quantitative “hard” science results, which are produced in this thesis and can provide such an audience with a satisfactory assessment. Additionally, ethnographic data concerning social, economic and cultural influences also allow for a richer picture of the chronic problems affecting this fishery to emerge from which more justifiable recommendations can be made to improve the long-term sustainability of the fishery. It is hoped that the thesis will also convince some readers of the benefits of mixed method and interdisciplinary approaches and their applicability to complex resource management issues.

This thesis also aims to provide additional evidence of the utility of addressing complexity and dynamism in social-ecological systems. Why this is such a pressing issue is conveyed through the observations of environmental degradation and social deprivation, which continually threaten the livelihoods of many of the world's poor – people like the divers in my study – who are often forgotten and voiceless at the distant reach of global trade, capitalism and science.

1.4 Objectives of the study

There are seven main objectives to this study, which were devised after reviewing all the research published on the ornamental fishery in Sri Lanka and several other countries. These objectives were also developed with the underlying themes of interdisciplinarity and complexity in mind. Therefore, integration of the disciplines would be required to sufficiently address these objectives and to uncover the complexity of the wider social-ecological system surrounding the fishery, something which has not been done previously. The objectives encompass an investigation of drivers on multiple temporal and spatial scales, in keeping with the notion of social ecological systems' panarchy (Chapter 2.13.2), to present a more vivid picture of the current situation and to delve deeper into the reasons why the fishery has developed along its current trajectory. The first five objectives are employed to answer the first part of the overall aim: how sustainable is the ornamental fishery? Objectives 6 and 7 provide the results to determine management routes toward sustainability. The study objectives are:

1) To investigate, within historical contexts, how the social and cultural aspects that support contemporary patterns of reef fish capture for the aquarium trade at selected fishing villages in southern Sri Lanka can be incorporated into fishery management for sustainable livelihoods in the future.

2) To assess the levels of current ornamental fish catches and catch per unit effort (CPUE) and record fishing behaviours across specific sites to determine the potential effects of local fishing practices on aspects of the wider reef ecology.

3) To derive the abundance of nearshore reef fish populations targeted by the ornamental fish capture market in southern Sri Lanka and compare this with local divers' knowledge and perceptions of their local marine resources to address ways to combine collective knowledge for the common good.

4) To assess the levels of resilience in all its forms (natural, social, community, economic) in the fishing villages and their nearshore waters to evaluate how social and ecological systems, related to the ornamental fishery in Sri Lanka reorganise around change and how they manage for resilience.

5) To analyse the links between the current ecological conditions and the social interactions, between and among, the different actors for the capture, transportation, holding and sale of fish across the current market chain and thus evaluate the strengths and weaknesses of the system.

6) To evaluate the success of current and past governance strategies applied to the marine ornamental fishery and hence predict future trends in ecological change and vulnerability of human coastal communities in relation to the reef health.

7) To assess the potential for alternative livelihoods through mariculture of exploited species of ornamental value as well as the social and economic acceptability of cultivation or other alternative livelihood options to those practising wild capture to determine their inclusion as sustainable livelihoods within fishery management in the future.

These objectives are addressed in different chapters within the thesis, with some spanning several chapters and others contained within a single chapter. Table 1.1 indicates which objective is predominantly addressed in which chapter and which methods and data are used and presented to investigate these objectives.

This study predominantly focuses on ornamental fish collection carried out by snorkellers rather than SCUBA divers. This was due to two main reasons: firstly, a greater number of divers in Sri Lanka snorkel to catch ornamental fish, therefore, the study aimed to elucidate patterns concerning the majority of actors in the fishery, however, SCUBA divers' influence on the fishery and their patterns of behaviour are included. Secondly, Durham University health and safety guidelines prevented the study involving SCUBA diving. Despite this, I collected data from ornamental SCUBA divers, by accompanying them on boats as well as meeting them onshore on their return from diving trips to record their catch. In addition I conducted numerous interviews, discussions and spent extended periods of time with SCUBA divers as well as snorkellers, at other social occasions. For the purpose of this thesis, *actor(s)* is used to denote a person (or group) linked to and/or with an active interest in the ornamental trade. I use this term predominantly but also refer to *participants* and *informants* who were people respectively from whom I collected data or with whom I interacted. For clarity, all direct quotations from informants, Sinhalese words and fieldnote excerpts are written in italics in the thesis. The names of informants who wished to remain anonymous have been changed to protect their privacy.

Table 1.1. Chapter numbers in which each objective of the study is addressed and the level of integration of the two disciplines within each chapter and objective

Objective	Chapter	Ecological data	Anthropological data
1	4		✔
2	5	✔	✔
3	6	✔	✔
4	5, 6	✔	✔
5	7	✔	✔
6	8		✔
7	9		✔

1.5 Overview of the thesis

The following chapter comprises a literature review covering the relevant areas surrounding my research study and the theoretical framework that is applied in the thesis. Within this review I situate my own study amongst work already done in this field within the separate disciplines, as well as among that of researchers working to bridge the gap between relevant disciplines in conservation, development and social anthropology. The theoretical framework explains the different concepts and approaches used within the thesis to analyse and contextualise my data and highlights where these approaches have been used in similar areas of research to date. This review, as well as this introduction, not only provides an up-to-date appraisal of the current knowledge and practices surrounding my study, but also defines the extent of my study and the areas which were examined more intensely than others. The breadth of my subject, spanning two disciplines, and extending from the global level of world markets to the local effects of fishing, is considerable and, therefore, a clear demarcation of the boundaries of this study are traced together with an explanation for the reasons why certain areas remain relatively unexplored.

The methodology utilised throughout the study is presented in Chapter 3 as well as a description of the study sites and their present socio-ecology. The methodology is presented as an ethnographic account of the entire research process from the acceptance of the PhD funding up to the writing up stages. It aims to convey how the interdisciplinary nature of the project has been central from the start, and how I have attempted to maintain it throughout my fieldwork and analyses. Via this chronological account of my research process, a deeper appreciation of the intricacies involved in data collection and the reliability of the data can be appraised by the reader. Detailed methodologies concerning particular pieces of work, such as the fish surveys, are expanded upon within the chapter where the results are discussed.

Chapter 4 aims to discover the reasons why the ornamental fishery is in its current state and format by employing a historical ecology framework. Historical ecology improves our understanding by laying out the policies and practices of the past which have shaped the social and ecological contexts of southern Sri Lankan fishing villages. This also helps the reader to comprehend the evolution of the ornamental fishery into its current form. As Erickson & Balée (2006: 187) state, historical ecology is the study of "...how the typically complex interactions of nature and culture have become historical and cultural landscapes...". One cannot discount the ways in which both ecological history and social history have shaped the present status of not only the coral reefs in Sri Lanka, but also the reef fishing communities and the livelihood options of these communities.

Chapter 5 examines the fishery in its current state from the viewpoint of the divers and those at the local village level. This chapter aims to determine the current level of resilience in all its forms, from ecological to social to cultural in southern Sri Lankan diving villages (Table 1.1), and assesses whether applying this concept is the most beneficial way of improving the situation for both local people and their natural capital in the future. This chapter presents data from both disciplines in quantitative and qualitative forms, illustrating how they complement one another, rather than contradict or blur the overall results. The first accurate catch rates and catch per unit effort (CPUE) data collected from the fishery are presented, as well as levels of coral damage and other types of fishing behaviour encountered during my field seasons. These data contribute to an evaluation of current practices, coping strategies and future resilience of the southern coastal diving communities and their reefs.

Chapter 6 provides a current snapshot of the health and status of nearshore southern Sri Lankan reefs by means of a fish and habitat survey. Contemporary surveys are important in providing baselines with which to compare future surveys to determine the effects of both natural and anthropogenic impacts. By comparison of the three fishing sites to a protected area, the effects of fishing on both reefs and fish populations are presented. The second section of this chapter highlights the evidence of local ecological knowledge (LEK) among divers about their own resources (Table 1.1) and their perceptions of the status of their reefs and fish populations are presented and compared with my own independent surveys. The case is argued for the need to ensure such LEK is not lost from the system and is moreover incorporated within future conservation frameworks and governance structures.

Moving from the village level to the national level, Chapter 7 applies the notion of sustainable supply chain management to disentangle the hierarchical ornamental fish trade market chain from its source at the coast to eventual exportation of the fish from Sri Lanka. Different sources of data on fish numbers collected and exported are presented and from these the national export of marine ornamentals from Sri Lanka is estimated. This is also unique as such data have been lacking in the past or were based on estimates from only one source. Each layer of the hierarchy is examined vertically and horizontally to derive the levels of trust, respect and beneficial behaviour occurring within the supply chain (Section 1.3). This analysis has important repercussions for the sustainability of the reef and all involved in the ornamental fish trade, which is discussed within the context of globalisation where modernity equates with capitalist consumerism.

Chapter 8 looks forward and explores the potential for change in the fishery through alterations to its governance. Weaving political ecology theory into an ethnographic account, written from my own experience and presence during the early stages of a new management initiative, it exposes the positive and negative signals attendant on the early stages of any attempt at reform. The new approach is compared to former and, in some places, still current, methods of fishery management in Sri Lanka to show the necessity of tailoring global conservation measures / proposals to local practices and cultures (Table 1.1). From an appraisal of the players involved in managing this fishery, and of the current management and monitoring system, it hopes to make clear that alternative approaches, that may incorporate the standard western scientific ones, are needed for sustainable fishery management and planning in Sri Lanka.

Continuing with the forward looking approach, the final data chapter assesses the acceptability among divers of alternative livelihoods in the future. Often alternative livelihoods are proclaimed as the only solution to systems in which natural resource degradation has occurred. (see Section 1.3). To investigate this, the applicability of alternative livelihoods, for the marine ornamental divers, is analysed. To deal with the unpredictability of social-ecological systems, one of these approaches was examined in more detail through a socio-economic filter via a small-scale fish husbandry trial. I conducted this trial during my study to explore the potential for income generating opportunities through aquaculture. A key factor assessed, that determines willingness to remain within the fishery, is the non-monetary benefits that the fishery holds for divers. This assessment provides clear evidence of the levels of attachment of different groups of divers to the fishery, which is reflected upon in terms of the implications for predicting future trends in decision making for a management driven approach to the ornamental fish trade that would involve both new and current divers.

In conclusion, the main findings from the seven specific objectives of the thesis are summarised and evaluated holistically within their theoretical frames and the logistical constraints of the study. Based on these findings, recommendations are made that integrate the study's objectives concerning the Sri Lankan marine ornamental fishery, into a framework that contributes to the overall aim of the thesis *i.e.* to improve sustainability of the coral reefs in Sri Lanka and the the livelihoods of its fishing communities. These recommendations are supported by proposals for further research. The contribution of this research to different bodies of knowledge, from interdisciplinary work of social-ecological systems to fisheries management is discussed as well as the implications and any applicability of this research at the broader global level. A reflection on the entire research process concludes the thesis, clarifying what could be improved upon in future work.

Chapter 2

Literature Review

2.1 Introduction

This literature review provides an overview of coral reefs showing how their structure and function creates the productivity and diversity that has resulted in close human interactions with coral reefs. The status, threats and impacts of coral reefs globally and in Sri Lanka around which the marine ornamental fishery operates, generated primarily from research by marine ecologists is reviewed before detailing how the growing concerns of conventional reef management failure and overfishing, have led to the application of innovative approaches and the merging of disciplines to find answers. I define and explain these interdisciplinary approaches which are used as the theoretical framework for this study and outline their suitability to frame the marine ornamental trade in Sri Lanka based on the application of these theories and concepts in similar environmental and resource use studies globally, and particularly focusing on their recent use in tropical reef fisheries research and management. The approaches within the theoretical framework are historical ecology, panarchy and the resilience concept, local ecological knowledge (LEK) and political ecology.

2.1.1 Coral structure and physiology

The majority of corals are members of the Phylum Cnidaria and the Class Anthozoa. Anthozoans are made up of anemone-like organisms which have a common body structure: the polyp. This is made up of a ring of tentacles surrounding the central mouth cavity. Corals which form reefs are colonial and comprise thousands of polyps. Anthozoans encompass many orders of corals with the most common being the Order Scleractinia (hard corals), which secrete a hard calcium carbonate exoskeleton and the Order Alcyonacea (soft corals), which do not possess large limestone exoskeletons but have small internal spicules of calcium carbonate instead. In addition to this variety, there are both warm-water and cold-water coral species. Warm-water corals are found in shallow waters in the tropics and maintain a symbiotic relationship with zooxanthellae, which are endosymbiotic algae of the Phylum Dinoflagellata, and the Genus *Symbiodinium.* Zooxanthellae are acquired by coral polyps through direct ingestion. Once ingested, they provide a food source to the coral through photosynthesis, hence these mutualistic corals exist in shallow waters and to depths where sufficient light for photosynthesis is received (Rowan & Powers, 1991).

Contrastingly, the majority of cold-water coral species live between 200 – 1000 m depth, do not possess zooxanthellae, as they live in darkness and instead filter-feed or actively capture food using nematocysts (stinging cells) on their tentacles (Roberts et al., 2006). Over millennia coral skeletons have accumulated on the seabed and formed layers of limestone, with the upper layers consisting of the most recently settled and living corals. This dynamic, three-dimensional structure existing within the euphotic zone of the oceans, with the optimal environmental conditions creates the extremely complex, co-evolved adaptations and interdependencies of coral reef ecosystems (Sale, 1977). Coral reefs are one of the most productive ecosystem of the seas, yet occupy less than a quarter of one per cent of our earth's marine surface (Smith, 1978; Alcala & Russ, 1990) and are often described as the rainforests of the seas (Connell, 1978). It is a unique and highly diverse ecosystem, with over 800 species of reef building corals worldwide and over 4000 reef fish species known to Western science (Paulay, 1997). The high productivity and diversity of warm-water corals means that reef ecosystems provide habitat, spawning grounds and feeding areas for a wide diversity of marine species, not just for resident species but also transitory oceanic species.

2.1.2 Human interactions with coral reefs

Coral reefs are known to be non-equilibrium ecosystems, which prevents the competitive exclusion principle from explaining species diversity patterns within these systems and instead community structure and biodiversity patterns are more likely to be caused by the high frequency disturbances and environmental stochasticity they experience (Huston, 1985; Dornelas et al., 2006). This diverse ecosystem close to tropical shores is a valuable resource providing many environmental and economic benefits to human populations (Moberg & Folke, 1999; Costanza et al., 1997; Nyström et al., 2000). Such ecosystem goods and services include: coastline protection; a vital protein source to coastal communities, large numbers of whom live in poverty; reef-associated tourism revenue; pharmaceutical potential of reef species and provision of saleable or building materials to local people *e.g.* coral and shell curios and ornamental reef fish for the aquarium trade (Bunting et al., 2003).

Coral reefs are also vulnerable ecosystems and the impact of climate change on these ecosystems is becoming an increasingly major focus of international concern. Coral reef biologists and ecologists in the face of increasing loss and degradation of coral reefs worldwide, have been re-examining ways to balance sustainable livelihoods and the preservation of tropical coral reefs. This area of research is reviewed from the ecologists' viewpoint in Sections 2.2 – 2.12. Anthropologists were interested in the anthropology of fishing before there was any awareness of the degradation of coral reefs. Although much of maritime anthropology and anthropology of fishing is only concerned with "...modern [commercial] fisheries, shipboard life and prehistoric marine adaptations..." (Acheson, 1981: 275), the emergence of anthropology of tropical small scale fisheries, which is relevant to my thesis, is discussed.

The father of ethnography and modern field anthropology, Malinowski (1935), conducted his primary research among the Trobriand islanders of Melanesia between 1914 and 1918 and studied the agricultural systems of the people inhabiting these coral atolls, in his magnum opus "*Coral gardens and their magic*". Many anthropologists interested in the socio-ecology of tropical traditional communities have focused, like Malinowski, on the land based activities of these people (Rappaport, 1968; Ellen, 1978; Sillitoe, 1983), while other anthropologists conducted participant observation and ethnography to record and analyse the cultures, customs, fishing methods, LEK and social influences within Polynesian and Puerto Rican fishing communities respectively (Johannes, 1978; Pollnac & Poggie, 1978), and by the 1980s many social anthropologists were concentrating research on indigenous tropical fishing communities and their knowledge systems (Ruddle, 1988; Hviding, 1989). Fewer ecologists working in tropical fisheries began to explore the social, economic and cultural factors influencing fishing communities until the mid-1980s (Polunin, 1984). Social anthropologists believed that small populations would not overexploit their limited resources (Klee, 1976; Johannes, 1981).

However by the late 1970s, as environmental degradation became a world issue after the United Nations Conference on the Environment in 1972 in Stockholm, ecological anthropologists, marine ecologists and others working across the social and ecological divide were examining this assumption in relation to fishing practices (Cordell, 1978; McCay, 1978). Debate centred on whether certain traditional communities were in "balance with nature" (Johannes, 1981; Polunin, 1984). Ecological anthropologists, working in other social-ecological systems (SES) such as the sacred groves in India (Gadgil, 1975), the Cree Indians of the Arctic (Berkes, 1977), the Wola in New Guinea (Sillitoe, 1978), central Andean communities (Orlove, 1980), and communities in the Amazon (Posey et al., 1984), have all shed light on how small-scale communities interact with their environments and the value and applicability of LEK (discussed in Section 2.14) to promote sustainable resource use, which is not often discussed in ecology studies of environmental degradation. Environmental anthropology, the applied arm of ecological anthropology, developed from this research focus as a field to recognise the intricacies involved in finding practical solutions to anthropogenic natural resource degradation (Shoreman-Quimet & Kopnina, 2011).

Within reef-dependent communities, there are now many environmental anthropological studies documenting fishing methods and LEK in particular, such as the Bardi Aboriginal People of Western Australia (Rouja et al., 2003), illegal fishing activity in Palawan coral reef fishing communities of the Philippines (Fabinyi, 2007) and in traditional management and knowledge of coral reefs in New Guinea (Cinner et al., 2005a) and in the Solomon Islands (Aswani, 1998). Now, in the wake of failed policies to help vulnerable small-scale communities still reliant on the ecosystems around them, environmental anthropologists and ecologists, particularly marine ecologists in the context of this study, are attempting to work together and share knowledge, methods and ideas to further not only research, but also policy and advocacy in these areas.

2.2 Status of coral reefs worldwide

Historically coral reefs were known to provide such a vast wealth of products and services in comparison to the requirements of the local people that they appeared inexhaustible (Roberts & Hawkins, 1999). It is only relatively recently that their plight has been highlighted due to increasing exploitation of reefs for resources as well as the myriad of deleterious threats from both human activities and environmental crises. Studies show that coral reefs globally are facing more threats than ever before (Pandolfi et al., 2003). For example, 20% of the earth's coral reefs have been destroyed and a further 24% are at high risk of being destroyed, moreover, 50-75% of these reefs are under threat from human impacts (Wilkinson, 2006).

Despite uncertainties as to the extent of anthropogenic impacts on reefs, many believe coral reefs are at a crisis point (Bellwood et al., 2004), as an increase in direct anthropogenic impacts, including climate change, is evident (IPCC, 2007). Many of these detrimental factors are hypothesised to be working together synergistically and potentially cause more rapid and intense destruction than was previously thought (Myers, 1995; Hughes & Connell, 1999; McClanahan et al., 2002). Some studies suggest that coral reefs could be extinct, or at least be far less productive than we know them today, within decades (Knowlton & Jackson, 2008; Hoegh-Guldberg et al., 2007), and that one third of reef building corals globally, without which coral reefs cannot exist, are at elevated levels of extinction risk (Carpenter et al., 2008). Restricted ranges of certain corals, reef fish, snails and lobsters have highlighted their risk of extinction; the ten highest endemism areas for coral reef associated species cover just 15.8% of coral reefs worldwide, but include approximately 50% of restricted range species (Roberts et al., 2002). These high biodiversity hotspots are viewed as conservation priorities and advocated for protection in a strategy similar to that for terrestrial biodiversity hotspots (Myers et al., 2000).

The importance of halting this trend or indeed reversing it is not just in order to preserve biological diversity and oceanic ecological interactions, but to safeguard the socio-economic benefits these reefs provide to local people (Hughes et al., 2003). With 50% of the world's population living within 60 km of tropical coasts, a total destruction of reefs would affect the livelihoods of nearly a billion people, and put additional pressure on already degraded terrestrial ecosystems as these populations seek alternative food sources (UNEP, 2010). Every possible human impact should be evaluated when considering the coral reef biodiversity and the ecological services and products they provide humans. One such threat is the trade in ornamental coral reef fish, which can have relatively major impacts on fish populations and coral habitat (Bruckner, 2000).

2.3 Status of reefs in Sri Lanka

Approximately 2% of Sri Lanka's coastline is characterised by fringing coral reefs with major coral reefs off the north-west and east coasts, whereas the south coast has predominantly patch and fringing reefs (Rajasuriya et al., 2002a). These reefs are home to 183 hard coral species, over 1000 species of reef fish, seven species of spiny lobsters, and several species of sea turtles, dolphins and dugongs (De Bruin et al., 1995). These reefs provide economic benefit to the country through fisheries, tourism and coastal protection. Generally, the most pristine reefs are furthest from high density human areas, such as Bar Reef Marine Sanctuary off the north-west coast and Pigeon Island off the east coast, with 70% hard coral cover reported in Bar Reef Marine Sanctuary in 2007 and approximately 50% around Pigeon Island (Rajasuriya, 2008). Another major coral reef protected area is Hikkaduwa National Park but it is situated within a densely populated coastal strip, south of Colombo, and only recorded 26% hard coral cover in 2007 (Tamelander & Rajasuriya, 2008). Other coral reef monitored sites have shown hard coral cover ranging from 12% to 40% in different locations around Sri Lanka. Coral reef fish abundance and/or diversity is correlated with hard coral cover and structural complexity of the inhabited reef and thus hard coral cover is used as a measure of reef health (Williams, 1991; McClanahan et al., 1994; Jennings et al., 1996).

2.3.1 Reef fisheries

Several reef fisheries exist in Sri Lanka: the demersal, semi-demersal, spiny lobster and the marine ornamental fishery and the economic importance of reefs to local livelihoods is significant (Rajasuriya, 2003). Coral reef associated edible fish constitute a vital part of coastal people's diets and reef fisheries account for 15% of national fish landings (Rajasuriya et al., 1995), with all fisheries contributing 2% to Sri Lanka's GDP (FAO, 2011). Thirty species of reef associated fish were recorded as sold for consumption locally (De Bruin et al., 1995), but this number has increased as fishers target secondary fish species when abundance of the preferred species declines (Rajasuriya et al., 2002b).

2.3.2 Ornamental fishery in Sri Lanka

Many ornamental species of fish, sea cucumber, urchin, starfish, anemone and shells are harvested for export exclusively (Rajasuriya, 2003). Ornamental fish make up 1.4% of all Sri Lankan exports and are the third highest fishery export product, in terms of volume and value, after prawns and lobsters (Wilhelmsson et al., 2002). Sri Lanka supplies between 3 and 5% of the world market of marine ornamental fish (Wabnitz et al., 2003; Export Development Board, 2010). Various aspects of the marine ornamental trade in Sri Lanka have been documented (Wood, 1985, 1996, 2001a), however, little empirical work has been carried out on the effects this trade is having on reef fish populations and reef ecology in Sri Lanka nor of the social, cultural and economic dimensions of the trade. In Sri Lanka, only some invertebrates are cultured for export but the majority of the trade depends on wild-caught specimens (Wilhelmsson et al., 2002). In Sri Lanka, an increase in the number of fish being exported has been seen with a five-fold increase from 200,000 (Wood, 1985) to 1 million (Ekaratne, 2000) between 1984 and 1995. The variety of fish caught has diversified over this same time period and an increase in the number of collectors has been noted (Ekaratne, 2000). The ornamental trade has become the most developed in the South Asia region and harvests over 250 different species of fish and invertebrates. Exports are sent to over 50 different countries and in 2000, the value of the entire ornamental industry in Sri Lanka was estimated at US$ 8 million with marine ornamentals estimated to comprise 70% of that value (Wijesekara & Yakupitiyage, 2001). The species exported in the greatest numbers are *Labroides dimidiatus* (blue-streak cleaner wrasse) and *Acanthurus leucosternon* (powder-blue surgeonfish), with 20,000 and 10,000 individuals exported annually respectively (Wood & Rajasuriya, 1999).

2.4 Threats to coral reefs

Coral reefs are threatened by both environmental and anthropogenic factors. These threats can be both local-based, such as overfishing, pollution or, coastal development and global such as ocean temperature increase and ocean acidification. From studying differences between coral reefs over different scales of time and space, changes that have occurred have enabled the identification of a variety of threats to coral reefs.

2.4.1 Environmental threats

Episodic events, such as large storms, El Niño Southern Oscillation (ENSO)[1] events, hurricanes and tsunamis characterise coral reef ecosystems and help maintain diversity and function of reef systems. These disturbances can cause large structural damage to the reef, however, such events also provide benefits to coral reefs in a similar dynamic to that of fire in terrestrial ecosystems. These include differential mortality leading to varied future succession (Hughes & Connell, 1999) as well as reef structure alterations, which alter water flows and erosion patterns with delayed mortality or recovery of coral areas (Connell, 1997). In the Caribbean, the movement of moderate-strength hurricanes cools ocean water, and can dampen or prevent bleaching events (Manzello et al., 2007).

[1] El Niño/La Niña Southern Oscillation (ENSO) is a climate pattern across the tropical Pacific ocean, with changes in sea water temperature and air pressure above the ocean. This oscillation cycles between warmer sea temperatures (El Niño) and cooler temperatures (La Niña) about every five years but with increasing unpredictability in recent decades and can be felt across the globe.

2.4.2 Anthropogenic threats

Many anthropogenic threats are constant and increasing (Hughes et al., 2003). Almost a quarter of all reef fish inhabit reefs that are under direct threat from human disturbances (Roberts & Hawkins, 1999) and one of the most severe threats is anthropogenic climate change. The average increase in sea surface temperatures (SST) globally, attributed to climate change, is ± 1 °C in the last 100 years and average SST is predicted to increase by a minimum of ± 2 °C between 2050 and 2100 (Hoegh-Guldberg et al., 2007). Short-term variability in SST also occurs due to changes in ocean circulation such as ENSO events. These usually occur every 3-4 years with a resultant increase in SST in the range of *ca.* 3-4 °C above average levels (Stone et al., 1999). Global climate modelling studies predict ENSO events to increase in frequency and intensity in the future as well as other natural hazards such as hurricanes (Done, 1999; Webster et al., 2005; Hoegh-Guldberg et al., 2007). In the past 15 years, three wide-scale El Niño events have caused extreme coral mortality globally, (see Section 2.6.4). Threats from climate change include increasing sea temperatures, which are affecting fish species distributions, particularly those species that have small and restricted geographic ranges (Perry & Ommer, 2003) and, a possibly greater threat to coral reefs, ocean acidification. Oceanic absorption of carbon dioxide from the atmosphere increases the acidity of the world's oceans and is already affecting marine species, particularly those with calcium carbonate skeletons or structures, such as hard corals. The increased acidity reduces carbonate ions and reduces the level of aragonite, a metastable form of calcium carbonate, in the ocean, which prevents coral growth and dissolves coral structures and skeletons (Orr et al., 2005). Climate change is therefore regarded as one of the most significant threats facing coral reefs in the future, with modelling studies of ocean aragonite levels under different climate prediction models showing that coral reefs could be unable to grow or remain stable after 2050 if current greenhouse emissions are not severely reduced (Veron et al., 2009) even if other pressures are removed.

Fishing has been the primary anthropogenic threat to coral reefs for millennia (Jackson et al., 2001). Fishing in reef areas began 35-40,000 years ago but the effect on reef ecology was minimal, however, increasing human populations has increased fishing intensity on reefs. Historic marine fish populations are believed to be far greater than even in the early part of the 20th century (Jackson et al., 2001) and this gives an insight into how dramatic and rapid the declines in fish populations globally have been due to overfishing and environmental effects (Smith, 1978).

Serious indirect threats to reefs originate from anthropogenic terrestrial and coastal activities. For example, poor land/farming practices and coastal development result in erosion and deposition of sediment onto reefs which results in reef death because sunlight is blocked to the zooxanthellae (Rogers, 1990). Large quantities of nutrients arrive in coastal waters via precipitation and irrigation run-off from agricultural areas. This high nutrient load in shallow marine systems results in algal blooms which cause light competition with corals and reduce water oxygen content, and ultimately in fish and coral death (Fabricius, 2005). Chemical pollution from industrial areas and run-off from towns and cities is another major threat to adjacent coral reefs.

2.5 Threats in Sri Lanka

Environmental threats, such as strong El Niño events, sea temperature increases and ocean acidification threaten all Sri Lankan reefs. Anthropogenic threats affect most reefs, except for a few protected, remote coral reefs. Threats comprise urban and industrial pollution, sedimentation from poor land use practices (Öhman et al., 1993), boat anchoring and increased tourism activities (Rajasuriya & White, 1994) and breaking of shallow corals by tourists and local people at low tide (Kumara et al., 2005). In open access reef areas, fishing is the main human threat followed by the other anthropogenic threats listed above (Kumara, 2008).

2.6 Impacts on coral reefs

2.6.1 Overfishing

Overfishing has always been cited as a major threat and today, overfished sites tend to suffer from other disturbances to a greater extent than non-fished reefs due to indirect negative feedbacks and synergistic impacts of environmental and human stressors, known as multiple stressor effects (Bunce et al., 2010). Some coral reef ecologists believe that impacts such as marine diseases and eutrophication may not materialise unless overfishing has taken place first (Jackson et al., 2001). Since the 1980s, massive state shifts in coral reef communities have occurred (see Section 2.8) from coral dominated to algal dominated reefscapes, with the most dramatic examples being in the Caribbean and the Great Barrier Reef (Jackson et al., 2001). These changes are linked with habitat loss and overharvesting of herbivorous fish, such as parrotfish and surgeonfish (Bellwood et al., 2004; Hughes, 1994; Jackson et al., 2001; Mumby et al., 2006). However, these recent shifts in dominant species, even in well protected areas such as the Great Barrier Reef, make it apparent that such changes stem back to the early impacts of fishing as well as current disturbances (Jackson et al., 2001).

Overfishing is linked to a reduction in top predators as piscivorous species are often preferentially targeted (Bohnsack, 1982; Russ & Alcala, 1989; McClanahan, 1994; Jennings & Lock, 1996). This was shown in a comparative study between lightly fished islands and heavily fished islands in Hawaii (Friedlander & DeMartini, 2002). High levels of exploitation were found to be changing reef fish assemblages in terms of density, size and biomass, with large reductions in average size and abundance of apex predators in particular, but similar effects were recorded for lower trophic groups (Friedlander & DeMartini, 2002). Reduction in diversity and biomass in areas of high fishing intensity has occurred in the Seychelles (Jennings et al., 1995), Jamaica (Koslow et al., 1988) and Indonesia (Pet-Soede et al., 2001a). Often in partnership with overfishing in tropical fisheries, is the use of destructive fishing practices such as blast fishing[2], and cyanide fishing[3], which destroy fish and their habitat (McManus, 1997).

2.6.2 *Trophic cascades*

Top predators and megafuana of reef ecosystems are all in steep decline or are already ecologically extinct, with resultant trophic cascades[4] already occurring in some locations (Dulvy et al., 2004; Mumby et al., 2006). Several, large, edible species of Epinephelidae (groupers) are endangered, threatened or vulnerable under the International Union for the Conservation of Nature (IUCN) Red list (Morris et al., 2000). Their removal from coral reefs is known to cause imbalances within the trophic food chain. In many reef habitats around the world trophic cascades are being observed and recorded, such as the outbreaks of the *Acanthaster* spp. (crown of thorn starfish) on the Great Barrier reef and algal dominance on Caribbean reefs (Pandolfi et al., 2005).

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[2] Blast fishing is the use of explosive devices such as carbide and dynamite to catch fish. Sticks of dynamite are released from a boat and detonate underwater. After the blast, the dead fish are collected by divers or snorkellers. The blast can pulverise submerged corals and rocks and kills fish indiscriminately and destroys fish eggs (Mous et al., 2000).

[3] Cyanide fishing is the use of sodium cyanide by divers in the live reef fish and ornamental trade, which is released into the water to stun fish and allows an easier catch. This method reduces the survival of the fish caught and affects other fish in the vicinity. Furthermore, the chemicals have adverse effects on the other marine fauna nearby including corals (Johannes & Riepen, 1995).

[4] Trophic cascades are ecological phenomenon where changes in top predators (top down) or producers (bottom up) result in reciprocal changes in prey and predator abundances in a food chain. *E.g.*, top predator removal releases predation pressure on their prey, whose population increases, this increase decreases their prey population, which results in large-scale shifts in ecosystem functioning.

2.6.3 *Ornamental trade*

The impacts due to the ornamental fish trade alone are difficult to isolate and quantify, partly because detailed data are not available and species need to be individually assessed (Wood, 2001b). However, the fishery has always been of concern to coral reef conservationists, due to its expansion over the past 30 years and its targeting of juvenile phases. In Queensland, Australia there are concerns of overfishing in certain locations and conflict has resulted between different economic sectors reliant on the reef, resulting in the authorities looking to reduce ornamental fishing effort (Ryan & Clarke, 2005). Several authors have described reductions in fish populations on reefs due to this trade, for example, along the Fort Lauderdale coast, Florida (Noyes, 1976), in Sri Lanka and Kenya (Lubbock & Polunin, 1975; Samoilys, 1988), in the Philippines (Albaladejo & Corpuz, 1984; Rubec, 1987), in Indonesia (Soegiarto & Polunin, 1982) and Hawaii (Tissot & Hallacher, 2003). Vulnerability of fish species to over collection will be determined by factors such as recruitment variability, abundance, level of exploitation and endemism. The targeting of juveniles for the ornamental trade may reduce recruitment success in future years, which means reefs will be reliant on influxes of juveniles from neighbouring reefs to sustain fish populations (Vincent, 2006). There is no evidence of reef fish being driven to extinction by the ornamental trade, yet declines seem to be commonplace, and if compounded by the narrow geographic range of some fish species, could result in irrecoverable losses (Vincent, 2006).

Other impacts that concern the wider reef community are trophic cascade effects, in particular how removal of fish species can affect coral, other invertebrate populations and algae. The importance of herbivorous fish in maintaining macro-algae levels on coral reefs is widely accepted (Mantyka & Bellwood, 2007); however, a study in Hawaii showed the removal of ornamental herbivorous fish did not alter macro-algae levels (Tissot & Hallacher, 2003) and in the Caribbean not only the removal of herbivores but also low coral cover was the reason for macro-algae increases (Williams et al., 2001). The removal of 'cleaner' fish species[5] for the trade is thought to have significant indirect effects within reef communities as client fish are known to interact with cleaners in order to remove ectoparasites (Arnal et al., 2000).

Physical destruction of the reef from the fishing methods of collectors is known to occur. Cyanide fishing (see footnote 3) is common in the Philippines and Indonesia

5 Cleaner fish are species which remove dead scales and parasites from other fish, a form of mutualism.

(Rubec et al., 2001). Nets used in ornamental fishing can become entangled, resulting in broken and damaged corals. 'Coral notching' in the Cook Islands breaks branches of *Pocillopora* spp. off until the fish hiding within can be caught (Passfield & Evans, 1991). However, the amount of physical damage to corals and the reef through the collection of ornamental fish has scarcely yet been quantified (Wood 2001a).

2.6.4 Coral bleaching

Reef building corals are sensitive to small changes in sea surface temperature (SST) and membrane lipid composition of zooxanthellae species dictates their thermal tolerance and hence the thermal sensitivity of different coral species (Tchernov et al., 2004). Small temperature anomalies cause zooxanthellae to produce toxins inside the coral, the release of which cause corals to expel the zooxanthellae (Trapido-Rosenthal et al., 2005). Corals without zooxanthellae are weakened, as they lack their main energy source. Some coral species are able to withstand these weakened periods and regain zooxanthellae, whereas others die from starvation and susceptibility to disease (Kleypas & Hoegh-Guldberg, 2008). As zooxanthellae give coral their different colours, when zooxanthellae symbionts are lost under thermal stress, corals turn white, hence the term coral bleaching is used to describe this form of coral weakening and likely mortality.

Recent severe El Niño Southern Oscillation (ENSO) events are strongly regarded as being accountable for the rise in coral bleaching events all across the tropical seas from the Indo-Pacific to the Caribbean, which demonstrates the “teleconnections” of ocean-atmosphere coupled systems (Lechowicz, 1982) and the increase in frequency and intensity of ENSO events is linked to anthropogenic climate change (Stevenson et al., 2011).

A strong ENSO event in 1998 caused bleaching in over 90% of coral reefs worldwide and 16% of global reefs were seriously damaged; only 40% of those seriously damaged are recovering or have recovered (Lechowicz, 1982). A further strong ENSO event in the Caribbean in 2005 led to the worst levels of bleaching and resultant coral disease and mortality ever in the region (Wilkinson & Souter, 2008). Corals and their symbionts have low or short-term levels of temperature acclimation and cannot adapt quickly enough to the unprecedented rate of warming expected in the next 50-100 years (Hoegh-Guldberg et al., 2007). However, if the expected global temperature rise can be minimised to 2ºC, it is possible that the more thermal tolerant species of corals alive today could adapt and remain but a significant loss of coral diversity would still occur (Hoegh-Guldberg, 2012).

Bleaching has indirect effects on fishery targeted species. High reef structural complexity is linked to high reef fish species diversity and biomass (Sale, 1977; McClanahan, 1994). Reductions in substrate heterogeneity due to environmental and human impacts such as bleaching and destructive fishing methods have been shown to reduce reef fish abundance and numbers in Sri Lanka, depending on the type of reef, and fish species (Öhman et al., 1997). Effects of bleaching on fish populations in the Seychelles included changes to the size structure of fish communities and a lack of juvenile replacement which occurred with a time lag response after the decrease in reef structural complexity (Graham et al., 2007).

2.7 Impacts on Sri Lankan reefs

Anthropogenic impacts are blamed for the discrepancies in coral reef health among different sites in Sri Lanka (Tamelander & Rajasuriya, 2008). Reefs were degraded considerably from coral mining[6] which was made illegal in Sri Lanka in the 1980s, yet as recently as 2004, mining still continued in southern Sri Lanka to produce building materials (Kumara et al., 2005). Dynamite fishing was common on coral reefs and, although still practised, it is to a lesser extent (Ekaratne, 2000). Coral bleaching affects the coral reefs of Sri Lanka; the 1998 El Niño event resulted in the mortality of 50–90% of the shallow, nearshore reefs of Sri Lanka (Rajasuriya & Karunarathna, 2000), killing many of the reef building corals, such as *Pocillopora* spp., *Acropora* spp. and *Echinopora lamellosa* (Rajasuriya et al., 1999). Rates of recovery since then have been extremely variable and site specific (Rajasuriya et al., 2005a).

During this recovery period when the nearshore coral reefs were in a weakened state, the 2004 tsunami occurred, which instantly impacted coral reef areas by physical disturbance, and altered the distribution of other substrate forms, such as sand, resulting in long-term adverse effects to nearshore coral reefs along the east, south and west coasts of Sri Lanka (Atapattu & Tharme, 2005). There was extreme variation in the spatial extent and intensity of the tsunami destruction on coastal areas, which was

6 Coral mining is the removal of live coral from marine areas, the collected corals are baked in onshore kilns to produce limestone for building roads, houses and other structures.

mainly due to the marine and coastal geomorphology and topography, which influenced wave direction and height (Wijetunge, 2006). However, some studies also linked the scale of damage with the presence, or absence, of offshore and nearshore reefs (Yamada et al., 2006). The wide-scale damage caused, especially along the east, south and south-west coasts means that natural recovery is the only viable form of rehabilitation, therefore stresses on the reefs need to be reduced or removed to allow for reef recovery (Rajasuriya et al., 2005a). After the tsunami, the abundance of smaller reef fish had declined to a greater extent than the larger, more mobile species, which is thought to have negative repercussions for the ornamental fish trade in Sri Lanka (NARA, 2005).

2.7.1 Overfishing on Sri Lankan reefs

Overfishing is well documented on the reefs in Sri Lanka, with open access and the uncontrolled usage of blast fishing, bottom set nets and *moxy*[7] nets (specifically for the ornamental trade) associated with declining fish and invertebrate populations (Rajasuriya, 2003; Wood & Rajasuriya, 1998). Destructive fishing practices have also been linked to varying levels of alteration to reef habitat structure (Rajasuriya et al., 1998). Catches nationally have declined and are thought to be due to a combination of destructive fishing methods and the coral bleaching in 1998 (Perera et al., 2002; De Silva, 1985). It is highly likely that both physical damage and chronic human impacts have negatively affected fish abundance and diversity on these reefs (Wilhelmsson et al., 2002). Despite these severe impacts, most of the threats remain and a lack of rigorous management and law enforcement undermines resilience of the system, hindering potential reef recovery (Rajasuriya, 2003) and the fulfilment of integrated coastal management objectives (see Section 2.10).

2.8 Alternating stable states of coral reefs

Evidence of these impacts is materialising in the form of algal dominated reefs globally (Hughes, 1994; Wilkinson, 2006; McClanahan et al., 2002). These shifts have most noticeably affected reef communities in the Caribbean (Done, 1992; Gardner et al., 2003; Pandolfi et al., 2003), but are also documented in south-east Asian (McManus, 1997), Australian and African reefs (Bellwood et al., 2004). Warming seas and reduced

[7] A moxy net is a large circular net with a float at the centre and with many lead weights around the perimeter used by ornamental snorkellers in Sri Lanka to catch their targeted fish.

intervals between high intensity storm events are hypothesised to reduce the regenerating ability of coral reefs, thereby weakening them and allowing for shifts to less diverse and productive states (Done, 1999).

However, a study of 1,851 reefs between 1996 and 2006 found that coral dominance decreased in the Caribbean and remained the same in the Indo-Pacific, increasing slightly specifically on the Great Barrier Reef (Lowe et al., 2011), which showed that some coral reef systems may be more resilient to these changes than previously thought. Despite this, at a local level, many communities are struggling to reverse the shifts that have already occurred to regain productive coral dominated states. Experimental work carried out to reverse a reef system, from algal dominance back to coral dominance, discovered that the fish species most expected to achieve this reversal (herbivorous parrotfish and surgeonfish) had little effect, whereas an unexpected single species, *Platax pinnatus*. (Dusky batfish), proved beneficial in reducing algal cover and allowing for coral settlement and rejuvenation (Bellwood et al., 2006). Studies like these starkly demonstrate the limited understanding of coral reef ecosystem processes and dynamics and how to protect them in the face of the compounding disturbances they encounter. Research and practice needs to be guided towards studying and comprehending the underlying intricacies of coral reef ecosystems to allow for the protection of essential components to reef resilience and recovery from unproductive states. The bigger challenge is how to reverse these shifts and increase resilience of coral reef ecosystems to avoid such changes (Folke et al., 2004).

2.9 Coral reef management

Improved adaptive reef management and monitoring of anthropogenic impacts are required to increase coral reef resilience in order to absorb higher frequency and intensity stochastic episodes, such as bleaching events (McClanahan et al., 2002; Hughes et al., 2003). The implementation of marine protected areas (MPAs) worldwide is unparalleled in marine management solutions with an estimate of approximately 1000 coral reef MPAs in existence (Mora et al., 2006) and these MPAs are seen as the most effective management tool to protect coral reefs (Lubchenco et al., 2003). There is evidence for increases in fish abundance within MPAs (McClanahan & Arthur, 2001; Polunin & Roberts, 1993; Wantiez et al., 1997). Well managed coral reef MPAs in Kenya showed recoveries in species richness after 10 years and fish biomass between

10 and 37 years depending on the site (McClanahan et al., 2007). However, overall MPAs are claimed to be ineffective in protecting the present state of global coral reefs due to poor management and many cover an insufficient marine area to protect all the diverse families and functional groups of fish and other reef associated organisms (Mora et al., 2006). The benefits of MPAs to coral reef food fisheries therefore remain dubious (Christie et al., 2009), they are highly species specific and dependent on contiguity of MPAs and fishing grounds (Tupper, 2006) as appears to be the case for West Hawaii's ornamental fishery (Tissot et al., 2004). The views of fishers about these rapid and often dramatic changes to their landscape and fishing rights have received less attention in the academic literature. Furthermore, most current MPAs do not provide reefs with the buffer they need to withstand bleaching events (Graham et al., 2007). Therefore, it is crucial that climatic disturbances are included and given high priority in reef conservation policy (McClanahan et al., 2008).

The individual threats to coral reefs need to be understood separately but tackled together in well crafted management schemes to restore their previous diversity and improve their health and promote their resilience and survival. Integrated coastal management (ICM) attempts to do this and is being implemented in tropical coastal areas (see Section 2.16.3). For example efforts such as the Transforming Coral Reef Conservation (TCRC) program look to establish MPA networks, according to sites where replenishment and resilience are maintained through the natural factors in that area, such as protecting reef fish spawning sites (Domeier et al., 2002). The historical record can help determine if efforts are succeeding (Pandolfi et al., 2003).

2.10 Management of Sri Lankan reefs

In Sri Lanka the nearshore fishing areas are informally controlled by the local villagers and only those from that village may fish there. Other than this basic form of sea tenure, there appears to be little enforced management of nearshore areas of Sri Lanka’s coastline, Hikkaduwa National Marine Sanctuary being the only exception (personal observation) and little effective management of offshore sites. However, there is more ecological, social and economic data on offshore fisheries than nearshore coral reef fisheries (Rajasuriya, 2003) because the closely interacting multi-species nature of reef fisheries makes management, that focuses on target species only, ineffective (Newton et al., 2007). The complexity surrounding reef fisheries necessitates a shift away from conventional forms of fisheries governance, as described in Section 2.9, however, altering national fisheries governance strategies is beginning in Sri Lanka but will take time and continued support and investment if it is to succeed.

According to Rajasuriya (2003), there is acceptance at the government level that nearshore reef fisheries are overexploited and development of offshore fisheries is planned. Such a simplistic shift of fishing effort has not materialised and nearshore coral reef habitats remain under fishing and other anthropogenic pressures (Kumara, 2008). Most studies concerning Sri Lankan fisheries suggest that little enforcement of fishing regulations exists or is possible from centralised external institutions such as the police or government marine conservation bodies (Rajasuriya, 2003). Socio-political issues continue to cause conflict and inertia at management levels in Sri Lanka, yet little research has investigated how these wider influences affect the status of coral reefs. Top-down government control and lack of capacity, political will and funding have prevented long-term research and integrated coastal management programs from reaching their full potential (Rajasuriya & White, 1994). More recently, an appraisal of the status of coral reefs and their management in Sri Lanka in 2008 states:

> *"Many reefs in Sri Lanka lack effective management with many illegal activities, such as live coral mining and fishing using unsustainable gear and dynamite. MPAs remain poorly managed and compliance with regulations is low with the possible exception of Hikkaduwa. The escalation of internal conflict in the country prevents active work in the northern and eastern parts of the country"* (Tamelander & Rajasuriya, 2008).

2.11 Who is to blame for the state of the commons?

The bleak picture of the current status, threats and their impacts on coral reefs is often explained by marine ecologists and economists by Hardin's (1968) "Tragedy of the Commons" (ToC), which presents an expected sequence of events when top-down centralised control is lacking. Hardin's model claims that without private property rights or tight access controls, the individual seeking maximum profit would benefit, while the costs were shared by the group and as each individual practised this strategy the common resource would eventually become exhausted. However, since then, as most commons are commonly held property (Feeny et al., 1990), many examples of successful collective management of common property have been described around the world, which disprove the ToC theory and show that it is not inevitable (McCabe, 1990; Feeny et al., 1996; Ostrom, 1999; Basurto & Ostrom, 2009). Common property theory is one of the pillars of contemporary political ecology (see Section 2.15) and its basis is formed on complex ecological systems such as fisheries, rangelands and forests that are often managed collectively or as common property (Robbins, 2011). Individuals do not always act and make decisions in isolation but live and function as part of a community who monitor and respond to outcomes created by group and individual actions within the community (Dietz et al., 2003). Therefore failures in management of common property rests more with the rules and structures within these local communities rather than a generalisation that collectively managing common property is impossible (Ostrom, 1990). Restructuring and altering these rules is seen as more beneficial than imposing state control to such management initiatives (Ostrom, 2003; Hanna, 2003).

Further critics of the ToC have exposed how capitalised economies were altering the political and social circumstances of the actors, as by coercing local people into the tragedy, through market forces and economic hardship, the communal capital was transferred to the elites and non-place-based actors (Muldavin, 1997). Furthermore, these external groups would then blame the disempowered and coerced local people into environmental degradation. Therefore, the ToC presents an incomplete picture of human-environmental interactions that needs fleshing out with historical socio-economics, the multiple scales of political influences and non-present actors, to understand more clearly the current situation. Fisheries are a classic example of extraction from a common property and, despite the discreditation of Hardin's thesis, many fisheries management plans utilise it although this may be one reason why so many fisheries are in crisis (Pauly et al., 2002).

2.12 Past and current management failures

Despite many studies demonstrating the widespread human impacts on fish populations and coral reefs, and the resultant management ideas and strategies, limited progress has been made in sustainably managing coral reefs and their fisheries using conventional forms of management. Many reef fisheries scientists and researchers have found conventional fisheries science methods irrelevant to tropical fisheries. Conventional fisheries science is often based around single species fisheries in temperate oceans, requiring large amounts of data to perform stock assessments and regular monitoring and recording of fishing intensity. Furthermore, governance is often hierarchical and/or market based in Northern and temperate fisheries of the global South. These fisheries are managed around equilibrium based models of maximum sustainable yield (MSY), which appear to be too simple and reductionist for complex, multi-species fisheries of tropical regions (Larkin, 1977; Polunin & Jennings, 1996).

There is also uncertainty in the fisheries science which guides conventional management (Daw, 2008). The typical metrics recorded for fisheries include catch per unit effort (CPUE), which is commonly expressed as the number or weight of fish caught per number of hooks per fishing line, or nets cast, or the number or weight of fish caught per unit time. However, CPUE is often assumed to be an indicator of abundance and so is used for large inferences without further evidence. For example, CPUE may remain high and apparently stable even while independently measured stock abundance is falling markedly. Only when stocks really decrease - this is often not the same as when fisheries scientists measure such decreases - does CPUE also drop. However, CPUE is not necessarily proportional to abundance and can remain constant when abundance declines (Figure 2.1), resulting in 'hyperstability' or decreases more rapidly than the decline in abundance, resulting in 'hyperdepletion' (Hilborn & Walters, 1992). Fish behaviour and spatial distributions and fishers can all affect this CPUE and abundance relationship (Walters, 2003).

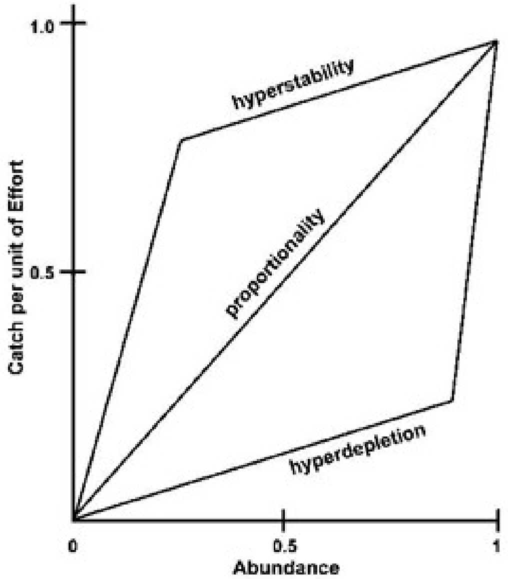

Figure 2.1. Catch per unit effort (CPUE) and abundance relationship, Source: Sadovy, (2005).

Previous management models were also too simplistic; for example, they grouped all fishers as one unit and made no allowance for differences in sociological characteristics that often delineate communities (Fabinyi, 2008). Alongside the backdrop of relatively abrupt and global change to coral reef ecosystems, fisheries researchers, practitioners and local communities are searching for innovative ways to approach and disentangle the common situation and trajectory of coral reefs from the fisheries associated with them. Many social and marine ecologists are calling for 'adaptive' forms of management to be incorporated into fisheries governance structures. Adaptive management is concerned with connecting individuals, organisations, agencies and institutions across nested organisational scales to promote a learning environment among management bodies. Different involved groups utilise different knowledge systems and self organise with support from government agencies and legislation to develop common policies (Folke et al., 2004). According to Dietz et al. (2003), there are five main requirements for adaptive governance of complex systems: 1) reliable, timely information provision; 2) dealing with conflict to promote learning and change rather than it causing inertia and debilitation; 3) inducing rule compliance through the use of formal and/or informal means enforced by respected and legitimate actors; 4) provision of technological, physical and institutional infrastructure; and 5) increasing preparedness for change by guarding against low probability, high consequence events and allowing adaptation. These all promote sustainable usage of common resources in the long-term. The resulting adaptive style and collective properties of participatory management are more appropriate to tropical fisheries (Christie & White, 1997), (discussed in Section 2.16).

The struggle for ecologists to solve or even effectively reduce natural resource exploitation and degradation may be a product of ignoring the human element of the situation, other than to lay blame with the resource harvesters. In contrast, some arms of environmental anthropology seek to explore human-environment interactions in areas where environmental degradation is occurring. Environmental anthropology, in its development, has absorbed many components into its application and is an eclectic mix of different approaches. I intend to analyse the various subsystems that constitute the ornamental fish trade in Sri Lanka through a set of theories and approaches that include historical ecology, panarchy, resilience, local knowledge, and political ecology. Each is outlined to illustrate how it can be used to address complex natural resource issues from a different angle to conventional approaches, particularly in the context of tropical fisheries.

2.13 Theoretical framework

2.13.1 Historical ecology

A theory used initially within the thesis is that of historical ecology. Historical ecology is a debated term with often divergent meanings or interpretations among different disciplines. One accepted definition, used in this thesis, conceives of historical ecology as the study of living ecosystems through time, analysing the interactions between humans and landscapes in order to unravel cause and effect relations resulting in the extant system (Crumley, 2007). As Winterhalder, (1994: 19) explains "...a complete explanation of ecological structure and function must involve reference to the actual sequence and the timing of the causal events that produced them." It has been utilised in many fields of study but is a particularly valuable framework to address issues of resource degradation or scarcity (Crumley, 1994a). Rather than just a description of human environmental impacts, historical ecology explains these impacts (Szabó, 2010).

Ingerson (1994) claims that historical ecology views humans and their environments as a dialectic interaction rather than a divide. Therefore historical ecology is an interdisciplinary approach, that aims to bridge the nature and culture discourse and with its concepts based in landscape, region, boundary, diversity and organisational structure, provide a method to analyse SES (Meyer & Crumley, 2012). To better comprehend these SES, an appreciation of historical events and the development of human-environment relations is required to prevent shifting baselines[8] of natural and social systems (Pauly, 1995).

Additionally, functional ecosystem properties, such as resilience, are only partially understood through their expression in present ecosystems; to grasp this more completely, an understanding of the ecosystem's history is necessary (Winterhalder, 1994). Historical ecology focuses on temporal change, disturbances and resilience, as opposed to ecosystem equilibrium theory, and is compatible with ideas of system complexity and adaptive management (Cronon, 1983; Balée, 2006). Importantly for policy and management decisions, long-term trends in these systems can be determined from examining changes in environments over time (Crumley, 1994a).

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8 Shifting baselines are the utilisation of an incorrect baseline of e.g. a fish stock, to which modern day measurements/data are compared. Often the true baseline is difficult to determine.

Three main points underpin historical ecology: first, human actions have always altered ecosystems, humans today pervade every ecosystem, hence not being remote from these ecosystems (Cronon, 1995). Second, interactions between humans and nature are not deterministic but dynamic and complex. People form representations of their environment based on their own needs, experiences and limitations and these different representations can cause conflict and competition, the resolution of which is expressed in the landscape (Crumley, 1994a; Balée, 2006). Third, as humans can alter and manage these interconnected systems, historical ecology is significant in directing restoration work and developing understandings of these complex processes (Egan & Howell, 2001).

Despite the significance of systematically analysing past events to determine reasons for current observations in natural and social systems, few ecological studies provide detailed historical background to resource management and/or degradation issues. Environmental anthropology utilises historical ecology to not only assess contemporary factors affecting resource management issues but also to evaluate the efficacy of certain conservation practices. This approach was exemplified by one study, which exposed a link between current environmentalist efforts to protect *Capra sibirica* (Himalayan ibex) in Pakistan with draconian colonialist laws and practices of the past (MacDonald, 2010). MacDonald (2010) shows that the International Union for the Conservation of Nature (IUCN) prevents local Pakistanis from hunting protected *Capra sibirica* in Pakistan but allows high paying foreigners to shoot them for sport. Thus by examining past and contemporary resource management practices, potentially workable solutions can be found to disentangle human-environment interactions that often seem unstoppable in terms of continued resource degradation (Cronon, 1995).

The historical and present use of fire on landscapes has been studied by historical ecologists, exposing the different effects that traditional and modern uses of fire have had in forest and grassland ecosystems. These studies showed that native swidden practices create landscapes of higher biodiversity (Salick, 2012), whereas preventing burning under a conservation ethos and establishing national parks has, in some locations, reduced biodiversity and inflicted unforeseen environmental degradation on remaining areas (Henderson & Keith, 2002). Thus it provides for a fresh approach to consider what has affected the landscapes experienced today.

In fisheries ecology and management, historical ecology has value in determining current and prior baselines, used to interpret current levels of fishing against present levels of fish and marine resource abundance. Such baselines provide accurate targets for recovery and conservation programmes, for example, the historical effects of overfishing (Jackson et al., 2001) help to characterise the potential effects of overfishing in less degraded marine ecosystems. Discoveries of historical artefacts associated with fishing are also useful in determining past practices in certain areas and establishing how communities came to sustain themselves in remote areas, such as through using fish weirs found in Amazonia (Erickson & Balée, 2006) or how coastal people became enmeshed with fishing as a livelihood and culture, and their impacts over far longer periods of time than is usually considered by fisheries managers today (Erlandson & Rick, 2008).

Using this analytical framework with my data, a historical causal chain is constructed backwards in time and outwards in space to identify, through specific events, the reasons behind the current situation rather than basing the causes on an a priori theory or model (Walters & Vayda, 2009). Historical ecology is a necessary precursor to understanding the current landscape in southern Sri Lanka, to determine why the ornamental fishery is moving along its current path and how future fishery management strategies need to be informed by the historical artefacts within local communities, their coral reef systems and the country as a whole.

2.13.2 Panarchy

The theory of panarchy was developed to comprehend global changes in complex systems by linking systems' dynamics and different scales. It was coined by Holling et al. (2002) and refers to the Greek god of nature, Pan, representing unpredictable change, interdisciplinarity and cross-scale hierarchies. Over the last decade, concern over human impacts on global processes such as the atmosphere and economic patterns have led to investigations of cross-scale influences (Levin, 1999). Panarchy conceives nature as comprising adaptive, evolving systems. It dispels the myths of nature being globally stable, in equilibrium and able to be maintained in optimal states or of nature being completely random and/or anarchic, which are all incomplete theories (Berkes & Folke, 2002). Instead it refers to nature as being resilient, existing in multiple stable states over multiple scales, which shift and transform gradually and abruptly. Policies to deal with these changes need to be flexible, active and adaptive (Gunderson & Holling, 2002). Panarchy also prescribes interdisciplinary work to transcend ecological, social, economic and institutional processes, because if viewed in isolation, our understanding is incomplete (Vitousek et al., 1997).

The theory of panarchy is utilised to understand social-ecological systems (SES), where the separation of the social or the ecological components of these systems would result in a misunderstanding of the processes and dynamics of the system due to their co-evolving nature. SES are complex, adaptive systems between which there are flows of information, capital and resources. These flows are directed and regulated by biophysical and social factors. SES theory originates from systems ecology and complexity theory, but differs in its inclusion of social variables and a merging of the human environment with the natural environment. Holling's (1973) seminal paper covering stability and resilience of biological systems, the work of Levin (1999) on resilience, the Scheffer et al. (2001) study on regime shifts, Gunderson and Holling's (2002) collection of studies on panarchy and sustainability and Berkes et al.'s (2003) work on robustness of SES, brought their overarching theory of panarchy to the forefront of current interdisciplinary research on complex SES. Social-ecological systems theory and the resilience approach have gathered a following and momentum in the scientific literature, offering alternative means to address all manner of complex resource problems with an amenable tool-kit, rooted in established ecological theory (Davoudi, 2012).

Social-ecological systems are considered to exist as an adaptive cycle with four distinct phases, which operate across multiple states known as panarchies. The first phase is a growth and exploitation phase (r), the second is a phase of conservation (K), the third is a release phase (Ω), and the fourth a reorganisation phase (α) (Figure 2.2). Social-ecological systems can move in both directions through the adaptive cycle and the rate of movement from one phase to another may vary, and certain stages can even be bypassed. Due to the dynamic nature of SES the third (release) and fourth (reorganisation) phases are unpredictable in where they return the system after a release. After such reorganisation, the same growth (r) phase may develop or a completely new trajectory may emerge.

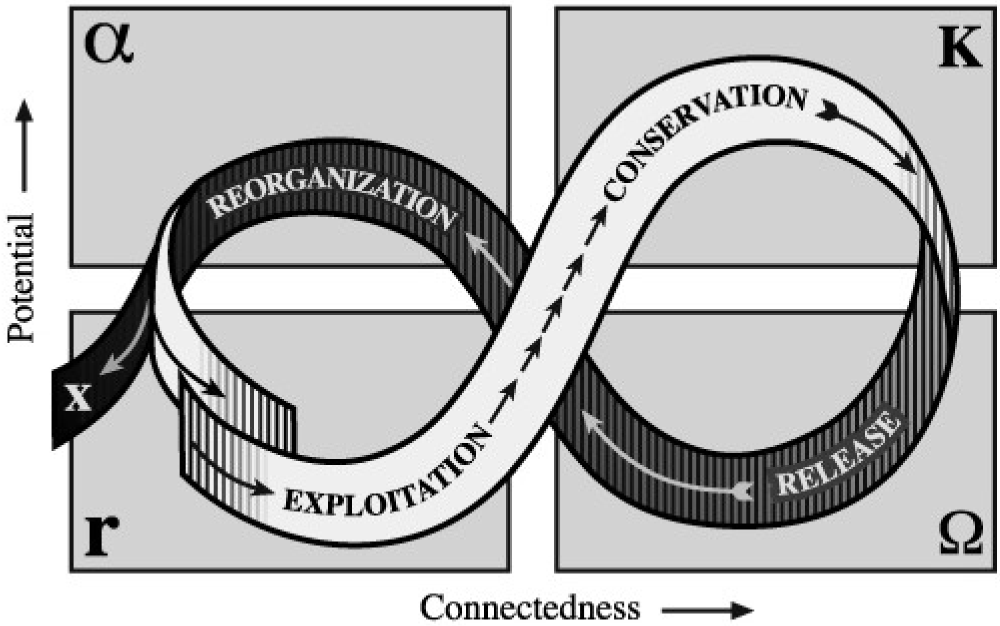

Figure 2.2. Adaptive cycle of complex SES. Source: Gunderson & Holling, (2002).

Such SES are inherently dynamic systems constrained by three factors: resilience, adaptability and transformability (Walker et al., 2004). Resilience comprises four factors: latitude, resistance, precariousness and panarchy. Latitude is the maximum level that a system can be changed before it is unable to recover, resistance means how resistant the system is to change and precariousness is how near to a threshold or limit the current system is while panarchy refers to the nested adaptive cycles operating at different spatial and temporal scales (Walker et al., 2004). Adaptability is the ability of actors to influence resilience along the four components that comprise resilience. Transformability is the ability to build a new system when the current one collapses due to maladapted ecological, economic and social structures (Walker et al., 2004).

2.13.2.1 Resilience

Resilience is defined in different ways by different researchers. The overuse of vogue concepts concerns academics that resilience and adaptability are becoming as meaningless as the word "sustainable" and it is necessary to discuss the different ontologies of resilience (Davoudi, 2012). Most studies are only a snapshot of a non-static situation but if concepts such as resilience are clearly defined and the inputs and outputs of the system are defined, then the application of such concepts is useful to the study of SES and their continued applicability to resource management issues.

Within this thesis, the concept of resilience is centred around the characteristics of persistence, adaptiveness, variability and unpredictability, which all relate to dynamic, evolving systems, which are able to flip into different stability domains (Holling, 1973), rather than a desired state of efficiency, where the equilibrium steady state perspective dominates (Connell & Sousa, 1983). A system's resilience is measured by the magnitude of disturbance it can absorb and then reorganise but still maintain similar levels of structure, identity, feedback and function of its previous state (Walker et al., 2004). Disturbances are not always negative events; they can be seen as a potential way to move from disadvantageous states to more advantageous states. However, ecological resilience, adaptive management and capacity within the social community are required (Nyström & Folke, 2001). Without resilience certain sectors of the system can become dysfunctional and potentially the entire system can collapse. Resilience is a produced property of SES and just as SES are dynamic and evolving, so too should resilience be; if resilience becomes stable and static, negative outcomes are common. Unchanging forms of resilience hold social or ecological parts of the system in unfavourable conditions; a social example is dictatorships, which are often strongly, yet statically resilient socio-political systems (Gunderson & Holling, 2002).

Walker et al. (2004) explain resilience with the following conceptualisation of the "stability landscape" of Holling (1973): SES are made up of components and variables, which exist within the "state space". This is the space in which "basins of attraction" (BA) occur and SES are situated within a certain BA. They are called BA because attractors (properties of the BA) move SES towards different basins and into different states, *e.g.* equlibrium is the attractor for equilibrium systems and 'alternate stable states' are the attractor for shifting systems such as coral reefs. Many forces interfere with the direct path towards the attractor state, such as disturbances, actors' decisions and random events (Walker et al., 2004). There can be several basins of attraction for any one SES, between which are "edges" or "thresholds" and together these various basins and their edges are defined as a stability landscape (Beisner et al., 2003). Returning to resilience's four properties of latitude, resistance, precariousness and panarchy, a change in the latitude of resilience means a change in the position of the edges of BA, changes in the depth of basins represent changes in the resistance of the SES to change, and movements of the SES within the basin mean changes in its precariousness to edges (Figure 2.3). Some basins may be desired, while others might be avoided by people.

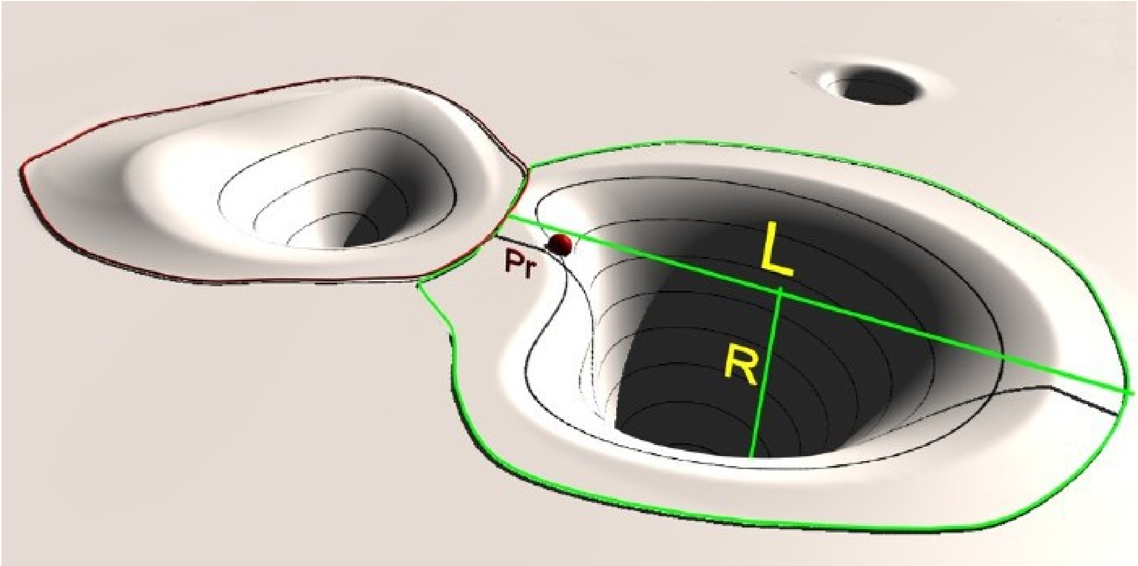

Figure 2.3. The stability landscape: basins of attraction,with edges between them and showing L (latitude), R (resistance) and Pr (precariousness). Adapted from Walker et al., (2004).

2.13.2.2 Forms of resilience

There are many types of resilience within SES: ecological, social, community, economic and cultural. Ecological resilience is often an ambiguous term yet its core attributes include high levels of biodiversity, spatial heterogeneity and connectivity; these criteria can be monitored through functional groups, and responses can then be reactive to changes in resilience factors rather than only after an abrupt shift has occurred (Nyström et al., 2008). Social resilience encompasses the local people who interact with ecosystems; an example of social resilience is the local knowledge individuals possess concerning their environment, which is often entrenched in local culture and helps in providing a subsistence living and/or greater livelihood security (Christie et al., 2003). Social resilience needs support from institutions which protect and nurture people's livelihoods. This broader social resilience is known as community resilience, which can be interpreted as a safety net for individuals during periods of unpredictability and disurbance in their lives. Economic resilience refers to the ability of local people to withstand changes in economic opportunities and income, as well as the adaptability of people to find different livelihoods or income generating opportunities. Cultural resilience ensures that local cultural identities and rituals that provide a sense of identity and belonging to those involved are preserved in the face of external disturbances such as encroaching external or foreign global pressures.

2.13.2.3 Ways to foster resilience

Various forms of capital, human, social, natural, financial and physical, can help engender resilience and can be a characteristic of the individual or the community. Human capital is the skill, knowledge, health and labour ability of people to work and accomplish their daily activities; without this they cannot access the other forms of capital (Senaratna, 2006). Social capital is an asset for building social resilience. Individual social capital relates to a person's access to different social resources and is important in creating a sense of belonging and in turn a sense of well-being among people. At the community level, social capital comprises "...relations of trust, reciprocity, common rules, norms and sanctions; and connectedness in networks and groups" (Pretty, 2003: 1913). Due to the four-dimensional interaction of capital and resilience, panarchy studies provide connections between community and individual social capital. Evidence shows that individuals can be resilient even when communities have low social capital (Pretty & Smith, 2004). Similarly, natural capital refers to the assets present in the natural environment providing an array of ecosystem services to human communities. These can be tangible, such as marine resources or intangible assets, such as clean air, rivers or seas.

Physical capital is in the form of infrastructure and produces goods needed to sustain livelihoods while financial capital is the financial resources people use to attain their livelihoods and activities. Financially poor communities will be lacking in financial capital and therefore more reliant on the other forms of capital which need to be protected or increased to improve their livelihoods and current situation (Allison & Ellis, 2001).

By encouraging diverse and varied strategies, mechanisms and processes of all sectors of SES, which helps increase levels of capital and dynamic resilience can be fostered which provides means of natural and anthropogenic elements to cope during periods of change and crisis. However, in many contexts people living in low resilience systems manage to cope with uncertain, oppressed and extreme situations. Such coping strategies are only effective in the short-term, and generally undermine or reduce resilience in the system (Nelson et al., 2007). If a coping strategy becomes effective in the long-term, it becomes an adaptive mechanism, which usually increases resilience (Adger, 2000). Whether coping strategies become adaptive mechanisms occurs via the adaptive learning capacity of communities (Nelson et al., 2007). All components of

SES adapt over the long-term and are forced to change by changes in the environment. Through successfully coping with the early onset and persistent effects of climate change in the Arctic, local communities have developed adaptive mechanisms to cope in the long-term with reduced sea ice coverage and a warming climate (Berkes & Jolly, 2001; Berkes, 2004; Turner & Clifton, 2009). Redundancy in coping strategies, *i.e.* multiple pathways available when disturbances and change occur, foster greater resilience and higher potential to form adaptive strategies.

2.13.2.4 Managing resilience

Identification of current levels of resilience, the drivers which impact on various parts of the system and how these factors interact and affect one another is crucial to managing resilience. Other important steps involve expanding the adaptive capacity and self-organising ability of local people; transparent and proactive governance and management frameworks which encourage such adaptation and organisation, as well as protection and help in times of high risk and crises. Managing for resilience requires good governance but also demands an active community empowered from the grass roots level, who with such power and knowledge, can incentivise local user groups to adapt and rebuild lost resilience in any sector of their system that is perceived weak and will gradually remove activities that destroy resilience in favour of those which promote it.

2.13.2.5 Resilience in coral reef systems

Coral reef systems exist in multiple stable states comprised of complexity and non-linear dynamics (Knowlton, 1992; Scheffer et al., 2001). Reef fisheries SES fit closely with the panarchy approach and can be incorporated into this model of evolving resilience and adaptive management to inform and derive solutions to the degradation of ecological and social resilience that has occurred during the 20th Century. There is a growing call among coral reef researchers to restore ecological resilience to coral reefs in the face of multiple increasing and accelerating threats globally. The overriding theme from these studies is that the chronic impacts on reefs from human activities make the reefs less resilient to natural disasters or large weather/ climactic events as well as further human impacts (Nyström & Folke, 2001; Hughes et al., 2007; Graham et al., 2006). For example, as the coral reefs in south-east Asia were showing signs of recovery from the 2004 tsunami, they still faced some of the many threats mentioned above, undermining their resilience, which prevents them from recovering at the same rate or at all (Hughes et al., 2010). It appears that the combination of stressors on reefs may induce threshold responses, *i.e.* SES fall into new basins of attraction (Figure 2.3) where wide-scale ecological alterations are experienced, such as destructive pathogen outbreaks or shifts to lower diversity states (Knowlton, 2001). Many long-term evolved SES are robust to thresholds that have maximised efficiency and are unlikely to be crossed, however, systems that have short co-evolutionary histories, such as fisheries management are more likely to pass thresholds more easily and fall into unknown basins of attraction (Walker et al., 2004).

Active reinforcement of resilience is needed for sustainable global reef management in heavily disturbed SES (Nyström et al., 2008). The cornerstones of resilience theory are helpful to furthering understanding of coral reefs and the linkage between coral reefs and human populations that depend on them (Folke, 2006). To build social and ecological resilience into these coastal communities requires a holistic view and also requires an understanding of what factors make a particular location unique among other similar coastal communities (Marshall et al., 2009) to help promote adaptability. This contradicts many conservation and fisheries management principles, which seek to find generic solutions and management options which can be unfurled across large geographic areas, in an effort to save time and money, but which are less likely to succeed due to the subtle differences and particularities of each separate location. An example is the formation of MPAs globally which often meet particular biological preservation targets but ultimately fail in many locations due to a lack of integration of local needs, knowledge and participation (Christie, 2004).

2.14 Local knowledge

The value of different knowledge systems has always been imbalanced. In general, objective, scientific and reductionist knowledge is valued in research, policy and development. However, the contribution of indigenous knowledge research in development and natural resource management is expanding and is being utilised as a further means to understand and improve human-environment interactions, especially in developing countries. This change in focus has resulted in a shift from top-down to more bottom- up approaches in development research, which has allowed for inclusion of local voices and perspectives (Sillitoe, 1998). A wider appreciation of the existence and importance of different knowledge systems among diverse communities has grown. The role of indigenous knowledge is not to replace scientific knowledge but to complement it or remain separate from it depending on the locality. Recently, endeavours to redress the imbalance of local people's knowledge systems and scientific knowledge have shown the complementarity of these divergent knowledge bases (Moller et al., 2004).

People who have lived or are living in close harmony with their natural surroundings possess indigenous ecological knowledge, concerning domains which scientific knowledge may not have discovered or of which it only has an incomplete picture, such as Palauan communities of Micronesia (Johannes, 1978) or Aboriginal people of Australia (Lewis, 1989). In countries where local people struggle with poverty and whose livelihoods rely on natural resources, often their specific knowledge systems have been overlooked in favour of western, expert-led scientific knowledge and technological solutions (Hoppers, 2002). If this western knowledge has failed to achieve its project goals, the fault has been placed with the local people or governments responsible for implementing the project (Jentoft, 2008). In contrast to seeking yet higher technological and scientific solutions, indigenous knowledge may enable vulnerable, local people to engage with and affect their own situations and environments more effectively when supported by local institutions and their own leaders (Jentoft, 2008).

How is indigenous knowledge and more specifically indigenous ecological knowledge to be defined? A suite of nomenclature has emerged due to the usage and research of local knowledge systems by various disciplines, professions and others. Indigenous knowledge, has been synonymised or at least linked with the terms 'traditional knowledge', 'local knowledge', 'folk science', 'people's science' and 'ethnoscience'. Traditional knowledge is commonly used but “traditional” has connotations of being unchanging and historical (Inglis, 1993). However, “indigenous” becomes a difficult term to place on people within parts of the world where migration and mixing of ethnicities and cultures has occurred for centuries (Posey, 2002). “Indigenous” is also a highly political term and generates a variety of images to different people (Heckler, 2009), as does the term local. Both appear to reinforce the difference and power-play between local and global scientific knowledge, or the assumption that this knowledge is inferior as it is not present globally. However, “local” does avoid politically weighted terminology and allows for the description of knowledge bases among modernised communities who gain their existence from natural resources (Heckler, 2009). In this thesis, I am concerned with modernised communities that have a strong connection and interaction with their environment and derive their subsistence from the marine resources around them. The divers I worked with are not "indigenous" in the sense that they are not the minority colonised people nor are they "traditional" in the sense of being static and from less modernised communities. Thus, I utilise local knowledge (LK) and local ecological knowledge (LEK) throughout this thesis.

Definitions of LK and LEK can be unclear, in terms of what knowledge they encapsulate. Inherent problems arise in defining these terms; some researchers believe it is restrictive to define such dynamic, shifting and gradually appropriated knowledge (Hobart, 1993). I interpret LEK as used in this thesis to refer "...to any knowledge collectively held by a population, informing interpretation of the world" (Sillitoe et al., 2006). Such knowledge can concern any issue, but in the context of this thesis, knowledge around marine natural resource management is of interest. Learned from birth, LEK is community based and enmeshed with local traditions and culture. It is not held in one place, person or group of people but is distributed among members of a community dependent on various factors such as age, experience, sex, or political power (Sillitoe et al., 2006). Transmission of this knowledge across generations occurs verbally and by repetitive practice. Learning is adaptive and dynamic as local conditions change or new ideas develop (Berkes et al., 2000) and, linked with the creation of institutions to harness this knowledge and methods to communicate it, forms the basis of an ecological model for conservation knowledge to evolve and for communities to self-organise and increase resilience after crises (Berkes & Turner, 2006).

LEK is based on the dynamic social, economic and environmental factors which influence a place and its people who have lived through events and observed the changes caused by these events and factors. LEK is paramount in scientific assessments that require local compliance and co-operation; the exclusion of local communities and their LEK is the reason why many conservation programmes fail and it is a compounding problem in the degradation of Sri Lanka's reefs and reef fish populations.
Environmental anthropological work has also shown the importance of local community involvement in conservation programs (Orlove & Brush, 1996). By working with and

complementing LEK, participation and interest in conservation or resource management initiatives are likely to be more acceptable to individuals or communities. With limited funding for conservation worldwide, it is hoped that conservation will become locally adopted and continued, rather than externally orchestrated as currently occurs.

There are inherent difficulties in working across knowledge systems and incorporating LEK with scientific knowledge, such as the challenges when LEK is incorrect on certain issues and/or where no consensus can be found, or agreed upon, among those with different epistemologies. However, by listening and comparing the local knowledge with scientific data allows for areas of overlap to be found (Sillitoe, 1998). Local knowledge can be too locally applicable and so unable to move into altered scenarios (Sillitoe, 1998). An example is the case of the Miskito Indian tribe of Amazonia and the turtle fishery, they relied upon for subsistence. The system changed rapidly from balance to decline and then collapse due to wider economic forces encouraging cash sales of turtles to nearby markets, which transformed the harvesting patterns and reduced subsistence strategies. The LEK and traditional management structures applied previously could not adapt fast enough to benefit from this opportunity and sustain the resource (Nietschmann, 1979). Local ecological knowledge is not a panacea for natural resource problems but should be appreciated for its potential in specific local contexts to complement top down management and provide a richer landscape for collaborative decision-making.

2.14.1 Local ecological knowledge among tropical reef fishers

The influential work of Johannes (1978) on Micronesian fishing communities raised awareness of LEK held among tropical fishers. Since then, LK systems among a variety of fishing communities across the tropics have been studied (Hviding, 1989; Aswani & Hamilton, 2004; Silvano et al., 2006; Wilson et al., 2006). Fishers are a source of detailed information on fish, their behaviours, habitat interactions, the seas in which they fish and meteorological and climatic changes. In tropical marine areas, until the last few decades, scientific knowledge of the marine resources and their interactions was scant and even now, despite the growth in research in tropical marine ecology, scientific knowledge is far from complete (Sadovy, 2005). Fishers who live and work in reef environments often hold far greater depth of knowledge in relation to timings of natural events and local fish ecology, such as fish spawning cycles and possess longer term knowledge concerning the changes in fish abundance over theirs and their ancestors lifetimes than visiting or newly trained marine biologists. Fishers' diachronic observations of oceanic species and their habitats, as well as their general focus on rare and extreme events are potentially highly valuable in filling scientific data gaps and broadening understanding of oceanic variability, especially in developing countries. By linking both the informal LEK and the formal training and scientific verification of such knowledge a management style more conducive to protection of nearshore reef fish populations could develop (Johannes, 2003; Christie & White, 2007; Poizat & Baran, 1997). Furthermore, improved research design has developed through the use of local specific knowledge (Drew, 2005). The participation of local people in the management and monitoring of tropical reef fisheries can also be more economically viable in areas where marine data are scarce; this could contribute to the development of management strategies applicable to multiple scenarios and locations (Aswani & Hamilton, 2004).

However, LEK may or may not conserve coral reefs and fish communities. This knowledge accrues from generations of attempts to increase catch and minimise effort in fishing and so, with increasing human populations in these localities, and the increasing threats described in Section 2.4, it is not guaranteed that LEK will serve to conserve and provide fish in a sustainable fashion. It is argued that if LEK is applied within a precautionary management framework it can provide valuable insights that can be verified with experimental work, which would take outsiders far longer to gain (Polunin, 1984; Aswani, 1998).

In addition to this, the collaboration of formally trained conservationists and local fishers and/or conservationists allows for a rich exchange of knowledge which enables local people to develop a scientific understanding or scientific ways of representing their local knowledge which would afford them respect, while the scientists could identify subtler intricacies of the area that may not be apparent to the visitor (Drew, 2005). An example of this is local people identifying culturally derived indicators of quality of life and sustainability far more different from those generated by external groups (Nazarea et al., 1998).

Possessing intimate knowledge of proximate drivers and causes of changes to locally important reef fish species means that LEK may help focus scientific studies to better determine the reasons for perceived declines using modern approaches and understandings that are not available to local communities (Moller et al., 2004). This was the case with the collaboration of western scientists and local communities concerning *Puffinus griseus* (the sooty shearwater) where the Rakiura Maori who harvest the chicks noticed a decline in numbers from their traditional monitoring methods and so western scientists began tracking the birds and discovered their trans-equatorial migrations brought them into contact with fishing vessels in the Pacific which resulted in drowning in nets. Their migrations also make them susceptible to global climate change of winds and their food supply (Lyver & Moller, 1999).

The broad variety of knowledge and wealth of information has been demonstrated by many studies in different parts of the world, and coastal communities are no exception. In one bay in the Philippines, local fishers utilise a folk taxonomy that covers hundreds of marine vertebrates and invertebrates, which not only names them based on physical characteristics but also identifies their economic and cultural importance (Whittingham et al., 2003). In the Indian Lakshadweep Islands, local fishers possess an intimate knowledge of many species of fish as well as their locations depending on the tides and lunar cycle (Hoon, 2003).

In traditional coastal communities the reliances and relationships people may have with the coastal resource has resulted in many customs, beliefs and traditions developing (Whittingham et al., 2003; McClanahan et al., 1997). Many spiritual beliefs result from close relationships with the sea and its resources. For example, in the Gulf of Mannar, India, it is believed that a god (*Muniyasamy*) lives in a coral mound near Appa Island so to avoid the god's wrath, the local fishers do not venture into this area, which happens to be a place of dangerous currents (Rengasamy et al., 2003).

2.14.2 Traditional forms of management

Traditional belief systems and LEK have often resulted in the development of forms of customary marine tenure (CMT), especially in the Pacific, which have roles in the social, economic and cultural spheres of local life but are still relatively unknown and yet provide lessons for local management efforts seeking to sustain marine resource yields (Ruddle et al., 1992). CMT systems regulate access rights or fishing gears[9] within their jurisdiction. They are powerful primary tools in managing and conserving

[9] Gear or fishing gear is the term given for equipment used to catch marine resources, whereas fishing methods refers to how this gear is used (FAO, 2005).

areas and also form an important part of societal relationships between neighbouring communities and within the same community (Hviding, 1998). Some examples of specific beliefs helping to manage fisheries include the sacred position of turtles in Samoa, which restricts their catch by fishers (Allen, 2007), and sharks are revered in many South Pacific islands as they were seen to be possessed by the souls of the deceased, which prevents them being fished in large numbers (Nichols, 1993).

Many forms of marine traditional management occur in different parts of the world, however most are linked to a sustainable livelihood, such as on Pacific islands, where fishers realise the finite nature of the resource and their isolation and hence harvest it sustainably (Ruddle et al., 1992). Other forms allow for interaction with neighbouring fishing communities, permitting fishing in exchange for products that are not available in their location (Johannes 1981).

There is a need for formal recognition of traditional management or local involvement, which has proved successful in other coastal areas, for example, in Vanuatu, where the government respects and encourages traditional management strategies which has created a positive relationship between government and their policies and local fishing communities (Jimmy, 1995). It may be more appropriate for management and enforcement to be dealt with by the local community, as they could implement and enforce strategies more effectively as they have an interest to protect their waters and coastline and have authority over those in their villages.

The potential for linking LEK with management schemes and formal scientific thinking remains largely undeveloped (Johannes, 1998a); however, more recent studies have often suggested involving LK and communities to improve conservation strategies, for example, in the Solomon Islands, indigenous knowledge and socio-spatial data has been incorporated into Geographical Information Systems (GIS) to help better plan and site marine protected areas (MPAs) (Aswani & Lauer, 2006).

2.15 Political ecology

Political ecology stems from cultural ecology, the viewpoint that culture was influenced and shaped by ecological constraints, and political economy, which politicises the economic practices and balances within certain contexts (Keil, 1998). Political ecology views current ecological systems against political, economic and social criteria that are inextricably linked each influencing the other, which leads to an appreciation of "...how ecology is political and politics are ecological..." (Robbins, 2011: 3). It extracts the relationships between these interacting factors to comprehend resulting environmental degradation or damaging practices.

Political ecology is also moving from linear chains of cause and effect, towards networks, which complement the shift in thinking from equilibrium systems to complexity and dynamism within ecological research. Power and control are central to the work of political ecologists, and one of political ecology's goals is to "...explain environmental conflict in terms of struggles over knowledge, power and practice and politics, justice and governance" (Watts, 2000: 257). Bryant & Bailey (1997) give three main characteristics of political ecology: the distribution of costs and benefits associated with environmental change is unequal, the alterations to the environment have implications for political and economic situations, and therefore this unequal distribution either reinforces or reduces current social and economic and political inequalities. Lastly, these inequalities are a feature of the resultant power relationships. Alternative power relationships between ecological, social, political and economic factors are suggested through political ecology. The theory follows a normative understanding, which according to Robbins (2011) asserts that there are alternative and more sustainable methods for resource management. From this richer understanding of interacting elements of environment and development, environmental governance can be improved. Furthermore, the decisions that local people make can be more clearly understood when an appreciation of the factors that shape those decisions are examined.

The applicability of political ecology within this thesis is that it helps focus on another level of complexity influencing SES, that of politics, governance and markets. This theoretical frame helps understanding of not only local level decision making, but also of the interaction across wider scales and among different actors, from businesses to governments to direct resource users commensurate with the panarchy theory detailed in Section 2.13.2. I focus now on fisheries governance styles, as the efficacy of the political ecology approach is seen when different styles of fisheries management found in different contexts are examined globally, and in relation to coral reef fisheries.

2.16 Fisheries governance

Governance is defined in the context of fisheries as "...a more informal based decentralised, shared, collective and inclusive decision making structure with multiple levels of engagement" (Gray, 2005: 2). Governance supplements government and creates respect among actors (Symes, 2006). Governance refers not only to the structure of decision making but also the principles involved, such as transparency, equity and the rule of law (Gray, 2005). The main three forms of governance in fisheries are extremely different in their outlook and means of application. These are hierarchical, market-based and participatory governance.

2.16.1 Hierarchical governance

Hierarchical governance is a centralised, top-down and bureaucratic system within which the state controls the usage of natural resources that fall under its jurisdiction and ownership. This system aims to prevent ToC (Hardin, 1968); critics of which argue that the ToC is far too general (Jentoft & McCay, 2003; Section 2.11). Furthermore, the state does not hold all knowledge on natural resource systems; usually such complex systems comprise other groups with valuable knowledge and insights (Kooiman et al., 1999). Without common approval, the state's control policies are often undermined and enforcement proves near impossible (Gray, 2005). However, the state must be involved in fisheries governance as there is a need for what the state can provide, "...democratic accountability, exclusive legal status in negotiations with third parties and legislative and revenue raising powers and coercive powers to enforce the law" (Symes, 1999: 87).

