The potential for tidal power generation at western European coastal wetlands: identification of sites and their biological importance

Ward, Robin Marshall

THE POTENTIAL FOR TIDAL POWER GENERATION AT WESTERN EUROPEAN COASTAL WETLANDS: IDENTIFICATION OF SITES AND THEIR BIOLOGICAL IMPORTANCE

by

Robin Marshall Ward, B.Sc Hons. (CNAA)

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ABSTRACT

THE POTENTIAL FOR TIDAL POWER GENERATION AT WESTERN EUROPEAN COASTAL WETLANDS: IDENTIFICATION OF SITES AND THEIR BIOLOGICAL IMPORTANCE

The possible threats to western European coastal wetlands from tidal power generation were ascertained in this study by means of "desk-top" calculations and literature reviews.

The physical characteristics of an estuary or embayment that may lead to economical tidal power generation were identified, the principal three being:
- a macrotidal environment, i.e. greater than 4 metre tidal range,
- a water depth along the barrage alignment of at least four metres,
- a tidal prism behind the barrage alignment which is of sufficient magnitude.

Using the "desk-top" Parametric Method which is based upon relationships amongst three of the key physical characteristics, the present study has tentatively identified 33 barrage alignments at 26 sites in western Europe which potentially offer economical tidal power generation. For each of these 26 sites, a provisional inventory of data relating to their natural resources was compiled. The inventory summarises the types of information available and their sources. Extreme variability exists between sites in the level of detail of such data.

Possible effects on the biological importance of an estuary from a tidal power barrage were considered from the ornithological viewpoint. A literature review suggests that our understanding of the mechanisms controlling an estuary's bird community is relatively well advanced. However, a review of environmental impact assessments showed that none have been able to predict, with any confidence, the effect of a tidal power barrage upon birds. This is due to a combination of factors: the lack of data on natural resources, an inadequate understanding of the interactive processes between the different estuarine components and an incomplete picture of the hydrological and sedimentation patterns post-barrage. An example of our current knowledge and its limitations is illustrated through a desk study of the ornithological implications of tidal power generation at the Burry Inlet, South Wales.

To my parents,
Ken & Ivy Ward

No part of this thesis has previously been submitted for a degree in this or any other university. The work described is my own except where duly acknowledged.

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GENERAL INTRODUCTION

BACKGROUND KNOWLEDGE

In the last few decades, concern has been increasingly expressed for the future availability of non-renewable fuels and the impact that utilisation of these energy sources is having upon the environment e.g. through global warming, acidification, radiation. Inevitably, attention has been focused on renewable energy sources (for producing electricity) which are regarded as environmentally more benign. The extraction of energy from the tides is one such renewable energy resource. Harnessing tidal power is not a recent innovation; tide mills for grinding grain were commonplace in Britain, Ireland and France until the mid-nineteenth century (Carter 1988). The present day concept involves the extraction of tidal power by turbines installed in barrages which enclose embayments and estuaries and thus develop a substantial differential head of water between high and low water levels.

In 1966 the first tidal barrage was commissioned at La Rance, France with subsequent barrages at Annapolis Royal (Nova Scotia), Kislaya Guba (N.W.Russia), and at several sites in China. These schemes were installed largely as prototypes with small effective power outputs, 1 - 240 MW. These pilot studies have successfully proven the feasibility of generating electricity from tidal barrages. Outside of Europe, schemes that are currently under detailed consideration are located in Brazil (Rio Bacanga), India (Gulf of Katchch) and Canada (Bay of Fundy). In recent years, interests in tidal power in western Europe have been focused almost exclusively upon Britain's west coast, in particular the Severn estuary. The large capital investment involved in commissioning tidal barrages has prevented work progressing beyond feasibility studies to date. However, proposals for tidal power generation are currently active at 8 British estuaries (Davidson et al. 1991).

A tidal power barrage is essentially safe in that, unlike most electricity generating technologies, it produces no toxic emissions or waste, has no plant running at high speeds or high pressure, has comparatively little visual impact and is quiet. However, the Nature Conservancy Council and Royal Society for the Protection of Birds have both stated their opposition at present to the construction of the Severn Barrage. This is based upon the fact that a tidal power barrage reduces, through necessity, the tidal range behind the alignment with an associated reduction in the strength of currents. A consequence of this is sediment redistribution which, together with the new tidal regime, potentially threatens to alter the fauna and flora that a given area can support.

Much emphasis has been focused upon the prediction that tidal power barrages must reduce the area of low water feeding grounds available for waterfowl. Any sediment redistribution may in addition alter the intertidal invertebrate communities and thus their availability to feeding waterfowl. Anxieties have therefore been expressed by ecologists as to whether estuarine conditions post-barrage would be able to satisfy the requirements of the bird populations that utilise a given site at present. Western Europe's estuaries support a very significant proportion of the 3.2 million waders (Smit & Piersma 1989) and 17.5 million wildfowl (Pirot, Laursen, Madsen & Monval 1989) that winter in the region. As a consequence many of the estuaries under consideration for tidal power generation support waterfowl populations of national and international importance.

In addition to any moral or biological reasons, western European countries are legally obliged under various international agreements e.g. EEC Council Directive on the Conservation of Wild Birds 1979, to protect areas of biological importance and those species populations whose survival is already threatened. Tidal power barrages are considered a potential threat to western European coastal wetlands and the species they support.

THE AIMS OF THE THESIS

This thesis examines the potential threat of tidal power barrages to western European coastal wetlands. A difficulty in assessing the threat is the lack of information available to ecologists and conservationists with which to ascertain the likely impact of a tidal barrage. In order to address this, the thesis is structured as follows:

i. The identification of those physical characteristics shown by an estuary or embayment that may lead to economical tidal power generation.

ii. The identification of those western European coastal wetlands at most risk from tidal power generation. With the exception of a few sites, an assessment of the tidal power generation potential for those western European estuaries and embayments away from south and west Britain has not yet been published.

iii. The compilation of an inventory of present knowledge of the nature conservation interest of western European coastal wetlands at risk from tidal power generation developments. (Through stating what is currently known about a site, gaps in our knowledge are identified).

iv. A general assessment of the potential impact a tidal power generation barrage will have upon the ornithological importance of a coastal wetland. The objective of this is to identify the nature of the threat posed by a tidal power barrage. Together with the above mentioned site inventory, those data required to provide a full environmental impact assessment of a given tidal power barrage can be ascertained.

This last section of the thesis focuses on birds because the most comprehensive biological data currently available from Western European coastal wetlands usually refers to birds. Hence, any inadequacies identified in the ornithological information available for a site, and required in order to conduct an environmental impact assessment of a proposed tidal power barrage, are likely to be less than in other aspects of the site's ecology. Conversely, even if adequate ornithological information is available, there are likely to exist gaps in data for other parts of the system which makes predictions of environmental impact on a whole wetland highly uncertain. As will be shown, not even the ornithological data are adequate at present to enable accurate forecasts of future changes to be made.

In summary, the thesis identifies some directions in which biological research needs to proceed to address the threat to western European coastal wetlands from possible tidal power barrages.

CHAPTER I

IDENTIFICATION OF WESTERN EUROPEAN ESTUARIES FULFILLING THE CRITERIA FOR ECONOMIC TIDAL POWER GENERATION

1.1 INTRODUCTION

The realization resulting from the oil crisis in the early 1970's that traditional energy sources i.e. oil, gas & coal, are not renewable, led in the late 1970's & 80's to governments seriously considering Europe's tidal energy resources. The British government began evaluating tidal power in 1975, initially concentrating on an estuary with one of the world's largest tidal ranges, the Severn. The Severn Barrage feasibility studies of 1978-81 (Severn Barrage Committee 1981) developed a proposed method of barrage construction that could be used for other tidal power schemes at sites with suitable physical characteristics. From the study's evaluation of a suite of barrage lines within the Severn estuary, a quick method of assessment and comparison was developed of the costs of construction, operation and energy for differing barrage alignments. Binnie & Partners later applied this reasonably accurate method of site evaluation to 14 other estuaries of varying shapes and sizes (Binnie & Partners 1980, 1984).