2.16.2 Market-based governance

Following Adam Smith's concept of the "invisible hand mechanism[10]", the economic rationalisation of market based governance is, that without government interference the market follows the rules of supply and demand, is consolidated by private property rights and as long as markets and users are protected by legal rights, the economic pursuit of self-interest benefits society at large (Dryzek, 1992). In this mode, governments should encourage those behaviours acted out by fishers or industry that benefit the common good and punish those that do not, thus leaving market forces to

[10] The invisible hand mechanism is the term used to describe the self-regulating mechanism of a free market, where individuals seeking to maximise gains and ambition benefit society overall.

move things through the "invisible hand" (Dubbink & van Vliet, 1996). Mutual self interest controls behaviour rather than the state or the community and this mode also holds the ToC as its conceptual model.

The individual transferable quotas (ITQs) bought and traded by fishers in commercial fisheries to avoid overfishing constitute an example of privatisation intended to ensure the market works for the common good (Jentoft & McCay, 2003). Nearshore fishing communities with a sense of ownership tend to manage their resources better than those under open access or state controlled management (Botsford, 1997). The widespread use of market-based governance is often underscored by the higher recognition afforded by the fishing industry to economic theory than other social sciences (Jentoft & McCay, 2003). Critics of market governance believe it benefits those within the system, but newcomers are penalised; it favours offshore resources and commercial fishing, not inshore and artisanal fishing, and can have adverse effects on entire communities who rely on inshore areas for income and services (Kooiman, 2005). As the market mode does not protect the marine environment directly or monitor fish stocks, there is concern that shifting control of the system entirely to market forces is not sufficient to ensure future sustainability of fish stocks and the ToC will result (Gray, 2005). However, there is evidence in developed countries that the use of ITQs for particular fish stocks (*e.g.* Australian southern bluefin tuna fishery) can aid sustainability (Campbell et al., 2000).

2.16.3 Participatory governance

Participatory governance operates at the level of the local community, rather than the state or individual (Schneider, 1999). Its overriding premise is that of consensus; it seeks negotiations rather than hierarchical styles of command or the market style of exchange. Participatory governance is gaining credibility as distrust has grown in expert opinions, in conjunction with the emerging agreement that experiential knowledge and public values are more important regarding social decisions than expert values (Sissenwine & Mace, 2003). Overall, it strives to find communalistic rather than individual solutions, by opening up lines of communication to all citizens and encouraging dialogue and the exchange of ideas. It is criticised for being costly, slow to respond to situations and potentially subversive of state-led policies (Mikalsen et al., 2007). There are four main types of participatory governance: industry self-regulation, co-management, community partnership and environmental stewardship.

Industry self regulation is common in developing countries where local communities, with high levels of autonomy over their marine resources, are left to self manage (Vandergeest et al., 1999). Co-management means power is shared between government regulators and fishing industry representatives (Jentoft, 2003). It is the role of both parties to find the best solutions although incentives are often needed to ensure co-operation, overall, users are proactive, not reactive and passive (Symes, 2006). However, issues relating to exactly who are defined as the actors, who is allowed a voice and to what extent government's role is still dominant, are all potential pitfalls with co-management (Mikalsen & Jentoft, 2001).

Community partnerships occur when the industry shares management responsibilities with all actors, excluding government (Sen & Raakjaer Nielsen, 1996). This appears to work well at the local level in artisanal nearshore fishing communities, where CMT exists and so incentives already exist to conserve local fish stocks (Sissenwine & Mace, 2003). Environmental stewardship has materialised due to the growing force of environmentalism in fisheries governance. It requires that the fishing industry adopts an ecosystems based approach to its management and ensures that views of society as a whole are represented. Examples are the Great Barrier Reef National Park, which is run entirely by marine scientists and environmentalists (Day, 2002) and the efforts to integrate Ecosystem Based Fisheries Management (EBFM) into Philippine reef fisheries (Aswani et al., 2012).

EBFM has recently supplanted Integrated Coastal Management (ICM) which sought to include different areas of the coastal zone as well as allow participation of all user groups, value LEK and strive for interdisciplinary and participatory research (Christie & White, 1997). It is now accepted that EBFM is a combination of customary marine tenure (CMT) systems and previous ICM strategies that were implemented in developing countries in the 1980s and 1990s. There is hope in the Philippines that by integrating all the attributes of EBFM, with existent ICM programmes and CMT, EBFM can be successful (Aswani et al., 2012). However, ICM had varied success depending on the location and whether existing forms of local management occurred with success and failure at initiation, acceptance, implementation or maintenance in the Philippines and Indonesia (Christie et al., 2007; Pollnac & Pomeroy, 2005).

Others claim that failures in tropical fisheries management lie with those who try to impose western models of fisheries management in developing countries with no genuine recognition of local methods, knowledge and management (Ruddle & Hickey, 2008). A further concern is that the continuing evolution of coastal management frameworks (single stock management to CMT to ICM to EBFM) may leave targeted local communities confused, disillusioned and/or disinterested in further schemes, especially if the promised benefits are not received (Pomeroy et al., 2010).

Implementing new paradigms such as EBFM is expensive and limited funding in the fisheries management sector of most developing countries prohibits such management without outside intervention (Aswani et al., 2012). However, in situations where these schemes are still a possibility, it is important to strive for local level participatory governance to mitigate anthropogenic threats and aid the recovery of fish populations and coral reefs. There is a need to integrate communities into fisheries management and planning; the close link between fishers and their communities due to their mutualistic relationship results in the actions of fishers having social and economic effects on the community. Changes in community structure affects fishers, and so more adaptive management can result from inclusion of fishers and their communities into fisheries planning (Jentoft & McCay, 2003). Often successful management schemes involving local communities have resulted from greater attention to local differences in culture and social complexity which influence actors in the community (Fabinyi et al., 2010).

A further advantage has been the empowerment of fishing communities through recognition of their forms of knowledge and through humility and tenacity between western scientists and local people (Johannes, 1998b; Berkes, 2008; Hickey, 2006). Embracing social and ecological complexity and utilising interdisciplinary methods can lead to not only potentially more successful management initiatives but also to valuable insights into reef ecology that western science is still struggling to uncover (Hughes et al., 2010; McClanahan, 2011).

Other forms of participatory governance include local-based pride and community action initiatives that are becoming more widespread in coastal communities, still reliant on their natural capital. These approaches may seem unscientific but may prove more effective than other more conventional strategies employed by natural scientists, such as MPA formation, which often disillusion local fishers and communities who feel excluded (Johannes, 1998b; Acheson, 2003). The need to collaborate more broadly involving other people's ways of thinking calls for a broad suite of tools and ideas to generate resilience in SES, fisheries and coastal communities.

2.17 Conclusion

It is important to study, explain and evaluate the threats and their impacts on coral reefs and other SES, as marine ecologists do. However, this thesis stresses that, once identified, such impacts need to be researched with new approaches that embrace complexity and interdisciplinarity – to bridge the divide between natural and social science – and seek to uncover the processes, controls and tipping points of these SES in order to create potential new knowledge from which solutions to human-environmental problems may be found. Ignoring the social or the ecological elements is only seeing and comprehending half the picture. The variety of approaches used in this thesis is selected to reveal the complexity in the ornamental fish trade of Sri Lanka and the necessity to comprehend the intricacies of this social-ecological system before interventions are applied.

Historical ecology can help understand what has shaped the present landscape and the current sociological characteristics of communities and their relationships with their environment. The theory of panarchy provides a conceptualisation of the SES in the "stability landscape" and raises awareness to view these systems as dynamic, evolving nested adaptive cycles influenced by resilience, connectedness and capacity. Knowing coral reef systems move between alternate stable states fosters learning and the potential for adaptability and/or transformation of elements of the SES or in its entirety. Methods to promote resilience and manage for resilience are required in vulnerable SES such as degraded coral reef fisheries and the importance of LEK in achieving this are strongly linked. Recognition of LEK and the potential for fishing communities to inform management, research and science all have the potential to increase resilience in locations where it is lacking. Collating all these elements is the need for adaptive participatory governance which, when analysed through the lens of political ecology, allows the wider national and global forces that affect a SES such as the ornamental fishery to be appreciated. Ideological forces often shape economic and political systems toward economic growth centred on capitalist consumerism and a desire for higher standards of living. Short-term profitability therefore often over-rides ecological sustainability and this is highly relevant to the international ornamental trade, especially in developing countries, such as Sri Lanka where tackling the unsustainable effects of economic growth are difficult as they are usually accepted as properties of modernity. These forces are significant in preventing sustainability as is the desire to simplify and statically manage resources.

The ability to predict future events and outcomes is based on the limits of our present knowledge and to capture the infinite complexities of the real world is not possible, therefore an optimal management approach is to allow for flexibility, dialogue and resilience to dominate as key attributes to ensuring sustained environments. By adopting such adaptive, non-reductionist approaches more of the complexity of human-environment interactions can be elucidated and provides a format to address in this study the question of the sustainability of the ornamental fish trade in Sri Lanka. Not only discovering if the fishery and trade are sustainable or not but identifying areas of the SES that are strong or weak, sustainable or not. Aided with this knowledge and an innovative approach framework more informed decisions can be made to manage for sustainability, which necessitates finding a dynamic balance between the health of coral reefs and the threats they face with the human needs of divers' future livelihoods in southern Sri Lanka.

Chapter 3

A narrative on the development of the project's methods

3.1 Statement of Purpose

This commentary aims to provide the reader with a clearer understanding of how this multi-faceted project came into existence and how different methodologies were employed in the field. It gives insight to the reader as to how I balanced my time between the various tasks, how I accessed various types of data and portrays the level of my interaction with local communities. Ways in which the interdisciplinary nature of the study enhanced the research process are demonstrated, without ignoring areas of difficulty and how these were tackled and / or overcome.

3.2 First field season: January 2009 – July 2009

3.2.1 Sri Lanka as my field site

I wanted to work on a project in an applied context, one that had an obvious conservation focus but that genuinely included local communities in efforts to find long-term solutions to unsustainable practices. The PhD position at Durham University to study the ornamental fish trade in Sri Lanka appeared ideal. I would work under two supervisors from two different departments of Anthropology and Biological and Biomedical Sciences, to investigate the aquarium trade of reef fish in Sri Lanka, from both a marine ecologist's view of conserving and managing the "resource" and from the anthropologist's view of uncovering the human dimensions of this system. What drives this trade? How might a sustainable conservation solution be found if all parameters were explored and understood by a one researcher adopting interdisciplinary research methods? One supervisor, Dr Sandra Bell, through collaborative links between Durham and the University of Ruhuna in Sri Lanka, had initiated the project concept and contacted a Sri Lankan marine biologist, Dr Pradeep Terney Kumara (hereafter referred to as Dr Terney), to co-supervise in Sri Lanka. My other supervisor, Dr Martyn Lucas, had not been to Sri Lanka but was eager to co-supervise an inter-departmental and international project. Jointly, Dr Lucas, Dr Bell and I, through consultations with Dr Terney, developed the initial concept and produced an interdisciplinary PhD proposal.

3.2.2 Pre-field planning & training

Once funding was secured via the Economic and Social Research Council and Natural Environment Research Council's (ESRC-NERC) unique interdisciplinary scholarship scheme, the process began to move fast. As we had to work to the seasons of the monsoon, my year of fieldwork was split into two six month seasons to coincide with the calm seas and peak fishing season in the south of Sri Lanka. Together with Dr Terney in Sri Lanka and my UK supervisors, we produced a preliminary methodology. We strove to ensure the methods were interlinked so that the entire project demonstrated clear linkages and complementarity between the two disciplines for its success.
A summary of the development of the methods in the project is described in this section but will be elaborated upon in later chapters. These comprise:

- Conducting coral reef surveys and underwater visual censuses of fish.
- Shadowing divers to assess fishing practices and record catch and effort data (focusing on snorkellers rather than SCUBA teams, as explained in Chapter 1).
- Recording catch data from direct and indirect sources onshore.
- Combining participant observation, individual and group interviews and focus groups, to identify the roles, motivation and attitudes of different sections of the coastal communities who are involved in, interact with or are affected by the ornamental fishery.

A few short months were spent in Durham preparing for the initial fieldwork season; other than the obvious preparation for a long field trip, I attended several taught Masters courses in the Anthropology department to learn social science methodology as my academic background was purely biological. Thus I arrived in Sri Lanka the first time, trying to assimilate interdisciplinary ideas which although new to me, are part of a burgeoning and thriving research area. My intention was for this project to contribute to the literature in interdisciplinary conservation, combine different epistemologies and straddle the activities of two departments. I had to determine how to translate the methodological framework on paper into reality on the ground in a country with which I was unfamiliar. Effective integration of both disciplines, whilst preserving their separate integrity was the key to attaining my aims and objectives.

3.2.3 Arrival

The timing of the first field season was planned to allow for adequate anthropological training, while coinciding with the perceived calm season. Landing for the first time in Sri Lanka, I had the contact details of two people: Dr Terney, my local supervisor and a fisherman whom I knew only as "Chintiga". I felt unprepared despite my clear and rigorously structured biological methodology. I needed to work quickly to select reef field sites where ornamental fish collection by snorkelling occurs; conduct underwater visual censuses of reef fish and coral cover at each site, and accompany divers on their snorkelling trips to determine catch and effort levels. I also needed a control site, somewhere where no or little fishing occurred, so as to compare the reef survey findings at fished sites compared to non-fished sites.

The anthropological side, on the other hand, was more open. Dr Bell and I had discussed some qualitative methods for conducting ethnographic studies and chosen participant observation and a combination of other research tools such as semi-structured interviews (SSIs) and focus groups. I decided not to use questionnaires or other quantitative based anthropological methodologies because of the constraints of sample size and time and moreover they would not provide the depth of response required. I had to trust in my anthropological supervisor's words that all would become apparent to me on the ground.

My early links began through Dr Terney at the University of Ruhuna's campus at Matara where I spent a lot of time during the first few weeks. I met very helpful postgraduate students and staff who were interested in my forthcoming fieldwork and appeared keen to assist me. My days varied between carrying out further background research and consulting sources at the library. I carried out frequent snorkelling excursions to improve my reef fish and coral identification work and to determine the optimal methodology for the reef surveys. I was perpetually seeking contacts with ornamental fish divers, buyers or others involved in the trade.

Dr Terney suggested six to eight possible field sites with adjoining villages where divers collect ornamental fish from the nearshore, shallow coral reefs. The choices were limited as not all coastal villages have divers who perform this type of fishing. With the help of postgraduate students from Ruhuna, I visited the potential sites to make contacts and assess which could become the field sites. When time allowed Dr Terney accompanied me on snorkelling excursions, which greatly enhanced my identification of coral, fish and other substrate organisms. After these morning trips, Dr Terney introduced me to locals in the villages, including fishers, with whom he was acquainted and could be useful to my work. His relations with the fishing communities in these villages are very positive and gave me a head-start in developing trust with the divers and in initiating further relationships with the communities at my eventual field sites.

After several visits both with Dr Terney and alone, and after discussions with my Durham supervisors, I decided to focus on four field sites. One site needed to be a control site and Hikkaduwa was selected for this purpose, being the only marine protected area (MPA) in the south west coastal region. I then selected three open access fishing sites, all of which had significant numbers of divers and several fish buyers within each village. Other sites were not included due to various factors, such as few divers seeming to fish regularly, few contacts or routes of introduction seeming available, or access would not be easy or would be met with some resistance. Although I was living at a potential field site, Bandaramulla, I omitted it for the same reasons. However, the divers and buyers I met in Bandaramulla introduced me to fish buyers or divers in nearby villages who were their friends.

I also chose the four sites based on their physical distance apart. To compare fish abundance across sites needs geographical independence, *i.e.* the individual fish to be counted should not move between sites. The total of four was chosen for logistical reasons; time was limited due to the approaching monsoon season and my fieldwork period so it would not be possible to conduct detailed research across more sites. I continued to live in Bandaramulla as it is located between two selected sites to the east and two to the west, helping to optimise time and cost efficiency in visiting each site. Another reason for choosing Bandaramulla was that I found people in my study sites were eager for me to stay in their village but indicated to me that they would feel snubbed if I lived there, but spent a lot of time in other villages during the day. I thus avoided upsetting people unnecessarily by not favouring any one site more than another through my residence.

3.2.4 Translator

During my first few weeks, I learnt as much of the national language, Sinhala, which is spoken ubiquitously in the southern region, as I could. Time to learn Sinhala had not been scheduled into the research plan so my competence was quite limited and to ensure good communications between the locals and myself I needed a reliable translator and assistant. I assumed one of the postgraduates who had helped me initially would fill the role but this proved impossible for several reasons. For example, some lacked the ability to interact with the divers on the divers' terms or failed to understand that I sought the divers' thoughts and so they answered my questions or led the diver in their answers. However, the over-riding reason was these students' lack of availability due to their study timetable. Then some undergraduates introduced me to Duleepa, who could speak English fluently but was not enrolled at the university. He was not from a fishing community nor had a marine science background; he asked my questions precisely and translated exactly the answers the fisherman gave, not colouring the questions or responses with his own slant. I hired him and he proved to be an invaluable translator and field assistant. For clarity I will refer to my activities in the first person, but in any situation where communication in Sinhala was essential, Duleepa was at my side.

Once the scoping activity was complete, my chosen sites (Figure 3.1) emerged as:

- Hikkaduwa, which is a tourist marine protected area, where Dr Terney introduced me to many of his friends and colleagues;
- Kapparathota, the village where Chintiga lived, and whom Dr Bell had met previously. University of Ruhuna students helped me to locate him initially;
- Polhena, where Dr Terney and some students and staff from the university introduced me to ornamental fish divers;
- Thalaramba, where I made acquaintances with marine ornamental fish divers and buyers with Duleepa.

Although the scientific method was consistent across sites, the social dynamics of how I worked and interacted in each village were quite different; I explain these in Section 3.4, which follows the discussion of the evolution of my methodology in a chronological framework.

3.2.5 Underwater visual censuses

A specific objective of the project was to assess impacts of fishing on each reef and to determine each reef's current condition and in order to do this, underwater visual censuses of fish and substrate were necessary. Once site selection was complete at the end of February, I had a short window of calm weather left before the start of the south-west monsoon, so I tested methods for underwater visual censuses of reef fish. Only a brief overview of these reef survey methods is given here; an in-depth description is given in Chapter 6.2.2.

Before entering the field, my aim was to stratify selected reef sites within overlaid grid squares, according to substrate type. Depth is often used as a stratifying criterion, however as my sites were limited to the nearshore environment and snorkelling, depth did not vary greatly. Extensive manta tows are needed to carry out such stratification when reefs are extremely patchy. Manta towing is a method that rapidly assesses a reef site; the observer is towed behind a boat while simultaneously observing the sea floor and stopping occasionally to record sea floor coverage by different biota.

Due to the shallow reefs in my study sites it was impossible to run a motorboat systematically over the reef area. I experimented with other crafts such as rowed fishing boats but these too failed to move easily over all reef areas. It was decided, after consultations with Dr Lucas, that the best strategy would be to select random grid squares overlaying the entire reef area which would be stratified by only surveying a certain number of points of each different main habitat type. Once an agreed upon minimum number of ten point counts per substrate were completed, then no further counts would be performed for that substrate type and further counts were only conducted in randomly selected squares comprising other habitat types.

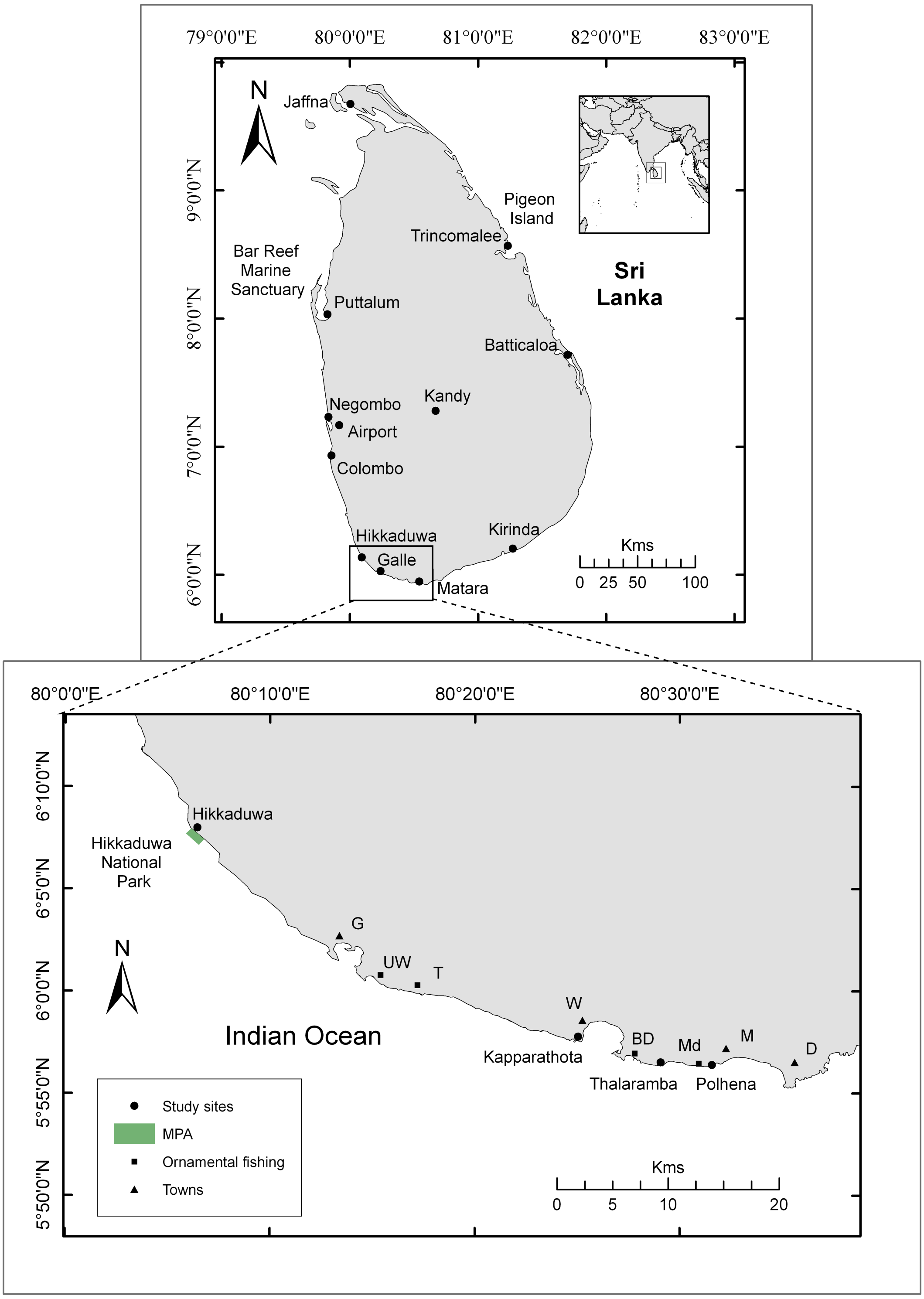

Figure 3.1 Map of Sri Lanka with major towns and cities related to the ornamental fish trade marked. Study sites are shown in the enlarged section, as well as other ornamental fishing villages: UW = Unawatuna; T = Talpe; BD = Bandaramulla and Md = Madiha; and nearby towns: G = Galle; W = Weligama; M = Matara and D = Dondra.

Initially fish counts were to be carried out using the belt transect method (English et al., 1997), however this method when tested at the study sites proved unsuitable in the shallow (0.5 - 1.5 m), high wave-action sites. This was for a number of reasons: ensuring the transect tape remained extended along the substrate proved difficult, as did swimming in a straight line without injuring self or damaging the coral due to the currents, wave action and shallow depth. Therefore it was decided to use a modified version of Bohnsack & Bannerot's, (1986) point count method, which was used in a successful reef fish census in Indonesia by I. Côté (pers. comm.) and suited these local conditions. This adjusted method was tested by performing fish counts at five different points at one reef site and deemed satisfactory. In addition, I decided to use a kayak to conduct the point counts so as to not damage coral, craft or observers. Many divers had helped me test the reef survey methodology as they had access to different crafts, were curious about my intentions and knew the reef areas well. Such cooperative interactions enabled me to slowly build up rapport and trust between us (Agar, 1996), which was necessary when accompanying them snorkelling.

3.2.6 Weather problems

The alterations to the reef censuses consumed time and the sea and weather conditions became unsettled even before the south-west monsoon season began. Local sea conditions are usually only calm in the mornings so little detailed work could be done later. By mid to late March 2009, the sea conditions had deteriorated so that visibility in the sea was too low to carry out surveys and fishing trips also became less frequent; consequently, no fish abundance data was collected during the first field season. The monsoon was building and various Sri Lankans at different times during March told me, "*it is now out-season*". Although disappointed, I knew I had worked hard for two months but felt I had achieved little except to ensure everything was in place to successfully complete the reef surveys which, as agreed with my supervisors, would now be postponed to the following field season (November 2009 – March 2010). It was further agreed between us that I should now focus on the social, cultural and economic data collection. Many divers told me that they stayed home for all or large periods of the out-season, so I interviewed people during this period when they were more accessible.

3.2.7 Shadow fishing trips

Testing and finding an appropriate survey method was interspersed with carrying out diver shadowing trips whenever possible. I had to carefully plan and organise my days to do reef survey work and to ensure I shadowed enough snorkellers, enough times for my data to be reliable. To compare catch and fisher effort levels among my fishing sites, it would be necessary to conduct a certain number of replicate shadow fishing trips. I also needed to carry out a certain number of replicate trips with the same diver as well as shadowing different snorkellers in order to examine variations in behaviour and to sample overall patterns of fish capture and possible coral damage. I intended this replicate number to be five; higher than three (the minimum number of replicates in any test) but low enough to be feasible for my schedule, yet high enough to reduce the variance of the mean recordings among different divers and sites. Therefore, in shadowing five different snorkellers, on five different replicate trips I planned to conduct at least 25 snorkelling trips at each village. By the end of March 2009, I had only carried out 16 snorkeller shadowing trips in total.

Fishing trips are not a guaranteed daily occurrence. Divers only work when the sea conditions are favourable as they need good visibility, and one trip can be over four hours long. Due to sea conditions deteriorating after 14:00, usually only one trip is made per day. I organised these trips with divers to whom I had been introduced during my site selection and through random meetings or snowball sampling, which is when one meets one person and from them discovers further contacts and that process is repeated (Bernard, 2011). In this way, I began to find different divers to accompany. Normally I would ask a snorkeller if I could shadow him the next time he was going fishing and if he agreed we would organise a time and place to meet before going out. I always took time to explain my project and the data I would collect while he was fishing and then check that he was agreeable. When the rendezvous time was kept, (they were often missed) I followed him to his point of entry armed with a waterproofed, hand-held Global Positioning System (GPS), camera and slates to record the data.

I snorkelled close enough to the diver to observe his behaviour and catching method, yet gave him enough space to carry out his fishing without me affecting his chances of success. During each trip, catch, effort, behaviour and environmental variables were recorded. These included: total time in the water; net and mesh size, the number of net throws; numbers, species and sizes of fish caught; number of times the metal bar was poked into coral; number of times corals were broken and size estimation of the damage; number of times coral was stood on; GPS markings where divers damaged coral and caught fish; sea surface temperature, visibility and sea conditions.

These trips lasted from two hours to over four hours. On returning, I accompanied the diver to where he sold the fish, usually a local buyer in the village. At the buyer's or at our beach exit point, other snorkellers were also returning so I could directly record their catches from their plastic bags. Through such trips, the divers and buyers gradually understood my research and became accustomed to me. After they had sold their fish I remained with the diver, or group of divers, and we would go to someone's home for lunch or a cup of tea. During these lunchtime meetings I could query observations I had made during the fishing trip or behaviours that confused me.

3.2.8 Daily routine and participant observation

I found the timing of the diving activity was conducive to interdisciplinary work. The divers and I went snorkelling between 08:30 and 10:00, rarely going out before or after that time and always returning by 14:00. A morning could be spent either on a fishing trip or on testing fish count methods, but not both. After a meal I could spend the whole afternoon talking with different participants or visiting buyers to record catches that arrived later in the day. On days of poor weather, my informants would stay at or near their homes and I had time to begin collecting ethnographic data through participant observation as well as collecting the fishing and ecological data. I found because I participated in an activity with the divers and thus saw and experienced their work at first hand, they were more willing to discuss the various factors I wished to investigate and uncover. These areas of interest are listed and described in Chapter 1. Evenings were spent transcribing data onto the computer.

3.2.9 Indirect recording of catch

Large numbers of ornamental fish are caught by SCUBA divers and are brought to the same buying facilities as the snorkel catches. SCUBA diving teams also catch a selection of "*food fish*" species for their own consumption or to sell in the village. To record the SCUBA catch and the snorkel catch on days I was unable to accompany divers I waited at the boat arrival points or at the buyers' facilities at particular times in the afternoon. Many divers and young boys from the village would gather to see the catch, or to bargain for the food fish caught, or to help with packing and sorting the ornamental fish. Those periods before the boats arrived were good to meet and talk with different divers or company officials who may be present to ensure their orders were filled. When the boats arrive, there is considerable activity and I made sure I did not hamper their work progress. Most buyers allowed me to directly record the numbers, species and sizes of fish as they sorted and packed them. Once the flurry of activity was over most people would cycle or wander home. By the end of the calm season through repeat visits, casual conversations and demonstrating my interest in their business and lives, I had built up trust with several buyers and I was welcome to visit their homes, watch and record any activities without causing concern. This was by no means a simple or quick process. It took time to find the various buyers in each village, discover their divers and the snorkellers and slowly gain this trust and acceptance.

The beginning of April brings preparations for Sinhala New Year and for two weeks the country comes to a standstill. Few people work and most return to their home town and spend the period with family, having meals together, exchanging gifts, partying and visiting temples. Fishers, university staff, students, and other Sri Lankans I had met in the area invited me to their homes for lunches and dinners almost daily over a ten day period. Sinhala New Year appeared to be the definitive sign that the out-season had begun.

3.2.10 Out-season and semi-structured interviews (SSIs)

The aim of the anthropological aspect of my project was to carry out a qualitative, ethnographic-based study on the social, cultural and economic aspects of the ornamental trade, using primarily participant observation. This would allow me to become involved with the daily tasks of the fishing communities, record my observations and develop a perspective on the activities and characters of the people involved (Bernard, 2011). I used this methodology throughout my two fieldwork seasons and recorded everything in an ethnographic journal. However, at this early stage in the fieldwork, not being able to converse fluently with many of the participants in my study, as well as the fact that I had spent considerable time either at the campus or in the sea, I was still relatively unknown by many of the diver groups. It would have proved fruitless to have spent each day unable to converse with the divers and might also have left them feeling uncomfortable, as I was always viewed as a special guest in their home or village. In consultation with my supervisors, I decided to carry out SSIs with divers, buyers, fish export company officials, government officials linked to the trade and tourism operators at my field sites.

Using snowball sampling, I could find and interview many divers and other actors of the trade. Informants varied from casually accepting my request for an interview to others demanding an interview. SSIs are widely used to collect specific information from key informants on a specific topic and the method allows the interview to follow a loose structure, which can be adapted as the interview proceeds (Bernard, 2011). I uncovered a lot of important background and detailed information in this way, because participants digressed from the topic to follow other thoughts and when that was exhausted we would return to the prepared questions. The focus of the questions also enabled participants to better understand my purpose and what I was investigating. Through open ended interviews, further trust was fostered which proved invaluable in later field seasons. I believe interviews were more valuable than just the information they generated as they provided a rewarding way to gain a deeper foothold within the communities. Interviews were conducted through my translator, were translated *in situ* and were audio recorded.

Interviews with divers were the longest and included their path into this fishery, the methods used, their earnings, their views on the sustainability of the fishery and their ecological knowledge. In addition, we also discussed family history, household data, experiences of the tsunami and perspectives on alternative livelihoods, particularly on breeding ornamental fish (see Appendix A). During the out-season, the different field sites demonstrated the few different income options available to the ornamental fish collector. I joined and observed the divers for short periods as they engaged with these various, different activities (see Section 3.3.1). Over the course of the study SSIs were carried out with 12 divers in Kapparathota, 14 in Thalaramba, 11 in Polhena and 14 at several other villages within the southern region, where ornamental fish are collected.

Interviews with local fish buyers covered similar areas to the divers, as many of these men are or were divers, but the interview schedule also included questions concerning their small businesses (see Appendix B). Tracing the market chain further, I conducted interviews with export company representatives; these focused on their business, the sustainability of the trade, and their role in protecting the resource base (see Appendix C). The relations of each actor type with other levels in the trade were determined.

As the ornamental fish trade is a predominantly male activity in Sri Lanka, there was little opportunity to speak with and meet women related to those involved in the trade. However, I wished to understand the role of women in the communities particularly in household decision making and their views on their husbands' or sons' livelihood choices (see Appendix D). It proved difficult to have open discussions with women as a foreign, young male. For this reason, I selected Sri Lankan female fisheries students to interview the women as then they talked more freely. The students were introduced to the wives and mothers of the fishers already involved in my study and then they returned alone at convenient times to conduct the interviews.

For the remainder of my time in Sri Lanka I visited each village, speaking with different actors and organising meetings on an informal basis with divers and buyers. More formal meetings were scheduled with company representatives and government officials in Colombo. Some actors were suspicious, mainly those higher up the market chain, but after explaining my project and background I was never refused a meeting, though some people were more informative and co-operative than others.

3.2.11 Focus groups

Towards the end of my first season, once I had carried out individual interviews with at least 10-15 divers and nearly all the buyers in each village, I organised a focus group in each of the three fishing sites with the help of a diver or buyer as discussed with my supervisors. Focus groups are an effective method to determine overall group ideas and derive local knowledge (Bernard, 2011; Olsson & Folke, 2001). By effectively using group communication this method would generate different data from individual or even group interviews (Kitzinger, 1995). The divers who helped me organize them ensured that approximately eight to ten divers, both old and young, attended and that attendees knew the time, place, duration and that refreshments would be provided. The focus groups were held at a location where all felt comfortable to talk and discuss freely. Divers' local knowledge was uncovered through making visual representations, such as fishing site and effort maps, useful in comparisons to scientific maps in other local knowledge studies (Sillitoe et al., 2004:177) as well as seasonal calendars of times when certain fish species breed (Silvano et al., 2006). Village social wealth maps were also created to show some comparison of financial wealth among the buyers of the village and social position amongst the ornamental trade actors in the village (Bunce et al., 2000). Divers' access to amenities, their safety and other factors considered important to their quality of life were also discussed. Different activities were performed such as: priority ranking exercises, to determine divers' reasons for their choice of livelihood and concerns they had; time use analysis of their activities during both the monsoon and non-monsoon periods; and historical timelines depicting fishing conditions, earnings and village conditions over time. Participants evidently took the tasks seriously, working conscientiously and apparently enjoying the process.

3.2.12 Alternative livelihood trial

Currently there are few alternative livelihood possibilities for fishers in these areas. Divers were keen to find alternative sources of income as ornamental collecting does not provide enough income alone during the out-season. From my extensive social interactions with the four communities, I determined which divers would be the best and most willing candidates to run the ornamental fish tanks, which my supervisors and I had agreed to provide in the second field season. From this, we could evaluate the feasibility of introducing ornamental fish cultivation as an alternative livelihood. We would supply one tank per village and assess the difficulty of growing and breeding *Amphiprion* (clownfish) or *Pomacentrus* (damselfish) species in captivity by the divers.

3.2.13 Independent reef fishing observations

I carried out independent observations of the different fishing activities performed during the out-season around the nearshore reefs when I had spare time, such as the stilt fishing, hook and line fishing from the beach or off catamarans. I recorded numbers of fishers, time spent fishing and species and numbers of fish captured. Fishers were comfortable with my presence by now and important data was collected to provide an indication of fishing intensity in the study areas.

After my first field season I had spent six months in the area both during the season and the out-season, visiting all sites and living with several fishing families and was developing an ever clearer overall picture of the current social and ecological characteristics of each of my study sites. These observations were enriched in the second and third field seasons; however, I portray here the situation as I found it initially in order to familiarise the reader with the study villages and reefs, how I was involved with local people at each site and articulate the way of life of divers in the ornamental fishery, which is beneficial to understanding the continued chronological development of the methodology later in the chapter as well as for clarity throughout the thesis.

3.3 Socio-ecology of the villages

My four field sites are situated between Colombo and Matara along the south-western coast of Sri Lanka. Kapparathota, Polhena and Thalaramba are fishing villages with separate nearshore coastal reefs where ornamental fishing occurs (Figure 3.2). Hikkaduwa is a small town where its nearshore reef has been designated a marine protected area (MPA). Hikkaduwa is bisected by the Galle road so the beach and reef area lies only 20 metres from the road's western edge, whereas the fishing villages nestle close to the coast in locations where a greater distance between the road and the beach occurs. All sites form part of a continuous ribbon development that stretches along the coastal Galle road between Colombo and Matara. The villages, with similar populations of 1000 – 2000 people (see Table 3.1 for exact figures), are predominantly Sinhalese, Buddhist peoples of the Karava caste, one that is traditionally associated with fishing. Fishing is thus the prime occupation of most males in the villages, whereas tourism and related service industries provide the major forms of livelihood in Hikkaduwa. All the study sites were affected by the 1998 El Niño event and the 2004 tsunami, both of these large-scale environmental disturbances have left lasting changes to both the reefs and the communities of these villages (see Chapter 4.4.5).

Most of the true coral reefs in Sri Lanka lie in particular coastal locations within 500 m of the shore. The coral reefs bordering the study areas are in this respect typical. The reefs are small, fringing and/or patch reefs[11] in shallow water with gently descending reef slopes, easily accessible from the shore and under constant human pressure. The reef in the National Park comprises a fringing coral reef with an inshore lagoon, a reef crest and a reef slope.

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[11] Fringing reefs are one of the three main classifications of coral reefs, the others being barrier reefs and atolls, and are comprised of a reef flat and a reef slope. In fringing reefs extending to the shore as in Sri Lanka, the reef flat extends to the shore line, there is no back reef, just the reef slope which slopes into deeper water behind the reef crest, which occurs where the waves break onto the reef. Patch reefs are, as their name suggest, comprised of small patches of live coral interspersed with other substrate such as sand, rock or seagrass.

The fishers in these villages engage in various forms of fishing which occur in the nearshore and offshore areas proximal to the village. In the nearshore areas, fishers engage in hand and line shore fishing, spearfishing, snorkelling for ornamental fish, lobsters and octopus, and occasionally net fishing for parrotfish (Scaridae), snappers (Lutjanidae) and mullet (Mullidae).

In contrast, SCUBA diving for ornamental fish, lobsters and octopus and subsistence food fishing from boats with engines or traditional rowed canoes with outriggers, *oruwa,* occurs mainly in offshore areas. For my study, I identified those who classify themselves as diving for ornamental fish as my specific informants and although I also consulted a specific group of those who fish for food, they were fewer in number and we met less frequently. A summary of the user groups I engaged with in the ornamental fishery in Sri Lanka is provided in Table 3.1, with details of numbers per group per location, including the total number with whom I interacted during my study.

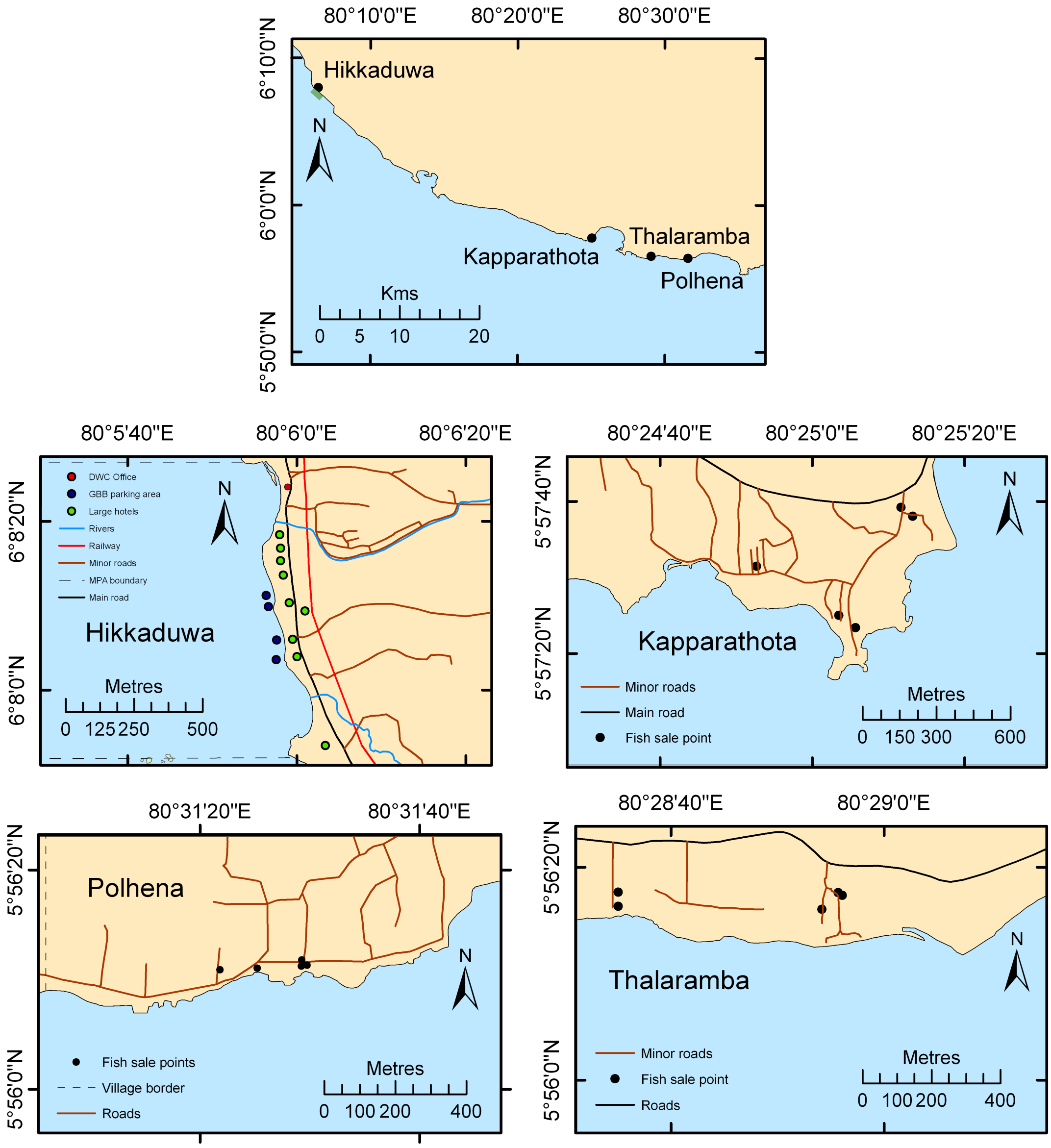

Figure 3.2. Map of study sites in the south-west region of Sri Lanka and each study site individually. The sea areas shown encompass the nearshore coral reefs where snorkellers fish or the extent of the marine protected area at Hikkaduwa.

To clarify all the different user groups referred to throughout this thesis, I provide some key definitions. For the purposes of this study, d*ivers* is a general term representing all ornamental fish divers in Sri Lanka, both snorkellers and SCUBA divers, where there is a need to distinguish the two groups I do so. As b*uyers* is the term divers use to denote the men who buy their fish, I use this term to refer to these individuals. These *buyers* are known by export companies as *suppliers*, so the two terms refer to the same groups of men and I use them interchangeably. I use the term e*xport companies* or *exporters* for the businesses that export marine ornamental fish from Sri Lanka to foreign destinations. I use the term *fishers* for all other types of non-ornamental fishers.

3.3.1 Way of life of divers

Snorkellers fish in the mornings, the best period for optimal weather and sea conditions, for between two and four hours, usually returning to the shore by lunchtime, when wind speed increases and sea conditions and underwater visibility deteriorate. They tend to fish alone, but some younger ones fish together or accompany more experienced divers. Earnings from a trip are split equally between divers; hence to maximise profits inexperienced snorkellers prefer to snorkel in groups, whereas experienced divers prefer to fish alone. After selling their fish to local buyers they are free in the afternoon and evening. Snorkellers use a mask, snorkel and fins and normally a *moxy* net (Figure 3.3) to catch fish. They also carry a metal pole about half a metre long, known as a *tickler.* They use the *tickler* to help them hold their position in strong current and wave areas or to poke into crevices to flush fish from hiding places as well as to beat the water to force fish to hide under rocks or coral fragments. They carry several clear plastic bags for caught fish that they tuck into a waist belt, that is usually made of rubber. Most snorkellers' fishing gear is basic, second-hand, well worn and damaged from the sea and substrate. Masks often leak, fins are cracked with pieces partially detached and snorkels do not have water purgers. Most snorkellers' gear is patched together with sections of rubber to preserve its functional qualities. The work is strenuous and tiring as it occurs in high wave action areas where currents can often be strong. The snorkellers cover a wide area of the nearshore village waters, only resting briefly to clean masks, bag fish or check their position. Snorkellers fish in shallow reef areas and few venture far from the shore and as most snorkellers are extremely fit they can perform repeated free dives of 1- 4 m depths without taking long recovery pauses between dives. Many snorkellers also snorkel on nights when calm seas occur with dive torches to spear food fish in the nearshore waters. Risks and dangers to snorkellers are few: cuts, grazes and bruises from impacts with coral and rocks, bites from moray eels (Muraenidae) and certain aggressive fish species and stings from jellyfish or scorpionfish (Scorpaenidae).

Figure 3.3. Ornamental diver placing the moxy *net over a hiding fish. Note the float attached to the centre of the net and the lead weights along the edge of the net.*

SCUBA divers leave the shore after assembling their gear into boats between 08:00 and 09:00 and usually only return around 15:00. Each SCUBA diver dives three to five times per day *i.e.* three to five air cylinders are used by each diver; the first two dives at the deepest sites and the latter dives in shallower locations. The physical strain on divers from this daily process is considerable, and physical fitness is relatively high in SCUBA divers as well. All SCUBA divers have a basic kit of mask and fins, harness (to attach the air cylinder), and regulator. Few SCUBA divers possess buoyancy control device jackets (BCDs) or weight belts. Regulators used are basic, generally with no alternative air hose, nor pressure or depth gauges. No-one I met had a dive computer. Regulators are also shared and well-used. SCUBA divers use small and medium-sized hand-held scoop nets to catch fish and invertebrates. Some use hooked spikes to catch lobsters from their crevices. *Moxy* nets are not used by SCUBA divers but many use barrier nets[12] which they place on rocky outcrops and then chase fish into the nets, gathering them into plastic bags held in their belts like snorkellers. However, SCUBA divers also carry hypodermic needles, secured in the fabric of their diving top, with

12 Barrier nets are short stretches of net with weights along the bottom and floats at the top, forming a "barrier". If fish swim into the net, they are entangled.

which to pierce the swim bladders of each fish they have caught as they ascend. This prevents fish mortality as fish swim bladders swell and potentially burst as the pressure decreases during the ascent. Air cylinders are provided by the buyer for whom they dive. Dive boats are also owned and maintained by the buyer and SCUBA divers on each buyer's boat form a team, but may dive separately or together during each dive, depending on skill, conditions and co-operation levels among divers. A more detailed discussion of buyers' SCUBA divers teams is given in Chapter 7.3.10.1.

Risks and dangers are far greater for SCUBA divers than snorkellers. Accidents are common and caused by poorly maintained or old equipment and the lack of formal SCUBA diving training. Air blocks in faulty regulators and /or moments of panic in less experienced divers can result in rapid ascents to the surface, which causes decompression sickness (the bends). Incidence of the bends is common due to the high number of dives conducted per day, several of which are at depths greater than 30 m and divers have little surface interval time to "off-gas[13]", remaining on average 15 minutes at the surface between dives. Several experienced divers had suffered multiple attacks, resulting in paralysis of parts of the body. SCUBA divers recounted to me many stories of injuries and deaths of divers, though exactly how many and the exact causes were not recorded. Treatment is usually limited, the affected diver re-descending with other divers and several air cylinders which are used to support the affected diver to re-ascend very slowly to the surface. Many divers explained that they used this method to cure symptoms of paralysis. There are only two decompression chambers in Sri Lanka, the nearest to my sites being in Colombo over four hours away and use is prohibitively expensive for divers. Many divers felt that export companies should provide compensation to divers when accidents occur, however, in very few cases did divers feel that fair compensation was received. There is an element of "macho" behaviour among SCUBA divers, as reported from Indonesia and Philippines (Johannes & Djohani, 1997); many SCUBA divers boasted of the depths to which they had dived. Most divers were aware of the dangers and those who recovered from their accidents usually returned to diving, although this may be due to a lack of alternative ways to earn money.

13 Off-gas is a term in SCUBA diving which refers to the necessity to remain at the surface between dives to allow for nitrogen which has been absorbed in the bloodstream during diving to be released. This is a slow process and most recreational divers remain at the surface for at least one to two hours between dives on the same day.

Other forms of fishing practised by divers when ornamental fishing is not possible are stilt fishing and food fishing from boats. Stilt fishing requires high skill and balance, as fishers remain seated on a thin wooden bar 2 m above the sea surface for two to four hours at a time (Figure 3.4).

Figure 3.4. Stilt fishers at work in the early evening during the SW monsoon, Polhena

They use a rod, line and hook with no bait to catch the fish below, only gently moving the hook in the water to lure their catch. As the out-season approaches, many divers in Polhena, where stilt fishing occurs, were involved in finding suitable 3-4 m long wooden poles to plant in the seabed in desirable locations. This was strenuous work which only the fittest and strongest divers would perform. However, stilt fishing was conducted by old and young divers alike.

Boat fishing involves tiring work too as fishers haul boats down and up the beach before and after fishing, and haul in large nets at sea. Moreover, on the one-day fishing boats, they often jump in the sea and scare shoals of fish into their nets. Divers who were prone to seasickness avoided working on offshore fishing boats. Dangers of offshore fishing include capsizing and/or sinking due to storms and rough seas. Some offshore boat fishers often fish outside of Sri Lankan waters and there are instances of fishers arrested and imprisoned in neighbouring countries as a result of these infractions.

Divers' lives were not always free of danger or difficulty onshore. Divers and other fishers, in all sites I worked, had long periods of free time between their fishing excursions and on days when fishing was impossible. Divers usually spend such time with others socialising, and in many cases drinking. Mostly these gatherings were genial and enjoyable for all involved. However, in several instances divers drank only to get inebriated, in an attempt to forget the stresses and difficulties of their lives and in this state old arguments and feuds, centred around money, debts or relationships, would emerge that frequently led to strong arguments, fights and other acts of violence among divers and other villagers. Several times I encountered older divers inebriated during the day, in the streets of the villages, shouting or talking loudly to anyone who would listen, and often crying openly while talking. Many were still grieving family and friends lost in the 2004 tsunami and others were usually in dire financial straits, unable to repay loans. Drug taking among divers was also relatively common with ready availability of heroin and marijuana. Several young SCUBA divers I knew spent the majority of their earnings on high priced drugs like heroin and, consequently, were often heavily in debt to drug-dealers, with one instance of murder of a boatman in Polhena as a result of a combination of drugs, drink and debt.

Diving and its associated lifestyle and economic pressures create a vicious cycle of physical and mental stress. Chronic debt is a characteristic of all my study villages and the overall ornamental trade (see Chapter 7). Pressures from debt result in SCUBA divers taking extra dives and risks during their excursions which may increase the incidence of diving accidents. Similarly, the high consumption of alcohol, drugs and fatigue may lead to an increased risk of dive accidents and the bends. These underlying tensions and pressures are not currently factored into the fishery debate or management.

Table 3.1. User groups with involvement in the ornamental fishery that I interacted with at each study site. Numbers indicate the quantity of people interacted with during the study out of a total number of people constituting that group at each site, indicated in brackets. Asterisks indicate estimated numbers. Colombo and Negombo are included to show the concentration of export companies and government departments at these locations. Two other reef sites (BD & UW) with lower numbers of divers are included to provide some comparison to the main four study sites. Site codes: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba, CO = Colombo, NEG = Negombo, BD = Bandaramulla, UW= Unawatuna.

User group or Sociological characteristic	**HK**	**KP**	**PO**	**TL**	**CO**	**NEG**	**BD**	**UW**
Population size	1243	1533	2601	1047	647000	137000	1000*	1728
Snorkellers	0 (0)	20 (50)	15 (30)	15 (30)	NA	NA	4 (5)	6 (20)*
SCUBA divers	0 (0)	5 (20)	8 (20)	5 (20)	NA	NA	2 (6) *	3 (10) *
Other fishers	8 (100+)*	7 (100+)*	5 (50+)*	3 (50+)*	NA	NA	4 (100+)*	2 (100+)*
Fishers' wives and mothers	NA	15 (70 +) *	5 (60 +) *	12 (50+) *	NA	NA	2 (10+) *	0 (30+) *
Fish buyers/ suppliers	0 (0)	5 (5)	4 (5)	5 (5)	NA	NA	1 (1)	1 (1)
Export companies	0 (0)	0 (0)	0 (0)	0 (0)	8 (30) *	4 (10) *	0 (0)	0 (0)
Tourist hotels	6 (40) *	2 (4)	5 (9)	0 (0)	NA	NA	8 (20 +) *	10 (30 +) *
Glass bottom boat operators	10 (30) *	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tourist dive schools	3 (5)	1 (1)	0 (0)	0 (0)	0 (5)	0 (0)	0 (0)	3 (3)
Schools	0 (2) *	1 (2)	2 (2)	2 (2)	NA	NA	1 (1)	0 (2) *
Customs	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)
National Aquatic Resources Agency (NARA)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)
Fisheries Department (DFAR)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)
Coast Conservation Department (CCD)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)
Department of Wildlife Conservation (DWC)	1 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)

3.4 Ethnography of village sites

3.4.1 Hikkaduwa

Hikkaduwa is a small bustling tourist town comprising numerous guesthouses, hotels, restaurants and tourist shops. The largest hotels and their diving schools are located on the beach-front of the National Park, which includes the marine protected area (MPA), forming a barrier between the street and the beach, which restricts public access to the beach to certain paths. For example, a visitor centre, which collects park entry fees, is at one such access point. The Department for Wildlife Conservation (DWC) office sits just north of the National Park with staff to monitor and manage it. Directly north of the National Park lies Hikkaduwa harbour and the local people's homes spread out from there. South of the National Park, the coral reef ends, but sandy beaches continue for several kilometres with small guesthouses and tourist restaurants filling every available space.

Coastal development has allowed hotel sites to follow the shoreline which means tourists are in the prime position to explore the coral reef and beach but are mainly unaware of coastal erosion and pollution that accompany such development; issues that have been highlighted before (Rajasuriya et al., 1995). They also experience a false image of typical Sri Lankan life as they remain separate from local people and their rhythms and activities which are not apparent in the ecotourist coastal stretch around the National Park, a criticised form of ecotourism found in many tropical holiday destinations (Carrier & Macleod, 2005). The Hikkaduwa Marine Sanctuary was formed in 1979 and upgraded to a Nature Reserve in 1998 and to the status of a National Park in 2002. It was Sri Lanka's first MPA and it currently covers an area of 104 ha from the shore (Rajasuriya et al., 2002b). Fishing is prohibited over the nearshore reef area within the MPA. Stricter control on fishing and coral mining has been effective since 1992, with the implementation of a Special Area Management Plan (SAM). It is the nearest to a control site in the study region. The National Park is open to paying tourists and during the tourist season (November to March), the beach is busy with a mixture of local and foreign tourists, who enjoy recreational activities, including swimming, snorkelling, glass bottom boat trips or SCUBA diving further offshore, activities that have been environmentally destructive (Table 3.1). For example, boat collisions with the reef and poor placement of boat anchors are common (Berg et al., 1998).

I made contacts with those involved in tourism including hotel owners to glass bottom boat operators as well as the Wildlife Conservation officials overseeing management of the National Park. From my interactions with all actors at the National Park, it is clear that illegal fishing does occur, but rarely and only at night. This is because the entire MPA is within sight of the shore and the constant daily presence of hotel staff, dive instructors and wildlife officials make illegal fishing difficult to carry out unobserved.

3.4.2 Kapparathota

Heading south east from Hikkaduwa, just before the town of Weligama, one finds Kapparathota. The main road through the village runs from the Galle road to the headland on which much of the village is sited. Within the village are two small guesthouses, one large hotel, one foreign owned dive school and a forlorn looking fisheries management building, now used as a radio shack to contact fishing vessels. There is little tourism in Kapparathota, with only one hotel in the village which mainly caters for local weddings.

The villagers' houses are tucked next to each other on small plots of land but with enough space for a veranda. Small general stores or communal wells occur at certain points among the houses which themselves vary from moderate sized brick buildings with tiled roofs, asbestos sheeting and concrete floors to smaller huts made of wood or tin sheets, with coconut palm thatched roofs and dried mud floors. Most of my ornamental fishing informants live in such homes with very basic indoor furnishings, outside toilets and a well for freshwater.

Kapparathota's population is approximately 1000 (Table 3.1), but is more densely populated and appeared poorer than the other three sites. As is common in Sri Lanka the villagers live in nuclear families, with usually a husband and wife, their children and often either a parent of the husband or wife forming part of the household. Male and female children remain living with their parents until they marry. Most are married within the village, although some spouses originate from different villages or regions. My married male informants had wedded on average at round 23 years of age. Women tend to be married younger at the average age, within this village, of 19 years[14].

[14] Calculated from my own data from SSIs with men and women in the villages, *n*=88.

Ornamental fishing is one of the main livelihoods available to men aged between 13 and 50. Men of various ages performed snorkelling for ornamental fish, whereas SCUBA divers tended to be aged between 25 and 40 years at the time of my fieldwork in this village (Table 3.1). Although most of my Kapparathota informants are predominantly ornamental fish divers, their livelihood options are more diverse than the other villages. During the season, men undertake various food fishing jobs, such as lobster fishing and a little shore or boat fishing. During the out-season or if ornamental fishing is poor, they often work on one-day fishing boats to be paid a share of the profits from catching "*food fish*" such as *Auxis thazard* (frigate tuna), or they work as crew on longer trips on "*tank boats*", (small trawler-style boats), to catch *Thunnus albacores* (yellow-fin tuna), and other large pelagic fish species far offshore. Many divers, however, migrate to the east coast during the out-season, for two week to one month periods to catch ornamental fish near Trincomalee and Batticaloa (Figure 3.1). Usually men in the village perform a mixture of these types of fishing during different seasons and weather conditions to maximise their income. As nearby Weligama has a sheltered bay for boats and a large fish market selling food fish, there is more direct contact between ornamental fishers and food fishers and so the fishers organise such fishing opportunities through their own social networks. Wives and mothers of these divers do not usually have paid employment as they look after the children and their homes.

In contrast, four of the five fish buyers in the village are relatively wealthy; they live in larger, well-furnished homes and own vehicles and /or boats, which are important assets in terms of both social and spatial mobility in these villages. Though divers accept that the buyers occupy a higher socio-economic status, the two groups often develop close friendships and ties of a social nature as well as the formal business relationship. I witnessed buyers in this village attending a divers' father's alms giving and another buyer drinking and mingling as an equal with several divers at the birthday party of a diver's child. These intricate relationships between divers and fish buyers were evident in all the fishing villages in the study.

Early in my field work I visited Kapparathota and met my second original contact, Chintiga. He proved to be a valuable gatekeeper for the divers in Kapparathota. He speaks relatively good English in comparison to most of the divers and buyers I met at my sites. His assistance made it easier for me to co-ordinate interviews, diving trips and attend other events in the village. Chintiga knew many ornamental fish divers and buyers in his village well, as he sells his fish to these buyers. When I visited Kapparathota each week, after an early tea at Chintiga's home I dived with whomever he had arranged for me to accompany. Afterwards, lunch was always offered at his home and I would stay until after 15:00 talking with him and other divers about various fishing and social issues. I often stayed for several nights at Chintiga’s house at various points during the fieldwork and his family invited me to many events, from alms givings to birthday parties, and this gave me invaluable insights into the community’s way of life.

3.4.3 Thalaramba

Thalaramba, with a population of approximately 800 people, (Table 3.1), is situated between the towns of Weligama and Matara. The beach is narrow and in some places the reef comes right to the edge of the beach. Houses, family structure and household arrangements are similar to those in Kapparathota. However, the livelihood options in Thalaramba are more limited than in Kapparathota. Most men are involved with the ornamental fishery, either as snorkellers or SCUBA divers. As Thalaramba has neither bay nor harbour for safe shelter, no possibilities of any boat based food fishing jobs exist. Some men do find such work in nearby villages, but most remain in their village as their social networks do not extend beyond it, and so must rely solely on ornamental fishing. During the out-season Thalaramba divers move to the east coast to dive or wait out the out-season, snorkelling or diving locally on the occasional day when the sea is calm enough to catch ornamental fish, octopus or lobsters for food.

I discovered the village of Thalaramba through a group of teenage divers I knew in Bandaramulla who told me of snorkel divers who lived and worked there (Table 3.1). This group took me, during my first field season, to sell their fish to a buyer there. My assistant, Duleepa, and I learned from this buyer, Jagath, where to find other Thalaramba buyers and concentrations of divers in the village, although Jagath was hesitant to show us the places himself. After informal discussions with these contacts, I found one family that very willingly agreed to assist me. The father, Patum, is a SCUBA diver and fish buyer, and both his sons are snorkel divers. The mother, Pradeepa, runs their fish holding facility; thus, she is highly involved with all aspects of their business onshore. This was unusual, as few women in southern Sri Lanka work in the trade. I co-ordinated most of my work in that village through Patum’s family who enabled me to find divers for small group interviews or larger group gatherings, as well as for individual fishing trips. Later, as I formed relationships with other divers I operated more independently of this family. My interactions with each Thalaramba fish buyer had to be in isolation, as with the buyers in the other villages, since they are in competition and tend not to cross each other's territory.

3.4.4 Polhena

Situated a few kilometres west of Matara, Polhena lies almost one kilometre from the Galle road. The beach though small is popular, particularly with local tourists who frequent the village at weekends. The beach area is also the site of several guest houses. An open area behind the beach becomes a parking area for buses, minivans and cars on weekends and holidays. Various sellers have small stalls, mobile selling trolleys or *tuk-tuks* offering ice-creams, clothes, toys and beach wares.

Polhena whose population is approximately 1300 people (Table 3.1), has a nearshore fringing coral reef and inshore lagoon with patch reef occurring in the shallow waters bordering the village. Livelihoods in the village comprise fishing, farming, labouring and some tourism. The majority of fishers in this village are ornamental fish collectors and most of my snorkeller informants here were young, single and still living with their parents. Older, middle-aged, married men SCUBA dive for ornamental fish (Table 3.1). Some fishers and divers alternate ornamental with food fishing from small boats 1- 2 km offshore during the night or for short periods in the day. No large boats anchor at Polhena and opportunities to partake in longer food fishing trips are limited to each fisherman's contacts elsewhere. During the monsoon season, many Polhena SCUBA divers move to the east coast to dive for ornamental fish, but some who remain together with other local fishers, undertake stilt fishing for the large schools of *Selar crumenophthalmus* (bigeye scad) and *Herklotsichthys quadrimaculatus* (bluestripe herring) that aggregate in the reef lagoon in Polhena as well as for larger predatory fish (Carangidae), attracted by these seasonal fish shoals. Fishers fish first for their own consumption but prefer if possible to sell their catch for cash to the inhabitants of the village or nearby townsfolk.

As mentioned previously, Dr Terney and students from the the University of Ruhuna introduced me to two or three divers and a guesthouse owner in Polhena who spoke good English and agreed to help. After explaining my research to these divers they helped me locate other divers and buyers so here I was not “attached” to any one individual or family, which remained the case for the entire period of my fieldwork.

Divers linked to certain buyers tend to congregate near the beach or the buyers’ huts in their spare time so I could always find someone to talk with, to locate others or make work arrangements for later. After going out with a diver in the mornings, I accompanied them to see where and to whom they sold their fish. After this we might have a tea, but then they would return home to shower, sleep and eat a late lunch, at which point I tried to find others to talk to or left to enter my data. Everything was an informal arrangement, from shadowing snorkellers on fishing trips to organising interviews or spending time with participants. Through this socialising process I became more closely acquainted with these divers who helped me engage with larger gatherings.

I returned to Durham in July 2009 to work on the data collected and prepare for the second season. The three months spent in the UK included a progression viva, and the discussion with supervisors gave further direction to the methodology for the second season which was agreed to coincide with the exact dates of the season for ornamental fishing in the south of Sri Lanka – November to April.

3.5 Second field season: November 2009 – April 2010

On my return in November, my ecology focus was to complete the fish censuses and my social anthropology focus was to carry out more participant observation but fewer interviews. My decision to live in or very close to the reef sites facilitated both these new objectives. I lived in Polhena first and it was very apparent upon my return that divers and other participants were pleased at my return. Due to the relationship established during the first season, the diving communities now knew the reason for my presence and I not only received daily offers to dive with them, but they also volunteered information about the fish they caught each day or other pieces of information they thought I would find interesting.

It had been difficult to find a Sri Lankan student with sufficient time to assist me with the ecological reef surveys during the first season, so in discussions with my supervisors and Dr Terney we decided to advertise for a volunteer and I selected a British marine science graduate, Philip McDowall (hereafter referred to as Phil), to assist me. He was expected in December which gave me some time to finalize the workplan before his arrival.

3.5.1 Participant observation

Living in Polhena was beneficial in terms of firming up relationships as I met the divers' families through meal invitations at their homes. On these occasions, we could speak more generally about their lives, not just about fishing. I was invited to parties and small gatherings for drinks in the evenings, which were common among the divers. My conversation Sinhala had improved and I could understand much of what was said and manage basic conversation. A few divers, or their friends, spoke enough English to provide translation if Duleepa was not present.

While I awaited Phil's arrival, I accompanied divers on snorkelling trips, spent lunch and early afternoons with the divers or entered data. I visited the buyers around 15:00, when the dive boats came in, to record the day's SCUBA and snorkel catches. I also began recording fish catches from the buyers' logbooks, where they record daily species, numbers and some sizes of fish to track what is sold on to export companies. To gain their trust and acceptance to enable me to record such information took considerable time, effort and diplomacy. In the early evenings I carried out my own data work or spent further time especially with the young divers as they socialised and walked around the village. Some nights I was invited to a diver's house for dinner and drinks. This arrangement was ideal if I had been restricted to only one village site; however, I was spending the majority of time in Polhena making it difficult to visit the other sites regularly. Although I had visited them on my return I was unable to split my time equally.

3.5.2 Reef surveys and ornamental tank setup

My assistant arrived and we focused on completing the reef survey at Polhena, operating in a two-man kayak and employing the tested point count method. The first task was to train Phil to identify the reef fish quickly and accurately, of which he had already had experience. We then tested our fish size estimation underwater following the protocol from English et al. (1997), using fish models of different sizes and comparing the estimated sizes against their actual sizes. After some extended practice, we found our size estimations improved so that they were within 15% of the actual sizes, a level of accuracy permitted in other reef fish surveys (Kulbicki & Wantiez, 1990). We also carried out several practice point counts after this, to familiarise Phil with the method and manipulate the various pieces of equipment alone underwater. Once he felt confident with the method and we were both estimating fish sizes accurately we began the reef surveys. Despite our meticulous planning and training, it took time to develop a swift daily survey routine, as we continually learnt and so improved our techniques. The weather was not always settled, sometimes making surveying impossible, so on these days we shadowed different snorkellers, and collected catch data from different buyers' huts. At first, Phil accompanied me on shadow fishing trips and to visit the buyers to observe how to perform the different tasks: particularly how to record the data and remain unobtrusive so as to gain acceptance from the buyers. Thus we collected the data more quickly and efficiently as we each shadowed a different snorkeller and visited different villages or buyers.

In any spare time, I planned and organised the construction of the fish tanks for the ornamental growing and breeding project. I had previously found an ex-diver called Umesh in Bandaramulla who breeds freshwater fish and was very interested in trying to breed clownfish. With his experience in fish breeding and husbandry I decided to set-up one tank and a protocol with him with the aim of transferring that tested protocol to the less experienced fishers I would select at other sites. A selected craftsman built four tanks with metal stands from the tank equipment I had, with Duleepa's local help and Durham University's financial support, sourced and purchased, which included bio-filters, air-pumps, lights and water quality test-kits. We sourced a pair of clownfish from a fish buyer I visited regularly. Although these are not a high volume species in Sri Lanka, by the end of December we had a suitable pair. Umesh took daily recordings of water parameters as well as feeding and behavioural observations. I visited Umesh at least once every two days to ensure optimal fish care, to provide maximum opportunity for the pair to breed.

Phil and I were initially predominantly in Polhena and the survey was time consuming; we were in the sea from 08:00 until 13:00 or 14:00, we ate and changed by 15:00 following which we had between two and four hours of data entry to complete. However, I was aware that we had to split our time more evenly amongst the villages so one of us returned to each of the other sites at least once per week to collect catch data from the buyers and spend time with the divers, while we completed the reef surveys. In this way if any major social activities were happening we would know and often be invited, such as alms giving, birthday parties, weddings, coming of age parties, as well as small drinking and meeting sessions amongst divers and friends. With the survey complete in Polhena, we moved to live in Bandaramulla, for the same reasons it had been chosen previously as equi-distant from all sites. We travelled daily to Thalaramba and completed the reef survey more quickly than the one in Polhena due to an improvement in the sea conditions in January and our surveying efficiency.

Each day before and after the survey work we spent time with Patum's family and I occasionally spent consecutive days in the village, residing with Patum's family. Their house was always open and people wandered in and out allowing us to meet many divers from that part of the village. We could record catch information and find out the daily news of the village from Patum's wife, who kindly fed us lunches. After this reef survey was complete, we carried out snorkelling shadowing trips, organised by Patum. As I had conducted few trips here during the first field season we continued until I had enough replicates of fishing trips. We then repeated this procedure to complete the survey in Kapparathota, with a further improvement in our time and efficiency. As in the previous fieldtrip in Kapparathota, we often had our lunch and spoke with Chintiga, his family and some of his diver friends. In the late afternoon I collected direct catch information from buyers in the village. Following that we would enter the data and I would check on Umesh's clownfish tank.

Being the furthest site from Bandaramulla, we moved to Hikkaduwa for the final reef survey to reduce travelling time. Our routine was similar except we had no buyers' catch data to collect here, instead the afternoons were used to enter survey data and to speak with tourist hotel managers, dive school operators, the wildlife conservation officers and the glass bottom boat operators using either SSIs or informal chats. In contrast to my first field season, it was peak tourist season so I was better able to gauge the extent of tourism in Hikkaduwa and its positive and negative influences on the reef and people's lives. The earlier introductions during the first field season again proved valuable in allowing us easy access to work on the reef and to ask more probing questions for further insights.

3.5.3 Fisher shadowing trips

The reef surveys were completed in early February 2010 and the next priority was to carry out further fisher shadowing trips at all sites and collect catch data. In interacting with divers and collecting this quantitative fishing data, I could easily ask informants questions derived from my observations in an informal manner, which led to my receiving information about other fishing related issues, social problems or just news and gossip within each village.

I firmly believe it would have been harder to receive freely such information or be accepted into these diving communities if I had not joined them in diving or not known the local fish names and their environments. Similarly, if I had only collected fishing catch data and conducted reef surveys without any involvement in the daily village life of the divers, it might have restricted my access or acceptability to work in these villages. Thus the two aspects of my work complemented each other elegantly, both in terms of accelerating my acceptance within each community and in maximising time efficiency, so as to allow for a productive field season that was already constrained to a five to six month window by the monsoon season.

The weather began to change during March as monsoon conditions developed and then many SCUBA diving teams moved to the east coast. The buyers in the southern villages mainly purchase fish from divers according to orders phoned through from the export companies in Colombo, who are filling orders sent from foreign importers. The number and sizes of orders received by the local village buyers from the export companies in Colombo varies and tails off at the end of the season. By March 2010, the southern buyers were making fewer orders and diving had noticeably declined, with only SCUBA divers who could still access relatively high visibility and calm offshore sites and the most valuable species still being collected occasionally. Phil’s work was now complete and so he returned to the UK and I shifted my attention to collecting the catch data from buyers’ logbooks and spending hours with Duleepa transcribing entries.

3.5.4 Ornamental fish tank aquaculture trial

The clownfish with Umesh were doing well and displaying courtship behaviours, yet no eggs had been laid. However, we now had a simple methodology and protocol for the other divers to run their tanks and so I set up two more tanks, one with Patum and one with Chintiga. From the difficulties and slow progress Umesh had experienced in attempting to breed clownfish, I realised it would be expecting too much from Chintiga and Patum who possessed far less fish husbandry experience to breed marine fish at this early stage. I decided to focus their attention on keeping small fish alive through good husbandry and seeing if they would develop whilst in tanks. Although I knew it would not be possible to obtain rigorous, quantitative data from so few tanks, I planned to gather valuable qualitative data, from a social perspective, as to how people managed the tanks and their attitudes towards such work. This would indicate if such an alternative livelihood had any future in these communities. The economics of setting up, running, maintaining and managing the tanks was recorded so as to provide data on the feasibility of a larger scale community aquaculture project.

With this in mind, Umesh explained the techniques and gave advice to the two novices on how to record daily water parameters and observations. They made their own decisions to run the tanks, with some guidelines, such as not to overstock the tank. From then until the end of the season, Chintiga and Patum regularly called me to address various problems or issues they encountered and I attended to them as was appropriate and feasible, further explaining the optimal care methodology. During regular village visits for catch data, I would simultaneously check on the tanks.

3.5.5 Interviews

Although I carried out fewer interviews, as planned, in the second season, I interviewed major actors whom I had previously been unable to contact; these were government and export company officials different from those I had met in the first season and I also conducted follow up interviews with women in the communities relative to the initial interviews, undertaken by the female Sri Lankan students, which had generated further questions. I returned with the same female students, and spoke with the same women they had interviewed in my absence the first time. The women were comfortable with my presence now and willingly answered my further questions. I now knew Sri Lankan people from many walks of life; from academics and doctors to farmers, to guesthouse owners to students and of course large numbers of fishers, particularly ornamental fish collectors. This enabled me to check queries or have information confirmed by different groups of people as well as to build a richer understanding of the different views people have of each other.

I spent my last month ensuring I had all necessary material including as complete a set of the catch data as could be acquired. I spent some nights staying with different divers in Kapparathota, Thalaramba and Polhena at their request and joined them in their daily activities as my work and data collection became more complete.

3.6 Follow up field season: November – December 2010

I had returned from the field in April 2010 believing that was my last trip, but after approximately six months back at Durham University working on my data and writing, Dr Lucas organised an opportunity to return to the field for one month to accompany one of his MSc students to carry out a study focused on reef fishing activities in two different nearby sites. With my contacts and guidance in methodology, his field work could be greatly accelerated and at the same time I could finalise any details.

I moved between my four field sites, spoke informally with nearly everyone I knew to find out what had happened since I had left, as well as the situation during this new season, the third I had witnessed since my study began. I compared the overall picture of the ornamental fish trade over the relatively short time of my study as I could identify some significant changes in terms of shifts in livelihoods and other factors in the market chain. I also conducted some SSIs with government officials and staff from local fisheries departments who had been difficult to contact during the two previous visits and focused on SSIs and life histories with the oldest generation of divers at each site to fill some gaps in my understanding of the differences in attitude to the trade and the changes between the youth and older generations of divers.

I was once again invited to many social events including welcome parties, and dinners. I spoke with many of my former contacts, as well as new informants, recording our conversations and any new information in my ethnographic journal. With no pressure to collect catch data or survey data this trip, I could accept invitations to many events and from discussions there was reassured as to my knowledge of the trade and the livelihoods of the divers. I spent time recording the experiences of the fishers who had the fish tanks, which they had continued to run and collect data. This continuation had been co-ordinated in my absence by Duleepa on his weekly visits who not only collected and sent me their fish tank data sheets but also passed information from me to the fishers in relation to these tanks.

I decided to stay with selected informants in the villages for some nights due to the brevity of my trip. As I had now become less of an anomaly I was integrated into their daily tasks more seamlessly than before when I was often treated as a very special guest. By the end of the month, I had drawn together a summary of the season and the current situation in all my field sites, as well as uncovering a few new areas that I had not fully understood previously.

Overall, the interdisciplinary methodological approach worked well in collecting the necessary data for the aim and objectives of the study. Acceptance into these communities was easier and quicker by being involved in all aspects of their lives both on and offshore. Having a multi-sited study did mean that I could not remain in one place for extended periods, although I managed to co-ordinate my time and interactions with divers and other participants across all my sites. Ecological data collection was restricted in the first field season by the changing seasons but permitted an experience of out-season conditions. The second field season was extremely busy in order to collect all remaining data but, in general ran smoothly, with few major problems.

3.7 Anthropological data analysis

This section details the way in which the social anthropological data was analysed. Quantitative data analysis is provided within the chapters that present such data. A specific explanation is also provided in any chapters for any anthropological data analysis that was different to the overall summary here of coding the qualitative data and subsequent usage of grounded theory.

The anthropological data collected using the methods described above was translated predominantly *in situ*, and transcribed and coded during periods in Sri Lanka and the UK. NVivo software was used to code and organise the data (Gibbs, 2002). The data were analysed using recurrent and relevant themes and topics to determine emerging patterns and to uncover any gaps in the data collection process (Miles & Huberman, 1994). Grounded theory, with "...its emphasis on the generation of theory and the data in which that theory is grounded" (Glaser, 1978: 12) formed the basis of analysis because it allows for theories to be developed from the data rather than determining theories or hypotheses prior to analysis (Glaser & Strauss, 1967). By analysing the qualitative data extensively, often line by line with constant comparisons, a detailed grounding of the data and well constructed theory was produced (Strauss, 1987). Many empirical indicators (drawn from the qualitative data itself) are compared and analysed and then coded to categories, usually a conceptual code. The indicators are then compared to these emergent conceptual codes, tightening and crystallising each concept to best fit the data (Strauss, 1987). Indicators will gradually saturate each code as they produce no further dimension to each code. On reaching saturation point, the researcher halts further analysis, as no further comparisons or coding of the data is likely to add any new concepts or ideas. In this way, "concepts and their dimensions have earned their way into the theory by systematic generation from data..." (Glaser, 1978: 46).

3.8 A marine ornamental fish's journey

Although a more detailed focus on the detailed processes and interactions within the market chain is laid out in Chapter 7, here I briefly summarise the process by which marine ornamental fish are moved from the coast, once caught, to export companies and ultimately shipped abroad. It is perhaps a simple description of a complex process, but is included for the reader to understand the basic route fish travel along the market chain before the complexities are examined.

Fish are caught by snorkellers and the fish they catch is taken by them to buyers in villages where these fishers live or the nearest village where these buyers operate. My three fished study sites are fish sale hubs where fish are sold to buyers by snorkellers from that village or nearby sites. If fish are bought, they are recorded by their local name and the number of each species in a buyer's logbook together with the date and snorkeller's name. From personal observations, fish that appear damaged or in poor condition as well as fish that are extremely small or excessively large are rejected by buyers. Fish that die in the buyer's care before the snorkellers receive payment, are not paid for by the buyer.

Fish are kept in the buyers' basic facilities for a few days, before being sold to the export companies which are based either in Colombo or Negombo, due to their proximity to Colombo international airport. Fish are placed individually or in groups, depending on the species, in two plastic bags one within the other, with a small volume of seawater, often dosed with antibiotics. Bags are oxygenated and sealed with rubber bands and are either stored in a room or packing area usually in plastic crates provided by the export companies. Fish are also kept in small tanks and plastic bowls with air supplies, until they are packaged as described above. Water in the fish's bags and bowls is changed and re-oxygenated daily. Usually fish are sold on within one to two days so no water-quality checks are performed and the fish receive no food unless they remain at the facilities longer than three days. Fish are well cared for by some buyers who may check water salinity to prevent fish fin and eye damage or dissolve tetracycline, a broad spectrum antibiotic, into the seawater to heal scale or fin damage. Antibiotic amounts are not measured but dosage is determined by the colour of the final mixture.

Fish are cared for and handled by one or two packers employed at the buyer's facilities. Fish are also cared for and packaged by some divers who work for or sell to these buyers. However, it was evident from my personal observations that fish are subjected to high levels of stress by handlers; fish are released onto the floor by accidental bursting of bags, fish are thrown between bags and bowls and sometimes miss their target and fish are handled excessively by inquisitive visiting children. Once fish are aerated and bagged, they are sometimes thrown or dropped from considerable height by handlers, often landing on top of one another.

Orders of fish required by foreign importers are sent to export companies and the fish species and numbers required are relayed to the village suppliers. Fish are usually sent to the foreign importer within one week of receipt of the order. The variability in fish catches can cause problems with this schedule as does space on flights or other unpredictable transport delays. With high demand during the season, fish are collected virtually daily by companies, which send trucks 120 km to the south coast. SCUBA divers' fish catches usually have to wait a day, as they return after the export company trucks gather to collect fish. Often each afternoon, at one supplier fish are bought by four or five different companies. Fish are inspected by representatives from the company and are purchased before trucks return to Colombo in the evening. Sometimes fish are purchased in cash, but mostly fish are paid for monthly by companies.

Approximately 10 large bags or 20 average bags of fish fill each plastic crate; 40-50 crates of fish are loaded and fill a small company truck. Fish are mostly not kept in trucks with cooling systems but only covered by canvas covers. Only fish bought by a few larger, wealthier companies are kept at optimal temperatures during transit to

Colombo. Fish are first collected by the trucks at sites nearest to the south of Colombo and then at each site further east along the coast until all the fish required are purchased. Fish are harder to sell to companies by buyers further east who complain that when the trucks arrive, company orders are almost filled.

Fish are unloaded at export company facilities and conditioned in tanks before shipment. Fish are stored in large capacity aquarium tanks with various flow-through systems, biological filters, protein skimmers and sometimes ultra-violet (UV) filtration systems. Fish are kept on average three to four days to ensure they have evacuated all digestive waste, so they do not foul the bag water during transport. The fish are not fed during this time. For shipment, fish are packed by the company workers, similarly to the buyers: in two plastic bags with the minimum amount of water necessary for survival, keeping overall weight as low as possible. Bags are again oxygenated and sealed with rubber bands. Fish stress is potentially reduced by placement of newspaper between the two plastic bags. The ambient temperature around the fish is maintained throughout shipping by ice packs placed by the workers among the bags in polystyrene boxes. The polystyrene boxes are then placed into cardboard boxes which are sealed and loaded onto trucks for delivery to the airport. At the airport, ornamental fish shipment export documentation is checked by Customs officials and sometimes some boxes of fish are opened to ensure the contents match the documentation. The boxes of fish are loaded and flown to foreign destinations, once the officials are satisfied.

This chapter provides an overview of the methodological approach taken in this study from proposal to write-up, as well detailing the current socio-ecology of the study villages, how I was involved with participants at each site and conveys an image of the life of ornamental divers in southern Sri Lanka. Finally, the summarised pathway ornamental fish take from reef to retail outlet depicts the daily process that occurs during the season. This is essential to have in advance so as to comprehend the impacts of this trade, its power structure and governance as well as the history of this fishery in southern Sri Lanka.

Chapter 4

Social history and historical ecology of the ornamental fishery in Sri Lanka

4.1 Introduction

With a small splash we are in and snorkelling quickly away from the shoreline. He scans from side to side, arms calmly held across his chest and there is hardly a sound. I follow Tusheera. It's very quiet and cool in the water after the heat and noise of the village. We move over seemingly lifeless coral rubble areas, then on to the bright colours of corals beneath us, where fish come into view moving around it. Tusheera is looking for particular fish and it isn't long before he stops and beats the water surface with his tickler, a short metal rod, to frighten a fish into a refuge. Tusheera positions himself over the coral where the fish is hiding and unfurls his moxy *net, then lowers it gently over the coral patch and ensures it is firmly down on the sea-floor to prevent any chance of escape. With the net in place, he returns to the surface and takes a breath and then with his tickler, he begins to poke underneath the edges of the net and works the rod up and down gently to disturb the fish while avoiding damage to the surrounding coral. He tries this from several angles until eventually the fish darts from cover into the net. Tusheera drops the tickler and dives down rapidly to trap the fish by gathering the net in around it gently, to avoid causing any damage.*

Holding the net and fish in one hand, Tusheera frees a plastic bag from his waistband, and expertly guides the fish from the net into the bag. He twirls the bag around several times to close it, pushes the coiled end under his rubber belt and gathers up his net and tickler. He stops and we bob up to the surface where he tells me the name of the fish as he adjusts and re-cleans his mask. "Connick", he pulls a face, "only 20 rupees this fish, very hard now to find quality fish here". I note it down; reflecting that it has taken over 15 minutes to catch a single fish worth just over 10 British pence. With a head wobble to ascertain everything is OK between us, we dip into the aquamarine water again. Tusheera swims on rapidly, scanning once more across the seabed, while the small, beautiful fish swims gently back and forth in the bag suspended from his belt. Fieldnotes, 25th November 2009.

I included this excerpt because it typically describes many diving trips I undertook with divers at various field sites. Though not identical, the waters, the reefs, their proximity to the villages and the overall livelihoods of these divers are similar in all my study locations and Tusheera's message on finding only low value fish was common: the struggle to find and catch high value fish for a better daily wage. Poverty and hardship of fishing communities are not uncommon in reports about coastal people across the developing world (FAO, 2011). However, it is the subtler differences and intricacies arising from the relationship between socio-cultural factors and human activities in these waters that I seek to elucidate to understand the reasons why a certain situation occurs (Dove & Carpenter, 2008). In particular, this study aims to discern reasons for the chronic degradation of the reefs in the nearshore waters of southern Sri Lanka.

Looking to the future, the continued resilience of these people and the productivity of the natural resources they rely upon, appear extremely uncertain. Explanations for this problematic but realistic prediction should avoid the simplistic and temptingly obvious issue that too many fishers using destructive gear have resulted in damaged reefs and scarce fish populations (see ToC debate in Chapter 2.11). I plan instead to uncover the wider orchestrating events that shape the situation in which divers currently find themselves (Fabinyi et al., 2010). This chapter, in accord with the overall purpose of this thesis, aims to provide such details, rarely reported on by natural scientists - by starting at the local level and moving out to the national and then international level - to identify the multi-layered causes and effects on the integrated social-ecological system.

This chapter aims to both examine the social history of my study villages and draw upon the historical ecology of the ornamental fishery in Sri Lanka, as described in Chapter 2.13.1, to explore the complex factors contributing to the state of the fishery and the uncertain circumstances of those people who rely on the reef for their livelihoods.

I collected the qualitative, social data for this chapter, during my three field seasons, in the four field sites and the capital, Colombo, using methodology detailed in Section 3.2.10/11 and involving the groups of people summarised in Table 3.1. In summary, these methods comprised participant observation, semi-structured and open interviews and focus groups. I based all the following sections on data emerging from my field methods, relevant literature and subsequent analysis on my return from the field.

4.2 Social history of the villages

It is not the intention of this thesis to detail the intricate chronological history of the villages themselves, many previous works have focused on the historical aspects of typical Sinhalese village life (Spencer, 2000; Leach, 2011) and Sri Lankan fishing villages in particular (Alexander, 1976; Stirrat, 1982a). However, it is necessary to briefly provide an overview of the changes that have occurred in village life and rural Sinhalese society over the historical record. Biotic and abiotic environmental factors constrain livelihood options for local people, and in their responses local people's cultural dynamics reshape their environment (Cronon, 1983). The study of environmental change can therefore provide insights into the current activities and to what extent these changes affect the livelihoods of the ornamental divers of Sri Lanka.

Pre-colonial village life (pre-1500) on the island was feudalistic, with peasants working the land under a complex system of landlord-tenant relationships. Landlords were granted land by the King, who would bestow it upon those of high caste status, including various officials and those aligned with religious institutions (De Silva, 1981). Agriculture, which was the main occupation of the people, depended upon ingenious irrigation schemes, comprising both cut irrigation channels and tanks to store river water (De Silva, 1977: 32). The agricultural system thrived for many centuries and it was, according to Shanmugaratnam (1981), "...characteristic of a society in which use value dominated exchange value". Polygamy and polyandry were common in these times creating the extended kin network vital to families in times of hardship. By the 16th Century and the Portuguese arrival, there was a significant shift of people and power to the south-west of the country, accompanied by a move from the irrigation based rice agriculture to subsistence rain fed agriculture. There was also an increase of trade in high value products, such as cinnamon, and the development of a pearl fishery in the north (De Silva, 1977: 44). These luxury commodities began to dominate state revenues, which represented a shift, in trade importance and volume, from domestic to export oriented commodities (De Silva, 1977: 57). The creation of thriving trade settlements at the coast attracted those from inland looking for stable and above average livelihoods, a situation that the arrival of the European colonial powers affected.

Colonialism altered the local structure, customs and belief systems of Sri Lankan villages. A lasting effect of the Portuguese who rarely ventured outside the south-west corner of Sri Lanka was the conversion of many coastal people to Roman Catholicism.

This is important in relation to the geographical area of my study because its impact is today more noticeable in western fishing villages and towns around Colombo and Negombo, where many fishers are Christians. The Christian influence attempted to reduce or remove polygamy and instate monogamy (De Silva, 1981).

The Dutch replaced the Portuguese in 1698 and their control was also limited to the coastal areas but they were more intent on trade and business than religious dominance. During the British rule (1796 – 1948), having gained control of the entire island the British also attempted to replace Buddhism with Christianity, which led to the legal enforcement of monogamy and created a patrilineal form of land inheritance. These changes in patterns of marriage and inheritance undermined the coping strategies and support systems of rural women who now became more thoroughly reliant on the family male for their livelihoods (Risseeuw, 1992), as remains the case today.

Secondly, the British initiated large plantation systems to reduce the power of village headmen and control the land directly. The subsequent redistribution of the land among certain local and mostly foreign elites not only restricted the headmen's power, but also removed much of the resilience and socio-economic support systems that had evolved among the peasantry to assist the rural poor (Shanmugaratnam, 1981). This became evident when the British sold most of the appropriated land back to entrepreneurial foreigners or Sri Lankans: many of the latter came from lower castes who thus elevated their status (Meyer, 1992). The collapse of the old caste structure followed as lower caste families could hold positions of superior wealth and status than those from higher castes. The colonial policies of plantation agriculture and trade developed a capitalist economy that spawned new elites, absorbed the old elitist groups and made wealth a source of social mobility. Members of the Karava caste (the caste typically associated with fishing) were effective in exploiting their new wealth to move above their traditional status and political level, although later colonial policies undermined this power (De Silva, 1977). In Sri Lanka today few functions remain for the caste system, except to influence marriage choices. As headmen in Sinhalese fishing villages do not exist, powerful families, supported by their relative wealth, control village politics resulting in greater competition among families than in earlier periods (Said, 2009).

Although the British managed to control inland areas, colonial influence remained strongest along the coastal zone of Sri Lanka, where much of the infrastructure, commerce and education remained concentrated. This focus on the coastal areas caused an increase in population, as people moved to gain advantage of these developments. Many small fishing villages in southern Sri Lanka were founded in the late 19th Century as people migrated towards the hub of colonial institutions (Alexander, 1977).

Fishing was controlled and regulated by the various colonial powers, however, control of subsistence harvesting from coral reefs was minimal. There is little mention of fisheries in the historical literature of the island, focussing mainly on agriculture and export crops. Fishing has therefore continued much as always, the only differences being improvement in fishing gear and increases in numbers of fishers over time. Traditional fishing practices in the early 20th Century varied from boat fishing and beach-seining[15], to lobster and rock-fish hunting, and shore fishing (Alexander, 1977). Stilt fishing is thought to have originated after the Second World War in certain southern coastal villages.

Sri Lankan coastal villages are sometimes described in the development literature as being "...autonomous, conservative, homogeneous, inward looking peasant villages..." (Alexander, 1976). However, as Alexander (1976) explains, this is not the full picture. Although in keeping with the statement above, most men in these villages still make a living by subsistence fishing and marriages are usually between people of the same or neighbouring villages, these small southern coastal villages are facing change as their isolation diminishes and potential livelihoods diversify. Large centres of commerce and services are now within easy reach and villagers often visit the nearby towns of Hikkaduwa, Weligama and Matara for shopping, health reasons or entertainment. Radios and televisions are ubiquitous throughout the homes of even the poorest fishers and therefore an awareness of national and international events is growing. Furthermore, interactions with tourists are increasing, which provide an alternative perspective on cultures and world-views. In addition, over the past 30 years, many young rural Sri Lankans have become migrant labourers. If the assumption that southern Sri Lanka consists of isolated peasant villages did not stand close examination in the mid 1970s, it is even less true today.

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[15] Beach-seining is a fishing method involving the shore usage of a seine net, a large semi-circular net with weights along the bottom and floats at the top. It is often deployed in the nearshore area from a boat. Large groups of people are required to haul the net back in pulling on the two ends. It still occurs in certain coastal villages of Sri Lanka.

4.3 Effects of Tourism

Among my field sites, Kapparathota has encountered few tourists and most residents have lived there all their lives. Locals may interact with any who visit, but are not reliant on them for money; instead the fishers welcome tourists as an extra source of occasional income through selling them fresh fish or taking them on fishing excursions. Thalaramba appears to be one of the poorest and least affected of my study sites by tourism with no tourist developments. On the other hand, Polhena has several guesthouses near the small beach, which is very popular with Sri Lankan visitors, although foreign tourists are relatively rare. The fishing communities of the three fishing villages in this study therefore meet tourists occasionally and predominantly by chance. They are aware of the potential to make relatively large amounts of money quickly from tourists compared to their usual livelihood activities but they see themselves as fishers and not reliant on the random nature of passing tourists to supplement their income. This is in stark contrast to the situation in Hikkaduwa.

All activities in and around Hikkaduwa National Park, focus on tourism and conservation of fish and corals, and illegal fishing is minimal. However, other environmental issues give rise to distrust, competition and allocation of blame among the separate groups involved with the functioning of the National Park. For example, hotel owners and their dive school operators blame the glass bottom boat operators (GBBOs) for breaking corals in shallow areas with their boats or anchors and for polluting the waters and beaches with oil and diesel leakages. The dive operators who see themselves as more professional than the GBBOs, claim their boats are better maintained and avoid the corals by using deeper channels between the beach and the offshore areas as they take tourists SCUBA diving. As this means they do not visit the shallow, nearshore corals and fish, it makes it easier to blame the damage on the GBBOs who do operate their boats in the shallow areas. The GBBOs, however, disagree that they damage the reef, arguing that without the beautiful corals and fish, they cannot entice the tourists to take their boat rides.

The GBBOs, in turn, complain that large hotels pump waste water directly into the sea, polluting the reef and that increased hotel construction has exacerbated beach erosion. Both groups agree that the DWC officials do not appear to be enforcing regulations in the National Park nor to be raising visitor conservation awareness. DWC officials argue they are doing their best on a tight budget (A. Gunawardena, pers comm.).

The tourist facilities are in strong competition to attract as much business as possible. The National Park has created a tourist bubble, which with its exclusive beach access and clear separation from the more typical neighbouring Sri Lankan communities, appears to have inflamed tensions among different Sri Lankan groups in Hikkaduwa. Some people are in fierce competition for the same tourist dollars as the National Park operators while others are unhappy with the effects of tourism on their town and coastal area. Many residents and workers do not originate from Hikkaduwa, but are drawn by potential earnings, thus community solidarity is weaker there than in the fishing villages. The lack of an identifiable community and the divide between the commercial operators in the town and other groups were cited, over 10 years ago, as two major reasons for failure in securing long-term sustainability of the Hikkaduwa Special Area Management (HSAM) plan and this level of social fragmentation remains today (HSAM, 1996; Kothari et al., 2000). An original aim of the HSAM plan was to demonstrate its benefits to all members of the community and in turn, encourage the adoption of SAM plans in other coastal locations around Sri Lanka (Kothari et al., 2000). The difficulties, problems and lessons from Hikkaduwa have limited the spread of this idea to a handful of locations, making it an unattractive strategy for others to adopt. The implications of these complex marine and coastal governance issues and their future directions in Sri Lanka are discussed in Chapter 8.

4.4 Historical ecology of diving in Sri Lanka

It is highly likely that the early location of primitive human settlements were either along shores or in riparian habitats. The abundant food sources these environments provide indicate that fishing is one of man's longest lasting activities (Sauer, 1962). However, the practice of diving for marine resources in early human history occurred in far fewer locations. It is believed that there may have been trade in sea cucumbers (Holothuroidea) across the Asian continent for over 1000 years, although confirmed documentation only dates back around 400 years. This trade owes much to the knowledge and skill of the Bajau[16], called sea gypsies, of present day Philippines, Indonesia and Malaysia, who have harvested the sea cucumber, amongst other resources, possibly for millennia (Schwerdtner Máñez & Ferse, 2010).

[16] The Bajau are an indigenous ethnic group of people of the maritime region of south-east Asia, who live at sea on small boats and their entire lives revolve around the sea from which they acquire resources often by free diving.

Another example of free diving, as a core part of an ancient tradition, is found among societies such as the Ama of Japan. The Ama are women divers who dive attached to a line held in a boat, descending to depths of 20-30 m to collect molluscs and other sedentary marine organisms, which the boatmen then haul to the surface. This traditional style of free diving still occurs in parts of Japan despite the divers seemingly anachronistic position and identity in contemporary Japanese society (Martinez, 2004).

Diving to collect live fish does not appear to have a long history, no historical records of such a long-held practice exist in Sri Lanka. However, diving for other marine resources off Sri Lanka is recorded in ancient chronicles, diaries and reports from early explorers, such as Marco Polo in the region (Latham, 1958: 260-261).

4.4.1 Pearl fishery in Sri Lanka

One ancient chronicle, the Mahavamsa, the great chronicle of Ceylon, describes pearls being collected off the north-western coast of Sri Lanka dating back 2500 - 3000 years (Turner, 1922; Mahroof, 1992) and, in the 5th Century AD, a visiting Chinese Buddhist monk, Fa Hsien, describes pearls as a prominent product of Ceylon (Bailey, 1952: 23). Many ancient civilisations and empires from the Romans to the Greeks make reference to pearls from this region, citing pearls from the Pearl Banks of the Gulf of Mannar as being the most desirable (Macmillan, 2005). Marco Polo proclaimed Sri Lanka "undoubtedly the finest island of its size in all the world" (Latham, 1958: 258), in part due to its cinnamon and pearl production (Schrikker, 2007). Therefore, it is clear that diving in Sri Lanka, particularly for pearls, has occurred for millennia. The high risk inherent in this form of diving in times when safety and equipment were less sophisticated than today, only serves to highlight the dangers these divers faced on every trip. This bears similarities to the risks taken by SCUBA divers of the ornamental trade today, who have to access great depths to collect particular ornamental species.

The records of the European colonial powers in Sri Lanka provide more detailed and regular accounts of the maritime and fishing history of the island. Food fishing was active and expanded upon with the arrival of the various European colonial powers but also the non-food industries, such as the pearl fishery. Although the Portuguese on arrival in 1505 were mainly interested in cinnamon for export, they saw the pearl fishery as an economic opportunity (Schrikker, 2007) and so utilised local divers' knowledge and diving skills to extract, and by 1524, export pearls on a commercial scale (De Silva, 1978). This pearl trade, based on diving, is most likely the country's earliest non-food fishery and appears to have been hugely successful during the 16th and 17th centuries, in the south Asia region under Portuguese rule (De Silva, 1978).

The Dutch took power from the Portuguese in 1658 and continued the pearl fishery. However, there were complications - despite pearls being valued only second to cinnamon among Sri Lankan exports at that time - the Dutch only had eight years of successful fishing. In 1802 when Sri Lanka became a crown colony of the British, the fishery was run privately by the Ceylon Company of Pearl Fishers (Turner, 1922) and there were often mentions of the Ceylon Pearl Fishery in newspapers in Sri Lanka and the UK through the latter half of the 19th Century (Figure 4.1). The centre of this fishery was in Silavatturai,[17] a town on the northwestern coast of Sri Lanka, where a large, vibrant centre developed. However, due to both poor management and the failing stock of oysters in certain years it was not always profitable. Finally, with the introduction of the cultured oyster by a Japanese businessman, a steady decline of the fishery began. Even though traditional methods were used up until 1950, the pearl fishery ceased to exist after that time (Mahroof, 1992).

17 Silavatturai is still mentioned as a place of good diving. Some older SCUBA divers I met had worked there relatively recently, collecting ornamental fish, sea chanks, *Turbinella pyrum* and sea cucumbers (Holothuroidea) for export companies.

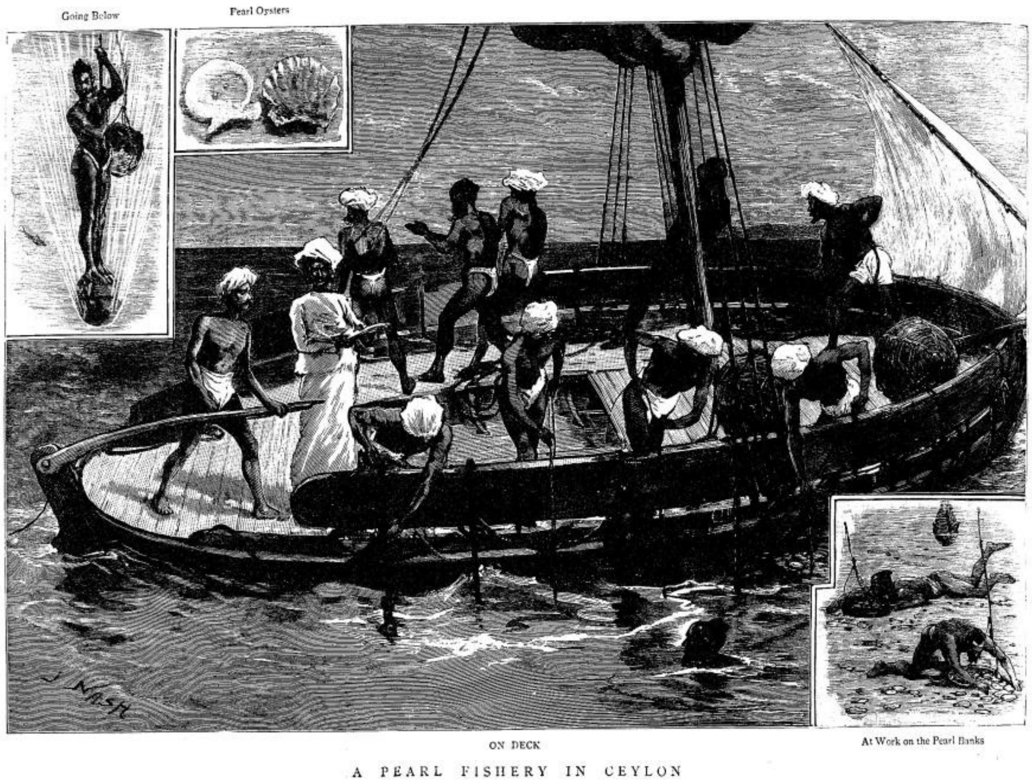

Figure 4.1. Artist's impression of the Ceylon Pearl Fishery published in The Graphic 22 Oct 1887, London, England. The picture depicts the crew on a pearl diving boat and pearl divers in the water near the edge of the boat as well as descending and collecting oysters (insets)

The pearl fishery generated the acceptance of harvesting non-food marine resources commercially and the communities involved developed a culture around it. Men dived for pearls for work, exercise, as well as enjoyment and adventure and this can be paralleled with the culture surrounding the young men of the ornamental fishery today. Divers today remark on the long history of diving in Sri Lanka and this living memory of the pearl fishery explains their cultural attachment to diving. Divers believe their skills in diving for pearls, shells or fish are unmatched partly derived from their long heritage of diving for non-food resources. This culture embedded around diving enabled the ornamental fishery to develop as conditions became suitable.

4.4.2 Ornamental fishery

During the 1930s, Sri Lanka was the first place in the world to collect fish for the ornamental trade (Jonklaas, 1985). At first the trade was limited to one or two export companies based around exporting mainly freshwater fish species, on ships (Ekaratne, 2000). After national independence in 1948, the trade increased, more export companies were established in Colombo and as air freight became more economically viable, the industry expanded at all levels. However, in the 1960s and 1970s, the number of divers was rather limited; they learnt and began their work in and around Colombo, before searching for good reefs and fishing locations (Wood, 1985).

According to my elderly informants, they recalled such divers coming from Colombo but that there were perhaps only five to ten skilled divers moving around the country during the 1960s and 1970s. These divers taught a few local men how to catch ornamental fish while providing them with the necessary equipment. Locals kept the fish for payment until the divers returned or they might convey it to Colombo. In this informal way, the supply chain from reef to export company selling it abroad emerged in several coastal villages in southern Sri Lanka. The divers from Colombo gained access to the village waters through a combination of payments and by exercising their higher social status. They were not competing with food fishers for the same fish stocks, so were not regarded as a threat. Informants recalled that even when the initial trainees began operating, the numbers of divers remained low – around 20 divers in the whole southern region, while the number who possessed the necessary equipment and could SCUBA dive were far fewer. Some informants claimed SCUBA diving for ornamental fish was rare at that time as the desired species were plentiful in the shallow seas and accessible by snorkelling.

Government policies and the national economic situation up to 1976, restricted the trade and thus the divers, as exports focused around plantations and agricultural products. State regulation and meddling in all export industries was prevalent and prevented free market led growth (Hossain et al., 1999). In 1977 the transition to a free market economy and focus on expanding foreign currency earning export businesses (Groves, 1996) suited the marine ornamental trade perfectly. Increased globalisation led to an increase in foreign trade including imports of foreign goods, such as fishing and diving gear, previously unattainable locally. These factors undoubtedly brought an increase in the number of divers, in the southern regions, who could eventually buy, or be provided with, the necessary snorkelling equipment for ornamental fish collection: a mask, a snorkel, a pair of fins, nets and bags.

4.4.3 The effect of the civil war

The growth and maintenance of a steady ornamental trade was negatively affected by the country's civil war, which began in 1983 and ended in 2009. Tourism which had peaked prior to the start of the conflict soon waned as did international trade, which shifted to more stable countries. This affected the ornamental fish trade in Sri Lanka. By the 1980s, many nations were exporting ornamental fish including the Philippines, Indonesia, Malaysia and Australia, which meant importers could select more reliable sources. Many international flight carriers discontinued services to and from Colombo during the war, thereby further restricting the export companies' fish trade activities.

The war also had direct impacts on the fishery. Historically, in line with the Sri Lankan monsoon seasons, divers tend to move between the southern and north-eastern coasts of the country following the calm sea periods (A. Rajasuriya, pers comm.). The southern coasts experience calm conditions during the north-east monsoon, (November - March), and then rough conditions during the south-west monsoon for the remainder of the year while the north and east coasts experience the complete opposite weather pattern. This means divers can collect fish all year in calm seas. However, northern and eastern parts of the country were difficult to access or dangerous to visit during periods of hostilities. Being from the Sinhalese majority, divers from the south could access these areas only if they accepted the risks. My Sinhalese informants spoke of their fear whilst in Tamil majority areas, and some buyers spoke of losing expensive equipment to members of "the LTTE [18]". Such experiences resulted in an early return to the south during a fishing season and many have not yet considered returning to the north-eastern areas.

In many parts of the coast where fighting was common, fishing boats and diving were banned amid the high security concerns. To dive and fish in these areas was challenging, but not impossible and many southern coast divers found the rewards outweighed the risks and continued to work every out-season there. Now, with the cessation of the fighting, divers and companies are hopeful of growth in the fishery along the eastern and northern coasts, as trade in the previous conflict zones builds. Informants, however, report that during the three years since the end of hostilities, licensing checks have become more regular on the east coast and, being outsiders, they are often prevented from diving there. The local people in the east, similar to those in the south, wish to safeguard their own resources.

[18] LTTE stands for the Liberation Tigers of Tamil Eelam and is the name of the separatist militant organisation, which fought the Sri Lankan government for an independent Tamil state in the civil war.

4.4.4 Other historical impacts on the ecology of the reefs

From the 1970s onwards, new types of fishing and improved fishing equipment spread throughout Sri Lanka. Different ways of exploiting coastal resources were also emerging and expanding alongside fishing. Coral mining has been recorded in Sri Lanka for five centuries (Premeratne, 2003). During the colonial period, a ban on the utilisation of lime for building houses was lifted, previously only utilised for royal and administrative buildings. This, in conjunction with the colonial centres of trade and education predominating along the coast, led to a rise in the coastal population, with a resulting increase in coral mining for locally available material to build houses and roads (Premeratne, 2003). By 1980 the annual requirement for limestone in the south-western coastal zone was approximately 18000 tons and 2300 tons of this was harvested from the coral reefs. Despite the practice being made illegal in 1983 (Premeratne, 1984), coral mining continued quite openly until around 2005 (Kumara et al., 2005), but the stricter law enforcement, together with its decreased use as a building material, meant I did not witness coral mining during my field work. Some informants believe that the species of corals most suitable for this practice were exhausted and / or have not returned following other large-scale environmental disturbances. The destruction of Sri Lankan coral reefs by coral mining is, however, extensive and has severely reduced previous levels of coral cover and available fish habitat. The reduction in fisheries yield for food and ornamental fishers due to coral mining has not yet been quantified.

It is widely recognised that as human populations increase, the exploitation of common resources necessitates the movement of harvesters to other areas for similar harvests (Dietz et al., 2003). Such pressures existed for food fishers in this region and the profits available from high fish catches tempted them to find more effective methods and gear. Dynamite fishing is highly effective in providing large catches of food fish making it a lucrative, though destructive, activity. Informants recalled dynamiting both within sight of the shore as well as in deeper waters. Scientists have warned against the destructive, irreversible damage of dynamite fishing in Sri Lanka (Beets, 1994) and across tropical Asian regions (Pauly, 1988) and it became illegal in Sri Lanka in 1996. Although in Sri Lanka, today, it seems to be less overt, SCUBA divers mentioned that dynamiting does happen in deeper waters often close to ornamental fish diving areas. Anecdotal evidence of both coral mining and dynamite fishing, and their lucrative profit margins was often rumoured to be linked to "*underworld*" or gangster communities. Fishers explained a system that ensured no-one spoke to the authorities from within villages, while certain officials took bribes to not report law breakers. However, recently, these activities have significantly decreased which villagers attribute to a combination of a feared and determined district police chief and a new naval patrol presence in the area.

Divers and other fishers appeared satisfied with this reduction in coral mining and dynamiting as both activities removed coral and rock habitats where fish would aggregate. Additionally, divers felt blamed for the destruction of coral and the reduction in local fish stocks by fishing, when these far more destructive practices of dynamiting and mining were widespread and yet left uncontrolled. The growth and prosperity of the ornamental fish trade is likely to have flourished more without the decades of coral mining and dynamiting of the reefs.

According to local people, ornamental fishing, coral mining and dynamiting reached a combined peak by the 1990s. The ornamental fishery comprised large numbers of divers, moving around the country, who had expanded to form SCUBA diving teams to collect fish from deeper and further-offshore habitats. Following the trade expansion, the supply chain was well established; divers caught fish for buyers within certain villages, and export companies sent trucks to transport the fish from these villages to Colombo or Negombo to await exportation. According to Wood (1985), there were around 50 export companies at this time operating from Colombo and Negombo, dealing in both freshwater and marine fish. Numbers of divers involved in the fishery were increasing, but as informants explained, the ornamental fish divers at that time were still a relatively small group of specialist divers able to dive virtually wherever they chose, as they were not threatening typical food fishing activities.

From the late 1970s local marine biologists and other academics (Jonklaas, 1975) highlighted the plight of the reefs and fish stocks due to fishing, pollution and agricultural run-off, and subsequently new government institutions were set up. Despite these adjustments, Wood's (1985) warnings regarding ornamental divers' increased use of destructive methods and the consequent unsustainable harvest of fish stocks, went unheeded and the ornamental trade continued relatively unhindered until 1998. Divers and export companies alike felt wrongly blamed for the destruction of reefs and fish populations, particularly as Wood's (1985) study concludes that damage by divers alone is difficult to determine and that other anthropogenic impacts on the reefs, such as dynamite fishing, coral mining and pollution are likely to have had a greater effect.

Coral dynamiting and mining although constantly cited in the literature surrounding Sri Lankan coral reefs, pinpoint no distinct group(s) to blame due to their illegal and secretive nature (Perera et al., 2002); therefore my informants believed that they, as a visible presence were mere scapegoats for the destruction of the reefs and current state of fish abundance.

A close relationship between people's local ecological knowledge (LEK) (see Chapter 2 and 6) and their sense of place is observed emanating from the deep rooted culture of diving and fishing in these villages. Although most divers are aware of the problems facing the reefs and their livelihoods, and so wish to preserve both, they often feel constrained by government action and powerless to find solutions when they are labelled as the culprits, a view many divers strongly disagree with. This is a case where the views of the resource users are mismatched with those of conservation officials or external scientists.

The degradation of the reefs in southern Sri Lanka results from a combination of actors and only a thorough natural capital accountancy study can ascertain the actual responsibility of each group of actors. Many anthropogenic impacts, which continually blight coral reefs and reduce their productivity worldwide, are sedimentation, eutrophication and pollution. Deforestation in Sri Lanka, as agriculture expands, results in high levels of soil erosion, which ultimately arrives in nearshore coastal areas. This sediment increases the turbidity of coastal waters, reduces light levels available to corals and their zooxanthellae (see Chapter 2.4.2), causing their death. Sri Lanka's intensive agriculture uses high levels of nitrogenous fertilisers, chemical pesticides and herbicides, which also accumulate in coastal waters, either killing corals directly or causing eutrophication, the increased nutrient load drives algal growth, which smothers coral and coral settlement locations. Many divers in Polhena commented on increased algal growth near the Nilwala river outflow to the east of Polhena beach.

Local scientists comment frequently on the various ways the nearshore areas in Sri Lanka have become polluted (Rajasuriya et al., 1995; Perera et al., 2002; Rajasuriya et al., 2002a). First, lack of a national refuse collection system means coastal household waste is deposited on beaches, which pollutes the sea, waste dumped from boats is often seen entangled in coral and nearshore areas, and industrial and domestic waste pipelines still flow untreated into the sea. Today, legal restrictions protect the coastal area from such impacts better than previously. However, they are still present and combine to form chronic stressors to the coral reef environment and may contribute as much, or more, to the decline in coral reef productivity as the fishing activities. Again, no group(s) are identified to blame and it seems that concerted action across all actors is necessary to reduce their combined effects. Assigning blame to one distinct group, such as divers or the GBBOs, may not be the solution to the problems.

4.4.5 Rare environmental events

The strong El Niño event of 1998 resulted in approximately 0.6 ºC warmer than average global sea surface temperatures. The increase in water temperature caused extensive bleaching of corals worldwide (see Section 2.6.4) and the coral mortality in nearshore Sri Lankan waters rose to 80% in some areas (Rajasuriya et al., 2002a). Informants described how the sea from the Galle road appeared white from the bleached corals in the shallow waters. Divers observed a reduction in fish abundance after the El Niño event and older divers describe this as the most significant impact on their livelihood in their lifetime. Since then, corals have to some extent re-grown in certain areas but never to previous levels. Certain coral species have not returned while other species have dominated this recovery process (Rajasuriya, 2008; Kumara, 2008), which affects the relative abundance of fish species on the reefs and many of the corallivores (coral feeding fish) desirable for the ornamental trade have subsequently remained at low levels since 1998 (Öhman et al., 1998).

Just as the reefs began to recover, the tsunami in 2004 hit Sri Lankan shores. Between 31,000 and 37,000 people lost their lives in Sri Lanka and it is estimated that round 27,000 of these were fishers and two thirds of Sri Lankan fishing boats were destroyed (Rajasuriya et al., 2005a). In the southern coastal region, the tsunami affected approximately 20% of households and caused loss of life, high levels of structural damage to both reefs and villages, resulting in the destruction of families' livelihoods and assets. All of my study sites were affected by the 2004 tsunami: Kapparathota, Polhena and Thalaramba were all severely affected, with many villagers relocated to tsunami villages[19] inland, although not all were satisfied with this arrangement, being relocated relatively far from the coast (see Chapter 8.3.3). Hikkaduwa and the western Sri Lankan coast was affected by the tsunami but to a lesser extent than the other sites. Despite the five years between the tsunami and my arrival, there were still signs of its

[19] Tsunami villages were constructed via foreign aid for villagers who lost their homes in the tsunami.

colossal power and the damage it caused to these villages and people. Much of the structural damage has been repaired, yet it is the lasting changes to the landscape and to these communities and their livelihoods that were explained to me by local people or became apparent to me and the different extent of its impact among the sites is worthy of attention here to appreciate the continuing recovery in the current context of everyday life in the villages. Most of my informants related extremely upsetting testimonies of their tsunami experiences that acknowledge the enormous impact on their livelihoods. The ornamental fishery ceased abruptly until life returned to some normality several months later. The enormous influx of foreign aid following the tsunami had such an effect on the ornamental fishery that the current structure of the fishery and its market chain today show the effects.

Fishers' talk contains many comparisons between the period before and that after the tsunami, reflecting the huge impact this event had and the large changes that consequently occurred. They often blame the tsunami for great destruction of the reefs and the negative impacts they perceive it had on their fishing grounds (see Chapter 5.3.3), as well as changes to village community life. A common refrain from the majority of the ornamental divers in my study regarding pre and post tsunami, was:

"*After the tsunami, the rich people became poor and the poor became rich*".

Strong feelings of injustice are common regarding the way foreign aid, in the form of boats, money, houses and fishing gear, was allocated. Informants who felt that they received less than their fellows told me they were grieving and unable to engage in the procedures and bureaucracy of aid allocation. They believed many people who had suffered or lost little, had exploited the system in the aftermath of the disaster. Stirrat's (2006) analysis of the Sri Lankan tsunami aid effort was characterised by chaos, much competition and a lack of co-ordination among aid agencies. One result was an increase in the fishing fleet through boat donations at a time when the Fisheries Department was trying to reduce fishing activities. Stirrat (2006: 13) comments on "...the vast numbers of NGOs which arrived in Sri Lanka intent on spending money" on highly visible relief efforts to satisfy the media and all the foreign and local interested parties who had invested in the relief effort.

NGOs competed to spend and deliver the aid, preferably in front of a camera, and to whom it was actually given appears to have been a secondary consideration. “In some cases, fishers received no assistance; in others individuals were given two...brand new boats” (Stirrat, 2006: 14). Fishers throughout the villages in which I worked spoke of similar inequities and the community divisions and resentment it has caused. Foreign aid in the way of basic snorkelling gear for ornamental divers or buyers is believed to have led to an increase in the number operating along the south coast.

Similarly, donations from other providers impacted on the ornamental fishery in unintended ways. One was the rise in the number of buyers per village. Export companies, eager to re-start trading again after the disaster provided assistance to their suppliers, ranging from new diving gear, cylinders and/or money. Furthermore, the generous foreign donations and government compensation for boats, nets, SCUBA and snorkelling equipment to Sri Lankan divers enabled some experienced ornamental SCUBA divers to establish their own fish buyer business in their village. One export company boss explained what happened at this time when he had thought the industry would collapse:

> *“...there were only 6-7 suppliers in the Matara area then, now there are over 20 suppliers in that same area, so we were lucky, a lot of aid work helped divers become suppliers. For us as companies, it is good to have more suppliers so I don't mind that the aid companies helped them.” - Akbar, HICOM Ltd. 12th March 2010.*

Therefore since the tsunami, competition had increased within each village and more sale points in the coastal villages exist for divers to sell their fish, potentially encouraging higher daily catches. My study villages had thus become fish sale hubs for divers along the south coast and main purchase points for the export companies.

Since the tsunami, village territoriality for ornamental fishing in nearshore waters has been incorporated into the village sea tenure system that already existed for other fisheries, such as beach-seining (Alexander, 1977). Current village sea tenure is limited to the nearshore area of coastal waters, extending 500 m from the village shore and along the coastline upon which the village is sited. This system is governed informally from within each village so only village people may fish in the village's nearshore waters and outsiders are not permitted and, as fishers in each village are a close-knit community, the system is easily enforced.

Exceptions to these informal laws are if a fisherman marries a woman from another village; after seeking permission, he may fish in both village waters and this applies if a fisher has close friends or family in other villages. Several ornamental snorkellers collected fish in different villages during my fieldwork under such arrangements. Others spoke of being chased away by angry villagers when they had not gained permission. However, it was rare to hear of people fishing illegally in others' nearshore waters as they risked harsh physical punishments if caught and there was a general acceptance of each village's right to its waters. Concern was raised among divers and buyers of SCUBA divers from other villages diving too close to the shore within sight of the village and then entering the shallow nearshore waters undetected to collect fish, lobsters and cucumbers.

Divers told me that before the tsunami these rules did not apply to the ornamental fishery and they moved to where they wished, as long as they limited themselves to collecting only ornamental fish. The cessation of the freedom to snorkel or SCUBA dive relatively freely after the tsunami is partly due to divers catching non-ornamental resources which angered local residents but has continued due to the increase of ornamental divers and buyers among coastal villages, the resulting rise in competition, and perhaps the perceived diminishing and thus more highly valued reef resources.

Although the ornamental fishery altered after the tsunami, it was otherwise proceeding much as before. Few alternative livelihoods exist for families involved in this trade, despite its relatively recent inception. Notwithstanding the major environmental impacts to the reefs (see Section 4.4.5 and Chapter 2.7) and their resultant social changes to the community, ornamental fishing is still considered to be a worthwhile pursuit amongst other low income livelihood options currently available in the south coast villages.

4.5 Conclusion

Fishing and diving culture in Sri Lanka have a long history, one deeply embedded in the livelihoods of the communities along the southern coast. It can be argued that diving for ornamental fish is not just a recent livelihood developed under the influence of globalisation but is another example in a historical series of commercial enterprises based on valuable natural resources, comparable to the pearl trade in previous centuries.

Some steps are being taken nationally to protect and sustainably manage the marine resources of Sri Lanka. However, in the context of the ornamental fishery, despite some positive achievements to date, both the social and ecological aspects of the system are foundering under current pressures. To have meaning today, an understanding of the historical ecology helps to inform the best course of action to restore resilience to the system (see Chapter 5.1.4). The efficacy of the historical ecology approach is evaluated by demonstrating how its three main concepts (outlined in Chapter 2.13.1) were met in the arguments provided in this chapter.

Human effects within this social-ecological system are evident; they stretch back centuries and accompany the lasting physical effects of the cultural practices that have developed around divers and fishers along Sri Lanka's coasts, over this period. The complex and dynamic interaction of humans with their environment is demonstrated through detailing the historical ecology of the ornamental fishery. Different groups and actors have formed different views of and rights towards the reefs resulting in contradictions and conflict that will continue. Blame for the destruction of the coral reefs has been apportioned across groups which has created distrust. Foreign intervention after the tsunami has also unbalanced the fishery and trade in Sri Lanka and created further tensions.

The dynamic nature of social-ecological systems, within which the ornamental fishery exists, is demonstrated by the upheavals that have been caused by natural disasters and climatic changes, as well as ethnic conflict and changing economic and socio-cultural conditions. Living with these frequent and rapid changes to their social world and proximate natural environments leaves divers and their families in a precarious situation of being unable to either predict the future or plan for it.

Without examining place and historical ecology to identify the root causes of the extant manifestations of the ornamental fishery, we can only be aware of some of the processes that have created current conditions. With a more comprehensive understanding of the influences and impacts on the ornamental fishery since its inception and the social history of the villages in which it operates, finding solutions and restoring resilience to the system appears more probable and tangible than without such analysis. The direct current impact of this fishery and the levels of resilience among the fishing villages are evaluated in the following chapter in order to continue a sustainability assessment.

Chapter 5

The effect of ornamental divers' behaviour on catch rates and the resilience of associated coral reefs

5.1 Introduction

Success in monitoring and managing the oceans so as to balance their exploitation with conservation of their resources and services for future generations has proved elusive (Worm et al., 2009), despite much study, debate and political intervention. Single-species management plans have failed (Pikitch et al., 2004). Much of the scientific study centres on commercial food fisheries, usually conducted at sea from factory sized ships. Fewer studies concerning fisheries data and their management focus on small-scale, artisanal and nearshore fisheries (Pauly, 1997) and even fewer on coral reef nearshore fisheries. A meta-analysis shows that since 1977 only 137 papers have been published concerning fishing effort in coral reef fisheries (McClanahan, 2011). The number that focus on non-food fisheries on coral reefs, such as the ornamental fishery in Sri Lanka, constitutes a small fraction of this total.

Most studies of the ornamental marine fisheries focus not on fishery data, but on trade volumes and customs packing lists (Wood, 2001a), which may not accurately reflect the direct catch data and could therefore result in ill-suited management plans. McClanahan (2011) states that the majority of papers about fishing effort on coral reefs call for a reduction in effort, despite the fact they have not measured it or determined the extent of impact at different levels of fishing. This is important because it highlights that many studies suggest solutions to alleviate human impacts on coral reefs without what others perceive to be adequate empirical data to support such recommendations. Moreover, as fisheries are human-centred, if no reference is made to the fishers, their decisions and lifestyles, essential empirical data is missing with which to inform management policy and future study needs.

Small-scale fisheries need more detailed yet holistic studies to provide this missing data which can inform suitable management options and this is the crux of panarchy theory, (see Chapter 2.13.2), which conceptualises human-environment relationships, such as fisheries, as social-ecological systems (SES) within an adaptive cycle. The stages of growth, conservation, release and reorganisation SES move through and their resilience, adaptability and transformability across different scales of time and space are its foci. This approach is more appropriate than that based on commercial fishing, which centres mainly on the economics of fishing. Although economics is an important concept in terms of fishing, other factors are considered to also have a great effect on small-scale fisheries (Salas & Gaertner, 2004). Fleet dynamics, which include data on fleet size, effort allocation, and harvesting efficiencies, are important not only for monitoring commercial fisheries but also for managing small-scale fisheries (Hilborn, 1985; Branch et al., 2006). More recently understanding fleet dynamics of small-scale fisheries and the social characteristics and behaviour of fishers is seen as a priority in efforts to manage these fisheries more effectively (Wilen et al., 2002; Stevenson et al., 2011).

5.1.1 Impacts of fishing and views of fishers and fishing

This recent focus on the fishers themselves has emerged slowly. The influence of the global environmentalist movement since the 1970s has placed large-scale, marine-based, commercial fishers in opposition to the marine ecosystems conservation group (Martinez-Alier, 2002). This group has presented globally an image of destructive, thoughtless fishers who appear to show little concern for the future of the oceans because they are focused on maximising profits at any cost to the environment. This negative stereotype is also used to depict both small-scale subsistence and commercial marine-based fishers in developing countries. Fishers are then blamed for much of the degradation of marine resources and the proposed generic solution is to reduce fishing effort; by reducing fisher numbers or fleet sizes or restricting access to allow marine environments to recover and thrive, such as through demarcating MPAs (Chapter 2.9).

MPAs are effective against fishing pressure and enabling fish populations to recover, if well enforced, but there is less evidence of the “spill-over” effect (Russ & Alcala, 1996), which is often cited to convince fishers of the benefits of MPAs (Dalton, 2010). Moreover, such measures are often implemented without collaboration with the fishers who are therefore ignored. Resilient, adaptive management requires inclusion of fishers in management proposals and in order to determine the levels of ecological and social resilience in SES, an increase in studies that record fish catch rates and examine their ecological impacts and social factors influencing fishers' behaviour could, despite requiring compromises, generate more successful outcomes.

5.1.2 Inclusion of Local Ecological Knowledge (LEK) in fisheries monitoring

Integral to this inclusion of fishers in decision making processes is recognition of their own knowledge systems (see Chapter 2.14). From collecting data on catch and effort among fishers, further data on how their fishing knowledge is learnt, adapted and utilised can be gained and is necessary in the study of the relationships between decisions fishers make, the subsequent impacts and ways to avoid, or alleviate, the negative effects. For example, local fishers may use their own assessments of CPUE to determine their future fishing decisions and incorporate them into their LEK (Moller et al., 2004). In places where western science data are scarce, if divers and/or buyers keep better catch records through log books (see Chapter 7), catch per unit effort (CPUE) can be recorded and until better ecological data are available on targeted species CPUE provides a good monitoring method to determine the state of ornamental fisheries (Shuman et al., 2004). Furthermore, by ensuring that changes in fishers' behaviours or efficiency are recorded scientifically or discovered through LEK, interpretations of CPUE data are more accurate (Daw, 2008). In addition to the fishers several other social drivers of fishing effort particularly in tropical small-scale fisheries need to be accounted for, and integrated with, pure fisheries data such as the socioeconomics of fishing communities and the effect of modernisation and globalisation on local management initiatives (Cinner, 2005). This helps identify adaptive mechanisms amid a multitude of behaviours in a particular fishing community. Further discussion of the utility of LEK in managing the ornamental fishery in Sri Lanka is provided in Chapter 6.

5.1.3 Social complexity behind fishing behaviour and activity

The social factors underlying the relationship between the behaviour of fishers and their catch rates and their impacts on natural resources are often complex and can only emerge gradually, especially to outsiders, because key factors may be hard to quantify, concern illegal or taboo subjects or relate to aspects of behaviour that are inherent to the local psychology of fishers (Mosler, 1993). Ecological anthropologists have applied the foraging model used to help understand predator-prey relationships in ecology (MacArthur & Pianka, 1966) to hunter-gatherer societies by also incorporating the seminal work of Steward (1955) on culture change (Smith et al., 1983). The model has since been employed to determine behaviour choices and strategies of various resource users, including fishers. Views in the literature differ between those who believe traditional fishers employ a conservation minded strategy of management and exploitation (Johannes, 1978) and those who believe they are optimal foragers, who have only been limited by space and numbers (Polunin, 1984). I argue that a richer understanding of fishers' outlook and practices can be determined by researchers interacting with them in relation to their everyday livelihood pursuits rather than through quantitative models derived from typical quantitative measurements.

A study from the Philippines shows the benefits of spending extensive periods with fishing communities which revealed how social complexity affects fishing behaviour and practices that could not be derived from interviews or questionnaire surveys (Fabinyi et al., 2010). This ethnographic study on small-scale reef fisheries found that coral reef management schemes affect different people within the same villages differently and, on this basis, are accepted or rejected. Such discoveries are important for fisheries managers to incorporate into the full suite of criteria that inform their decision making and thus many larger scale projects try to ensure all aspects of social-ecological systems are included in these decision making frameworks from natural sciences data to the lived experiences of local people within different socio-economic cultural backdrops. For example, among coastal communities in Canada such interdisciplinary projects have achieved success over large scales of space and time (Ommer, 2007).

5.1.4 Concept of resilience in both fishing and management

The application of panarchy and the adaptive cycle within ecosystem management is pertinent to the multi-tiered systems of coral reef fisheries as it is based on three principles: the potential to change, the interconnectedness of controlling variables and the resilience of the system to change (Gunderson & Holling, 2002). The three main points central to system resilience (level of self-organisation in the system, magnitude of the shock that a system can withstand and remain in the same state and capacity of the system to learn and adapt) are useful with which to conceptually frame and analyse coral reef SES. By monitoring these factors and recording trends in direction of the system in terms of attractors and towards which basins of stability (see Chapter 2.13.2.1) the SES is moving are helpful to make sense of new and unusual situations in which SES can arrive, for example the current degraded and worsening state of the SES of the ornamental fishery in Sri Lanka. This is a new and unknown position to be in for all actors involved. Attempting to frame in which stage of the adaptive cycle the SES is in and understanding the drivers of actions which weaken resilience can then help efforts to support and rebuild resilience in the system. The users of the resources are intricately involved in all areas of the system and therefore focusing on social complexity, local knowledge and assessing resilience are all invaluable in determining the responses of such systems during periods of change or unpredictability (Drew, 2005). Small-scale tropical fisheries are well suited to this model which demystifies complex SES both for biodiversity conservationists, and local people reliant on such natural resources for their livelihoods.

5.1.5 The need to build resilience in the ornamental fishery in Sri Lanka

Although the ornamental fishery in Sri Lanka is relatively unregulated, it is continuing to expand both in the numbers of exporters and the numbers of fishers involved. As mentioned in Chapter 4, the deterioration of many of the country's reefs is blamed to varying degrees on the ornamental divers. Many of my informants are aware of the risk to the future of the fishery, from both the decreasing returns of deteriorating reefs and the demands of profit driven exporters and middlemen supplying western luxury markets up the chain. Most fishers want a better managed system, that is focused on sustainability. By analysing data concerning the fishery in relation to the system's resilience using a multi-faceted approach, its strengths and weaknesses can be identified.

More data about the fishery itself is also needed to convince all decision makers involved in the trade to not only take action but also determine the size and scope of this action. Without such data many in the trade see little evidence to suggest the fishery is unsustainable and thus resilience is continuously undermined both in the coral reefs and the fishing communities.

A paucity of data exists about the ornamental fishery in Sri Lanka, other than numbers of live export weights and shipments from Customs. No records of the species and the number exported are available, unlike in other ornamental fish export countries, such as the Maldives and Hawaii, where more detailed recording occurs (Wood, 2001a; Wabnitz et al., 2003). Few data have been, or are currently, collected from the divers nor from the fishery considered as a set of biological and social factors. To date fisheries studies in Sri Lanka include general descriptions of the marine sector (Fernando, 1985; De Bruin et al., 1995), the biology of certain commercial species and food fisheries statistics of Sri Lanka's coastal and inland waters (Dayaratne et al., 1995; Amarasinghe & De Silva, 1999; De Silva & Sirisena, 1987; Dayaratne & Sivakumaran, 1994; Dayaratne, 1998), the documentation of traditional community management of lagoon shrimp fisheries (Amarasinghe et al., 1997), a coastal ecosystem modelling study (Haputhantri et al., 2008) and marine fisheries landings data (NARA, 2001). More recently, the status of MPAs and fish refugia in the country were assessed within Sri Lanka (Perera & de Vos, 2007) and for all countries within the Bay of Bengal Large Marine Ecosystem Project (BOBLME, 2011).

Data concerning catch rates, catch per unit effort, the allocation of effort or other useful metrics to determine the state of the fishery are non-existent for the marine ornamental fishery in Sri Lanka. Most of the published studies concerning Sri Lankan reefs and coral reef fish are ecological, describing the status of reefs and fish populations and only refer to the ornamental trade as one of many negative human impacts (Öhman et al., 1997; Perera et al., 2002; Rajasuriya et al., 2005a). The most extensive studies of the trade in Sri Lanka detail the overall trade, from a top-down approach (Wood, 1985, 1996). Trade volumes were estimated from years of customs packing lists. Wood (1985), after interviewing exporters, middlemen and divers about their methods and impacts, concluded with the warning, that the ornamental fish trade appears unsustainable. However, few data record actual fishery statistics or the behaviour and social interactions of divers and buyers, which is necessary for successful management implementation. Wood (2001a) subsequently published a global assessment of the ornamental trade, which features Sri Lanka, updated with the value of exports per country and a similar appraisal of future trends as in 1985, with the need for further management at all levels of the fishery. Local-based academics have also reported on the ornamental trade from a similar top down approach (Ekaratne, 2000; Wijesekara & Yakupitiyage, 2001); however, none feature data directly collected from the fishery or from a holistic view necessary to comprehend the panarchy of SES.

5.1.6 Aims

This chapter aims to present, from directly collected fishing data, the catch rates of snorkellers at three nearshore reef sites. The overall data is also analysed for differences in the catch rates depending on the age of divers and their experience level as well as comparing catch rates among and between sites. It presents individual divers' behaviours and levels of damage. These data are presented visually through GIS maps, to illustrate fishing and coral damage patterns at the reef sites.

Interwoven with these more quantifiable results are the corresponding qualitative results, taken from extensive participant observation, interviews and focus groups involving all actors in the fishery. These data bring to life the fisheries data, exposing the underlying complexity in divers' decisions and behaviours which influence the statistics. From this integration of social and ecological data, the resilience in all sectors of the fishery is assessed to provide direction in potential future management strategies. In addition, it aims to describe the iterative process of LEK generation in the ornamental fishery in Sri Lanka and the extent of the transmission of LEK among members of the fishing community, which influence future divers' behaviours.

5.2 Methods and Data analysis

The directly recorded catch data and spatial GPS data were collected by means of fisher shadowing trips, the detailed methodology of which is described in Section 3.2.7. Data concerning social complexity and fishers' behaviour as well as the multitude of factors which influence fishing effort, including, but not limited to, social, cultural and economic factors, were collected using qualitative social anthropological methods described in Sections 3.2.10-11 and 3.5.1. All data in this chapter were collected using a combination of these methods. Social data were analysed as described in Section 3.7 and quantitative catch, effort and damage data, were compared across sites and age groups of divers using a Poisson regression model, if count data such as catch, were recorded in whole numbers (Maunder & Punt, 2004). A Gaussian regression model was used for continuous data, such as for CPUE. The continuous data were log transformed to conform to assumptions of normality and equal variances before running the analyses. All analyses were performed in statistical software R (Version 2.14.1). Regression methodology followed Zuur et al. (2007).

Overall fishing pressure per area, per unit time and per site was calculated based on the number of regular divers per village, the area of each site's nearshore reef, and the average number of fishing trips per week. Also a ratio of fish caught to coral damage at each site was calculated from the directly recorded shadowing trips. With only three sites, a full analysis of this fishing pressure in Sri Lanka's reef areas was not planned, rather a simple comparison of the three sites is shown. GPS waypoints and tracks collected in the field were imported into ArcMap 10.0, and maps made, detailing locations of fishing trips, actual fish catches and instances of habitat damage.

Foraging studies use electivity indices to quantify the harvesting of foods in relation to their abundance or availability in the environment (Lechowicz, 1982). One such index, known as Ivlev's electivity index was effectively used to determine the preference of divers to catch certain fish in West Hawaii's aquarium fishery (Stevenson et al., 2011); I used the same index to identify divers' selectivity when catching fish on reefs in Sri Lanka. It compares the probability of each species being caught against the likelihood of it being surveyed or, more simply, its abundance on reefs locally. Having conducted reef fish censuses on the same reefs where fishing activity occurs, this index was calculated from directly shadowed fishing trips on the three reefs and data from my own surveys on the same three reefs.

Ivlev's electivity index (E_i) is defined by the equation: $E_i = \frac{(r_i - p_i)}{(r_i + p_i)}$ where:

$$r_i = \frac{(number\ of\ fish\ caught)}{(total\ number\ of\ fish\ caught)} \quad \text{for each species}$$

$$\text{and} \quad p_i = \frac{(number\ of\ fish\ seen\ \text{in}\ survey)}{(total\ number\ of\ fish\ seen\ \text{in}\ survey)}$$

for each species.

A negative value denotes avoidance or non-preference of that species by the divers and a positive value indicates a preference in catching that species by divers (Lechowicz, 1982).

5.3 Results

5.3.1 Shadowed snorkelling trips

During the two field seasons, a total of 102 directly shadowed diver trips were conducted. This equated to 218 hours of direct underwater observation of snorkellers fishing for ornamental fish among the three fished sites of the study. Between six and nine different snorkellers were shadowed at each site and each snorkeller was accompanied on a minimum of four trips and a maximum of seven trips. Snorkellers shadowed ranged in age from 15 to 50 years old, and their experience in the fishery varied from one year to 35 years' experience. Divers tend to dive and interact in similar age groups, rather than across the spectrum of experience. Therefore, divers were split into three age and experience groups: young/inexperienced, middle aged/mid-experience and old/experienced.

Table 5.1 provides a summary of the catch statistics of all the directly shadowed snorkelling trips, with mean values calculated per trip, as well as per diver, over all the shadowed trips. The most fish caught overall, 789, was in Kapparathota, followed by Thalaramba, 461 and the least fish caught was in Polhena with a total catch among all shadowed trips of 269 fish. Under the Poisson model, the mean number of fish and the number of species caught per trip were significantly lower at Polhena and Thalaramba (p<0.001), and furthermore, the sizes of fish caught in Polhena were significantly lower than in Kapparathota (Table 5.2). Kapparathota snorkellers had the highest catch per trip of 21.92 ± 10.8 fish and the highest number of species caught per trip of 9.66 ± 4.7 species and the highest earnings of 945.2 ± 594.5 LKR (Table 5.1). This resulted in significantly higher average earnings per trip among Kapparathota snorkellers than the other two sites (p<0.001), Polhena recording the lowest earnings and being Thalaramba between the two. However, time spent fishing per trip was not significantly different among sites. Time spent fishing was consistent across age and site with an average time of between 2.09 and 2.46 hours, similarly the sizes of fish caught varied only between 7.14 and 8.04 cm across sites and age groups.

Table 5.1. Site comparisons of directly observed snorkellers' catch data. Site codes: KP = Kapparathota, PO = Polhena, TL = Thalaramba. Fish sizes are total lengths (TL).

Site	**KP**		**PO**		**TL**	
Outcomes	**Total**		**Total**		**Total**	
Total catch	789	-	269	-	461	-
Total species caught	81	-	43	-	59	-
Per trip	**Mean *n*=36**	**SD**	**Mean *n*= 31**	**SD**	**Mean *n*=35**	**SD**
No. fish caught	21.92	10.8	8.65	7.19	13.17	10.62
No. species caught	9.66	4.7	4.96	2.81	5.01	3.1
Income (LKR)	945.2	594.5	330.9	224.1	453	449.7
Time fishing (hr)	2.46	0.8	2.09	0.84	2.35	1.16
Depth fished (m)	1.83	0.9	2.29	1.2	2.8	1.33
Size of fish (cm)	8.04	1.61	7.14	2.82	7.89	2.45
Size of fish, range (cm)	5.72 - 13.57	-	4.6 - 14.0	-	4.0 - 15.71	-
Per diver / season	**Mean *n*=9**	**SD**	**Mean *n*= 6**	**SD**	**Mean *n*=7**	**SD**
No. fish caught	78	43.73	39	22.65	65.9	24.81
No. species caught	23.44	11.25	15	5.73	17.86	4.81
Income (LKR)	3360.55	1786.02	1489.17	701.97	2265	1177.88
Time fishing (hr)	2.42	0.52	2.18	0.47	2.35	0.68
Depth fished (m)	1.94	0.38	2.42	0.55	2.91	0.72
Size of fish (cm)	7.98	0.99	7.31	1.67	7.47	0.96
Size of fish range (cm)	6.70 – 9.55	-	5.08 – 10.05	-	6.58 – 9.47	-

Table 5.2. Results of Poisson and linear regressions of snorkeller fishing statistics compared across sites (reference site = Kapparathota) and across age/ experience categories (reference group = Mid).

	Estimate	Std. Error	Pr(>|z|)
No. fish caught			
(Intercept)	2.92	0.05	0.000
Site PO - KP	-0.95	0.08	0.000
Site TL - KP	-0.43	0.06	0.000
Age Old - Mid	0.27	0.06	0.000
Age Young - Mid	-0.08	0.07	0.25
No. species caught			
(Intercept)	2.19	0.07	0.000
Site PO - KP	-0.64	0.11	0.000
Site TL - KP	-0.52	0.10	0.000
Age Old - Mid	-0.01	0.10	0.95
Age Young - Mid	-0.14	0.10	0.17
Size of fish caught			
(Intercept)	2.04	0.08	0.000
Site PO - KP	-0.26	0.10	0.01
Site TL - KP	-0.06	0.10	0.53
Age Old - Mid	0.18	0.10	0.06
Age Young - Mid	0.12	0.10	0.22
Earnings			
(Intercept)	6.33	0.24	0.000
Site PO - KP	-1.58	0.30	0.000
Site TL - KP	-0.91	0.29	0.000
Age Old - Mid	0.65	0.30	0.03
Age Young - Mid	0.12	0.29	0.67
Time spent fishing			
(Intercept)	4.79	0.09	0.000
Site PO - KP	-0.21	0.12	0.08
Site TL - KP	-0.10	0.11	0.39
Age Old - Mid	0.23	0.11	0.05
Age Young - Mid	0.16	0.11	0.15

Older snorkellers caught significantly more fish per trip than mid-age snorkellers ($p<0.001$) but young snorkellers caught similar numbers of fish as middle age snorkellers (Table 5.2). The number of species and sizes of fish caught did not differ among age groups. Older divers earned significantly higher income and fished for longer than middle age divers ($p<0.05$ for both) but between mid and young divers there was no significant difference in earnings or time spent fishing (Table 5.2).

These findings were corroborated by information from interviews and discussions with divers concerning the same practices and behaviours. Specific snorkellers' interview questions are attached in Appendix A. Over 58.3% of interview respondents in Kapparathota, 82% in Polhena and 93% in Thalaramba said they fished between two and three hours each fishing trip. In Kapparathota and Polhena, the time periods were uncovered from interviews as predominantly to favourable sea conditions and/or snorkeller fatigue. In Thalaramba, snorkellers gave reasons including bags being full of fish or the catch having a value of *ca.* 1000 LKR. When asked about actual income earned per fishing trip, 84% of those asked in Kapparathota replied that they earned 500-1000 LKR per trip, whereas in Polhena 42% of respondents reported earnings of 100 – 400 LKR and in Thalaramba 55% of respondents claimed earnings of 300 – 500 LKR per trip. Respondents' answers outside of these majority earnings ranges varied and only made up small percentage groups; those who claimed higher earnings explained increased earnings resulted when they caught valuable species; a key factor that attributes for the high variation in earnings among divers and trips. Different fishing strategies based on individual choice were practised by divers from different locations, which shows how accepting this variation and understanding reasons behind diver behaviour is necessary to monitor and manage for resilience.

Another key factor uncovered from informants was the unpredictability of the daily catch due to the system of orders through the market chain. Respondents gave mixed responses when asked about their fishing strategies. Most divers interviewed said that they primarily fished to meet any orders they had received and on days without orders they would usually catch anything they encountered. A smaller number of snorkellers at each site claimed they caught only "*quality fish*", to ensure all their fish were bought. The problem with this strategy was that, as nearly all divers confirmed, it was becoming increasingly difficult to find the high value species, which resulted in small catches from skilled divers, who abjured the low value species. Divers explained that this had become commonplace towards the end of the season, when few high value species remained. Both local drivers, such as degraded reefs and global drivers of consumer demand were directly affecting the divers' strategies and was one example of how the interlocking web of the ornamental trade in Sri Lanka fits the panarchy theory that SES need to be examined as sets of hierarchical scales of space as well as time in order to better predict future trends in ecological change and social community dynamics.

5.3.2 Catch per unit effort (CPUE) and overall fishing pressure

Two methods of calculating catch per unit effort (CPUE) per trip were performed and compared across sites. The first method defined catch per unit effort as the number of fish caught per trip hour ($CPUE^t$) and highlighted differences in $CPUE^t$ among sites (a) and among divers (Figure 5.1). The second method defined CPUE as the number of fish caught per *moxy* net throw per trip ($CPUE^n$), usually, a successful net throw would result in one fish being caught. Catching two fish in one throw was rare due to the precise method of fishing. However, when catching low value shoaling fish, such as *Neopomacentrus azysron,* (yellowtail demoiselle) more than one fish might be caught in one net throw.

Table 5.3. GLM Gaussian regression results comparing $CPUE^t$ and $CPUE^n$ across sites and across age/ experience categories. Model reference site = "Kapparathota" and model reference age = "Mid".

	Estimate	Std. Error	Pr(>|t|)
$CPUE^t$ (fish/hour)			
(Intercept)	2.15	0.12	0.000
Site PO - KP	-0.81	0.15	0.000
Site TL - KP	-0.38	0.14	0.01
Age Old - Mid	0.11	0.15	0.45
Age Young - Mid	-0.12	0.15	0.41
$CPUE^n$ (fish/net throw)			
(Intercept)	0.48	0.05	0.000
Site PO - KP	0.01	0.06	0.93
Site TL - KP	-0.07	0.06	0.26
Age Old - Mid	0.02	0.06	0.79
Age Young - Mid	0.01	0.06	0.82

$CPUE^t$ among Kapparathota snorkellers was significantly higher than Polhena ($p<0.001$) and Thalaramba ($p <0.01$) (Table 5.3). Kapparathota snorkellers had the highest mean $CPUE^t$ of 8.42 fish per hour fishing and Polhena had the lowest $CPUE^t$ of

3.44 fish per hour (Table 5.1 and Figure 5.1a). CPUE^t did not differ significantly between middle experience snorkellers and young snorkellers nor between middle experience snorkellers and old snorkellers. Old snorkellers recorded slightly higher CPUE^t than middle experience snorkellers and young divers recorded slightly lower CPUE^t than middle experience snorkellers (Table 5.3). There was great variation in CPUE among age and experience groups in all sites.

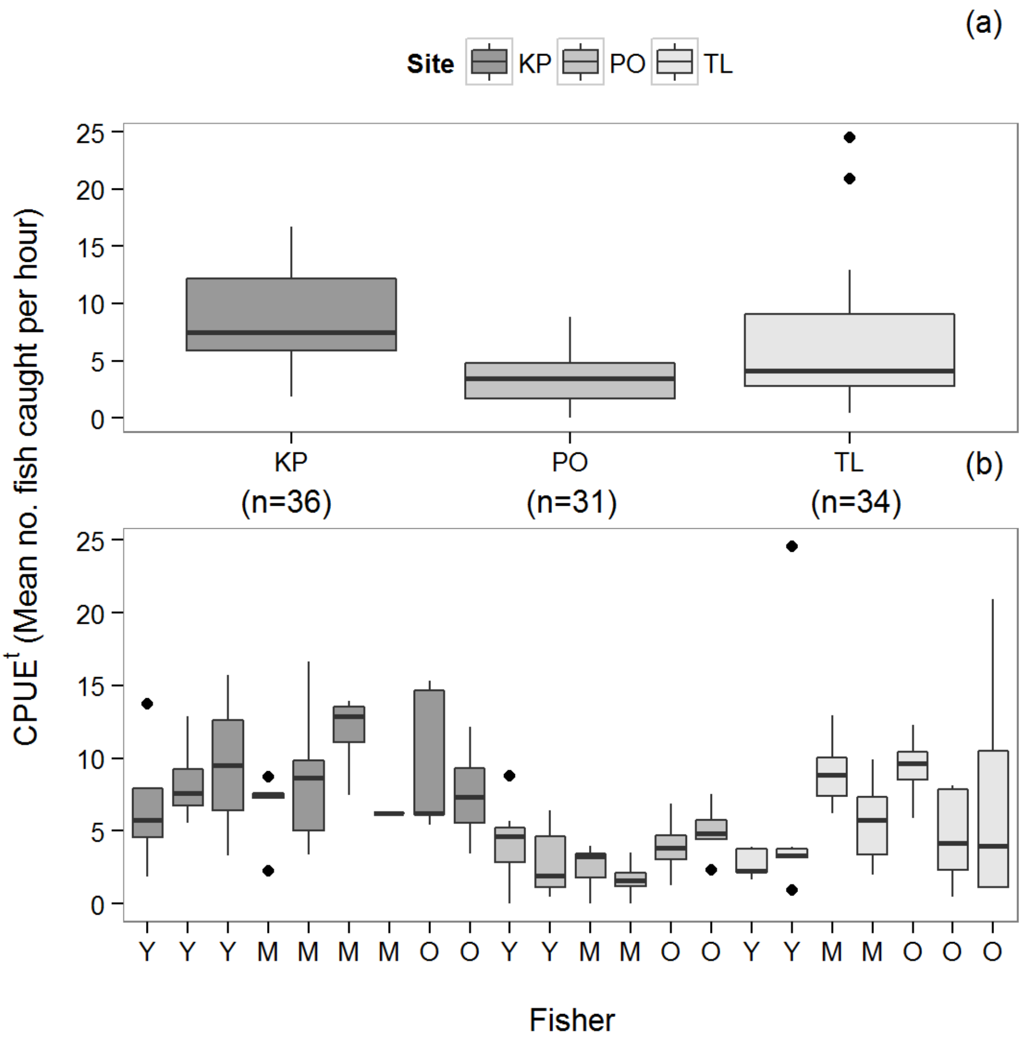

Figure 5.1. Mean number of fish caught per trip hour among (a) sites and (b) snorkellers, each letter denotes a different individual. Site codes: KP = Kapparathota, PO = Polhena, TL = Thalaramba. Fisher codes: Y = Young, M = Mid, O = Old.

There were no significant differences in CPUE^n among sites nor among age categories (Table 5.3). The contrasts in CPUE^n among sites and across divers experience groups are shown in Figure 5.2. From the two CPUE measures, a success ratio was calculated which gives a measure of fishing success per site. It translates as the number of net throws per hour per trip divided by the number of fish caught per hour per trip.

Kapparathota had the highest success with a ratio of 0.72, whereas Polhena and Thalaramba had lower success ratios of 0.61 and 0.57 respectively.

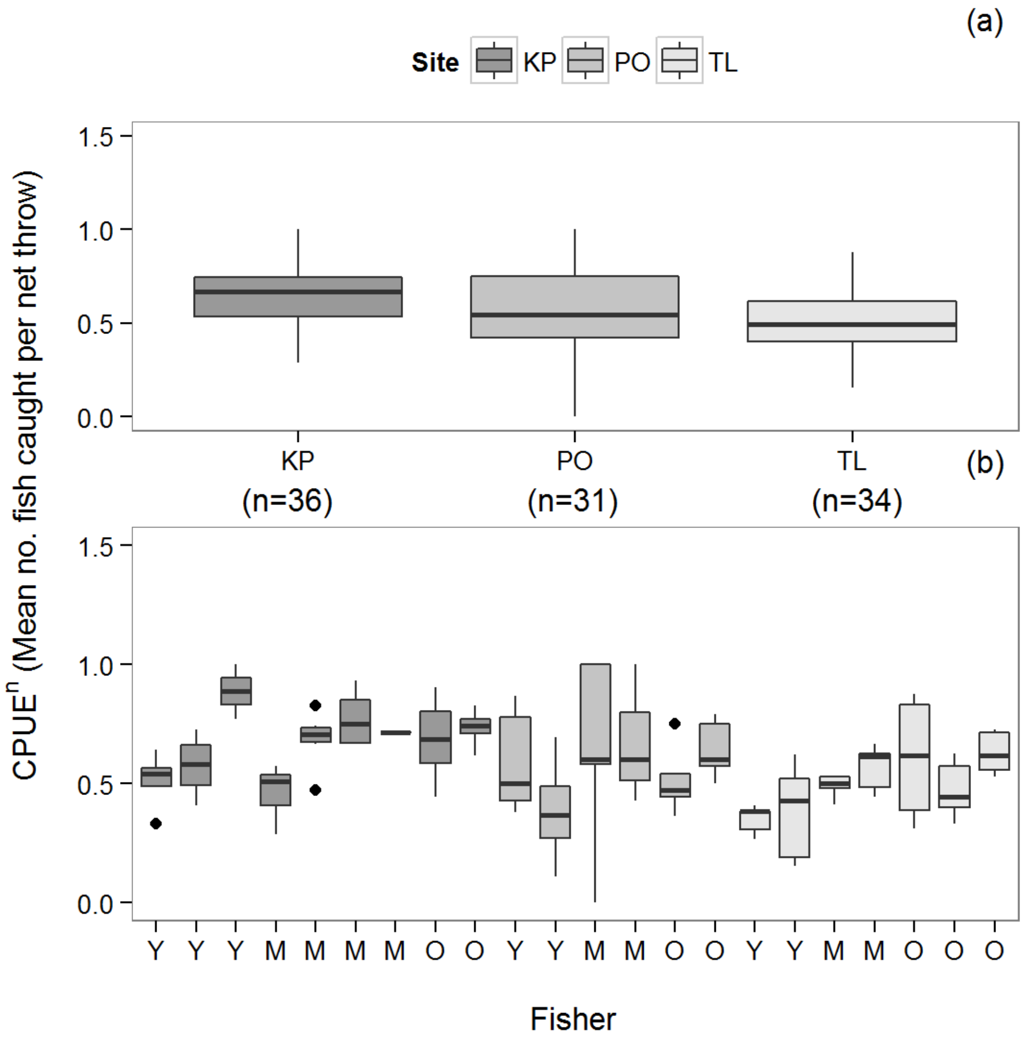

Figure 5.2. Mean number of fish caught per net throw per trip among (a) sites and (b) snorkellers, each letter denotes a different individual. Site codes: KP = Kapparathota, PO = Polhena, TL = Thalaramba. Fisher codes: Y = Young, M = Mid, O = Old.

5.3.3 Effect of divers' behaviour on fishing pressure and resilience

The following section outlines the results synthesised from analysis of coded field notes and interviews with divers and fish buyers across all my sites.

To collect ornamental fish, divers require good visibility, calm waters and plenty of sunlight, hence on days when such criteria are not met, many divers do not attempt a trip. Usually during the south-west monsoon period, none of these criteria are met and so fishing for ornamental fish ceases and this reduces the fishing pressure on these reefs for a five to six month period. However, any divers remaining in the village still fish daily when weather and sea conditions permit during this out-season. My data show that many divers are aware of weather pattern changes; recent unpredictability of the arrival and duration of the monsoon seasons as well as there being no guarantee of a reliable calm season during the north-east monsoon. Often, even during my fieldwork periods, which were timed to coincide with calm sea conditions and dry weather in the south of the country, I experienced rain for several days, so diving, particularly in the nearshore areas, was impossible because the sea was very turbid. Most divers I spoke with blamed these weather and sea changes on the recent tsunami, whereas a minority blamed climate change. Experienced divers' LEK of weather patterns and sea conditions is constantly evolving and in blaming “climate change”, it is evident that some divers have, through exposure to the global climate change discourse disseminated by tourists and the media in Sri Lanka, made links between this phenomenon and their observed changes in local climatic patterns, which affect their fishing trips.

Often in response to changes in the natural environment, resource users find themselves in the learning phase of the adaptive cycle and often diversify their strategies: with enough redundancy among strategies increases in resilience can occur but if disturbances become persistent and chronic, resource users shift to intensification stages or short-term effective coping strategies, which undermine resilience. However, these decisions cannot be viewed solely from the effects and impacts on the natural environment (McCay, 1978). Outside influences, such as the role of the state, social and community factors and economic constraints need to be accounted for to determine the valid reasons behind these behaviours. Extensive work with Arctic communities and other traditional peoples is attempting to incorporate their LEK and adaptive strategies into broader scale climate change research and policy (Turner & Clifton, 2009; Salick & Ross, 2009). Thus the long-term observations and coping strategies of such people are important and I was interested to see if my data uncovered whether the Sri Lankan divers current strategies were only coping strategies or might evolve into adaptive strategies in the face of these sea and weather pattern changes, which over time might provide much needed solutions to mitigate and adapt their ways of life to the predicted effects of climate change (Berkes et al., 2003).

From my observations, divers tend to switch from ornamental fishing to food fishing when weather conditions prevent diving, usually divers try to work on offshore one-day boats to earn a percentage of the day's profit, or others will fish from smaller boats that friends or relations own. Most divers have several strategies to either catch fish to eat or to sell when the weather is poor as these are the same strategies they use during the monsoon season but no strategy ensures guaranteed income on any given day. However, the majority expect bad weather not to last and so wait out the day, in the hope of suitable diving weather occurring the following day. This usually results in gatherings and drinking, which reduces already limited money among divers and only exacerbates issues of debt and poverty.

These strategies appear to be only coping strategies, as few are fail-safe strategies to provide income or subsistence and reduce future resilience. The alterations in the predictability of the monsoon seasons means that the short-term methods to subsist during the monsoon months are less secure as divers need to rely on these strategies for longer periods of time or at inopportune moments during the season. All divers related how economic hardship is more common during the monsoon season if they remain in the southern region. However, some ornamental divers supplement their income with not just other forms of fishing but also labouring or tourism. Divers with potential for alternative livelihood activities and social connections to aid such opportunities, dive and in particular snorkel for ornamental fish less than those without such opportunities, as they find the income either more reliable in the case of labouring, or more profitable in the case of tourism. The livelihood options are discussed in Chapter 3.3.1. and Chapter 9.

No strict rules or taboos exist as obligatory no fishing days, except perhaps for *Poya* days (Section 5.4.6). Usually the decision to fish or not rests with the individual diver. Some divers will attempt fishing in poor conditions because they need money, or they believe they are more skilled than others. However, despite the different factors that affect fishing pressure, divers agree that on average, during the season, they dive for ornamental fish around 20 days each month, or 4-5 times per week for both snorkellers and SCUBA divers. Each snorkel trip constitutes one dive, whereas SCUBA divers on average perform 3-5 dives per trip.

From observations and asking informants at each village as well as examining the buyers' logbooks an estimate of the total number of regular snorkellers and SCUBA divers at each site was made. Additionally, the area of the reef accessible to divers in each village was estimated from asking informants and taking measurements from satellite images. From all these separate frequencies and estimates, an overall. Maximum fishing pressure per area per unit time was greatest at Kapparathota with a greater number of regular snorkellers and 0.42 hours of fishing occurring per hectare of reef every day (Table 5.4). Thalaramba had a lower fishing pressure of 0.31 hours per hectare per day and Polhena had the lowest pressure of 0.23 hours fished per hectare per day.

Table 5.4. Overall maximum fishing pressure expressed as hours fished per unit area per unit time for each site. Site codes: KP = Kapparathota, PO = Polhena, TL = Thalaramba.

	Sites		
Factor	**KP**	**PO**	**TL**
Number of snorkellers	34	16	29
Mean time fishing per trip (hrs)	2.46	2.09	2.35
Average trips per week	5	4	4
Reef area (ha)	114	84	126
Hours fishing per week	334.6	133.8	272.6
Hours fishing per day	47.79	19.12	38.94
Hours fishing / ha / day	0.42	0.23	0.31

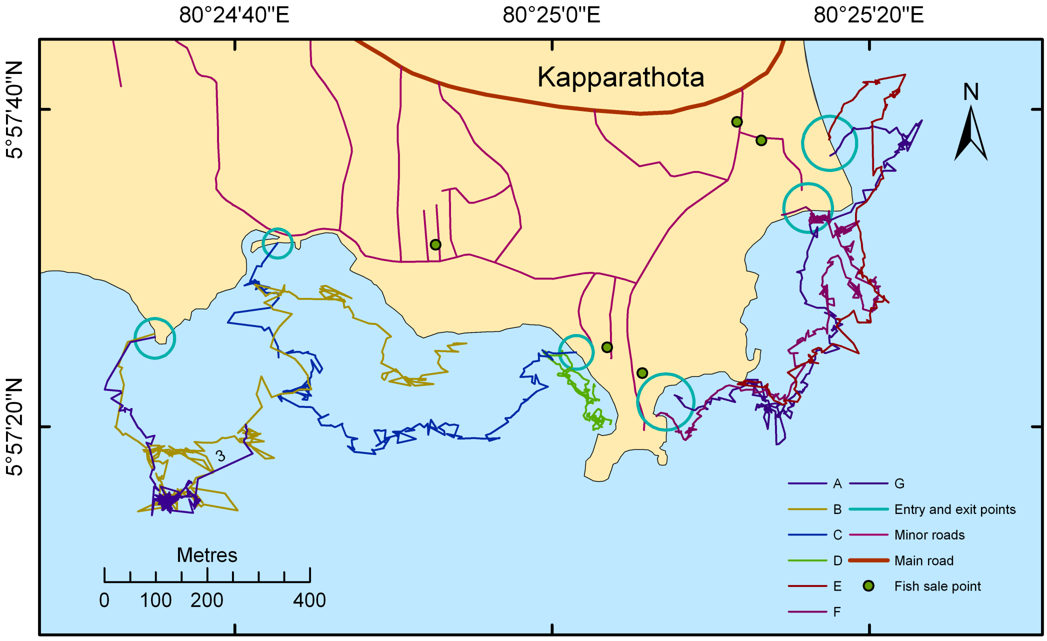

Figure 5.3a. Snorkelling fishing trip routes in Kapparathota's nearshore waters. Each coloured line is a separate snorkelling trip. Only seven trips are shown for clarity. Fish sale points are the fish buyers' locations in the village.

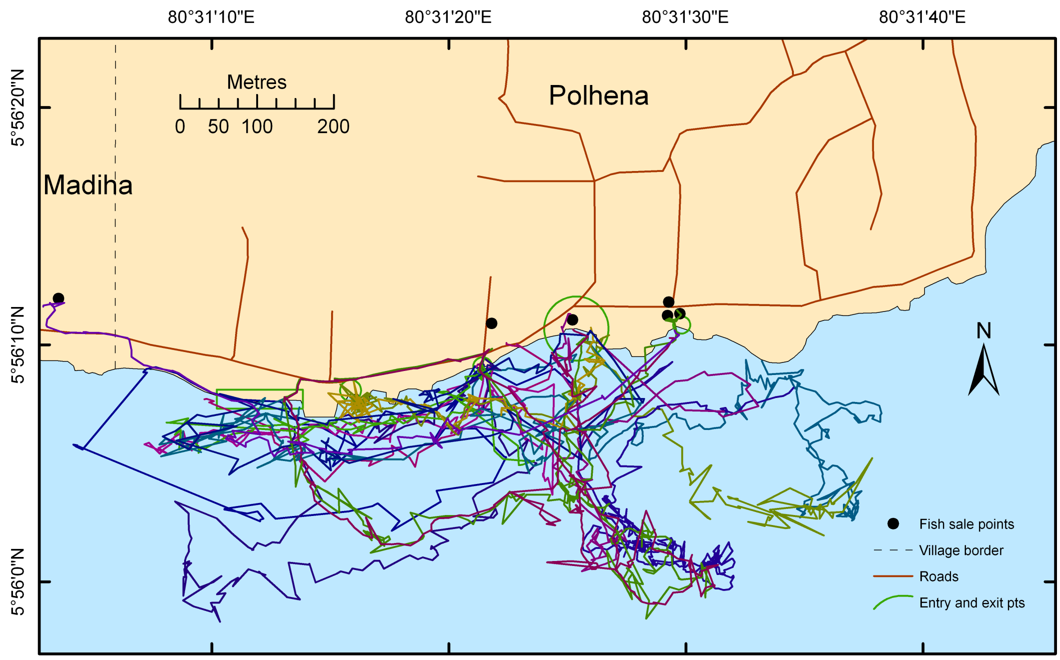

Figure 5.3b. Snorkelling fishing trip routes in Polhena's nearshore waters. Each coloured line is a separate snorkelling trip. Fish sale points are the fish buyers' locations in the village.

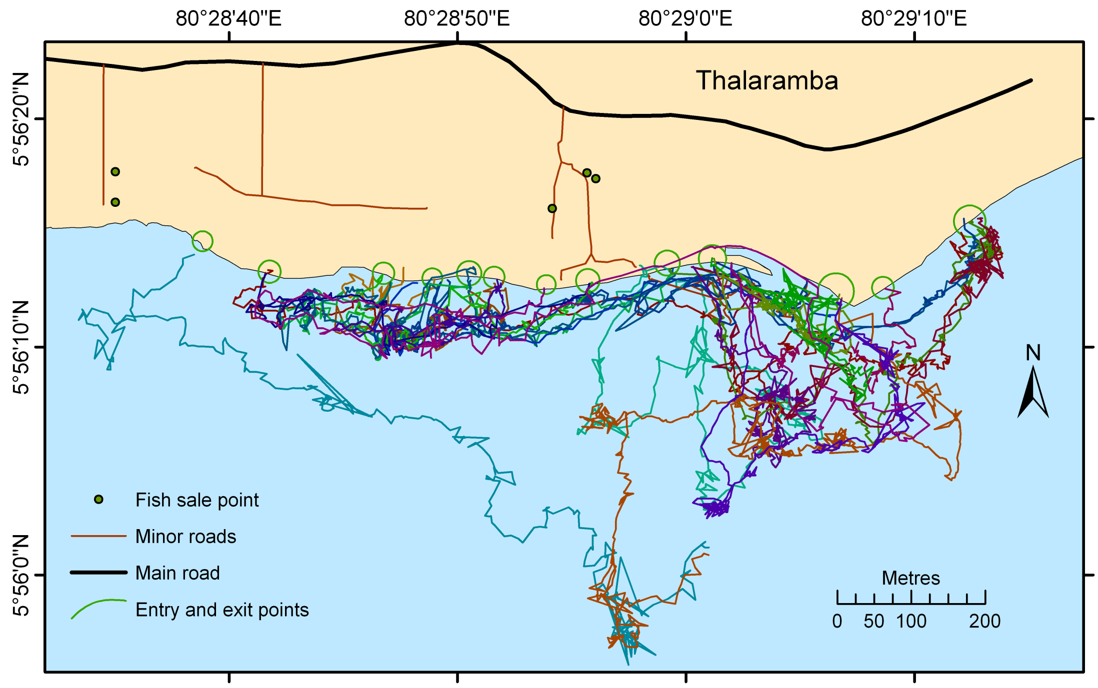

Figure 5.3c. Snorkelling fishing trip routes in Thalaramba's nearshore waters. Each coloured line is a separate snorkelling trip. Fish sale points are the fish buyers' locations in the village.

Maps of each study site show the overlapping routes snorkellers took (Figures 5.3a-c). Fewer fishing trips are shown at Kapparathota to clarify actual routes and indicate length of individual trips (Figure 5.3a), whereas more GPS recorded fishing trips are included in Figures 5.3b and 5.3c to show the concentration of fishing effort at these sites.

5.3.4 Catch composition of shadowed fishing trips

These data can be an indicator of ecological resilience and whether fishing practices are undermining it. During the 102 shadowed fishing trips made across all sites, a total of 1397 fish and invertebrates were caught by the snorkellers shadowed (Table 5.5). The most targeted fish family was the Acanthuridae totalling 32% of the catch with the most common fish species caught of this family being *Acanthurus triostegus* (see Appendix F for common fish names), with 11.7% of the total catch. The other main fish families targeted included Labridae (22.5%), Chaetodontidae (8.9%), Gobiidae (7.4%), Balistidae (6%), Pomacentridae (5.7%) and Pinguipedidae (3.6%). Only three chaetodontid species caught are obligate corallivores and they were only caught in small amounts: *Chaetodon plebeius* (*n*=1), *Chaetodon meyeri* (*n*=3) and *Chaetodon trifasciatus* (*n*=5). However, several other species deemed unsuitable for life in aquariums (Wood, 2001b) were also targeted in the catch; including: *Hemigymnus melapterus* (*n*=4), *Labroides dimidiatus* (*n*=106), *Ostracion meleagris* (*n*=1), *Naso brevirostris* (*n*=62) and *Zanclus cornutus* (*n*=22).

Ten species (*n*=766) comprising four families composed approximately 54% of the recorded total catch. The average price paid for these 10 most caught species was 35.6 LKR, which is low relative to the price range of ornamental fish in Sri Lanka (see Appendix F). These highly targeted species belong to only two functional groups: herbivores and invertivores (Table 5.5).

Table 5.5. Ten most frequently caught species of fish and invertebrates, from direct observations across all sites. Functional group key: HB = Herbivore, INV = Invertivore. Sale prices gathered from buyers logbooks and directly from divers and averaged across size and site price differentials. Prices in LKR = Sri Lankan Rupee, US$ 1 = 113 LKR[20].

Family	**Species**	**Number caught**	**Percentage of total caught**	**Mean price per fish paid to diver**	**Functional group**
Acanthuridae	*Acanthurus triostegus*	165	11.68	25	HB
Labridae	*Labroides dimidiatus*	106	7.51	25	INV
Gobiidae	*Valenciennea sexguttata*	88	6.23	20	INV
Acanthuridae	*Acanthurus lineatus*	88	6.23	76	HB
Labridae	*Halichoeres nebulosus*	74	5.24	25	HB
Acanthuridae	*Naso brevirostris*	62	4.39	30	HB
Acanthuridae	*Naso lituratus*	53	3.75	63	HB
Labridae	*Halichoeres marginatus*	46	3.26	25	INV
Labridae	*Coris formosa*	42	2.97	57	INV
Pomacentridae	*Chrysiptera leucopoma*	42	2.97	10	HB

The mean size of nearly all species of fish captured ranged between 4 and 10.3 cm, indicating the strong selective pressure in the fishery for small and juvenile fish with only occasionally large sized individuals being caught (Table 5.6). Most captured fish were juveniles of target species. Both the average sizes and the size ranges of the fish caught were lower than the known or estimated size at first maturity of each of the most

[20] Based on 2010 US$: LKR exchange rates

commonly caught species listed (Table 5.6). Only seven of the 20 most commonly caught species had electivity indices less than 0.7, the high positive E_i values for the most targeted fish species indicating they are actively sought by divers even though – as by the same measure it shows that – these species were relatively uncommon on the same reefs (see Chapter 6).

Of the seven species with lower electivity indices, only one species, *Halichoeres nebulosus,* has a negative score, which indicates this species is either slightly avoided or not preferred by divers or is in far greater abundance than the catch rates would suggest. This species was relatively ubiquitous across the reefs in the surveys (see Chapter 6). Some of the other most commonly caught species appear also to be relatively abundant locally, such as *Acanthurus lineatus* and *Halichoeres marginatus*, with relatively low positive E_i scores of 0.28 and 0.27 respectively. However, the most commonly caught fish in nearshore reef areas were highly targeted by divers, due to their worth within the ornamental fish trade (Table 5.6).

Table 5.6. Top 20 most caught species, sizes and electivity indices (Ei) from 99 shadowed fishing trips across all sites. All lengths are total lengths. Lm = Total length (cm) at first maturity calculated from Linf and von Bertalanffy equation (Froese & Pauly, 1997). Real data Lm = actual known size at maturity (Froese & Pauly, 1997).

Species	Mean length (cm)	s.d.	Range (cm)	*n*	Lm	S.E of Lm	Real data Lm	Ei
Acanthurus triostegus	6.48	2.09	4.0-15.0	165	12.3	9.2-16.5	7.5	0.68
Labroides dimidiatus	6.98	2.43	4.0-14.0	106	9.4	7.1-12.7	6	0.92
Acanthurus lineatus	8.67	3.85	4.0-16.0	88	15	11.2-20.1	18	0.28
Valenciennea sexguttata	6.3	2.15	4.0-11.0	88	9.4	7.1-12.7	-	0.95
Halichoeres nebulosus	6.97	2.18	4.0-11.0	74	8.2	6.2.-11.0	-	-0.1
Naso brevirostris	7.5	2.61	3.0-13.0	62	22.1	16.5 – 29.6	-	0.99
Naso lituratus	7.33	3.05	4.0-14.0	53	24.1	18.0-32.3	-	0.83
Halichoeres marginatus	9.41	2.86	3.0-13.0	46	12.3	9.2 – 16.5	7	0.27
Chrysiptera leucopoma	6.8	1.3	6.0-8.0	42	5.8	4.3-7.7	-	0.59
Coris formosa	8.21	3.63	3.0-16.0	42	34.1	25.5 - 45.7	-	0.97
Rhinecanthus rectangulus	5.33	2.09	3.0-10.0	38	18.5	13.8 – 24.8	-	0.86
Chaetodon decussatus	7.71	3.21	3.0-14.0	37	12.9	9.6 – 17.3	-	0.4
Acanthurus sp. *(A. blochii statistics used)*	7.13	2.89	4.0-12.0	35	20.8	15.5 – 27.9	-	0.56
Parapercis clathrata	9.19	3.33	4.0-13.0	32	15.2	11.3 – 20.4	-	0.98
Plectorhincus orientalis	10.32	3.35	5.0-15.7	26	40	29.9 – 53.7	-	0.73
Chromis viridis	4	NA	4.0-4.0	25	5.8	4.3 – 7.7	-	0.99
Rhinecanthus aculeatus	5.82	3.75	3.0-13.0	22	16.8	12.5 – 22.5	14	0.71
Zanclus cornutus	8.21	1.93	5.0-12.0	22	14.6	10.9 – 19.6	-	0.86
Chaetodon citrinellus	5.79	1.65	3.5-7.5	21	7	5.2 – 9.4	-	0.75
Chaetodon auriga	4.06	0.99	2.0-6.0	20	10.9	8.1 – 14.6	13	0.97

Selectivity for certain species became apparent in my interviews and discussions, where over 60% of respondents at each site listed the mid to high value species as their targets, which included species such as *Acanthurus leucosternon, Pomacanthus semicirculatus, Coris formosa, Naso lituratus, Chaetodon lunula, C. auriga*, and many other Chaetodontidae as well as high value eel species such as *Gymnothorax favigeneus* (see Appendix F). Approximately 30% of respondents said they targeted a mix of high value and more common low-value species – naming some of the species above with more common species such as *Acanthurus triostegus* and *Acanthurus lineatus*, while less than 10% said they caught the species according to orders and fewer still said they caught anything they encountered.

5.3.5 Divers' behaviour and habitat damage

Significantly fewer pieces of coral were broken, fewer dead corals moved and fewer tickler pokes and bag water changes were performed by snorkellers in Thalaramba and Polhena when compared to Kapparathota. Old snorkellers broke more pieces of coral, moved more dead coral and changed their bag water significantly more often than did mid-age snorkellers (Table 5.7). Young snorkellers broke more coral, moved more dead coral and changed their bag water more than mid-age divers (Table 5.7). There were no significant differences in the sizes of the pieces of coral broken among sites or among age groups. Polhena snorkellers stood on live coral significantly more often than Kapparathota snorkellers and old divers stood on coral significantly more than mid age divers (Table 5.7). There was no significant difference in the number of tickler pokes between old and young divers and the reference mid age group. The mean and standard deviation values of these fisher behaviour and damage measures for each site and age group are summarised in Table 5.8.