Aware of the relationship between a site's 'natural' parameters and tidal power 'engineering' parameters, Baker (1986) compared the groups of parameters in terms of mathematical functions. The reasonable correlation attained between the two groups of parameters was further strengthened when additional analysis utilized results from foreign schemes already in operation, including La Rance in northern France. Binnie & Partners later applied the simple cost & energy functions developed by this work, the so-called Parametric Method, to 118 possible barrage alignments along Britain's west and south coasts to tentatively identify tidal power schemes that may be potentially economically viable (Binnie & Partners 1989a). In the present study, the parametric method is applied to those remaining estuaries and embayments in Britain and Western Europe, tentatively to assess their respective potential for tidal power generation. Initially, the chapter examines those physical characteristics favoured by coastal engineers in considering where to build tidal power generating schemes.

1.2 THE PHYSICAL CHARACTERISTICS OF A TIDAL POWER SITE

Tidal power is produced by impounding a large volume of sea water whose tidal prism (the volume of water between high and low tide) passes through turbines to generate electricity. As a consequence, tidal range (the difference in height between low and high water) is a major component of a site's physical character that limits the quantity of electricity that can be produced at that given site.

Tides (the periodic rise and full of oceanic and coastal waters) vary in timing during a day, in amplitude and in space. They are propagated through the combined or opposing attractive forces originating from the centres of the moon, sun and earth. At any one time, the overall gravitational force acting upon the earth's surface will differ with locality dependent on the latter's positioning relative to the centres of the three planetary bodies. At a fixed locality, that gravitational force will alter with time and so generate an overall periodicity, as the moon elliptically orbits the spinning earth which itself orbits the sun. In response, water bodies adjust their water levels to achieve an equipotential surface through mass and energy transfer, and thus produce the tidal rhythm. The periodicity of the gravitational force leads to the periodicity of both the tidal wave usually semi-diurnal, and its amplitude i.e. tidal range. However, for a given locality, both variables are modified by the local bathymetric and meteorological conditions e.g. wind and barometric pressure.

3 metres is generally accepted to be the minimum tidal range (measured on mean spring tides) from which a sufficient head of water can be established to drive a normal axial-flow turbine efficiently for electricity generation (Carter 1988; Baker 1989a). However, potential tidal power sites are best sought along macrotidal coasts, i.e. those with a spring tidal range in excess of 4 metres (Davies 1964). Such tidal ranges are characteristic of coasts where the tidal wave is dissipated across wide shoaling shores (Carter 1988); a correlation apparently exists between continental shelf width and inshore tidal amplitude (Cram 1979). Where frictional dissipation of the tidal energy is insufficient, as in many confined channels and estuaries, the height of the tidal wave will increase towards the head of the narrowing estuary, often creating or contributing to a macrotidal environment e.g. Severn estuary.

The tidal range is only one of three parameters of the tidal prism impounded by a barrage, the others being the enclosed basin area and its depth which together dictate its volume. The greater the area enclosed, in particular that of depths of water equal to or below mid-tide, the greater the tidal prism available for tidal power. Whether a barrage is able fully to utilize the tidal prism impounded is determined by the number and size of turbines installed. This in turn is dependent upon the water depth along the barrage alignment. A depth at low water of spring tides of at least twice the turbine runner diameter (the rotating part of a water turbine which converts the energy of flowing water into mechanical energy for driving a generator) is generally accepted as the minimum required to provide a barrage turbine with adequate submergence (Binnie & Partners 1989a). A 3 metre turbine runner diameter is generally accepted in tidal power literature to be a practical minimum. Binnie & Partners (1989a) consider a depth at spring tide low water of 5 metres to be a reasonable minimum for the location of turbine housing with such a location requiring some dredging. However, the analysis below will take 4 metres as the minimum water depth, in agreement with Baker (pers comm.). Estuaries and embayments that either dry out at low tide or are very shallow are unsuitable sites for tidal power generation.

The horizontal axis bulb type of turbine generator is widely incorporated into tidal power feasibility assessments; such turbines are installed at La Rance. This design has been utilized extensively in run-of-river hydroelectric schemes with comparable low head of water and large discharges. Several hundred are operational worldwide (DEn 1989). Small turbine runner diameters from 3-6 metres are available without a full prototype. Recently, sizes up to 8.4 metres have been installed into hydroelectric schemes, though the Severn Tidal Power Group (S.T.P.G.) consider a 9.0 metre runner diameter may be developed in time and available for installation into the proposed Severn Barrage (DEn 1989). This latter runner diameter is currently used as the working maximum (3 metres being the minimum, as indicated above). The development of air turbines or air/water generating plant that functions properly without full immersion, would overcome the barrage depth constraint but seems currently very futuristic (A. Baker pers. comm.).

The extent to which the barrage alignment can provide adequate turbine submergence obviously limits its turbine housing and therefore generating capacity. Alignment selection, however, also requires the positions of the three remaining major components of any tidal power barrage to be considered. These are:

- Sluices, which allow water into the enclosed basin (for ebb tide generation with or without pumping - see below),
- Ship locks, where necessary, to allow continued navigation,
- Embankments, on either side of the turbine housing, to complete the alignment across the site.

A compromise may be necessary between the length of embankment required to contain the ideal tidal prism and the costs (maintenance and capital) such a length would incur. The former two components - sluices and locks - compete together with turbines for adequate water depths along the barrage alignment. However, a degree of flexibility exists with both components. Dredging may offer the possibility of creating and maintaining an alternative safe navigation route (and hence lock position) to that currently used. With regard to sluice positioning, the dimensions of these structures are not necessarily so rigid as those for turbine housing. In summation, the barrage alignment requires to be a compromise between providing an adequate enclosed tidal prism and accommodating as many turbines and sluices as possible, so as to enhance energy yield for minimum unit cost from the impoundment.

Critical examination of two further physical characteristics of a site are needed when assessing the feasibility of a barrage alignment:

- the adequacy of seabed materials to support the barrage structure,
- the effect upon currents and sedimentation patterns upstream and downstream of the barrage.

A bedrock close to the seabed surface is necessary to offer a solid foundation for a barrage. The foundations must also be of a sufficient depth to provide an adequate cut-off against water inflow through any porous substrate. Obviously the civil engineering works increase, in terms of costs and difficulty, the deeper the foundations are laid. Data for establishing the geological features of the soil and rock, sufficient for preliminary foundation design of a barrage, require detailed bathymetric and geophysical surveys.

The degree to which currents are altered by the construction of a barrage influences the post-barrage sedimentation patterns. Extensive alteration to channels and mudflats are usually considered unfavourable, though the post-barrage environment is impossible to predict with certainty. Estuaries with high sediment loading from rivers are avoided as tidal power sites, as a consequence of the threat of siltation after barrage construction, but for certain sites dredging may alleviate this condition. A meaningful assessment of a site's sediment regime requires extensive mathematical and physical modelling and analysis e.g. DEn, CEGB & STPG (1989).

It is known that the number of sites in Europe exploitable as tidal power sites is limited. Therefore, physical characteristics such as the distance of the generating site from connection points to a National Grid, material and product supplies, social and environmental impacts, and construction site accessibility, etc., initially are minor considerations when identifying potential tidal power sites.The barrage with its turbines is constructed to generate electricity from one of four operating modes:

- ebb generation only (turbines generating power on the ebbing tide only),
- ebb generation with pumping (pumping into the impoundment at or before high water, enhancing the tidal prism),

- flood generation (turbines generating power on the flooding tide only),
- two-way generation (turbines generating power on both the flood and ebbing tides).

Ebb generation with pumping is considered to be the optimum operating regime in terms of cost, energy production and to a lesser extent, the minimization of environmental damage (ETSU & NORWEB 1989); ebb generation with pumping is the operating mode incorporated into the majority of proposals and existing barrages.