Table 5.7 Poisson and Gaussian regression model results of snorkellers' behaviours and damage compared across sites and age. Reference site = "Kapparathota" and reference age = "Mid"

	Estimate	Std. Error	Pr(>|z|)
No. of corals broken			
(Intercept)	2.27	0.07	0.000
Site PO - KP	-0.71	0.09	0.000
Site TL - KP	-0.36	0.08	0.000
Age Old - Mid	0.21	0.09	0.01
Age Young - Mid	0.35	0.08	0.000
Size of broken corals			
(Intercept)	2.42	0.20	0.000
Site PO - KP	-0.36	0.25	0.15
Site TL - KP	-0.29	0.24	0.23
Age Old - Mid	-0.16	0.25	0.52
Age Young - Mid	0.24	0.24	0.32
No. of times coral stood on			
(Intercept)	1.78	0.08	0.000
Site PO - KP	0.35	0.08	0.000
Site TL - KP	-0.01	0.09	0.91
Age Old - Mid	0.55	0.08	0.000
Age Young - Mid	0.14	0.09	0.13
No. of tickler pokes			
(Intercept)	3.21	0.04	0.000
Site PO - KP	-0.63	0.06	0.000
Site TL - KP	-0.26	0.05	0.000
Age Old - Mid	0.07	0.05	0.23
Age Young - Mid	0.05	0.05	0.36
No. of dead corals moved			
(Intercept)	2.74	0.06	0.000
Site PO - KP	-1.35	0.09	0.000
Site TL - KP	-2.26	0.13	0.000
Age Old - Mid	0.37	0.08	0.000
Age Young - Mid	0.21	0.08	0.01
Bag water changes			
(Intercept)	2.51	0.06	0.000
Site PO - KP	-1.90	0.12	0.000
Site TL - KP	-0.84	0.08	0.000
Age Old - Mid	0.60	0.08	0.000
Age Young - Mid	0.20	0.09	0.02

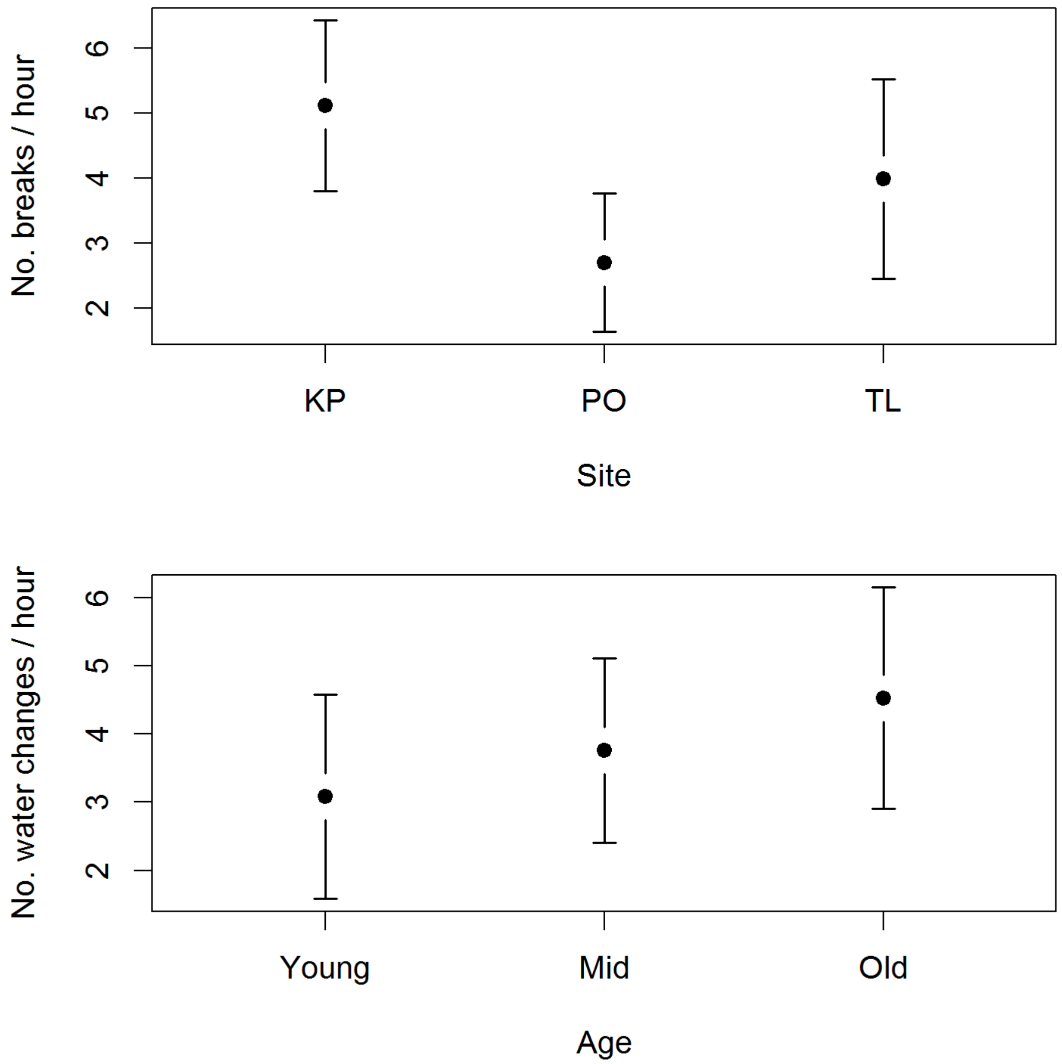

Figure 5.4. (a) Mean coral breaks (± 95% C.I.) per trip hour by snorkellers among sites. Site codes: KP= Kapparathota, PO= Polhena, TL= Thalaramba (b)Mean water changes of holding bag (± 95% C.I.) per trip hour by different aged and experienced divers over all sites.

Older divers on average dived with greater care and broke fewer corals than younger divers (Table 5.8). Furthermore, the sizes of those corals broken were smaller among more experienced divers who moreover changed the water in the holding bag more frequently (Figure 5.4b), thus increasing chances of survival of the fish caught. However, older divers stood on more corals than younger divers while other damaging behaviours, such as use of the *tickler*, are relatively equal among all age groups. These results show that certain less damaging behaviours are more common among older, more experienced divers than younger divers and in certain sites more than others.

Table 5.8. Mean values of coral damage measures and different fishing behaviours among sites and among divers of different age and experience. Young = 14-17 yrs old & 1-4 yrs experience, Mid = 17-28 yrs old & 4-10 yrs experience, Old = 30-50 yrs old & 10-30 yrs experience.

Fishing behaviours	**Sites**						**Age & experience of divers**					
per trip	**Kapparathota**		**Polhena**		**Thalaramba**		**Young**		**Mid**		**Old**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of pieces of live coral broken	11.42	8.7	5.94	7.3	8.22	7.8	9.76	9.57	7.64	7.5	8.62	7.53
Mean size of coral pieces broken (cm)	13.98	9.72	12.64	10.98	11.3	9.39	14.9	10.43	13.8	10.94	8.9	7.14
Number of times live coral stood on	7.25	5.8	10.71	13.44	7.83	5.4	7.85	6.65	6.53	4.78	11.53	13.02
Number of pieces of dead coral moved	18.33	11.04	4.97	5.05	2.06	1.77	8.24	11.53	8.81	8.89	9.26	10.4
Number of tickler pokes	25.52	13.7	13.74	7.07	19.94	10.25	19.44	11.76	20.28	13.49	20.39	9.83
Number of bag water changes	15.64	10.69	2.45	2.96	7.62	9.59	7.38	10.76	7.78	7.71	11.84	11.53
Number of deep dives (>2m)	2.05	5.06	1.16	1.85	13.82	11.29	5.76	8.57	5.33	10.95	6.19	8.03
Mean visibility distance (m)	3.53	1.29	2.84	1.27	3.13	1	3.21	1.35	3.22	1.22	3.11	1.09

5.3.6 Self awareness of behaviours and coral damage

From interviews and discussions with divers, an awareness of their impact on the fish populations and the coral reef itself emerged. Nearly all divers I interviewed admitted to breaking corals when catching fish, although a few denied this because they use hand or barrier nets rather than the *moxy* net; using the moxy net has been linked to coral damage and all the divers I shadowed used the *moxy* net. The divers were, however, aware of the negative effects of breaking coral and explained that they try to avoid it and that coral breakages do not occur every trip, which the shadowed trips confirm, yet they said sometimes they cannot avoid breaking some coral to catch high quality fish for an adequate daily income. As one fisherman stated:

> *" If I don't break it another guy will break it, we are trying to avoid breaking coral but we have to get the fish out somehow. It is impossible not to break them".*

Some believed that it was less serious to break older looking corals than newer looking ones while many believed coral damage is mainly caused by the younger, less experienced divers, who *"break the corals really badly"*. However, evidence from the shadowed trips did not confirm this. It is difficult to support assertions as to damage levels based on average values as the range and variation within the quantitative data is high, which is itself due to the high variation in abilities, experience and conservation awareness of the divers involved, together with unavoidable diver error amid difficult sea conditions.

It is necessary to determine where and to what extent direct habitat damage is occurring as this is a disturbance to reef resilience, which can lead to a threshold response in the SES, *i.e.* a shift to a less desirable state or preventing reversal from low productivity states. An overall map of where coral damage occurred during shadowed trips at each site, and whether fish were caught simultaneously provides a visual pattern of these disturbances (Figure 5.5). In Polhena, most fish catches did result in coral damage, however in Kapparathota and Thalaramba most fish were caught without damage to corals. Table 5.9 provides the total and mean numbers of fish caught per trip, pieces of coral broken and other non-fish ornamental organisms caught (urchins, starfish, octopus, lobsters). The ratio of number of fish caught to the number of coral pieces broken was higher at Kapparathota (4.65), followed by Thalaramba (2.04) and Polhena (1.36) (Table 5.9).

In an informal discussion, a well experienced diver presents his summary of the ornamental fishing situation in his village, in which he highlights some of the complexities and drivers of negative impacts, such as coral damage:

> *"One boat for every four people is needed, then people could earn better money. The reasons youngsters fish for colour fish is that their parents have no job or little money and so they have to earn something. If their parents were earning more money through, say boat fishing, they wouldn't do this and would go to school. At the moment if they couldn't do this they would be stealing. Most divers know its bad to break corals to get a fish worth 10 -15 rupees but they have to make some money. Sometimes at night guys are catching gobies as they want to earn money, buyers don't normally buy them, I saw them with two bags of gobies … there were orders for them and then lots of corals get damaged, I told them not to do it but they said they had no choice and have to catch them for money."*

Samit, a 42 year old ornamental fish collector. (The "gobies" he refers to are illegal to catch as the coral head in which they live is broken to extract the fish.)

An adaptive approach to restoring reef resilience is to attend to these community and livelihood concerns among divers. Diversification of livelihoods and increased community resilience are integral to promoting less destructive fishing activities, which when combined with necessary gear restrictions that are respected by these communities then more fruitful attempts to reduce habitat damage are possible.

The majority of divers recognised that some fish die during their fishing trips or soon after arriving at buyers' facilities. In interviews 100% of respondents said they take fish directly from the beach to the buyers in the village, which are usually within five to ten minutes' walk from snorkellers' exit points (Figures 5.3a-c). However, over 90% of respondents at all sites admitted to low levels of fish mortality either during fishing trips or before the fish are paid for by the buyer later that day but asserted that fish did not die on every trip. The main reason given for the fish deaths was a lack of water changes for the fish they carried in the bags during fishing trips. Those who denied any mortality of the fish they catch, explained how they change the water extremely regularly during their trip and on shore up until they reach the buyer.

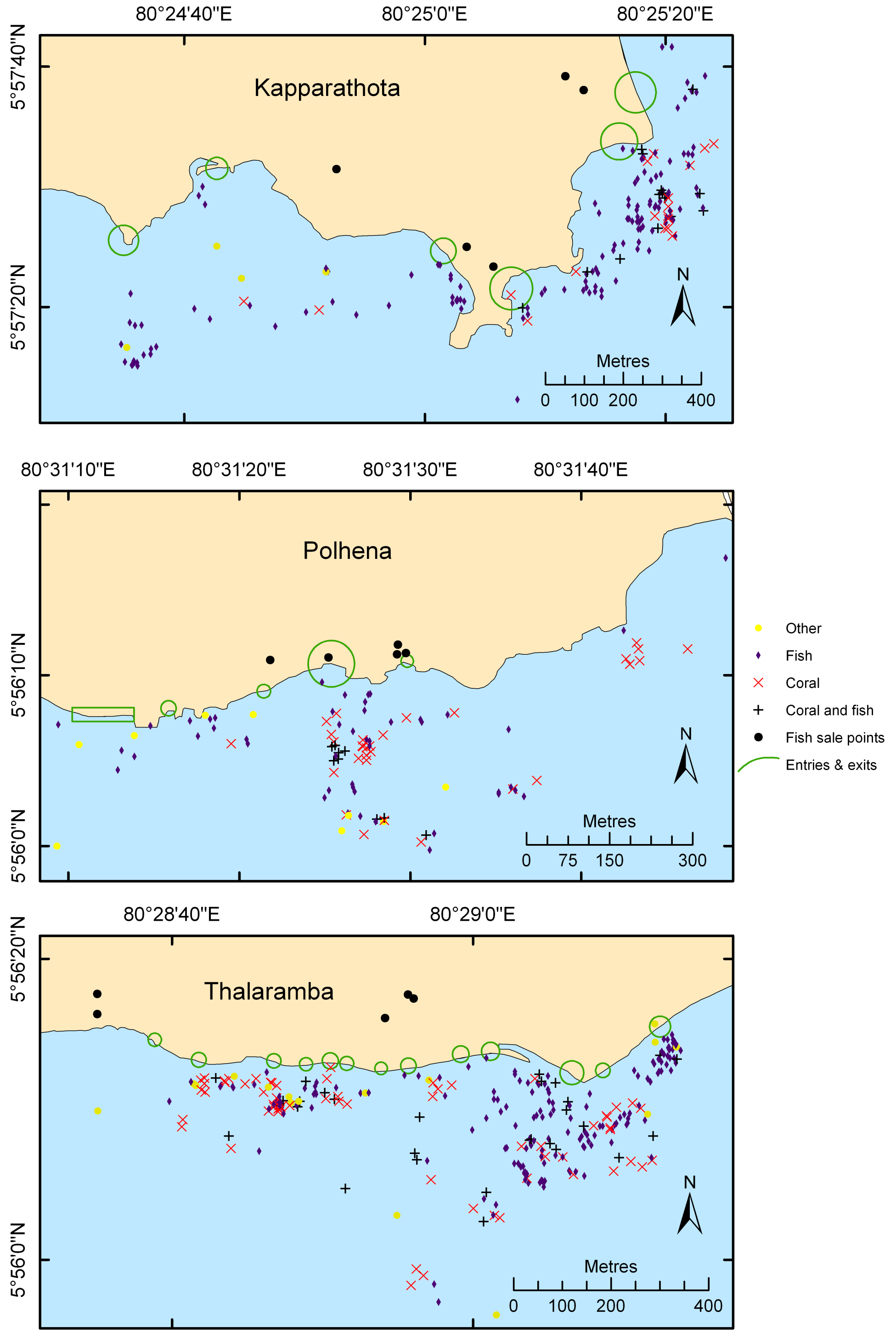

Figure 5.5. Locations where fish were caught, where coral was damaged or where both events occurred at the same point from shadowed snorkelling trips in nearshore waters at all three fished sites. "Other" denotes non-fish organisms collected. Fish sale points are the buyers' location.

Table 5.9. Comparison of total fish caught, total coral pieces broken and other ornamental organisms collected during GPS recorded shadow trips. F = Fish and shrimps, C = Coral, Other = lobsters, octopus, urchins and/or starfish collected.

Site	Total Fish	Total Coral	Total Other	Total trips
KP	789	169	21	36
PO	268	196	43	31
TL	461	227	37	35
	No. fish/ trip	**No. coral/ trip**	**No. others/ trip**	**Ratio F : C**
KP	21.9	4.7	0.6	4.65
PO	8.65	6.32	1.38	1.37
TL	13.2	6.48	1.06	2.04

Changing the water increases oxygen availability, limits ammonia build up in the water and also removes toxins leaked into the bag water from some fish, with certain fish releasing deadly skin toxins, such as *Grammistes sexlineatus*. Most divers I shadowed were aware of the need to bag toxic fish species separately, having learnt this from other divers and/or losing their entire catch from toxicity of one species. This diligence appeared to be a behavioural trait linked to age and experience, with older divers more aware of the need to change the water often particularly on long fishing trips (Figure 5.4b). My observations during shadowing trips confirmed this, across all shadowed trips mortality was approximately one fish per trip per diver and most divers accomplished 100% fish survival during and up to delivery to the buyer.

Some divers claimed that buyers bought all the fish they caught every trip and others said that fish not bought by the buyers were returned to the sea either by the fisher or the buyer. The latter would sometimes try to sell the fish to companies that visited that day and they claimed if this were unsuccessful, the buyer returned the unsold fish to the sea. I was told that buyers might keep for several days fish in containers awaiting onward sale to companies but that the longer fish are kept like this, the lower the likelihood of survival. Divers said that they moved around to sell all their fish and obtain the highest price; therefore, it became apparent that fish are not returned to the sea soon after a diving trip but later when less likely to survive. Most divers were of the opinion that during the season buyers would take their entire catch. As one middle aged diver explains:

"If you catch a lot of one species, they [the buyers] cannot sell them all, but normally there just aren't that many [fish] in the sea anymore, so you can't really catch too many to not sell them all now."

This is confirmed from my discussions with buyers who agreed that fewer fish are rejected because of the unrelenting demand from export companies and the declining abundance of fish in nearshore waters.

5.4 Discussion

5.4.1 Impact of fishery on reef ecology

Concern over the effect of the ornamental fishery on local coral reef ecology is ubiquitous, from government agencies to the divers themselves. It is difficult to compare results with other ornamental fisheries because so few have recorded measures such as CPUE (Vincent, 2006), however, the CPUE results from my study of this fishery appear low: a recent CPUE assessment of the Hawaiian ornamental SCUBA fishery recorded CPUE at between 111 and 237 fish per person per trip (Stevenson et al., 2011), which is approximately 2-5 times higher than Sri Lankan SCUBA divers (see Chapter 7). The low CPUE of snorkellers in the nearshore reefs, despite high effort levels indicates low abundance of fish across the reefs (confirmed by my own reef surveys – see Chapter 6), as well as the high selectivity of the fishery on particular species, functional groups and sizes of fish. These are all worrying trends that continue to adversely affect the local reefs' resilience. Herbivorous fish comprise a large portion of the overall catch of this trade and their removal from coral reefs reduces grazing pressure and may contribute to shifts in coral reef systems from coral dominated to algal dominated substrate (Hughes et al., 2007).

Three main functional groups are required to ensure reef resilience: bio-eroders, which remove dead coral stands, scrapers which remove algae and sediment to allow coral settlement, and grazers which prevent macro-algae out-competing corals for light and space; fish families perform all these roles (Bellwood et al., 2004). However, the removal of these functional fish groups, such as triggerfish, pufferfish, and parrotfish via ornamental and food fishing, results in destructive bio-erosion of reefs directly or through increases of urchin populations and starfish populations, such as COTS, which consume live coral (McClanahan & Shafir, 1990; Jennings et al., 1995).

Another concern surrounding ornamental fisheries is the knock-on effect of removing cleaner species, such as cleaner wrasses and cleaner shrimps from coral reefs. Both *Labroides dimidiatus* (blue-streak cleaner wrasse) and *Lysmata amboinensis* (scarlet cleaner shrimp) are highly desirable ornamental fish species and my results show them to be amongst the most frequently caught species. As these cleaner species feed on the parasites and dead scales of other fish, as well as remove food from the mouths of predators on the reef, such as Muraenidae (moray eels), they are important in reducing the incidence of disease and the parasite load of reef fish (Grutter et al., 2003). Cleaner stations, where cleaner species are found in high concentrations are established over coral reefs, where fish arrive to be “cleaned” and it is highly likely that with a reduction in these species and their cleaner stations, the general health of reef fish declines (Arnal et al., 2000).

The high selectivity and targeting of certain valuable species increases the risk of local extinctions. For example, in Kapparathota many divers report the disappearance of species such as *Oxymonocanthus longirostris* from their nearshore waters. My reef surveys in these same areas confirm the scarcity of the same species indicated by the divers (see Chapter 6). However, despite the middle aged and older divers' awareness of the increasing scarcity of certain species that had been widespread during their childhood, such as *Acanthurus leucosternon* and *Coris formosa*, it does not appear to be affecting their choices.

Most of the chaetodontids and the most valuable species in the trade, such as *Acanthurus leucosternon* exhibited highly positive Ivlev's electivity scores, indicating the high preference shown by divers for catching these species. Some species, such as *Valenciennea sexguttata* may have inflated Ivlev's scores being a cryptic species, which are not sampled well using underwater visual census (UVC) methods, and may therefore have skewed this index for such species. However, all the other species in Table 5.4 are non-cryptic, diurnal species, which are well sampled with UVC methods and therefore the index provides a good representation of divers choices in catching fish in relation to their local abundance.

It is highly probable in the case of fisheries such as the ornamental trade, that as species become scarcer, the economic benefit of catching the few remaining individuals will outweigh the costs; the anthropogenic Allee effect (Courchamp et al., 2006). Such heavy selective fishing on coral reefs therefore provides the potential for local extinctions (Graham et al., 2011a). Furthermore, the removal of juveniles by this trade indicates that growth overfishing[21] may be occurring, as results indicate that the majority of fish have not reached maturity before they are caught and are therefore at a size that would not attain a maximum sustainable yield per recruit. To compound this, many of the same species, such as *Plectorhincus orientalis* are also fished as adults for food by ornamental collectors and other fishers. This could lead to recruit overfishing[22], i.e. the depletion of the adult spawning stock. The reefs in this situation are therefore more reliant on stock replenishment from other reefs than from their own reef.

Many reef fish and particularly juvenile individuals are strongly associated with the reef habitat; therefore habitat in good condition results in higher fish biomass (Öhman & Rajasuriya, 1998). Although the reef habitat in sites in Sri Lanka has been degraded (see Chapter 4.4.4 & 4.4.5), differences in habitat quality among the sites studied exist and may account for the difference in catch rates among sites overall. For example, the differences seen in total catch and species catch among sites could be due to the inferior quality of the habitat at the Polhena site rather than diver ability, as divers of all ages showed low CPUE, whereas at other sites CPUE amongst divers varied and often was higher with older divers, as in Thalaramba.

5.4.2 Optimal foraging or resource conservation?

The need to provide data at the level of the fisherman, and not only at the level of systems, is stressed in both the coral reef fishery (McClanahan, 2011) and the anthropological literature (McCay, 1978). An understanding of the decisions made by individual fishers is important in understanding the effect of their actions. Many maritime anthropologists have claimed that traditional marine tenure systems and customary management institutions result in effective resource management, and have identified social criteria that are needed for this (Dahl, 1988; Johannes, 1981). Other studies believe that traditional institutions were created to aid the fisher's harvest and not to conserve it (Polunin, 1984; Carrier & Carrier, 1983). Foraging theory is used to show that fishing, even in communities with rich traditional knowledge and customary management systems, is governed by reducing energy consumption and increasing

[21] Growth overfishing occurs when individual fish are harvested at smaller sizes than the size which would provide maximum yield per recruit.

[22] Recruit overfishing occurs when the adult population of a fish stock is overfished to the point that the reproductive capacity of the spawning biomass (adult stock) is unable to replenish itself.

forage returns (Aswani, 1998). This can be applied to not only subsistence food fishers from an evolutionary perspective but also to commercial and non-food fisheries. This was evident from the data collected: divers tended to minimise time spent fishing, either by time to just over two hours or by catch if they felt their catch would yield sufficient cash value. Furthermore, as shown, these divers were highly selective in which fish they targeted and which they ultimately landed on the known value per fish as well as the likelihood of the sale of that fish to a buyer on their return. Although religious and social customs may prevent fishing for brief periods, very little place or time based fishing restrictions occur, unlike the case of *tabu* (traditional fishing closures) in Fiji (Clarke & Jupiter, 2010). The monsoon season which reduces fishing pressure on the nearshore reefs is an environmental event but if it were to discontinue, it is likely that ornamental divers would fish all year, the need for money being so great.

From the data gathered the majority of divers are apparently motivated by the need to earn money and so are profit driven with few indications of motivation from a conservation mindset, as only a select few divers deliberately reduced their impact by fishing less or in less destructive ways. This differs from the belief held by certain academics that all traditional divers have a conservation mindset (Foster & Poggie, 1993). Although it can be argued that Sri Lankan ornamental divers are not traditional fishers in the sense of those in Oceania, who have more entrenched customary management of their village reefs, they still boast a strong connection to the ocean and can trace this history back centuries (Chapter 4.4.1). However, it is more important to determine the cause of the highly apparent degradation of the reefs in Sri Lanka when compared with the more pristine reefs in the Pacific islands, where such studies were conducted. Recently with global threats to coral reefs such individual and community level data are being collected in places where customary marine management is effective in order that lessons be applied to other locations where such management is lacking or non-existent (Cinner et al., 2007; Cinner & Aswani, 2007).

The quantitative evidence in this chapter indicates divers, whose numbers have increased since the last in depth study, act individually and, based on the electivity index scores, utilise an optimal foraging strategy, over small reef areas, that are severely damaged by environmental and anthropogenic factors, and as many divers admitted *"if I don't catch that fish, someone else will"*. This can be likened to Hardin's "Tragedy of the Commons" but as explained in Chapter 2..11, many environmental anthropologists disagree with biologists' and economists' acceptance of this model, and declare there is need "...for appreciation of the embeddedness of resource users in social and moral fields of meaning and action" (Jentoft & McCay, 2003: 297). Therefore only interpreting the quantitative data is too narrow a view. The effect of other interacting processes in ecological, social and cultural arenas and the extent of resilience within these spheres must be considered to derive a conclusive understanding of whether the system is within the tragedy Hardin describes or not.

5.4.3 Ecological Resilience

Reef degradation over the past 40 years and unregulated fisheries operating across the nearshore reefs in southern Sri Lanka (Chapters 2 & 4), suggest that resilience in these reef systems is low; but by uncovering the actual levels of fishing pressure on unit areas of reef, the selective pressures on certain species and the expected level of damage to the coral substrate, this low resilience might be strengthened. The catch rates in this nearshore fishery may be low compared to subsistence and commercial food fishing as well as ornamental fishing by SCUBA divers, but snorkellers have smaller accessible fishing areas which means the cumulative impact of ornamental fishing on the small, highly degraded areas of reef is worsening and considerable. Divers are in agreement regarding the decline of fish abundance and habitat quality and understand the need to conserve both corals and fish to preserve their livelihoods.

In addition, increasing competition for elusive high-value fish also impacts on this fishery. Conflict did erupt in the form of arguments between fishers, with ornamental divers telling food fishers to leave the adult reef fish to spawn juveniles as they had more value than the adults they sold for food and the food fishers telling me that the fish resource should not be the reserve of certain fishers. It would therefore be useful to measure the fishing effort of these other fishing activities, operating in the same areas, and link their impact to this study. For example, if food fishers target spawning aggregations of reef fish, as occurs in many tropical reef fisheries (Sadovy & Domeier, 2005), the effects on reef fish recruitment could be substantial. Similarly, the impact of different types of gear on coral and catch rates need to be investigated further.

Ecological resilience in coral reefs is evidently dependent on maintaining diversity of functional groups (such as herbivores and large predators), of species within these functional groups and diversity within populations (Chapin III et al., 1997; Luck et al., 2003; Bellwood et al., 2004). After heavy fishing pressure, the restoration of these multiple forms of essential diversity requires the creation and maintenance of fish refuge areas that can protect both close and wide ranging fish species (Mora et al., 2006). Furthermore, response diversity[23] of functional groups is critical for resilience of the ecosystem (Chapter 2.13.2.1).

To restore ecological resilience in the southern coastal waters of Sri Lanka, greater levels of collective action are required and a closer sense of pride and community needs to be fostered in the fishing villages. Although the inhabitants' lives are intricately entwined, the divers' ready admission of high coral damage levels and other poor diving practices is prevalent and these actions need addressing. Certain of my informant divers told me that with greater pride in their own reefs and fishing methods together with better training of newcomers to the fishery, coral damage and poor diving practices could be reduced. My results show that certain divers are more careful around corals during fishing trips and some of the divers in the study rarely broke coral and yet had high success in fishing. These should train the young and unskilled divers and older divers should share their greater LEK of fishing in the reef environment with the younger divers (discussed in Chapter 5.4.4).

Such training may prove difficult as despite the close bonds between most divers of the same village, social gatherings are usually age stratified, and diving, especially snorkelling, occurs alone or with groups of the same age. Knowledge transmission predominates among a diver's peer group which means experienced divers rarely deliberately share knowledge with young divers unless a young diver has a relative involved in diving but this is uncommon. Older divers corroborated my impression that there is not enough intergenerational learning and are concerned their knowledge is fading. They said that it is difficult advising the young because they perceive this advice as a device to prevent them from making money or from pursuing the high value fish while others prefer to discover the knowledge for themselves.

[23] Response diversity is the range of ways that species within functional groups cope with environmental change, high response diversity provides greater redundancy – a key factor for high resilience, in that multiple strategies are available for a system to absorb a disturbance (Chapter 2.13.2.1).

5.4.4 Deriving local ecological knowledge

Ruddle (1993) names three essential processes necessary for social learning to occur in rural communities: observation of others' activities, listening to stories and advice and practice of what has been seen and heard; all of which concur with my observations in Sri Lanka. Most divers responded in interviews that they learnt to fish by themselves from watching and observing others closely and then practising alone with borrowed or newly acquired gear. Although the style of fishing is very different to other forms of fishing practised locally and requires several other skills in order to catch fish in the water (e.g. swimming and free diving to depth), less than 10% of divers claimed to have been taught by someone else; a few were schooled in the basics by a relative, but approximately 85% learnt by observing others in the water, and more than 50% of those interviewed said they practised the skills alone. Learning is ongoing and continually shaping and changing the way divers fish until they arrive at optimum knowledge. There were many ways learning can occur, from diving with friends in the sea and watching them catch fish or helping to find fish and deploy the gear to catch the fish to more indirect means, such as discussions before and after fishing.

From early interviews and subsequent observations and my interactions with divers on an almost daily basis, the majority of divers socialise and form a tight knit village community, which shares knowledge of good fishing sites or techniques. Divers, in their free time, enjoy drinking together, usually somewhere discreet and hidden from public view, I was invited to many such gatherings and despite relaxing among friends, conversation often turned towards discussing sea conditions, where different divers had found "*quality fish*", diving tales, reminiscences of "good" catches, odd experiences and playful mockery of those who recently suffered misfortune while fishing. I was often alerted to the fact (without asking) that a certain diver had caught more than an average catch on a certain day or had found a rare or a particularly valuable species during these gatherings. The importance of these different arenas in which learning of skills and accumulation of knowledge occur is vital to the transmission of local knowledge between experienced and less experienced divers as well as crucial for effective adaptive management of the fishery (Cundill et al., 2012).

Through a tripartite system of observation, listening, chatting, experimentation and practice, knowledge transmission takes place as is found in Polynesian island fishing communities (Borofsky, 1987). However, with decreasing interaction today between young and old divers, these processes do not occur to a sufficient extent, according to older divers, to enable young divers to learn good diving practices from the onset so there is a need for more integration among the different generations of divers to re-stimulate ecological resilience so that divers could together organise more concerted efforts to restore fish stocks and avoid reef damage. However, it may be economically beneficial for older, experienced divers to not pass on experiential knowledge to younger divers at a time when resources are scarce and diver numbers are high.

5.4.5 Social resilience

Few strong institutions exist to support divers; only Polhena has an association which provides occasional support and cohesion for divers. However, community resilience has the potential to be strong due to the tight-knit village way of life; yet, divers still act individually. Several factors indicate that both the ecological and the community resilience is low in these villages which makes it difficult for them to live and cope with the changes they are currently experiencing.

Divers feel trapped but without feasible alternatives nor the means of reducing the numbers of divers in the short-term. The main methods through which social resilience is regained after and during disturbances is through the social memory held within the diversity of individuals and institutions within the community. However, divers' and communities' knowledge, values, practices and worldviews need to be preserved among different generations and circulated among all members of coastal communities to better prepare them for future change whether positive or negative (Adger et al., 2005).

The low income from snorkelling for ornamental fish does not deter young children, who, as stated by Samit in Section 5.3.6, are expected to earn money from a young age in these communities due to high levels of poverty. In this way, school attendance is substituted by fishing for ready cash in what soon becomes their way of life. Social resilience is thus hard for the divers to develop themselves in their current situations; it is through the more affluent members of the market chain, and government initiatives that some social resilience can be restored. This can be effected, either through the formation of co-operatives and village-level diving institutions or through small local-level programmes to provide alternative employment opportunities (see Chapter 9).

A recent example of building resilience into reef communities to prevent illegal fishing is in the Philippines, where a combination of raising awareness of the importance of certain fish species locally while simultaneously reinforcing the cultural heritage of these communities with their natural resources has resulted in communities regaining their pride and identity within the context of their coastal environments and its success (Bornstein, 2012). This is an approach that could be introduced in Sri Lanka.

There is a tendency for the environmentalist discourse to view such a degraded reef system as a crisis beyond help. However, framing the socio-ecological system in that of an adaptive cycle (Gunderson & Holling, 2002), shows such periods of upheaval are to be expected. Gunderson et al. (1995: 500) hold that "...crises occur... resulting in subsequent institutional transformations" and changes in practices which undermine common property resources because such disturbances force social learning upon the actors and institutions (see Chapter 8).

5.4.6 Cultural resilience

In the villages where I worked, the majority of the divers are Buddhists and in accordance with their religion they do not work on certain religious days or festivals, the latter often spanning several days. For example, no fishing occurs on the day of the monthly full moon (*Poya)* and at the Sinhalese New Year (mid April), when celebrations continue for about one week. Similarly, many divers cease work in May at *Vesak*, the celebration of Buddha's birth, enlightenment and death. Divers explained that the buyers issue no fish orders during the New Year holiday. All the buyers in my study sites are Buddhists too and observe these same religious and cultural festivals. However, some of the export company owners are Christians or Muslims and so they often still work during these times but they know that it is highly likely that any orders sent during these times will be fulfilled. The interplay of who controls whom within the ornamental fish supply chain is discussed in Chapter 7.

At the community level, funerals and almsgiving affect fishing although the number of days vary. For example, during my stay in Polhena, a young boatman belonging to one of the SCUBA diving teams was murdered and as he was part of the fishing, and more specifically the diving community of the village, no diving occurred for four days after his death, in respect to him and his family. Buddhists attend almsgiving celebrations offered for dead friends and relatives which are offered one week, three months and one year after the death of a person and once a year subsequently. As funerals and almsgivings are attended for even relatively distant acquaintances and family, the number of days in a year when fishing ceases can be substantial. Participation in these cultural and religious customs demonstrated the strong ties of divers and their communities to these practices which are unlikely to change. These customs not only reduce fishing effort over many days in a season which is an asset in finding ways of decreasing fishing pressure but also show that group adherence to locally respected traditions and forms of respect are high and these are assets for community management of resilience at the local level (see Chapter 8).

5.4.7 Local versus global effects on the fishery

A global view of this fishery can be found in the panarchy or nested adaptive cycles of the SES theory and the resilience approach (Folke, 2006; Chapter 2.13.2). Effects at the grass-root level and within lower levels of the panarchy can create change across the multiple layers in which the system operates. The ornamental fishery in Sri Lanka is driven by the demand for a luxury product in the homes of foreign people, which means that the pressure placed upon the coral reefs and fish populations of southern Sri Lanka stems from aquarium hobbyists overseas. Thus the behaviour of these hobbyists directly affects the livelihoods and actions of divers in Sri Lanka.

During my fieldwork, buyers in the villages were noticing a decrease in the number of orders typical for certain seasons or periods, which they tended to attribute to the economic recession in Europe and North America. As these are two of the biggest importing world regions of ornamental fish, the reduced demand for luxury goods such as ornamental marine fish has resulted in a slump in sales for buyers in coastal villages. Several times divers would not be fishing when conditions were suitable as there were no orders and the buyers could not buy fish. Thus the rise and fall of demand heighten or slacken the pressure on the fish and indirectly on the coral.

However with the advance of technology, globalisation exposes these divers to alternative viewpoints. Some divers meet members of the growing tourist community since the end of the civil war in Sri Lanka in 2009, who explain they wish to find healthy coral reefs with abundant fish and not watch divers catching the fish they have paid to see. Again with the influence of the global media, it is hoped that the growing number of hobbyists will wish to source their fish sustainably in future which may result in divers having to change their behaviours and take group actions to meet the specific demand from other countries (see Chapter 7).

5.5 Conclusion

Combining, in this chapter, the need for greater fisheries monitoring data and an appreciation of the complexity behind divers' behaviours within an overarching theme of panarchy, that is centred on a concept of resilience has allowed for a fishery such as the ornamental trade in Sri Lanka to be scrutinised at different levels, from the individual divers to the global drivers of the fishery. These are the first extensive catch, effort and coral damage data to be recorded for the ornamental fishery in Sri Lanka and provide a useful baseline for future monitoring. There is a potential for divers to record their own data, buyers already do (see Chapter 7) and divers may be incentivised under a more adaptive and communicative management framework.

The social, cultural and economic factors which force or contribute to certain actions occurring whether they build or undermine resilience are important to uncover, especially in a multi-tiered system like the ornamental trade where the complexity of local and global drivers upon divers' actions is essential to grasp before restrictions or regulations are implemented. Coping strategies occur during bad weather and in the monsoon season, as well as at other periods of disturbance and these should be monitored in detecting adaptive strategies that may be transferable to other sites. A delineation of the levels of resilience currently within this SES is useful to future management strategies. As resilience is based on information flows, the transmission and learning of LEK is important to document and the merging of different knowledge systems in adaptive management. The complementarity of these systems in the context of this fishery is explored in Chapter 6.

Chapter 6

Complementary scientific and local knowledge to determine the status of reef sites and the potential of divers to become "citizen scientists"

6.1 Introduction

Evidence for the types of local ecological knowledge (LEK) referred to in Chapter 2 has existed for several decades (Berkes, 1977; Johannes, 1978) but is frequently sidelined by mainstream fisheries researchers. They tend to view LEK as the preserve of aboriginal peoples living in remote locations and thus unlikely to affect the mainstream issues surrounding the exploitation of the world's oceans. The arguments presented in this thesis challenge such a narrow view and suggest that LEK is significant for the following major reasons: first to preserve coral reefs and provide sustainable livelihoods for vulnerable communities, exemplified by the divers of southern Sri Lanka, secondly, to demonstrate how working with local fishers can assist in broadening understanding of not only variability across and within populations of species in the oceans but also levels of productivity and the varied ways by which fisheries are exploited.

Compared with the temperate waters surrounding developed nations, present fisheries in tropical regions are rarely delineated or regulated clearly (Crawford et al., 2004) and thus present particular difficulties as from a scientific point of view they are data deficient (Johannes, 1998a). With regulations and/or their enforcement often lacking, little interaction occurs along the chain between the various managers and the fishers; hence, the people perhaps most suited and entitled to manage the resource they exploit, are excluded from the process. In contexts where this ineffective management occurs, evidence shows that fishers tend to over-exploit the common resource (Berkes et al., 1989; Dietz et al., 2003; Ostrom, 1999). Furthermore, the subtle differences between managing a food fishery and a non-food fishery, such as the ornamental trade are ignored in conventional methods of fisheries' management, making them even less relevant in this fishery in Sri Lanka.

For these reasons the inclusion of LEK as a data source, a form of continued data collection and a tool for fisheries management has been advocated (Jentoft et al., 1998) and increasingly more studies are linking local knowledge of marine systems to customary use and co-management frameworks, particularly in parts of the Pacific and south-east Asia (Drew, 2005; Rakotoson & Tanner, 2006; King & Faasili, 1999; White & Vogt, 2000; Pet-Soede et al., 2001b; Aswani & Hamilton, 2004). In these cases fishers govern their own fishing grounds and are thought to be maintaining resilience in the system using LEK to inform decision making and management rules. This has often worked where there is a need for more resource management in areas where LEK is deep rooted such as the communities of islanders in the Pacific where fishers are said to possess a traditional conservation ethic (Johannes, 2002a), such as the Solomon Islands (Aswani & Lauer, 2006), Oceania (Johannes, 2002b), Brazil (Rosa et al., 2005) and the Arctic (Berkes, 1977).

The importance of combining disciplines and knowledge bases to inform management and policy decisions in conservation and sustainable development is highlighted throughout this thesis and was discussed at length in Chapter 2. Although resource users, fisheries managers and researchers may disagree on the best management strategy, through sharing their differing views in collective discussions more appropriate management strategies could be agreed. On the other hand, by ignoring certain fishery actors in the decision-making, a skewed vision of "good management" may result which could not only increase the problems for the future, but also strengthen the existing resentment between management bodies and resource users (Bennett et al., 2001).

The reliability of LEK is often questioned by natural scientists and cannot be ignored; however, it can be determined and accounted for through the utilisation of appropriate methodology and by objectively identifying the limitations in data collection or methodological assumptions, as is done for most quantitative analyses (Pollnac & Johnson, 2005). By comparing LEK to more conventional methods to quantify the status of particular fisheries or resources, an indication of its utility for resource management decision making can be determined (Daw, 2008).

Sceptics of LEK and its uses, either actors outside of local communities (Peters, 2003) or Western scientists are often dismissive or hold myths about such extensive and complex local knowledge and customary management systems (Sherry & Myers, 2002) and claim its incorporation into management plans is too difficult to facilitate, ensuring dominance of Western science (Huntington, 2000). However, there are many examples of this LEK worldwide and ethnographic studies are often effective in showing the extent of LEK. For example, in Kerala there is " an inextricable link between people and the sea", highlighting the deep connectedness of fishers with their environment and in particular the accumulated knowledge of fishing boat skippers who protect and guide their employed crews to good fishing grounds off Kerala (Hoeppe, 2007).

In Sri Lanka, national examples of LEK and customary management exist: in Negombo, on the west coast of Sri Lanka, fishers organised a lagoon fishing management system in the 1940s, which later acquired legal status to grant access rights and maintained sustainable exploitation over many decades despite problems with all factions (Amarasinghe & De Silva, 1999). Similarly, an extensive ethnographic study on fishers in Chilaw in western Sri Lanka revealed deep local knowledge in matters relating to fishing, to weather, to boat usage, fish catches and the markets in order to make an income (Stirrat, 1982a). Thus there is evidence that coastal communities in Sri Lanka not only possess such knowledge but also use it to manage their marine environment in collaboration with the law.

A major advantage of utilising complementary approaches in coral reef monitoring is that it can circumvent some of the limitations that are inherent in almost all indicators of fish abundance or fishery trends currently used in studies to manage fisheries. Catch per unit effort (CPUE) used to monitor a fishery can overlook increases in effort within the effort type measured, fish behaviour and spatial distribution of this effort (Aswani, 1998; Pet-Soede et al., 2001b). Similarly, fisheries independent measures have their own limitations, such as surveys (Watson et al., 1995) and underwater visual censuses (UVC) (see Section 6.2.) where differences in methodologies of UVC can make for weak comparisons among different studies and locations (Weinberg, 1981). Effort in the scientific reef community is being applied to identify an agreed standardised method that can be more widely used to enable greater comparisons across study areas and topics (Caldwell, unpublished). As this does not exist currently, no method is free of problems as to what data are produced and what they may indicate. However, a more complete picture can be constructed if different forms of knowledge are compared and contrasted; these can serve to increase our understanding of these complex systems.

Often management ideas are designed and implemented based on the results of studies elsewhere, without consideration of specific local factors that emerge from inclusion of local knowledge. As discussed in Chapter 2.9, marine protected areas (MPAs) are an example of a management tool that has been utilised extensively worldwide in both total numbers and areas. Local knowledge is relevant to the development of such management tools and by employing a social-ecological systems (SES) framework to make management decisions, the inclusion of LEK would be guaranteed (Christie, 2004; Pollnac et al., 2010). Few MPAs exist in Sri Lanka, however one of the few MPAs was included in this study and its use and efficacy were evaluated in Chapter 4.

This chapter aims to show the current status of four nearshore reef sites. This is provided by a comparison of divers' current perceptions of reef fish abundance and reef health with that determined from UVC reef fish abundance and habitat data. Furthermore, the historical perceptions of older divers is examined and compared to the present day status of local villages and reefs as well as previous scientific studies concerning these reef areas.

Specific questions addressed are: Do fish assemblage variables - fish abundance, biomass and species richness - derived from UVC estimates differ between a protected site and fished sites? Do these same measures vary among habitat types within fished and non-fished sites? How do these survey results compare to divers' current and historical perceptions of fish abundance and reef health? What evidence is there of divers' LEK in these communities and in what ways does the level of knowledge vary? If such LEK exists, what potential is there for divers to act as "citizen scientists" considering this knowledge and their position as long-term monitors of the reef through their daily activities?

6.2 Methods

6.2.1 Study area

UVC reef fish surveys were carried out in the nearshore areas of four reef sites, Hikkaduwa, Kapparathota, Polhena and Thalaramba. These sites are described in detail and maps are provided in Chapter 3.2.5 and 3.3.

6.2.2 Sampling design and underwater visual census method

Fish counts were restricted to areas that could be accessed by snorkelling, therefore the total areas sampled were determined by depth and the coastal extent of each village's reef site. However, similar sized reef areas were sampled at each site. Stratification of sampling between distinct depths or habitat types was near impossible due to the non-varying depth and the shallow water preventing manta tows from being performed in these nearshore areas, it was decided to utilise a randomised sampling design. A satellite image of each reef area from Google Earth was gridded into 625 m^2 squares and each square numbered. Using a random number generator, squares were selected for sampling and a point count of fish was carried out in the centre of each square selected, using co-ordinates taken from Google Earth. Each point count was therefore an independent replicate, with at least 25 m between adjacent point counts. A minimum of 30 point counts per reef were carried out, however, more counts per reef were carried out where time and logistics allowed.

Due to the extremely shallow (0 - 3 m), but high wave action nature of the selected sites, the most appropriate survey method was a modification of the Bohnsack & Bannerot (1986) point count sampling method, which best suited the local conditions and which is detailed below. This method has been used in estimates of reef fish abundance in Indonesia by I. Côté (pers. comm.). Furthermore, the point count method is known to influence the behaviour of target reef fish communities less than other census methods (Jennings et al., 1996). The main drawback to this method is that biomass estimates of shy species produced from it are unreliable in areas of spearfishing (Samoilys & Carlos, 1992; Jennings et al., 1995). Spearfishing does occur in Sri Lanka but in relatively small amounts and this survey was not focusing (like most reef surveys) on target food fish species which are spearfished.

From reconnaissance work prior to the survey, substrate was characterised into the four main groups present: live coral, dead coral, coral rubble and sand. Each point count would sample over one of these substrate types. A minimum of 10 replicate point counts over each substrate group were performed and if a maximum of 15 replicates of any substrate type was reached prior to 10 replicates of all substrate types had been conducted, further point counts over this substrate were stopped and the next random number generated would be selected to ensure adequate sampling of all substrate types.

Table 6.1. Number of replicates performed at each reef site and substrate group during the UVC surveys.

Site	Substrate	Replicates	Total site replicates
Hikkaduwa	Dead coral	16	52
	Live coral	11	
	Coral rubble	11	
	Sand	14	
Kapparathota	Dead coral	11	45
	Live coral	10	
	Coral rubble	12	
	Sand	12	
Polhena	Dead coral	11	47
	Live coral	10	
	Coral rubble	13	
	Sand	13	
Thalaramba	Dead coral	13	44
	Live coral	10	
	Coral rubble	10	
	Sand	11	

Final replicate numbers of each substrate group are shown in Table 6.1. A marker was placed at the centre point of the chosen square, the observer swam out from this centre point and moved round in a clockwise direction approximately 12 m (measured in finstrokes) from the centre point to assess if the substrate at the centre point was representative of the entire 625 m^2 square. If it was, then a 9 m^2 area was demarcated from the centre point with four small transparent plastic markers attached to small weights, the observer would then remain in or near the area calmly for five minutes to allow fish to resume normal activity and become accustomed to the observer's presence. The observer positioned himself above the centre point of the sampling area and would turn periodically to enable a 360º view. First a count all fish of all sizes located in the area, those that passed through the area or moved into the area during a five minute period was performed. Fish were identified to species level, counted and their total length estimated to the nearest cm and recorded on prepared waterproof data sheets fixed to underwater slates. Following this, a one minute search of all cryptic habitat in the area to identify, count and estimate total length of any cryptic species was done and finally a count of any benthic creatures was carried out over the sampled square.

If the centre point was not representative of the larger square then the point was always moved directly south of the centre point onto an area that was representative of the predominant substrate type of the large square. The size of the sampling area was chosen after determining typical underwater visibility in these areas, which tends to be between 2 - 4 m. All censuses were done between 0830 and 1530 in the day to avoid the diurnal-nocturnal changeover period of reef fish. Surveys were carried out between December 2009 and February 2010 with the help of a field assistant, Philip McDowall. Total inshore reef areas varied among villages from approximately 0.2 km^2 to 0.5 km^2. A total area of 1692 m^2 was surveyed directly (9 m^2 squares) and an overall area of 0.118 km^2 was surveyed indirectly (625 m^2 squares). Thus approximately 11% of total reef area of all four sites was surveyed.

Prior to beginning data collection using this method, training was carried out by both observers to ensure reef fish identification was proficient and that fish size estimation underwater was accurate. Using the method described by (English et al., 1997), wooden fish models ranging in size from 2 – 65 cm in 1 cm increments were attached to weights haphazardly and placed underwater. Both observers took it in turns to estimate the total length of each fish model and then to compare their estimates with the actual sizes. Other studies (Kulbicki, 1988; Kulbicki & Wantiez, 1990) have shown that with training, diver precision in size estimation is within 15% of actual sizes. Analysis of these data showed that all estimates were within ± 11.7% of the actual sizes and the mean error estimate was ± 2.8%. For the smallest wooden models (2 – 5 cm), a larger percentage error did occur, as a 1cm error would result in a higher percentage error than larger models, and these were allowed. Once both observers were within this 15% range the surveys began. Size estimation testing was performed regularly throughout the survey periods to ensure consistency at all sites and by both observers. Neither observer consistently estimated sizes greater or less than acutal sizes and therefore, no size corrections were made.

6.2.3 Substrate surveys

A visual estimate of major habitat forms was performed by the observer at the end of each point count. The observer recorded the percentage cover (based on plan view) of hard and soft coral groups (identified to the genus level), dead corals, sand, coral rubble, rock, sponges, algae (functional group) and seagrass. Using the six-point scale of

Polunin & Roberts (1993), structural complexity of the habitat was recorded, using the following scoring: 0, no vertical relief; 1, low and sparse relief; 2, low but widespread relief; 3, moderately complex; 4, very complex with numerous caves and fissures; and 5, exceptionally complex with high coral cover, and numerous caves and overhangs. The height of the substrate from the seabed to the highest point within the sampled square was measured to the nearest cm as a crude measure of site rugosity.

6.2.4 Statistical analysis of data

Fish biomass was estimated by converting total length estimates from the UVCs to mass using the length-weight relationship: $W = a.L^b$, and published length-weight relationships (Froese & Pauly, 1997; Kulbicki et al., 1993), where W = weight in grams, L = total length in cm and parameters a and b are constants. Where length-weight relationships did not exist for a species censused then the parameters for a species of the same genus and similarly morphology was used. Species were grouped into trophic guilds according to diet (planktivore, omnivore, herbivore, invertivore, piscivore and corallivore) using published data from previous studies of reef fish assemblages and online databases (Froese & Pauly, 1997; Hiatt & Strasburg, 1960; Kulbicki et al., 2005) as well as their importance in local fisheries (ornamental target, food target, not-targeted).

Length, biomass and abundance data were tested for normality using histograms, QQ plots and Shapiro Wilk's test for normality, as well as Bartlett's test for homogeneity of variance. A ln(x+1) transformation was conducted when necessary to allow data to approach normality. Arc-sin square root transformations were carried out for the habitat percentage cover data. MANOVA was performed to simultaneously compare differences between species richness, abundance and biomass among sites and habitats. The Pillai-Bartlett test statistic was selected as it performs better under conditions of heterogeneous variance (Hand & Taylor, 1987). Substrate type and site were the independent factors of comparison. Subsequently, when MANOVAs were significant, one- way ANOVAs and Tukey tests were performed to assess the differences in species richness, abundance and biomass of fish among sites and substrate types. Significance was set as $\alpha = 0.05$.

The analysis of abundance using one way ANOVA assumes that the random variation in the data arises from independent and identical normal distributions and equal variances, which may not be the case because count data are in general non-normally distributed, and fish abundance and biomass depends on species. Consequently, a random effect model through a Generalised Linear Mixed Effect Model (GLMM) was also applied to the abundance data assuming a Poisson-Normal distribution with a log link, whilst a linear mixed effect model (LMM) with Normal-Normal distribution, with an identity link, was applied to the biomass data. These models decomposed the total variation in the data into two sources, namely the random variation and variation due to the differences between species. It should be noted that for non-normal data, GLMM and Generalised Estimating Equation (GEE) are not equivalent. Parameters from the GLMM are conditional parameters investigating how individual specie respond to change in habitat/site whilst the parameters from the GEE model are population average parameters investigating how change in habitat/site affects the abundance of all species. However, an LMM can be interpreted as a conditional model and a population average model because both are theoretically equivalent for normal data. An evaluation of the differences in results between these models with those from more conventional population average models (ANOVA) was carried out. Results of both types of analyses are presented.

Mean percentage cover of the main substrate components and their standard deviations is presented. These habitat data were arcsin transformed and then analysed using one way ANOVAs and Tukey tests to determine differences among sites.

In addition, a Spearman rank correlation was performed to find correlations between habitat and fish assemblage variables. Habitat variables included in this analysis were percentage cover of: live coral, dead coral, rubble, sand, rock, as well as structural complexity, maximum substrate height, substrate composition diversity, temperature, depth, *Acropora* cover, and the number of coral genera. Fish assemblage variables included were abundance, biomass, species richness and Shannon-Wiener diversity index, which takes into account densities, unlike species richness.

6.2.5 Anthropological methodology

The same methods were used for collecting the social science data analysed in this chapter, as explained in Chapter 3.

6.2.5.1 Focus groups

During each focus group, the divers, from each of the fished sites, were asked to engage in three activities. Each task and its purpose was described and explained to the divers in Sinhala by Duleepa before they began. Brief demonstrations were done prior to each task and if divers needed further clarification during the task, it was provided. First they were asked to discuss their experiences of variations in the weather and sea conditions, and the specific month(s) when the main target fish species breed.

Secondly, the divers drew maps of how they saw their village nearshore waters and to mark coral areas, good fishing locations as well as any landmarks and features they considered important. The coastal outline, which encompassed the same areas that were surveyed using the UVC methods, was drawn on A1 sheets of paper by one of the divers who wished to begin drawing the map. No features were pre-drawn. No set outcome was required or requirement asked of participants in order to avoid forcing a foreign mindset or perspective on the divers' perception and visualisation of their nearshore waters. Participants were asked to draw the extent of their territorial waters, to outline different habitats' locations and to mark the areas they fished for different species. I sought to determine how divers, as a group, visualise their territorial waters and the extent of detail portrayed. These maps took between two and three hours to draw. The final task asked the divers at each site to create time-lines by which to compare conditions across 15 years to the present.

6.3 Results of Underwater Visual Census Fish and Habitat Surveys

6.3.1 Overall patterns

The surveys conducted at the four nearshore reef sites covered areas that are the primary fishing ground for ornamental snorkellers and therefore the results can be compared to catch data from these sites and can also be informed by the ornamental divers' LEK. A total of 158 reef fish species were recorded from 39 families by UVC (Table 6.2). Eighty-seven species recorded are exploited in the ornamental fishery, a further 28 species recorded are exploited in food fisheries and 43 fish species recorded are not targeted by either fishery. Knowledge of which species are targeted by different fisheries and groups was gathered from interviews, discussions and participant observation of fishers involved in both types of fishing, as well as discussions with export companies to identify the ornamental fish in demand by foreign buyers.

Despite the number of species observed, only 20 species were seen in more than 10% of all replicate point counts across all sites and substrates. The most ubiquitous species was a non-target species, *Pomacentrus chrysurus*. Among the 158 species recorded, 26 (16.5%) were observed on all four study reefs, 38 species were observed only at Hikkaduwa reef (24.1%), 15 only at Kapparathota (9.5%), 14 only at Polhena reef (8.9%) and seven only at Thalaramba reef (4.4%). Forty one species were recorded at two reefs (25.9%) and 17 species (10.8%) were recorded at three reef sites. The more valuable fish species in the ornamental trade (see Appendix F) were scarcely found in most sites and substrates sampled. Abundance and biomass of certain fish species was far greater than others, with 45 species contributing more than 45% of their family biomass across all sites.

Table 6.2. Fish species observed in the UVCs, their maximum length (L_{max} from (Allen & Steene, 1994; Allen et al., 2003; Froese & Pauly, 1997; Anderson, 1996), their assigned functional group, main target fishery, their biomass as a percent of total family biomass and their percent ubiquity over all 188 point count sites. Fishery role codes: OF = Ornamental fishery, FOOD = Food fishery, NT = Not targeted. Functional group codes: HB = Herbivore, PL = Planktivore, PI = Piscivore, IN = Invertivore, CO= Corallivore, OM = Omnivore.

Fish species recorded	L_{max}	Funct. group	Fishery role	Biomass (% total family)	Ubiquity % total family)
Acanthuridae					
Acanthurus blochii	42	HB	OF	5.88	1.06
Acanthurus leucosternon	38	HB	OF	0.08	0.53
Acanthurus lineatus	38	HB	OF	58.08	27.66
Acanthurus maculiceps	20	HB	NT	0.32	0.53
Acanthurus nigricauda	40	PL	FOOD	5.10	3.72
Acanthurus spp.	42	HB	OF	0.18	10.64
Acanthurus tennenti	31	HB	OF	0.84	1.60
Acanthurus triostegus	27	HB	OF	6.17	23.40
Acanthurus xanthopterus	56	HB	NT	4.61	4.26
Ctenochaetus binotatus	22	HB	OF	0.20	0.53
Ctenochaetus striatus	26	HB	OF	13.71	26.60
Ctenochaetus strigosus	18	HB	OF	0.00	0.53
Naso brevirostris	50	HB	OF	0.00	0.53
Naso lituratus	30	HB	OF	0.56	3.19
Naso unicornis	70	HB	OF	4.26	2.13
Zebrasoma scopas	20	HB	OF	0.00	0.53
Apogonidae					
Apogon novemfasciatus	9	PI	OF	4.56	2.13
Apogon taeniophorus	10	PI	OF	35.82	7.98
Cheilodipterus macrodon	20	PI	NT	58.13	1.06
Rhabdamia gracilis	6	PL	NT	1.49	0.53
Aulostomidae					
Aulostomus chinensis	80	PI	NT	100	0.53
Balistidae					
Balistapus undulatus	30	OM	OF	78.79	9.04
Balistoides viridescens	75	CO	OF	0.44	0.53
Pseudobalistes flavimarginatus	60	OM	OF	0.01	0.53
Rhinecanthus aculeatus	25	OM	OF	10.57	4.26
Rhinecanthus rectangulus	25	OM	OF	9.48	3.19
Rhinecanthus verrucosus	23	OM	OF	0.71	1.06
Bleniidae					
Plagiotremus rhinorhynchos	12	IN	OF	3.07	0.53
Salarias fasciatus	14	IN	OF	96.93	2.13

Table 6.2. (cont.)

Fish species recorded	L_{max}	Funct. group	Fishery role	Biomass (% total family)	Ubiquity % total family)
Bothidae					
Bothus pantherinus	39	PI	OF	100	0.53
Caesionidae					
Caesio caerulaurea	35	PL	NT	16.72	1.06
Caesio cuning	50	PL	NT	51.56	1.06
Caesio xanthonota	40	PL	NT	10.74	0.53
Pterocaesio chrysozona	21	PL	NT	16.48	0.53
Pterocaesio tessellata	25	PL	NT	4.50	0.53
Callionymidae					
Synchiropus marmoratus	13	IN	OF	100	0.53
Carangidae					
Carangoides spp.	90	PI	FOOD	100	0.53
Centriscidae					
Aeoliscus strigatus	15	PL	NT	100	0.53
Chaetodontidae					
Chaetodon auriga	23	OM	OF	0.00	0.53
Chaetodon citrinellus	13	OM	OF	2.04	4.26
Chaetodon collare	16	CO	OF	4.99	2.66
Chaetodon decussatus	20	CO	OF	67.04	16.49
Chaetodon guttatissimus	12	OM	OF	0.59	0.53
Chaetodon interruptus	20	IN	OF	0.62	0.53
Chaetodon kleinii	14	OM	OF	0.77	0.53
Chaetodon lineolatus	30	CO	OF	1.25	0.53
Chaetodon lunula	21	CO	OF	13.31	3.19
Chaetodon trifascialis	18	CO	OF	2.05	3.19
Chaetodon trifasciatus	15	CO	OF	0.43	1.06
Chaetodon vagabundus	23	OM	OF	6.90	1.60
Cirrhitidae					
Cirrhitus pinnulatus	28	IN	OF	56.73	0.53
Paracirrhites forsteri	22	PI	OF	43.27	1.06
Diodontidae					
Diodon hystrix	71	IN	NT	100	0.53
Fistulariidae					
Fistularia commersonii	150	PI	NT	100	4.79
Gerreidae					
Gerres oyena	25	PL	NT	100	2.66
Gobiidae					
Amblyeleotris periophthalma	8	PL	OF	0.79	1.06

Table 6.2. (cont.)

Fish species recorded	L_{max}	Funct. group	Fishery role	Biomass (% total family)	Ubiquity % total family)
Asterropteryx semipunctatus	6	DE	OF	21.34	4.26
Cryptocentrus caeruleomaculatus	8	IN	OF	7.59	2.13
Cryptocentrus leucostictus	9	IN	OF	42.05	2.66
Istigobius decoratus	9	IN	OF	3.42	1.06
Valenciennea sexguttata	12	IN	OF	24.82	3.19
Haemulidae					
Diagramma picta	94	IN	FOOD	8.54	0.53
Plectorhincus albovittatus	100	IN	FOOD	22.14	1.06
Plectorhincus orientalis	85	IN	OF	69.32	2.13
Holocentridae					
Neoniphon argenteus	19	IN	OF	3.07	1.06
Sargocentron diadema	17	IN	OF	96.93	0.53
Kyphosidae					
Kyphosus cinerascens	45	HB	FOOD	42.52	0.53
Kyphosus vaigiensis	70	HB	FOOD	57.48	1.60
Labridae					
Anampses melanurus	12	IN	OF	0.07	0.53
Cheilinus chlorourus	36	IN	NT	3.23	4.26
Cheilinus fasciatus	36	IN	NT	4.90	0.53
Cheilinus trilobatus	45	IN	NT	1.17	0.53
Coris formosa	60	IN	OF	2.12	1.06
Gomphosus caeruleus	28	IN	OF	5.75	16.49
Halichoeres argus	11	IN	NT	0.63	10.11
Halichoeres cosmetus	13	IN	OF	0.39	2.13
Halichoeres hortulanus	27	IN	OF	8.75	9.57
Halichoeres marginatus	17	IN	OF	10.63	25.53
Halichoeres nebulosus	12	IN	OF	15.12	47.87
Halichoeres nigrescens	14	IN	OF	0.05	0.53
Halichoeres scapularis	20	IN	OF	2.44	11.70
Halichoeres vrolikii	13	IN	OF	0.34	1.60
Hemigymnus fasciatus	50	IN	OF	2.91	1.60
Hemigymnus melapterus	60	IN	OF	0.66	1.06
Labroides dimidiatus	12	IN	OF	0.26	6.38
Novaculichthys taeniourus	27	IN	OF	0.01	0.53
Pseudocheilinus octotaenia	14	IN	OF	0.63	2.13
Pteragogus ocellatus	10	IN	NT	3.94	9.57
Stethojulis spp.	14	IN	NT	2.13	20.74
Thalassoma hardwicke	20	IN	OF	11.04	15.43

Table 6.2. (cont.)

Fish species recorded	L_{max}	Funct. group	Fishery role	Biomass (% total family)	Ubiquity % total family)
Thalassoma jansenii	20	IN	OF	16.04	19.68
Thalassoma lunare	25	IN	OF	5.66	15.43
Thalassoma spp.	25	IN	OF	1.14	21.81
Lethrinidae					
Gnathodentex aureolineatus	30	IN	NT	2.79	0.53
Lethrinus harak	50	IN	FOOD	97.21	5.85
Lutjanidae					
Lutjanus decussatus	30	PI	FOOD	26.83	5.85
Lutjanus ehrenbergii	35	PI	FOOD	4.88	3.72
Lutjanus fulvus	40	PI	FOOD	44.84	3.72
Lutjanus lunulatus	35	PI	FOOD	18.24	1.60
Lutjanus vitta	40	PI	FOOD	5.22	0.53
Monodactylidae					
Monodactylus argenteus	27	IN	NT	100	1.60
Mugilidae					
Crenimugil crenilabis	40	OM	FOOD	100	1.60
Mullidae					
Mulloidichthys flavolineatus	40	IN	OF	2.97	3.19
Parupeneus barberinus	50	IN	OF	17.04	5.32
Parupeneus indicus	35	IN	OF	51.97	7.45
Parupeneus trifasciatus	35	IN	FOOD	28.02	2.13
Muraenidae					
Echidna nebulosa	75	IN	OF	100	1.06
Nemipteridae					
Scolopsis auratus	24	IN	NT	97.83	2.13
Scolopsis monogramma	38	IN	NT	2.17	0.53
Ostraciidae					
Ostracion cubicus	45	IN	OF	71.22	0.53
Ostracion meleagris	18	IN	OF	28.78	0.53
Pempheridae					
Pempheris oualensis	22	IN	NT	100	1.06
Pinguipedidae					
Parapercis clathrata	18	IN	OF	1.71	0.53
Parapercis hexophthalma	28	IN	OF	89.64	6.38
Parapercis millepunctata	18	IN	OF	8.66	1.60
Platycepahlidae					
Thysanophrys arenicola	37	PI	NT	100	0.53

Table 6.2. (cont.)

Fish species recorded	L_{max}	Funct. group	Fishery role	Biomass (% total family)	Ubiquity (% total family)
Pomacanthidae					
Pomacanthus semicirculatus	35	HB	OF	100	5.32
Pomacentridae					
Abudefduf bengalensis	17	HB	NT	2.20	2.13
Abudefduf lorensi	15	PL	NT	1.80	1.60
Abudefduf septemfasciatus	19	PL	NT	1.06	1.06
Abudefduf sexfasciatus	15	PL	NT	0.03	0.53
Abudefduf sordidus	19	HB	NT	2.48	3.19
Abudefduf vaigiensis	19	HB	OF	38.66	31.38
Chrysiptera glauca	8	HB	NT	0.16	2.13
Chrysiptera leucopoma	8	HB	OF	0.63	9.04
Chrysiptera leucopoma (var)	8	HB	OF	0.83	4.79
Chrysiptera oxycephala	8	PL	NT	0.14	1.60
Dascyllus trimaculatus	14	PL	OF	0.09	1.60
Neoglyphidodon bonang	13	HB	NT	20.87	34.04
Neopomacentrus azysron	8	PL	OF	2.24	5.85
Plectroglyphididon dickii	11	OM	NT	0.85	4.26
Plectroglyphidodon lacrymatus	10	HB	NT	6.44	6.38
Pomacentrus chrysurus	9	HB	NT	16.31	59.57
Pomacentrus indicus	11	HB	NT	0.18	4.26
Pomacentrus proteus	10	HB	NT	0.16	3.72
Pomacentrus similis	7	PL	OF	0.04	5.32
Pomacentrus tripunctatus	10	HB	NT	0.44	1.60
Stegastes nigricans	14	HB	NT	3.54	4.79
Stegastes obreptus	15	HB	NT	0.85	1.06
Scaridae					
Bolbometopon muricatum	126	HB	FOOD	25.84	0.53
Chlorurus rhakoura	44	HB	FOOD	2.48	1.06
Chlorurus sordidus	40	HB	FOOD	0.03	3.19
Scarus ghobban	75	HB	FOOD	1.97	2.13
Scarus rubroviolaceus	70	HB	FOOD	61.14	3.19
Scarus sordidus	40	HB	FOOD	8.54	2.13
Serranidae					
Cephalopholis argus	60	PI	OF	70.70	4.26
Epinephelus faveatus	32	PI	FOOD	8.23	0.53
Epinephelus flavocaeruleus	90	PI	FOOD	16.18	0.53
Epinephelus hexagonatus	26	PI	FOOD	0.56	0.53
Epinephelus merra	31	PI	FOOD	3.89	1.06

Table 6.2. (cont.)

Fish species recorded	L_{max}	Funct. group	Fishery role	Biomass (% total family)	Ubiquity (% total family)
Pseudanthias squamipinnis	15	PL	OF	0.43	0.53
Siganidae					
Siganus canaliculatus	29	HB	FOOD	4.17	0.53
Siganus guttatus	35	HB	FOOD	77.80	0.53
Siganus puelloides	31	HB	FOOD	1.12	0.53
Siganus spp.	35	HB	FOOD	16.91	4.79
Syngnathidae					
Trachyrhampus bicoarctatus	40	IN	NT	100	0.53
Tetraodontidae					
Arothron immaculatus	28	IN	OF	100	0.53
Zanclidae					
Zanclus cornutus	16	IN	OF	100	2.13

6.3.2 Habitat differences and similarities among sites

The average proportions of different substrate and habitat types varied among reef sites (Figure 6.1). Live coral cover and dead coral cover did not vary significantly between sites (Table 6.3, Figure 6.2 a & b), nor were there differences in the percentage cover of soft corals, or ascidians across sites. However coral rubble cover did vary among sites (Table 6.3 & Figure 6.2c; F=7.65, df=3, p<0.001) being significantly greater in Polhena (Tukey, p<0.05). Hikkaduwa had significantly higher amounts of sand than Kapparathota (Tukey, p<0.05), whereas rock was more common in Thalaramba than all other sites (Tukey, p<0.01). The amount of macro-algae observed differed significantly among sites (Table 6.3, Figure 6.2d; F=10.53, df=3, p<0.01) with most found in Kapparathota (Tukey, p<0.001). Further one-way ANOVAs indicated that seagrass, algal turf, calcareous coralline algae, sponges and zooantharians all differed significantly among sites (Table 6.3). Sponges and algal turf were found in significantly higher amounts in the protected area than the fished sites (Tukey, p<0.001, p< 0.05 respectively), whereas zooantharians were found in the highest numbers in Thalaramba (Tukey, p<0.05) and calcareous coralline algae was in significantly greater amounts in Kapparathota than other fished sites (Tukey, p<0.05). Seagrass was more common in Polhena than the other sites (Tukey, p<0.05). A Poisson regression model fitted to the number of coral genera at each site, showed that coral diversity was significantly lower at Kapparathota than the protected area (p<0.01), but did not differ among other sites.

Table 6.3. Average percentage cover and standard deviations with ranks given of substrate component types across the four study nearshore reefs. Site codes: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba. Differences among sites were measured using one-way ANOVA after percentages were arcsin transformed (level of significance: p *< 0.05, n.s = not signficant.). "Other" category includes corallimorpharians.*

Site		**Hikkaduwa**			**Kapparathota**			**Polhena**			**Thalaramba**			
n		52			45			47			44			
Substrate type	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	p-value (ANOVA)	Tukey HSD
Hard coral	12.90	17.21	3	11.22	18.47	3	11.64	17.62	4	15.91	20.74	2	n.s	
Dead coral	11.37	11.84	5	9.09	11.06	8	14.57	16.12	3	13.66	16.53	3	n.s	
Rubble	6.69	11.92	7	14.56	13.06	5	23.60	26.67	1	13.20	16.18	4	<0.001	KP < PO > TL; PO > HK
Sand	27.77	37.17	1	15.78	21.28	1	19.66	17.90	2	26.80	21.14	1	<0.001	KP < HK
Rock	0.48	2.85	9	0.22	1.49	9	0.43	2.92	9	3.36	6.77	9	<0.001	KP < TL > PO; TL > HK
Seagrass	0.44	1.32	10	2.96	12.26	6	11.68	17.18	6	4.61	13.25	8	<0.001	KP < PO > TL; PO > HK
Macroalgae	12.52	13.96	4	24.44	19.08	2	11.98	12.70	5	8.70	9.28	5	<0.001	PO < KP > TL; KP > HK
CCA	7.67	10.19	6	12.38	11.24	7	3.79	7.26	7	6.75	8.73	6	<0.001	PO < KP > TL
Algal turf	16.25	17.26	2	8.20	13.85	4	2.09	6.25	8	5.11	9.56	7	<0.001	KP < HK > PO; TL < HK
Soft corals	0.28	1.19	12	0.36	1.26	10	0.06	0.25	12	0.48	1.39	11	n.s	
Ascidians	0.34	1.02	11	0.58	1.13	11	0.31	1.37	10	0.40	0.89	12	n.s	
Sponges	3.21	6.04	8	0.07	0.33	13	0.00	0.00		0.27	0.87	13	<0.001	KP < HK > PO; TL < HK
Zooantharians	0.02	0.12	14	0.11	0.48	12	0.00	0.00		0.58	1.45	10	<0.001	KP < TL > PO; TL > HK
Other	0.06	0.19	13	0.03	0.05	14	0.20	0.77	11	0.17	0.76	14	n.s	

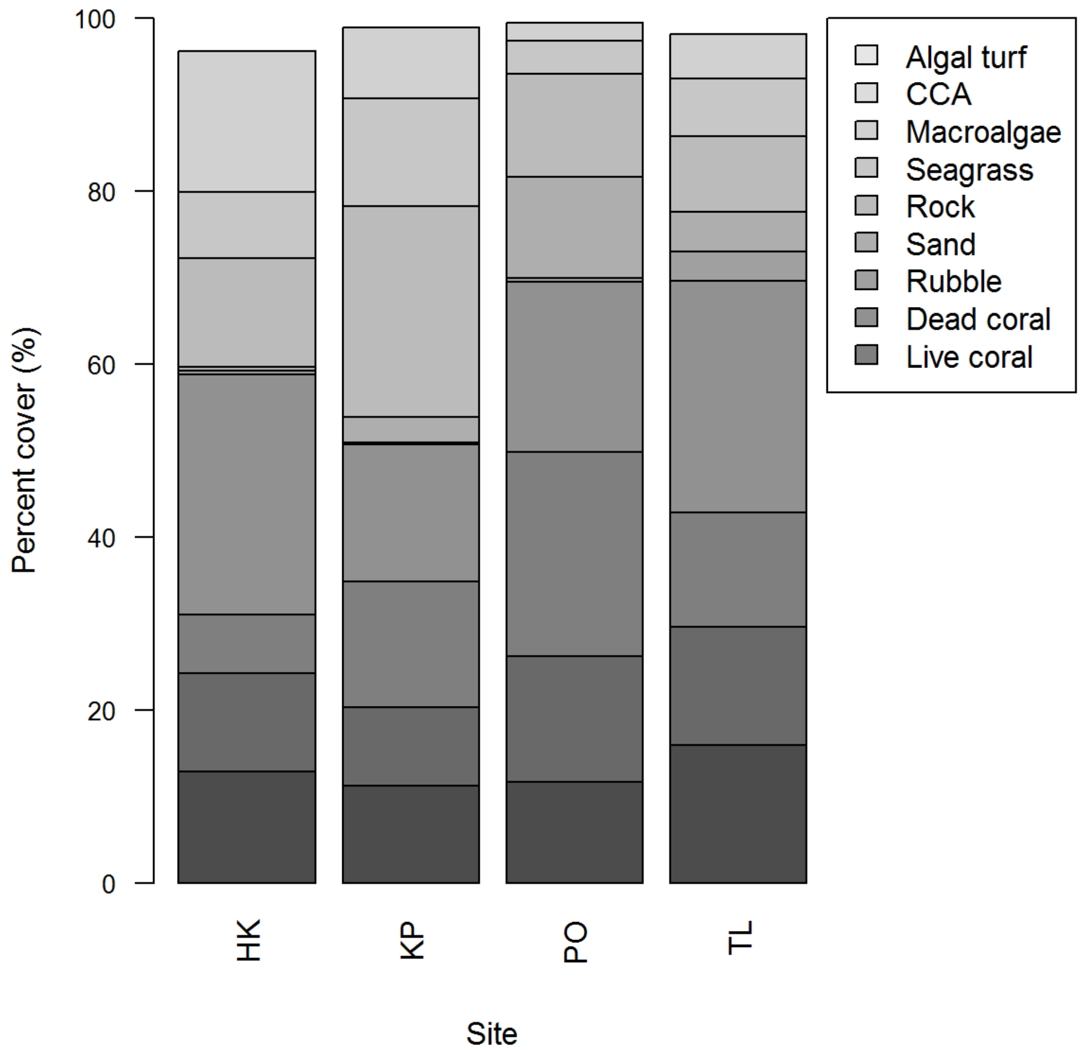

Figure 6.1. Habitat composition among reef sites expressed as percentage cover from census sites. Site codes are: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba

Structural complexity of the substrate did not differ significantly among sites, with the lowest mean structural complexity of 2.1 at Kapparathota and the highest of 2.7 at Thalaramba. However, vertical height of the substrate did differ significantly among sites (F= 7.97, df=3, p<0.001). Although Thalaramba had greater substrate height than the other three sites (Tukey p<0.001), it was minimal, a difference of 0.3 - 0.4 m in substrate height depending on sites (Figure 6.2f). These data suggest that differences in fish abundance and diversity among sites are not due to differences in reef structure or overall forms of coral cover. Therefore differences can be attributed to exploitation rates and differences in other habitats, such as rubble, sand and macroalgae.

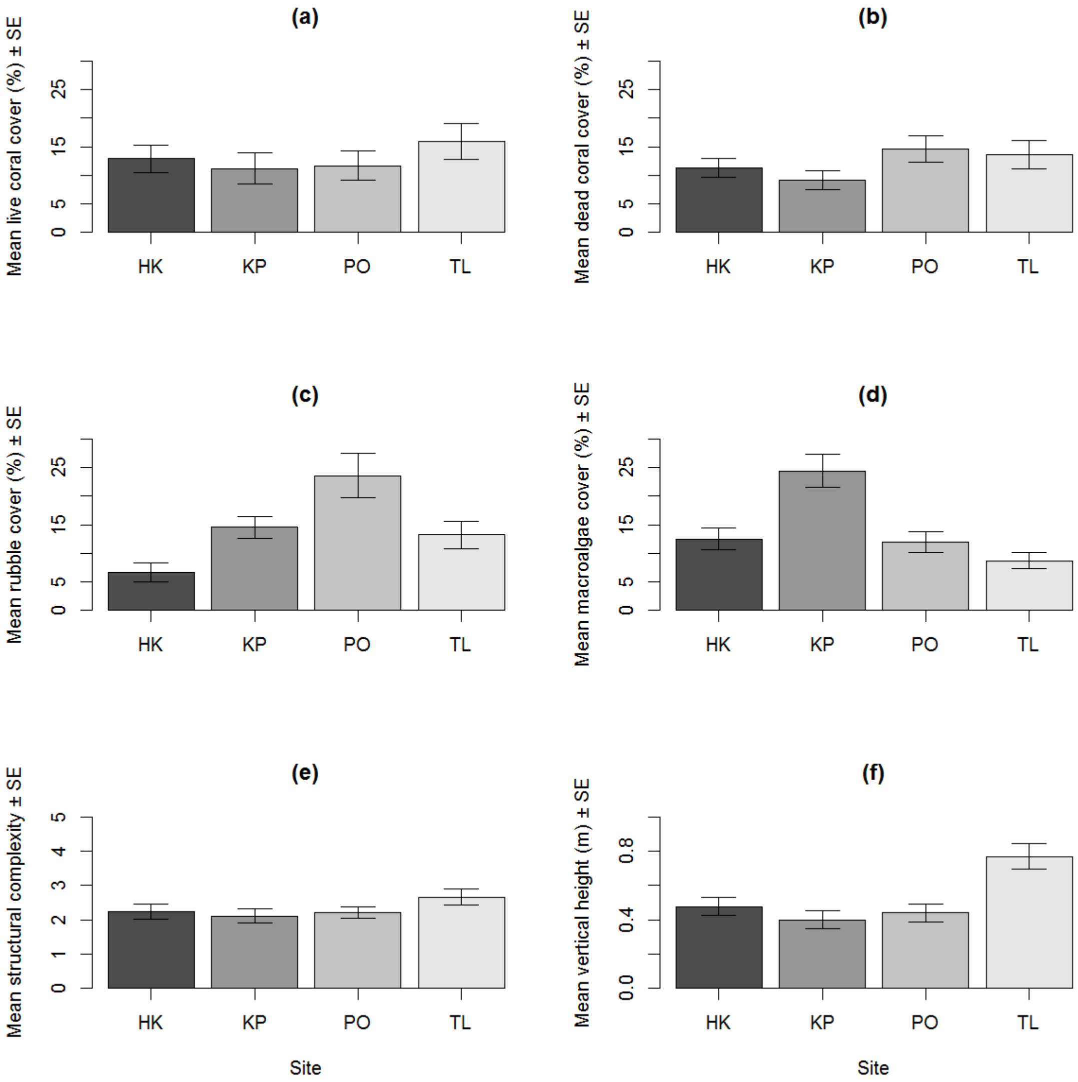

Figure 6.2. Mean cover of (a) live coral, (b) dead coral, (c) rubble, (d) macro-algae, (e) structural complexity and (f) mean vertical height among the four reef sites. Site codes are: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba.

6.3.3 Comparison of fish diversity and evenness among sites and substrates

In order of decreasing diversity according to the Shannon Wiener (H') scores, the highest fish diversity was 3.49 at Hikkaduwa, 3.16 at Kapparathota, 3.09 at Polhena and 2.9 at Thalaramba (Table 6.4). Pielou's (J) evenness measure did not vary greatly across sites with a value of 0.75 at Hikkaduwa, 0.73 at Kapparathota, 0.74 at Polhena and 0.69 at Thalaramba. These results indicate a general decrease in diversity from live coral and dead coral grid squares in the surveys to rubble and sand grid squares surveyed. However, the same substrate could have different diversity and evenness scores (Table 6.4).

Table 6.4. Mean Shannon- Wiener (H') diversity and Pielou's (J) Evenness measures of reef fish encountered at each site and substrate combination and its associated measure of evenness.

Site	Substrate	H'	J
Hikkaduwa	Dead coral	3.212	0.764
Kapparathota	Dead coral	2.605	0.693
Polhena	Dead coral	2.413	0.741
Thalaramba	Dead coral	3.029	0.782
Hikkaduwa	Live coral	3.094	0.756
Kapparathota	Live coral	2.575	0.713
Polhena	Live coral	2.519	0.727
Thalaramba	Live coral	2.842	0.776
Hikkaduwa	Rubble	2.905	0.728
Kapparathota	Rubble	2.269	0.624
Polhena	Rubble	2.824	0.830
Thalaramba	Rubble	1.574	0.489
Hikkaduwa	Sand	2.300	0.756
Kapparathota	Sand	2.412	0.702
Polhena	Sand	2.785	0.811
Thalaramba	Sand	1.736	0.580

6.3.4 *Differences in species richness, abundance and biomass among sites and substrates*

The MANOVA performed on species richness and log transformed abundance and biomass data tested two factors: substrate and site and gave significant results for both factors (F=13.74, df=3, p<0.001 and F=10.28, df=3, p<0.001 respectively). The univariate statistics performed following the significant MANOVAs showed species richness, abundance and biomass were significantly different among substrates and sites.

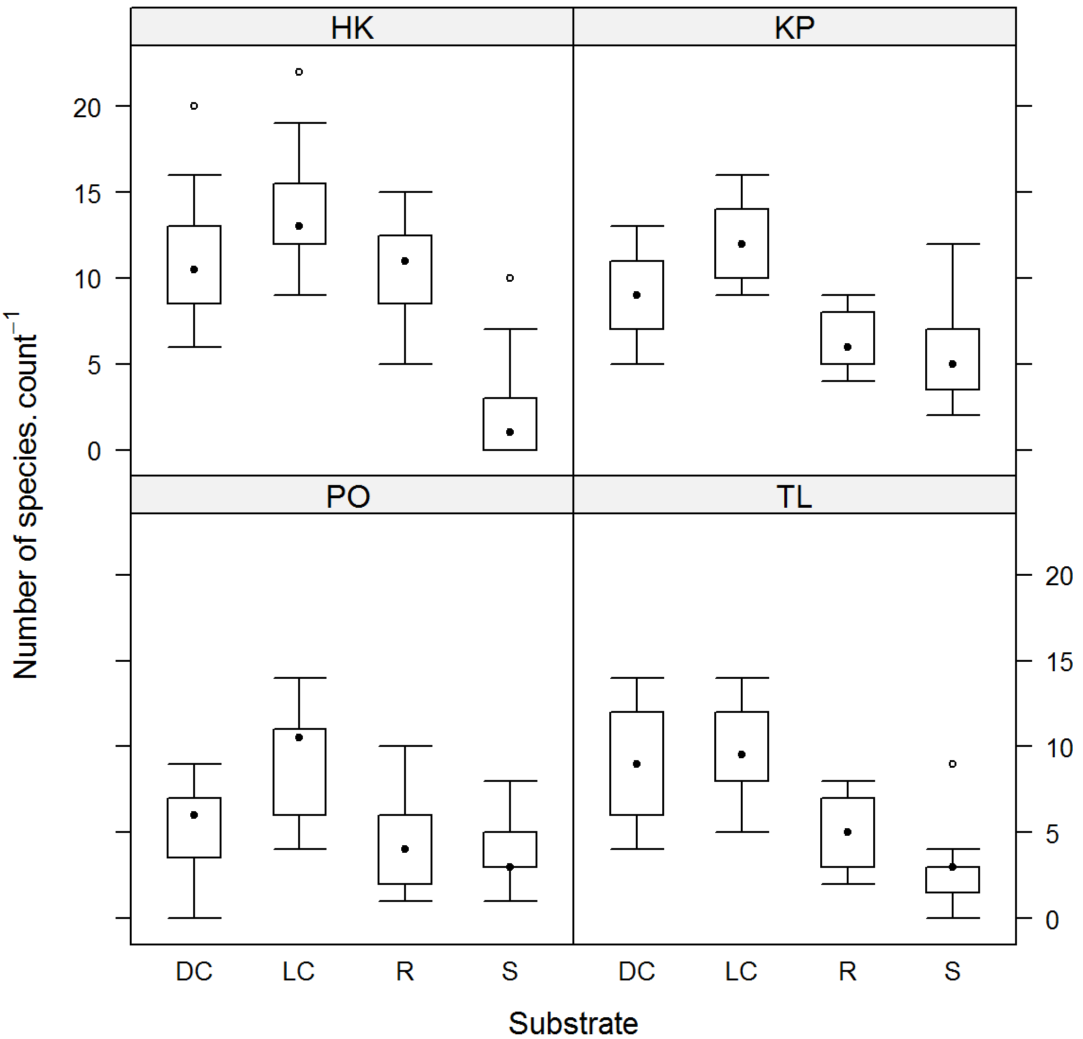

Figure 6.3. Reef fish diversity among substrates at each site. Solid dots indicate the median and open dots indicate outliers. Substrate codes are: DC = Dead coral, LC = Live coral, R = Rubble, S = Sand. Site codes are: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba.

Species richness was significantly different among all pairwise comparisons of substrate (Tukey, $p<0.001$ for all) with the greatest mean species richness of 11.4 per point count over predominantly live coral areas with lower levels of 8.8 species per count over dead coral, 6.5 species per count over rubble and the lowest mean richness of 3.6 species per count over sand areas (Figure 6.3). Greater mean species richness of 9.2 species per count was detected at Hikkaduwa compared to 5.4 species per count at Polhena and 6.7 species per count at Thalaramba (Tukey, $p<0.001$ for all). Kapparathota had a greater species richness of 8 species per count than Polhena (Tukey, $p<0.001$). Species richness did not vary significantly between Kapparathota and Hikkaduwa or Thalaramba, or between Polhena and Thalaramba.