1.3 IDENTIFICATION OF POTENTIAL TIDAL POWER SITES IN EUROPE BY THE PARAMETRIC METHOD

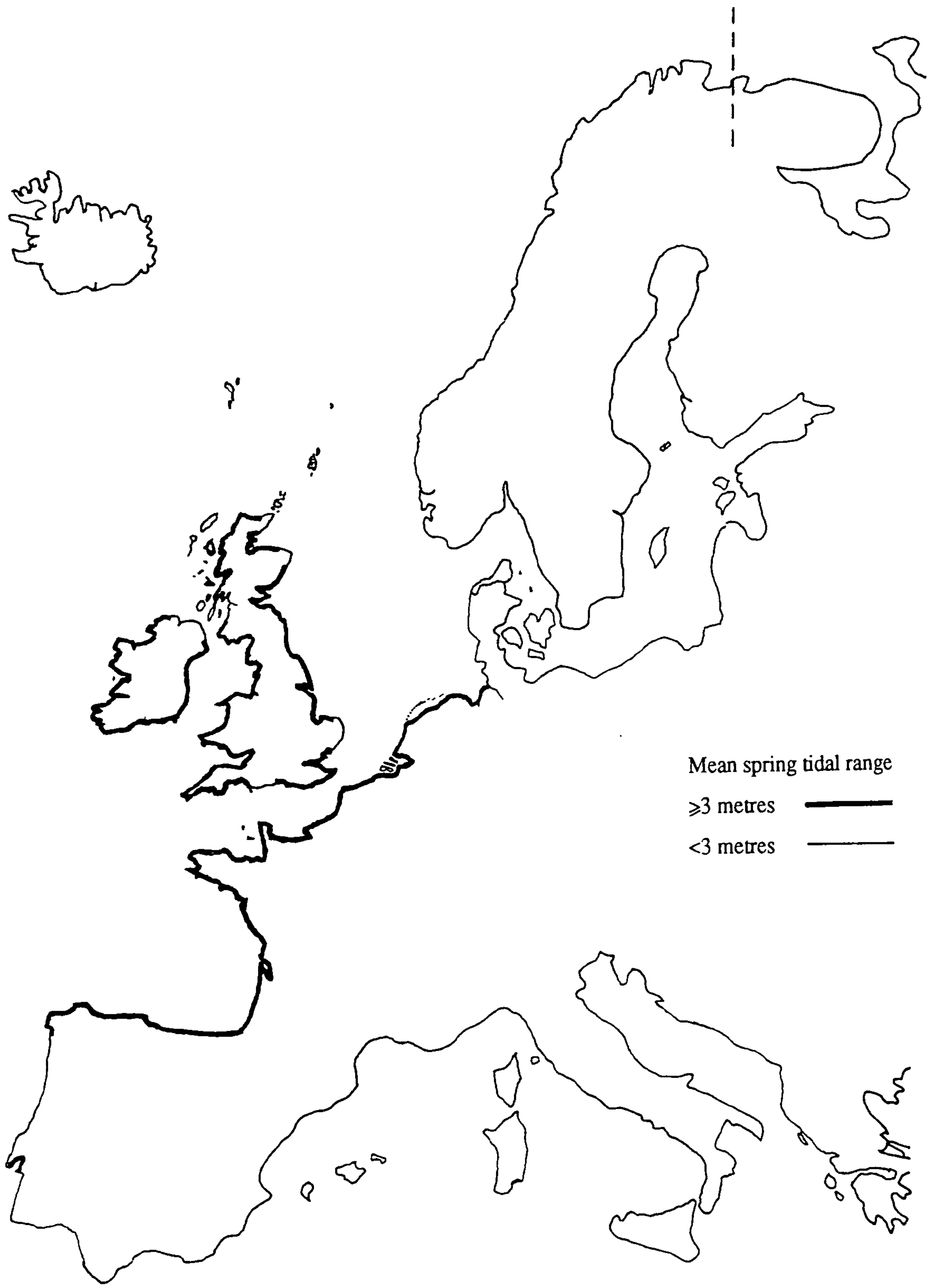
Western European coasts with a mean spring tidal range of less than 3 metres are very unlikely to possess sites favourable for tidal power generation (see above); such coastlines were examined no further in this study (Figure 1.1). For the remaining coast, from the River Elbe to Northern Spain, including the majority of the British Isles, the parametric method (Baker 1986) was applied in this study to all of the estuaries and embayments which:-

i) were estimated to be greater than 1 km^2 in basin area; thus providing a suitable volume of water for power generation;
ii) did not dry out at low tides as indicated by superficial inspection of maps
iii) had not already had the parametric method applied by Binnie & Partners (1989) or ETSU & NORWEB (1989);
iv) had not already had a tidal power generation feasibility study undertaken.

On applying the parametric method to a site, the following 'natural' parameters are required of the given site:

- R, the mean tidal range ($2xM_2$) in metres at the barrage site. Where a site was remote from a standard tide gauge, careful interpolation or extrapolation was used. The value of M_2, a harmonic constant, for given sites is published annually in the Admiralty Tide Tables (e.g. Admiralty 1988).
- A, the area of the enclosed basin in Km^2. This was taken as the area at MHWS measured by a planimeter from either:
  a) 1:50,000 Ordnance Survey maps for the British Isles,
  b) Admiralty Charts of as near as possible to 1:50,000 scale for Spain, Portugal and parts of Eire,
  c) 1:100,000 Institut Geographique National tourist maps of France,
  d) 1:250,000 Dutch Department of Defence maps,

Figure 1.1 Western European coasts with a mean spring tidal range ≥ 3 metres



e) an assortment of land maps for the remaining parts of Eire and Germany.

The area measured for an estuary extended upstream as far as the tidal influences.

- L, the length of the barrage in metres.
- H, the maximum depth of water along the barrage alignment, taken as the depth shown on the Admiralty Charts plus the mean spring tidal range ($2M_2+2S_2$). A minimum H value was imposed equal to the mean (spring) tidal range plus four metres. Doing so provides an improved capital cost where the depth is so shallow that the barrage has to be sunk into the river bed (ETSU & NORWEB 1989). The two harmonic constants, M_2 & S_2 are published for given sites in the Admiralty Tide Tables (e.g. Admiralty 1988). When a site was remote from a standard tide gauge, careful interpolation or extrapolation was used.
- X, the maximum depth of water along the barrage alignment, taken as the maximum depth shown on the Admiralty Charts at MLWS.

A water depth at low water of spring tides of at least twice the turbine diameter is needed to provide the turbines with adequate submergence. Therefore in this analysis an appropriate turbine diameter (D) was determined from the value of X, the minimum depth of water. A minimum and maximum of 3 and 6 metres, respectively, was assumed in the analysis for the turbine runner diameter. Many of the sites studied were found to be very shallow (less than 4m) and, though these shallow sites are not feasible for barrages incorporating axial flow water turbines, their natural parameters have been listed in case air turbines could be used instead at a later date.

Having assembled the 'natural' parameter data and assumed an appropriate turbine runner diameter for a potential barrage alignment, five additional 'engineering' parameters were then obtained from the updated versions of five graphs presented in Baker (1986) (Binnie & Partners 1990 unpubl. - Figures 1.2-1.6).

These five engineering parameters are:

- N, the number of turbines,
- P, the total installed capacity of the generator in megawatts (MW),
- E, the annual average energy output in Giga (10^9) watts per hour (GWh),
- U, the unit cost of electricity from the barrage, in p/KWh. at January 1989 price level and using a discount rate of 5% (which reflects public sector investment criteria)
- C, the capital cost.

Figure 1.2 Ratio of installed turbine capacity (ND^2) to energy resources $(R-1)^2$ plotted against mean tidal range (R) (from Binnie & Partners 1990)

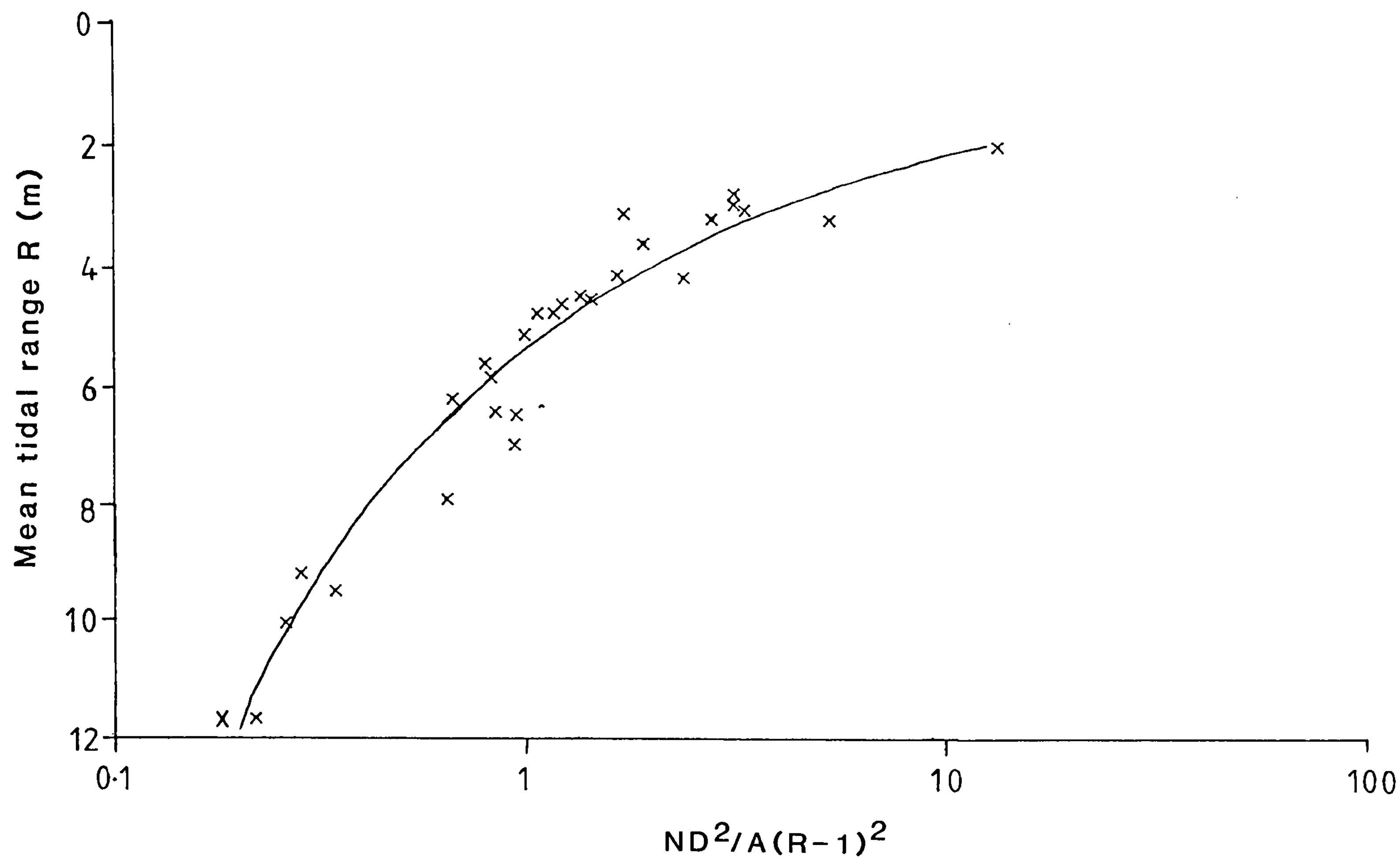


Figure 1.3 Ratio of energy output (E) to installed turbine capacity (ND^2) plotted against mean tidal range (R) (from Binnie & Partners 1990)

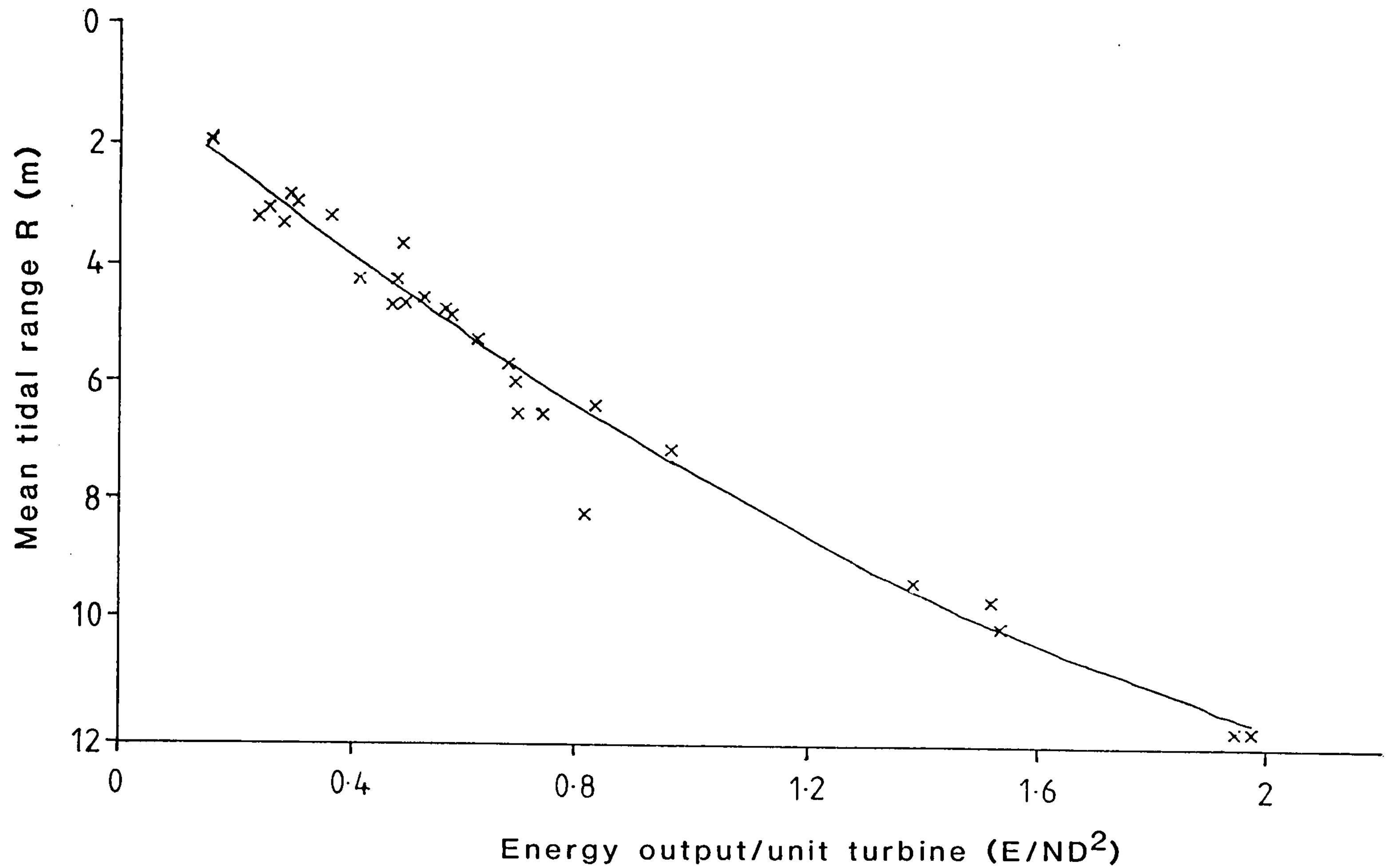


Figure 1.4 Ratio of installed generator capacity (P) to installed turbine capacity (ND^2) plotted against mean tidal range (R) (from Binnie & Partners 1990)