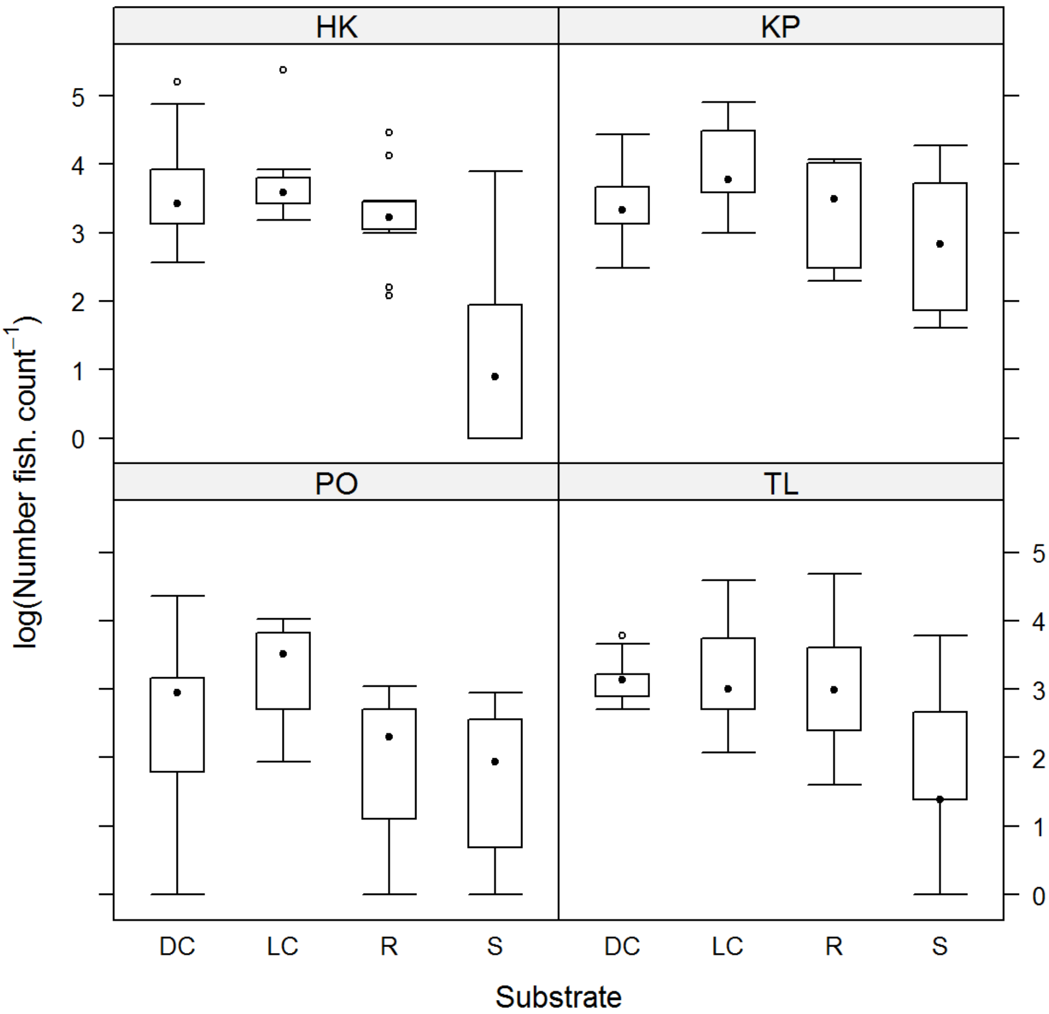

Figure 6.4. Natural log transformed reef fish mean density among substrates within sites for all fish censused. Substrate codes: DC = Dead coral, LC = Live coral, R = Rubble, S = Sand. Site codes: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba.

A mean density of 12.1 fish/ $9m^2$ in sand areas was significantly lower than mean density for all other substrate types (32.6 – DC; 44.1 – LC; 24.6 – R) (Tukey, $p<0.001$) and was significantly lower in rubble areas compared to live coral areas (Tukey, $p<0.001$). Fish density over dead coral areas did not differ significantly when compared to live coral or rubble areas (Figure 6.4). Kapparathota exhibited a higher mean fish density of 36.6 fish/ $9m^2$ than the other two fished sites, Polhena (mean = 15.7/ $9m^2$, Tukey, $p<0.001$) and Thalaramba (mean = 23.8/ $9m^2$, Tukey, $p<0.05$) but not significantly different from Hikkaduwa (33.9/ $9m^2$). Fish density was significantly higher in Hikkaduwa than Polhena (Tukey, $p<0.05$) but not significantly different from Thalaramba.

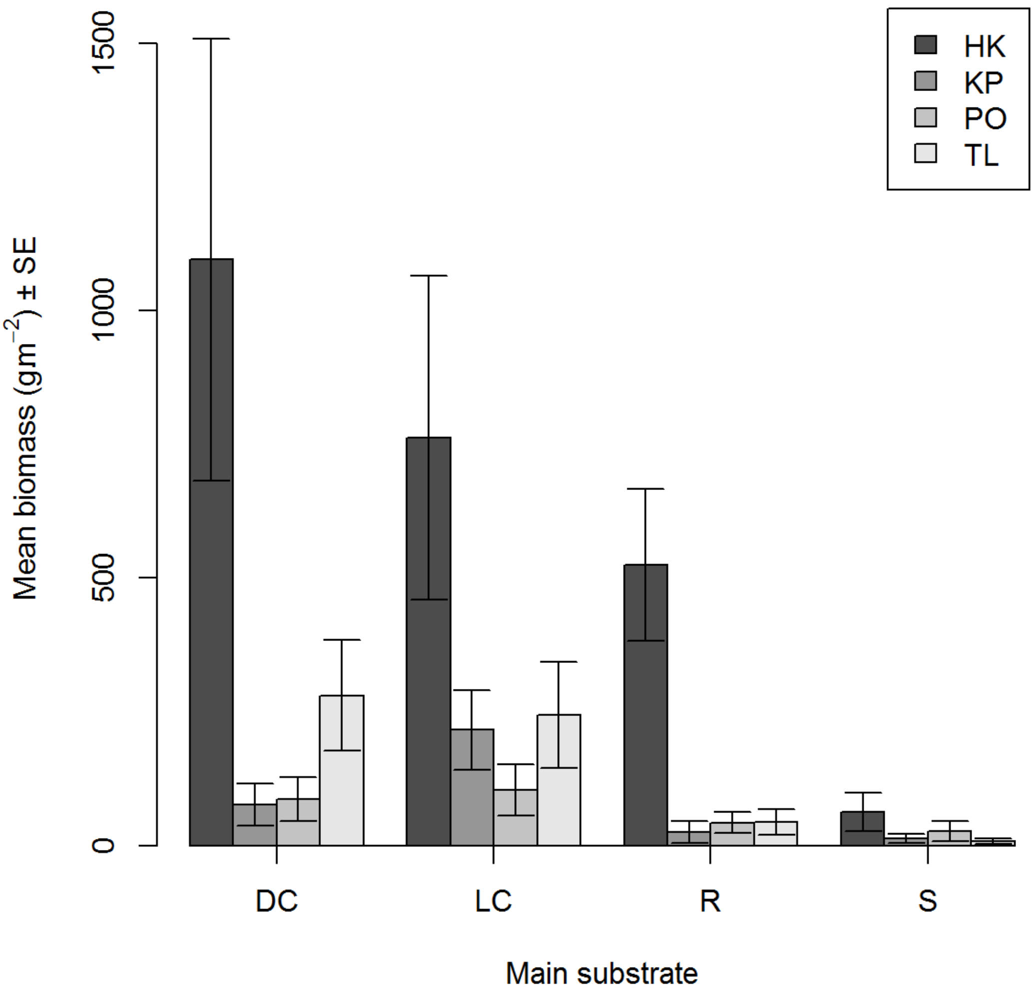

Figure 6.5. Mean reef fish biomass among sites and habitats for all species censused in the survey. Error bars denote ± standard error. Substrate codes: DC = Dead coral, LC = Live coral, R = Rubble, S = Sand. Site codes: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba.

Mean fish biomass did not differ significantly between live and dead coral areas but did differ significantly between all other substrate comparisons (Tukey, $p<0.001$). Among sites, total fish biomass of 626.5 g/ m^2 at Hikkaduwa differed significantly from Kapparathota (75.5 g/ m^2), Polhena (61.3 g/ m^2) and Thalaramba (150.2 g/ m^2) (Tukey, $p<0.001$), however total fish biomass did not differ among the three fished sites (Figure 6.5).

There were significant Spearman rank correlations among the majority of measures and variables tested (Table 6.5). There were no significant correlations between any of the fish community measures (abundance, species diversity, biomass and Shannon-Wiener diversity) and the following variables: temperature, depth, rock and rubble. All the community measures (abundance, species diversity, biomass and Shannon-Wiener diversity) were positively correlated with all the variables tested except sand where the opposite correlation for each measure was true. Also there was no significant correlation between total fish abundance and dead coral cover or *Acropora* cover. Among the functional groups abundance of piscivores and planktivores were not significantly correlated with any of the habitat variables (Table 6.5). Omnivore abundance was the only group positively correlated with sand (r_s = 0.38, $p<0.001$), whereas herbivore and invertivore abundance were negatively correlated with sand. Corallivore abundance were positively correlated with *Acropora* cover (r_s = 0.38, $p<0.001$). Herbivore abundance were positively correlated with dead coral cover (r_s = 0.31, $p<0.01$) and herbivore and invertivore abundance were positively correlated with substrate diversity (r_s = 0.49, $p<0.001$; r_s = 0.52, $p<0.001$ respectively). Abundance of corallivores and herbivores were positively correlated with substrate vertical height, whereas abundance of corallivores, herbivores and invertivores were positively correlated with structural complexity, live coral cover and the number of coral genera (Table 6.5).

Among the family groups, Pomacentridae abundance was found to be positively correlated with all the habitat variables tested except for sand (r_s = -0.47, $p<0.001$) and temperature, depth, rock and rubble (no significant correlations). Acanthuridae, Chaetodontidae and Labridae abundance were positively correlated with structural complexity, live coral cover and the number of coral genera present (Table 6.5). Acanthuridae and Labridae abundance were positively correlated with substrate diversity (r_s =0.39 and 0.5, $p<0.001$ for both) and negatively correlated with sand cover, whereas Acanthuridae and Chaetodontidae abundance were positively correlated with the vertical height of the substrate (r_s =0.33, p<0.001; r_s =0.39, p<0.001). Chaetodontidae and Pomacentridae abundance were positively correlated with *Acropora* cover (r_s =0.35, p<0.001; r_s =0.39, p<0.001), but Pomacanthidae and Scaridae abundance were not significantly correlated with any of the habitat variables (Table 6.5).

6.3.5 Comparisons of abundance and biomass by family group

Pomacentridae accounted for between 29 and 45% of total numerical abundance at sites. Three families, Pomacentridae, Acanthuridae and Labridae, accounted for 65% (Hikkaduwa), 69.7% (Kapparathota), 82.7% (Polhena) and 62.9% (Thalaramba) of total abundance (Figure 6.6).

Total biomass was dominated by a few families at each site. In the fished sites, the same above three families accounted for most of the biomass, (82.3% Kapparathota, 67.6% Polhena and 77% Thalaramba); whereas at Hikkaduwa, the non-fished site, total biomass was dominated by Scaridae, Acanthuridae, Haemulidae and Balistidae, accounting for 69.7% of total biomass at this site (Figure 6.7).

Species belonging to Haemulidae and Balistidae were not encountered at the fished sites and Scaridae species only infrequently, if at all. Similarly, abundance and biomass across substrate types were dominated by a few family groups. Around dead coral areas, 73% of total abundance comprised Labridae, Pomacentridae and Acanthuridae; these same three families accounted for 84% of abundance around live coral areas.

Abundance in rubble and sand areas was dominated by the families Labridae, Pomacentridae, Apogonidae and Siganidae (Figure 6.6). These four families made up 78% and 65% of total abundance across rubble and sand areas respectively. Seventy percent of total biomass over dead coral areas was contributed by Scaridae, Acanthuridae, Carangidae and Haemulidae. Over live corals 63.8% of biomass was attributed to Pomacentridae, Acanthuridae, Scaridae and Haemulidae (Figure 6.7). Scaridae, Balistidae, Acanthuridae and Pomacentridae accounted for 62.9% of biomass over rubble areas, and 57.8% of total biomass over sand areas was represented by Acanthuridae, Pomacentridae, Lethrinidae and Mullidae (Figure 6.7).

*Table 6.5. Spearman rank correlation summary between reef fish assemblage measures and habitat variables from all reef sites. (*n *= 188). Significant correlations are marked for* $p < .01$ *** and* $p < .001$ ****. S-W = Shannon – Wiener diversity. Habitat variable codes: SC = Structural complexity; VHT = substrate maximum vertical height; LC = live coral cover; DC = dead coral; SCD = substrate composition diversity; Temp = temperature (* ^{o}*C).*

	SC	VHT	LC	DC	SCD	Temp	Depth	Acropora	Rubble	Sand	Rock	No. coral genera
Total abundance	0.52***	0.4***	0.5***	0.26	0.45***	-0.14	-0.09	0.27	-0.1	-0.44***	-0.05	0.46***
Number species	0.69***	0.54***	0.66***	0.31**	0.58***	-0.1	-0.07	0.32**	-0.19	-0.52***	-0.03	0.64***
Biomass	0.67***	0.56***	0.62***	0.36***	0.43***	-0.07	0.09	0.32**	-0.21	-0.44***	-0.03	0.63***
S-W diversity	0.54***	0.43***	0.52***	0.3**	0.41***	-0.12	-0.04	0.34***	-0.08	-0.36***	-0.02	0.5***
ABUNDANCE												
Corallivores	0.34***	0.36***	0.32**	0.14	0.21	-0.11	0.28	0.38***	-0.07	-0.22	0.12	0.38***
Piscivores	0.06	0.18	0.08	0.06	0.07	-0.01	0.14	0.09	0	-0.18	-0.11	0.11
Herbivores	0.57***	0.37***	0.56***	0.31**	0.49***	-0.09	-0.17	0.26	-0.15	-0.46***	-0.1	0.52***
Invertivores	0.45***	0.26	0.36***	0.18	0.52***	-0.04	-0.28	0.14	-0.04	-0.38***	0.05	0.35***
Omnivores	0.23	0.19	0.27	0.08	0.28	0.01	-0.04	0.03	-0.07	0.38***	-0.02	0.23
Planktivores	0.23	0.25	0.19	0.13	0.13	-0.07	0.14	0.17	-0.07	-0.19	-0.04	0.18
ABUNDANCE												
Acanthuridae	0.57***	0.33***	0.53***	0.28	0.39***	-0.11	-0.13	0.23	-0.24	-0.42***	-0.06	0.48***
Chaetodontidae	0.33***	0.36***	0.34***	0.13	0.25	-0.12	0.25	0.35***	-0.07	-0.27	0.1	0.39***
Labridae	0.45***	0.26	0.42***	0.22	0.5***	-0.1	-0.33	0.15	0	-0.37***	0.01	0.39***
Pomacanthidae	0.23	0.2	0.23	0.06	0.09	0.04	0.06	0.03	-0.11	-0.12	0.1	0.22
Pomacentridae	***	0.54***	0.7***	0.42***	0.53***	-0.09	-0.11	0.39***	-0.17	-0.47***	-0.05	0.66***
Scaridae	0.04	0.06	-0.01	-0.06	0.04	-0.01	0.05	0.02	-0.13	-0.14	-0.03	0.04

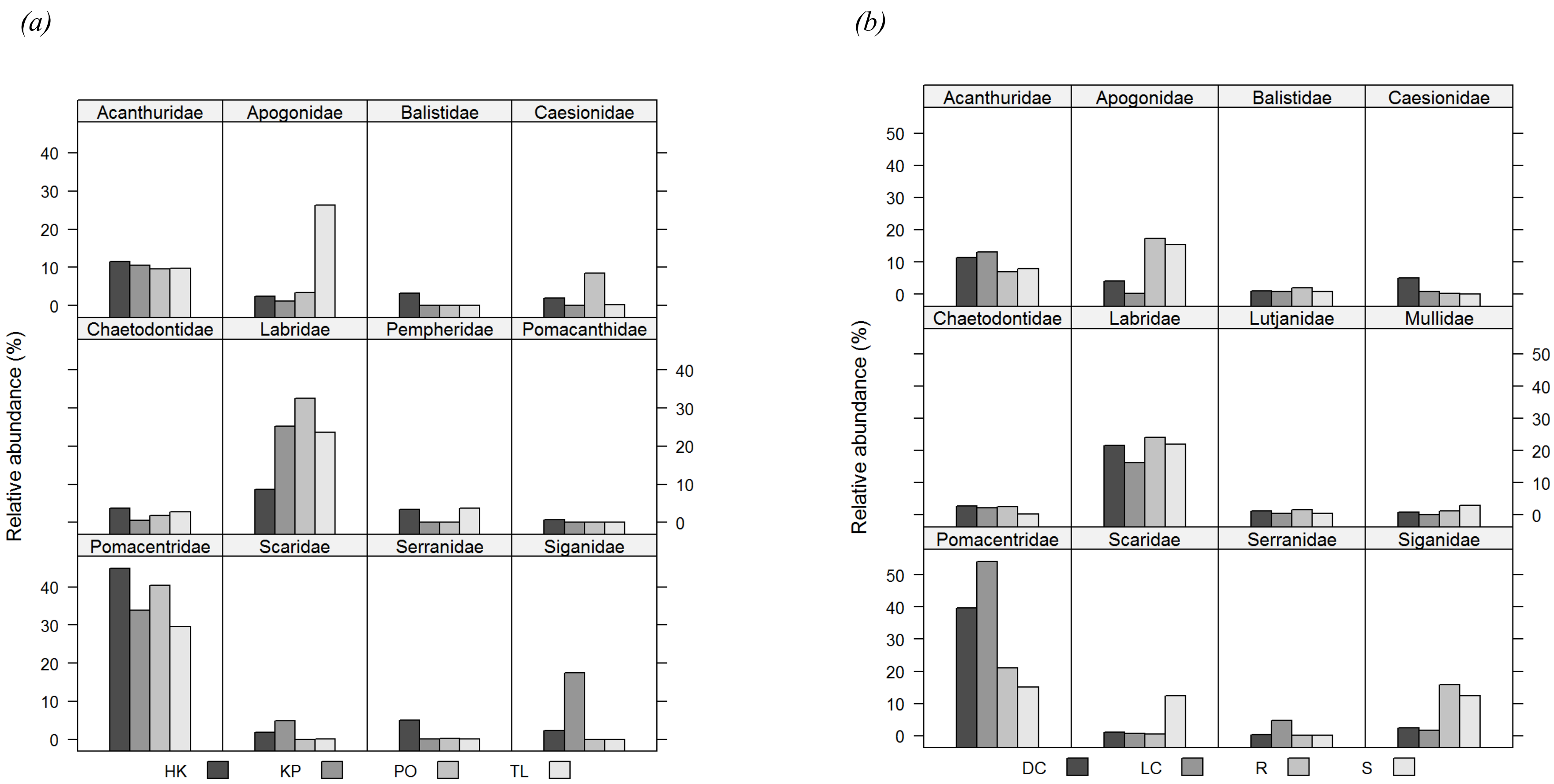

Figure 6.6. Relative % abundance by family groups for each (a) site and (b) substrate. The families contributing to between 80 and 95% total abundance are shown. Site codes: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba. Substrate codes are: DC = Dead coral, LC = Live coral, R = Rubble, S = Sand.

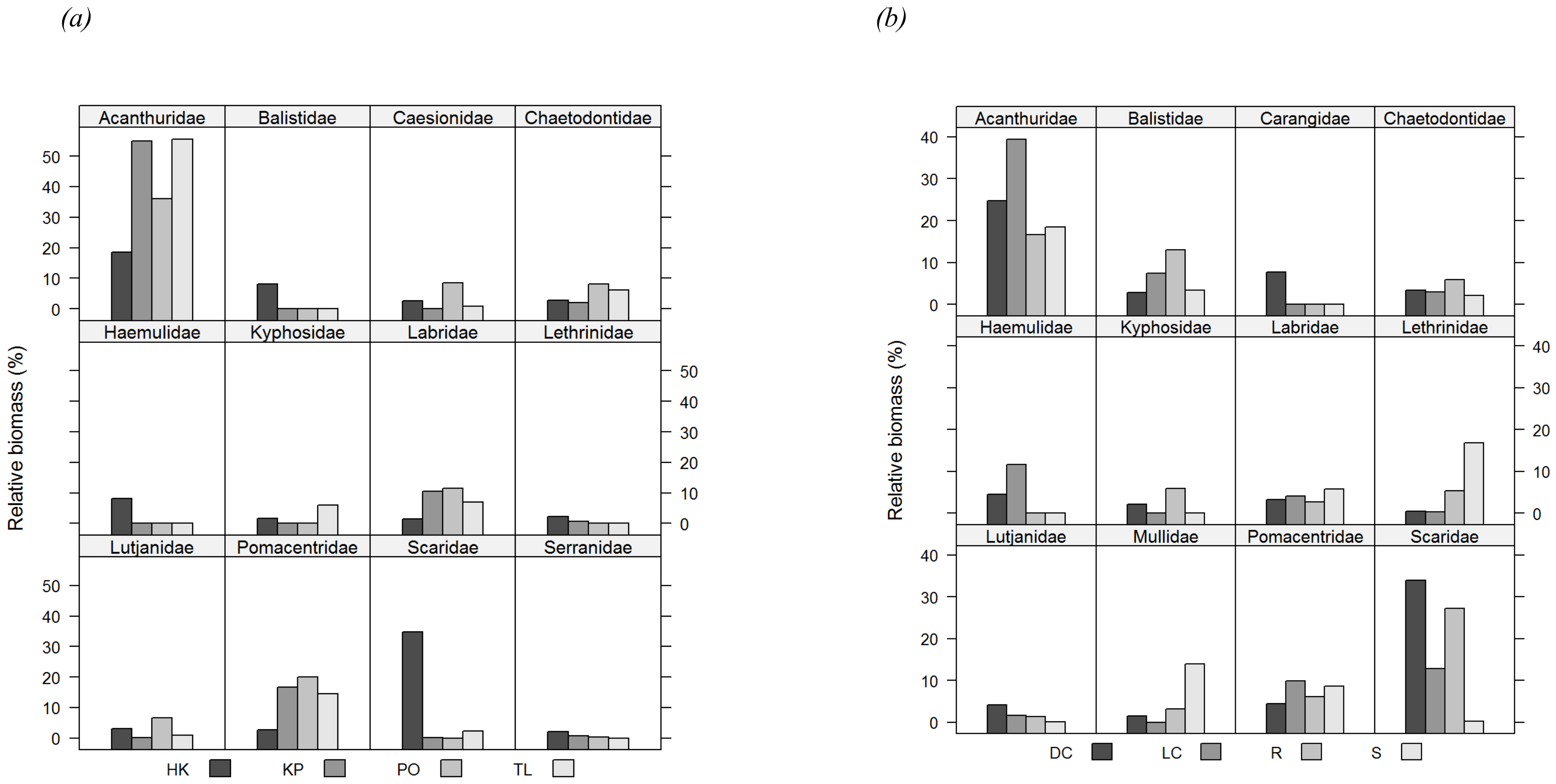

Figure 6.7. Relative % biomass by family groups for (a) site and (b) substrate. The families contributing between 80 and 95% total biomass are shown. Site codes: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba. Substrate codes are: DC = Dead coral, LC = Live coral, R = Rubble, S = Sand.

6.3.6 Comparisons of density and biomass by functional group

Overall herbivores and planktivores were the most numerically abundant groups across all substrates and sites with the other functional groups having very low abundances across all site and substrate combinations (Figure 6.8). There was no significant difference in abundance among sites and substrate for piscivores, corallivores, omnivores or planktivores. However, there were significant differences of abundance among substrates and sites for invertivores (substrate: F=12.5, df=3, p<0.001; site: F=8.6, df=3, p<0.001) and herbivores (substrate: F=16.7, df=3, p<0.001; site: F= 11.2, df=3, p<0.001).

There were significantly fewer invertivores in sand areas than the other substrate types (Tukey, p<0.001 for live coral and dead coral, p<0.01 for rubble). There was a greater abundance of invertivores at Kapparathota than Hikkaduwa (Tukey, p<0.001), and this functional group was significantly less abundant at Polhena and Thalaramba than Kapparathota (Tukey, p<0.001, p<0.05 respectively) (Figure 6.6). Differences in invertivore abundance among other site comparisons were not significantly different.

Herbivore abundance differed significantly between dead coral and rubble and sand (Tukey, p<0.05, p<0.001 respectively) and between live coral and rubble and sand (Tukey, p<0.001 in both cases). Abundance of herbivores did not vary between live coral and dead coral areas, nor between sand and rubble areas (Figure 6.8). Greater herbivore abundance was found in Hikkaduwa than Polhena or Thalaramba (Tukey, p<0.001, p<0.01 respectively) and in Kapparathota than Polhena or Thalaramba (Tukey, p<0.001 in both cases).

There was no difference in herbivore abundance between Hikkaduwa and Kapparathota, nor between Polhena and Thalaramba. Piscivore (ANOVA, substrate: F=10.16, df=3, p<0.001, site: F=30.2, df=3, p<0.001), invertivore (substrate: F=13.1, df=3, p<0.001, site: F=5.3, df=3, p<0.01), omnivore (substrate: F=3.8, df=3, p<0.05, site: F=20.7, df=3, p<0.001) and herbivore (substrate: F=38.9, df=3, p<0.001, site: F=23.2, df=3, p<0.001) biomass differed significantly across both substrates and sites (Figure 6.9).

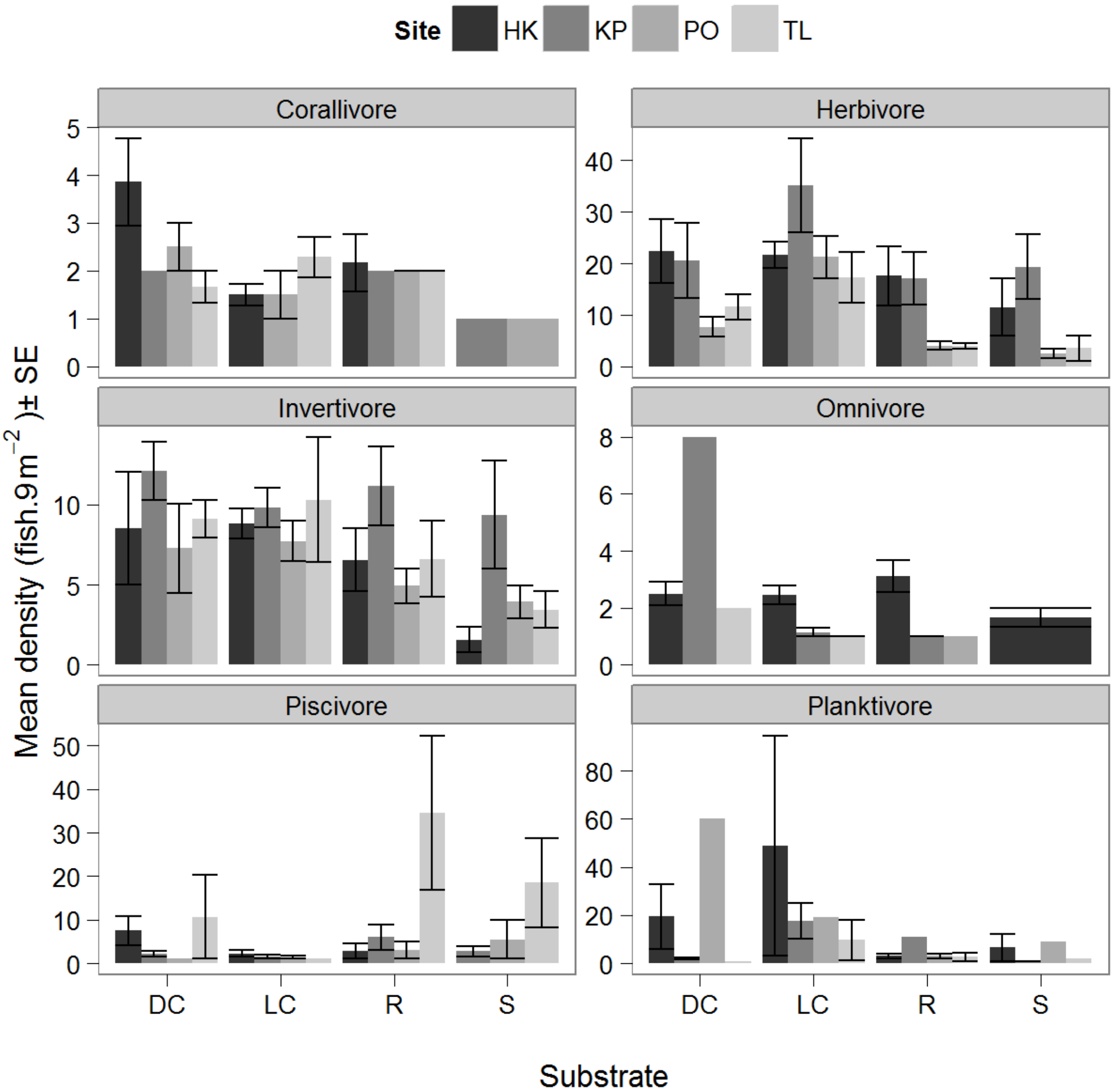

Figure 6.8. Mean density (fish. 9m^{-2}) of different functional groups among substrates within sites. Substrate codes: DC = Dead coral, LC = Live coral, R = Rubble, S = Sand. Site codes: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba.

Corallivore biomass differed significantly among sites (F=3.8, df=3, p<0.05) whereas planktivore biomass did not differ significantly among substrates or sites (Figure 6.9). Piscivore biomass was significantly greater in dead coral areas than rubble or sand (Tukey, p<0.001 in both cases) and greater in live coral areas than rubble or sand areas (Tukey, p<0.01 in both cases). There was no difference in piscivore biomass between live coral and dead coral areas nor between rubble and sand areas. These same directional differences were observed for invertivore and herbivore biomass as well.

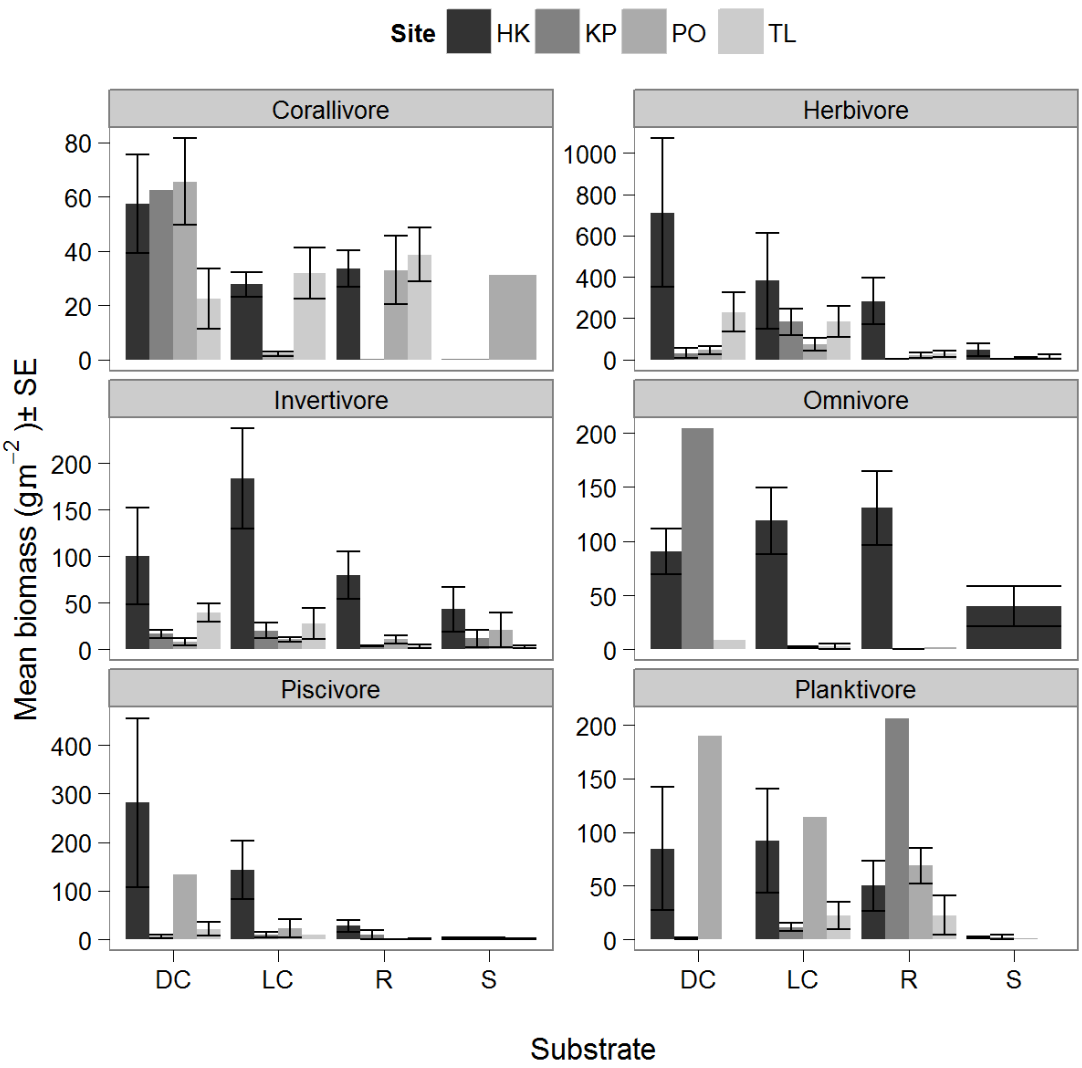

Figure 6.9. Mean biomass (g. m^{-2}) of different functional groups among substrates within sites. Substrate codes: DC = Dead coral, LC = Live coral, R = Rubble, S = Sand. Site codes: HK = Hikkaduwa, KP = Kapparathota, PO = Polhena, TL = Thalaramba.

There was significantly greater piscivore biomass at Hikkaduwa than Kapparathota and Thalaramba (Tukey, p<0.001 in both cases), but not compared to Polhena (Figure 6.9). A greater biomass of invertivores was found at Hikkaduwa compared to Polhena and Thalaramba (Tukey, p<0.01). Herbivore biomass was significantly higher in Hikkaduwa than all the fished sites (Tukey, p<0.001 in all cases) and was significantly higher in Thalaramba than Kapparathota (Tukey, p<0.001). Corallivore biomass was only significantly higher in dead coral areas than sand areas (Tukey, p<0.05) and was greater at Hikkaduwa than Kapparathota (Tukey, p<0.05). Omnivore biomass was higher in dead coral areas than live coral areas (Tukey, p<0.05) and was greater at Hikkaduwa compared to Kapparathota or Thalaramba (Tukey, p<0.01 in both cases).

6.3.7 Generalised linear mixed model (GLMM) results

Using a GLMM, abundance at each site was compared to the reference site, Hikkaduwa, and was found to be significantly lower at two of the fished sites (Polhena and Thalaramba) compared to the non-fished site ($p<0.001$) (Table 6.6). However, abundance at the third fished site, Kapparathota, was significantly higher than the protected site, Hikkaduwa ($p<0.001$). Abundance around live coral areas was significantly higher than the dead coral ($p<0.001$), whereas abundance in sand areas was significantly lower than around dead coral areas ($p<0.001$). Abundance in rubble was not significantly different from dead coral areas.

This corresponds well to the parametric tests in that there were no differences in abundance between rubble and dead coral areas and abundance was less in sandy areas than dead coral areas described above. However, the tests differ in that abundance at Kapparathota and Hikkaduwa was not significantly different in ANOVA and here the fished site shows higher abundance. A significant difference in abundance between Thalaramba and Hikkaduwa was not apparent under ANOVA but was in the GLMM, with Thalaramba having significantly lower abundance. Furthermore, fish abundance in live coral areas was significantly higher than dead coral areas under the GLMM, whereas it was negligible under ANOVA. The difference in results between ANOVA and GLMM could be explained by the difference in the assumed distribution and the fact that GLMM results are conditional on the response of individual specie to changes in habitat or site. To highlight this further, the results from ANOVA seek differences between the sites and habitats, independent of which species are present, whereas the GLMM results show, given these species in the data, whether there are differences or no differences between the sites and habitats.

Table 6.6. Generalised linear mixed model results of overall abundance compared across site and substrate with species set as the random effect.

	Estimate	Std. Error	z value	Pr(> |z|)
(Intercept)	1.26	0.09	13.39	0.000000
Site KP - HK	0.14	0.04	3.54	0.000000
Site PO - HK	-0.57	0.05	-11.75	0.000000
Site TL - HK	-0.25	0.04	-5.89	0.000000
Substrate LC - DC	0.14	0.04	3.87	0.000000
Substrate R - DC	-0.07	0.04	-1.68	0.090000
Substrate S - DC	-0.45	0.05	-8.75	0.000000

Under the LMM, total biomass was found to be lower at all fished sites when compared to the protected area, Hikkaduwa. However, only Polhena and Kapparathota were significantly lower in biomass than Hikkaduwa ($p<0.05$ in both cases), biomass at Thalaramba was not significantly lower than Hikkaduwa (Table 6.7). Similarly biomass in all substrate types (LC, R and S) was lower than dead coral areas, however, only biomass in rubble areas was significantly different from dead coral areas ($p<0.05$). Biomass recorded in live coral and sand areas was not significantly lower than dead coral areas. This contrasts sharply with the ANOVA results, which showed that biomass at Hikkaduwa is significantly greater than biomass at all the fished sites. The test results agree that fish biomass in live coral and dead coral areas do not significantly differ, however, they disagree in that biomass in sand areas is lower than dead coral areas under ANOVA and marginally not significantly different under the LMM.

The danger of analysing the data with ANOVA is the potential for false positive findings. The ANOVA model assumes more information than the actual information in the data because it considers the data as independent, which is not the case because the abundance and biomass for each fish species across different habitats or sites will differ in respect to the abundance and biomass of other fish species across these habitats and sites. In other words, there is intra-species dependency in the data that is ignored by the ANOVA model. It is theoretically expected for the above reason to find more significant results with ANOVA than GLMM or LMM because GLMM and LMM typically result in bigger standard errors than the classical ANOVA model.

Table 6.7. Linear mixed model results of biomass compared across site and substrate with species set as the random effect.

	Value	**Std. Error**	**DF**	**t-value**	**p-value**
(Intercept)	1508.32	273.85	438	5.51	0
Site KP - HK	-539.49	222.66	438	-2.42	0.02
Site PO - HK	-669.96	238.74	438	-2.81	0.01
Site TL - HK	-385.59	223.7	438	-1.72	0.09
Substrate LC - DC	-238.27	206	438	-1.16	0.25
Substrate R - DC	-530.64	212.6	438	-2.5	0.01
Substrate S - DC	-468.33	243.49	438	-1.92	0.06

6.4 Divers' knowledge of their village waters

I present evidence of divers' knowledge and perception of the status of their reef and its fishery. These findings result from analysis of a combination of fieldnotes, interviews, focus groups, casual discussions and hours of participant observation with divers both in and out of the water. The significance of working with local people and appreciating their knowledge of factors, that are still unknown, such as reef fish biology, was promoted by Johannes (1981) to improve management of tropical fisheries.

6.4.1 Fish breeding knowledge

The divers noted on a monthly calendar the specific months in which the fish species important to the ornamental fishery breed. The divers in Kapparathota and Thalaramba appeared to know more about fish breeding than the divers in Polhena (Table 6.8), perhaps because more of the old divers attended these two focus groups and perhaps they took more time to complete the task. The divers in Kapparathota and Thalaramba indicated exact months in which important ornamental fish breed, while in Polhena, they only provided the season (out-season or season), not the month, in which the different species breed. The divers in the group in Polhena were mainly younger divers (under 30 years of age) and so it may be that they were less interested in the task and/or they had no more precise knowledge due to a lack of experience. Divers in Kapparathota all agreed that as well as the months marked (Table 6.8), all the fish listed also breed in January. It is difficult to corroborate the data presented by the divers of fish breeding timings without further study, as only the exact life histories and breeding behaviour of well studied reef fish species in certain locations are known to western science (Claydon, 2004). This new piece of information illustrates clearly that by incorporating LEK into further studies new insights and improvements in our understandings of such complex ecosystems could emerge.

6.4.2 Divers' conception of the reef and their perception as to its current health

Divers explained that very little of their knowledge about fish and coral came from those outside their communities. They had learnt predominantly from talking to one another and experience, watching fish and observing the state of corals and other reef organisms during their almost daily fishing trips. These diachronic observations accumulate over many years of witnessing natural activity and changes on the reefs. It is knowledge that is culturally situated and forms as social product, whether it induces sustainable practice is not relevant (Antweiler, 1998). Out of school education comes occasionally from government and NARA officials (see Chapter 8), who highlight the importance of not breaking coral and its importance to fish populations. After the 2004 tsunami, there was a call for greater levels of community preparedness and awareness in Sri Lanka to disasters (UNEP, 2005) and to develop greater awareness of the linkages between human-environmental interactions, such as the benefits of healthy coral reefs in regards to future disaster management (Srinivas & Nakagawa, 2008). Some NGOs, such as United Nations Volunteers were involved in coral reef restoration and awareness raising programmes post-tsunami, however these were in certain locations only (Mohotti, 2007). At the time of this study, no such programmes existed in the study sites. However, the divers maintained that they receive little new information from such external agencies. Interaction between western science and local forms of knowledge is hard for scientists to navigate or even contemplate (Gadgil et al., 2003) and so their local knowledge is dismissed or overlooked (Johannes et al., 2008) even by local scientists in Sri Lanka, tasked with managing this fishery. One elder diver made clear his understanding of the importance of coral to fish abundance and therefore to their livelihoods:

> *"I protect the coral that's why I don't dive in coral areas any more, some species are associated with corals, I don't catch those. El Niño came and the coral went all white, lots corals died then and haven't come back. The best corals were in Weligama [Kapparathota] before that time. Now not many fish since that incident, not many fish growing and the tsunami also destroyed corals."* -
>
> Thilak, 50 year old skin diver from Kapparathota.

The dramatic changes to their reefs and village waters that the divers and many others even half his age had witnessed in the fifteen years since the 1998 El Niño event, provided stark examples of how the reef system operates and fails. The comparison of coral health and reef fish abundance over the 15 year period allows divers to compare the status of the reef and its fish populations on a monthly basis over these years.

Table 6.8. Seasonal calendar showing sea and weather conditions and the months when main target fish breed according to ornamental divers at three reef sites. Site codes: KP = Kapparathota, PO = Polhena, TL = Thalaramba. Fish names are local names used by divers. See Appendix E & F for list of local, common and scientific names of ornamental fish.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Season**	**All year**	
Weather	Showers	Dry	Both	Both	Rain	Rain	Dry	Dry	Showers	Rain	Showers	Showers	Dry	-	
Sea Conditions	Calm	Calm	Calm	Change	Rough	Rough	Rough	Rough	Rough	Change	Calm	Calm	Calm	-	
Type of fishing	Colour	Colour	Colour	Colour	Boat	Boat	Boat	Boat	Boat	Colour	Colour	Colour	Colour	Both	
Income (Rs)	10000	10000	10000	6000	4000	1000	1000	1000	5000	15000	15000	15000	12000	8300	
Fish species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Season**	**All year**	**Rare**
Blue surgeon	KP	KP	TL					KP		KP		TL	PO		
Koran	KP		TL			KP						TL		PO	
Coris	TL	TL						KP					PO		
Dragon wrasse	TL	TL						KP					PO		
Volitans							KP	KP				TL		PO	
Striped surgeon		TL	TL		TL							TL	KP	PO	
Vaga				TL	TL	KP	KP	KP						PO	
Convict				TL	TL								KP	PO	
Naso	KP, TL	KP, TL				KP	KP	KP						PO	
Diesel	TL	TL	KP,TL									TL		PO	
Auriga	KP	KP			KP	KP						TL		PO	
Trifasciatus														KP,PO,TL	
Citro	KP			KP,TL	TL									PO	
Meyeri			KP	KP										PO	TL
Zanclus	KP		TL	TL	KP,TL	KP								PO	

Table 6.8 (cont.)

Fish species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Season	All year	Rare
Wildeeson	TL	TL						KP						PO	
Aculeatus	KP, TL	TL						KP					PO		
Tennetti		KP	KP,TL	TL										PO	
Green bird	KP	KP		TL	TL			KP						PO	
Collare	TL	KP,TL	KP												PO,TL
Heniochus	KP,TL	TL					KP	KP							PO,TL
B Naso			TL	TL	KP			KP						PO	
Weliferam	TL	TL			KP	KP	KP			PO	PO				
Rectangulus	KP, TL	TL	TL			KP	KP							PO	
Kleinii	TL	TL						KP	KP					PO	
Yellow surgeon	KP		KP	KP,TL	TL								PO		
Blue damsel	KP	KP	KP											PO, TL	
Rock damsel				TL	TL									KP, PO	
White goby	KP	KP	KP	TL				KP	KP					PO	
Polhendras	TL	TL												KP, PO	
Hardriggy	TL	TL												KP, PO	
Macitatus							KP	KP				TL		PO	
Diodon	TL							KP				TL		PO	
Soapy grouper	TL											TL		KP, PO	
Blue argus	KP, TL		KP									TL		PO	

During the focus groups, divers led the discussion in Sinhalese about some of the changes they had witnessed over the 15 years. For example, *Ostracion cubicus,* (yellow boxfish) abundance had declined in nearshore reef waters, which divers believed is due to their value in the ornamental trade. A single *Ostracion cubicus* today is worth 1500 LKR, whereas the average price divers receive per fish is approximately 50 LKR and so this species is targeted for capture. Other fish which had disappeared over the past fifteen years are several species of Pomacanthidae (angelfish); these were present in these waters five years ago, but were now not seen. Two older divers told me of the higher abundance of fish in the Maldives and the conditions and the techniques used there that support the health of the reef:

> *"I have been to Maldives for 5 months fishing, all catching is done with hand nets, we cannot use hand nets here. There are lots of coral and fish in the Maldives, so it's easy to use hand nets. In the Maldives we can catch many fish that we can't find in Sri Lanka."*
>
> Samantha, 45, who dived in the Maldives for an export company in 2002.

As many older divers have fished outside Sri Lanka in countries such as the Maldives, Saudi Arabia and Malaysia, they are aware of the differences between their coral reefs and the abundance of fish in Sri Lanka compared to these places. Only older, experienced divers knew that compared with the Maldives, Sri Lankan reefs are smaller, less rich and in a worse condition than there. This prevents a shifting baseline mentality (Pauly, 1995) among older divers, who know that the degraded reefs they currently fish are not in the same state of health as when they were young or those in other countries.

6.4.3 Time-line of reef and fishing conditions

To determine the extent of the changes that have occurred on the reefs at each of the three fished sites, the divers generated time-lines over a fifteen year period (Table 6.9). This time period was taken as a comparative benchmark spanning before, during and after the large environmental impacts of the El Niño event in 1998 and the tsunami in 2004, and was a timespan over which current divers could still recall the conditions. The changes that divers reported included: fish abundance, the reef condition, illegal fishing practices, the number of divers, their village structure and people's livelihoods.

Negative changes identified by divers across all sites over the time period were a reduction in reef fish abundance and size, a reduction in their catch and coral reef health. Polhena and Thalaramba divers on average estimated reef fish abundance to be at 10 and 25% of levels 15 years ago respectively. Reef fish diversity was noticeably lower than 15 years ago at two sites (Polhena and Thalaramba) but the same as 15 years ago at Kapparathota (Table 6.9). An increase in diver numbers had also been observed at all sites with a concomitant increase in village populations. All noted a decrease in incomes from 1000 LKR to 400 LKR per fishing trip while costs have increased. Options for alternative livelihoods, such as tourism were difficult until 2009/10, because of the civil war (Table 6.9), but they further noted that the location of most fishing villages does not make tourism a viable option. Positive outcomes noted over the 15 year period were that dynamiting and coral mining appeared to be absent or much reduced and the education of divers was greater due to increased school attendance.

6.4.4 LEK contrast between young and old divers

Finding divers older than 50 was a challenge, this age of diver had either died or not been involved in diving. However, interviews and discussions with many divers aged between 40 and 55 confirmed my understanding that the elder members of the diving community held significant LEK. Many older divers expressed a concern for the future of their livelihoods and that of their families who rely on the reefs. They related how they perceived the reefs had changed from abundant rich resources to producing barely anything during their lifetimes. They saw a lack of fish and thus livelihoods, hoped it could be averted, but saw more negative than positive changes in the near future, as more divers enter the fishery.

> *“ 'Habli surgeon' – we could catch 10-20 altogether before, but now we hardly see one. It was not that valuable a fish but was only caught as a colour fish not food fish. Also 'Melonnatus' has gone, only see one or two around, before we would see 40 at a time. 'Lunula' is quite rare now, 'Zebrasoma', 'Santo', 'Pericula', 'Weliferam' and 'Meyeri' - earlier we could see schools of them but now only a few.”*
> Chamira – 51 year old snorkelling diver.

By comparison, during interviews younger divers gave mixed responses, some saying that the reef health and abundance of fish were good, whereas others complained of how difficult it is to find any fish and the barrenness of some fishing grounds. Yet both young and old feel there are no real alternatives to this occupation, as part of the multi-occupational livelihoods of their households, and feel helpless to change things (Table 6.9). Despite holding unique local knowledge which enables them to depend on these natural resources for a living, the SES is moving towards chaos and crisis (Walker et al., 2004), which means the entangled web of external influences and resultant lock-ins that the social and political pressures exert on the system prevents, even those who wish to change their livelihoods, from doing so.

The eldest divers' views are important; their generation was the first to witness large-scale reductions in fish numbers and coral cover. Many divers aged around 40 and older described how, when they were boys, as the tide went out it left pools full of "*colour fish*" that they scooped up with their hands. Notes of such comments and the current rarity of valuable fish appear frequently in my fieldnotes. For example:

> *'He said there are so few fish here now... not like before . He said, "It was very easy to catch many fish before'* - Ganesh, 48, ex-snorkel and SCUBA diver.
>
> *"All we can catch if we go skin diving are striped surgeon, convict surgeon, black surgeon and vagabond butterfly fish and the buyers and companies don't want that. Each guy catches three of each, then the buyer gets 15 of each and he can't sell them! James, what to do? "* - Tharindu, 38, snorkeller
>
> *" There are few fish in the shallows for the skin divers to find due to the removal of the coral before by the coral miners and dynamiters. So instead they try other things like going for conch shells at Kirinda, lobsters or spearfishing."* - Mahesh, 50, ex-diver, now fish buyer
>
> *"Before the tsunami we could catch 100-120 anthias each day but now it is between 5-20 for one day, if we are lucky. There is less breeding of the fish in shallow and deep areas".* - Chintiga, 37, tank diver and fish buyer

Many younger divers do not report the same intensive changes to the reefs, so if they are to act in more responsible ways it is important they have more regular opportunities to meet together with the elder divers to listen and discuss the arguments made about the previous state of the reefs and better ways to manage the situation. However, the majority of the older divers say that the young divers do not fish responsibly because they are only interested in making money. They maintain the young lack an appreciation and true passion for the reef and its marine life which they believe they felt in their youth and still have.

6.4.5 Knowledge generation among ornamental divers

The claim that LEK can sometimes develop over relatively short periods is substantiated by these Sri Lankan divers, the modern ornamental fish trade only spanning three decades (see Chapter 4.4.2). Despite the brief time scale, however, evidence can be found of particular forms of LEK among ornamental fish harvesters that is not evident from my less structured, but frequent discussions, with food fishers.

The first is the use of fish names. Local Sinhala names for varieties of food fish in these waters have always existed (MFAR, 2012; Anderson, 1996), but a new level of precision has emerged among ornamental divers who need to identify individual species, particularly those more valuable for the ornamental trade. The reason for this and its incorporation into the LEK system derives from practices within the supply chain; orders from abroad are passed along the chain to the divers who adopt the English and/or Latin names for the fish while adding their own touch. Over time I understood that these divers' LEK has increased in three different ways, and all in relation to the need to survive as ornamental divers. First, through developing their own nomenclature for ornamental fish, second through their naming of targeted fish to the species level, and third, through the acquisition of intimate knowledge concerning the life history and characteristics of each specific species.

Two examples illustrate these three points. The first is *Labroides dimidiatus* (the blue-streak cleaner wrasse), one of the most commonly caught and exported ornamental fish species. Sri Lankan fishers (non-divers) call this fish "g*ireva*", a generic Sinhalese name for all wrasses and parrotfish but divers call this fish "*diesel*". They have formulated their own name for this particular species, as well as many other wrasse and parrotfish species which are caught for the trade. Many older divers also know when this species breeds (Table 6.8) and showed me on fishing trips in what habitat they are likely to find "*diesel*", indicating detailed knowledge of fish biology and habitat interactions.

The second example shows a further difference between the fish nomenclature of divers and food fishers. Juveniles of *Plectorhincus orientalis* (oriental sweetlips) are targeted in the ornamental fishery and adults of the same species are targeted by food fishers. Food fishers know this fish as "*boruluwa*" (a generic Sinhalese name for all sweetlips), whereas divers call the juveniles of this species "*gaterin*", after the earlier scientific name for this species of *Gaterin orientalis.* This highlights the level of specificity due to the highly selective nature of the ornamental fishery in comparison to many food reef fish species. Appendix F provides names used by local Sri Lankan divers for the most commonly snorkel-caught fish, with common English and scientific Latin names used within the ornamental trade. It highlights the extent of local naming and how far these names depart from the naming practices of western science.

Table 6.9. Timeline comparison of conditions and factors between 15 years ago and today, affecting ornamental divers in Kapparathota, Polhena and Thalaramba, with brief reasons given for each, derived from focus groups and discussions with divers.

Site	**KP**			**PO**			**TL**		
Factor	**15 years ago**	**Now**	**Reasons**	**15 years ago**	**Now**	**Reasons**	**15 years ago**	**Now**	**Reasons**
Fish diversity	Same	Same	-	High	Less	Dead corals Tsunami damage El Niño damage	High	Less	Dead corals Commercial fishing
Fish abundance	High	Low	Too many fishers	High	Low	10% of previous levels Less breeding	High	Low	25% of previous levels Pollution & dead corals
Fish sizes	Larger	Smaller	Companies buy small fish	Large	Smaller	High levels of food fishing Few big fish to catch	Large	Smaller	Less coral and fish breeding Too many fishers
Daily catch	More	Less	Too many divers	More	Less	Above reasons	More	Less	Above reasons
No. of divers	Less	More	Few job options	40 men	150 men	Few alternative jobs	Approx. 15	Approx. 50	Few alternative jobs
Coral reef health	Good	Bad	Tsunami damage Pollution	Good	Bad	El Niño events Tsunami damage	Good	Bad	El Niño events Tsunami damage
Dynamite fishing	High	None	Police enforcement	High	Less	90% less Police enforcement	High	None	Police enforcement Fisher awareness
Coral mining	High	None	Police enforcement Lack of demand	High	None	Fisher awareness of negative effects	High	None	Police enforcement Fisher awareness
Income	Higher	Less	Too many fishers Low fish abundance	Higher	Lower	Low fish abundance Low fish prices	Higher	Lower	Living costs are high Low fish abundance
Education	Less	More	NGOs and schools	Less	More	Self learning from experiences	Less	More	Schools and experience
Village Population	Less	More	Natural increase Little immigration	130-150 families	200 families	Natural increase No migration	Less	High	50% natural increase More family members
Tourism	Higher	Less	Civil war	High	Less	Beach & reef damaged	None	None	No hotels here

6.4.6 Divers' mental maps of the reefs

Often when I accompanied young divers on snorkelling trips, they would meet together on the shore and find a vantage point overlooking the bay or the reef to decide, through discussion, or sometimes argument, about weather and sea conditions, the suitability of diving that day which area might be best to dive and which species to target. An assessment of the weather and sea conditions they considered to be necessary for successful diving. I was often surprised by their ability to judge whether the "*water is clear*" just by glancing at the sea from the shore. One fisher explained to me how he studies breaking waves to discern the clarity of the sea water on a particular day at a specific location. He notes how the wave curls over and breaks, the amount of spray from the wind, as well as the subtle changes in the colours of the water.

As they dive over the relatively small nearshore areas around their village, these divers develop detailed mental maps of the underwater environment from which they determine which species are found in which habitat across different areas of the reef. For example, a diver I was shadowing one day regularly informed me of the different species expected over the different substrate types we were snorkelling across, such as seagrass, rubble or dead coral. He revealed detailed knowledge of fish and habitat interactions as well as of the reef's layout and its variations; details of which were not only dependent on him being there, as he could visualise them as clearly when back on shore. While these communities of divers may not be able to produce the high-resolution seabed maps created by marine resource agencies they have developed a tangible, qualitative understanding and visualisation of the marine ecosystem in their village, similar to that found among mountain villagers in the Himalayas (Duffield et al., 1998). The maps created demonstrate the divers' ability to mentally conceptualise the detailed topography and ecology of their reefs (Figures 6.10-6.12).

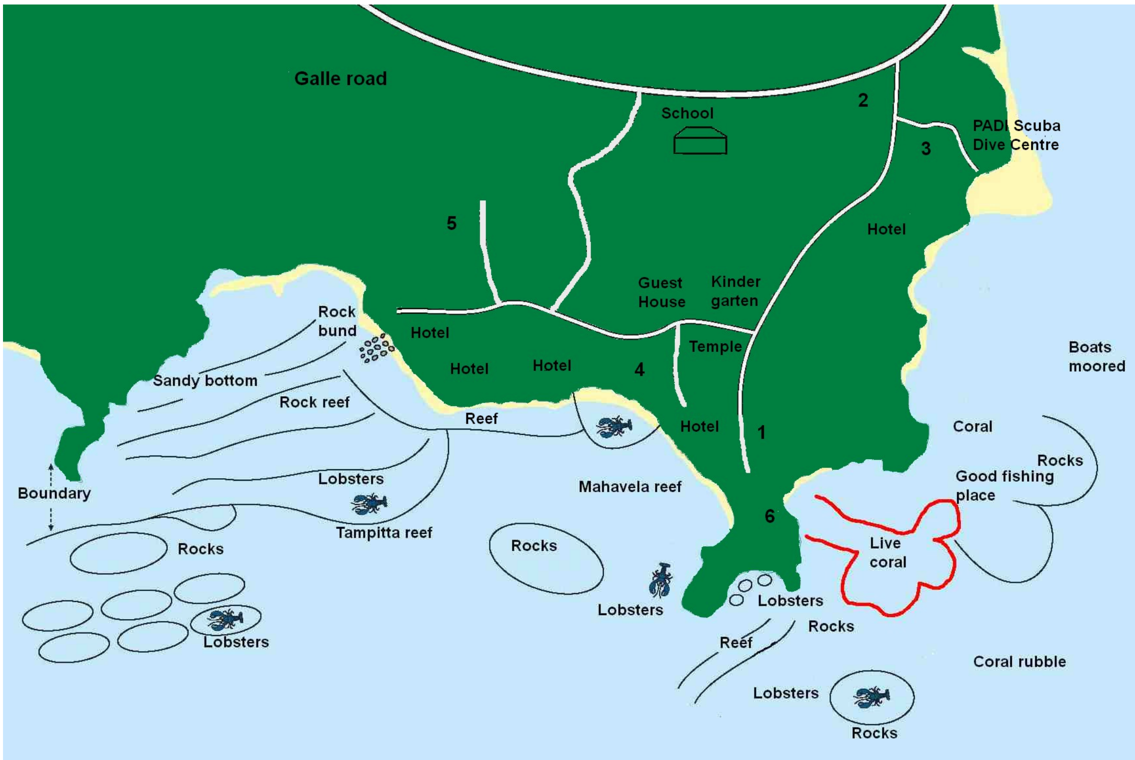

Figure 6.10. Map of Kapparathota village and snorkellers' fishing areas. Numbers 1-6 denote fish buyer sites in order of wealth. Circles and curved dark lines denote rocks.

The Kapparathota map was collectively drawn with one diver drawing while the other 12 divers contributed information and advice. They drew the coastal outline and this was altered as time went by and the participants became more confident in the task. They marked areas with good coral cover (drawn like flowers or labelled as such) as well as locations good for lobster (lobster symbols) which a diver known by others in the village as the "*master lobster catcher*" marked and only a few of the most experienced divers could question. Some zones were drawn to delineate areas of coral and rock reef, rubble and sand areas (Figure 6.10). The only time I needed to intervene, during the production of the map, was to clarify a question about its scale. The divers here were comfortable to mark and rank the six buyer locations by wealth (1 being the wealthiest buyer and 6 the poorest).

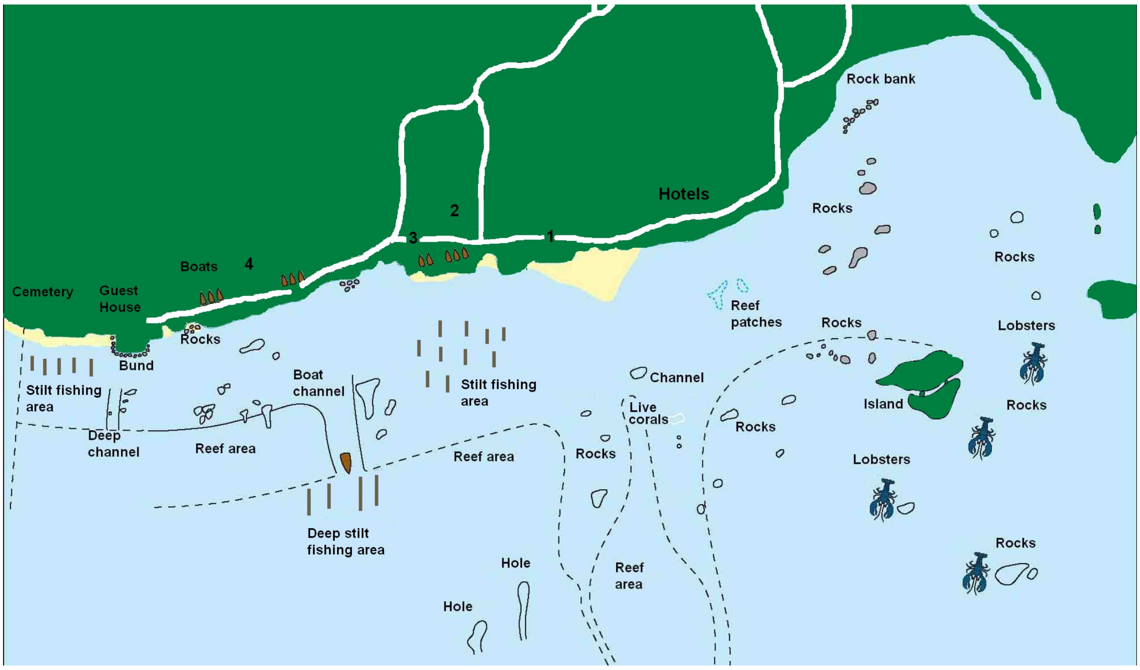

Figure 6.11. Map of Polhena village and snorkellers' fishing areas. Numbers 1-4 denote fish buyer sites. Stilt fishing areas are also marked.

In Polhena, the divers took great care and precision in completing their village map; there was a great deal of discussion and argument for most points and lines drawn on the map, until all present were satisfied with the outcome (Figure 6.11). The eldest divers contributed most to this task, with the three youngest divers remaining less involved or only contributing on group consensus or with small nuggets of information. During this exercise the divers also informed me that at times they snorkel for ornamental fish further offshore, at depths up to 5 m and approximately 0.5 km offshore. This is roughly the boundary between "shallow" and "deep" areas and between the SCUBA and snorkelling diving areas. This is also the boundary of their village waters, within which they assert control in terms of fishing access rights. While all agreed that they fish the whole area shown as ornamental fish can occur everywhere in that area, some maintained that places known as "*gal-mal places*" (coral flower or coral areas), provided better catches than others. In contrast, they said lobster prefer specific areas and the places they aggregate were only marked after much discussion (Figure 6.11). Divers expressed the belief that the areas further offshore are healthier in terms of coral cover, than those closer to shore where sand, rocks and rubble dominate the substrate.

Divers seemed unwilling to divulge their own wealth, or data of their own and others' comparative wealth during this group exercise apparently for fear that others may overhear them or spread word of what they had said around the village. They were even uncomfortable in telling me which ornamental fish buyers they considered to be more wealthy than others, even though none were present at the meeting. At the end of the session I asked all the divers what they considered to be essential for their jobs to improve. Their main hopes were for: better prices for the fish they caught; a little harbour area for their boats; a deeper and wider boat channel to prevent boat and coral damage, especially during rough seas; and heightened efforts to stop visitors at Polhena beach from breaking corals.

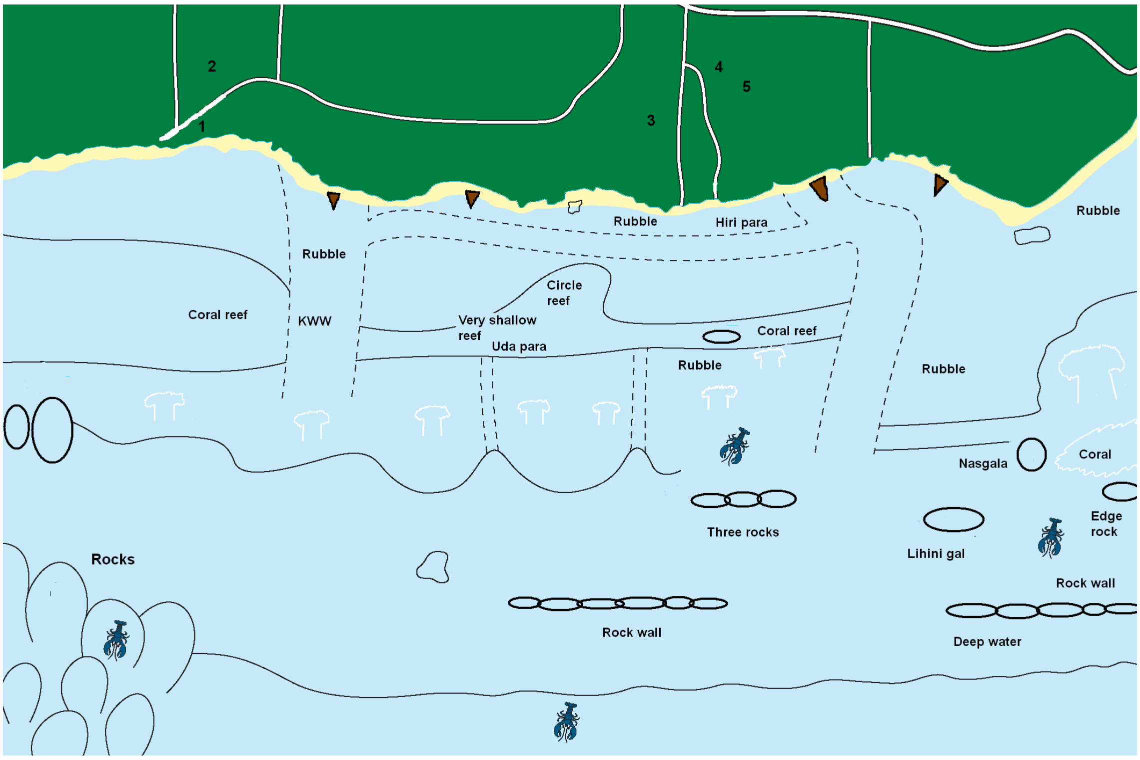

Figure 6.12. Map of Thalaramba village and snorkellers' fishing areas. Numbers 1-5 denote fish buyer sites. All the circular shapes are rocks. Brown triangular boats mark boat entry points and boat roads ("paras") are marked with dotted lines. White shapes are live coral areas.

Ten to 15 divers helped construct the Thalaramba fishing map (Figure 6.12). There are strong currents and much sand further east so they do not fish there and they all agreed that the rock on the eastern side of the map has appeared quite recently, but were unsure why or how it could have occurred. The large rocks to the west mark the boundary of the village waters. The divers described how tank diving happens on the far side of the outer rocks and the nearshore reef is patchy and not continuous so the snorkellers stay close to the shore over the coral areas. The best coral cover is where "coral" or white "*gal mal*" symbols are marked. Sand occurs in the areas drawn between the spurs and there are granite boulder patches between the shallow and deep reef areas. Lobster catching occurs all along the deep reef areas by the rocks. The comparative wealth of buyers could not be marked as some buyers were present and this was considered disrespectful to them.

6.5 Discussion

This chapter aims to determine the current state of fished and non-fished reef sites combining quantitative and qualitative methods and western science and LEK; to demonstrate the importance of both knowledge bases; and demonstrate how the results from these respective methods compare and thus provide a more complete picture of current reef resource exploitation and management. The last focus was to determine the potential for these divers to become citizen scientists who could participate and help direct future scientific research on these reefs and their future management. By blending different approaches and working alongside the divers at these reef sites, I was able to access different forms of knowledge and grasp a firmer understanding in a local as well as global context than would have been possible from either an exclusively quantitative or purely qualitative approach.

Purely scientific studies in tropical marine resource management are important and can highlight current impacts or alert reef users to evolving trends, however, an understanding of local practice, knowledge and world-views is also necessary to share the often western-generated, scientific knowledge with the end users: the fishers (Sillitoe, 1998). In Kenya even though fishing practice and LK beliefs did not map scientific results well, dialogue between all actors allowed them to overcome their differences (McClanahan et al., 1997). Additionally, scientists and resource users should respect and value the knowledge and practices of one another (Campbell, 2000).

It is important to identify potential similarities in local knowledge and scientific knowledge (Garcia-Quijano, 2007), however there is a division amongst LEK researchers as to the benefit of rigorously comparing LEK against western scientific methods; some believe it is necessary to help ecosystem management (Gilchrist & Mallory, 2007) whereas others believe if the usual power holders remain then such comparisons may only marginalise local communities and their knowledge further

(Brook & McLachlan, 2005). However, Agrawal (1995) critiques the simplistic division of LEK and scientific knowledge and stresses there are similarities and differences within the respective knowledge forms and between them and that a more important angle to ensure LEK is conserved and utilised effectively is for local people to control their own resources. In agreement with this viewpoint, the stated aim of this research and chapter is to look for similarities and differences and uncover how LEK and scientific knowledge might complement each other in order to determine strategies for future improved management of coral reefs and consequently the livelihoods of the local people. For this reason, a brief general discussion of the UVC surveys is included but not an exhaustive focus on the results of these UVC surveys alone.

The UVC analysis provides both expected and less expected results. Live coral areas showed higher species richness than other substrates but did not differ in abundance when compared to dead coral, and dead coral areas were rarely significantly different from live coral areas in any outcome. This may indicate the reduced diversity of live corals and their associated fish species diversity due to the long-term stressors on these nearshore reefs. The negligible differences between live and dead coral areas in their fish assemblage measures confirms the finding that intact structural coral, or rock with sufficient complexity for niches, is a more crucial factor in the abundance of many fish species than live coral itself (Stockwell et al., 2009).

It was hypothesised that the protected area, Hikkaduwa, would have higher fish species richness and abundance than any of the three fished sites due to the absence of fishing pressures. This hypothesis holds true for two of the fished sites, Polhena and Thalaramba but not the third, Kapparathota. This result is difficult to explain as temperature and depth were similar at all sites, and protected and fished sites had similar levels of live coral cover and dead coral cover. However, levels of other substrate components did vary between sites and may help explain this result. Macroalgae cover was significantly greater in Kapparathota than other sites, which may attract a greater abundance of herbivores than the other sites, which had low levels of corallivores and herbivores. Before the El Niño bleaching and the tsunami, Hikkaduwa and Kapparathota had higher levels of live coral cover (Figure 6.13) with Kapparathota known to have some of the greatest live coral cover and coral diversity in the southern area. Perhaps this has resulted in higher than expected fish populations compared with other fished sites with less healthy corals.

Although coral diversity was marginally higher in Thalaramba than all the other sites, the number of coral genera is a crude measure of coral diversity and a more focused study on coral diversity at these sites is needed to explain these differences.

Reef fish diversity, abundance and biomass were most correlated with structural complexity, live coral cover and the number of coral genera present, which corroborates other reef ecology studies (Luckhurst & Luckhurst, 1978; Öhman & Rajasuriya, 1998). Omnivores and planktivores showed the least correlations with habitat variables indicating their ability to find food among various substrates, whereas corallivores, herbivores and invertivores were predominantly influenced by sites that were more diverse in substrate components, complexity and with diverse live coral, which corresponds with prior research on corallivores and their habitat preferences in Sri Lanka (Öhman et al., 1998). Few individual Scaridae, Pomacanthidae or piscivores were observed and this may explain why few correlations were found between these groups and habitat variables but may also be due to their more transient movement patterns over wide areas (Friedlander & Parrish, 1998).

Comparison of my results to previous coral cover assessments (Figure 6.13) indicates that in all reef areas, except Polhena, live coral cover has declined drastically over the last 14 years. The biggest reduction in coral cover occurred after the 1998 El Niño bleaching event, although coral recovered in some areas by 2004. The tsunami then reduced coral cover again by 2005 (Figure 6.13). Polhena had not been surveyed in the ten years before my survey and Thalaramba's reefs had never been surveyed.

Figure 6.13. Live coral cover changes since 1997 (pre-bleaching), after 2004 (tsunami) and 2010 (this study) at each site. Site codes: HK= Hikkaduwa, KP=Kapparathota, PO= Polhena, TL=Thalaramba. Years marked are years when reef surveys were carried out. Sources: Rajasuriya, et al. (2000; 2002; 2005; 2008) & this study.

Fish biomass, at the protected site far outweighed biomass at the fished sites; which can be attributed to the presence of families including larger fish such as Scaridae, Carangidae and Lutjanidae, not seen at any of the fished sites. The mean biomass of 626.5 g/ m^2 for Hikkaduwa is a relatively high estimate when compared with other reported biomass values from coral reefs worldwide.

The highest biomass value reported in a study conducted in the Caribbean across both deep and shallow and protected and fished sites was 593 g/ m^2 (Newman et al., 2006). My value is within the possibility of protected areas and moreover in the Caribbean study belt transects were employed which are known to underestimate densities, and in turn biomass, compared to point counts (Colvocoresses & Acosta, 2007).

The use of non-instantaneous point counts in my study may have also resulted in some species being counted twice, however, both observers were aware of this issue and were conscientious in avoiding this error. The problems and caveats in estimating fish assemblage measures from different survey methods have been examined by several studies; the issues include census area and timing, visibility, fish movement and behaviour, taxonomic level of recorded data, observer variability and the number of species and sizes recorded (Watson & Quinn, 1997; Samoilys & Carlos, 2000; Ward-Paige et al., 2010; Colvocoresses & Acosta, 2007). For example, fish below a size threshold are not counted during some surveys, whereas in this study all fish seen were counted and lengths estimated. This was an intensive small scale study, counting fish over a relatively small area, which means fish counted in one point count could have been recounted elsewhere on the reef later on that, or another, day. Furthermore, it is known that point counts do not account well for highly clumped and mobile species such as Scaridae (Bellwood & Alcala, 1988), yet sightings of such mobile species were rare, except in the protected area and so it may be only due to the influence of these sightings that the biomass appears high in the protected area. However, as these reef sites are degraded and fish abundance is generally low, it would appear that the biomass estimates are high. The low abundance on the reefs allowed for all individual fish to be counted and very rarely were estimates of group numbers made because it was possible to see all individuals within the count area during the timed count, especially the smaller substrate associated species, which are potentially overlooked on timed swims and belt transects. It is not possible to identify one single reason why the estimates appear high for the degraded and in some cases fished reefs. It is possible that a combination of small errors and caveats of the methodology employed were accumulative and resulted in an inflation of the biomass figures.

However, conclusions concerning these study sites and their relative biomass values are still valid and of importance, even if comparison to other reef sites can only be made with caution. Furthermore, the primary aim of this study, which was to compare and contrast the levels of reef fish populations among these sites within Sri Lanka and compare these findings with divers' LEK, should be stressed.

Therefore the expected conclusion that the protected area, Hikkaduwa, is a more healthy fish habitat than the fished sites can be neither completely accepted nor refuted. Fish biomass was far greater in the reserve than outside, however there were departures from this in the species richness and abundance data. These may be attributed to other factors that were not measured in this study. However, all sites appeared to have relatively similar habitat characteristics, and so differences exhibited are likely attributed to fishing and its associated effects (Polunin & Roberts, 1993; McClanahan & Kaunda-Arara, 1996; Russ & Alcala, 1998a). However, the study sites have all been degraded by multiple external influences, not just by fishing (see Chapter 2.7 and 4.4.5). Since the 2004 tsunami, there have been smaller coral bleaching events, which have hindered the recovery of corals and their associated habitats at these sites (P.B. Terney, pers.comm.). The habitat data show there are differences among other substrate types such as rubble and sand, and with the patchy nature of these reefs, the differences in such lesser quality habitat is also of importance and may influence the reef fish abundance estimates. Divers' perception that fish abundance and hence biomass would be higher in Hikkaduwa was confirmed in comparison to two of the three fished sites. Furthermore, local user groups in Hikkaduwa sensed that fish abundance was greater than in fished areas but that the reef was still degraded. This was found in negligible differences in fish abundance and habitat between Kapparathota and Hikkaduwa.

The high cover of macroalgae recorded in the survey, particularly at Kapparathota is striking, and corroborates what many divers and locals told me about the spread of macro-algae such as *Halimeda* spp. there, which they said had occurred since the tsunami when large amounts of sand were deposited into the bay and over the corals. The physical destruction and covering of coral may have allowed more space for macroalgae to dominate (Williams et al., 2001). As herbivores and sea urchins are highly targeted in food and ornamental fisheries, low herbivore abundance, a rarity of herbivores capable of preventing macroalgae domination and low urchin abundance after the tsunami may have also promoted this shift in reef state. In Hikkaduwa there was algal turf cover which is linked to increased sediment inputs retarding the succession to macro-algae, particularly in protected areas where the effects of fishing are removed (McClanahan, 1997). At Hikkaduwa sand coverage was the highest of all sites and is attributable to the tsunami effects. Being a protected area, the higher herbivore and urchin abundance may have prevented macroalgae domination but could not prevent an increase in algal turf (McClanahan, 1995). Urchin abundance was highest in Thalaramba in the UVC survey and was commented on by divers in the village and these populations may be the reason for the lowest recording of macroalgae in Thalaramba, however, high urchin abundance could also be eroding the coral reef, as the predators of urchins are rare due to a well developed fishery in the area (McClanahan et al., 2002). Generally, shallow, degraded reef sites shift from higher levels of algal turf to higher levels of macroalgae (McClanahan & Obura, 1997), which is the case for Kapparathota, Polhena and Thalaramba. However, it is difficult to predict such direct and indirect effects of external inputs from large-scale environmental disturbances, from food webs alone (Polunin & Pinnegar, 2002), especially in unprotected areas where anthropogenic actions add a further level of interactions to factors affecting reef coral and fish diversity, variations in different habitat coverage and structural complexity (McClanahan et al., 2002).

The abundance of herbivores and planktivores in the surveys relates to the high productivity of algae and algal dominance in many areas of the reefs. The more specialist feeders such as corallivores were low in abundance as were piscivores, either fished out by both food and ornamental fisheries and/or occuring in deeper waters not covered in these surveys. However, the diversity of fish families was low with a few families comprising the majority of abundance and biomass recorded at each site. The absence of predator families at the fished sites compared to the protected site indicates the low levels of such high trophic level families and piscivores in general and is probably due to their removal by fishers, as fishing is a stronger factor in their abundance than prey abundance (McClanahan et al., 2007; Graham et al., 2003; Mumby et al., 2006). This also indicates that the protected area is, despite the concerns of local people as to the efficacy of the park and the health of the coral (Chapter 4.3), performing its function as a fish refuge and could be a source of spillover into neighbouring fished areas (McClanahan & Mangi, 2000).

A GLMM was deemed appropriate as there are now more complex modelling techniques to analyse such ecological data which is often non-normal and highly variable. This is preferable than forcing data to meet conventional test assumptions by transforming the data or relying on the robustness of ANOVA, even with data that violates certain assumptions or resorting to non-parametric tests (Bolker et al., 2009).
The GLMM results differed from those of the ANOVA, with one fished site having a higher fish abundance than the protected area and a different fished site having no significant difference in biomass when compared to the protected site. Note that ANOVA assumes the data are independent. This may provide a more objective model, and these results may show more clearly that the protected area is not as abundant in

fish or have such high biomass as originally thought. The apparent differences may be due to certain species being over-represented in certain counts. Despite this, the other results all correspond with the ANOVA results and show the protected area to have greater abundance and biomass than two out of the three compared fished sites. It would prove interesting to compare more sites to this and more protected areas in Sri Lanka to determine if this pattern remains.

These types of surveys and analyses are important in pinpointing differences among sites or, over time, in coral reef systems and with sufficient monitoring can provide living experiments in terms of the efficacy of management and conservation policies (Russ & Alcala, 1998b; McClanahan & Arthur, 2001; Graham et al., 2007, 2011b). However, as the lack of surveys in Thalaramba shows, in many locations where they are needed regular UVC surveys and subsequent results dissemination does not occur.

Instead of working with knowledgeable local people and transferring control and decision making to them, monitoring and management methods continue to overlook the potential of citizen scientists in these areas. LEK is often undervalued because it is mainly tacit knowledge and therefore not always easily accessed by outsiders. Although all fishers have LEK, other aspects are restricted by fishery type and some is even more tacit and kept within certain close-knit groups within larger fishery groups, such as the case with the ornamental divers I was working with.

Ornamental divers in Sri Lanka possess a valuable form of LEK, unique from boat and shore fishers, as they are observers not only of fish catches and weather changes but also of the reef situation underwater. As they dive almost every day throughout the season, and cover their small local reefs regularly, they witness changes or see unusual occurrences first. This ability to see both gradual changes and identify rare events through diachronic observations makes them even more valuable as citizen scientists to those researchers wishing to further understand these dynamic and fluctuating systems (Haggan et al., 2007). Many reef surveys undertaken by natural scientists are completed quickly and then observation stops so the data represent snapshots which are deficient in comparison with the long-term observations of divers.

Ornamental divers at all my field sites acknowledged that the reefs have been degraded and the fish abundance had decreased but in addition many could give percentage reductions between what they see in the water and what they can catch over time (Table 6.9). In fact, divers were often incredulous that I was conducting surveys to determine the abundance of fish and health of corals on their reefs, as they felt that they could just tell me because they knew the situation so well and expressed the wish that I spent the time doing something positive to improve conditions. This means they are comparing each day the habitat quality and the corresponding abundance of fish and species diversity associated with those substrate types. Worryingly, many older divers mentioned the potential extinction of some local species valued in the ornamental trade, a phenomenon that has occurred in other tropical marine areas (Courchamp et al., 2006; Graham et al., 2011a). Few, if any of these cited species, were seen during the surveys or when shadowing divers on their fishing trips. Divers complained of the overgrowth of algae, particularly in Kapparathota and how sand and rubble areas had increased since the tsunami, particularly in Polhena; all of which corroborates with studies published since the tsunami (Tamelander & Rajasuriya, 2008; Kumara, 2008) and with my observations and survey results (Figure 6.2). Similarly the percentage levels of current fish abundance compared to pre-1998 levels given by divers in the time-line exercise (Table 6.9), ranged between 10 and 25%, which is similar to recent government survey findings that show targeted ornamental fish species abundance at 5-10% of pre-1998 levels (NARA, unpublished; see Table 8.1). All other trends in the divers' time-lines agree with government and external scientific studies: the increasing fishers numbers, the recent decrease in dynamiting and coral mining and the degraded state of the coral reefs. This level of agreement between divers perceptions of reef health and factors influencing it with western science provides evidence that ornamental divers are well placed to act as citizen scientists who can monitor and provide valuable data regularly to local and government management institutions.

If we are to frame these socio-ecological systems as complex systems, the utilisation of different sources of data and knowledge is imperative to construct more adaptive approaches to deal with the complexity (Folke et al., 2002). Western science may be trying to adopt a holistic approach but several local and indigenous systems already show a holistic understanding of ecosystem dynamics and appreciate the complexity of these systems, for example, Balinese farmers conduct, via a system of Hindu water temples, co-operative agriculture without centralised control and overcome water scarcity and high prevalences of disease and pests (Lansing, 1987) and Sahelian herders monitor pasture status to decide on rotation of grazing areas for their herds as well as allow for buffer areas (Niamir-Fuller, 1998). However, such LEK may often provide different reasons to other knowledge forms as to the causation of certain observations, which can make resolution difficult. Identifying LEK in adaptive and/or coping communities can lead to insights into how this knowledge is learnt and how future decisions are made. In a tropical fisheries context, fishers' LEK linked with scientific knowledge can develop inferences and actions based on the two forms of data so that resolutions can emerge from divergent cosmologies (Grant & Berkes, 2007). Fishers' LEK is seen as a fuzzy logic expert system: fuzzy logic deals with reasoning that is approximate rather than exact and expert systems are "...computer programs ... used to infer solutions and provide assistance in solving complex problems..." (Mackinson, 2001: 534). Utilising LEK fuzzy logic with scientific knowledge can provide simple prescriptions for adaptive management (Berkes & Berkes, 2009).

Before such knowledge can be learnt from and complemented, to provide more promising management approaches, it must be preserved. The apparent gradual loss of local knowledge over time, which was expressed by older divers in southern Sri Lanka, is of major significance. Firstly, without sustaining the context of how productive these systems once were among younger divers, particularly if efforts are to be made to reverse the current trends, then the shifting baseline syndrome (Pauly, 1995) results, in which each younger generation resets what is "normal" and alters their behaviour based on this reconstructed view, rather than a more historical view of the resource capital. Secondly, as LEK is lost over generations, resilience to change decreases as fewer strategies or mechanisms are known in times of disturbance. This socio-ecological memory is important if changes are to occur among institutions after crises and for adaptability or transformability of the system (Walker et al., 2004).

The maps drawn and presented in this chapter show that divers know with relative precision the underwater location of certain substrates, various permanent features and orientation landmarks they use whilst offshore in order to navigate and find good fishing areas. They possess knowledge of good fishing not just generally but for specific species, especially lobsters. In most sites with SCUBA divers this intimate knowledge of the sea floor and habitats would extend to the deeper offshore areas as well. In countries like Sri Lanka, there are no detailed maps of the current state of the seabed and this is a clear area where expert science could integrate with local knowledge to generate up to date, accurate representations of the marine environment.

Although there is concordance among these types of knowledge, this study, does not aim to find a correlation between every result and outcome of the two forms of data, as it never proposed to substitute one knowledge form with the other. Similarly, the study does not seek to convert local knowledge into a form of scientific knowledge, with which local divers can monitor and manage their resources in a way western scientists would deem appropriate, as is found in some of the literature (Steinmetz et al., 2006; Chalmers & Fabricius, 2007). It would be preferable to base the monitoring on LEK and utilise a synergistic approach combining the two to fill knowledge gaps in each knowledge system and provide insight for further research or improvements to local livelihoods (Berkes et al., 2000). Although both similarities and differences exist between scientific knowledge and LEK, it is the differences that are the most interesting, because where one method or knowledge base has a "weakness", the other knowledge base often provides a strength (Table 6.10).

Table 6.10. Complementarity of scientific knowledge and LEK for population monitoring (adapted from Moller et al., 2004).

Local Ecological Knowledge	**Scientific Knowledge**
Diachronic study	Synchronic studies
Focuses on extremes	Focuses on averages
Qualitative data	Quantitative data
Allows for better formulation of hypotheses	Can provide better tests of causation
Subjectivity based	Objectivity based

Although these differences are not a total dichotomy; there are many examples of traditional management systems and local knowledge which have characteristics from both LEK and scientific knowledge. Although, the above factors are often reasons given by practitioners on both sides to reject the validity of the alternative knowledge base and possibly, as a result, progress in linking scientific knowledge and LEK and establishing citizen scientists in developing countries has been slow to date. However, by showing where they can complement and examples of where they confound these generalisations, the idea of their synergistic use within an adaptive management framework appears possible (Gunderson, 1999), although in the wider context, researchers are still debating how close is this ideal of "integration" (Bohensky & Maru, 2011).

6.6 Conclusion

The UVC method used is known to underestimate biomass, though point counts less so than line transect methodology (Ackerman et al., 2004). The data under-represent cryptic species, nocturnal species and in areas of spearfishing, point counts are relatively poor at estimating abundance of larger fish families such as Scaridae and Lethrinidae. Additionally in some cases rapid surveys are done by scientists, unfamiliar with the area and the reefs, as was the case in my work. A better approach than to analyse this survey data alone and use the results as a basis for recommendations is to cross compare these results with local users knowledge and views of the study sites. The objectivity of my survey results was in some cases assessed against what fishers said (*e.g.* quotations in Section 6.4.4) and how they perceived the state of their reef (e.g. maps in Section 6.4.6). When comparing their diachronic views with my synchronic view, a basic baseline emerges of how conditions were, not just of the reef but of the village and daily life there which show how social and cultural drivers have changed over time (Table 6.9). Divers recounted not only instances of rare or unusual events, which is often assumed to be a characteristic of LEK (Table 6.10) but also relatively “normal” or mundane observations e.g. that all targeted ornamental fish recorded in Table 6.8 breed also in January, which can be a revelation to a foreigner not trained to think that way or expecting such information and is what Johannes (1978) calls “curious data”, which even local scientists who visit more regularly to do surveys or other research work would miss.

Many divers told me that local government scientists recruit the help of divers, boatmen and other helpers when they come to their areas to conduct reef surveys or other marine work and they proudly mentioned their involvement in this formalised system of research. I realised from this that certain actors within the ornamental trade already understand the importance and potential for collaboration as citizen scientists, which could bring future benefits. The integration of both management and researchers with local divers through co-management appear possible (see Chapter 8). However, this fishery is not restricted to its immediate environs but is strongly orchestrated by the market chain. This chain along which fish and invertebrates move from the reefs to their final purchaser is complex and not only poses many challenges for fish survival but also has a strong impact on the actors' decision making at each level. It is vital to understand this hierarchical system to fully comprehend the patterns of behaviour, outlined in Chapter 5, to determine ways to restore resilience to this fishery.