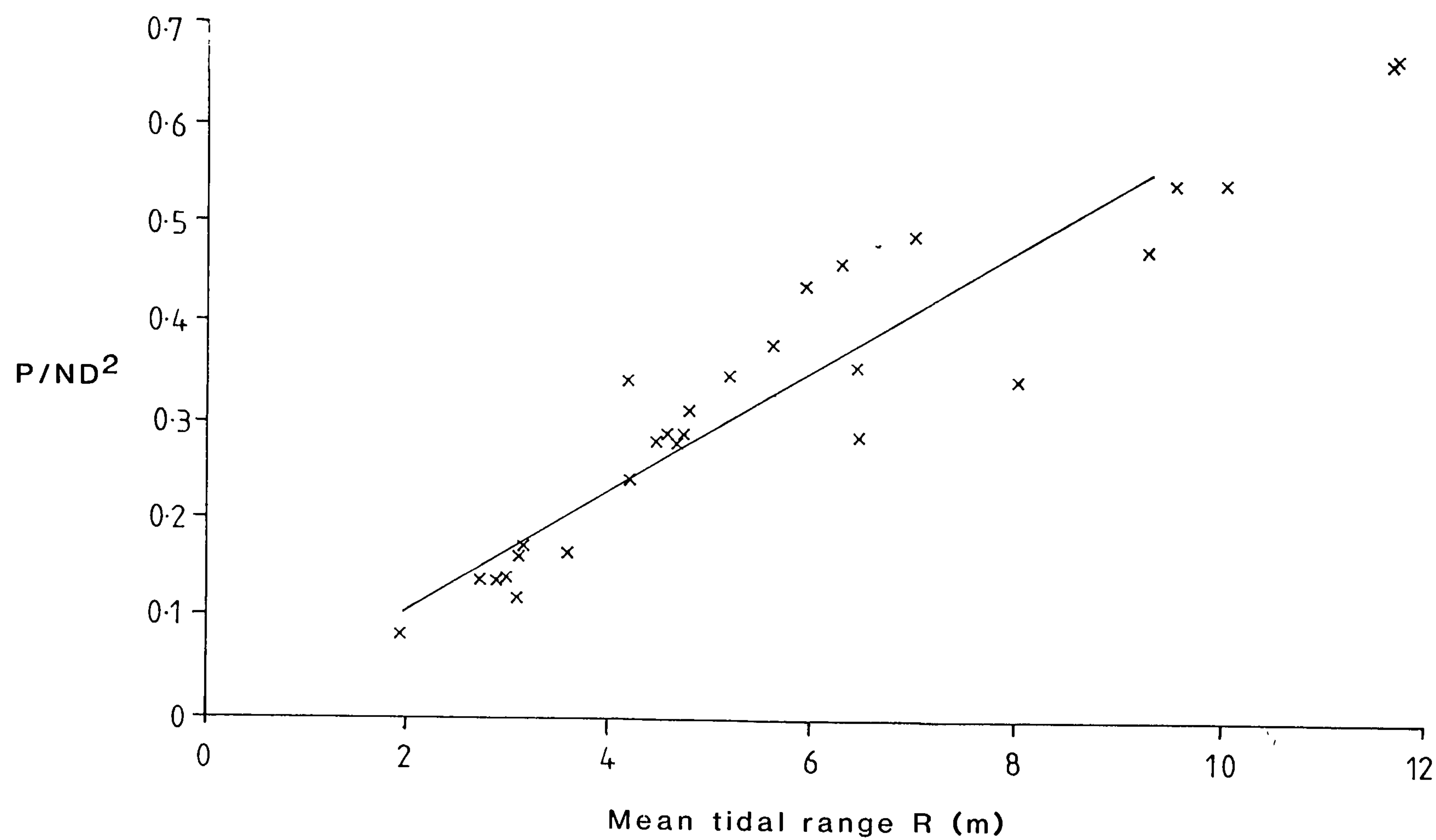


Figure 1.5 Capital costs (C) plotted against site function (related to barrage length and maximum water depth) (from Binnie & Partners 1990)

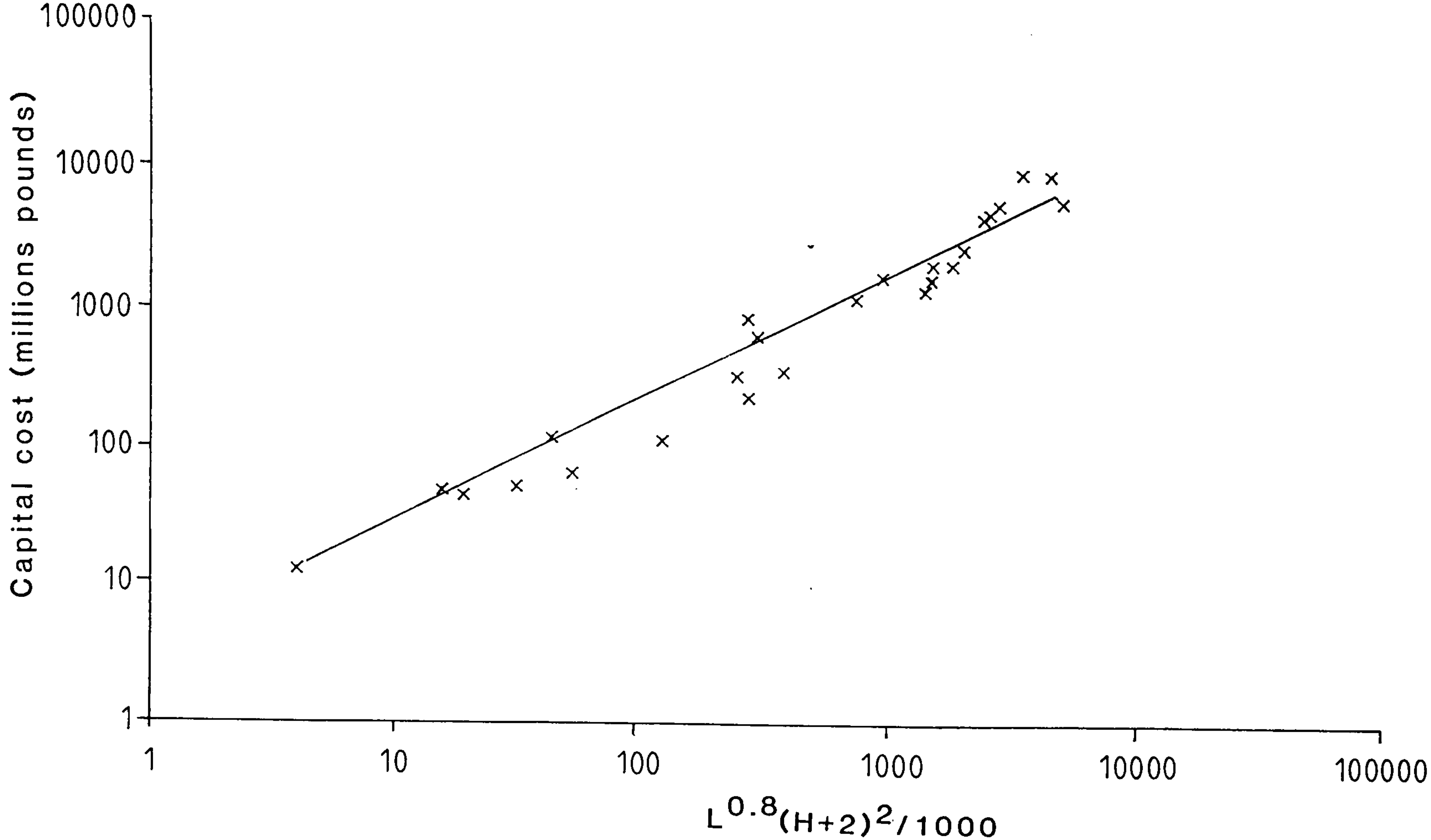
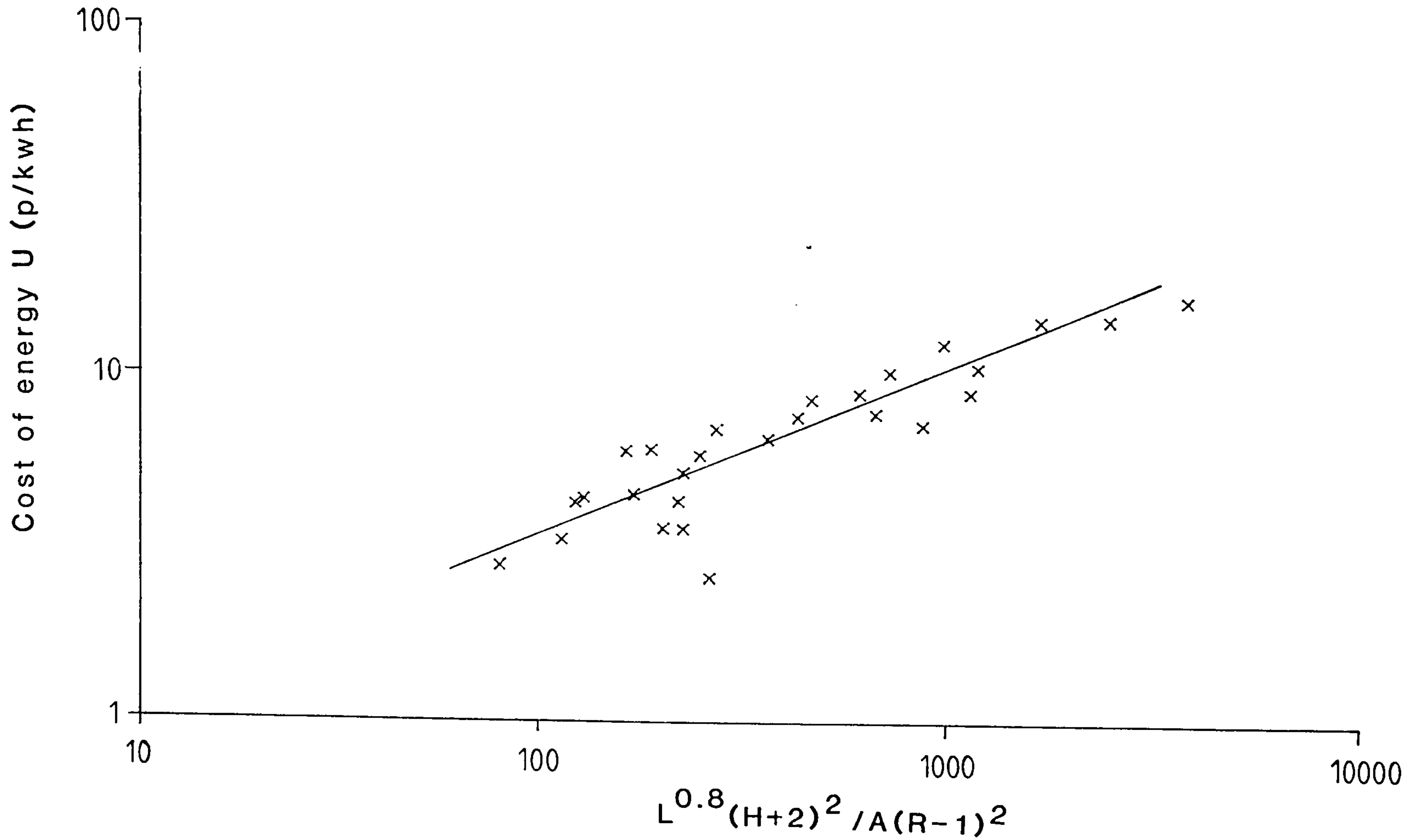