Chapter 7

The intricacies of the market chain and its influence on the marine ornamental fishery

7.1 Introduction

The marine ornamental fish trade in Sri Lanka is primarily an export trade and as such must be understood as one element in a complex, sophisticated web that is constantly making connections both domestically and internationally. Like any global trade, it is driven by supply and demand, which affect and is affected both internally and externally by natural, economic, political-legal, socio-cultural, technological, and competitive factors. For example, the tsunami and the recent recession significantly disturbed the ever-evolving patterns that constitute this 30 year-old trade. The motivating factor is economic, ranging from small-scale local income generation for the divers to a major profit oriented business for the many middlemen between the collectors and the users. Only by exploring this intricate market chain holistically, tracing its interconnectivity from the seashore to the international market place, can the subtle influences exerted both by and on the different actors all along the chain, be realised. If in the future a sustainable ornamental fish trade might be established, it is first important to determine where in the market chain there is most need for change.

The international trade in marine ornamental fish has gained a negative reputation globally and is deemed unsustainable within the scientific literature (Perera et al., 2002; Bruckner, 2000; Rhyne et al., 2012), in the global media (Garthwaite, 2012) and among certain circles in Sri Lanka, where it is often criticised for exacerbating reef destruction. As has been discussed in Chapter 4, the divers who collect these fish are all too easily blamed. In Sri Lanka, these divers are in effect trapped by the market forces, the structure of the trade and the pressures inherent in their working lives. Their behaviour and action can be even better understood through a greater appreciation of the complex network of the trade.

Meaningful progress for sustainable development may therefore depend on international or globally accepted solutions. However, this chapter moves from the local Sri Lankan context of the previous chapters to a global appraisal of the ornamental trade as an export industry cataloguing the differing actors and viewpoints that comprise it today. It provides an overview of the ornamental fish trade from both local and global studies before exploring how the industry and trade have been and could be managed in the future with a recognition of the key question of how to balance human needs, currently played out within an economic context of capitalist modernity, with ecological needs.

7.1.1 The division between the industry and conservationists

As a developing country, Sri Lanka seeks to expand its economic export sector and the sales of marine ornamental fish fall into this sector. The trade earns much needed foreign currency for a country in the midst of attempting to boost its economy at the end of a 30 year civil war. As ornamental fish are a high-value product, those businesses involved argue that the trade is advantageous in generating high earnings from low volumes, unlike the export and local sale of food fish species. In the Maldives, in the 1980s, 1 kg of food fish was valued at US$ 6, whereas the same weight of marine ornamental fish was worth US$ 500 (Edwards & Shepherd, 1992). However, those who view the trade as unsustainable point out that high fish mortality along the supply chain results in increased fish volumes than those claimed. Opponents of the trade argue further that fish are worth more left on the reef, by attracting higher levels of foreign exchange through tourism, than transplanting the fish to a foreign destination. This is a global debate relevant to many biomes (Briassoulis, 2002), for example hunting of big game species in African countries, relative to their high value to the tourism industry (Hurt & Ravn, 2000; Novelli et al., 2006). Perhaps in the case of ornamental fish, as they are shipped alive, those people who participate in the supply chain may not see themselves in the same light as hunters.

In contrast to media attention on topics such as hunting versus conserving elephants, frequently creating arenas for national and international debate, media attention on the marine ornamental trade is rare and sporadic, a situation which does not pressurise either the industry or source countries to consider, let alone alter their practices. Environmental NGOs and scientists have applied pressure to the ornamental fish industry to bring about changes and regulations have been implemented by some importing nations. Those involved in the marine ornamental trade tend to dislike and deny the accusations that the trade is unsustainable, exploitative or a major threat to coral reefs globally (Tropical Marine Centre, UK, Ornamental Aquatic Trade

Association, pers. comm.). Many industry insiders claim they have self imposed regulations to protect their trade (K. Davenport, pers. comm.). However, those outside of the industry who have tried and are still trying to initiate certification schemes for the global ornamental trade at all levels have found the industry to be hugely resistant, uncooperative and aware of their power to block monitoring or regulatory actions (D. Cooper, pers. comm.).

At the local level there are also deep divisions between industry and conservationists. In Sri Lanka, the Export Development Board (EDB) is involved directly with the development of the ornamental fish export sector but are not part of the arena of fisheries science or coastal conservation. The EDB employees are economists and financially-minded people who wish to expand businesses in Sri Lanka. They have a plan to increase exports by 15% by 2020 (P. Daluwatta, pers. comm.). Both government researchers at NARA, the research arm of the Ministry of Fisheries and Aquatic Resources, and Sri Lankan academics believe there should be a limit to the number of export companies so as to help regulate the trade in Sri Lanka. The EDB disagrees; their view is that limitations would impose an unacceptable level of control over the market and stifle healthy, competitive business. The EDB is responsible for providing operating licences to the export companies and therefore has ultimate power in deciding which new companies can start up and which cannot. Although most registered ornamental-exporting companies, with whom I met, support a cap on the number of companies, the EDB explained they do not intervene on issues that they consider reflect competition among rival companies. Indeed, the EDB told NARA who presented recommendations for such a cap that this was discrimination against export companies.

Currently, the relations between the ornamental industry and environmentalists both in Sri Lanka, and worldwide, appear frayed and tense. Industry representatives feel caged by those restrictions and regulations that have been introduced, while environmentalists feel that changes have been insufficient to improve standards and enhance the sustainability of the trade.

7.1.2 Global trade and the ornamental fish industry

One reason for the lack of attention paid to the difficulties associated with the ornamental fish trade by people living in the importing countries is that the traded fish are caught in remote places. The demands for fish by aquarium hobbyists in predominantly wealthy countries far from coral reefs, sustains and drives the ornamental fish trade, which in turn fuels destructive fishing practices and unsustainable catch levels. It also, inadvertently, maintains local divers in poverty and places them in evermore uncertain futures. These are the effects of a typical capitalist, market driven global business model, which relies on mass consumer demand to generate profits for the industry. However, as is common with global capitalist models and commodity chains, the distribution of wealth generated from such trade and the way power is shared within the system is unequal (Gereffi, 1994; Gray, 2000). The influence of power wielded in this system affects all involved and results in trapping local divers into certain behaviours and strategies discussed in Chapter 5.4.1. The commonly quoted "trickle-down effect" that capitalists use to support this global trade, was questioned in studies 30 years ago (Grant, 1973; Thornton et al., 1978) and does not appear to be a valid description of the scenario in Sri Lanka. Divers receive the least income from the trade but, as some argue, typically do the hardest and the most essential work. With little income and power, and with few safeguards or security within the industry, they are vulnerable to minimal changes in the international markets and alterations in business patterns of national export companies.

From estimates over the past 33 years of the value of the entire ornamental fish trade worldwide (Table 7.1), it appears that the value of the both freshwater and marine trade has increased roughly ten-fold in 20 years. The lack of accurate data in trade volumes for most countries, domestically and globally, makes it difficult to monitor and manage this combined fish trade (Rhyne et al., 2012). Studies which were carried out between 1984 and 2003 and focused exclusively on the marine ornamental trade either in a particular country or globally provide more accurate volume and trade estimates, separate from FAO statistics (Table 7.2). They are the most up-to-date studies in the published literature for each country and are therefore most used despite the known inaccuracies and difficulties inherent in collecting such data.

The volumes of marine fish exported from source countries and their monetary value, the number of jobs the trade provides locally and the selectivity of the exports in terms of targeted fish species or families are shown in Table 7.2. Dufour's (1997) study analyses the volume of marine ornamental trades in several island states and argues that labour costs predict the final cost per fish and the economic viability of the trade. Dufour (1997) concluded that 100,000 fish can yield a turnover of US$ 200,000 free-on-board (FOB)[24] value and provide 10 – 20 jobs to such islands (Table 7.2.) and the need for management to control fishing and numbers of fishers is mentioned. However, how to enforce this or to cap the volume exported or the numbers joining the fishery are not mentioned.

[24] Free-on-board or freight on board value, this is the cost of goods (fishing, storing, packaging and local transport costs) without freight, packing and duties and is the export value sent to an importer

Table 7.1. Global estimates of the overall value of the ornamental fish trade (marine and freshwater combined). Data derived from official country and Food and Agriculture Organisation (FAO) statistics, which are often based on weight and value data, from which estimates of fish numbers are made.

Year & Author	FW : Marine split	Captive bred marines	FOB** estimate (US$)	Airlines share (US$)	Wholesaler estimate (US$)	Retail estimate (US$)	Total global estimate (US$)
(UNCTAD/GATT, 1979) *	90:10 Quantity 80:20 Value	0%	120 million	80 million	300-400 million	1 billion	1.5 billion
(Pedini et al., 2000)	90:10 Quantity	2-5%	207 million		321.25 million		15 billion

* United Nations Conference on Trade and Development/ General Agreement on Tariffs and Trade. GATT was replaced by the World Trade Organisation in 1995.

** Free-on-board value, this is the cost of goods (fishing, storing, packaging and local transport costs) without freight, packing and duties and is the export value sent to an importer

Table 7.2. Estimates of the value of the marine ornamental trade in various source countries as well as global estimates from earlier studies

Country	Year of study	Number of fish exported annually	FOB annual fish value (US$)	Number of jobs	Export selectivity	Mean price per fish (US$)	Source
Sri Lanka	1984	200,000	600,000 – 1,200,000	500	50% = 5 families	3.0 – 6.0	Wood, 1985
Maldives	1989	100,000	120,000	25	70% = ~20 species	2.43	Edwards & Shepherd, 1992
Philippines	1996	> 5 million	6.4 million	4000 divers	-	1.5	(Wood, 2001a)
Puerto Rico	1992	160,000 – 200,000	400,000	40 to 70	60% = 5 species	2	(Sadovy, 1992)
Hawaii	1994	430,000	850,000	< 100	70% = 4 species	1.97	(Miyasaka, 1997)
Average island state	1997	100,000	200,000	10 to 20	-	2	(Dufour, 1997)
Global	1984	14-30 million	28 – 44 million	-	-	-	Wood, 1985
Global	2003	20-24 million (1471 species)	200 – 300 million	-	-	-	(Wabnitz et al., 2003)

Global studies of the marine ornamental trade estimate the value and volume of the trade from official statistics and Customs packing lists (Wood, 2001; Wabnitz et al., 2003; Table 7.2). These studies provide useful comparisons amongst countries and benchmarks to compare and monitor the trends in the export trade of source countries. Wood (2001) highlighted the changing composition of the trade, in that the demand for invertebrates from hobbyists is increasing as they seek to create reef aquaria, comprising live rock[25] and invertebrates as well as fish. In Florida imports of marine ornamental fish dropped from 55% of total value in 1990 to 40% in 1998, with 60% of the imports by value in 1998 being invertebrate species, including live rock and live sand[26] for aquaria (Adams et al., 2001). In the Philippines, Vallejo (1997) reported that 20% of exports were invertebrates and by 2000 30% of UK imports of marine ornamentals were invertebrates (Wood, 2001a). All export companies I spoke with in Sri Lanka export large volumes of invertebrates, particularly several high-demand species of shrimps (Table 7.12).

The studies summarised in Table 7.2 agree that the quantities of fish exported need to be well monitored, so that accurate numbers are known, rather than only value or weight figures. To date, in most source countries, this recommendation and many other management suggestions provided in these studies have not been implemented and are similar to those currently proposed (Table 7.3).

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25 Live rock is dead coral or pieces of rock taken from the ocean, often encrusted with coralline algae or other organisms. It is highly valued by aquarists due to live rock harbouring denitrifying bacteria which is necessary to maintain optimal water quality in marine aquariums. Live rock acts as a biological filter and is also decorative.

26 Live sand is natural reef sand that contains denitrifying bacteria and acts similarly to live rock in aquariums to break down organic wastes.

Table 7.3 Comparison of concerns, research needs and management suggestions stated in reports on the Sri Lankan and global marine ornamental fishery over 25 years.

Concern	**1985 (Wood)**	**1994-6(Wood)**	**2001a & b (Wood)**	**2010 (this study)**
Over collection & habitat damage	✔	✔	✔	✔
Ecological change	✔	✔	✔	✔
Fish mortality			✔	✔
Conflict			✔	✔
Lack diver training		✔	✔	✔
Lack scientific information			✔	✔
Research/ data needs				
Reef fish and ecology		✔	✔	✔
Catch, effort, collection impact, socioeconomic		✔	✔	✔
Management recommendation				
Quotas for rare or unsuitable species	✔	✔	✔	✔
Create marine reserves/ closed season	✔	✔	✔	By community
Monitor trade – catch, effort, fish sizes	✔	✔	✔	Community and scientists
Licensing divers and control gear used	✔	✔	✔	By community
Involve communities, education & diver training		✔	✔	✔✔
Size restrictions		✔	✔	Buyer and company level
Mariculture of ornamental species		✔		✔
Improve standards along chain			✔	✔
Number collectors	<500	~700	1000	>1000
Number species traded	~200	>200	>200	>200
Export value of the trade	US$ 1.22 million	US$ 5.06 million (1994)	US$ 1.5 million	US$ 5 million

Many of these suggestions are also contained in a report, the recommendations of which aimed to ensure sustainability and continued growth in the trade of ornamental fish globally (UNCTAD/GATT, 1979). However, over three decades later, most of these recommendations have not been implemented (Table 7.3) and hence the same problems concerning reef degradation and poor business practices within the trade remain (Wabnitz et al., 2003; Wood, 2001b; Bruckner, 2005). Costanza et al.'s (1997) global evaluation of each biome's ecosystem services provision identified coral reefs as one of the highest value of all biomes in terms of the ecosystem services they provide humanity. Consequently, as this finding has since been corroborated, (Moberg & Folke, 1999; Worm et al., 2006; Nyström et al., 2000), greater emphasis has been placed on assessing and restructuring all exploitative practices on reefs, including those resulting from the ornamental trade. However, to protect ecosystem services and biodiversity as well as achieving increased human well-being, is relatively rare (Tallis et al., 2008). This would require improved understanding of ecosystem services functions, as well as the nature of trade-offs among ecosystem services (Rodriguez et al., 2006). It is not clear currently how the valuation of ecosystem services will affect the trade in products derived from such services and whether it will reduce these services in coral reef ecosystems in Sri Lanka.

The future trajectory of the ornamental trade in Sri Lanka is generally left to market forces, which means some actors within the system are largely powerless to govern their own livelihoods. However, others, such as Holthus (1999), believed the role of market forces to be positive if harnessed for sustainable practice and he helped develop the first eco-labelling scheme for the marine aquarium trade. Known as the Marine Aquarium Certification scheme (MAC), Holthus' project, launched in 1996, had 63 operators by 2007 at various levels of the market chain, in several countries (UNEP-WCMC, 2007). The MAC scheme was supported by scientists (Wood, 2001a) and industry (OATA, 2002) alike, as the necessary framework for improving sustainability of the marine ornamental trade and although initially widely recognised and adopted the MAC scheme terminated in 2008. Its failure is attributable to three factors: the complexity of the task, a lack of adequate funding and the extra costs incurred by all actors willing to participate in the scheme, who had no guarantee they could recoup these costs through higher fish prices (Mathews et al., 2009). It is interesting to note that, despite its quick adoption, few in the industry appear to have attempted to re-launch the idea, or improve the prototype, despite continued pressure to improve the trade's image. A notable exception, although not originating directly from within the ornamental fish industry, is the work currently underway by Cooper (2012) on the GreenFish Initiative, an eco-labelling scheme for the freshwater ornamental fish trade (see Section 7.4.6).

7.1.3 Aims

A lack of data is often cited as a key reason why little control, and few changes, can be applied to the industry. This chapter aims to provide such empirical data of aquarium fish volumes collected and exported from southern Sri Lanka during one six month season. By extrapolation of these data, using clearly stated assumptions, a current annual marine ornamental species export value estimate is made for Sri Lanka. Previous studies (Table 7.2) on trade volumes of ornamental fish have been carried out via a top-down approach, based on shipping invoices and Customs packing lists. These studies are useful but the data can be unreliable in terms of actual numbers of fish, due to the varied data recorded on packing lists, inaccuracies in species naming or mis-categorisation. Furthermore, these data were far from the point of collection in time and space, which makes estimation of mortality difficult. The present study uses data collected via a bottom-up approach to more accurately estimate the number of fish and species being collected and eventually exported from Sri Lanka.

In addition, a social analysis of the Sri Lankan market chain is provided to more fully appreciate the issues influencing fishing effort, behaviours and actions at all levels of the industry. For a clearer understanding of why the systems operates as it does and why actors behave as they do, it is essential to determine the relations between the different actors along the market chain in Sri Lanka.

7.2 Methods

This chapter provides four sites for comparison of snorkel fish catch and three sites for comparison of SCUBA fish catch, that is: snorkel and SCUBA fish catch data from the buyers' logbooks in each of the study sites from November 2009 to April 2010, (described in Chapter 3.2 and 3.5), and from a sole buyer in Bandaramulla who only buys snorkel-caught fish. Logbook data comprised for each fishing trip: the date, the diver, the species, the number of each species caught and earnings. Buyers record size only for certain species, and different prices paid depending on size category, which range, in decreasing size, from Adult to Large, Medium and Small. As these are relative categories, they vary according to the individual species and the accepted adult size. To identify differences among sites and among buyers in terms of numbers of fish caught, numbers of species caught, and average earnings per snorkel and SCUBA trip, Poisson regression models were fitted to count data and Gaussian regression models to continuous data and tested within the statistical software R (Version 2.14.1)

In Kapparathota, of the six fish buyers, only four were present during the 2009/10 season and all four provided their logbook data. All buyers here deal with snorkel fish but only two of these buyers have SCUBA teams. In Polhena there are five buyers and again the logbook details of four buyers are recorded; the fifth being an insignificant buyer. Two of the four buyers deal only with SCUBA caught fish and the other two buy both snorkel and SCUBA catches. In Thalaramba there are four main buyers, three of whom provided their logbook details, who all deal in both snorkel and SCUBA catches. The fourth buyer here provided details from only one of his two SCUBA divers' records and none from his snorkel catch purchases. From these buyers' data, the total numbers of fish bought from snorkellers and SCUBA divers over one season were calculated as well as the number of unique species. These totals give an indication of the major buyers within each study site and how they rank in terms of volume of fish moving through their facilities.

The three main fished study sites are hub sale points along the southern coast and form a concentration of onshore fish holding sites in the southern region of Sri Lanka. This area is one of three regions nationally in Sri Lanka where ornamental fish are collected and therefore from the volumes of fish moving through these buyers in the villages an estimate of total national fish volumes collected and shipped is made. These are compared to three other methods for calculating the volume of marine ornamental fish.
A mixture of social anthropological methods was used to gather data concerning the relations and interactions among divers, buyers and export companies in Sri Lanka. Semi-structured interviews predominated to collect data from eight different export companies in Sri Lanka, Customs, the EDB and government officials, as well as

communications with ornamental industry representatives and international conservation NGO groups. These data were analysed as described in Chapter 3.7. Data were also collected from online trade sources, primary and secondary literature and media concerned with trade statistics and these data were examined in terms of the industry practices and specific external pressures.

7.3 Results

7.3.1 Snorkel catches among sites

Kapparathota (19.3 fish) and Thalaramba (13.7 fish) recorded significantly higher numbers of fish caught per trip than Bandaramulla (12.4 fish) (p<0.001 for both). There was no significant difference in the numbers of fish caught between Polhena (11.7 fish) and Bandaramulla (Table 7.4). Similarly, significantly more fish species were caught per trip in Kapparathota and Thalaramba than in Bandaramulla and no significant difference in the number of species caught was found between Polhena and Bandaramulla. The number of fish species caught was similar at Bandaramulla, Polhena and Thalaramba with mean values of 4.9, 4.4 and 4.4 respectively, while Kapparathota had a significantly higher mean of 6.3 species caught per trip (Table 7.5). Earnings per trip were similar at Polhena and at Thalaramba with mean earnings of, 578 LKR and 656 LKR respectively and no significant difference was detected between these sites and the reference site, Bandaramulla (666 LKR), while Kapparathota recorded significantly higher mean earnings per trip than Bandaramulla (p<0.001) with a mean of 987 LKR (Table 7.4 and Figure 7.1).

Table 7.4. Poisson and Gaussian regression model results comparing snorkel catch data recorded by buyers among sites. Site codes: KP = Kapparathota, PO = Polhena, TL = Thalaramba. Bandaramulla is the reference site in the model.

	Estimate	Std. Error	Pr(>|z|)
Number fish caught			
(Intercept)	2.52	0.03	0.000
Site KP - BD	0.44	0.03	0.000
Site PO - BD	-0.05	0.04	0.13
Site TL - BD	0.10	0.03	0.000
Number of species caught			
(Intercept)	1.59	0.04	0.000
Site KP - BD	0.24	0.05	0.000
Site PO - BD	-0.11	0.06	0.06
Site TL - BD	-0.11	0.05	0.02
Earnings			
(Intercept)	6.16	0.08	0.000
Site KP - BD	0.43	0.09	0.000
Site PO - BD	-0.09	0.10	0.39
Site TL - BD	-0.01	0.08	0.87

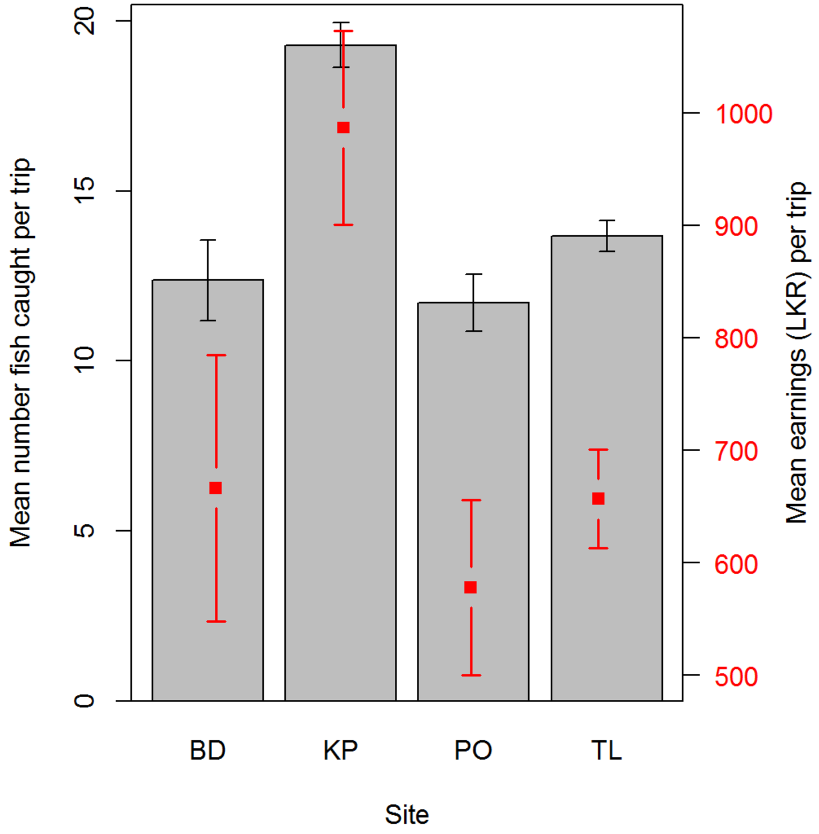

Figure 7.1. Mean number of fish caught (± S.E.) (bars) and mean earnings (± 95% C.I.) (LKR) per snorkelling trip among sites. Site codes: BD = Bandaramulla, KP = Kapparathota, PO = Polhena, TL = Thalaramba. C.Is from replicate trips.

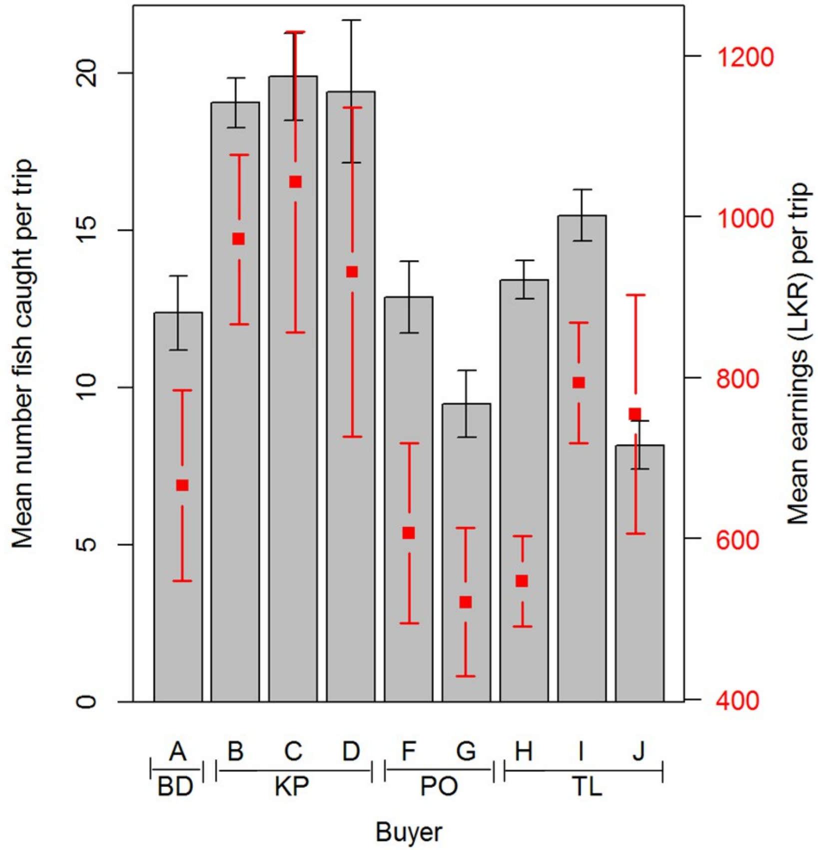

Figure 7.2. Mean number of fish caught (± S.E.) (bars) and mean earnings (± 95% C.I.) (LKR) per snorkelling trip among buyers. Buyer codes: A = Bandaramulla, B-D= Kapparathota, F-G = Polhena, H-J = Thalaramba. C.Is from replicate trips.

Table 7.5. Means and standard deviations of the three factors recorded in buyer's logbooks at each site for snorkel-caught ornamental fish. Site codes: BD = Bandaramulla, KP = Kapparathota, PO = Polhena, TL = Thalaramba. Data are for the 2009/10 season.

Site	**BD**	*n*=110	**KP**	*n*=511	**PO**	*n*=152	**TL**	*n*=681
Factor per trip	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Number fish caught (NFC)	12.37	12.51	19.29	14.83	11.72	10.32	13.68	12.04
Number species caught (NSC)	4.89	3.16	6.25	3.07	4.38	2.6	4.37	2.4
Earnings (LKR)	666.32	625.27	986.83	994.61	578.11	484.93	656.87	583.25

Table 7.6. Means and standard deviations of snorkellers' fish catch data compared across all buyers. Buyer codes: A = Bandaramulla buyer, B-D= Kapparathota buyers, E-G = Polhena buyers, H-J = Thalaramba buyers. Data are for the 2009/10 season. All earnings given in LKR (US$1 = 113 LKR based on 2010 US$: LKR exchange rates).

Site	**BD**		**KP**						**PO**						**TL**					
Buyer	**A**		**B**		**C**		**D**		**E**		**F**		**G**		**H**		**I**		**J**	
Factor	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Per trip																				
NFC	12.37	12.51	19.06	14.83	19.9	15.38	19.42	12.98	21	-	12.88	11.07	9.48	8.15	13.43	11.85	15.48	13.01	8.17	6.15
NSC	4.89	3.16	6.18	3.16	6.32	2.95	6.73	2.6	6	-	4.27	2.38	4.47	2.84	4.3	2.56	4.79	2.26	3.15	1.36
Earnings	666.32	625.57	972.34	1007.43	1043.5	1048.02	931.52	577.34	575	-	607.31	542.97	521.38	349.7	547.19	547.1	793.91	599.61	755	598.92
Totals																				
NFC	1361		6768		2448		641		21		1198		550		4944		3840		531	
NSC	72		91		79		49		6		60		57		105		94		53	
Earnings	73295		345180		128350		30740		575		56480		30240		201366		196890		49075	
n	110		355		123		33		1		93		58		368		248		65	

7.3.2 Snorkel catches among buyers

Buyer B, C, D, H and I recorded significantly higher numbers of fish caught per trip and buyers G and J recorded significantly lower numbers of fish than buyer A ($p<0.001$ for all, except buyer H, $p<0.01$). No significant difference was found between buyer F and A (Table 7.7 and Figure 7.2). Buyers in Kapparathota recorded significantly higher numbers of species than the buyer in Bandaramulla and buyers in Thalaramba and Polhena either recorded significantly lower numbers of species per trip than buyer A ($p<0.05$; $p<0.01$; $p<0.001$) or no difference (buyers G and I). Similarly, buyers in Kapparathota showed significantly higher earnings per trip than buyer A ($p<0.001$ for all) and buyer H recorded significantly lower ($p<0.01$) and buyer I significantly higher ($p<0.01$) earnings than buyer A (Table 7.7 and Figure 7.2). All other buyers showed no significant difference in earnings to buyer A.

Earnings differed significantly among different buyers and correspond in this study to the number of fish caught per trip. Therefore the highest earnings per trip were recorded from buyers in Kapparathota (Figure 7.2), ranging between 931 LKR and 1007 LKR per trip. Buyers A (Bandaramulla), F, G (Polhena) and H (Thalaramba) recorded similar diver earnings per trip ranging between 400 LKR and 450 LKR, whereas two other buyers in Thalaramba recorded higher earnings per trip of 565 LKR and 635 LKR per trip (Table 7.6).

Generally, the higher the total number of fish a buyer bought, the higher the total number of unique species, although in Polhena despite a two-fold difference in the total number of fish caught, 550 for Buyer G and 1198 for Buyer F, similar numbers of species were caught between the two buyers: 57 and 60 species respectively (Table 7.6). The highest volume buyer of snorkel caught fish is in Kapparathota with 6768 ornamental fish from 91 different species. Thalaramba has the second highest volume of 4944 fish from 105 different species and the third highest volume buyer who bought 3840 fish from 94 different species in one season. Total money paid to snorkellers by each buyer over one season was approximately proportional to the number of fish sold to them (Table 7.6). In Kapparathota the total number of fish bought by the three buyers ranged from 641 fish to 6768 and in Thalaramba ranged from 531 to 4944 fish.

Table 7.7. Poisson and Gaussian regression model results comparing catch statistics of snorkellers among buyers. A = Bandaramulla buyer, B-D= Kapparathota buyers, F-G = Polhena buyers, H-J = Thalaramba buyers. Buyer E removed as n=*1.*

	Estimate	Std. Error	Pr(>|z|)
No. fish caught			
(Intercept)	2.52	0.03	0.000
Buyer B - A	0.43	0.03	0.000
Buyer C - A	0.48	0.03	0.000
Buyer D - A	0.45	0.05	0.000
Buyer F - A	0.04	0.04	0.31
Buyer G - A	-0.27	0.05	0.000
Buyer H - A	0.08	0.03	0.01
Buyer I - A	0.22	0.03	0.000
Buyer J - A	-0.42	0.05	0.000
No. species caught			
(Intercept)	1.59	0.04	0.000
Buyer B - A	0.23	0.05	0.000
Buyer C - A	0.26	0.06	0.000
Buyer D - A	0.32	0.08	0.000
Buyer F - A	-0.14	0.07	0.04
Buyer G - A	-0.09	0.08	0.23
Buyer H - A	-0.13	0.05	0.01
Buyer I - A	-0.02	0.05	0.68
Buyer J - A	-0.44	0.08	0.000
Earnings			
(Intercept)	6.16	0.08	0.000
Buyer B - A	0.41	0.09	0.000
Buyer C - A	0.49	0.10	0.000
Buyer D - A	0.47	0.16	0.000
Buyer F - A	-0.05	0.11	0.63
Buyer G - A	-0.15	0.13	0.26
Buyer H - A	-0.22	0.09	0.01
Buyer I - A	0.24	0.09	0.01
Buyer J - A	0.19	0.12	0.12

In summary, a total of 22, 302 fish and invertebrates were collected by snorkellers and bought by village buyers in the four sites between November 2009 and April 2010 and a total of 1,112,191 LKR was earned by snorkellers. From my own observations and surveys, I estimate that there are 115 snorkel divers among these four sites (Table 3.1).

Therefore, if this total were split equally among the 115 snorkellers each would earn an average of 9671 LKR per season, which equates to approximately US$85 for six months' work. In reality, many snorkellers exist on far less than this, whereas others earn more. The prices of these snorkel-caught marine ornamental fish vary between 5 LKR and 900 LKR per specimen (Appendix E) which equates to a variation in price by a factor of 180 depending on the species caught and sold. The average price paid for a snorkel caught fish in these villages over the season studied was approximately 50 LKR (US$0.5)[27] which is six to ten times lower than the average export price of marine aquarium fish in Sri Lanka in 1984 (US$3-6) and today's average export price per fish of US$5.16 (Table 7.2 & Appendix E)

7.3.3 SCUBA catch among sites

Data from the Bandaramulla buyer were not comparable with the other buyers because there were only data for two trips and he dealt mainly in snorkel caught fish. Kapparathota buyers record significantly greater numbers of fish caught on SCUBA trips than Polhena (p<0.001) and hence significantly higher earnings (p<0.001) and Thalaramba records significantly less fish caught than Polhena (p<0.001) and consequently significantly less earnings (p<0.001) (Table 7.8). There were no significant differences in the number of species caught among sites. The highest number of fish caught per trip was 97.7 fish in Kapparathota followed by 67 fish per trip in Polhena, 49.3 fish per trip in Thalaramba (Table 7.9). Earnings per trip were highest in Kapparathota (10,030 LKR), 7799 LKR in Polhena, 3759 LKR in Thalaramba (Table 7.9). Diving trip costs were also significantly higher in Kapparathota compared to Polhena and significantly lower in Thalaramba than Polhena (p<0.001 for both); despite this, overall profit at each site tracked patterns of the number of fish caught, with highest profit: Kapparathota, followed by Polhena and lastly Thalaramba (p<0.001 for both comparisons). The number of divers operating per trip/ team were also significantly higher in Kapparathota than Polhena (p<0.05) and significantly lower in Thalaramba (p<0.001); as a result of there was no significant difference in profit per diver among sites (Table 7.8).

[27] Calculated by dividing total earnings by total fish from buyers data over the 2009/10 season (Table 7.6) and based on 2010 US$: LKR exchange rates, the year that these data were collected.

Table 7.8. Poisson and Gaussian regression model results of catch statistics of SCUBA divers compared across sites. KP = Kapparathota, TL = Thalaramba. Reference site = Polhena.

	Estimate	Std. Error	Pr(>|z|)
Number fish caught			
(Intercept)	4.20	0.01	0.000
Site KP - PO	0.38	0.01	0.000
Site TL - PO	-0.31	0.01	0.000
No. species caught			
(Intercept)	2.09	0.02	0.000
Site KP - PO	0.00	0.03	0.95
Site TL - PO	0.00	0.03	0.87
Earnings			
(Intercept)	8.72	0.04	0.000
Site KP - PO	0.37	0.07	0.000
Site TL - PO	-0.72	0.06	0.000
Costs			
(Intercept)	7.96	0.05	0.000
Site KP - PO	0.23	0.06	0.000
Site TL - PO	-0.24	0.07	0.000
Diver			
(Intercept)	0.62	0.04	0.000
Site KP - PO	0.13	0.07	0.04
Site TL - PO	-0.59	0.07	0.000
Profit			
(Intercept)	8.63	0.05	0.000
Site KP - PO	0.21	0.07	0.000
Site TL - PO	-0.67	0.06	0.000
Profit per diver			
(Intercept)	7.89	0.04	0.000
Site KP - PO	0.16	0.08	0.24
Site TL - PO	0.34	0.05	0.17

Table 7.9. Means and standard deviations of the three factors recorded in buyer's logbooks at each site for SCUBA caught ornamental fish. Site codes: BD = Bandaramulla, KP = Kapparathota, PO = Polhena, TL = Thalaramba. Data are for the 2009/10 season.

Site	BD		KP		PO		TL	
Factor per trip	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number fish caught	14	9.89	97.7	62.3	66.98	38.8	49.33	63.3
Number species caught	3.5	0.71	8.01	5.71	8.06	3.95	8.02	4.35
Earnings (LKR)	1165	869.7	10030.1	4800.6	7799.6	5120.3	3759.6	2556.5
No. trips (*n*)	2		183		288		353	

Table 7.10. Totals of SCUBA divers' fish catch data compared across all buyers. Buyer codes: A = Bandaramulla buyer, B = Kapparathota buyer, C-F = Polhena buyers, G - J = Thalaramba buyers. Data are for the 2009/10 season. All earnings given in LKR (US$1 = 113 LKR based on 2010 US$: LKR exchange rates).

Site	**BD**	**KP**	**PO**				**TL**			
Buyer	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Total fish	28	17888	602	7221	2025	9443	7102	5216	3082	2014
Total unique species	7	88	20	74	46	87	65	98	72	53
Total earnings	2330	1835510	63530	1052556	272935	857263	577944	704722.3	501436.4	230616.3
Total costs	1800	696830.6	20054.3	326598.6	131785.4	346652.9	289653.5	335193.3	246381.4	106001.3
Net profit	530	1136705	43475.7	725957.4	141149.6	510610.1	288290.5	369529	255055	124615
n	2	183	7	114	46	121	113	117	86	37

Table 7.11 Means and standard deviations of SCUBA divers' fish catch data compared across all buyers. Buyer codes: A = Bandaramulla buyer, B = Kapparathota buyer, C-F = Polhena buyers, G-J = Thalaramba buyers. Data are for the 2009/10 season. All earnings given in LKR (US$1 = 113 LKR based on 2010 US$: LKR exchange rates). Asterisks and bold values indicate where significant differences in each catch statistic occurred when compared with buyer D (bold and no asterisk column).

Site	**BD**		**KP**		**PO**								**TL**							
Buyer	**A**		**B**		**C**		**D**		**E**		**F**		**G**		**H**		**I**		**J**	
Factor	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Per Trip																				
No. fish	14	9.89	**97.7***	62.3	**86***	34.4	**63.3**	38.4	**44.02***	26.8	**78.04***	39.02	62.9	98.9	**44.6***	40.8	**35.8***	28.7	**54.4***	20.2
No. species	3.5	0.71	**8.01***	5.71	6.86	3.24	**6.31**	2.9	**5.17***	2.1	**10.87***	3.6	5.67	2.62	**8.71***	4.61	**8.62***	4.46	**11.6***	3.9
Earnings	1165	870	**10030***	4801	9076	6821	**9233**	6334	**5933***	3751	7085	3664	**5115***	3049	**6284***	3112	**5831***	2985	**6233***	3652
Costs	861		3840		2865		**2865**		2865		2865		2677		3125		2865		2865	
Net earnings	304		6191		6211		**6368**		3069		4220		2438		3158		2966		3368	
No. divers	1		2		2		**2**		1		2		1		1		1		1	
Income per diver	304		3095		3105		**3184**		3069		2110		2438		3158		2966		3368	
n	2		183		7		**114**		46		121		113		117		86		37	

7.3.4 SCUBA catch among buyers

Buyer D was used as a reference in the regression models as this buyer was a medium volume buyer (bold column, Table 7.11). Buyers B, C and F recorded significantly greater numbers of fish than buyer D, whereas all other buyers except buyer G recorded significantly fewer fish than buyer D ($p<0.001$ for all). All buyers recorded significantly more species caught per trip than buyer D, except buyer E with less species recorded and buyers C and G where there was no significant difference (Table 7.11). Highest mean number of fish caught per trip was recorded in Kapparathota (buyer B) and three of the four buyers in Polhena (buyers C, D and F), whereas buyers E (Polhena), G, H and I (Thalaramba) have lower and similar mean numbers of fish caught, ranging between approximately 35 and 50 fish caught per trip (Table 7.11).

Only buyer B in Kapparathota recorded higher earnings than buyer D, with all other buyers recording significantly lower earnings than buyer D, except for buyer C and F where there was no significant difference (Table 7.11). Earnings per trip relate to the number of fish caught per trip and therefore the highest earnings per trip were recorded from buyer B in Kapparathota and buyers C and D in Polhena, ranging between approximately 9000 LKR and 10000 LKR per trip before costs (Table 7.11). Buyers E, F (Polhena) and G (Thalaramba) recorded mid-level earnings per trip among all buyers, ranging between 5000 and 7000 LKR. Buyers H, I and J (Thalaramba) recorded the lowest earnings per trip of between 3000 and 5000 LKR (Table 7.11).

Differences among buyers of costs and profit could not be calculated as these data were not available for many buyers and would only be an approximation, which is given in Table 7.11. Average costs per SCUBA diving boat trip varied among different buyers and ranged between 861 and 3840 LKR depending on the number of divers and distance travelled, which related to fuel costs. An average cost of 2865 LKR was applied to buyers whose costs were not possible to record. Subtracting these average trip costs from average trip earnings and dividing this by the median number of divers per trip, net earnings per diver per trip was calculated for each buyer (Table 7.11.). These averages, per buyer, ranged between 2110 and 3368 LKR per diver per trip over the 2009/10 season (Table 7.11). However, many trips with such high costs would end in losses for each diver who worked a specific day.

A higher total number of fish bought by a buyer did not necessarily result in a higher total number of unique species; buyer H bought 5216 individual fish of 98 different species, whereas buyer B in Kapparathota bought 17,888 individual fish of only 88 different species and was the highest volume buyer and buyer D bought 7721 individual fish of 74 different species (Table 7.10). The total number of fish caught was correlated with the number of trips made.

In summary, from the logbooks to which I had access, a total of 54,647 fish and invertebrates were collected by SCUBA divers and bought by village buyers in the four sites between November 2009 and April 2010 and a total of 3,595,915 LKR was earned by SCUBA divers after costs. From my own observations and surveys, I estimate that there are approximately 66 SCUBA divers among these four sites and 16 buyers (see Table 3.1). Therefore, if this total were split equally among 66 SCUBA divers, each diver would earn an average of 54,483 LKR per season, which equates to approximately US$480 for six months work. This is approximately six times more than the average estimates made for snorkellers from their fishing over the same period.

In contrast to to the price of snorkel caught ornamental fish explained in Section 7.3.12 and shown in Table 7.2 and Appendix E, the average price per fish caught by SCUBA divers and sold to buyers was approximately 100 LKR (US$0.91) before costs and 70 LKR (US$0.64) after costs[28], which is five to eight times lower than the average export price of marine aquarium fish in Sri Lanka in 1984 (US$3-6) and today's average export price per fish of US$5.16 (Table 7.2 & Appendix E).

7.3.5 Estimate of marine ornamental fish collected in Sri Lanka in one year from logbook data

Ornamental divers and buyers trade in marine ornamental fishing in several villages along the southern region of Sri Lanka as it is one of three main areas for the trade. Another five sites exist in the southern region (Galle to Dondra; see Figure 3.1) other than the four sites from which data is taken for my study. A recent NARA study states there are only 15 buyers in the southern region (Rajasuriya, pers. comm.). I visited four

[28] Calculated from an average of total earnings divided by total fish before and after costs from buyer logbook data (Table 7.11) and based on 2010 US$: LKR exchange rates, the year data were collected.

of these five sites and after meeting buyers at each site, I estimate that there are eight additional buyers in these five other southern villages which do not include the 10 buyers from my study sites. Of these eight additional buyers, four were major and four were minor buyers. Therefore, by using average values for major and minor buyers in my sites, each additional buyer can be assigned a fish volume for the season. A major snorkel caught fish buyer in my study sites bought 3872 fish per season (average of top five buyers' totals), compared with a minor snorkel caught fish buyer who bought 730 fish per season (average of lowest four buyers' totals). Therefore four additional major buyers each buying 3872 fish equates to 15,488 fish and four further minor buyers each buying 730 fish per season equals 2920 fish. This would amount to 18,408 snorkel caught fish collected and sold to the other southern buyers over the course of one season (2009 - 2010). This, added to the total calculated from the logbook data of 22,302 fish, gives an estimated total of 40,710 fish and invertebrates collected and sold to buyers from snorkellers in the whole southern region for 2009 - 2010.

From my own data at my four southern region study sites, approximately 70% of the volume of exported fish are from SCUBA and 30% from snorkel catches. A major buyer of SCUBA-caught fish in my study sites bought 9374 fish per season (average of top five buyers' totals), compared with a minor buyer who bought 2374 fish per season (average of lowest three buyers' totals). Therefore, four additional major buyers each buying 9374 fish equates to 37,496 fish and four further minor buyers each buying 2374 fish per season equals 9496 fish. This would total to a potential of 46,992 SCUBA-caught fish and invertebrates collected and sold to the other southern buyers over the course of one season (2009-2010). This, added to the total calculated from the logbook data of 54,621 fish, gives an estimated total of 101,613 SCUBA-caught fish and invertebrates collected and sold to buyers in the whole southern region for 2009 – 2010.

There are two other major collecting regions in the country, the east coast (Batticaloa and Trincomalee areas) and the west coast (Colombo area). Multiplying the total number of fish and invertebrates bought by buyers in the south by three provides a very rough national estimate of approximately 122,000 snorkel caught and 305,000 SCUBA caught fish. From combining these two estimates, approximately 427,000 marine ornamental fish and invertebrates are caught in Sri Lankan waters each year. In 1984 it was estimated that approximately 200,000 marine fish and invertebrates were exported from Sri Lanka every year (Wood, 1985). This would indicate an increase in volume of approximately 2.14 times in the 16 years between 1984 and 2010.

7.3.6 Estimate of ornamental fish volumes from interviews with buyers

From my own data and from interviewing buyers, I estimated how many SCUBA and snorkel caught fish pass through their holding facilities each day diving occurs. My data recorded between 10 and 20 snorkel fish per day and between 20 and 80 SCUBA fish per day for small buyers, whereas large buyers reported between 120 and 300 SCUBA fish and 40 – 110 snorkel fish per day. If the two average values for snorkel and SCUBA fish are combined for small and large buyers, on average, a large buyer processes approximately 285 fish per day in the season and small buyers 65 fish per day. The number of days in a season that diving occurs was estimated from discussions with divers (see Chapter 5.3.3) and, usually only four days per week is suitable for diving during the six month season. From these data, in one season, 27,360 fish move through a large buyer's facility and 6240 fish through a small buyer’s. Therefore, totalling the ten buyers in my sites (six large, four small) and the eight other buyers in the south (four large, four small), 273,600 fish can potentially be handled by the ten large buyers and 49,920 fish are handled by the eight smaller buyers, totalling 323,520 snorkel and SCUBA caught fish and invertebrates collected from the southern region. If it can be estimated that a similar number of fish are caught in the other two main collecting areas around the country, then approximately 1 million marine ornamental fish and invertebrates are caught in Sri Lanka each year, which is five times higher than the estimate made from data in 1984 (Wood, 1985).

7.3.7 Ornamental fish volumes estimates from interviews with exporters

The number of shipments that companies made per month varied between three and thirty shipments depending on the size of the company (Table 7.12). Some companies (D-G) provided me with the number of boxes per shipment and the number of fish and/ or shrimps (the predominant invertebrate exported) packed in each box. From these data the number of fish sent per shipment was calculated. Other companies (A-C and H) gave me the number of fish or shrimps sent per shipment and the number of shipments per month, with which, I estimated the total number of marine fish and the total number of shrimps exported per month from each of these eight Sri Lankan export companies. In one month, these eight companies made a minimum of 110 shipments to foreign importers (Table 7.12). The number of boxes per shipment varied depending on the size of the company and the order received but ranged from 10 to 50 boxes. Small fish predominated therefore the estimates use values of the number of small fish per box, which range from 10 to 50 fish per box. The minimum value given by each company was used to calculate the number of fish sent per shipment to provide a lowest range estimate. The number of shipments in a month are taken to have been made up of 70% fish and 30% shrimp (based on data gathered from companies), which resulted in the estimate that the number of marine fish exported monthly ranged between 400 to 9900 with an average value of approximately 5000 fish and the number of shrimps varied between 1000 and 4000 with an average of 2875.

The total number of marine fish exported per month by these eight companies was thus, 40,050 and 23,000 shrimps resulting in a total monthly export of 67,050 fish and invertebrates (Table 7.12). Most exporters agreed that there are approximately 24-30 registered companies in Sri Lanka exporting marine fish. Therefore, if we take the minimum number of marine fish exporting companies as 24 and I collected data from eight of these, then a further 16 companies need to be accounted for. Using the average monthly values of fish and shrimps exported by the eight companies I sampled, the other 16 companies export approximately 80,100 fish and 46,000 shrimps per month. Therefore, the total number of marine fish and shrimps for all companies exported per month would be approximately 189,150. Extrapolated across a year and assuming such good orders only occur 6 months of every 12 (an apparently low estimate), then total exports of marine fish and shrimps per year from Sri Lankan companies would equal approximately 1.13 million specimens. In 1999 5% of these exports comprised fish that were import-export specimens from the Maldives *i.e.* caught in the Maldives, and imported into Sri Lanka by an export company and re-exported with Sri Lankan species in consolidated shipments (Wood, 2001a). Even accounting for an increase in the percentage of import-export specimens since 1999 and from other countries to 10%, it remains likely that approximately 1 million specimens are exported from Sri Lankan waters. This estimate is higher than the logbook data calculation of approximately 500,000 specimens collected per year but similar to that from the buyers' interviews.

Table 7.12. Marine ornamental fish and invertebrates volumes exported per month by eight export companies in Sri Lanka calculated from data provided by export companies. Data for the 2009 – 2010 season. Figures in grey shading are the numbers provided by companies and those in white are calculated or estimated from the shaded figures. Blank cells are values that cannot be calculated from the data provided. Values given are minimums, with maximum values in brackets. The minimum values are used to calculate all other values.

Company	Large fish per box	Small fish per box	Shrimps per box	Boxes per shipment	Fish per shipment	Shrimps per shipment	Shipments per month	Marine fish per month (70% shipments)	Shrimps per month (30% shipments)	Total fish & invertebrates per month
A		50		15	750	1000	15 (20)	8250	4000	12250
B					900	1000	15	9900	4000	13900
C					700 (800)	1000	15 (30)	7700	4000	11700
D		20	100	10 (30)	200	1000	3 (4)	400	1000	1400
E		25 (50)	200	10 (50)	250	1000	15	2750	4000	6750
F	5	10	50	40	400	1000	15 (20)	4400	4000	8400
G				40	200	1000	10	1400	3000	4400
H					750	1000	10 (15)	5250	3000	8250
Totals							**113**	**40050**	**23000**	**67050**

7.3.8 Estimate of ornamental fish volumes exported from Sri Lanka from official statistics

A fourth method to determine the total volume of marine ornamental fish and invertebrates exported from Sri Lanka per year is via the official statistics provided by the Sri Lankan government, in particular the Sri Lankan Export Development Board. The Sri Lanka Export Development Board (commonly called the EDB) was established in 1979 under the Sri Lanka Export Development Act No. 40 of 1979, and now functions under the Ministry of Export Development and International Trade as the premier state organisation dealing with the promotion and development of exports. Their figures show the rapid increase in monetary value of the freshwater and marine ornamental fish trade during the 1980s and 1990s, these exports having stabilised at US$ 7-9 million annually since 1998 (Table 7.13).

Table 7.13. Sri Lankan official export statistics for aquarium fish (freshwater and marine fish). Source: Export Development Board (2010).

Year	Value (US$ millions)	Growth (%)	Weight (kg)
1983	0.28		No data
1990	0.68	142	No data
1995	3.3	385	No data
1996	5.6	70	No data
1997	8	43	No data
1998	8.1	1.25	No data
1999	7.9	-2.5	No data
2000	7.8	-1.26	1040942
2001	5.9	-24	803281
2002	5.5	-6.8	652167
2003	5.4	-1.8	703745
2004	7.46	38	794537
2005	7.56	1.3	863030
2006	8.88	17.5	898567
2007	9.06	2	765934
2008	8.98	-0.9	756073
2009	8.52	-5.1	882649
2010	8.11	-4.81	716875

According to Wijesekara & Yakupitiyage (2001), the marine sector is only 10% of the volume exported but 70% of the value in Sri Lanka so this information was used to separate the official export figures of marine ornamental fish and invertebrates from exports of freshwater fish and invertebrates in order to estimate the monetary value of these marine ornamentals from Sri Lanka. In 2010, the estimate of these exports would have been approximately US$5.7 million. This is greater than Wood's (2001a) estimated export value of US$1.5 million for Sri Lankan marine ornamentals, because Wood (2001a) estimated the percentage value of the marine sector at 20% not 70% as has since been shown. The average current export price of marine ornamental fish from Sri Lanka is approximately US$5.2 (Appendix E). If this average export price per fish of US$5.2 is taken and divided into the overall value of marine ornamental exports for 2010, one attains a total number of 1.1 million marine fish and invertebrates exported. This corresponds well to the estimates calculated from the data provided by buyers and exporters in Section 7.3.6 and 7.3.7 but is over double the estimate calculated from the logbook data at my study sites (Section 7.3.5).

7.3.9 Further data taken from buyer's logbooks and interviews with buyers and exporters

7.3.9.1 Mortality

The mortality rate of ornamental fish after catch is also difficult to estimate in terms of accurate figures. From the four southern villages' buyers' logbook recordings in the 2009/10 season, only seven fish were recorded as dead and they were from seven different fishing trips by seven different divers, two in Thalaramba and five in Kapparathota. Three fish were recorded as damaged over two trips carried out by two different divers. However, from my own recordings, made after far fewer shadowed fishing trips, I observed higher levels of mortality, which shows a tendency for village buyers and divers not to record all fish mortalities. From interviews and discussions, village buyers all admitted that fish die between capture and sale to the export companies, and cited 5% as an average mortality rate but the figure provided by different buyers across all sites ranged from 2% to 20% with many buyers speaking of between five and ten fish dying out of every 100 and 200 at their facilities daily. Moreover, all agreed shrimps have a ten percent mortality rate compared to the 5% for fish. This value depends on several factors: the number of fish in their care; the care with which divers catch the fish to reduce damage; whether the bag water is changed frequently and correctly as well as the resilience of different species and individual fish to withstand the stresses to which they are exposed. These values are considered true as long as fish are sold to export companies within three days of capture with buyers reporting that few fish survive after four days, especially if kept in plastic bags.

Older, more experienced buyers gave more details explaining that only fish damaged on capture might die, while undamaged ones could survive in their care for the few days before onward transportation. They believed that more experienced divers minimise physical damage to the fish, whereas usually the younger, inexperienced divers often try to sell damaged fish. Experienced buyers claimed they know whether a fish will survive after 24 hours and if not, they may return it to the sea. However, they maintained that it is impossible for divers to know this at point of fish capture and for them at time of delivery. All buyers highlighted the high mortality of poisonous fish species, such as the Ostraciidae (boxfishes); one cited that 75% of Ostraciidae die after capture because although buyers keep each fish in a separate bag, they can poison themselves due to the small volume of water in which they are contained.

All export companies hold the suppliers accountable for fish losses during transport from the coast but some also hold them accountable for fish mortality whilst in transit in their facilities pre-shipment. Buyers told me the average deduction is usually 10%, but buyers cannot verify this, even if some companies return dead fish, there is no guarantee they are “their” dead fish. Most buyers believe this value is inflated so companies can increase their profits by selling on fish for which they have not paid. Company representatives inspect fish at buyers' facilities before purchase and so buyers believe they make informed decisions concerning fish survival and therefore, if competent to select only healthy fish, the 10% mortality rate is certainly dubious.

Export company officials reported that on average mortality during transportation between the south coast and their facilities ranged between 1-5%, which was the same range in relation to the pre-shipment mortality rates at their facility. Although company officials emphasized these figures were rough estimates because no figures are recorded, they did stress that fish mortality was relatively low and they endeavour to keep it low. However, this contradicts the reports in interviews with fish buyers who said that often 10% of their sales are lost due to mortalities. Company officials further explained that most importers accept a 5% mortality rate without deductions from the payment but buyers were suspicious that exporters sometimes pass other deductions on to them. Most exporters stated the main factors for maintaining a 5% mortality rate at their facilities was due to two factors: their investment in the latest equipment for aquarium filtration to ensure optimum water quality for the fish and their accumulated experience in fish husbandry. For example, one company boss claimed he only bought fish that have been kept and treated with medication by the village supplier for at least one day because this increases fish survival during travel and prevents discolourations. He believes large fish losses are due to transportation delays during shipment.

7.3.9.2 Gender selectivity & size of fish caught

Capture of fish based on gender selectivity could risk imbalances between male and female ratios in the wild but from the logbook data there is little evidence except for the *Gomphosus caeruleus* (bird wrasse) which is selected based on its sexual polymorphism. Over all trips recorded in the buyers' logbooks, 27 females and 119 males were caught. These numbers relate to cash value with each female worth 40 LKR, whereas a male is worth 200 LKR. Other species selected on sexual differentiation, include, *Ostracion meleagris* and *Arothron hispidus* and some similar species of the families Tetraodontidae and Ostraciidae (pufferfish and boxfish).

Thirty-four species of fish and invertebrates from snorkelling catches were recorded by size and these size categories continue to be recorded along the market chain (Table 7.14). Only five species were recorded of adult size, whereas the others ranged between small, medium or large juveniles (Table 7.14). Only 698 fish and invertebrates, from the total of 22,302 collected by snorkellers, were assigned a size in buyers' logbooks. Only *Pomacanthus semicirculatus* adults were caught and recorded in large numbers (42), but as these are also valuable as juveniles they were recorded in various juvenile size classes. Those species always classified by size that are highly targeted in the trade are *Coris formosa, Novaculichthys taeniorous, Rhinecanthus aculeatus* and *Rh. rectangulus, Naso lituratus, Chaetodon collare* and *Ch. auriga* and *Acanthurus lineatus,* and were species most recorded in the separate juvenile size categories (Table 7.14).

Table 7.14. Marine ornamental fish and invertebrates caught and recorded in four size categories in buyers' logbooks. All other species caught and recorded were not given a size category in logbooks.

Species	Small	Medium	Large	Adult
Acanthurus lineatus	77	8	76	0
Acanthurus spp.	3	0	5	0
A. triostegus	2	2	0	0
A. tristis	1	0	0	0
Bothus pantherinus	1	0	0	0
Centropyge flavipectoralis	2	0	0	0
C. multispinis	0	0	2	0
Cephalopholis argus	1	0	0	0
Chaetodon auriga	20	4	3	0
C. citrinellus	6	3	0	0
C. collare	10	9	17	0
C. decussatus	1	1	0	0
C. kleinii	3	1	0	0
C. lunula	2	0	4	0
C. meyeri	2	0	2	0
C. plebeius	1	0	0	0
C. trifascialis	1	0	0	0
C. xanthocephalus	3	0	1	0
Coris formosa	39	60	34	5
Ctenochaetes truncates	2	0	0	0
Gymnomuarena zebra	0	0	5	1
Halichoeres marginatus	1	0	1	0
Labroides dimidiatus	7	1	0	0
Naso lituratus	1	13	46	0
Novaculichthys taeniourus	14	1	23	0
Pomacanthus annularis	2	2	0	7
P. semicirculatus	4	5	12	42
Pterois volitans	4	2	0	0
Rhinecanthus aculeatus	50	4	8	0
R. rectangulus	9	2	16	1
Scuticaria tigrina	1	0	0	0
Stenopus hispidus	1	0	0	0
Valenciennea sexguttata	2	0	0	0
Zebrasoma scopas	1	0	0	0
Total	**274**	**118**	**250**	**56**

7.3.10 Relations between the different levels of the market chain in Sri Lanka

The diagram below depicts the simplified form of the market chain in the ornamental fish trade in Sri Lanka (Figure 7.3). From interviews, discussions and considerable amounts of time spent with divers and village buyers in particular, and observing the complete process from fishing to husbandry to shipment over two seasons, I developed a clearer picture of the market chain as it is shaped by a myriad of human activities that affect, and are affected by, domestic and global as well as natural and social processes. Results and descriptions provided in this section come from participant observation at various points in the chain.

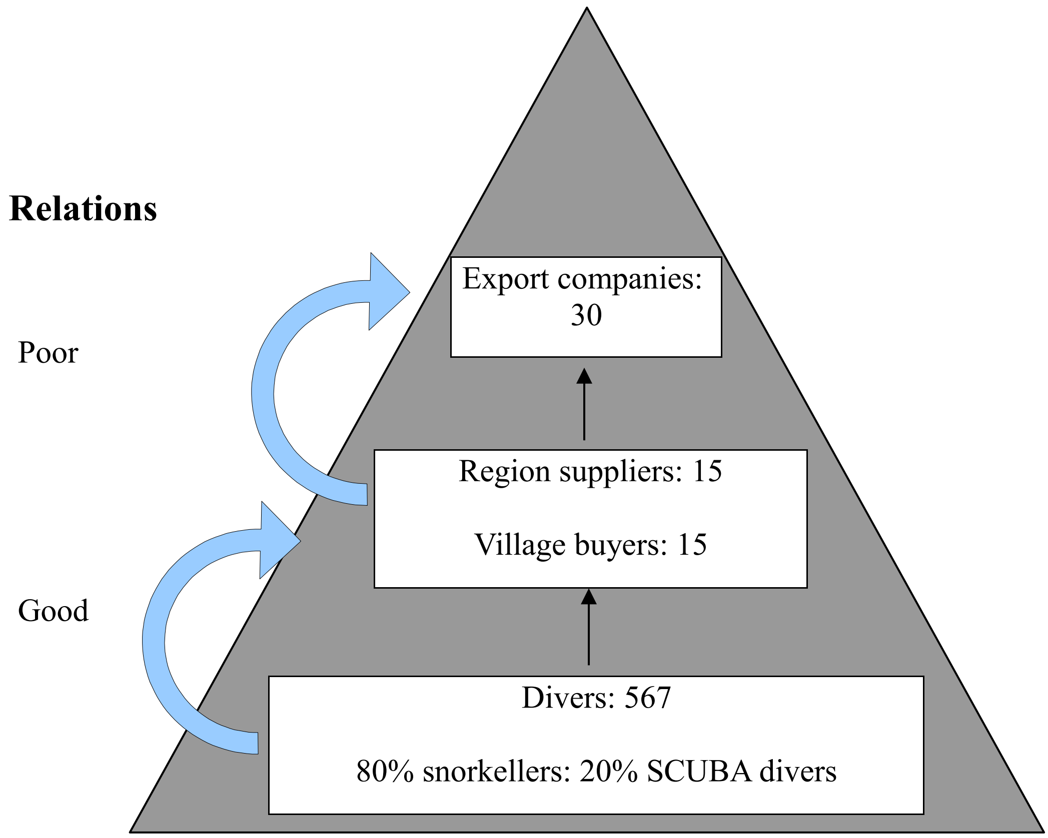

Figure 7.3. The basic structure of the marine ornamental trade market chain in Sri Lanka, with estimated numbers involved in each sector of the ornamental fish trade in the southern region of Sri Lanka. Source of numbers: NARA, Sri Lanka, (2010).

7.3.10.1 Divers and village buyers

Snorkellers are self employed and, as all the actors in the market chain, are reliant on the effective operation of each level of the chain for their livelihoods. They usually work alone and choose which village buyer to sell their fish to. SCUBA divers, however, work in teams of two or three; each for a particular village buyer and the profits of the catch made by the pair or trio of divers on a boat are split equally between the team of SCUBA divers after costs have been deducted by their buyer. Village buyers have one to four teams of divers depending on the size of their operation and often help with the initial costs of SCUBA kit purchases, which SCUBA divers pay off in fish catches over time. Buyers train their SCUBA divers in basic diving techniques and after only a few dives novices are left together to form a team and try to make a profit. Teams are not balanced with experienced and novice divers, as this will reduce profits of skilled divers.

Buyers are selective in which SCUBA divers they hire, only accepting those they trust and are therefore willing to teach and equip because they want to ensure the divers' long-term profitability. Some buyers expressed concern that a decrease in profits and equipment recently has meant they cannot currently increase their dive teams. As stated in Chapters 3 and 6, divers and buyers usually come from the same village, so relations are generally good which allows for a high level of trust between them. Buyers are one group of the middlemen between the divers and the users, hence divers must trust them to provide the optimum pay for their catches, even allowing them time to procure the best price from the export companies. On the other side, the buyers trust that divers will seek the species and sizes they require for orders and in the absence of orders, they will catch easy to sell, good quality fish. Buyers are known by reputation and selected accordingly; for example, those who pay on time or rapidly, those who give optimum prices and those who occasionally provide financial help to divers in hard times.

A further factor which supports relations of mutual trust between buyers and divers is the openness and transparency of most of their dealings. The homes and facilities of the village buyers are situated within the heart of each village, in accessible locations and divers claimed they are comfortable to go and ask for payment or make other requests. Divers help sort and package the fish and they can see for themselves whether all their fish have been sold, died or damaged. Divers often visit village buyers' facilities when export company representatives come to buy fish so they can overhear conversations with the exporters. The high levels of social capital (see Chapter 2.13.2.3) held by those within and originating from the village allow for this tight cohesion. Buyers work to develop reputations for fair dealings so that they may gain preferred dealer status, even to attract divers from other villages.

7.3.10.2 Divers, suppliers and export companies

In contrast, there is much distrust between divers and export companies. Relations between divers and the export companies are distant; although divers may risk their lives to collect the fish, the export companies do little to ensure their safety or provide better training because they do not consider these their responsibility. Indeed, they can dismiss accidents as poor judgements on the part of the *"uneducated"* diver or that divers know the risks when they choose the livelihood. Some even suggested diving in Sri Lanka is less dangerous than in the Philippines or Indonesia where diving with hookahs[29] and cyanide occurs. In cases of accidents, companies pay little compensation to divers' families although one company official admitted that over 30 SCUBA divers had died from diving accidents in recent years and another 30 had been paralysed after suffering from "the bends" (see Chapter 3.3.1). Where responsibility lies is difficult to pinpoint in a multi-tiered international trade, where ultimately the demand for these fish arises from hobbyists in foreign countries.

Overall the same distrust pervades the buyer-export company relationships. Various buyers referred to the export companies as *"cunning" "liars",* accusing them of *"cheating them"* and one described them as *"bad people, thieves!"*. Export company workers mostly do not originate or reside in the divers' villages and are sometimes of different religions and castes. This means a social basis for trust can only be fostered, over time, through their business dealings. The difference in wealth among the three groups – divers, buyers and exporters – also creates distrust, especially towards the export companies who are the wealthiest group.

Export companies conduct their business through the village buyers who complain that export companies cheat them by either not paying for high value fish, which the

[29] Hookah or airline diving is a form of diving when an air compressor onboard the boat delivers air to divers via plastic or rubber airlines. The divers hold the airline in their mouths to breathe, no SCUBA cylinders are used allowing freedom of movement and less skills needed to begin such diving. This type of diving is common among fishers in the Philippines and Indonesia as well as some Pacific Island nations, however the quality and maintenance of the gear is often low and risks of injuries and death from the bends is high.

companies claim die during transportation or under paying them for high value fish. They also claimed that sometimes companies break promises to collect fish, resulting in the death of fish and loss of sales. Some told of long overdue payments, which, if the export company goes bankrupt, as occasionally happens, owing money to several buyers sometimes as much as 40,000 LKR per buyer can have a knock-on effect for the buyers who might be similarly affected.

Older buyers told me numbers of exporters were fewer in the past, so buyers had much closer connections, like those of a family, with particular export companies who would provide diving equipment, financial aid, as well as firm orders with purchases guaranteed for all the fish. However, these arrangements meant divers and suppliers collected fish for a particular company that bought fish for lower prices resulting in companies exerting much control over their associated buyers until eventually buyers traded with other companies thus avoiding this tight control. Today export companies are viewed as businessmen purely interested in buying the cheapest and best fish from any source; few help with equipment or provide financial assistance. The increase in the number of buyers in the south, especially since the tsunami, has also contributed to the changed relationships between buyers and companies which has led to heightened levels of insecurity for the trade at village level. Suppliers today have to cultivate close relations with different companies or trade with many separate companies to sell their fish. In addition, the annual boom and bust of new companies hinders buyers from fostering strong ties with companies and from developing mutual trust and respect. Many new companies tempt buyers from established companies by offering better prices that they cannot sustain over an entire season, often leaving the buyers in considerable debt. According to the older buyers such cut-throat practices are why several “good” companies have gone bankrupt. Some buyers preferred the established large companies with whom they have had strong links over time while others prefer the newer, small companies eager to initiate positive relations. All buyers talked of trusting only a few companies, with delayed payment only acceptable from this trusted few. Dealings with untrustworthy companies are limited to same day payment for delivered fish.

Few buyers understood reasons for small or no payments for fish because they, as the divers, believed export company representatives got richer while they remained poor. SCUBA divers who regularly dive to depths of 40 m multiple times a day, often with limited training and sub-standard SCUBA kit complained of export companies' uncaring attitude to the dangers involved. Many divers believed the wealthy export companies should pay for sound equipment, adequate training and fair compensation in the case of injury or death.

From the buyers' perspective, the companies appeared to be free agents with no governmental control and therefore no responsibility to their suppliers. If management regulations are in place, buyers claim the export companies undermined them in various ways; for example, by continuing to buy "*wrong*" fish - rare species or wrong sized specimens. Some buyers maintained they were pressured to supply certain companies with these "*wrong*" fish, whereas others blamed certain buyers for supplying the companies with the "*wrong*" fish only to increase their income. Not all buyers to whom I spoke did this but without a set of agreed regulations and an overall willingness to comply, the self interest of the different bodies will have deleterious effects on both the reef and its inhabitants. Where good relations existed between suppliers and export companies, it was usually because they had traded successfully together over many years or because a company had helped a diver make the transition to buyer. One or two of the wealthier suppliers would not critically examine the export companies' practices with me, which was in stark contrast to many other poor and wealthy suppliers.

Only two of the nine export companies, whose owners and managers I spoke with, admitted that relations with suppliers could be difficult at times. From their perspective, these difficulties revolved around suppliers' belief that companies were making large profits, as well as their disagreements over fish pricing. In the views expressed by these two companies, suppliers had become corrupt with scant regard for the integrity of the system; they claimed suppliers only collected high value species in irregular flurries for quick profit, rather than providing a steady supply of a wide range of fish. Concern for closer interaction between divers, suppliers and the export companies was often expressed. However, there was clearly a lack of understanding between these three groups which leads to entrenched misconceptions that only further undermine the relationships as expressed by most divers, who did not understand these constraints and were accused of catching anything and everything they saw, hoping to make money from all of their catch rather than being more selective. The divers were not concerned if the exporters were left with excess stock, as they were paid immediately, but the exporters have to sell excess fish cheaply to clear their stocks and were pressured to fulfil at least 80% of orders from foreign importers to whom they felt obliged to give discounts on large orders of certain species. One company official gave an extreme view of the divers and some suppliers, which exposes underlying tensions, when he said these two groups are *"not educated and not from a proper background, these people they want to get money, drink and be finished!"*.

7.3.10.3 Export companies and foreign importers

It takes many years and many transactions to foster trust and reliability between export companies and foreign importers. Companies spoke of the need to provide discounts, offers and free samples to attract custom and promptly and efficiently deliver the orders to maintain continued business. Many exporters have had bad experiences with foreign importers in particular relating to non-payment for fish shipments, resulting in millions of Sri Lankan rupees of bad debt. There is no guarantee that foreign importers will pay as there are no written agreements and until recently, no advances were paid, but even now it is hard to trace foreign importers if payment is not received. Some exporters insisted on advance payments rather than sell fish on credit and attended trade fairs to share contact details and foster closer relationships. Most exporters knew that importers sell fish for increased prices to retail outlets, but they understood extra costs were incurred by wholesalers in handling the fish and did not complain that their profits were small.

7.3.11 Power of the buyers and exporters

Many of the village suppliers belonged to the Southern Ornamental Suppliers' Association, which met monthly in the season and every few months at other times to discuss and resolve issues. Approximately 30 export companies belonged to an association known as the Association of Live Tropical Fish Exporters of Sri Lanka and occasionally meetings between these two associations occurred to voice concerns over issues such as fish prices, commission rates or box charges for suppliers. The suppliers' association was important for providing suppliers with a platform from which to interact with the export companies and this was summarised well by the secretary of the suppliers' association, Damnika:

> *"We can often challenge the companies through the association, alone we have no voice or power but together we do".*

The suppliers' association succeeded in procuring 15% instead of 10% commission from the export companies and a higher rate of 100 LKR per box sold, rather than the 75-90 LKR per box of the past. However, although the association had not been very successful since it lost Japan International Cooperation Agency (JICA) backing for small loans of up to 5000 LKR, suppliers still remained largely positive, as did the export companies who preferred to conduct business through this association rather than interact with many separate companies.

Members of the exporters' association were meeting every three months, to discuss their concerns, such as agreeing fixed prices per species of fish with government bodies. Proposals could be put forward to the exporters' association, such as placing size limits on fish bought and sold and the suggestion, not yet agreed upon, to ban the collection of ornamental shrimps during one month of their breeding season, as accepted for lobsters in Sri Lankan waters. Matters concerning reef and fish conservation were normally discussed at the less frequent joint meetings between the suppliers' and exporters' associations. Many smaller export companies to whom I spoke found no benefits in joining the exporters' association because it cost to join and they claimed serves the interests of the large well-established and well-connected export companies.

7.3.12 Fish pricing system

During focus groups, divers in each of the three main study villages were asked to rank, in order of priority, the factors that affect their job and livelihood. Of the eight factors provided, changes to the fish pricing system received a score (see Chapter 9.3) in all villages that rated it a mid-level concern, with many divers and buyers complaining stable fish prices had changed little in decades and that contrasted with the rising energy costs which most buyers claimed are a bigger reason for falling profits than lower fish catches. However, price data gathered from divers, buyers, export company price lists and prior studies show that both export prices and diver/ buyer fish prices had increased in the past 25 years (exports) and 15 years (divers/buyers) but these have remained stable for nearly ten years now (see Appendix E and F). Village buyers argued they had little control over these fish prices as they were dictated by the export companies who blamed the prices on foreign importers as well as the stochastic nature of market forces. An example of such unpredictability is when supply of certain species such as *Lysmata amboiensis* (banded cleaner shrimp) were high during certain periods, causing the price to drop steeply from the usual average of 300 LKR to 75 - 100 LKR for several weeks as happened in January 2010. Buyers and divers earned less as a result and were disgruntled that their catches did not realise the usual higher prices. While the price of many fish species changed little or never during a season, the price of the most lucrative species could suddenly change, causing much annoyance, particularly when prices dropped.

Another factor affecting fish prices in Sri Lanka was the issue of the different collecting regions. When the south coast was in season, the organised nature of the permanent buyers and divers who were resident in the villages allowed them to maintain standard prices and fight to ensure a fair deal from the export companies. Companies paid lower fish prices for fish caught off the east than the south coast; the reason given was that larger quantities of fish were caught there but buyers claimed it is because they were only temporary residents in the east and had no association to represent them. Although the export companies exploited this by dealing directly with the divers, they might earn relatively more overall. As one buyer told me, in the east you find a mixture of ethnicities, religions and interest groups, therefore it is difficult to establish one group that speaks for all divers. Consequently, during the south-west monsoon season, prices drop nationwide to match the fish prices in the east. Buyers who remain in the south and attempt to sell on fish caught there in the out-season were finding it hard to cover their costs due to these lower prices particularly as it was a time when lower quantities of fish are caught in the south. For example, if an *Acanthurus leucosternon* (powder blue surgeonfish), normally worth 300 LKR, fetched only 150 LKR on the east coast, this price became fixed nationwide during that period.

Buyers knew and often contested fish prices paid them by export companies. In contrast, most buyers did not know what fish prices were paid between export companies and foreign importers which they believed was kept secret. However, a few buyers told me they did know the pricing system all along the chain and found it unjust. For example, one buyer told me he received US$3 for one *Acanthurus leucosternon* (powder blue surgeonfish), but it was sold on for US$8 and he believed that hobbyists in the West pay US$20 for the same fish. Despite knowing that exporters and importers have increased costs to cover, he still believed the profits were larger than necessary and should be shared more equitably. Buyers learn of the price differentials from tourists who tell them the cost of certain species of fish in retail outlets in their home country.

One buyer said most of the profits are made by the large buyers and the export companies and that small buyers and divers get very little of the share. He said it was obvious and then laughed:

> *"Export officials drive luxury cars but I have to walk to get around!"*

One export company representative admitted that if his suppliers are *"educated people and...they can find out the prices on the internet"* he gave them fair prices close to the export price while with others he could make more money. In defence the export companies defended the fixed prices in terms of their high costs for transport and expensive aquarium facilities, paying salaries and rates as well as absorbing losses incurred from suppliers' orders or from some foreign shipments that are frequent in Sri Lanka. These export companies reminded divers that they had almost no costs once in possession of their diving kit and buyers that their costs were low in comparison. Companies also told suppliers and divers that air freight costs were high and that Sri Lankan fish prices were higher than other source countries, which reflected the fact they were hand and net caught, rather than with toxins like cyanide in the Philippines and Indonesia, as well as the high costs of labour, fuel and packing. With Sri Lankan prices higher than most other competing source countries, any further increases in the price would reduce the demand from foreign importers for Sri Lankan ornamental fish. As one company official explained:

> *"….we cannot keep increasing the price as we are competing on the international market".*

Some of the more established export companies complained of new, unskilled and inexperienced companies that they claimed altered the price structure without mutual agreement, did not care for the fish in a professional manner, resulting in higher mortality rates along the supply chain, which was tarnishing Sri Lankan exporters' reputation. Although the export companies, would like as a group, to formulate an agreement concerning fish pricing, it was difficult to achieve because according to World Trade Organisation (WTO) rules no price fixing of products is allowed, and so in lieu each company sets its own prices and fierce competition ensues. Moreover, for example, the biggest marine ornamental export company in Sri Lanka, Aquamarines International, remains outside of the Association of Live Tropical Fish Exporters of Sri Lanka, which means they are not bound by that association and pay only a 10%

commission to suppliers rather than the 15% that other export companies agreed to pay. Several informants, from buyers to government officials, believed that close ties between Aquamarines International and the government of Sri Lanka has provided them with the sole permit to breed and export seahorses, whose harvesting from the wild is prohibited by the Sri Lankan government in accordance with Convention on International Trade in Endangered Species (CITES) regulations.[30] Furthermore, many others involved in the trade asserted that these close political ties had enabled Aquamarines International to become the largest company and operate in its own interests.

7.3.13 Business trajectories

Overall, divers and buyers, claimed they struggled to make profits each year. The tsunami evidently had a sharp impact on trade and since that time their earnings were decreasing and the subsequent increase in the number of buyers and divers had prevented fish price increases as competition was so high. Inflation was relatively high in Sri Lanka and the Sri Lankan rupee continued to lose value over time (Figure 7.4), which along with rising costs, presents hardships for the buyers, especially when fish prices do not track inflation (See Appendix E for 1985 to present price comparisons).

In contrast, when I asked export companies about their business trajectory, they described how their businesses were doing well. Even relatively new companies said once established, after one to two years, business tended to be good and some said they were managing without loans if they were small-scale. The manager of the longest running export company in Sri Lanka, with nearly 50 years of operation, said fish prices were 50% higher now than when he started, but conceded that this was mainly due to the changing value of the Sri Lankan rupee. Export companies have always recouped and continue to recoup their losses from the fluxes of the Sri Lankan rupee against the US dollar because export companies earn foreign currency yet their costs are paid in local currency (LKR). Therefore companies would keep foreign exchange in cash and only when they experienced losses and the Sri Lankan rupee had weakened against the dollar, would they exchange it for Sri Lankan rupees. In this way they could invest or repay local debt and/or costs, Figure 7.4 shows rupees per dollar value increased significantly during the 1980s and 1990s.

30 2000 coral species are prohibited or restricted from trading under CITES regulations. In Sri Lanka all corals are protected by the Flora and Fauna Protection Act (1993) as well.

Many exporters complained of the rising costs from increased commissions to suppliers, to rising fuel and packaging and electricity costs. Those with their client base in Europe and North America were concerned about the recession, which had caused a recent drop in ornamental fish sales. There were also more restrictions and paperwork and, in turn, costs in exporting to Europe. Depending on the breadth of their client base, many cannot immediately make up the shortfall from the rising affluent regions of the world, such as the Far East. Companies, however, with clients predominantly in the Middle and Far East, had not noticed a reduction in demand or sales. Others were employing methods to attract further custom from abroad, such as more import-export of fish from locations such as the Maldives and Australia in order to stock fish that were not indigenous to Sri Lankan waters which they claimed help retain important clients who preferred to buy all ornamental fish from one exporter. Captive breeding was also emerging as an alternative way to meet the constant demand (see Chapter 9.4.2.3) and currently, Aquamarine International in Sri Lanka was conducting this successfully with *Hippocampus* spp. (seahorses) and *Amphiprion* spp. (clownfish). Employees of two unrelated companies told me these species were in high demand and generated extra profits over and above the sale of wild caught fish.

With the end of the civil war in Sri Lanka in 2009, many companies expected easier access to the north and east coasts where aquarium fish were reported to be in higher abundance than in the south. More airlines were also flying to Colombo, providing more flights to export fish to both old and new markets.

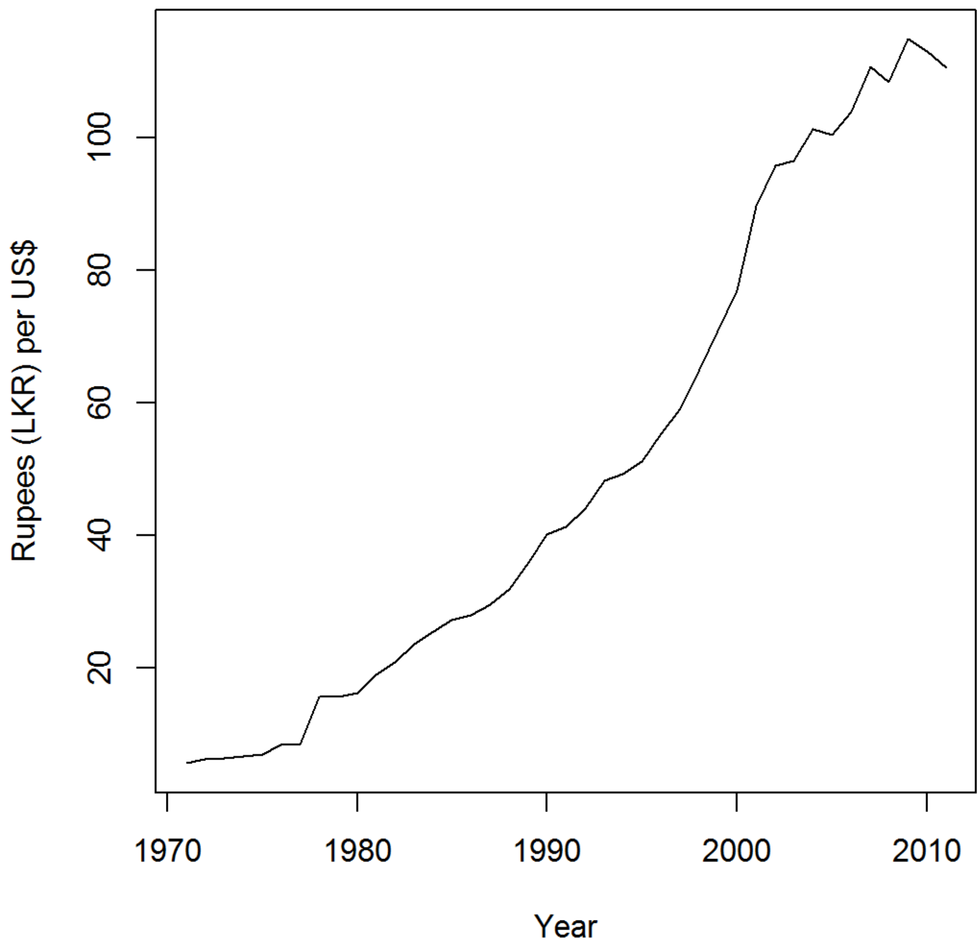

Figure 7.4. Value of the Sri Lankan rupee (LKR) against the US dollar between 1971 and 2010. Source: Officer, (2011).

7.4 Discussion

7.4.1 Comparison of snorkel catches among sites and buyers

Divers' catch results taken from buyers' logbook data corroborate direct observations of snorkel catches in Chapter 5.3. Kapparathota showed the highest fish catches per diver trip and also slightly higher species diversity within that catch compared to all other sites. Similarly to the direct observations, Polhena showed the lowest fish catch per trip. This further agrees with the results in Chapter 6.3 that the reef habitat and fish abundance are healthiest in Kapparathota and least healthy in Polhena. There was a positive correlation between the catches and earnings at each site.

Comparing the average number of fish caught, the number of species caught and the average earnings made per fishing trip by village buyer helped validate these catch volumes per fishing trip both within and across sites due to there being multiple buyers in most sites. In Polhena some buyers bought roughly double the number of fish compared to other buyers in the village over the 2009/10 season, yet the number of unique species bought did not differ significantly between these buyers (Tables 7.4 & 7.6). In contrast in Kapparathota and Thalaramba the more fish bought by a buyer resulted in a correspondingly higher number of unique species bought. This is potentially an indication of the lower ornamental fish diversity on the nearshore reefs in Polhena, compared to Thalaramba and Kapparathota. Furthermore, a greater number of different species were caught in Thalaramba and Kapparathota than Polhena, even though a similar total number of fish were caught at all three sites. This agrees with results from recent studies concerning the status of the coral reefs in southern Sri Lanka, which found Polhena's nearshore reef as one of the most degraded (Rajasuriya et al., 2005a; Öhman et al., 1993; Kumara et al., 2005).

SCUBA catch statistics show that the volume of fish caught and hence earnings are 70% of the trade whereas snorkel caught fish only provide 30% of the volume and earnings. However, buyers do not show great overlap between the two streams of the trade, with only the highest volume buyer of snorkel catch also being the highest volume buyer of SCUBA caught fish. The four next highest volume buyers of snorkel caught fish are either not SCUBA caught fish buyers or buy low volumes of these fish. Many buyers focused solely on SCUBA or snorkel catches and relatively few dealt in both. Another difference from the snorkel caught fish sector are the costs, which reduce net earnings by one third to one half of total SCUBA earnings. Despite this, the potential earnings are, on average, six times higher than snorkelling for ornamental fish and this encourages many snorkellers to become SCUBA divers. As is to be expected, the skill of each SCUBA diver and his team influences the amount each diver earns. The lowest net earnings per diver were among dive teams that comprised younger, less experienced divers and/or divers who do not dive to depths greater than 30 m to avoid further incidents of “the bends”, whereas highest net earnings were among divers who dive to depths > 30 m to find valuable species and are known as experienced and skilled divers.

As explained in Section 7.3.2, the prices for marine ornamental fish vary between 5 LKR and 900 LKR per fish depending on the species which only heightens the highly selective nature of the fishery, as divers actively seek the most profitable fish. In comparison, prices of aquarium fish in the Maldives in 1989 varied, by less than half that, by a factor of 100. The highly skewed price differential in Sri Lanka is likely to incentivise divers to catch specific high value fish to a greater degree than in other countries such as the Maldives (Edwards & Shepherd, 1992). A concern among marine conservationists is that focused searching for rare species by fishers makes such fish increasingly vulnerable and potentially rare which is the case among ornamental divers in Sri Lanka (Chapter 5) and yet detecting local depletions of even charismatic marine species, such as *Bolbometopon muricatum* (bumphead parrotfish), is low (Dulvy & Polunin, 2004), which means monitoring such reductions in abundance is difficult.

Using the buyers' informal data collection system for recording fish catches has proved to be a useful way to help record catch and effort data because currently, most buyers' logbooks are accurate in terms of the data they record because the information is important financially as each entry is an irrefutable record that fish were traded on a certain date between buyers and divers and also between buyers and exporters. All outstanding debts are traced through the logbook and I rarely witnessed a disagreement between a diver and a buyer concerning these records.

However, there are three main drawbacks to relying only on the logbook data. Firstly, buyers only record successful fishing trips in their logbooks when fish are caught and bought by them. Secondly, caught fish sizes are recorded only in general categories (Adult, Large, Medium, Small) and even then only for certain species. Thirdly, buyers rarely record morbidity data whether the death of the fish is due to divers' mishandling or while at the buyers' facilities awaiting collection. For the buyers' logbooks to become a main source of catch and effort data all trips and fish numbers must be systematically recorded.

Despite the three caveats above there is much potential for collaboration with fish buyers to utilise their data rather than attempting to introduce new methods of data recording, which may not be either easily accepted or implemented in such communities. Many studies concerning the ornamental reef fish trade across different countries, deplore the lack of recorded data concerning actual numbers and species of fish collected (Wood, 2001b; Pyle, 1993; Tissot et al., 2010). However, the records shown in this study provide an example of such data, accurately recorded with many key measures included for scientific monitoring. If buyers were encouraged, possibly via a system of incentives, to record other forms of data in a similar way, it is likely these data would also be accurately recorded. A recent study on the Hawaiian ornamental trade used divers' fish invoices as data to calculate catch per unit effort, which demonstrated that informal data can be thus used (Stevenson et al., 2011). If more community management and self regulation is the future for the ornamental fishery in Sri Lanka, it is important to incorporate all current good practices and local methods of data collection into the plans. The importance of local knowledge and record keeping through fishers' logbooks as well as any other means of local data collection has been stressed in other coral reef fishery studies (Jennings et al., 1995).