Figure 1.6 Cost of energy (U) plotted against cost function (from Binnie & Partners 1990)



The procedure used in this report to obtain the value of each engineering parameter was as follows:

1. The mean tidal range of a site (R) was used to read the ratio of installed turbine capacity to energy resource from the graph illustrated in Figure 1.2. Binnie & Partners provided no equation for the line illustrated and used in this analysis; the lines were hand drawn (Binnie & Partners in litt.). Algebraic manipulation of the equation describing the ratio of installed turbine capacity to energy resource then provided a value for N from value (X) taken from the graph:

$$N = \frac{((R-1)^2 A)X}{D^2}, \text{ the no. of turbines}$$

2. With the value of N determined, algebrabic manipulation of the ratio of energy output to installed turbine capacity allowed the next engineering parameter E to be ascertained upon reading the x-axis value of Figure 1.3:

$$E = x(ND^2), \text{ the annual average energy output (GWh)}$$

The "equation of the line of best fit" (Binnie & Partners in litt.) describing the relationship in Figure 1.3 is:

$$-y = 1.146332x^2 - 7.74x - 0.8392$$

3. The parameter P was next evaluated from the graph (Figure 1.4) of the ratio of installed generator capacity to installed turbine capacity (P/ND^2) plotted against mean tidal range (R). A linear regression was obtained for this graph, the equation of which is:

$$y = (6.298030313 \times 10^{-3}) + 0.057121461x$$

where $x = R$
$y = P/ND^2$

From this equation algebraic manipulation gave the value of P, the total installed capacity of the generator in megawatts:

$$P = ((6.298030313 \times 10^{-3}) + 0.057121461R)(ND^2)$$

4. Binnie & Partners (1990 in litt) described the relationship existing between the capital costs and site function as:

$$y = -0.016832x^2 + 0.9559252x + 0.534421$$

where $y = \log_{10}C$, the logarithm of the capital cost (millions of pounds)

$x = \log_{10}(L^{0.8}(H+2)^2/1000)$, the logarithm of the site function

Figure 1.5 illustrates this relationship. With the natural parameters L and H already known, capital cost (C) was calculated from the above equation.

5. The final engineering parameter to be determined, U (cost of energy), was ascertained from the relationship between U and the cost function, $L^{0.8}(H+2)^2/A(R-1)^2$ described by Binnie & Partners (1989a) and illustrated in Figure 1.6. A regression analysis of the data was undertaken, the result of which was:

$$y = -0.40591785 + 0.471044284x$$

where $y = \log_{10}U$, the logarithm of the cost of energy

$x = [L^{0.8}(H+2)^2/A(R-1)^2]$, the logarithm of the cost function

U was calculated from inputting the respective L and H parameters into the above regression equation.

Appendix I links the 193 barrage alignments to which the parametric method was applied in this study with their respective parameter values. The geographical locations of the barrages are mapped in Figures 1.7, 1.8, 1.9 & 1.10. For those additional 118+ alignments that have been assessed previously by Binnie & Partners, the parameter values are documented in Binnie & Partners (1989a).

1.4 IDENTIFICATION OF POTENTIALLY ECONOMICALLY VIABLE ALIGNMENTS

Binnie & Partners (1989a) took the maximum unit cost of energy that was considered economic in the foreseeable future to be 6p/Kwh, at January 1983 price level. Transformed

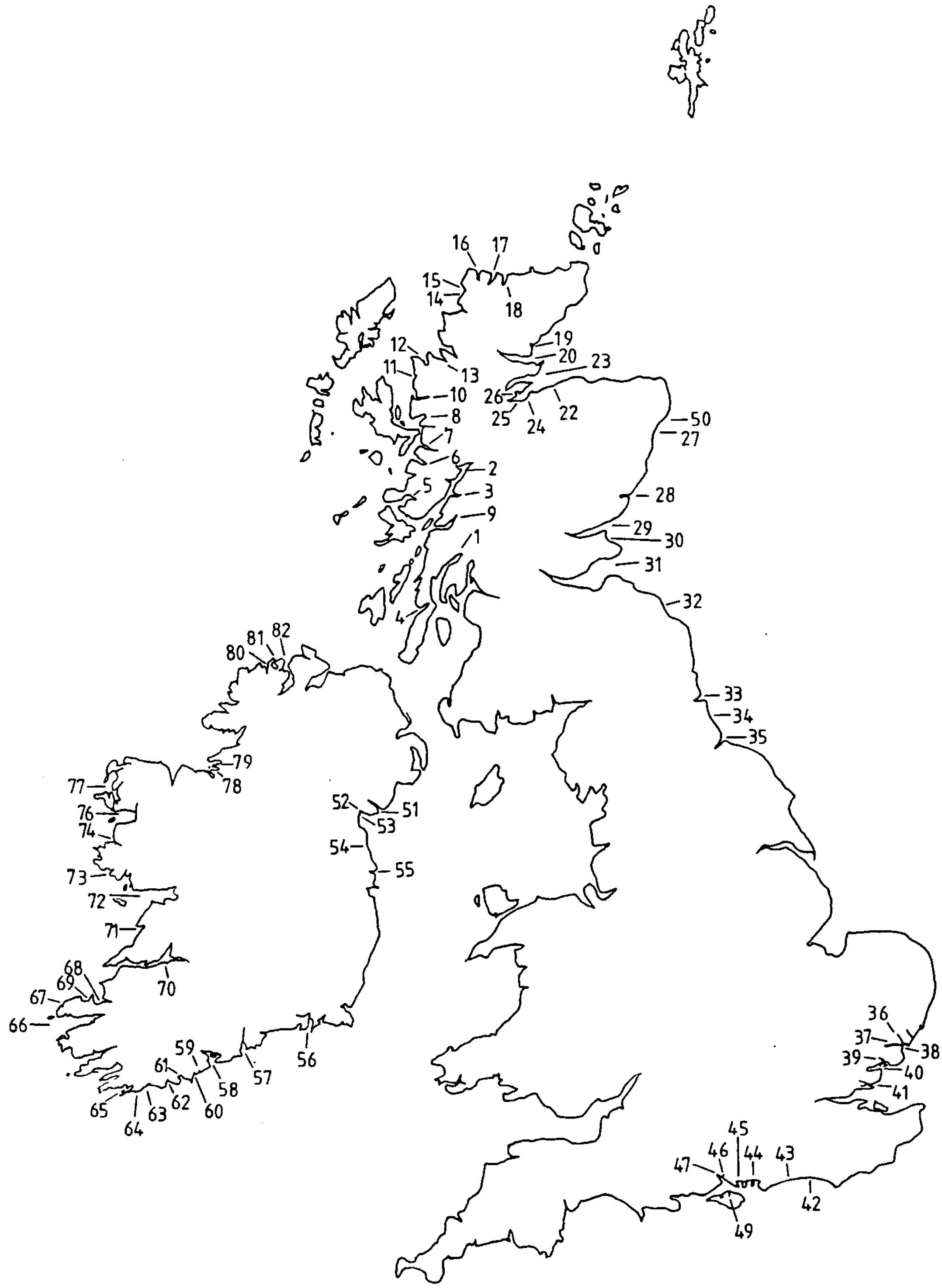
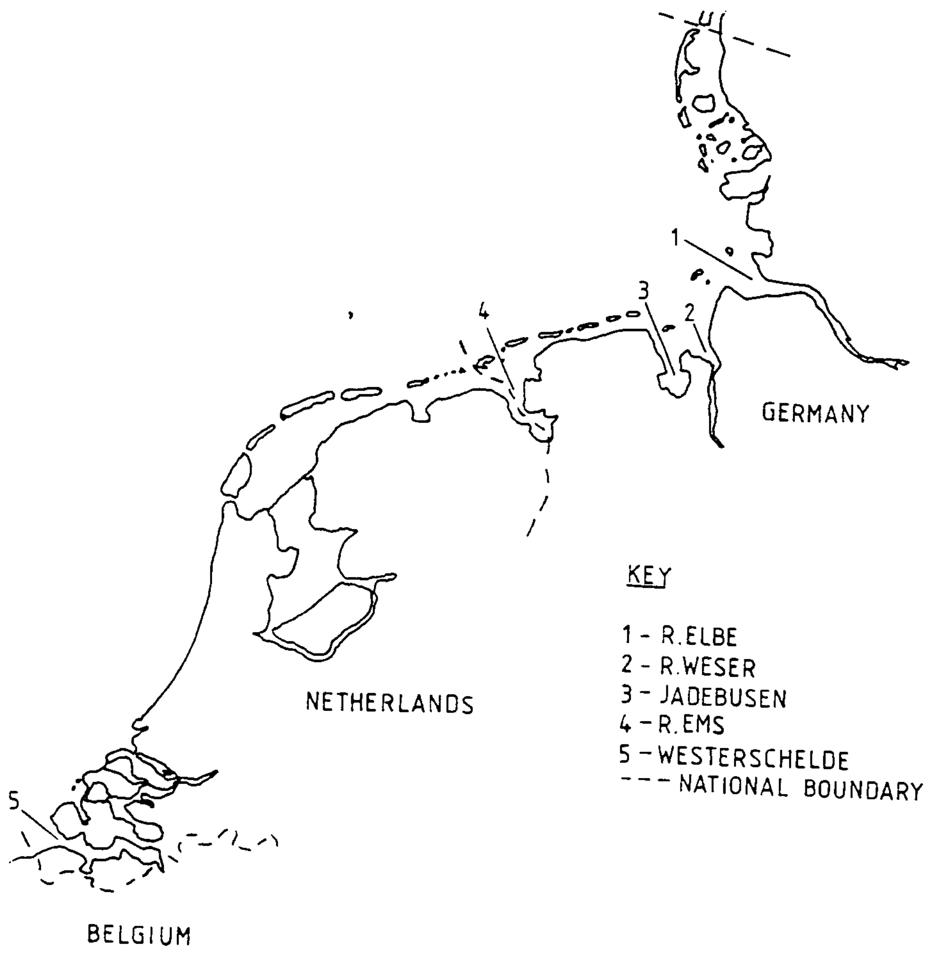


Figure 1.7 Sites studied in Britain and Ireland

Figure 1.7 (cont.). Key to the estuary/embayment site numbers

1 Loch Fyne
2 Loch Linnhe
3 Loch Leven
4 West Loch Tarbert
5 Loch Sunart
6 Loch Nevis
7 Loch Hourn
8 Loch Carron
9 Loch Creran
10 Loch Torridon
11 Loch Ewe
12 Loch Gairloch
13 Little Loch Broom
14 Loch Laxford
15 Loch Inchard
16 Kyle of Durness
17 Loch Eriboll
18 Kyle of Tongue
19 Loch Fleet
20 Dornoch Firth
21 Inver Bay
22 Findhorn Bay
23 Tarbert Ness - Burghead
24 Inverness Firth
25 Beauly Firth
26 Munlochy Bay
27 Dee estuary
28 Montrose Basin
29 Tay estuary
30 Eden estuary
31 Firth of Forth
32 Tweed estuary
33 Tyne estuary
34 Wear estuary
35 Tees estuary
36 Orwell estuary
37 Stour estuary
38 Landguard Fort (Orwell & Stour estuaries)
39 Colne estuary
40 Blackwater estuary
41 Crouch/Roach estuary
42 Adur estuary
43 Littlehampton Harbour
44 Chichester Harbour
45 Portsmouth Harbour
46 Hamble estuary
47 Southampton Water
49 Medina estuary
50 Ythan estuary
51 Carlingford Lough
52 Dundrum
53 Dundalk
54 Boyne estuary
55 Malahide Inlet
56 Waterford Harbour
57 Blackwater estuary
58 Cork Harbour
59 Oyster Haven
60 Kinsale
61 Courtmacsherry
62 Clonakilty
63 Glandore
64 Castle Haven
65 Baltimore Harbour
66 Dingle Bay
67 Smerwick Harbour
68 Tralee Bay
69 Brandon Bay
70 Shannon estuary
71 Liscannor Bay
72 Galway Bay
73 Bertraghboy Bay
74 Killary Harbour
75 Ballynakill Harbour
76 Clew Bay
77 Blacksod Bay
78 Sligo Harbour
79 Drumcliff Bay
80 Sheeps Haven
81 Mulroy Bay
82 Loch Swilly