Another area of local knowledge that I witnessed is the skill of many buyers, and some older divers, in fish husbandry which should be shared amongst the village as a way to further reduce mortality, despite the low-technology gear available. Currently, new buyers often move through a cycle of trial and error rather than learning directly from experienced buyers. The incorporation of these local knowledge and skills in future management schemes is discussed in Chapter 8 and 9.

7.4.2 Catch and trade volumes estimates

The four methods used in this chapter to calculate an overall estimate of the volume of marine ornamental fish and invertebrates caught in, and exported from, Sri Lanka have generated two levels of estimates. The first method, derived from extrapolating the logbook data of snorkellers' and SCUBA divers' catches to the scale of the whole country generated a lower estimate of 427,000 fish and invertebrates captured over one year. The second estimate, calculated from the interviews with buyers in the southern region, accords more closely with the approximate estimate of one million fish and invertebrates exported in 2010 derived by the third and fourth methods. However, the first method uses a large-scale extrapolation of the figures, recorded from buyers' logbooks, in only four villages and from only certain buyers who were willing to share these data, which therefore does not represent the majority of the fish catch overall, and so leaves this estimate somewhat dubious and at best rather low. All extrapolations also have to be treated with caution, especially as large areas of the country were not sampled in the study.

The second, third and fourth methods used in this chapter to calculate export volume estimates produced an overall yearly estimate of approximately one million fish and invertebrates. The estimate from the export company data represents the lower estimate and was calculated using the minimum values of the range of average values I was provided by the companies and the estimate from the buyers was mean values of fish processed per day, and a mean price per fish was used for the official statistics calculation. These higher level estimates are approximately double that generated from the direct logbook data, yet these higher estimates could be more accurate figures. The same reasons for caution in the first method are applicable to these higher estimates of export volumes. Using the exporters' data and official statistics removes the need to extrapolate for non-sampled regions, as in the first two methods, because these latter data are generated from all ornamental collecting regions of Sri Lanka and so can be consolidated as national export figures. Only an extrapolation to include the total number of exporters and to convert the monthly data to yearly data was performed using this method. For these reasons it is more probable that the number of marine ornamental fish and invertebrates exported from Sri Lanka each year has increased five-fold since 1984.

However, the estimates made from the official statistics and the export companies may still also be low estimates for several reasons. Firstly, the official statistics do not record accurate numbers of individual fish or species exported, therefore the simple use of an average export price is an imperfect method and may have underestimated total fish and invertebrates exported, particularly as many high volume species are also high value species, such as ornamental shrimps. Furthermore, it is well known that official trade statistics within the aquarium trade globally are under-reported for a range of reasons (UNCTAD/GATT, 1979). These include the fact that small shipments, though common, are often not recorded; payments in cash are often not recorded and therefore not taxed, which is a reason for businesses to so co-ordinate their shipments.

If it is assumed that under-reporting of export sales occurs, and the official statistics lack accurate numbers of fish exported, then it is likely that the official export volumes will be lower than actual values which means a higher estimate than the official statistics is more likely. The data from the export companies contained a representative sample but was still only perhaps one quarter of all registered ornamental fish export companies in Sri Lanka; therefore this estimate may be at the lower end of the range. Additionally, some companies were reluctant to provide accurate details of their shipment volumes, perhaps, as is relatively common in Sri Lanka, not wishing to declare all their earnings, particularly to an outsider, (S. Gunasekara, pers. comm.), and so their figures may be low range figures compared to actual export volumes.

Additional data collection and monitoring are required to distinguish which estimate is the most accurate. However, the volumes calculated from the buyers' information, as well as from my directly collected catch data for the southern region, suggest that at least double to triple the number of fish and invertebrates are collected in that region than were collected from all of Sri Lanka in 1984 (Wood, 1985). However, there is nothing unusual about a large increase in overall collection and export of marine fish and invertebrates from Sri Lanka since that date, particularly taking into account the increased diver numbers and availability of improved diving gear. Perhaps also, Wood's (1985) estimate, which was calculated from official export statistics and using 15% as the volume of marine exports of all ornamental fish exported, may well have been an under-estimation. However, whether overall export volumes have increased, decreased or remained constant since 1985, divers in southern Sri Lanka have made clear (see Chapter 5.3) that catches and earnings for individuals have decreased over that time, especially for snorkellers. The notion that increasing the volume of trade will benefit everyone within the market chain, which is the hope of the ornamental fish industry and the Sri Lankan government, appears elusive for the divers and small buyers, in particular whilst the trade and supply chain in Sri Lanka remains in its current form.

7.4.3 *Relations among all sectors*

The examination of the interactions and relations along the supply route is of significance because it reveals that the market chain, in its present form, is not advantageous to those at the lower end of the supply chain. It is a dynamic and unpredictable global system where trust and reputations are easily lost between those involved at each stage of the chain at local, national and global levels. Interviews reveal that if foreign importers receive bad quality fish, they may refuse to send advance payments or not pay at all if the the experience is repeated. If export companies have to operate without advances or sufficient foreign exchange earnings they might not pay their suppliers on time who in turn lose confidence and may turn to other export companies, or send only low value fish. Co-operative relations are thus inhibited, giving way to destructive and opportunistic behaviours. This is a common feature of any supply chain and research concerning a manufacturing supply chain discovered that changing levels of collaborative or opportunistic behaviours does influence exchange relationships and affect the current arrangements of the system in non-linear and dynamic ways (Wilson, 2006).

Both suppliers and companies are ideally looking for one partner with whom they can deal exclusively but this is impossible at present due to the way the Sri Lankan system has evolved. The increase in population of Sri Lanka and the decrease in subsistence livelihoods inland has attracted people to the coast; consequently, there are far more divers, more village suppliers and more companies than before (Wood, 1996). At all three levels, some individuals operate sporadically or part-time, which makes controlling and monitoring the fishery more difficult. The imbalances in size and operation of the buyers and export companies affects the relations among these two groups. The larger export companies are more firmly established and reliable, but mostly deal with large overseas orders and consequently offer lower unit prices than smaller companies that place smaller orders. Small companies do not need fish every day in the main supply season as they despatch fewer and smaller shipments thus they cannot guarantee high prices to their divers and suppliers.

The system is dynamic and extremely diverse in terms of variation in fish throughputs, pricing, payments, methods and time-frames as well as the unpredictability of the marine environment. All these factors mean consistent, steady supplies of required amounts and types of fish to the end users are improbable. Guarantees of satisfactory monthly earnings and good relationships within and across the chain are also unlikely. Indeed, buyers', export companies' and previous divers' associations, have grown to combat levels of uncertainty in the system, to absorb the worst set-backs and to attempt to regularise some aspects of the process. But associations among suppliers and divers weakened after the 2004 tsunami, mainly because of the influence of new entrants at all levels of the chain and the drop in individual catches as a result of the tsunami.

Export companies are struggling to adapt to the increase in suppliers since the tsunami as they are no longer supplied by one or two trusted suppliers, they exert less direct control now over suppliers. Nevertheless, companies prefer having several suppliers to ensure their fish orders are always covered or if relations sour temporarily with one supplier, they can easily turn to another. The images that the export companies, the buyers and divers have of one another tend to the stereotypical and result mainly from the wide divide between wealth and lifestyles, which is hardest for those at the bottom of the chain, the divers, who have low incomes, insecure, dangerous livelihoods and unpredictable futures, with no voice.

7.4.4 Fish pricing

All export company officials spoke of pressure to maintain low fish prices to attract foreign importers while also placating divers and suppliers who want to earn more for each fish caught and traded. There are distinct imbalances as to where profits are made along the market chain, which render many of the arguments about greater costs further up the chain redundant. It can seem unjust that many divers risk their lives and live close to the poverty line, while export companies who trade with the rich end-user live comfortably in Colombo. Sri Lankan fish command a premium price when compared with ornamental fish from Philippines and Indonesia, two of the major suppliers of marine ornamental fish globally, because these countries utilise destructive methods, particularly cyanide, to catch ornamental fish (Mous et al., 2000; Rubec et al., 2001).

7.4.5 *Dynamics of power and debt within the market chain*

The scenario of sustainably and ethically sourced marine ornamentals in Sri Lanka seems improbable while the power relations throughout the market chain remain skewed. Nationally, the export companies hold the most power; in competition with other companies globally, they decide the fish prices, whether to give financial assistance or compensation and with whom they conduct their business. Despite strong grievances, divers have no united voice or platform from which to speak or negotiate with the other groups. Their only channel is through the buyers' Southern Ornamental Suppliers' Association, but this meets infrequently and does not have much significance. However, one of the largest single problems within the system is debt. It erodes the power of the buyers and divers to debate issues with the companies.

The entire system is run on debt; money is owed at all times at all levels from one group to the next. Most buyers pay divers rapidly, otherwise in the future the divers will sell their fish elsewhere. However, buyers are not paid rapidly by the export companies yet have to pay divers each day for their catches. Companies are usually awaiting payment from foreign importers so do not pay the buyers until they are reimbursed for their shipments. Foreign importers are awaiting payment from the retail outlets and hobbyists to whom they sell. In addition there are loans and advances between different levels of the trade. Some foreign importers pay advances to export companies to ensure the shipment; however, this is only done between trusted companies and importers and is the exception not the rule. Export companies often pay advances to their suppliers to keep them loyal through debt. Buyers often pay advances or loan cash to divers in need of spending money, once more ensuring their loyalty through debt. Many divers pay this debt off with fish, as do buyers to export companies. With high levels of debt accumulating at all levels of the chain, and limited ways to pay off debts, the chances of significant losses that bankrupt companies or buyers or strip divers of their assets are relatively high. As divers and buyers, relatively speaking, live with heavy debt and are reliant on mostly seasonal, irregular and insecure incomes, it is extremely unlikely they would confront those groups to which they are indebted and that wield greater power in the supply chain about issues of inequality in the system. Many divers and buyers are nervous of destabilising a close connection with a buyer or an exporter, upon whom they have become totally reliant through these systems of debt and repayment. The system of debt thus locks participants into the current arrangements of the market chain.

7.4.6 Future ways

In order to address the problems that have been apparent since the 1970s (Jonklaas, 1985; UNCTAD/GATT, 1979; Wood, 1985) changes are needed to the overall global international trade in marine ornamentals; changes to improve the image of the trade, sustain the industry and preserve the coral reefs and their fish for the future (Wabnitz et al., 2003). In order to redress some of the inequality and imbalances in the system, it is conceivable that stronger forms of diver, buyer and exporters associations need to develop in Sri Lanka, as they have proved to be effective in sustaining reef fisheries communities elsewhere including Belize (Gibson et al., 1998) and Kenya (Obura et al., 2002). The strong bonds, high social capital and close-knit communities within the fishing villages in Sri Lanka suggest that closer connections could be forged between divers and buyers, who if more united and sure of their needs and concerns could gradually help to shift the balance of the trade to one that is more just, equitable, responsible and accountable.

Frameworks and practices drawn from those associated with Fairtrade products could be adopted to guide all relevant actors in their decision making to improve the efficiency and effectiveness of the market chain. Various Fairtrade products are enjoying rising popularity among consumers in the developed world (Raynolds, 2000), who are willing to pay more in the belief that those at the furthest point of the chain will receive a fair wage and satisfactory working conditions (Arnot et al., 2006). This underpinned schemes like MAC during the 2000s (Shuman et al., 2004) but the main reason that MAC failed was that CITES, and similar groups, added so many stipulations to the marine ornamental trade that the costs and bureaucracy became too elaborate to support it. Lessons have been learned from such initiatives; The GreenFish Initiative (Cooper, 2012) eager to avoid these shortcomings, suggests a more incremental change to regulations and requirements of all the trade chain actors. Sri Lankan fish are generally healthier and in better condition than the majority from Asia, and as efforts for sustainable certification schemes are re-launched, hobbyists are likely to face price increases (Cooper, 2012), which are unlikely to exclude Sri Lanka from world markets. Furthermore, these schemes have the potential to maintain global trade levels as well as to alleviate the power and wealth gaps within and across the market chain. However, to date The GreenFish Initiative has struggled due to lack of funds, time constraints and industry resistance (Cooper, pers. comm.).

Nevertheless, steps can be taken by those involved in the trade in Sri Lanka to readdress the imbalances and poor practices. A reliance on such global schemes to heal the dysfunctional system is ill-advised and reconfigurations of power, profits and interactions across all levels remains the first priority, whether such sustainability schemes are adopted or not. In other global supply chains, such as the food industry, more pressure is being applied for greater corporate social responsibility (Maloni & Brown, 2006). In terms of the ornamental fish trade, such pressure might come from changing consumer perceptions which would force greater information flows and transparency across all levels of the market chain. One articulated hope was that fewer corrupt practices can survive when more and better information is available.

Furthermore, to move from a purely market-led management system that has controlled the trade domestically and globally since its inception is urgently required because the promised trickle down effects have not materialised and moreover, the essential natural capital is eroding rapidly. As the north and eastern coasts of Sri Lanka become more accessible, with the termination of hostilities in those areas, a similar trade pattern is inevitable, with the repetition of the deleterious effects currently experienced along the southern coast of Sri Lanka, unless there are major reforms. Attempts to manage this fishery in Sri Lanka in the past and alternative methods of future management are discussed in Chapter 8.

Chapter 8

Political ecology and governance of the ornamental fishery

8.1 Introduction

8.1.1 Political ecology of the ornamental fishery

Political ecologists believe that the reformist approach of liberal capitalism has hit an impasse with current environmental problems (Dryzek, 1992; Adger et al., 2001). As explained in Chapter 2.15, overall political ecology disagrees with the World Bank, and other such global institutions, that environmental degradation and social injustice is due to policy failures, but rather their sources lay in the effects of broad political and economic forces. However, the hegemony of the global capitalist system is such that these alternative explanations are rarely considered (Pepper, 1993; Robinson, 2004). Some propose a solution whereby local level decision-making by grassroots actors replaces the power of non place-based actors, such as government, monetary institutions and global companies that should then take a supportive role (Dryzek, 1987).

Pathways to sustain socio-ecological systems (SES) are intertwined with the nature of governance. Both how problems and solutions are framed by different actors affect how dynamic systems of sustainability will organise in terms of risk, uncertainty, ambiguity and ignorance. Similarly, power relations and political influences also affect the relationship between modes of governance and pathways to sustainability (Leach et al., 2010). Despite its long history and noticeable success in many fisheries worldwide, participatory governance is an innovative idea and direction only recently introduced by the Sri Lankan government within the fisheries sector. In this chapter, the political influences, governance methods and changes in management of the marine ornamental fishery in Sri Lanka are explored to shed light on the various connections between the various actors and identify where the power imbalances lie. This fishery is not on a trajectory to dynamic sustainability and this chapter aims to disentangle the tangled net of outside influences that have steered its course to date. This approach looks to trace steps that can be made to redress not only the ecological balance of the coral reefs of southern Sri Lanka but also the balance of power which determines the lives of the various actors in the ornamental fishery, particularly those of the divers. Positive alterations made at any level of the panarchy (see Chapter 2.13.2) can create positive effects at the different interlocking scales of this SES.

8.2 Signs of change for the ornamental fishery?

This chapter is centred on a meeting I attended with divers, buyers and government officials in Polhena, on 24th November 2009 during my second field season. The meeting was one of several to occur between October 2009 and March 2010 in each ornamental diving village in all the collecting regions of Sri Lanka aimed at introducing and discussing a new governance strategy for the ornamental fishery. In late 2009, the government announced its intention is to set up a co-management system for the ornamental fishery in every area in which it operates (BOBLME, 2010). This new management initiative is known as the Capacity Enhancement of NARA (CENARA) project, funded by the Canadian International Development Agency (CIDA), and aimed at increasing capacity at the National Aquatic Resources Agency (NARA) to undertake resource surveys and stock assessments in selected fisheries in the coastal waters of Sri Lanka; the ornamental fishery being one such fishery. Food and Agriculture Organisation (FAO) representatives worked alongside NARA and Department of Fisheries and Aquatic Resources (DFAR) officials during this project which ran as a joint programme with the International Fund for Agricultural Development (IFAD) that had funded a post-tsunami rehabilitation and management programme, aimed at promoting participatory forms of fisheries management.

The CENARA project's aim is for ornamental divers to run and manage their own fishery within their territorial waters with external support from government agencies and officials. Ostensibly, the main seat of power, control and enforcement will shift from the state to each community. The main reason for this new initiative is that the previous methods of hierarchical and market-based management have, in the eyes of the state, failed (see Chapter 2.12). It is hoped that it will devolve power to the ornamental fishing communities that will take responsibility and care for their village waters rather than leaving it to the government or other non-local actors. As they live in the area, they are better placed to monitor, police and enforce the regulations that they, as a community, agree upon and implement. In addition, the ornamental divers have an informal system of marine tenure of their village waters over which they will control the fishing and access. This area is an appropriate scale for managing and covers the areas where snorkellers catch fish, if not SCUBA divers.

I focus this chapter around an ethnographic account of this initial meeting. By re-creating this meeting in the style of plain ethnography, using the ethnographic present, I aim to transport the reader to the meeting to provide a first-hand Sri Lankan diver's perspective into how this co-management strategy was introduced to one such local community. This device highlights the efficacy of ethnographic reporting over more conventional methods employed in apolitical studies and reports concerning resource governance. These conventional methods tend to limit the reports to a dry summary of events and outcomes thus masking the interactions between participants, the way the participants receive new ideas and events and the extent to which exchanges between inherently different groups of people remain positive in relation to the initial aims (Fetterman, 2009: 11-12).

I find many of the divers standing and sitting by or on the boats just before 9am, the time they had told me the previous night to arrive. These boats are on the sand drawn far up the beach between the palm trees, which border a quiet village road. It is a meeting and hang-out point for many divers in Polhena. It is a cloudy day, it had rained in the night and the air is heavy with humidity; it will rain most of the day. The sea looks rough and the wind is picking up again, it is a day when diving is unlikely. As we wait together for the meeting to start, several 4x4s stop on the other side of the road, from which smartly dressed government officials, I presume from Colombo, emerge. There are few greetings between the officials and the divers as the two groups are separated by the small road. By the time most of the officials arrive, it is past 9.30 am. They begin to encourage the divers towards the village temple where the meeting is to be held. At this moment, a 40 year old diver, Jegan wanders down the road from the west and staggers towards the group of officials. It is clear that he is completely inebriated and he begins to shout a few slurry remarks towards both groups and then begins to talk loudly to the smart, demure officials. I ask a friend to translate, his outburst seems remonstrative and aggressive at the same time. My friend tells me he wants to know, from the officials, why the meeting has to be held in the temple. He says *that everything is done in the temple but they [divers] cannot speak freely in the temple. He tells the officials they should hold the meeting on the beach or in a place near it where the divers feel comfortable and in their usual surroundings. He punctuates his speech with curses and disrespectful language and a few of the divers laugh and watch the officials' reaction. The officials seem slightly unnerved by this public display yet they just smile politely and tell him that he does not have to attend if he does not want to, but that the meeting will be held in the temple. They walk towards the temple, whereas Jegan lurches away up the road after delivering a few more rude remarks that draw some further laughs from the divers.*

Before the meeting had even begun, it strikes me how clearly defined and entrenched the power relations are between officials and villagers; those from the city or town and those from the village. Even though co-management is defined as "a political claim [by users or community] to the right to share management power and responsibility with the state" (McCay & Acheson, 1987: 31) and relies on integrative discussions among all groups involved, the divers were neither consulted nor allowed to contest the venue of the meeting. Conducting the meeting in a Buddhist temple also added a layer of control over the divers, whether Buddhists or not. Buddhists believe the place to be sacred and a place of reverence and, as Jegan had clearly stated, not where many felt at ease to speak their minds. Non-Buddhists, of whom there were several present, were similarly uncomfortable in another religion's sacred space. This showed, whether intentionally or not, that the government officials placed the local people in a location where they were not equal, where the officials were still in control. No other villagers, present at the roadside that morning, boycotted the meeting with Jegan, probably because of his public drunken behaviour, but other divers in the group told me they agreed with his sentiments on the issue. However, they say it is difficult to confront the officials about such an issue so it took the power of alcohol for a local man to voice the villagers' view which though shared by others, is muted by social norms and the existent power relations between the tiers of Sri Lankan society.

In the temple, there are plastic chairs set out in lines from the front of the room. There are tables set up along the front of the room with several chairs behind the table at which the officials sit facing the divers and buyers who sit on the plastic chairs. A screen stands in front of a projector and laptop to one corner of the room for the presentations. A banner on the wall says "International CENARA project, Galle & Matara districts, South Coast Fisheries Management Area". There are 42 local males in attendance from Polhena and seven male and one female official present; no females from the village are present and very few men who are not divers. Divers and buyers gradually arrive and find seats with their friend and age groups. I sit with the divers and Nirosh, a friend[31]*, translates quietly as the meeting progresses, while I take notes and observe. Handouts are provided to all present, which state the structure of the meeting, the constitution of the new committee which will be created by the end of the meeting as well as guidelines for the committee. Officials representing the CENARA project, DFAR and NARA take charge of the meeting through a series of presentations. These cover the reasons for the meeting, the concept of co-management; results from community surveys to assess interest in participatory management; the current situation of marine ornamental fish resources in the southern Sri Lankan coasts and how the co-management system could work in the southern region.*

Once everyone is seated the proceedings begin. First, there is a welcome by a DFAR official to all present after which he introduces the other officials and explains the nature of the meeting and the order of events. He introduces the aims and objectives of the CENARA project. The divers do not have a chair representing them and no introductions of divers or buyers are made. He swiftly moves on to warn divers to stop breaking the coral when they catch fish as this is preventing coral growth and, in turn, fish growth. Attendees are reminded of the laws and the guidelines relating to the fishery, such as the illegality of the moxy *net, to the breaking of corals and catching of small fish. They are criticised for not attending meetings that have been organised by government agencies in the past to discuss new regulations with them. He accuses the divers of not knowing these laws or guidelines and warns that this must change. He tells them that the Sri Lankan government wants divers to protect the coral reefs and*

[31] The young man who translated for me, is not a diver himself but is a close friend of the divers in Polhena and spends much of his time with them. His English is much better than many of the divers and by hearing the meeting from his view and his neighbours at the meeting, allowed me to record their experience rather than my own had I been fluent in Sinhala.

will provide money to help them do this via the CENARA project. This DFAR official also explains that the aim for the future is to discuss all issues together and that this is very important in order to find the best solution and way forward. He explains that the same problems are afflicting the ornamental collecting regions in the north and east and similar meetings are occurring all over the country.

This opening speech laid out clearly what the aims were and the seriousness of the situation to all present, however many of the "issues" that were expected to be discussed together had already been decided by officials prior to the meeting and therefore there was no discussion with divers about what they thought were the main issues affecting the fishery and its future. The official's use of language is controlling and coercive as he admonishes, blames and warns the villagers about their actions and future consequences and it reinforces who is in charge of the meeting. There had been little encouragement to ensure a maximum number of participants attended either divers or other interest groups from the village, and only those known to be divers attended the meeting. From evaluations of successful co-management nearshore tropical fisheries in other Asian countries, it is essential that divers/ fishers are involved in all stages of the process and not just at a midway point after the state has set up the framework and ring-fenced who could attend (Wamukota et al., 2012).

A lady official from DFAR then gives a short presentation. She explains that interim committees will be set up in each ornamental fishing village so each community will have a discussion group and no-one will be excluded. She also explains that there will be more meetings in the future between divers and officials and that all divers will be able to share their opinions with the officials present at any time and can call for a meeting when they need one.

The third presentation is from a male NARA official who details the status of the reefs and fish populations according to NARA's recent surveys. The results he presents are from a snapshot survey[32] *of 142 offshore and nearshore sites between Galle and*

[32] My repeated attempts to procure a copy from NARA or even see these results have been unsuccessful and unfortunately the extensive work of NARA and DFAR cannot be included in this thesis.

Matara. He shows where these surveys were conducted and explains that these surveys show that all fish populations are lower than in the past and coral cover has reduced considerably. He highlights the five fish and invertebrate species and several lobster species which are the most important for the export trades from Sri Lanka. He also outlines the concerns voiced at previous meetings between ornamental fishers and NARA as follows: too many divers, rubbish caught in the coral, boats breaking the coral, oil from boats affecting the fish, dynamiting that still occurs in some places, turtles dying out because of egg collection and by some fishers at sea. He summarises the numbers of divers in current operation. Matara [Polhena and Madiha] and Weligama [Kapparathota] have the most divers in the southern area, with over 100 in each area and the third highest concentration of divers is Thalaramba. According to NARA a total of 567 divers operate in the southern area. NARA's opinion and that of the Sri Lankan government is that divers must have a licence to catch ornamental fish. He explains that the licence exists and costs 25 LKR and he believes it will be beneficial for all divers to own a licence to regulate numbers of divers. He also suggests that the fee should be higher so that more benefits would reach the ornamental fishing communities from these licence fees. He reassures everyone that export companies will be forced to have licences too. He then switches his focus to the survey results and shows the abundance figures of some of the targeted species for the marine ornamental trade (Table 8.1).

Table 8.1. Abundance figures presented by NARA official at the meeting highlighting the reduction in some of the highly targeted fish species for the ornamental trade between their surveys conducted in 1998/99 and 2009.

Fish species	**1998/99**	**2009**
Abudefduf spp.	2 million	113000
Acanthurus leucosternon	8000	487
Acanthurus lineatus	183000	9260
Acanthurus triostegus	138000	6000
Acanthurus tristis	3333	167
Apogon spp.	64000	3224

The plan is to establish several areas as no-take zones (NTZs) to allow fish to recover. The official recommends that the divers should choose areas 500m from the beach for catching fish and leave other areas for the next season. In this way, they can *fish rotationally among these areas each season. He explains the behaviours of certain species that are targeted, highlighting the sensitivity of some of these species to current methods of collection. For example,* Rhinecanthus rectangulus *(wedge triggerfish) emerges from the coral to feed at night but remains within the coral in the day and so divers often break the coral to extract this species and other fish species with similar nocturnal habits. He stressed that fish numbers were lower near Polhena than the Weligama area due to coral breakage here and many of the highly targeted species cannot be found in Polhena waters at all. The NARA official continues to express his concern that if these fish are not found in the shallow areas, divers move to deeper areas to find the same species. But he stresses that if corals are broken and continue to die, fish will not breed in either the deep or the shallow areas.*

Few divers were enthusiastic about closed areas for protection or fish refuges; they see no benefit mainly because they do not believe they can enforce them. As described in Chapter 4.4.5, divers already attempt to fish in each others' waters and trying to protect an NTZ where fish abundances may become higher, or are thought to be higher, would be very difficult and could generate conflict.

Fifty minutes had passed at this point since the meeting began and most people present are listening attentively, though some look bored, the official's talk is presented in a dull manner, the lights are off to see the projected images and the poor weather makes it dark inside the room. Often mobile phones ring or beep during the talks and some divers happily answer their calls. It is clear that the opinions of divers and buyers will only be voiced after the government officials have spoken and questions are taken. However, for the most part, there is relative quiet and people are listening. Suddenly, loud shouting is heard from outside the temple and the voice of Jegan can be heard drifting through the open windows. Many divers laugh and shake their heads and I am told Jegan is using "very bad words about the meeting". The speaker ignores this intrusion and continues his summary of the reef status.

He says that in the past large fish were present but no longer and the reasons he gives for this are fishing and pollution. He says the divers must protect the coral themselves and make good decisions "now that we have told you the information". He continues by saying that some people will continue to break the corals and take the fish but that these actions can no longer be stopped by government level management. He pushes on, saying that the trade in Gobiodon citrinus *(poison goby) must stop as branching corals are broken to extract these fish. Furthermore, he tells everyone that companies cannot buy these fish as exports are restricted. He continues to say* Lysmata amboiensis *(Scarlet cleaner shrimps) should not be caught when they are with eggs as this removes future generations of shrimps.*

Suddenly a commotion commences among the divers concerning the official's comments to stop breaking corals. Many divers shout out to the speaker that they do not break corals but the official replies that they may not realise that in fact they are breaking corals. And with this, the official continues to list continued violations of the laws and guidelines applicable to the ornamental fishery. He states that usage of the moxy *net also results in coral breakages and so this net should not be used. Dynamiting he believes has stopped in Polhena but must never be restarted. He stresses that spearfishing is not advisable either as once the larger fish are taken from deep sites by spearing, smaller fish leave that area too as they will have lost their protection in the form of these larger fish.*

Again a reaction comes back from the audience. A buyer this time speaks up saying that the export companies should not buy the fish NARA recommends restricting and if the companies do not place orders, then divers will not collect them. He goes on to say that companies always want small fish so they have to catch these small sized fish as they cannot sell large sized fish to the companies. He talks too of how, in the past, company representatives were friends but now there are many suppliers, the companies can choose who to buy from just on prices. Another man interjects saying that the river water is killing the corals here in Polhena. Other divers shout out that new divers are the ones causing problems, as they break the coral and fish die when they catch them. Another man claims that many fish die during the packing and transport stages and this is not the fault of divers. By now the divers have taken over the meeting and everyone *feels more confident to add their own opinion and comment. The official's talk is sidelined for the moment. Another man says that the government always wants more money but they never receive any benefit from this money like before and after the tsunami. All the divers in the room laugh at this comment. Others then say that it is the fault of people who come from other villages who destroy their corals, if they were working here alone they could control the issue. One older man recounts how many years ago the divers from Colombo came here and dived, they gave the village communities 50% of their earnings and they could dive everywhere and asks why this cannot be the same today. The disquiet grows with many people trying to talk at once or with their neighbours and eventually the NARA official still standing at the front of the room quietens them.*

The divers gradually rebutted several of the official's comments unable to remain in silence when they disagreed or disputed his message and brought the whole talk from a formal presentation to a noisy commotion. A more levelled discussion had begun after the strong initial words from those in charge earlier in the meeting. This period of the meeting indicated that there were differing opinions between officials and local people over the main problems affecting the fishery, the local reefs and how to deal with these problems. In addition to this, it highlighted again the way in which divers were rebuffed immediately by the official when they made their feelings or thoughts known, exemplified by his saying "*you [divers] do not realise you break the corals*", rather than opening up any form of discussion concerning this issue to determine different views. The official's language and tone, similarly to the first speaker, was dictatorial, admonishing the divers with accusation after accusation and attempting to convince them of the officials' decided upon management measures rather than asking for advice or encouraging discussion. He only manages to quieten the crowd by raising his voice and calling for silence.

Throughout this meeting pervades the lack of trust between local people and government agencies linked to broken promises. This is unsurprising as recent experiences after the 2004 tsunami are still fresh in the villagers' minds. Most local people in Polhena, and my other study sites, describe negative dealings with government agencies in terms of support post-tsunami. Similar findings have been reported in several studies that point to an inept government response and high levels of corruption throughout the process, which left communities in disarray and disillusioned as to who would support the most afflicted (Said, 2009; Amarasiri de Silva, 2009). When I spoke with the NARA official after the meeting he realised this process will take time and that the most important task is to engender trust between all parties involved. The lack of trust and reliability of the local people for the government presents a considerable barrier before a long-term co-management program can be established let alone achieved through interactions that will involve negotiations, exchanges and constitute the re-shaping of interests and perspectives, as has been found in other studies of fisheries co-management (de Vos & van Tatenhove, 2011).

Eventually the noise subsides in the room and the NARA representative tries to complete his presentation, he reiterates that at present there are 567 divers in the southern region and this number must not increase. A diver shouts out that only 20 people should be allowed to dive and this comment as well as the official's stir the gathering once more. However, one buyer's voice is able to command some respect and he puts his point across clearly, saying:

> *"How can we stop them [local newcomers] diving? They need jobs and people would revert to robbery and crime if not. If you limit it to 567, what would the young people do for a job and new people who wanted to enter the fishery? You should provide them with another job if you block them doing this.... if they had a decent job they wouldn't be diving in the first place!" (much laughter from all present).*

This was the most significant moment in the meeting: the man who questioned the government's strategy to limit diver numbers exposed the flaws of this plan in their locality. Most in the room made it clear, by way of nodding heads or assenting noises, that they concurred with his view that just limiting diver numbers is not an easy or workable solution. It highlighted to all present that often ideas and solutions to problems conceived by non-local actors are too simplistic and ideal in such socio-ecological systems. There are external drivers which often lock local people into livelihoods they do not choose freely but from necessity (Béné, 2003; Cinner et al., 2009a). Such drivers in Sri Lanka, may include the difficulty for poor families' children to go and/or stay in school and gain qualifications in order to obtain a "good job", because of the external pressures to earn money for themselves or their family once they become teenagers (see Chapter 5.3.5). Additionally, under the instrumental view *i.e.* if in the eyes of end-users, banning or restricting certain activities is done via unfair regulations and non-legitimate institutions, compliance is likely to be low and illegal activities will occur (Kuperan & Sutinen, 1998). However, often results from such studies do not reach the policy makers in developing countries who continue to set government bans on activities or gear rather than spend time working collaboratively with communities to find manageable solutions.

The official once again restores order and states that there should be fewer snorkeller divers than SCUBA divers - a ratio of 15:100. He realises at this point that it might be better to allow the group to express more viewpoints. One buyer complains of the large debts owed to them by companies and says that the government should help them recoup these debts. He also complains of the unchanging fish prices and their feelings of being cheated by companies who rarely give credible proof of fish deaths. He believes the companies must act in a way that benefits divers as well in the future. In response the official explains they are creating these committees in each village, like today, so they [divers] can discuss their complaints more openly with the companies. This answer does not deter the buyer who goes on to criticise the fisheries department saying they continue to collect licensing money but are not doing anything or giving anything back to these fishing communities. He questions the banning of the moxy *net to collect fish, if they [DFAR & NARA] want to ban this, they should provide an alternative method that is as effective. He proposes that NARA should have a local office, so that issues are not forgotten and can be continued in their specific interests and not spread across the whole country. The money paid in licences to this office is traceable and should be available to the divers during difficult periods or to improve local conditions and not lost in the national coffers. He moans about NARA officials never staying at the coast or spending time with them long-term. These complaints are made by buyers, most of whom are the older men present and the divers are now quiet with apparent respect for these men who are representing their interests. Murmurs of support are heard after each concern is voiced. There are also complaints about divers from other areas who fish in their waters and yet they [Polhena divers] do not go into other areas.*

In fishing communities in Pacific island countries, where such co-management schemes have already been implemented, the different user groups held several separate meetings first to discuss the key problems and potential solutions and then representatives from each group were elected to form their Marine Advisory Committee (MAC[b]) (Adams, 1998). Instead from my observations in Sri Lanka, the government officials arrived with the key problems and potential solutions already decided upon, in an attempt to convince their audience. Even while the divers express their opinions and complaints, it is unclear whether the officials are taking them seriously or just allowing them to talk before steering the meeting back to their pre-determined schedule. There is a distinct lack of dialogue over these issues between officials and divers. Governance procedures rarely follow neat, linear and predictable pathways towards expected results, in reality, the process is messy, unpredictable and unintended consequences are inevitable (Jessop, 2003).

Another official stands and announces that a Management Advisory Committee (MAC[b]), which includes members both from the community and also from DFAR, needs to be created for the village before the end of the meeting. He then reads the constitution, which declares that participatory management will allow for the management, protection and development of fishery resources within the committee's area, will protect the legal rights and heritage of divers and committee members within the domain and will develop the economic, social and cultural conditions of members and their relations. The committee leaders are required to meet regularly to decide on issues they need to discuss with the community, after which any suggested regulations or procedures must be ratified by DFAR officials and finally communities must enforce these new rules. Government agencies will support and supplement the MAC[b]'s decisions with information, financial aid, legal protection and enforcement when needed. Fish catch records must be kept by the committee and a register of members of the scheme. Only local people who are members can gain benefits of financial aid and other services from the committee. A decision is required whether there should be one MAC[b] representing both Polhena and Madiha (a neighbouring village) or one each. This is debated for some time before it is agreed that each village should have its own committee. Next, a group name and number are decided on, after a lengthy open discussion, among the divers. By now it is 12pm and many people begin to leave the venue, a few have left earlier during the discussion.

Following agreement upon the name, nominations for committee leaders are taken from the dwindling group, some volunteer themselves, whereas others are nominated, but no overall vote is taken. In the end six men are nominated with one overall leader to represent the Polhena MAC[b] *and be the voice piece between government, export companies and the divers. Many of these are senior men in the village and/or buyers in the trade, and there is little room to debate these nominations and few seem interested as they wish to leave the meeting at this point.*

Disappointingly, this important process was rushed and there was no proper election of committee members; instead, the committee was formed by several of the most senior and powerful members of the ornamental fishing community in the village. This is likely to prevent any different views being expressed on the committee from those who currently hold most power in the community. These positions of power within the village are not earned through working in or with the community but from economic success with their businesses. The officials orchestrated and steered the meeting almost entirely, with little room for discussion from the divers. The time management throughout the meeting was poor; officials delayed the start by their late arrival and took up most of the meeting time with their own unnecessarily long presentations which prevented adequate time being allocated to form the committee and nominate its leaders. Furthermore, the meeting ran late and many divers wished to go elsewhere or had lost interest at this important stage of the meeting. It is unfortunate as this is a major step to laying the foundations of a fishery management transition and it was not given the time and deliberation it deserved. There was also little mention of the future funding capacity of government for the work of these MAC[b]s or detailed explanations of the plans and strategies to ensure funding is available when needed.

In closing, another official thanks everyone and tells everyone present that they have been provided with information in the handouts and some authority has been given to local people in the newly formed committee. He encourages everyone to go home and read these notes. There are only 27 people left by the end of the meeting. The banner from the wall is presented to the nominated leaders and there is cheering and much applause from the remaining group. A monk enters and everyone stands in respect to him. The monk speaks from the front saying there will be another meeting in January *and they can use the temple again for that meeting. He encourages everyone to come to that meeting as there is a lot of work to do. He then leaves and everyone stands again for him and those closest to him bow as he walks out. In closing, the nominated committee leader gives a formal thanks to the government officials saying:*

> *" Thank you, before we had little knowledge of fish and corals. Still we are not protecting our sea, the situation now is very bad, we need to protect it better, it is good you have come and we can help each other and make improvements".*

Divers then disperse to their homes or in the case of many of the divers I knew to the area around the boats. The officials from Colombo climb back into their vehicles and set off on the four hour drive back to Colombo. I ask the divers by the boats of their impressions of the meeting and most think it was useful but they are now concerned about using moxy *nets to catch fish. They are unsure whether the government will actually enforce their ban of the* moxy *net this time. I notice the paper handouts are soon lost or lying around and few divers are reading them. They begin to play a game of karram*[33] *in the fish packing hut and soon several packers and divers who had not been at the meeting arrive. Jokes are made about these being the divers who break coral or pack small fish that was upsetting the authorities and they tell the absentees they gave the officials their names and addresses. Two divers arrive drunk having also missed the meeting and are intent on finding more people to drink with them or lend them money to buy more alcohol. Soon the meeting's outcomes seem to be forgotten.*

From observing this meeting and the behaviours and reactions of those involved it exposed the inadequacies of the current methods of government agencies in working with these communities, which stems from a long and distanced relationship between these two groups. Both groups recognise the same chronic environmental and social problems that are present today and have attempted to work together on several occasions over the years to improve the situation. However, a lack of understanding between each group is still prevalent. For example, the divers had little incentive to attend the meeting other than it was targeted at them. If the weather had permitted diving that day, very few local people would have attended the meeting when all diving

33 Karram is a game of Indian origin played on a square table with corner pockets. It is similar to pool in that the object of the game is to flick with your finger a wooden disc (similar to a checkers piece) into a pocket to score points. Players play seated around the table and take alternate shots.

occurs in the morning and divers are only available in the afternoons. Officials complain of this apparent disinterest in their efforts to collaborate with them yet dictate when and where these meetings will be held and overlook the basic tenets of divers' lifestyles. There is a continuous struggle between the local people and the government officials to work co-operatively and alter the trajectory of the fishery amid concern for its future benefits.

Without concerted effort by government to spend more time and show genuine interest in divers' livelihoods and their marine resources, the miscommunication, the argumentative nature of their discussions and the lack of trust between the two groups will continue. The speed with which the divers stopped talking about the meeting and moved on to their day to day activities was rapid which indicated that little of what was said, was unknown and that the ways the state and divers perceive the environment, the fish and the reefs differ. This relates to the fact that varying representations of nature by different actors is an important consideration within political ecology (Fairhead & Leach, 1996; Forsyth, 2003) and can be expanded to the social construction of nature and material processes, which is affected by people's social position, knowledge and experiences (Descola & Pálsson, 1996). The different social positions and worldviews of the actors relevant to the ongoing fishery management struggle are now introduced through their roles and responsibilities as well as the level of their performance during this intended transition period.

8.3 Past and current governance of the marine ornamental fishery in Sri Lanka

At present, the centralised system of fisheries governance is run from the Ministry of Fisheries and Aquatic Resources in Colombo. Within this Ministry, there are a multitude of government departments and organisations charged with managing the coastal and marine areas of Sri Lanka, and five in particular that oversee the management and development of areas involving coral reef locations (Table 8.2). In most interactions I had with actors in the ornamental trade, these sub-sectors of the Ministry were referred to more than the Ministry itself. All are based in Colombo, and I was able to meet with members of each during my study, except the Central Environmental Authority (Table 8.2). Drawing on information gathered from interviewing these representatives, it is possible to outline the overall system, the extent of involvement of each body with the ornamental fishery itself and the level of knowledge possessed by officials and their departments on issues concerning the trade. I also visited the Department of Wildlife Conservation's office in Hikkaduwa which is tasked with managing the marine protected area there and the District Fisheries office of MFAR in Matara, which monitors fishing activities in the Matara district. The role of the DWC and the ensuing management problems affecting Hikkaduwa Marine Sanctuary have been discussed in Chapter 4 and so are not re-visited in this chapter.

Table 8.2. List of ministries and government departments involved in coral reef management in Sri Lanka, adapted from Rajasuriya et al., (1995).

Department	Role
Department of Fisheries and Aquatic Resources (DFAR)	Development and management of all fisheries activities, licensing fishers, crafts and gear and construction of fisheries harbours
Department of Wildlife Conservation (DWC)	Management of protected areas and species
National Aquatic Resources Agency (NARA)	Research and development of all aquatic living and non-living resources
Central Environmental Authority (CEA)	Oversees EIAs and establishes national environmental standards; co-ordinates all environmental related activities.
Coast Conservation Department (CCD)	Regulates development activities within the coastal zone and responsible for safeguarding coastal resources. Implementation of the coastal zone management plan.
Export Development Board (EDB)	Monitors exports of Sri Lanka and responsible for expansion and development of new export businesses.

8.3.1 NARA

Officials at NARA are well trained and skilled in their tasks of monitoring and performing research on the coastal and marine environment, however, they struggle to exhibit this positive image to divers, as was made clear in the meeting (Section 8.2). Only a few older, relatively affluent divers and fish buyers, who have forged personal relationships with some government officials over many years, see NARA's work as meaningful and relevant (Chapter 6.6). Officials at NARA concede that they are often met with concern by fishers, who suspect their visits will result in further restrictions on their fishing or way of life.

8.3.2 DFAR

It was made clear to me by government officials as well as export company owners and employees, that few DFAR employees have an educational or occupational background in fisheries management, ecology or any other science. Officials at the Matara district fisheries office were interested in whether the University of Ruhuna provided distance or part-time courses in Fisheries Management or Oceanography so they could re-train themselves, as their whole team consists of people with Arts degrees and therefore lack the underlying knowledge of the resources they are tasked with managing. Many divers and export company owners made this clear to me before I visited the regional office. They often question some of DFAR's regulations and law amendments concerning the ornamental fishery, because they seem misguided in relation to the realities divers observe through time. The resource users are concerned that those managing the use of marine resources and ultimately governing divers' livelihoods are less knowledgeable about the marine environment than themselves. As one source told me:

> *"I don't think there is one person in the Fisheries Department who has gone fishing or caught one fish.... they have no understanding of the sea!"*

NARA and DFAR both voice faith in the new co-management system. They both told me they have been working with these divers for many years now and there have been successful agreements in the past, such as the voluntary ban on collection and export of *Gobiodon citrinus* (poison goby) made in Weligama in 2007. Officials at NARA aim to update their fish stock surveys every three to five years and disseminate the results to these communities. Issues that were brought to government from the divers both in the meeting I attended and from speaking with NARA and DFAR officials was that of too many divers in all areas. Government believes a better licensing system that limits the total number of divers would be the best first step. As Arjan Rajasuriya, the main NARA official connected with the CENARA project explained to me:

> *"We need to register all the people who are there now fishing but no others can join the fishery. We cannot exclude those who are already there but some guys who leave the fishery or who die etc. will not be replaced and so this may reduce numbers involved slowly but it seems unlikely. They [divers]are reluctant to put a maximum number on how many divers there should be optimally, so I am not sure how we can control the joining of other divers but everyone agrees there are too many divers."*

8.3.3 Coast Conservation Department

The Coast Conservation Department (CCD) is mostly involved with coastal zone management and approves or intercedes on construction/ development plans in the coastal area. Since the 1980s Sri Lanka has had a setback policy, whereby development within 300 m of the coast required a permit (Lowry & Wickmeratne, 1989). However, lack of enforcement has allowed construction to occur within this area, hence many people do not believe such a law existed. After the tsunami, a government disaster response policy was to prohibit the repair, reconstruction or new-build of any structures within the coastal buffer zone[34] and attempted to relocate people to foreign-funded "tsunami villages" inland (Harris, 2005). However, this was met with huge resistance by many coastal dwellers, who felt the regulation violated their right to reconstruct or build on their own land (Ingram et al., 2006). Fishers felt forced relocation would be detrimental to their livelihoods and were furthermore, emotionally attached to their, often ancestral, land (Luthra, 2005). Ten months after the buffer zone law was created, the government revised the policy. Although the coastal peoples are still unsure of the details about the forms of construction and development permitted in the buffer zone (Hyndman, 2007), they are nevertheless constructing many buildings in that zone.

This history is relevant to CCD's only interaction with the ornamental fishery, which is to grant permission to new developments in the coastal zone, usually in response to requests from export companies to build facilities near the coast. I was told by the CCD representative that they are encouraged to provide planning permission for businesses involved in foreign trade, so they do not block export companies from developing their facilities in the coastal zone. In contrast, a fish buyer, whose facilities I visited, told me he was in contravention of "building laws" having built a large concrete fish tank in the coastal zone (at the back of his house). The tank was so close to the sea that waves broke over the outer wall mixing and aerating the water within it, without fish escaping. He believed this reduced fish mortality and was preferential to keeping fish in plastic bags while awaiting transportation to the export companies. It appears that the laws are enforced differently with different groups of people, with those in higher social positions better able to navigate the restrictions, permits and policies to suit their needs.

[34] The coastal buffer zone was implemented days after the tsunami, without consultation of the local people and forbade new-build or re-construction of damaged properties within 100 m of the shoreline. This distance varied in different parts of the coastline. Coastal dwellers were promised government-built free, new houses inland but near their current home (Wong, 2009).

8.3.4 Sri Lanka Customs

Customs are the bottleneck in the flow of fish along the ornamental trade supply chain. With adequate checks, powers and trained staff, Customs officials could closely monitor exports and streamline the path to sustainability in the overall trade. Many Sri Lankans I met from both the general public and the ornamental fish trade expressed negative and cynical views of Customs, with assumptions that checks are poor and bribery is rife, which means shipments pass with the right connections or enough money. However, an individual who genuinely sets out to purge his organisation of corruption and such mistrust runs the Biodiversity Protection Unit (BPU) of Customs in Sri Lanka, which was set up in 1993. Samantha Gunasekara was trained in the USA, and has now been in Customs for 32 years in both export and import lines and has developed a reputation around the country as a non-corruptible Customs Officer. The unit is linked to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and was the first of its type in the world (S. Gunasekara, pers. comm.).

Gunasekara hand selects his team of biodiversity officers. He has improved their training, ensures they are paid well and provides an excellent reward system for making arrests, so as to reduce the temptation of bribery. For these reasons, he trusts his team, saying: *"We are very different to other departments in this country!"*. Most of his officers are selected for their active personal interest in the environment so the rewards are seen as a bonus. Furthermore, Sri Lankan academics and government officials who specialise in reef fish help train the officers, both at Customs and in the field, to enhance their fish identification skills and further develop their knowledge about the trade. Mistrust due to corruption is institutional in Sri Lanka, yet the BPU has avoided it by implementing incentives to reduce the temptation of bribery, careful selection of employees and creation of a team with genuine interest in their work and its objectives.

Gunasekara does not pretend there is 100% control, but feels it has improved due to his and his officers' efforts. In his opinion detection rates of smuggling now are the best they have ever been in Sri Lanka; better than other countries in the South Asia region. His unit holds unique forms of power to reduce attempted smuggling and in his words: *"make people scared of us"*. He explained further that Customs can hold an inquiry similar to those empowered by a magistrate. If an inquiry is carried out, they can punish offenders, seize goods and issue fines for up to treble the value of the illegal shipment. Fines are usually given at an "affordable" level, depending on the offender. This system of inquiry is a special feature of Sri Lankan Customs; other Ministries and government bodies have to go through the courts. A maximum possible fine imposed by a magistrate would be 25000 LKR, but Customs' highest fine to date is 39.6 million LKR, which shows the special powers they possess. However, Gunasekara believes his unit's control could weaken at any time as there is insufficient strong legislation to ensure adequate control over the longer term.

In Gunasekara's view, to become more effective for the ornamental trade, the BPU needs improved accurate numbers and sizes of ornamental fish exports and updated legislation and restricted fish lists every two to five years. He is also concerned that the BPU does not have a vehicle, so his officers must use their private cars and have been followed by what he called "*threatening types of people*" filming them and potentially misconstruing their actions. A shortage of trained staff is another problem and as new ports and airports are due to open soon in Sri Lanka to meet tourism needs after the end of the civil war in 2009, there is a need for more well trained officers.

8.3.5 Laws and regulations

The struggle to improve the marine ornamental fishery and improve co-operation among the players charged with its management has been ongoing for nearly 20 years. Up until the mid 1990s the fishery was regulated and governed by the market, the fluctuations of supply and demand on world markets dictated the export levels of marine ornamental fish from Sri Lanka (see Chapter 2.16.2). Fish abundances and consequently catches were high and few in positions of power were concerned for the future. Only in 1996 did the Ministry of Fisheries and Aquatic Resources (MFAR) bring in legislation pertaining to the ornamental fishery. Since then government control has crept in steadily, yet to a large degree, the fishery remains under a market-based governance structure. The combination of government interference with market-based governance structures can be cause for concern, with disastrous consequences for small scale fisheries, as seen in Senegal (Chauveau & Samba, 1989). Dufour (1997) argues that government regulations for ornamental fish collection must not hamper the economic viability of the trade; otherwise, fishing will continue illegally or by destructive means and so reduce long-term national economic benefits. However, the excessive damage to fish populations and the coral reefs in Sri Lanka is causing many involved with the trade to call for more stringent restrictions.

Today most fisheries in Sri Lanka are subject to management restrictions and regulations that are enacted as laws. DFAR implements laws which are based on recommendations provided by NARA. The marine environment of Sri Lanka is protected by the guidelines and regulations of Sri Lanka's Coastal Zone Management Plan, the National Environmental Act, the Fisheries Ordinance and the Fauna and Flora Protection Ordinance (NOAA, 2012). The Fisheries and Aquatic Resources Act, No. 2 of 1996 is the overarching legislation concerning all types of fishing, aquaculture and trade of fisheries products in Sri Lanka. Appendix G clarifies the laws that apply to the ornamental fishery.

8.3.6 Compliance with the laws

According to NARA and DFAR officials, licensing by area has always existed, but implementation has been poor, especially on the east and north coasts often because many divers believe one licence allows them to fish anywhere. This was the sentiment of most divers I spoke with who migrate to fish each season. Divers migrating to fish, (especially southern coast divers moving to the east coast) has occurred for decades, and if there are conflicts they are usually settled among the divers with DFAR rarely intervening. Regular, daily fishing is beginning again along the north and east coasts after the end of the civil war. In contrast the southern region has always operated, with locals carrying out the diving, unlike the north and east where the diving that occurred in the past was predominantly done by migrant southern divers. Locals in the east and north now express unease that southern divers are fishing out their resources. As they begin to acquire the gear and knowledge to dive and fish their own areas, they are looking to protect their own areas in similar ways to the southern divers and are asking for government support to enforce the area licensing laws.

Many divers I met have never owned a fishing licence and it became apparent to me that the only people who regularly buy and renew their licences are the fish buyers in each village and the export companies, who need to obtain several licences to run their businesses. Records on the ornamental fish buyers, and on the registered export companies are kept by DFAR and the EDB, which means they are traceable for inspection and checking purposes, which is why they ensure they possess valid licences. In contrast, most divers are not traceable by DFAR, meaning there is little risk of being caught without a licence and so divers do not buy a licence. Furthermore, divers claim, during their diving, they have received little government support to aid them and so question the reason for paying a licence fee which they view as a form of tax. Fish buyers and export companies, who do buy their licences, agree with the divers' view in that they also see no evidence that their payments aid their businesses or livelihoods through government support. Locally, licence checks by government officials appear to be extremely rare, with few informants having ever been checked and I observed no checks during my stay in the villages; in fact, there appeared to be no type of systematic government visit to these villages.

The District Fisheries Office of DFAR in Matara is responsible for licensing and enforcing fishing regulations in the Matara district. However, when I spoke with the Assistant Director there, he admitted that with the current capacity of his office and team, it is difficult to conduct these licence checks across the entire region. Matara has nine districts and he has two officers per district. Ostensibly, team inspectors are sent to check licences and ornamental divers found without one can be tried in court and fined up to 2000 LKR. The Assistant Director's team is also tasked with preventing illegal fishing even though they have no boats for such work. Team members either borrow fishers' boats or rely on tip-offs from the community to find the perpetrators. I was told by NARA officials that illegal actions such as individuals fishing without licences will only be reported to the fisheries officer if there is a personal grudge between two fishers; otherwise few checks occur. Other than this ineffective licensing system, few other restrictions apply to divers. The *moxy* net continues to be used by nearly all snorkellers despite its illegality, which is based on concerns regarding damage to corals during fishing (Rajasuriya & White, 1994; Beets, 1994). Enforcement appeared non-existent and some divers still do not know using a *moxy* net is illegal and walk around the village with the nets clearly visible.

Few legal amendments have been made recently which affect the ornamental fishery. However, those that have occurred appear to create some degree of confusion and many divers even lack awareness of such regulations. Among my diver informants, there was misunderstanding and differing views on nearly all legal issues that apply to their work: the legality of the *moxy* net and other fishing gears, the applicability of the licensing system, as well as the restricted and prohibited species they can collect. It seems paradoxical to continue with further legislation, which cannot be enforced via the current centralised, top-down approach to fishery governance, as evidently, the laws, combined with the current management system, are not effective.

8.3.7 Interaction of all the players

The various organisations and government bodies tasked with monitoring, managing and regulating the ornamental fishery trade should act together, but from my observations, it seems they work in increasing isolation from one another, resulting in a disconnect between sectors, which hinders appropriate management of the ornamental trade. Officials at NARA call for a cap on export company numbers and greater enforcement of licensing and monitoring of catches, yet the Fisheries Department, the EDB and DWC do not, and it seems, make little effort to enforce these requirements. Meanwhile, both the CCD and EDB are under a remit to encourage the expansion of ornamental export companies and their facilities along the coast. As a government source told me, the EDB motto concerning export companies is *"..the more, the merrier"*.

Outside of the thinking in Colombo, the divers and fishers are struggling to find the fish required for this promised growth and increase in fisheries production. Their views and concerns are sidelined in meetings involving the representatives of the trade further up the supply chain. Hence the fishers' perceptions concerning government bodies and export companies deteriorate (see Section 8.5). Without trust among, and appreciation of, the diverse groups within the fishery, any attempts to engineer new management schemes are likely to be met with resistance as one group distrusts another's reasons for change.

8.4 Continuing problems in the ornamental fishery

I outline below my understanding of the main problems relating to the ornamental fishery, which are derived from interviews and discussions with a variety of actors in, and around, the trade in Sri Lanka. They range from both the local people, such as divers and buyers, to the non-local actors, that is the export companies, environmentalists, academics and government officials. Although, among this broad suite of informants, there is a high congruency in terms of the most pressing concerns they mention, few I spoke with had any feasible acceptable visions of how to resolve these challenges.

8.4.1 DFAR 's perception of the problem and high task load

From interviews with both DFAR officials in Colombo and Matara, it appears that the ornamental trade, and in particular the marine ornamental trade, is not a high priority issue in terms of management and action. I was told that for DFAR *"endemic freshwater fish species are more of a concern than marines..."* and their reasons for this priority were *"...because marines [species] can be restocked from other places due to the seas being connected".* While this may to some extent be true, the most revealing fact from this comment is the acknowledged lack of manpower or effort to manage effectively both the freshwater and the marine ornamental trade sectors, only one sector can be managed at one time. Furthermore, DFAR is under pressure to reduce or eliminate illegal fishing activities, such as dynamiting, coral mining or catching of lobsters out of season, which are all seen as more important than the ornamental fishery. By relegating the marine ornamental trade to a matter of low concern, the accumulated impacts of the established business patterns are not addressed in both the natural and social environments.

In line with a hierarchical control system, only those actions which can be categorically defined as illegal, where charges can be made and punishment delivered, appear to be on DFAR's agenda. Raising awareness through education or interactions, changing behaviours and other such work of good management appear to be overlooked or impossible under current financial and staff logistics. I was told by DFAR: *" We would like to restore corals but our financial situation is very little".* Since 2004 MFAR has provided compensation both in the aftermath of the tsunami to fishers in all affected coastal locations and now after the end of the civil war, to help fishers on the northern and eastern coasts return to work. Post-tsunami, the provision of boats and fishing gear was seen as an immediate remedy to restore livelihoods, rather than the slower process of repairing livelihoods in agriculture. There is belief in DFAR that fisheries management problems can be overcome and solutions found internally by expert Sri Lankans, but external funding is needed.

8.4.2 Continuing trade in "cut-flower" species

"*Cut-flower*" species is the term given in Sri Lanka to those marine fish species which are unsuitable for life in aquariums yet are highly sought after in the trade. Their inevitable death in captivity resembles the trade in cut flowers for bouquets in the international flower trade, which remain alive and colourful for a few days before dying. They have high post-harvest mortality rates, and are usually species adapted to feed on corals thus cannot survive without live corals. Despite their fragility, "*cut-flower*" fish species are collected in large numbers for the ornamental trade. It is difficult to produce hard evidence that might support changes to this behaviour because mortality is not recorded anywhere along the chain. As there is a constant need to replace the fish that die, their short-term turnovers are advantageous to the collector and exporter, but not the end user and definitely not the reef or the fish. There is growing pressure to prevent the capture, sale and export of these *cut-flower* species, not only in Sri Lanka but worldwide (Gunawardene, 2002). The largest wholesaler in the UK, Tropical Marine Centre no longer imports marine species deemed unsuitable for life in aquaria, which is promising (E. Wood, pers. comm.). Additionally obligate corallivores are becoming rarer in Sri Lankan waters due to the large reduction in live coral cover that has occurred over the last 30 years from impacts detailed in Chapters 2 and 4.

8.4.3 Fishing down the coral reef value chain

The majority of actors in the ornamental trade in Sri Lanka believe fishing down the value chain is occurring, akin to fishing down the food chain (Essington et al., 2006), and many examples highlighting this problem were provided. As the more valued fish become rare in reef areas, divers either move to fresh sites to find them or collect more abundant species from lower down the value chain. Yet in order to maintain their daily income, the divers need to catch more of these lower value fish which in turn will become rare. There is concern that divers will continue to fish down the value chain as different groups of fish become rare. Many older informants told me the valuable species in the trade were abundant - even in shallow, nearshore waters - in the past and were collected in approximate quantities of ten individual fish per diver per day. These were species such as *Pomocanthus imperator, Acanthurus leucosternon* and *Amphiprion clarkii* and their host anemones. If ten *Pomacanthus imperator* were caught, a diver would earn 2500 LKR, which is a very satisfactory daily wage among divers, even today. The high prices and resultant targeted fishing, however, reduced numbers and now these species are rare, particularly in the nearshore reefs, only occurring at depth where fishing pressure has been less intense. Other high value species such as *Carcharhinus melanopterus* (blacktip reef shark) and various species of sea cucumber are all but gone from the nearshore waters in Sri Lanka (NARA, pers. comm.). The current rarity of many fish and invertebrate species especially on the nearshore reefs in southern Sri Lanka is the clearest evidence to many of the urgent need for change in the management of the fishery.

8.4.4 Enforcement and political interference

There was consensus amongst the informants I spoke to that regulatory enforcement of all laws pertaining to fishing is poor, with those responsible under-staffed and unable to control illegal activities. The DWC is more focused on land-based fauna and flora than on marine areas and so once again less attention is directed toward the marine ornamental trade from those charged with managing it. Officials at DFAR and DWC stressed that legal action is possible against offenders and believe that there are sufficient regulations. However, officials felt that government fines are too low to deter or prevent re-offenders and they see a general disregard for the law at all levels of society. This may be linked to the style of management, with such hierarchical control disputed by place-based actors, such as divers. Those outside government, suggested there is general apathy in government for enforcement, with most government officials ensuring only that permits and licences are issued, being more concerned with keeping their jobs. The hegemony of the current system is exhibited in arrests being made of only small-volume exporters or collectors who have the least impact on the system. A generally held opinion is that those with powerful connections are ignored by enforcers.

Government officials corroborated this view, describing how pressure to release certain prisoners or remove fines and other punishments can be experienced by law enforcement officers. I was told that *"Powerful people control this, criminals can be released and carry on with the same practices afterwards"*. Field officers struggle to perform their duties against corruption and other political influences across government and the export companies. One official admitted: *"Even though I am a government civil servant I know this to be happening"*. Management is resisted by the export companies through their political connections and I heard of decisions to bring about improved management practices or schemes being defeated by political influence at all levels of the trade. Those inside and outside government believe that with any new initiative linked to this highly profitable export trade, politicians will intervene but laws will not be enforced. Many informants claim politicians turn a blind eye to illegal activities or bad practices either to increase voter support in the rural communities or in return for donations from wealthy companies to party funds.

8.4.5 Inappropriate restricted species lists

The restriction of certain species from the trade in 1998 appeared to be a positive step in controlling the collection of unsuitable and rare species from Sri Lankan waters. However, today all assert these lists of restricted species need updating: many species listed do not even occur in Sri Lanka and/or are of no consequence to the trade, whereas other sensitive species, such as sea anemones are exported in large quantities and are missing from the restricted list. Again, the political connections with export companies may have ensured that certain recommendations to add species have been ignored. The laws appear different in terms of the protection of terrestrial and marine wildlife. Under the DWC, all terrestrial species are protected and only certain listed species are allowed to be traded, whereas all marine species are traded and only a few are restricted. Some environmentalists believe if marine species were protected in the same manner as terrestrial species, the ornamental trade could be more tightly controlled at Customs.

8.5 Dynamic sustainabilities

In summary, the challenges facing the ornamental fishery are increasing in number and severity. This chapter has teased apart some of the reasons for previous governance strategies and examined some of the deleterious consequences. There are now positive signs of a change in the fishery governance system to a more participatory, co-managed system. It is fairly common for fishery governance systems to move from hierarchical to market-based and then progress to participatory forms of management (Berkes, 2009). The homogeneity, close networks and high levels of social capital within Sri Lankan fishing villages make them suited to this style of management (Grafton, 2005). However, the longer term criteria for success in co-management programmes, such as the level of empowerment or community organisation, cannot be assessed at this early stage.

Adaptive governance (see Chapter 2.12) is essential to manage such complex socio-ecological systems. Rather than attempting to model and categorise every eventuality in the system, adaptive governance relies on experimental learning, by building capabilities on past experience and through social learning. Self- organised and self-enforcing local actors are best placed to reassess their current strategies and adapt or devise new ones that ensure more sustainability. Already in southern Sri Lanka there are positive signs that suggest co-management and adaptive governance are feasible and possible. When more localised policing efforts were implemented - such as in greater enforcement of laws through strong, local police initiatives and highly visible naval outposts - immediate reductions in the most damaging behaviours to the reefs was observed (see Chapter 4.4.4. and Table 6.9). This strong arm approach is available and may be necessary to prevent extreme forms of destruction, such as dynamiting, but is not optimal in encouraging actors' involvement in the everyday management of the ornamental fishery. Already the state is transferring authority to the users and divers of the village reefs; for example, local forms of sea tenure, the methods of diver training and agreements among fish buyers on various issues, are all made without outside involvement (see Chapter 4 and 7). Good communication within the villages is also possible via the usual channels, which local people know and use to ensure that changes and new strategies will be communicated effectively. Already efforts to raise awareness of the programme are noticeable, such as signs in some villages (Figure 8.1).

As this new co-management initiative is a national strategy it is occurring at an ideal time as areas in the north and east are developing their fisheries again after the protracted civil war. There is belief among the export companies that the opening up of the north and east coasts to more permanent, local ornamental diving communities will reduce pressure on the coral reefs and ornamental fish species across Sri Lanka. NARA, academics and environmentalists, however, are less convinced, believing that if divers are unable to migrate to fish on different coasts following the calm conditions around the island, then local divers will fish as long as is possible all year, which will increase pressure on the resources and reduce the period that fish and reefs currently have to rejuvenate. The reefs are known to be in better condition in the east and north coasts than southern Sri Lanka (Öhman et al., 1997; Rajasuriya et al., 2005b; Tamelander & Rajasuriya, 2008), due to the lack of fishing owing to the hostilities in the north and eastern areas. All forms of prior management were also lacking in the north and east and so the co-management initiative will be seen as a new concept in these area and may result in effective uptake.

Figure 8.1. An information sign erected in 2010 showing the efforts of the new co-management project and government and institutional participants. The sign is located along the main path to the bay in Kapparathota where boats are moored and divers enter the water.

In contrast, the south has been operating under different management styles in the past and it may be harder and more complicated for the co-management method to gather momentum. In any case, government officials appear more hopeful of promising results in the north and east coast areas. There are fears amongst DFAR, NARA and environmentalists that the short-term views of politicians and their relations with the rural fishing poor, as well as the short-term profit driven mindset of many fishers, may scupper these early hopes of co-management as it is a long-term view management method.

Currently, there is much work to be done if the system is to be re-arranged and a new pathway to be created. There is still a strong sense of distrust of government bodies by most fishers; when I began my study and asked to talk with fishers, I often had to make it clear I was from a university and not a government department. Finding a common ground for understanding between government and communities will take time as trust has to be built so more concerted action can take place, as is found in successful co-management initiatives (Berkes, 2009). Worrying signs of continued inertia between government and local communities means the system may work more effectively with external facilitators, such as university researchers or other national institutions in whom local people have greater trust and respect. Using such local facilitators was a necessary inclusion in effective co-management in tropical nearshore fisheries in south-east Asia (Pomeroy et al., 2001).

During my last visit at the end of 2010, very little progress had been made in relation to this process, despite nearly a year since the meeting described in Section 8.2. Regular meetings amongst either committee leaders or members had not occurred, government officials were still rarely seen and no new restrictions or changes to fishing behaviours had been initiated. Motivation and support for the plan from those in government responsible for its continuation appeared the same but interest among divers had decreased. As one buyer told me when I enquired of any development with the co-management plan:

"Nothing happened after that, there was one meeting in Polhena, then nothing".

Changing management systems is a slow process, but it appears that without some long-term commitment by government bodies in the coastal villages to shore up this initiative it is highly unlikely to have the desired effect. Such commitment could include more regular visits and interaction with the divers on a personal basis or providing time for 'fishery surgeries' to receive and deal with issues or feedback from the divers. As mentioned previously, an underlying attitude among divers is to view government officials' visits as transitory, relatively meaningless and without follow-ups; and this will continue so long as these divers remain unclear as to what the proposed changes and visits mean for them and the future of the fishery. Schemes targeting grass-roots local people require close collaboration from government supporters and external facilitators. Supporting this view is that before the tsunami, the EDB attempted to cluster the village suppliers to allow them to export fish directly, and in turn, reducing or even removing the control of the export companies. This program failed due to a lack of participation and co-operation between the government officials and these local suppliers, as well as discontent from the export companies.

However, other fisheries in Sri Lanka have co-operative societies, which have been reinvigorated by adoption of a co-management framework, such as gill-net reservoir fisheries where co-operatives are helping to enforce regulations, license fishers and provide equitable distribution of benefits among participants (Nathanael & Edirisinghe, 2002). Similar co-operative success in Sri Lanka also occurs in the shrimp lagoon fishery (see Chapter 6.1). In Kapparathota, I was told that an ornamental fishery co-operative existed in the 1990s but collapsed due to low levels of co-operation and mismanagement. Some more cynical informants told me that Sri Lankan fishers found it difficult to work together and to share profits and so the whole system collapsed. Others cited the non-payment of large loans provided by the co-operative funds as the reason for their dissolution. Either way, it appears divers can still remember the difficulties of co-operative activity and without a more sustained dedication of man-power and finances on the part of the authorities to address previous government shortcomings and to re-introduce this plan; the potential barriers that actors foresee based on past experiences may be too difficult to overcome.

8.6 Conclusion

This chapter aimed to examine past, present and future management plans of the ornamental fishery through the lens of political ecology, and hence predict future trends in both the ecology and productivity of shallow water reefs as well as the vulnerability of the diving and their village communities. Having explored prior governance schemes in the region, it is evident that efforts up until the initiation of the recent co-management strategy have failed to protect either the coral reefs or the livelihoods of divers. By exposing the political processes and positions of control which have strongly influenced previous governance failures and still permeate these early stages of co-management implementation, it is essential that the non-place based holders of power, recognised knowledge and control relinquish these properties to the coastal communities. This transfer of power and trust needs to occur in such a way that ornamental diving communities procure property rights and are allowed to take collective action concerning their village resources with only the advice and support of government. This is by no means a simple task and needs to run parallel to other initiatives with bridging institutions to foster and regenerate lost resilience among different sectors. Restoring reef productivity and securing local livelihoods against disturbances is an adaptive process and if management is fitted around that notion, then, as success stories have shown in other parts of the world, communities motivated and empowered to sufficient extent can prevent further ecological degradation and heightened livelihood vulnerability. The need for release from the fishery's current blocked pathway are required in tandem with more participatory and equitable forms of governance. The creation of community based alternative livelihoods are a possible source of release to shift the poor human-reef relationship of the SES towards a more desirable state and this potential is discussed in Chapter 9.

Chapter 9

Non-monetary benefits of fishing and the potential of alternative livelihoods

9.1 Introduction

Frequently in circumstances where certain human livelihoods cause direct natural resource degradation, a typical strategy is to reduce or remove unsustainable practices and foster new, sustainable ones, through the implementation of alternative income generation (AIG) strategies or livelihoods. The premise is sound yet application and take-up of alternative livelihoods has proved difficult globally (Scoones, 1998; Sayer & Wells, 2004) including some marine contexts (McManus, 1997). Factors that affect the success of AIG opportunities are profitability, the new occupation must be more or as profitable as the previous form, access to capital and assets for start up costs and for coping during times of hardship, attitudes to risk, vulnerability and the influence of institutions (Ireland, 2004). In line with finding sustainable solutions to human-environmental relationships, current thinking is to design schemes that utilise local people's skills and knowledge alongside locally available assets to derive often multiple alternative sustainable livelihoods. These need not be wholly different from their prior livelihoods but should not undermine the natural resources.

However, livelihood diversification involves transforming the political and social environment to enable more sustainable activities to occur and become competitive economically or dominant over unsustainable practices (Start & Johnson, 2004). Ideally, livelihood alternatives need to be introduced in tandem with local conservation programs to redress the erosion of natural capital that has occurred. Usually this can only occur effectively if local people are provided with a different means of income to alleviate the destructive stresses on the natural environment. Conservation projects operating in these areas should focus on improving the land and seascape territory of local people and not just one aspect of the interconnected system (Moberg & Folke, 1999). Without such multi-directed action, the promised improvements to local people's social and economic conditions will probably not materialise (Kühlmann, 2002).

Unfortunately, it is reported that "...there are unrealistic expectations of how and when alternative livelihoods can be developed and the concept often remains a virtual one" (Mansfield & Pain, 2005). Often these alternative livelihood programmes do not come to fruition as the complexities and the interactions of the social-ecological system are ignored or unknown and so future efforts must be aligned with local people's concerns, priorities and conditions (Eder, 2009). Furthermore, in coastal contexts such as the ornamental fishery in Sri Lanka, most fishers are relatively poor and therefore risk averse, due to their precarious incomes so they may be the least likely to entertain alternative livelihoods without guarantees concerning increases in income, security and social mobility. A further stumbling block to alternative livelihood initiatives among rural fishers is that they often have deep connections with their daily activities and enjoy their work (Pollnac, 2001; Cinner et al., 2009a), thus convincing them that a different activity will provide comparable levels of income, enjoyment and spiritual fulfilment (Lilette, 2006) is a tough challenge.

Many ecological studies describing the unsustainable practices of fishing in coral reef areas and of the ornamental fishery in particular, recommend the development of alternative livelihoods, such as fish and/or seaweed farming or ecotourism, as means to reduce human pressures on fragile and depleted marine resources as well as increasing local incomes (Fabinyi, 2010). My aim in this chapter is to determine the perceptions of ornamental divers around alternative livelihoods, particularly mariculture of ornamental fish species, which has been suggested in Indonesia (Pet-Soede, 2003), the Pacific islands (Thomas, 2003) and the Philippines (Pomeroy & Balboa, 2004). Furthermore, I wished to determine the likelihood of divers either remaining or leaving the ornamental fishery and explore the current and future possibilities of alternative sustainable livelihoods available to them. Finally from synthesising the advantages and disadvantages of all the options, make a recommendation for future alternative livelihoods, in particular, for those involved in the nearshore ornamental fishery.

9.2 Methods

The data analysed in this chapter was generated during focus groups with divers in the three fishing villages (Kapparathota, Polhena and Thalaramba). Focus groups were used for the data presented in this study as I wished to use the "group effect" (Carey,

1994) to determine motivations and behaviours through interactions among the divers rather than from individual data (Morgan, 1996). Also linking focus group data with ethnography provides added depth and significance to comprehension of the data (Agar & MacDonald, 1995). I had conducted many interviews and discussions and spent considerable time with the divers before I carried out the focus groups in each village. From consultation with divers in earlier interviews and discussions I formulated eight main factors that divers identified as important to them and their livelihood and others that they said were of concern to them. Similarly, I had also filtered out six main reasons that divers provided for why they had chosen this occupation. These were the factors that divers I met found to be most significant but there may be other factors and reasons that are important to other divers. In the focus groups I conducted a priority ranking exercise, in which each diver there ranked from 1-8 the factors of importance and concern after which, they ranked their reasons for choosing ornamental fishing as their job from 1-6. I assessed the diver's level of attachment and enjoyment for diving and their reasons for liking or disliking the job during the semi-structured interviews and discussions, as well as from my observations made whilst accompanying them on fishing trips. Similarly, I held discussions with a wide range of divers of different ages and experience about their future concerns, if any, for their livelihoods and analysed the data for differences in outlooks between the younger and older divers. Diver perception of alternative livelihoods and particularly the potential to farm marketable ornamental fish species emerged from discussions during semi-structured interviews.

9.3 Job satisfaction and future livelihoods

From the focus groups and interviews with divers in both Kapparathota and Thalaramba it was clear that the majority enjoy their occupations as ornamental fish collectors, with over 80% giving a positive appraisal. In Polhena, approximately half of the respondents said they enjoyed their work, with the other half claiming they do it only for the money and have little or no attachment to the job. The continued existence of coral reefs and earning money for their families are the two most important factors for divers (Factors B & E respectively, Figure 9.1). However, this does not necessarily mean that divers believe they are ensuring the continued existence of coral reefs by their actions, but demonstrates the level of importance divers attached to the continued existence of coral reefs for their livelihoods. Earning money for themselves and the feeling that fish prices remain too low were the next two most important concerns with similar ranked median values. The inequitable supply chain system and the risk of accidents at sea were ranked as mid-level concerns (Factors G & H respectively, Figure 9.1). The anxiety of low earnings during the out-season, or the desire to find a new job were of least concern to these southern region divers. Factors that have been found to be important to divers in Philippines and Indonesia, such as adventure and prestige did not come up among the snorkellers in the focus groups, because certainly among the young, snorkelling is not viewed as a prestigious occupation. These were sentiments more associated with SCUBA divers who were not involved in these focus groups (see Chapter 3.3.1).

Using the same score system, where a score of one denotes high importance and a score of six denotes lowest importance, it is evident that divers consider this job neither safe nor reliable in terms of income provision (Figure 9.2). The need to earn money and the autonomy provided by the job were the two most important reasons for job choice (Figure 9.2). Enjoyment and being able to spend more time with their families were ranked next and of equal importance. It appears that these data correspond well to the notion found in several other studies that fishers find a strong sense of enjoyment and attachment to their work, even in times of decreasing catch or when threats are evident in the system (Smith, 1981; Pollnac & Poggie, 2006).

Those who said they enjoyed the job, gave several reasons for this attachment which ranged from it being a relatively easy job, compared to perhaps manual labour jobs they have experienced; the freedom the job allows in not working for an employer directly and the length of time that can be spent with friends and family each day; the appreciation of the beauty and diversity of the coral reefs and fish that they dive amongst; the health benefits of an active livelihood as well as the connection some divers have had with the sea since a young age (Table 9.1). Reasons given by those who do not like the job, were the low and irregular income it generates and the destructive nature of the job: the removal of fish from the reefs and the damage to the corals, although this was a concern of few divers (Table 9.1).

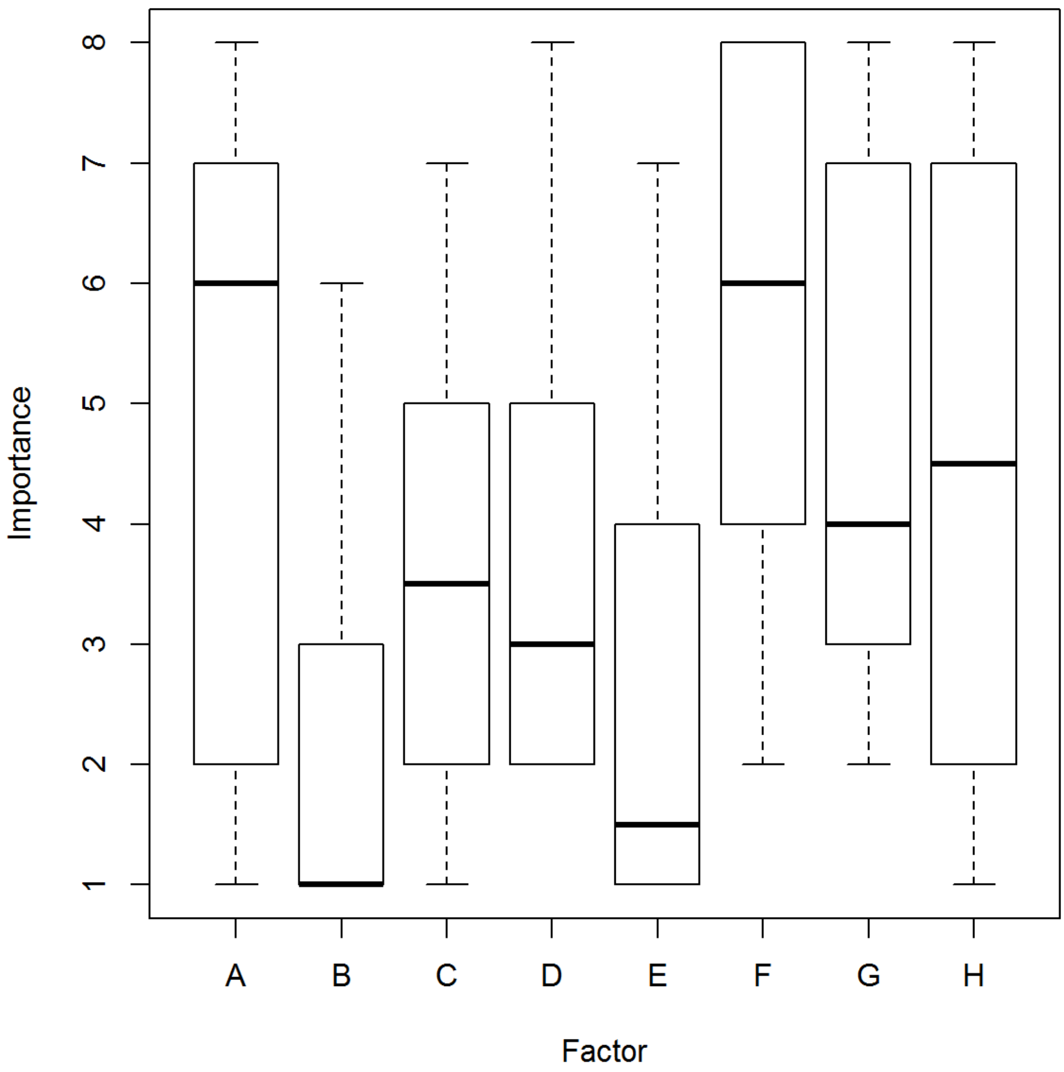

*Figure 9.1. Boxplot of medians,quartiles and ranges of respondents answers. The data shows the relative prioritisation by divers of factors relating to diving as an occupation at all sites. Importance scale: 1 = most important and 8 = least important. Factor codes: A =Having little money in the out-season, B = Continued existence of coral reefs, C = Earning money for yourself, D= Low fish prices, E = Earning money for family, F = Desire to find an alternative job, G = Inequity in supply chain system, H = Having an accident at sea. Respondents (*n*) = 37.*

Divers gave many reasons as to why they are concerned for the future including: a lack of fish and corals, decreasing incomes and the unpredictability of the sea. Many claimed conditions have changed dramatically since the 2004 tsunami in terms of weather and sea patterns. Others voiced concerns about their age and continuing fitness and viewed diving as a risky job in terms of health and safety.

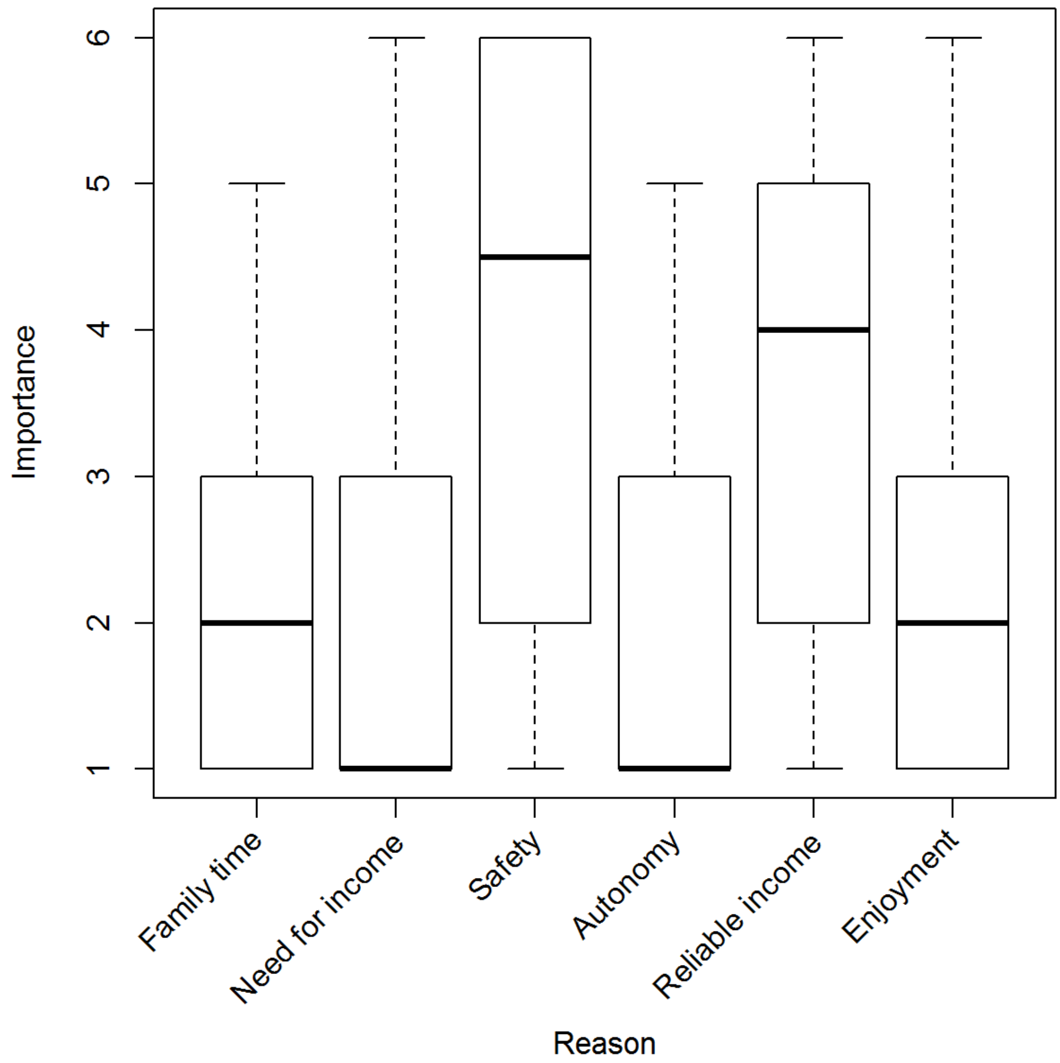

*Figure 9.2. Divers reasons for choosing their job, in order of importance. Importance scale: 1 = most important and 6 = least important. Family time means ability to spend more time with family than other jobs. Respondents (*n*) = 37.*

Older divers were less concerned for the future, with many hoping to reach pensioner age[35] as divers and so avoid the need to re-train or find an alternative job. Other participants who appeared unconcerned about the future of their occupation were some of the young divers, one of whom confidently told me *"Where there is a sea, there will be fish."*.

However, the data showed that 65% of divers aged 18 to 45 were concerned about their future following this livelihood; with most of those aged between 18 and 30 not seeing it as their permanent occupation. These divers said they wanted a more reliable job, that

[35] The Ministry of Fisheries and Aquatic Resources provides a pension to fishers over the age of 65.

would provide a more comfortable lifestyle. Those aged between 30 and 45 were concerned for the future but saw few alternatives for themselves, except alternative fishing jobs. These findings of how divers' age and experience affects their attitude to permanence in the fishery corresponds to the Hawaiian ornamental fishery, where older more experienced divers were found to be less likely to leave than those new to the fishery (Stevenson et al., 2011).

Others spoke of concerns raised from images and information from TV and radio programmes which assessed the situation of Sri Lankan coral reefs; depicting the deterioration of the reefs, the threat from future rising sea levels and the subsequent plight of coastal communities. Many divers having thus become aware of these external events and their possible impact on their own livelihoods and villages are concerned for their futures. This realisation of the impact of both local and global stressors to their local surroundings could influence decision-making in two possible directions. Divers may realise the situation will only grow worse without a reduction in fishing effort and so encourage a search for and uptake of alternative livelihoods. However, it could cause divers to perceive they can do little at the local level to prevent the predicted effects of global climate change and result in increased levels of fishing, as divers seek to catch as many fish as possible before further ecological marginalisation occurs (Kousis, 1998). It is of interest to note the strong effects the global environmentalist discourse, via such radio and television programmes produced by local and international environmentalist organisations, can have on relatively remote rural fishers. Here, it has created distress which is unfounded and panic where there is really need for rational thought and gradual change. It is often debated whether the well intentioned practices of NGOs and other environmentalist actors cause more benefits or harm at local grass-roots levels through such indirect shock-tactic awareness campaigns (Fisher, 1997).

Table 9.1. Divers' likes and dislikes of their job as ornamental fishers, data includes SCUBA divers and snorkellers from all sites. Multiple responses were allowed.

Liked most	% response	Liked least	% response
Ease of the job	23.6	Low, irregular income	64.8
Autonomy	36.4	Destructive effect of fishing practices	2.7
Amount money earned	17.5	Risk of injury or death	13.5
Exposure to nature	28.4	Unpredictable weather and sea conditions	45.4
Health benefits	15.6	-	-
Total interviewed	37	Total interviewed	37

When asked about possible alternative employment, responses varied by site. In Thalaramba 83% of divers saw few employment alternatives either within the fishing industry in general, or outside, and replied they would carry on with ornamental fish diving. In Kapparathota, as there are more possibilities for food fishing jobs, 72% of the respondents said they would continue to combine boat food fishing and ornamental diving, as this would earn most. Less than half of all snorkellers at all sites wanted to progress from snorkelling to SCUBA diving, citing the cost of necessary SCUBA kit as prohibitive.

In Polhena, 81% of those asked (n = 11) said they were searching for an alternative job outside of fishing, which was greater than in either of the other two sites, with only 24% and 45% of divers in Kapparathota and Thalaramba, respectively, looking for jobs outside fishing. Virtually all divers across all sites said they have no other skills and are therefore unable to find work outside of fishing; however, despite most divers saying they lack other skills, those in Polhena said the prospects from continuing their current job were so poor that that they felt compelled to search for alternatives. Divers leaving the village to find work are relatively rare, as described in Chapter 3.4; they seldom leave the village, except for essential activities in nearby towns or visits to the capital. Divers feel more secure staying in their villages to live and work because they have strong kin networks and possess high levels of social capital to draw upon in times of need; advantages that disappear outside the village limits. The strength of these societal bonds and their importance for sustaining communities and natural resources through collective management is well recognised (Pretty, 2003). Therefore, in order to maintain these positive aspects of high, local social capital, any alternative livelihood initiatives should aim to be located within each village's limits. Otherwise, livelihoods based outside the villages would begin an emigration of young local people and the community level institutions and networks would gradually diminish and their benefits will be lost.

During interviews in consecutive field visits, divers spoke of divers or village members who had left to dive or do other work elsewhere and on hearing their news, they would discuss whether other options might suit them. Such a case was reported in Polhena. Divers told me that one diver had gone to the Maldives to collect ornamental fish for six months; the incentive being that there were more fish and therefore more work and better pay. Several of his friends had considered following him, but while trying to raise the money for the necessary paperwork, he had returned with reports of late payments and much less than he had been promised, which had deterred his friends. Thus, from the data it appears that divers look for and assess alternative jobs mainly through word of mouth from kin and friends; which consequently means mainly within the fishery sector.

9.4 Alternative livelihoods

The ornamental fishery's important contribution to local livelihoods is often cited as a reason for its continuation; a view confirmed by my own data. However, some strong critics of the ornamental trade in Sri Lanka, such as Prasanna Weerakkody, a local environmentalist, and certain Sri Lankan academics I met, consider that its defence on the basis of livelihood is weak. During interviews they explained that the damaged reefs cannot sustain the numbers currently reliant on them. In their view, it would be better for both the divers and the nearshore reefs, if the divers were to find alternative livelihoods and so allow the coral reefs to regenerate because otherwise the reefs will be decimated to irrecoverable levels. These views were mostly expressed in relation to a small nearshore reef site, which is now partially protected, known as Rumassala reef. This reef is situated east of Galle between Kapparathota and Hikkaduwa within my study region. It was a reef rich in coral and fish diversity before various infestations of ascidians and corallimorpharians since 1996, the 1998 El Niño event and the 2004 tsunami dramatically reduced live coral cover (Weerakkody, 2006). Since then, with its new found protection, coral restoration work is ongoing at Rumassala reef to remove invasive substrate species and to improve the current, slow coral regeneration (Weerakkody, 2006). Data from my three study sites show that the majority of local villagers, divers, buyers and officials believe it inconceivable to prevent ornamental fishing completely. Only if viable economic alternatives are provided would most divers be prepared to stop diving for ornamental fish. In the conservation literature, alternative livelihood strategies are often suggested or recommended but sometimes there is little explanation of what these might be or whether they are at all viable or accepted by the local people (Mak et al., 2005; Fox et al., 2005). Stopping ornamental fishing in all sites at the same time is not possible and even rotational ornamental fishing by area is likely to be impossible due to the high numbers of divers involved all over the country, no viable AIG opportunities and the disproportionate influence of other actors in the supply chain. Non-local actors are wealthier and are involved to augment that wealth and therefore have more power to ensure the continuation of ornamental fishing, even if it were to become illegal. Consumer demand and the power and leverage of higher placed actors in natural resource supply chains ensure persistence of the trade and any associated destructive activities. This is observed among the illegal ivory and rhino horn trades (Warchol, 2004) and the live reef food fish trade (Johannes & Riepen, 1995; Cesar et al., 2000). Alternatives that local people, during my study, had switched to, or participated in occasionally, or were fully engaged in, as well as those proposed as future potential alternative livelihoods are outlined below.

9.4.1 Current strategies

9.4.1.1 Fishing diversification

As explained in Chapter 3.3.1., many ornamental divers resort to different forms of fishing in the out-season, such as food fishing, stilt fishing to sell food fish for cash or longer term food fishing from boats. Many also catch lobsters which are another valuable export product, if of sufficient size. As many of these divers dive for subsistence and to earn money and have diverse coping strategies in hard times, they are able to switch, especially within the fishing trade, between ways to generate income. These temporary changes of livelihood are not ideal to fisheries managers and conservationists, however, the effects of different fisheries on the reefs are markedly different and so a reduction of fishing effort in and around nearshore reefs could be achieved if snorkellers could earn better, or equivalent income, from food fishing further offshore. Although some said the risks are greater in offshore fishing, which could prevent younger snorkellers from switching to this form of fishing, I encountered 16 year-old boys working on fishing boats offshore for one to two months at a time. The resultant decrease in snorkellers may be viewed as a "vacuum" to be filled by young and trainee snorkellers so, to prevent this, local communities would need to agree this reduction in fishing effort and enforce the limited numbers during this period. This is often a strategy encouraged in early stages of community based management initiatives to remove fishing pressure from village reef lagoons along Pacific island coasts (King, 2005). However, diversification of fishing is usually seen more as a supplemental income, than a true alternative livelihood, which it is argued often does not reduce fishing pressure on overexploited resources (Sievanen et al., 2005).

9.4.1.2 Skills development and education

Some of the younger divers are following courses run through the Ocean University of Sri Lanka,[36] to broaden their skill base and earning potential, particularly during the out-season, when it is hard to earn money from ornamental fish diving. It is possible at the university to follow practical courses in marine industry skills, such as underwater welding, boat handling and types of industrial diving. With a diploma from such an institution, they are more likely to find work in Sri Lanka as a diver at harbours and new port constructions. Many divers also wish to gain a certified SCUBA diving qualification, such as PADI[37] licences. Most ornamental SCUBA divers, do not have formal diving qualifications or any record that they can dive, therefore finding long-term or regular contractual work as commercial, scientific or even recreational diving is difficult. Most divers across all sites have few qualifications, the highest being O-levels,[38] therefore to pursue further qualifications in mainstream subject areas is a further difficulty as without A-levels, they cannot enter university or college.

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[36] The Ocean University, linked to the National Institute of Fisheries and Nautical Engineering and part of MFAR, is based in Tangalle, a coastal town approximately 40 - 50 kms east of my study sites.

[37] PADI is the Professional Association of Divers International and is the largest and most widely recognised dive qualification group in the world, providing all levels of qualifications for recreational divers.

[38] Sri Lankan schools examine students using the earlier British education system of O & A-levels.

9.4.1.3 Migrant labour

Several inhabitants of the fishing villages – divers, other fishers and their relatives – have increased their income and sent remittances home through various full time jobs for several years in other Asian countries. This is an increasingly common coping and livelihood strategy amongst the young in developing countries; the number of migrants from less economically developed countries working in emerging economies, such as the Middle East and parts of South-East Asia, now almost equals the number of migrants working in established economies, such as Europe and USA (Ratha & Shaw, 2007). From my discussions with young people in Sri Lanka, both those from within fishing communities and those outside from more affluent communities, I found they believe that working abroad for a few years is one way of increasing wealth and living standards. The majority of migrant labourers are young men, who travel abroad before they are married. Within the fishing communities, I only met one woman who had worked abroad. This strategy is easier for young men than women, as men in these communities in general marry later (see Chapter 3.4.2) and are only expected to settle and have a family of their own at a later age than women. They view those Sri Lankans who have migrated and returned to be wealthier, with fewer problems than before. Young, unskilled men are particularly enthusiastic to move abroad, with South Korea, the Middle East and Singapore being choice destinations. Most want to work in Europe but visa, work and financial requirements deter them. Several divers I spoke to who were over 40 had worked abroad either collecting ornamental fish or in the hospitality industry in the Middle East. Although none recommended the move mainly because of cultural differences, the young did not appear to be deterred and during the period of my study, five young fishers I knew moved to Korea, Dubai, Qatar, Singapore and the Maldives as car factory workers, lifeguards, hotel workers and ornamental fish collectors respectively. They all planned to remain abroad for between six months and two years. This is the aspiration of many young divers I met who consider those with large social networks and the ability to procure the necessary funds to be extremely fortunate.

9.4.2 *Future possibilities*

9.4.2.1 Coral propagation

Many Sri Lankans, including divers, concerned about the ornamental fishery talked about the possibility of the divers working to farm corals, in order to reduce fishing pressure and re-stock corals in the nearshore depleted reef areas. Experts in coral reef restoration, considered it could only be done on a small, experimental scale, because coral would only regenerate in locations where the water and other abiotic conditions allow for natural regeneration (Rajasuriya, pers. comm.; Clark & Edwards, 1999; Fox et al., 2005). Kalptiya Bar Reef, in the north-west of the country has naturally recovered over 80% of its live coral cover - mainly branching and table corals - since the bleaching event in 1998, whereas recovery of live coral cover in the southern reefs has only been round 10% (Tamelander & Rajasuriya, 2008). Coral reef biologists view attempts to re-stock corals on a large scale where they cannot recover naturally as a redundant exercise (A. Edwards, pers. comm.). To date, only small-scale, experimental attempts at coral growing have been tried in Sri Lanka, mostly after the 1998 bleaching event but without success, although the reasons are not yet clear. These efforts have, however, piqued the interest of local communities, which are enthusiastic to attempt to increase live coral cover in their village waters.

I was informed by the Department of Fisheries and Aquatic Resources (DFAR) that there are no plans to culture corals in Sri Lanka, but there are future plans to culture corals for export as live rock. However, this looks likely to be carried out directly through export companies and fish farms, overseen by the National Aquaculture Development Agency (NAQDA). With the multitude of stressors on Sri Lankan reefs, the viability of propagating corals is poor, but the culture of live rock has potential as an AIG practice that could be performed by divers and fish buyers in their village waters. For the moment though, the government bans all exports of coral and its removal from the natural environment, and after such a disastrous history of coral mining in the recent past, DFAR is understandably tentative about allowing any culturing of corals in the coastal area or trade in corals. Live rock culture occurs today in the USA, Europe and other marine ornamental trade import markets where its demand among reef aquarists is increasing (Chapter 7.1.2).

9.4.2.2 Tourism

The southern coast of Sri Lanka is popular with tourists; many villages predominantly generate their income from tourism, major examples are Hikkaduwa, Unawatuna and Mirissa, which neighbours Bandaramulla village. These locations all have nearshore and offshore coral reefs as well as white sand beaches. Many local people have guesthouses, restaurants, shops and other services to accommodate tourists and the relatively higher income they can generate above other local economic activities. Some ex-divers and fishers told me they engaged in tourism focused businesses, with financial help from foreigners, from which they now earn more than they did from fishing. The costs and benefits of tourism are complex and although it is not the aim of this study to examine the potential and pitfalls of tourism as a newly acquired livelihood in Sri Lanka, a study in the Philippines (White et al., 2000) in the marine context, suggests that small scale tourism can generate revenue that is otherwise lost from destructive activities on coral reefs. However, there are concerns over the ecological impact of too many tourism livelihoods and activities especially in coral reef areas (Kiss, 2004; Roberts et al., 2002; Camp & Fraser, 2012) and some have even branded ecotourism as "neo-liberalism" in that the process creates further uneven distribution of wealth among local people and provides a contradictory image to the values of ecotourism (West & Carrier, 2004). It is also important to stress that tourism activities are not guaranteed AIG strategies, particularly in Sri Lanka. Tourism has been put forward as the best alternative to reef extraction activities in other tropical countries as the potential revenues are higher than most other options (Cesar et al., 1997; White et al., 2000; Hodgson, 1997) but its negative effects on coral reefs and local communities leave many divided about its net benefits (Allison, 1996; Harriott et al., 1997).

Steady income from tourism relies on many factors such as location and environmental and political disturbances. For example, for villages situated off the major tourist routes, as are several of the southern fishing villages, this income opportunity proves challenging. Secondly, the 30-year civil war, as well as the recent tsunami, kept many tourists away. So during my first field season, located in Bandaramulla/Mirissa, I was one of a handful of foreigners. By 2010, I was one of several hundred there during the season. Local people are confident this increase in tourism will continue and the potential for divers to act as informal reef and marine guides in their village waters will also grow. Some snorkellers who exploit these opportunities find they can earn significantly higher amounts showing tourists fish and corals along the reef, in one hour than they can in four hours of ornamental fishing. Divers do not even need boats as the reefs are accessible from the shore with snorkelling gear.

9.4.2.3 Aquaculture

Another possible AIG strategy and a possible solution to the problems of the wild capture of marine ornamental species is to culture these same species. However, it is still not possible to-date, to culture most tropical marine ornamental species (Wabnitz et al., 2003); only certain species, such as *Amphiprion* spp. and other Pomacentridae species can be cultured successfully. Highly sought after fish species, such as chaetodontids (butterflyfish) and pomacanthids (angelfish) are not bred commercially and look extremely unlikely to become so soon, due to their complex life-cycles, the small size of their young and the fact they are pelagic spawners (Pomeroy et al., 2006). Therefore, government and reef conservationists in Sri Lanka believe there is little hope that the idea of marine ornamental aquaculture can reduce fishing pressure or become a permanent alternative livelihood to divers.

As stated in Chapter 7.3.13, Aquamarine International, the largest export company in Sri Lanka, now breeds *Amphiprion* spp. and *Hippocampus* spp. for export. However, *Amphiprion* spp. are also cultured in the UK by Tropical Marine Centre (TMC), and this could be a threat to the entire trade because if import countries can culture their own fish then they can outcompete by price those same species cultured in source countries, located far from retail markets. Although from speaking with representatives at Aquamarine International and two other Sri Lankan export companies, it seems cultured fish are currently in high demand from source countries, and their higher prices are accepted due to the hardier nature of such fish compared to the wild caught fish.

The costs of culturing the fish in source countries may still be cheaper than culturing them in import countries; but despite the low labour costs in Sri Lanka, setting up and running an aquaculture facility is expensive, therefore few involved in the industry are attracted to this whilst wild fish are available with divers willing to catch them. The high costs of aquaculture are usually synonymous with large-scale farm style facilities, and, for other than the wealthiest of companies, prohibitively expensive, thus most companies and certainly all divers do not consider it at present. Even government officials and the EDB admit reluctance to invest in hatcheries and aquaculture facilities due to the initial high costs and long uncertain returns.

Smaller scale aquaculture could be more cost-effective, if run at the local grass–roots level and could provide a higher price for specific fish and divers could do this work in place of diving on some days or periods. Such small-scale systems to breed marine aquarium fish have been initiated in other Asian countries under community based management schemes, and proved successful; for example, aquaculture of *Amphiprion* spp. in Indonesia (Black et al., 2006), as an alternative and supplementary income generator (Job, 2005). In Sri Lanka, ideally, by breeding certain species divers might fish less as their incomes would increase by removing the buyers in the supply chain, who often make a profit with the mark-up on each fish between diver and export company. However, divers would still be affected by those actors in higher levels of the market chain, such as the export companies, and it is likely divers would be pressured to catch wild fish and culture fish to increase profits for everyone. This point highlights that all potential AIG options must be evaluated on their effects on the whole market chain, as no group or element of the chain can be isolated but all changes have to be traced vertically and horizontally in terms of the supply chain to evaluate their efficacy.

9.4.3 Home-based aquarium fish keeping

During my study I investigated the possibility of home-based small tank aquaculture and/or fish husbandry work. It was not possible to conduct a full-scale aquaculture trial study, as logistics and finances were not available. I thus viewed it as a social and economic experiment rather than a biological one and attempted a scaled down version. Three glass tanks were built locally each measuring 90 cm long by 30 cm wide and 45 cm high, and each equipped with a biological filter, an air pump with tubing and airstones, a light, a general aquarium antibiotic kit and water quality test kits; all sourced locally. One tank complete with kit was given to one diver in each village who had been selected based on their interest in the idea and the location and suitability of their home. Together we placed the tanks in the most suitable position; in the shade and away from excessive noise or activity and I recorded their experiences over a six month period. Local, freshwater fish breeders provided training on basic aquarium care and fish care as well as further guidance concerning marine species breeding (Wittenrich, 2007). At first, a pair of *Amphiprion clarkii* (Yellowtail clownfish) were kept as they are caught for the trade and known to breed in small scale systems (Wittenrich, 2007). Although we observed signs of courtship and pre-egg-laying behaviours, no breeding had occurred after two months and two of the tank users wished to use the tank differently, which was agreed (see Section 9.4.3.3). One diver continued to care for his *Amphiprion clarkii* pair in the hope they would eventually breed. These data, collected by monitoring their experiences, may be of a small sample size and not quantifiable, but are useful in terms of the practical limitations and the potential of such a future scheme.

9.4.3.1 Economic feasibility

A total cost to build and kit out one aquarium of the size stated above to breed and keep fish in is approximately 15,000 LKR (US$ 110)[39], which is well beyond most divers' means, and indicates that some outside funding is needed for the initial capital. In addition, running costs ranged from 1000 to 2000 LKR per month per tank (Table 9.2) and aquarium test kits to ensure optimal water quality are needed every three months and are relatively expensive in Sri Lanka. This meant both the capital investment and operational costs were too high for the small-scale Sri Lankan divers to afford without both external financial assistance and some guarantee of immediate income. These findings from my small project were similar to those of a financial feasibility study of full cycle *Amphiprion* spp. (clownfish) aquaculture trials conducted in the Philippines (Pomeroy & Balboa, 2004). Other costs encountered through this experiment ranged from accidental breakage of the glass tank to aquarium equipment failing. Replacement and repair costs were relatively low during the six month trial period, with the tank operators only needing some financial support twice, which means fish buyers could manage the maintenance costs without outside help and divers could manage it with relatively little financial aid.

[39] Current exchange rate of LKR to US Dollars.

9.4.3.2 Other challenges

The supply of electricity was the most serious problem encountered. Power-cuts of more than a few hours, which are relatively common in this area, usually with no advance warning, resulted in the mortality of some or all the fish. The purchase of a generator is obviously not feasible. A long-term problem encountered by all the tank owners was water temperature control. The water temperature was very close to the ambient indoor temperature and remained very high (>30ºC) for long periods. During cooler months the water temperature decreased to more optimal levels around 25ºC. From the literature on breeding *Amphiprion* spp. and general good fish husbandry in aquariums, maintaining the optimal temperature range for the fish is crucial to success as the simulated temperatures and photoperiod in captivity replaces the natural cues for spawning in the wild (Holt & Riley, 2001). We hypothesised that the variations in temperature may have prevented the *Amphiprion clarkii* pair from breeding in the tank where the owner continued with the clownfish breeding experiment, as all other variables appeared stable and optimal and the fish were in good condition. A cheap solution to stabilise tank water temperature slightly cooler than ambient temperature is required.

Table 9.2. Costs to build and maintain one 90 cm x 45 cm x 30 cm aquarium per month in southern Sri Lanka

Item	Initial cost (LKR)	Running cost per month (LKR)
Glass for tank	2000	0
Labour to make tank	2500	0
Metal for stand to hold tank	500	0
Labour to make stand	500	0
Bio-filter	4500	0
Airpump, airstones, tubing, light	1000	500 (repairs/ replacements)
Thermometer	200	0
Interior items (tiles/pots)	Free	0
Electricity per month	-	1000
Water	-	Fetched from sea for free
Fish food	200	200
Test kits x 2 (minimum required)	3000	1500/test kit (per 3 months)
Fish medicine	400	-
Total	14600	~ 2000

9.4.3.3 Attitudes and skills of home-tank owners

Analysis of the data collected regarding attitudes toward this activity, and the speed by which new skills and processes were learnt, showed that attitudes were positive, but skill and success varied among the participants. The diver who pursued the idea of breeding *Amphiprion clarkii* over the six month period improved his husbandry skills and even though he was accustomed to keeping freshwater fish, learnt new techniques. He was the most comfortable with the task. His fish remained healthy throughout the trial and courtship behaviours were observed. Thus he would be a key person to transfer and disseminate his skills and knowledge to others in the future rather than employing outside "experts" whom the community may not receive and work with so easily. The owners of the second tank were fish buyers and after two months they used the tank to store ornamental caught fish rather than keeping them in bags or bowls. They found this to be extremely beneficial to both their business and the divers' incomes, as fish mortality was reduced. Therefore, this could be beneficially replicated for all fish buyers in the villages in the future.

The third recipient, a diver with little experience of keeping fish, found fish husbandry a steep learning curve at first, but after several setbacks and further training, managed to keep fish alive and healthy in his tank. He used the tank after the two month period to keep fish that he could not sell, rather than discarding them. He and his family enjoyed having the fish in their house, they found it pleasing and therapeutic to watch the fish, a factor cited by several studies justifying the popularity of aquaria in developed countries (DeSchriver & Riddick, 1990). The gradual success of the inexperienced diver created interest among divers in the same village to have a tank. In all three participants' homes, various family members and friends became involved and interested through sharing maintenance tasks. Children of the households were noticeably intrigued by the fish, as I would often find groups of children watching the fish when I arrived at their homes. Their participation in such fish husbandry is valuable in developing respect for the fish and learning that fish need care and attention and are not just objects to make money, which may extend to their neighbouring reef and inhabitant fish and other organisms.

Some divers had tried to grow marine invertebrates and small fish in the past and claimed they were successful in growing *Lysmata* spp. (ornamental shrimps), caught in the wild, from small sizes (worth 75 LKR) to larger sizes in their tanks (worth 300 LKR each) before selling them on. This is a criticism, and concern for some, that in the hands of the divers the tanks could encourage divers to increase fishing effort to catch their usual quantities for daily sale plus extra fish for their tanks (Tlusty, 2002). Divers may be tempted to target small sized fish to grow them to more valuable sizes in the tanks. If small-scale tanks were introduced at the village and community level, it would be advisable to utilise these tanks specifically for breeding certain species, and provide community-based local monitoring to ensure poor fishing practices are not encouraged.

9.4.3.4 Future initiative

A collective small tank breeding scheme in the village would be an interesting trial to consider for further research. Furthermore, the system could benefit in several ways by being run and managed by the women married or related to the divers. The potential for women to run aquaculture among rural communities has been explored in other developing countries (Shaleesha & Stanley, 2000). From interviews I conducted with females related to divers (n=32), over 90% had no job and were occupied with housework and childcare. However, most women would like to work and provide some income, especially in households where the income is low and/or unreliable. Although there are no jobs within the village limits for women, there are jobs occasionally in nearby towns, however, the men did not want them to work in the nearby towns for several reasons but would be content for women to work within their village. Within the village, due to the close-knit structure of the community, women can move freely alone or with other women without causing concern to their men.

Working within the accepted gender social constraints, women said they could undertake the daily maintenance of the tanks and appeared agreeable to sharing the proceeds of their work either within the home or with others at a communal fish breeding station within the village. The increased income to each household could then indirectly reduce fishing pressure but adversely it could increase it. A trial study would clarify the effect of this initiative on fishing behaviours. In addition, many studies in rural communities show that a higher percentage of money earned by women reaches the home and family, rather than from the men who tend to spend it on alcohol, cigarettes and status consumer goods (Hoddinott & Haddad, 1995). The work would only involve a few hours a day; therefore the women would still have time to attend to their children and home as expected.

Already most fish buyers' wives, in each village, help with the packaging, care, ordering and sale of the fish, as well as other daily tasks, such as filling SCUBA cylinders and cleaning diving equipment. Thus women in the village with experience and knowledge of fish husbandry could teach and mentor those without these skills. From this mini-study, it is clear that several social and economic elements of such an alternative or supplementary livelihood need to be considered in terms of the viability of such an initiative. However, the benefits could provide not only an AIG opportunity but also a form of empowerment for women in these coastal communities.

9.5 Conclusion

The results of this fish husbandry experiment and the examination of the other alternative livelihoods available to divers show that developing village fish breeding stations fit the current dynamics of these communities. However, this should be focused on breeding freshwater fish to prevent overfishing of marine ornamental species. The freshwater ornamental trade has both local and international markets and the knowledge and technology necessary to accomplish this are available in the southern region of Sri Lanka. Local freshwater breeders can teach the diving families the necessary skills and identify talented individuals to become the local leaders of the breeding work. Operating at the community level, initial investment costs and any losses are shared among the members and in such tight knit communities this can prevent jealousy and competition among households, which is a typical characteristic of Sinhalese villages (Said, 2009; Stirrat, 1982b). It has the potential to foster increased collective action, which is argued for in all operations associated with the management of this fishery, such as provision of AIG ideas.

Moreover, the divers and their families indicated a strong interest in developing this idea and adapting it to their economic, social and technological ends. Ultimately, external advisers can only introduce ideas but cannot control people's lives and actions, for success in such schemes, it is necessary for local people to devise the system and processes themselves and outsiders only provide advice and training when needed. These fish breeding stations could also involve local schoolchildren, through school projects to learn about fish, animal husbandry and raise awareness of the local coral reefs and their rich diversity. In this way, this AIG idea balances the needs and interests of local communities and others in the market chain against the environmental needs to sustain the reef ecology.

Chapter 10

Conclusion

10.1 Introduction

This interdisciplinary research commenced with the aim to determine the sustainability of the marine ornamental fishery in southern Sri Lanka from the perspective of the fishers and divers of this region and in finding evidence of unsustainability, to seek and evaluate potential methods and management approaches that might move the fishery onto a more sustainable route. It explored this aim through seven objectives for which data was collected by living as a member of the fishing communities and interacting in each of my four village sites with, not only those involved in the ornamental fishery trade, but also other community members, talking with government officers, reviewing documents and analysing both my observed and collected data. The key findings from these objectives are summarised below to understand the extent to which the southern Sri Lankan coastal reef ornamental fishery is sustainable and if not, to identify potential approaches that can move the fishery towards sustainability for both the reef and the local livelihoods.

The first step in this study, to review the academic literature from ecological, social anthropological and interdisciplinary studies concerning human-environmental interactions of natural systems and coral reefs in particular, clearly showed that there were many reasons for concern both to the sustainability of coral reefs globally and the marine ornamental trade in Sri Lanka. For example, in Sri Lanka, several elements highlighted in other studies (Wood, 1996, 2001b) as critical to providing a holistic view of the situation, had either never been researched or not recently. The review also showed from an examination of the strengths and weaknesses of past and present management and governance approaches in the context of tropical fisheries, as well as ways of framing complex social-ecological systems, that the most promising methods and approaches are not currently being used in the Sri Lankan marine ornamental fishery. These findings confirmed the need to determine the current sustainability of the ornamental fishery in the southern waters of Sri Lanka, both from the perspective of the reef and the divers' livelihoods, so as to find a sustainable trajectory.

As the overall aim of this study was explored through seven objectives (see Chapter 1.4), this chapter will first present the key findings of each of those objectives in turn, discuss any implications and use the accumulated data as a basis to make recommendations, including areas for future research. These recommendations are then woven into a holistic organic framework that centres upon consultation and dialogue with all the actors in the ornamental fishery trade. This framework, presented as a Way Forward has been so designed as to address not only the sustainability of the reef but also the livelihoods of its dependent communities. The penultimate section of this chapter examines the contribution of this research study to different bodies of knowledge; from interdisciplinary work of social-ecological systems to ornamental fisheries management, to assess the implications and/or applicability of this research globally. The chapter finally concludes with, a reflection on the entire research process.

10.2 Summary of main findings

The main findings of the research and their implications are presented below in relation to each of the seven objectives to provide the basis for recommendations to be made in answer to the overall research question.

The first major finding is the embedded nature of diving and place in Sri Lankan coastal communities; despite the recent introduction of the marine ornamental fishery in Sri Lanka, the practice of collecting non-food marine resources has a long history and culture. This finding is based on Objective 1: to investigate, within historical contexts, how the social and cultural aspects that support contemporary patterns of reef fish capture for the aquarium trade at selected fishing villages in southern Sri Lanka can be incorporated into fishery management for sustainable livelihoods in the future, as covered in Chapter 4.

Sri Lanka's historical and cultural background has shaped the sociological and ecological characteristics of the coastal villages today in terms of how they are organised, the livelihood options available and the sense of community that exists in each. These factors, in turn, shape the daily lives of the individual ornamental divers who struggle to earn a basic living and cope with the impact of constant disturbances, both human and environmental, past and present. These divers' economic difficulties lead them to take considerable risks which often further endangers their physical and / or mental health. Despite their tight-knit communities, the frustrations of their lives, its insecurities and inequalities are exhibited in a prevalent culture of drug taking and alcoholism which often lead to instances of violence, which can result in stigmatism by others, injury, brushes with the law and even death; all of which further threaten the sustainability of their already precarious livelihood.

The second major finding is that the high variation of both total and individual species' catch rates across all study sites is dependent on the site and the age and experience of the snorkellers at each site. This finding is based on Objective 2: to assess the levels of current ornamental fish catches and catch per unit effort (CPUE) and record fishing behaviours across specific sites to determine the potential effects of local fishing practices on aspects of the wider reef ecology; as covered in Chapter 5.

The local effects of environmental disturbances (El Niño and the tsunami) have coincided with peak periods of ornamental fishing, pollution and illegal practices which have severely degraded the natural capital. Catch per unit effort (CPUE) at all sites is low and the majority of the total catch was comprised of low value species from only certain functional groups and fish families; all indicators of low abundance of target fish species in the nearshore waters. 70% of the total catch, in southern Sri Lanka, by volume and earnings is from SCUBA catches, the rest from snorkellers', yet snorkellers outnumber SCUBA divers by approximately a factor of five. This finding highlights the lack of alternative income opportunities available to the unskilled, untrained men in these coastal communities and the reason why divers numbers are increasing despite the low catches and earnings.

Divers appear to be optimal foragers as they were found to be highly selective in their targeting of high value and juvenile fish species with nearly all fish collected of juvenile size for their species. However, the mid to older divers are more successful than the young snorkellers, and poor and good fishing practices are similarly stratified by age and experience. Coral damage is high, with an average of 10 pieces of coral broken per diver per trip in the season. Certain positive behaviours are observed from the more experienced divers such as changing the water in collecting bags more frequently to ensure fish survival.

The third important finding is that surveys of the nearshore reef habitat show that species richness, abundance and biomass are low in all fished sites and lower than in the protected area in general. This finding is based on Objective 3: to derive the abundance of nearshore reef fish populations targeted for the ornamental fish capture market in southern Sri Lanka and compare this with local divers' knowledge and perceptions of their local marine resources to find ways to utilise collective knowledge for the common good, as covered in Chapter 6.

From the surveys, it is clear that the fish belonged to certain functional groups, such as herbivores, and certain families, such as Pomacentridae and Acanthuridae, with several functional groups and families absent. Large fish and predatory fish were only observed in the protected area. The habitat of all reefs, both protected and not, is degraded with low levels of live coral cover at all sites and certain sites showing higher levels of substrate associated with degradation, such as rubble and macro-algae.

Divers' local ecological knowledge of their reefs and fish populations corroborated these findings at a broad level, with divers concerned for the reduction in fish and coral abundance visible in their lifetimes. The LEK in these communities is similar to those in other rural and coastal communities. Clear examples of LEK among these diving communities, such as their intricate mental maps of their fishing grounds, coupled with their knowledge of fish breeding, behaviours and interactions with the reef habitat highlight their importance in future reef and fishery management. Although the findings show, as expected, that mid to older divers exhibit most accurate knowledge, the levels of knowledge transmission among the generations of divers appears to be decreasing.

The fourth finding is that while ecological resilience is assessed as low at all sites, social resilience among the diving community is high. This finding is based on Objective 4: to assess the levels of resilience in all its forms (natural, social, community, economic) in the fishing villages and their nearshore waters to evaluate how social and ecological systems, related to the ornamental fishery in Sri Lanka reorganise around change and how to manage for resilience; as covered in Chapter 5

This finding shows that even the protected site exhibits low ecological resilience due to the severe environmental impacts on all the southern reefs in the past with the subsequent reduction in diversity and productivity. And, although social resilience among the diving community is high, providing strength and options for the individual at difficult times, high levels of social capital that promote resilience are limited to the extent of the village. Highest forms of social resilience are found, when dealing with change to the SES, in the development of coping strategies or seeking alternatives.

Economic resilience was higher in certain villages due to the livelihood options available allowing for diversification of income opportunities. However, overall such diversification was mainly restricted to different occupations in the fishing sector and economic resilience is lowest for divers but is assessed as higher for buyers and export company officials, *i.e.*, increasing at each level up the market chain. Cultural resilience is relatively high, with most divers being Buddhists and respecting traditions, customs and festivals throughout the year including abstaining from fishing for short periods.

The fifth important finding is the major influence of the vertical and horizontal interactions of the ornamental fish market supply chain on divers' and buyers' behaviours, the current condition of the nearshore waters and the sustainability of the ornamental fishery trade. This finding is based on Objective 5: to analyse the links between the current ecological conditions and the social interactions, between and among, the different actors for the capture, transportation, holding and sale of fish across the current market chain and thus evaluate the system.

A crippling system of debt and inequities permeates the supply chain. Trust, reciprocity and co-operative behaviours have been eroded, creating deep divisions between actors in the trade as it has expanded. The divers' feeling of powerlessness to alter the system corroborates this finding. The weaknesses in the supply chain driven by cut-throat business and profit-driven practices, render it unstable and ineffective to promote long-term sustainability. Historic, social and cultural reasons have created the inequities of the market chain which result in continued unsustainable behaviours of all; but particularly the divers and buyers, who perceive themselves as locked into this cycle by debt.

One strength in the system is the presence of buyers and export company associations, which provide platforms for these groups to interact to address issues and try to find consensus at their level and between levels of the chain. Another strength is the village buyers' logbooks in which they keep records of exact numbers and species caught over time, which provide a form of continual catch monitoring.

The sixth key finding shows that past and current governance approaches, from market based to hierarchical management, concerning the ornamental fishery in Sri Lanka have failed in protecting coral reefs, fostering resilience of any kind and protecting the livelihoods of local people. This finding is based on Objective 6: to evaluate the success of current and past governance strategies applied to the marine ornamental fishery and hence predict future trends in ecological change and vulnerability of human coastal communities in relation to the health of shallow water reefs, as covered in Chapter 8.

A new participatory governance initiative was introduced in 2009/10 for the ornamental fishery, however, it appears not to have changed the past relationships of distrust and misunderstanding. Power and control has not effectively been transferred to local communities and support from government to implement the rules and regulations is still lacking, as is involvement of those lower down the market chain in the decision-making process. Both old and new barriers prevent dialogue with others about their livelihoods; these deepen the divers' disillusionment with government so they feel helpless to actively seek a more equitable and effective management system.

The final finding from this study, relates to alternative livelihoods for the divers and shows that interest in finding alternative livelihoods and acceptability of different jobs that provide the same or greater income, particularly among younger divers, is high as is interest in the mariculture and fish husbandry experimental tank work. This finding is based on Objective 7: to assess the potential for alternative livelihoods through mariculture of exploited species of ornamental value as well as the social and economic acceptability of cultivation or other alternative livelihood options to those practising wild capture to determine their inclusion as sustainable livelihoods within fishery management in the future, as covered in Chapter 9.

Although divers claim a close attachment with diving, despite the low and unpredictable earnings, it is apparently because overall few alternative livelihoods are available. Most alternative income sources were mainly found within the fishing industry, *e.g.* on food fishing boats or subsistence shore fishing, and are organised via an individual's networks within their fishing community. Only those divers with different skills or networks were able to engage with livelihoods outside the fishing sector. However, as the main driver for any livelihood is economic sustainability, interest in my experiment to attempt to breed marine ornamental fish in tanks was high.

The results of this social and economic experiment were not per the original aim to breed fish but instead showed the power of the economic considerations: two of the three participants decided to change which fish they would keep and how they would operate their tanks in an effort to enhance their economic benefits. The economic feasibility of building and running small-scale tanks in Sri Lanka showed that external funding is needed for tank construction for both buyers and divers, but that only the buyers have the financial means to maintain the tanks.

10.3 Recommendations for the ornamental fishery in Sri Lanka

Recommendations aimed at relieving pressure on the coral reefs in southern Sri Lanka in the short-term and providing for greater levels of sustainability in the long-term are set out below. These recommendations, emerging from the accumulated findings, suggest the need for different approaches in terms of governance and management of the coral reefs in southern Sri Lanka; thus an overarching framework for the co-management of these nearshore reef sites is proposed. It is designed to incorporate many of the discrete recommendations emanating from the separate objectives into a dynamic, organic whole. Co-management means it would involve all actors in the ornamental fishery trade, to share their knowledge, as a basis to make, implement and monitor decisions at their level, in ways consensually agreed by all (Armitage et al., 2009).

This recommendation would be most innovative for the divers in this study who to-date have had little or no involvement with others in the decision making processes of the ornamental trade. The envisioned co-management framework would necessitate the creation of new formal and informal institutions or associations, and the refining of existing ones, to act as communication channels to facilitate regular and easy interaction among the actors in each group as well as across the different groups. The removal of real or perceived barriers to communication is a key step towards open knowledge exchange. This would work to build the necessary trust and respect, essential for rebuilding relationships to foster knowledge sharing, which means meetings should be in a place each group chooses so they feel comfortable, for the divers this may be the beach or a bar or their home. Each group needs to value both themselves and the others focusing on their contribution to the national economy so that they can work together within the parameters of the agreed rules and regulations.

This co-management framework would drive the reiterative management process; to assess, plan implement, monitor and re-assess on the basis of the information collected. The initial cycle would begin with a base line assessment of the natural resource, the reef coral and its fish populations, and the human resources; conducted by all involved in the trade, particularly the ornamental fish divers. The collected wisdom of all actors would inform the development, implementation and management of a sustainable driven ornamental fishery policy and its accompanying management strategy. Thus the co-management framework would provide unity through a single coherent all-inclusive approach, designed to generate a sustainable cycle of action that is based on diversity for resilience.

A change in policy and strategy is recommended and there are signs of change orchestrated by government efforts in Sri Lanka to renew methods and practices and steer SES towards a more sustainable pathway. These efforts should include researching successful management transitions emerging among other global tropical fisheries where co-managed and traditionally managed areas show greater compliance among communities, and healthier ecological indicators, to be shared through the framework with the other actors (Cinner et al., 2010; Leach et al., 2010).

This shift to co-management needs to be genuine with complete transfer of power and decision-making to all levels (Berkes, 2009). It is recommended here to move power and decision making from mainly top-down to a cyclical flow involving the agreement of all via both vertical and horizontal communication channels (Ostrom, 2007). The divers and their communities, for example, should make decisions about fishing restrictions and their enforcement that meet specific local needs whilst remaining within the broad government policy and management strategy to whose design they have also contributed.

This would meet another recommendation that a greater value is placed on the local ecological knowledge (LEK) of all these groups, but particularly the divers, which, in turn, would provide greater flows of up-to-date, accurate information between the various groups. As the nearshore coral reef system of southern Sri Lanka looks likely to remain in its current low diversity and productivity state as have other coral reef systems that have shifted to algal dominated states, the vulnerability of coastal peoples is likely to increase. A co-management framework would allow for local people to utilise their LEK to develop means, through collective ownership to decide on how to attempt to reverse this predicament and prevent further erosion of their environment while sustaining their livelihoods.

It is further recommended that the government should encourage divers to exchange their knowledge and ways of doing with scientific and technological knowledge, from national and international sources, to make as much knowledge as possible accessible by different means, so that informed decisions can be taken actively to move these systems into more desirable states. Some successes have occurred in other reef systems globally in reversing shifts from algal dominated to coral dominated reefs (Bellwood et al., 2006) thus the recommendation to learn lessons both within and across the system locally, nationally, regionally and internationally.

More research is needed to uncover LEK among the divers in Sri Lanka and to test which forms of knowledge and practice map well to scientific knowledge and so could be used to inform the management decisions for their own areas. Recommended research is to conduct further, more detailed ethnographic studies of local ecological knowledge and the methods local ornamental fishing communities are employing to manage the natural resources to provide their livelihoods.

The remainder of the recommendations are made through the implementation of the above co-management framework for without these essential changes enabling continued generations of divers and their village communities to take local pride and ownership of the marine resources, it is unlikely that the recommended improvements in economic benefits or ecological and social resilience in the system can result.

With the cessation of the civil war in 2009, it is predicted that the more abundant northern and eastern coastal waters of SL could become rapidly degraded as divers move to these sites in search of the targeted ornamental fish absent in southern waters. Therefore, the baseline assessment, referred to above, would include not only the remaining ornamental fishing sites in the south but also those along the eastern and northern coasts and would follow the same interdisciplinary approach used in this study. The amassed data would be used to formulate a refined policy for ornamental fisheries in Sri Lanka, which would be discussed by all groups in their specific locations to draft the related management strategy. One specific area of research, emanating from discovering that 70% of the trade is derived from SCUBA catches, would be to conduct a comparable study to shadow SCUBA divers to gather CPUE data as well as fishing behaviours at deeper sites, utilising the same interdisciplinary methods as this research.

Rules and regulations are needed to ensure the market chain operates, from reef capture to overseas buyer, with a focus on sustainability of its base resource. Discussions at the local sites should decide ways to monitor and enforce the rules and regulations so as to strengthen and develop new practices or ban, restrict, change poor ones, while taking account of the communities' livelihood survival needs. For example, it is recommended that snorkellers collaboratively improve their skills whereby the experienced transfer positive reef capture behaviours to novice snorkellers thus changing poor fishing practices and activities that damage coral cover. Similarly, it is hoped that eco-certification of traded live fish will become a reality from efforts triggered in import countries so that benefits of these schemes will filter to collectors, like these divers.

To reduce current chronic pressure on these small reef areas from, among other things, overfishing, the provision of several supplemental livelihoods for divers is crucial. Three specific work recommendations that would provide similar income, and could be undertaken instead of diving activities on certain days are suggested: reef restoration, tourist reef guides and small-scale aquaculture of marine or freshwater ornamentals.

10.3.1 Small-scale freshwater fish aquaculture

To avoid small-scale aquaculture initiatives leading to an increase in catches as divers seek to maximise income by both keeping fish and diving, it is advised that freshwater ornamental fish aquaculture should be introduced at the village level. Freshwater fish are in demand from both local and international markets. Furthermore, tank breeding of freshwater species is more established than that of marine fish, making this a more immediate income generating strategy. Village fish breeding stations could be set-up at hub sale points and run and managed by the women villagers, as described in Chapter 9. Those local people with freshwater fish breeding expertise, such as the one participant in my tank trial could become leaders to teach the women the husbandry and breeding skills required. These hub leaders would identify and select women to act as freshwater aquaculture leaders within their communities. This is advised over using expert, outside freshwater breeding assistance, which is likely to be less effective among these communities. Further research is needed to locate the most suitable species for small-scale culture in the specific local conditions and a feasibility study to determine the potential of freshwater breeding as a viable income generator in Sri Lanka.

10.3.2 Tourist reef guides

Alternative livelihoods targeting the predicted increase in tourism in the coastal areas could be initiated. Tourist coastal sites and the local divers should together develop systems to engage the snorkellers to escort tourists for set periods over the reef, indicating species and structures. Other income generating options after guiding could be to stay or spend time with or enjoy local meals with diving families for a a pre-arranged fee. A formal payment system should be established between the tourist sites and the snorkellers to ensure the latter receive the main share of income.

10.3.3 Reef restoration

Sri Lankan environmentalists are currently working on restoring coral reef areas under protection in certain locations in Sri Lanka (Weerakkody, 2006), divers should collaborate and contribute their knowledge and skills to provide basic reef restoration efforts. If external funding is sought from conservation groups, the snorkellers should be paid a daily wage to clear macro-algae or plant coral fragments. The diversification of divers' activities, recommended here, would enhance coastal community resilience and in the case of reef restoration work, ecological resilience.

10.3.4 Education and training

Education is crucial when discussing sustaining future environments as the future lies with the children; thus their incorporation into these initiatives, both in and out of school, is vital to ensure local ecological, cultural and traditional knowledge is not lost and reverse the findings that such transmission may be decreasing. In some developing countries, incorporation of local knowledge and skills into the education curriculum is being encouraged, such as in India (Sundar, 2010) and this should be investigated in Sri Lanka with regard to the island's seas so that children living in reef communities can gain knowledge and skills about their reef and its biota and the reasons for its importance. This would engender pride in their local environment so that curiosity and interest in protecting the reef and its inhabitants can be nurtured and encouraged.

Currently tertiary education is closed to many younger divers, in their teens or early 20s yet they possess excellent marine knowledge and skills. Thus a key recommendation is to provide them with opportunities to attain a diploma in marine biology, via an independent institution, or to enter courses that are applicable to their skill-set, such as scientific and commercial diving. This should be expanded to include any females involved in breeding ornamental fish and working alongside buyers and would allow many of the younger generation to find work at other levels or outside fishing. This initiative should be encouraged by respected elders within the diving community and respected local academics, such as Dr Terney, and taken to the national level. At the local level it could be further supported by the provision of a channel of communication whereby those with marine knowledge and skills could interact with Sri Lankan students and academics studying fisheries, science and marine ecology at local universities, who have theoretical knowledge of western scientific approaches but lack local knowledge and practical skills. This should be a win-win situation for all actors who essentially derive an income from the same ecosystems.

All above recommendations will contribute to building and strengthening the much needed resilience, particularly at the community level. The strong kinship systems and diverse community ties that already exist informally to help each other in times of need should be encouraged and nurtured to encompass wider groups of individuals, particularly the most vulnerable. The positive social and cultural aspects of the diving communities, such as their tight-knit community and their cultural resilience in upholding religious beliefs, festivals and customs should be encouraged to increase awareness and build community pride in the villages. Through a heightened awareness of social, ecological and cultural capital each village possesses and the uniqueness of their position, villages would forge new understandings of the importance of safeguarding their culture and seascape. These methods work well in areas where co-management programmes are in place, as proud communities have the capacity to make decisions related to sustainable management of their reefs and fishery. These recommendations have attempted to subsume the discrete findings attached to each specific objective, within a co-management framework that incorporates formal and informal institutions for communication within and across, up and down the framework. That is, the importance of livelihood issues in assessing the fishery; the contribution of fisher knowledge in management and planning; a focus on all strategies as opportunities to enhance social and ecological resilience; the value of exchanging and linking knowledge locally, nationally, regionally, and internationally to better manage the disappearing natural resources, while simultaneously providing secure livelihoods for the reef fishing communities.

10.4 Global applicability of the results and approaches used

Interdisciplinary studies of human-environment interactions are growing worldwide and covering a wide range of ecosystems (Cinner et al., 2005a; Lélé & Norgaard, 2005). They appear to be producing unique insights to chronic conditions of unsustainable practices (Hecht, 2012), resource degradation (Pretty, 2011) and commons governance (Romero & Agrawal, 2011; Campbell, 2005). My study contributes, albeit on a small scale to this literature, not only by demonstrating how a richer data set can be collected but also the methodology of data collection through full collaboration of outsiders with insiders, which in this case has provided some unique insights that would not have been gathered by single discipline approaches as it allowed for greater integration with the local community in all their activities and provided much greater access and trust, and *e.g.* allowed for damage and illegal behaviour data to be derived and quantified.

Interdisciplinarity is growing among academics but in the correct setting is of benefit among practitioners and academics in developing countries where it has not advanced as far as in western developed countries and where the local researchers LEK have yet to be valued. Studies such as this, which is to be shared with the participants in Sri Lanka, therefore, can contribute to raise awareness and change mindsets of both local and foreign-based academics as well as practitioners at every level, of the potential, and enjoyment, of interdisciplinary studies to provide a holistic data web from which more informed decisions can be proposed.

Few ecological studies provide much historical context in their appraisals of SES that they research and potentially overlook important significant factors for analysis or integration in management plans (Erlandson & Rick, 2008). Thus assessing how the current research study site and context came about from a historical approach avoids drawing on baselines only set in living memory and enable the findings to be viewed within longer time-frames (Pauly, 1995; Jackson et al., 2001; Crumley, 1994b). This is necessary to interpret more accurately the current interrelationships among users within SES globally.

Results from my reef fish surveys corroborate the body of literature that NTZ forms of MPAs are effective in increasing fish biomass. This contributes to the global argument for more MPAs but that social and ecological data need to be collected and analysed before siting MPAs (McClanahan et al., 2007) and creating networks resilient to future human and environmental threats (Mora et al., 2006). Otherwise, as this study shows, MPAs can be ineffective and community divisive if this process is not conducted carefully resulting in degraded coral reefs and local livelihoods.

This study contributes to a growing literature on the benefits of LEK in tropical marine research and management, (Aswani & Hamilton, 2004; Sillitoe & Pottier, 2002; Rouja et al., 2003; Hickey, 2006; Heckler, 2009) and provides further stimulus for more research utilising participatory, collaborative and interdisciplinary approaches to identify similarities and differences between LEK and western science but most of all to find complementarity of knowledge systems to promote citizen scientists as future conservation monitors, researchers and managers (Lawrence, 2010).

The unfortunate current situation of the market chain system in the ornamental trade in Sri Lanka encourages the ongoing environmental degradation due to external capitalist market forces driving exploitation of local resources for use elsewhere. This can be seen globally in other studies from the boom and bust of the beche-de-mer trade in the Solomon Islands (Christensen, 2011) and the Miskito turtle fishery in Nicaragua (Nietschmann, 1979). However, although the ornamental fisheries market system in Sri Lanka currently represents an unsustainable supply chain, it could be used to provide lessons to other export sectors of fishing communities globally as well as other international product supply chains that are striving to shift towards "sustainable supply chain management" (Darnall et al., 2008).

The ethnographic data depicting the path, to-date, of the transition to co-management governance makes this study an important contribution for it shows how such changes can provide a fresh start to communities locked into poorly run, centralised governance structures. This transition was proposed on the basis of its success in other developing countries (Aswani et al., 2012; Pomeroy et al., 2010) but needs to be tailored from its western origins to local contexts (Ruddle & Hickey, 2008).

10.5 Reflection of the research process

An interdisciplinary approach was employed because it was argued that the credibility of the ethnographic research and the suitability of the quantitative methods as well as the level of integration of the mixed methods employed would enhance the research compared with that conducted over these same areas through single discipline studies.

The value of an interdisciplinary approach to this study of ornamental fisheries in Sri Lanka is for me a major overall finding. To effectively understand and assess the natural ecosystem, policies, management systems and human activities in relation to the sustainability of the southern coral reef, it is clear that different tools, concepts and methods are needed. Thus, the variety used in this study which mixed qualitative and quantitative methods, adopting those best suited to answer the research objectives gave me as an outsider a better understanding of the insiders' points of views, especially the divers and should have relevance to a wider audience.

That said, it is not an obvious approach and is not applicable to every scenario; the work is more challenging than single discipline inquiry and in certain contexts it is excessively complex. However, as more interdisciplinarity between subjects is explored and researchers learn not only from the results but also from the methods and difficulties encountered, this process is likely to become more widely adopted and the results viewed by all as comparable to more conventional methods and approaches. The training of young researchers, like myself, in more than one discipline will enhance this track as they comprehend and open their perspective to different forms of data, epistemologies, methods and analyses.

More specific reflections relate to certain methods, actions and directions I might have taken knowing what I know now. Additional time to become proficient in the local language, Sinhala, would have been the most important difference if this research was carried out again. I was able to understand and communicate at a basic level, but required a translator which impeded certain interactions. As I was new to coral reef survey methods, some further training in survey methods and performing a mixture of methods to determine the most suitable method may have been useful in providing more robust results.

As my focus was on the ornamental fishery, I spent most of my time with divers, yet had the opportunity to spend time with other fishers. If more time had been available it may have been beneficial to spend further time with other fishers from the same villages (such as the SCUBA divers and offshore boat fishers) to determine differences and similarities between divers and them and to form a picture of divers' activities when diving in unknown areas as compared to their home waters.

Appendix A – SSI questions for divers

Name: Date:

Location: Age:

Occupation: Context: Tape No:

Background

How long have you been collecting ornamental fish?

When did this fishery first begin in this area?

How did you become involved in ornamental fishing?

Why did you choose this rather than another job?

Do you go/did you go to school? Until what age?

How many other snorkellers operate in the area?

What is the age group of people involved in this fishery

Fishing effort and behaviour

What gear and/or methods do you use?

Did you own the gear yourself?

How much does gear cost and how often does it need replacing?

Where do you usually fish?

How many times a day do you fish and for how long each time?

When is the best time of day to fish?

What species do you target?

What size of fishes do you try to catch?

How do you decide when to stop fishing?

Do you fish with others or alone?

Do you talk with other divers about where fishing is good/bad?

Do you catch food fish if you see it on these trips too? If so, what?

Do you do snorkel fishing and SCUBA diving? Which do you do more of and how much does each contribute to earnings and time?

How do you decide when to SCUBA or when to skin dive?

(If only snorkelling) - Do you want to do SCUBA diving in the future and why? OR Why did you not want to SCUBA dive?

Have you ever had any accidents whilst doing your fishing/job?

Illegal fishing and enforcement

Have you witnessed any illegal fishing activity?

Are *moxy* nets legal?

Have you ever been questioned about what you are catching or have to show catches to anyone?

Are there any ornamental fish which are illegal to catch or any restrictions on your fishing activity?

Earnings

How much do you earn per fishing trip on average?

How much do you earn per month on average?

Conflict and marine tenure

Are there ever conflicts between fishers?

Can outsiders fish in these areas or only people from your area/village?

What happens if someone breaks this rule?

(If only those from the village allowed): - When did these rules begin and who made them?

Fish sales

Where do you sell your catch to?

Do you take fish straight to dealer once collected?

How many fish die between capture and handing on to companies?

Are different fish asked for as season progresses?

Do you catch only what buyers ask for or anything you see that they "might" buy?

If they don't buy your fish, what do you do with them?

What is your opinion of the buyers as people to deal with and why?

Do you know the prices paid to dealers for fish and or the export price of ornamental fish?

Fish abundance

Can you always find the fish required by dealers?

Has this changed over the time you have been fishing?

If so, when and what reasons do you think have caused this?

Are there any species which have become very rare?

Out-season and diversity of income strategies

What do you do if you cannot fish on certain days?

What do you do in the out-season?

(If move in Sri Lanka): - Where to and for how long?

Do you come back and visit your family or does your family move with you?

How does fishing compare between there and here?

Can you earn the same amount of money there as here?

(If different activity to ornamental diving): - What is this activity and how much do you earn from this per month?

Social data

Do you live with your parents still or do you have your own house?

Who makes up the family/household?

Are you married and if so, for how long?

Are you the only money earner in the family?

If not, who else and what is their job and monthly income?

How many people do you support with your income?

Is your money shared with all the household?

What is the attitude of your wife/children/parents to you being an ornamental diver?

Are women/children involved in the fishery in any way?

Tsunami effects:

What was your experience of the tsunami?

Did you receive any help after the tsunami?

Have things changed in the village or amongst the divers since the tsunami in any way?

Has fishing changed since the tsunami?

Management and the future of the fishery

Do you think there is a need for more management of the ornamental fish capture in your area? If so, what needs to be done?

In your opinion, are coral reefs in your fishing area:

a) the same as they have always been,
b) slightly damaged
c) badly damaged
d) improved since you were a child?

Do you think coral reefs are important to preserve and why?

Do you stand on corals or break corals during your fishing trips?

Is it a problem to do that or is it OK to do that?

Attachment to ornamental fishing

Do you enjoy your job/fishing and why?

Are you concerned for the future of this fishery and making money from it?

What will you do in the future?

Acceptability of alternative livelihoods

Have you heard of fish farming/breeding?

Would you view that as a good job and an activity you would want to do in the future?

What problems do you see with this alternative livelihood?

Local ecological knowledge:

Do you know when ornamental fish breed?

Do you know where certain species breed?

Additional comments:

Appendix B – SSI questions for local fish buyers

Date: Occupation:

Name: Age:

Location: Context: Tape No.

Background

When did the ornamental fishery start?

How long have you been buying ornamental fish and how did you become involved in this business?

Were you ever or do you dive for ornamental fish as well?

How many other buyers are there in the area?

Nature of the operation

Do you run ornamental fish SCUBA dive teams or are you only a buyer?

If so how many divers, boats and SCUBA tanks? Where do they fish?

How do you decide which SCUBA divers will work for you?

How many snorkellers sell to you and where do they fish?

Buyers' strategy

Do you mainly ask divers to catch for export company orders or any fish they see?

How do you inform the divers when there are orders and generally which fish to catch?

Can you always sell all the fish you buy from divers?

What size fish do you buy and sell, are there any minimum or maximum size limits?

Are there any illegal fish to catch or buy and sell?

Conflict and marine tenure

Are there ever any conflicts among divers or between buyers and divers? If so, what do they concern?

Can outsiders fish in these areas or only people from your area/village?

What happens if someone breaks this rule?

When did these rules begin and who made them? (If only those from the village allowed)

Holding facility and fish volumes

How many fish move through your facility each day?

How many days do the fish stay in the holding facility?

Who looks after the fish?

Are any checks done on water quality and water properties?

How often is the water changed in the holding facility?

Do you feed the fish or use antibiotics while they are here?

What percentage of fish die in your care?

Costs and earnings

What are the predominant expenses of running the facility?

What is the average cost of a SCUBA dive trip?

How are SCUBA diver earnings split among divers and yourself?

How much do you earn per month from fish sales?

Interaction with export companies

How many companies buy from you?

What are your views concerning the export companies?

Do you know the export prices of ornamental fish from Sri Lanka?

Do they provide you with diving equipment or assistance

Do buyers have an organisation or society to interact with the export companies about the ornamental trade? If so, is the organisation and discussions useful?

How could things be improved between buyers and exporters?

Out-season and diversity of income strategies

What do you do in the out-season? (If move elsewhere in Sri Lanka): - How long do you go for and do you take all your equipment with you?

Do you work for others there? How much do you earn there per month?

If you remain here in the out-season, what activity do you do and how much do you earn from it?

Concerns for the future

How is the business been going over the years?

Are you concerned for the future success of your business and the fishery?

What will you do as a livelihood in the future?

Awareness and knowledge of coral reefs and fish abundance

In your opinion, are coral reefs in your fishing area:

a) the same as they have always been,
b) slightly damaged
c) badly damaged
d) improved since you were a child?

What are the reasons for that?

Have there been changes in fish abundance since you were a child? If so, what are the reasons for that?

Are there any rare fish species now?

Management and conservation

Is there a need for management/ control of the ornamental fishing in this area? If so, what should be done?

Are there illegal fishing activities happening here in this area? If so, what activities?

What is your opinion of the work done by NARA and DFAR?

Tsunami effects

What was your experience of the tsunami?

Did you receive any aid or compensation

What has changed in the village and the fishery since then?

Social data

Are you married and if so, for how long?

Who makes up your family/ household?

Are you the only money earner in the family? If not, who else and what is their job and monthly income?

What is the attitude of your wife/children/parents to you being a diver and/or buyer?

Are women/children involved in the fishery in any way?

Appendix C – SSI questions for export companies

Company name:	Tape:	
Name of interviewee:	Context:	
Date:	Address:	Phone number:

Background

How long have you been operating as an export company of marine ornamental fish?

How did you become involved in the business and were you ever a diver?

How many people work for you and what are their roles?

How many other export companies are there in Sri Lanka? Can anyone start a new export company?

Are there ever conflicts among export companies?

State of the marine ornamental trade in Sri Lanka

How has business been over the years since you started?

Are you exporting more or less fish than when you started?

In your opinion, are you now a large, medium or small export company?

Are you a member of any trade certification scheme?

Export company facilities and tasks

How many suppliers do you have? Where in Sri Lanka do you locate fish from?

Are trucks sent everyday to these places?

How long are fish on the trucks before arriving here?

What occurs between fish arriving from the coast and being shipped abroad? How long are fish in your care?

Do you feed the fish or treat them with antibiotics?

What facilities do you have for the fish?

How do you minimise mortality here?

In what packaging are fish exported?

Which countries do you export fish to and are they exported directly by you or via an intermediary?

Interactions with coastal suppliers

Do you have good relations with the suppliers you buy from?

Do you provide suppliers with any form of assistance?

When do you pay the suppliers?

Who incurs the loss of fish that die in transport and holding in your facility?

How do you prove that a certain buyer's fish died?

Do you ever have meetings to discuss concerns of the buyers or divers?

If so, what are examples of these concerns?

Interactions with foreign importers

Do you sell to companies, wholesalers or individuals?

How are fish sales set up?

Do you import fish from any other countries and then export them and what percentage of your stock is from sources abroad?

When do foreign importers pay you for fish shipments?

Fish export volumes, earnings and costs

How many fish are exported by you in a year?

What is the value of the fish you export per year/earnings of your company?

Who decides the fish prices and how is this controlled?

How do Sri Lanka fish prices compare with other source countries?

What are the costs you incur and what would be an average month's costs?

How much are freight costs?

Do you know for how much fish are sold on to retailers abroad?

Trends in fish exports

Which are the most commonly exported species and their percentage of total export?

What percentage of fish are juveniles?

Are there any rare species with very high price tags?

Are there any endemic species you trade in?

Do you export freshwater fish species too?

Have there ever been shortages of fish at any time?

Can divers still find all the fish you require?

Fish mortality

What percentage of fish die whilst in transport, at your facility and during shipment abroad?

Who is accountable for fish mortality during each of those stages?

Do you record fish mortality within your facility?

Legal issues

Are permits or licences required to export marine ornamental fish?

Do any species have export quotas?

Are any fish illegal to export?

Are there species that you think should be placed on or removed from the restricted or banned ornamental fish export lists?

Are there any legal size limits for exporting ornamental fish?

What procedures must be followed at Customs and are they strictly followed?

Tsunami effects

Did the tsunami affect your business?

Was there a reduction in fish collection then?

After the tsunami how long was it before divers were working again?

Did you provide assistance to the buyers at that time?

Status of coral reefs and reef fish populations in Sri Lanka

In your opinion, what is the state of the coral reefs in southern Sri Lanka?

How would you describe fish abundance in the main regions you buy fish from in Sri Lanka?

Does your business impact on natural fish populations and coral reefs?

Do you think the fishing methods used are destructive?

Does the ornamental fishery create conflict with other reef uses?

Appendix D – SSI questions for women in diving communities

Date: Fisher's name and relation:

Location: Context:

Name: Age Tape:

Family background

Are you from this village or did you marry into the community?

Are you married to a diver and how long have you been married?

Do you have children? How many sons or daughters and what are their ages?

Attitude to job of men and children in the family

What is your attitude to your husband/son/father doing ornamental fishing?

What would you like your children to do as an occupation when they grow up?

If your children already have a job, what do they do and are you pleased with their choice of work?

Work experience and income generating options

Do you have, or have you had a job or a way of generating income?

If so, what is/was it and how much do/did you earn in a month?

If not, what are the reasons for not earning an income? Would you like to do a job?

Roles, fiscal responsibility and decision making within the household

How do you spend your time each day?

Are you involved in different activities at different times of the year?

How much of the benefits of income from you or your husband do you control?

Do you help make decisions on what the money is spent on?

What is your role in household work?

Who owns the family assets?

What are the rights of men and women in your household?

Do you participate in household decision making?

What do you make decisions about and what do the men of the household make decisions about?

Have income levels remained the same or dropped in the household in your lifetime/marriage?

How difficult has it been to run the household on the money earned by your family?

Do you take out loans to cover the financial costs of the family and are you involved in these decisions?

If so, where do you get them from and are loans easily available?

Women's role in the village

Are you involved with any community organisations? If so, do they make decisions for the community?

Have there been times of insecurity for you as a woman or for women generally in the village?

When has been the hardest time in your life and when was the best time?

Women's role in the ornamental fishery

Have you ever wanted to fish as well?

Are you interested in your husband's job and do you play a role in his work?

Do you know a lot about the ornamental fishing business?

Future outlook

What are your feelings about the future and the prospects for your household family?

Will you have more or less responsibility in decision making and running the home in the future?

Appendix E – Comparison of marine ornamental fish and invertebrate export prices between 1985 and 2010

Table E.1. Export price list of marine fish and invertebrates from Sri Lanka showing the differences in price between 1985 and 2010. Updated from Jonklaas (1985) and Sri Lankan export company price lists (2010)

Fish species	Common name	Mean price 1985 (US$)	Mean price 2010 (US$)
Abudefduf spp.	Sergeant major spp.	0.2	0.5
Acanthurus lineatus	Striped surgeonfish	2.5	3.5
A. triostegus	Convict surgeonfish	0.5	1.5
A. leucosternon	Powder blue surgeonfish	4	5.5
Amphiprion melanopus	Cinnamon clownfish	0.5	1
A. sebae	Sebae clownfish	0.6	1
Antennarius spp.	Frogfishes	2.5	2.25
Anthias squamipinnis	Blue eye anthias	2	2
Rhinecanthus aculeatus	Picasso triggerfish	1.25	2
R. rectangulus	Wedgetail triggerfish	1.25	2
Sufflamen bursa	Bursa triggerfish	1.25	1.75
Balistapus. undulatus	Orange-lined triggerfish	2	2
Balistoides viridescens	Titan triggerfish?	1	1.5
Balistoides conspicullum	Clown triggerfish	40	20.25
Canthigaster margaritata	Pearl toby	0.75	1.2
C. janthinoptera	Honeycomb toby	1.5	1.75
C. valentini	Valentine's toby	1.5	1.75
Centropyge multispinis	Dusky angelfish	1.5	1.75
Cephalopholis argus	Peacock grouper	3	2
C. boenak	Chocolate hind	1	1.5
C. miniata	Coral hind	7	6.5
Chaetodon collare	Redtail butterflyfish	1.25	3
C. auriga	Threadfin butterflyfish	1	2
C. citrinellus	Speckled butterflyfish	1.5	1.5
C. ephippum	Saddle butterflyfish	4	3
C. falcula	Falcula butterflyfish	4	4.6
C. guttatissimus	Peppered butterflyfish	1.5	2
C. kleinii	Klein's butterflyfish	1.5	2
C. plebeius	Blue-spot butterflyfish	1.5	1.75
C. decussatus	Indian vagabond butterflyfish	1	1.5
C. lunula	Racoon butterflyfish	1.75	3.5
C. melannotus	Blackback butterflyfish	2	2.25

Table E.1. (cont.)

Fish species	Common name	Mean price 1985 (US$)	Mean price 2010 (US$)
C. meyeri	Scrawled butterflyfish	2	2.25
C. ornatissimus	Ornate butterflyfish	3	2
C. triangulum	Triangle butterflyfish	3	4
C. trifascialis	Chevron butterflyfish	1	1.75
C. trifasciatus	Melon butterflyfish	1	1.6
C. unimaculatus	Teardrop butterflyfish	3.5	5.5
C. vagabundus	Vagabond butterflyfish	1	1.5
C. xanthocephalus	Yellowhead butterflyfish	2	5.25
Chromis caeruleus	Blue damsel	0.5	0.4
Coris formosa	Queen coris	1.25	3.5
C. aygula	Clown coris	4	4
Diodon hystrix	Spot-fin porcupinefish	2.5	3.75
D. liturosus	Black-blotched porcupinefish	3	4
Dascyllus carneus	Indian dascyllus	0.2	0.65
D. trimaculatus	Three-spot dascyllus	0.2	0.35
D. aruanus	White-tail dascyllus	0.5	0.4
Dendrochirus zebra	Zebra lionfish	2	2
Diploprion bifasciatum	Barred soapfish	2	2
Forcipiger longirostris	Longnose butterflyfish	5	3.75
Plectorhincus lineatus	Yellowbanded sweetlips	1	1.75
P. orientalis	Oriental sweetlips	1	1.25
P. albovittatus	Two-striped sweetlips	2.5	1.5
Gomphosus varius (M)	Bird wrasse	2.5	3.75
G. varius (F)	Bird wrasse	1.5	1.5
Grammistes sexlineatus	Soapy grouper	2	1.5
Hemitaurichthys zoster	Brown and white butterflyfish	6	3.75
Heniochus acuminatus	Pennant coralfish	1	2.75
H. chrysostomus	Threeband bannerfish	2.5	2
H. singularis	Singular bannerfish	2	2.5
Apolemichthys xanthurus	Yellowtail angel	2	2
Sargocentron diadema	Crown squirrelfish	1	1.5
S. rubrum	Redcoat	1.5	1.5
Lactoria cornuta	Longhorn cowfish	2.5	2.25
L. kasmira	Blue striped snapper	1	1.75
L. sebae	Emperor red snapper	4	7

Table E.1. (cont.)

Fish species	Common name	Mean price 1985 (US$)	Mean price 2010 (US$)
Macolor niger	Black and white snapper	10	5.5
Echidna nebulosa	Snowflake moray	1.5	1.6
Gymnothorax favagineus	Tessolate moray	3	18
Gymnomuraena zebra	Zebra moray	3	5.5
Myripristis murdjan	Pinecone soldierfish	1	1.5
Naso lituratus	Orangespine unicornfish	3.5	4.25
N. brevirostris	Spotted unicornfish	1	2.5
Odonus niger	Redtoothed triggerfish	1.5	2
O. cubicus	Yellow boxfish	2	2.75
Tetrasomus gibbosus	Humpback turretfish	2	2.5
Oxymonocanthus longirostris	Harlequin filefish	3	2.5
Paracanthurus hepatus	Regal tang	6	12
Paracirrhites forsteri	Forster's hawkfish	2	2.5
Pomocanthus imperator (small)	Emperor angelfish	6	6.5
Pomocanthus imperator (large)	Emperor angelfish	4	10.75
P. annularis (small)	Bluering angelfish	2	6
P. annularis (large)	Bluering angelfish	3	10
P. semicirculatus (small)	Koran angelfish	1	3.5
P. semicirculatus (large)	Koran angelfish	2	5.5
Pomacentrus similis	Similar damsel	0.2	0.3
P. caeruleus	Caerulean damsel	0.2	0.4
Platax orbicularis	Orbicular batfish	1.5	3
P. teira	Teira batfish	2.5	3
Plotosus lineatus	Striped eel catfish	0.25	0.5
Epinephelus lanceolatus	Giant grouper	2.5	15
Pseudobalistes fuscus	Yellow-spotted triggerfish	6	6
Pterois radiata	Radial lionfish	4	5.25
P. milies/ antennata	Devil/ Broadbarred firefish	2	2.25
P. volitans	Red lionfish	1	2.5
Bodianus diana	Diana's hogfish	1.5	2
Thalassoma lunare	Moon wrasse	1.5	1.25
Zebrasoma veliferum	Sailfin tang	4	4.5
Z. xanthurus	Purple tang	2	35
Zanclus cornutus	Moorish idol	1.25	2.25

Table E.1. (cont.)

Invertebrate species	**Common names**	**Mean price 1985 (US$)**	**Mean price 2010 (US$)**
	All anemones	1.75	10
Discosoma sp.	Anemone	2	20
Stoichactis sp.	Anemone	1.5	3.25
Cerianthus sp.	Anemone	1.5	1.8
Lysmata debelius	Fire shrimp	1.5	3.5
Odontodactylus scyllarus	Mantis shrimps	4	2.25
Lysmata amboiensis	Painted cleaner shrimp	0.75	2
Stenopus hispidus	Boxing shrimp	0.75	1.2
	Orchid shrimp	2.5	5
Rhynochocinites sp.	Dancing shrimp	0.5	0.6
Fromia elegans/monilis	Red starfish	0.5	0.9
Pentaceros sp.	Starfish	2	2
Pentaceros sp.	Yellow starfish	1	2
Ophiuroids	Brittlestars	0.1	0.75
Phyllidia spp.	Slugs assorted	0.5	0.8
Holothuria sp.	Sea cucumbers assorted	1	1
Echinometra sp.	Sea urchin	1	1
	Sea pencils	1	1
Dendronephyta	Soft coral	1	1.5
Pycnogonida sp.	Coral crab	1.5	0.75
Subella	Tube worms	0.75	0.75
Hippolysmata grahami		1.75	1.5
C. arabica, C. tigris, C. mauritania	Cowries	0.5	0.4
C. ocellata, C. erosa, C. errones	Cowries	0.25	0.25
	Tiger cowries	1.5	0.75
	Egg cowries	2	1.5
	Sea plants	1	1
	Sea lilies	0.5	1

Appendix F – Comparison of marine ornamental fish and invertebrate divers' prices between 1997 and 2010

Table F.1. Prices of marine fish and invertebrates paid to divers in southern Sri Lanka showing the differences in price between 1997 and 2010. Names and prices gathered from multiple divers across multiple sites. Prices are given in LKR. Most species listed are snorkel caught as well as some of the most valuable SCUBA caught fish.

Fish scientific name	Common name	Local name	Price 1997	Price 2010
Abudefduf sexfasciatus	Scissortail major	Scissortail damsel	7	20
Abudefduf vaigiensis	Sergeant major	Abudefduf	2	10
Acanthurus leucosternon	Blue surgeonfish	Blue surgeon	110	250
Acanthurus lineatus	Striped surgeonfish	Striped surgeon	15	75
Acanthurus spp.	Surgeonfish spp.	Black surgeon	7	25
Acanthurus tennenti	Lieutenant surgeonfish	Tennetti	25	50
Acanthurus triostegus	Convict surgeonfish	Convict	7	25
Acanthurus tristis	Eibli surgeonfish	Eibli surgeon	50	75
Amblyeleotris steinitizi	Steinitz's prawn goby	Zebra goby	35	50
Amblygobius phalaena	Half-banded goby	Gurami goby	7	25
Amphiprion clarkii	Clark's anemonefish	Clown	15	50
Anampses lineatus	Lined wrasse	Deep sea wrasse	15	40
Apogon spp.	Cardinalfish	Apogon	7	20
Arothron nigropunctatus	Black spotted pufferfish	Dogfish yellow	500	1500
Balistapus undulatus	Orange-lined triggerfish	Annulatus	25	50
Balistoides conspicullum	Clown triggerfish	Conspic	300	500
Balistoides viridescens	Titan triggerfish	Wildeeson	7	25
Bothus spp.	Flounder spp.	Patow	7	20
Canthigaster janthinoptera	Honeycomb toby	Jacktayta	15	50
Canthigaster solandri	Spotted toby	Marcitatus	10	25
Canthigaster valentini	Valentin's sharpnose toby	Valentini	25	50
Carcharinus melanopterus	Black tip reef shark	Black tip shark	250	1500
Centropyge eibli	Eibli's angelfish	Eibli	75	125
Centropyge multispinis	Dusky angelfish	Centropyge	25	50
Cephalopholis argus	Peacock grouper	Argus	40	75
Cephalopholis formosa	Blue-lined hind	Bonicky	25	50
Chaetodon auriga	Threadfin butterflyfish	Auriga	25	50
Chaetodon citrinellus	Speckled butterflyfish	Citro	15	40
Chaetodon collare	Redtail butterflyfish	Collare	60	100
Chaetodon decussatus	Indian vagabond butterflyfish	Vaga	15	25
Chaetodon falcula	Saddleback butterflyfish	Pericula	75	125

Table F.1 (cont.)

Fish scientific name	Common name	Local name	Price 1997	Price 2010
Chaetodon guttatissimus	Spotted butterflyfish	Gutta	25	50
Chaetodon kleinii	Klein's butterflyfish	Kleinii	25	50
Chaetodon lineolatus	Lined butterflyfish	Lineolatus	75	125
Chaetodon lunula	Racoon butterflyfish	Lunula	60	100
Chaetodon melannotus	Black-back butterflyfish	Melonatus	25	50
Chaetodon meyeri	Meyer's butterflyfish	Meyeri	35	75
Chaetodon octofasciatus	Eightband butterflyfish	Octopatiatus	75	125
Chaetodon vagabundus	Vagabond butterflyfish	Pictus	15	25
Chaetodon plebeius	Bluespot butterflyfish	Babius	25	50
Chaetodon rafflesi	Latticed butterflyfish	Raporci	75	125
Chaetodon triangulum	Triangle butterflyfish	Triangulum	75	125
Chaetodon trifascialis	Chevroned butterflyfish	Megapottidum	15	40
Chaetodon trifasciatus	Redfin butterflyfish	Typy	7	25
Chaetodon unimaculatus	Teardrop butterflyfish	Unimaculatus	75	125
Chaetodon xanthocephalus	Yellowhead butterflyfish	Santo	75	125
Chaetodon xanthurus	Yellowtail butterflyfish	Chyturius	75	125
Chiloscyllium plagiosomum	Bamboo shark	Other shark	200	500
Chrysiptera leucopoma	Surge demoiselle	Rock damsel	3.5	10
Cirrhitchthys bleekeri	Pixy hawkfish	Coral hopper	15	30
Cirrilhabrus sp.	Fairy wrasse sp.	Phytus	100	200
Coris formosa	Queen coris	Coris	50	90
Ctenochaetus strigosus	Gold-ring bristletooth	Yellow eye surgeon	25	50
Ctenogobiops pomastictus	Gold-speckled prawn goby	Leopard goby	15	25
Dascyllus aruanus	Humbug dascyllus	Aruwanus	7	20
Diodon histrix	Spotfin porcupinefish	Diodon	50	100
Echidna nebulosa	Snowflake moray eel	Nebulosa eel	10	25
Epinephelus lanceolatus	Giant grouper	Blue grouper	75	150
Escenius bicolor	Bicolor blenny	RT goby	25	50
Forcipiger longirostris	Longnose butterflyfish	Forci	75	125
Gomphosus caeruleus (F)	Bird wrasse	Brown bird	7	25
Gomphosus caeruleus (M)	Bird wrasse	Green bird	110	200
Grammistes sexlineatus	Sixline soapfish	Soapy grouper	10	25
Gymnomuraena zebra	Zebra moray	Good zebra eel	60	200
Gymnothorax favagineus	Honeycomb moray	Tessolata	500	1000
Halichoeres hortulanus	Checkerboard wrasse	Halicoris	15	30
Halichoeres marginatus	Dusky wrasse	Pea parrot	7	25
Hemitaurichthys zoster	Black pyramid butterflyfish	Tricolour	25	100

Table F.1 (cont.)

Fish scientific name	Common name	Local name	Price 1997	Price 2010
Heniochus pleurotaenia	Phantom bannerfish	Formitatus	25	50
Heniochus singularis	Singular bannerfish	Seeni Angus	25	75
Labroides dimidiatus	Blue-streak cleaner wrasse	Diesel	7	25
Lysmata amboiensis	Scarlet cleaner shrimp	Hippolis	125	250
Lysmata debelius	Red fire shrimp	Asoka	125	250
Macropharyngodon ornatus	Ornate wrasse	Marta wrasse	15	35
Myrichthys colubrinus	Harlequin snake eel	Zebra eel	50	100
Naso brevirostris	Spotted unicornfish	B Naso	10	35
Naso lituratus	Orangespine unicornfish	Naso	35	100
Neopomacentrus azysron	Yellowtail demoiselle	Green damsel	1	7
Novaculichthys taeniourus	Dragon wrasse	Dragon	75	100
Odonus niger	Redtooth triggerfish	Odonus	20	50
Ophiuroidea	Brittlestar	Seal eel	7	20
Ostracion meleagris	Spotted boxfish	Dogfish black	70	350
Ostracion cubicus	Yellow boxfish	Marley boxfish	50	150
Ostracion meleagris	Spotted boxfish	Dogfish brown	25	50
Oxymonocanthus longirostris	Longnose filefish	Oxymonocanthus	25	100
Parapeneus indicus	Indian goatfish	Goatfish	7	25
Parapercis clathrata	Sandperch	Viva goby	10	25
Pervagor melanocephalus	Redtail filefish	Filefish	5	20
Platax spp.	Batfish spp.	Batfish	40	90
Platax teira	Longfin batfish	Teira	40	80
Plectorhinchus orientalis	Oriental sweetlips	Gatting	15	25
Pomacanthus annularis	Bluering angelfish	Blue king	325	350
Pomacanthus imperator	Emperor angelfish	Emperor	300	450
Pomacanthus semicirculatus	Koran angelfish	Koran	110	150
Pomacentrus similis	Neon damsel	Blue damsel	3	10
Pseudanthias kashiwae	Silver streak goldie	Caseeva anthias	15	60
Pseudanthias squamipinnis	Lyretail anthias	Blue eye anthias	25	85
Pseudobalistes fuscus	Blue triggerfish	Fuscus	75	150
Ptereleotris heteroptera	Blacktail goby	Green goby	25	40
Ptereleotris evides	Blackfin dartfish	Scooter goby	25	50
Pterois miles	Red lionfish	Milies	25	100
Pterois volitans	Brown lionfish	Volitans	25	100
Escenius midas	Persian blenny	Persian goby	10	40
Rhinecanthus aculeatus	Picasso triggerfish	Aculeatus	25	50
Rhinecanthus rectangulus	Wedge triggerfish	Rectangulus	25	50

Table F.1 (cont.)

Fish scientific name	Common name	Local name	Price 1997	Price 2010
Scorpaenopsis oxycephala	Tassled scorpionfish	Dentochirus	25	75
Scuticaria tigrina	Barred-fin moray	Leopard eel	40	75
Siderea thyrsoidea	White-eye moray	Brown eel	10	25
Stenopus hispidus	Boxer shrimp	Stenopus	10	25
Stonogobiops sp.	Prawn goby sp.	Diamond goby	35	50
Synchiropus stellatus	Starry dragonet	Scorpion blenny	25	50
Syngnathus spp.	Green pipefish	Green eel	25	50
Thalassoma hardwicke	Sixbar wrasse	Hardriggy	7	25
Thalassoma lunare	Moon wrasse	Lunare	7	25
Valenciennea puellaris	Maiden goby	Javelin goby	15	50
Valenciennea sexguttata	Six-spot goby	White goby	7	25
Valenciennea strigatus	Blue-streak goby	Watchman goby	35	50
Variola louti	Yellow-edged lyretail	Mayura lutea	50	100
Various genera	Crabs	Crab	7	20
Various species	Sea cucumber	Cucumber	5	15
Linckia sp	Green starfish	Green starfish	10	40
Zanclus cornutus	Moorish idol	Zanclus	15	50
Zebrasoma scopas	Brushtail tang	Iscorpus	25	50
Zebrasoma desjardini	Desjardini's sailfin tang	Zebrasoma	25	50
Zebrasoma veliferum	Sailfin tang	Weliferam	75	125

Appendix G – Laws and regulations concerning the marine ornamental fishery in Sri Lanka

G.1. The Fisheries and Aquatic Resources Act, No. 2 of 1996

The Fisheries and Aquatic Resources Act, No. 2 of 1996 bans destructive and poisonous fishing methods, such as usage of dynamite or cyanide. The Fishing Operations Regulations of 1996 included the prohibition of the use of the *moxy* net in fishing operations as well as the use of gill and trammel nets[40] on coral reefs or rocks. These regulations also stipulate that licences valid for one year are required for all fishing operations and provides a list of which activities require licences. These licences are valid only in the district of the country in which they are bought. All fishing operations, with or without boats, concerned with the ornamental fishery require separate licences. These include operating a fishing boat, beche-de-mer[41] fishing, diving to catch ornamental fish and diving to catch chanks[42]. The fees for these annual licences range from a maximum of 250 LKR for a boat with an outboard engine (the craft used by SCUBA diving ornamental fishers) to a minimum of 25 LKR for a snorkeller diver.

G.2. Export and Import of Live Fish Regulations

In 1998, the Export and Import of Live Fish Regulations were introduced. These regulations detail which species of fish are prohibited from being exported or imported and denote that permits are required to export certain fish species and/or live fish eggs, roe or spawn. Permits cost 1000 LKR and are valid for 6 months (see Appendix H for the full list of marine fish species prohibited and restricted by quantity from export in live form). The Fish Products (Export) Regulations were also enacted in 1998, which contain rules on handling of live fish, the facilities export places must maintain and the checks and inspections they must comply with. Export permits are issued every six months with their quota for each restricted species. Export data from the companies is required by DFAR and their officials monitor for unusually high demand on certain restricted species.

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40 Gill nets and trammel nets are similar net types which are held in the water column by weights on the bottom and floats at the surface. Fish usually become stuck in the mesh of a gill net attempting to pass through the net, whereas fish become entangled in the folds of a trammel net.

41 Beche-de-mer are also known as sea cucumbers and are members of the Holothuroidea class.

42 Chanks are a common name for Queen conch shells, *Strombus gigas*, which occur off the coasts of Sri Lanka and are also exported.

G.3. Amendments to the Export and Import of Live Fish Regulations

Following this, two amendments to the Export and Import of Live Fish Regulations were made. The first in 1999 was to add certain marine fish species to the list of those restricted by quantity from export (see Appendix H). Mostly Serranids (groupers) were added to the restricted list. Via tip-offs and Custom checks, DFAR discovered that under the guise of ornamental fish, companies were exporting live groupers to Hong Kong and the Far East for the live reef food fish trade. The second amendment was introduced in 2003 and added freshwater fish species to the restricted list. The latest regulations to be brought into effect were the Monofilament Nets Prohibition Regulations in 2006, banning the use, sale and purchase of nets made from monofilaments to catch fish in Sri Lankan waters. These nets were banned after divers complained that they damage the reefs and cause ghost fishing[43] if left entangled in corals (DFAR, pers. comm.).

G.4. Laws regarding Protected Areas and National Parks

In the case of protected areas, such as Hikkaduwa Marine National Park, the regulations of the Fauna and Flora Protection Act 1937 are valid and no fishing without a permit is allowed. Permits are only given for "traditional usage", and from my meeting with the DWC official in Hikkaduwa, only four such fishers remain. Hikkaduwa is only one of two legally protected marine national parks in the country.

G.5. Certificates required to Export Live Fish from Sri Lanka

There are five certificates that are required to export live fish from Sri Lanka (Table G.1.). Export companies must ensure this paperwork accompanies their shipment. Different destinations often require different documentation, with European Union (EU) destinations requiring the most documentation, including the Generalised System of Preferences (GSP) Form A, which provides beneficial tariff rates to emerging markets exports to developed economies. Health certificates are also required for exports to the EU, most other destinations do not require this.

[43] Ghost fishing occurs when fish and other marine fauna die due to entanglement in discarded or lost fishing nets that remain in the sea and continue to catch fish. It is believed to be a significant cause of fishing mortality around the globe but our knowledge of the extent of ghost fishing is still limited (Mikalsen & Jentoft, 2001).

Table G.1. List of certificates required to export live ornamental fish from Sri Lanka

Certificate	**Provider**
Health certificate	Department for Animal Quarantine
GSP Form for marine fish	Department of Fisheries and Aquatic Resources
Water quality certificate	NARA/ITI
Certificate of origin	Department of Commerce
Permit for any restricted species	Department of Fisheries and Aquatic Resources

Appendix H - List of prohibited and restricted marine fish species from export in live form from Sri Lanka

Table H.1. List of prohibited and restricted marine fish species from export in live form from Sri Lanka (1998). = added by amendment 20th September 1999.*

Family	Species	Prohibited	Restricted
Chaetodontidae	*Chaetodon semeion*	✔	
Pomacanthidae	*Centropyge bispinosus*	✔	
Pomacanthidae	*Pygoplits dicanthus*	✔	
Labridae	*Coris aygula*	✔	
Labridae	*Labroides bicolor*	✔	
Scorpaenidae	*Pterois radiata*	✔	
Ephippidae	*Platax pinnatus*	✔	
Serranidae	*Ephinephelus lanceolatus*	✔	
Serranidae	*Ephinephelus flavocaeruleus*	✔	
Haemulidae	*Plectorhynchus obscurum*	✔	
Haemulidae	*Plectorhynchus albovittatus*	✔	
Pomacentridae	*Chrysiptera kuiteri*	✔	
Chaetodontidae	*Chaetodon octofasciatus*		✔
Chaetodontidae	*Chaetodon ornatissimus*		✔
Chaetodontidae	*Chaetodon falcula*		✔
Chaetodontidae	*Chaetodon xanthocephalus*		✔
Chaetodontidae	*Chaetodon ephippium*		✔
Chaetodontidae	*Chaetodon unimaculatus*		✔
Chaetodontidae	*Chaetodon madagascariensis*		✔
Chaetodontidae	*Chaetodon benetti*		✔
Chaetodontidae	*Chaetodon meyeri*		✔
Chaetodontidae	*Chaetodon triangulum*		✔
Chaetodontidae	*Heniochus monoceros*		✔
Chaetodontidae	*Heniochus pleurotaenia*		✔
Pomacanthidae	*Centropyge flavipectoralis*		✔
Balistidae	*Balistoides conspicullum*		✔
Balistidae	*Pseudobalistes fuscus*		✔
Serranidae	*Variola louti*		✔

Table H.1. (cont.)

Family	Species	Prohibited	Restricted
Serranidae	*Variola albimarginata*		✔
Serranidae	*Cephalopholis argus*		✔ *
Serranidae	*Cephalopholis boenack*		✔ *
Serranidae	*Cephalopholis formossa*		✔ *
Serranidae	*Cephalopholis miniata*		✔ *
Serranidae	*Cephalopholis sonnerrati*		✔ *
Serranidae	*Cephalopholis areolatus*		✔ *
Serranidae	*Cephalopholis caeruleopunctatus*		✔ *
Serranidae	*Cephalopholis hexagonatus*		✔ *
Serranidae	*Cephalopholis malabaricus*		✔ *
Serranidae	*Cephalopholis merra*		✔ *
Serranidae	*Cephalopholis morrhua*		✔ *
Serranidae	*Cephalopholis tauvina*		✔ *
Serranidae	*Cephalopholis tukula*		✔ *
Serranidae	*Cephalopholis undulosus*		✔ *
Serranidae	*Cephalopholis laevis*		✔ *
Centropomidae	*Lates calcarifer*		✔ *

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