Figure 1.8 Sites studied in Germany and the Netherlands



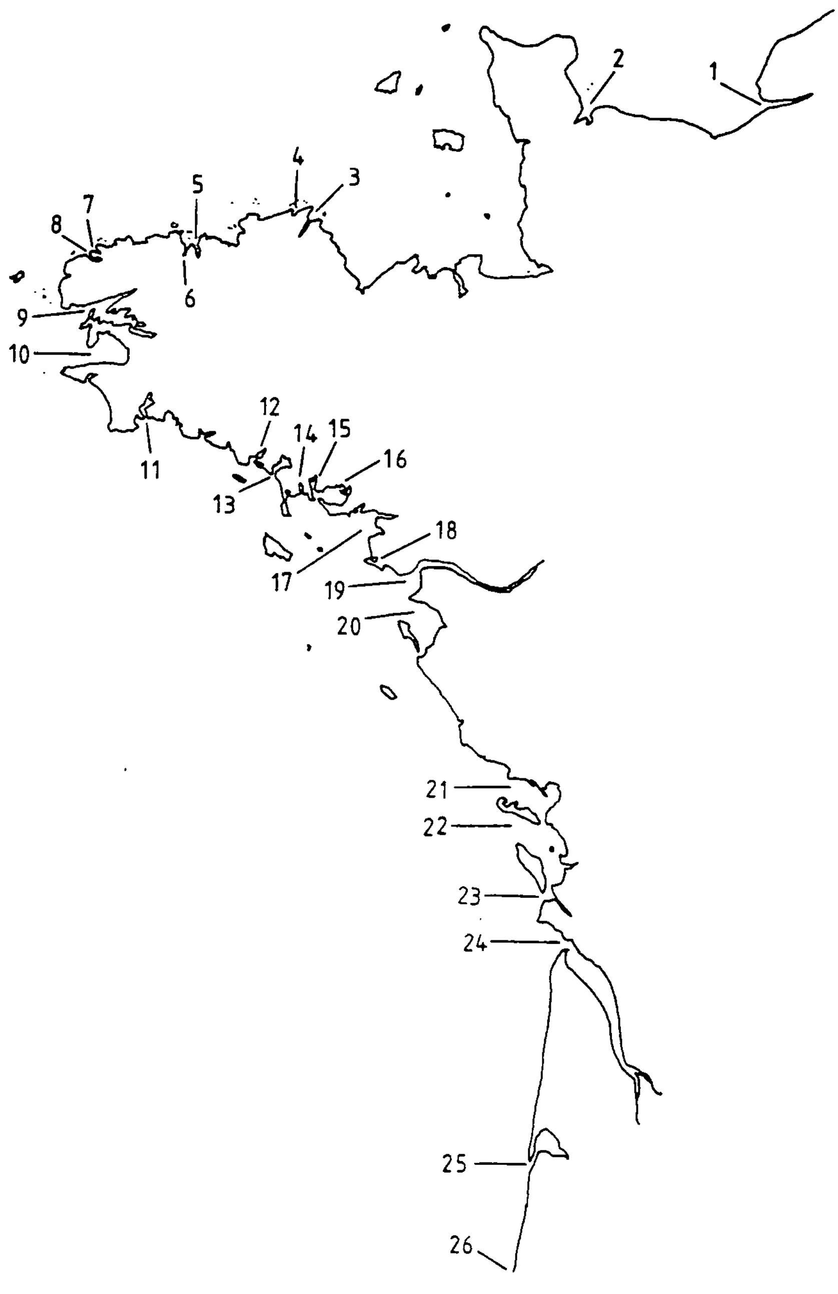


Figure 1.9 Sites studied in France

Figure 1.9 (cont.). Key to the estuary/embayment site numbers

1 Estuaire de Sienne
2 Estuaire de Vire/Carentan
3 Estuaire du Trieux
4 Estuaire du Jaudy
5 Baie de Morlaix
6 La Penze Riviere
7 Aber Wrac'h
8 Aber Benoit
9 Rade de Brest
10 Baie de Douarnenez
11 Estuaire de l'Odet
12 Lorient
13 Riviere d'Etel
14 Riviere de Crac'h
15 Riviere d'Auray
16 Golfe du Morbihan
17 Estuaire da Vilaine
18 Estuaire de Croisic
19 Estuaire Loire
20 Baie de Bourgneuf
21 Pertuis Breton
22 Pertuis d'Antioche
23 Pertuis de Maumuson
24 Estuaire du Gironde
25 Bassin d'Arcachon
26 L'Adour Fleune

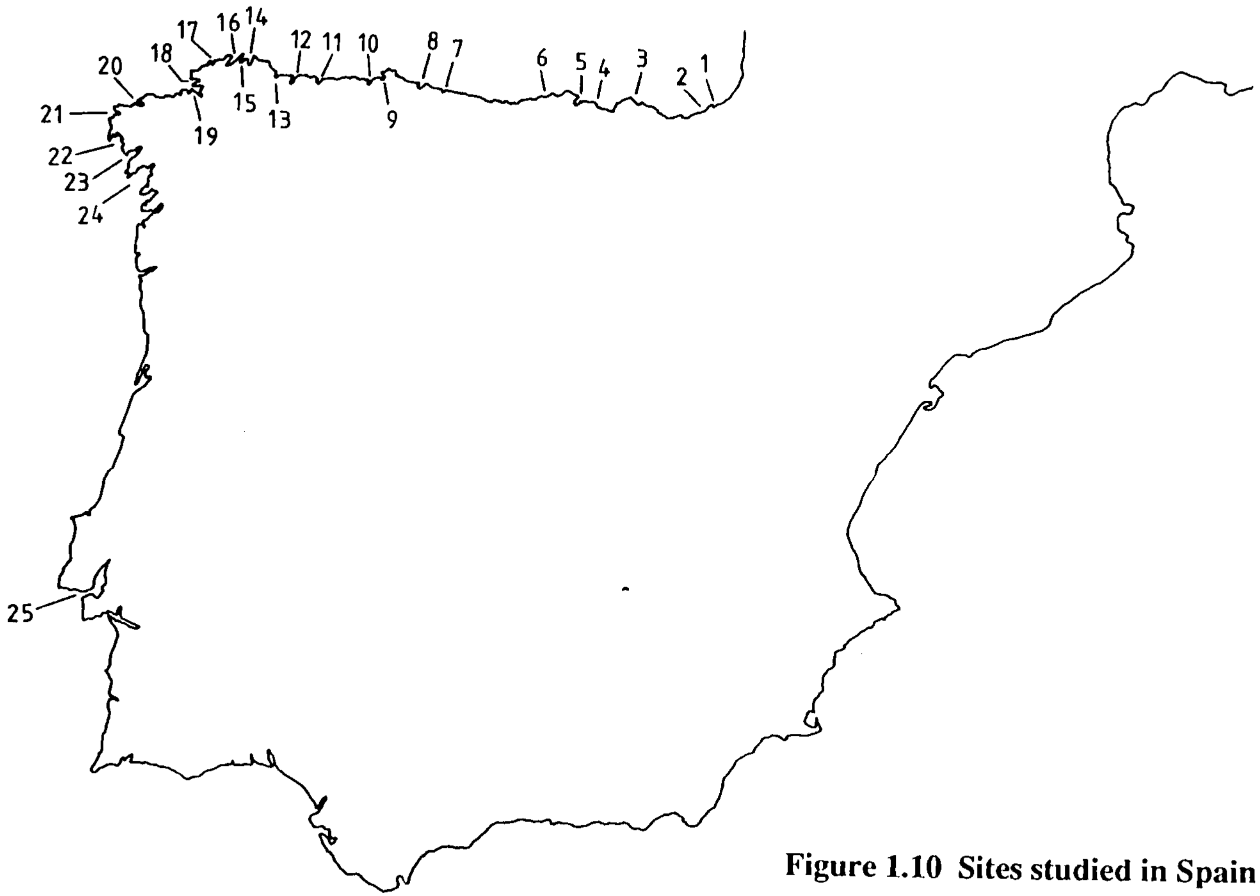


Figure 1.10 Sites studied in Spain and Portugal

Figure 1.10 (cont.). Key to the estuary/embayment site numbers

1 Baie de Fontarabie
2 Ria Oyarzan
3 Rio Mundaca
4 Ria de Santona
5 Rio de Solia
6 Ria de Suances
7 Rio Sella
8 Ria de Villaviciosa
9 Ria de Aviles
10 Rio Nalon
11 Rio de Navia
12 Ria de Ribadeo
13 Ria de la Masma
14 Ria de Vivera
15 Ria del Barquero
16 Rio de Mera
17 Ria de Cedeira
18 Ria de el Ferrol del Caudillo
19 Ria de la Coruna
20 Ria de Corme y Lage
21 Ria de Camarinas
22 Ria de Corcubion
23 Ria de Muros
24 Ria de Arosa
25 Rio Tejo

to January 1989 price levels, the respective value is approximately 7p/Kwh. From those western European estuaries/embayments examined by the parametric method or a more detailed study , the calculated cost of energy for 33 of the alignments falls at or below 7p/Kwh (These include the alignments in Binnie & Partners (1989a) as well as in Appendix I of this study).

When considering the engineering feasibility of a tidal power scheme, the minimum depth of water for turbines at the barrage site requires consideration. With current technology, a water depth of about 4m is considered a practical minimum (A.C.Baker per comms.), even allowing for some dredging, within which to achieve adequate submergence for turbines. This parameter constraint will be much reduced or removed only when an alternative to the traditional axial-flow turbogenerator is developed, for example the unlikely possibility of a air turbine (A.C.Baker per comms.).

Of those alignments with a unit cost at 7p/Kwh or less, 30 offer an adequate water depth for turbine submergence i.e. >4m. Five sites [Aughinish Bay (Galway Bay), Mulroy Bay, Dee Estuary (Aberdeen), Montrose Basin & Portsmouth Harbour], possess very narrow sea entrances across which the alignments run. It is doubtful whether the number of components assigned to their respective barrages could be accommodated in the alignment. This problem is apparently overlooked by the Parametric Method; Binnie & Partners have not replied (in litt) when questioned upon this point. However, due to the uncertainties, these latter five estuaries are retained with caution amongst those 33 alignments identified.

The regular dredging of channels in order to maintain a sufficient depth of water for local shipping is noted in the tables alongside the relevant alignments that dissect such channels. It should be realized that the Parametric Method utilizes the depths given on Admiralty Charts (the only readily available data source), which where relevant , is the dredging depth. This does not imply that the assessment of such alignments are invalid since dredging is also feasible post-barrage. What it does imply is that sediment loading in the estuary/embayment may be high, presenting a possible post-barrage problem (see above). Among the sites whose alignments dissect dredged channels, three estuaries mentioned above, the Dee, Montrose Basin and Portsmouth Harbour, are once again candidates.

By the criteria set out above, a total of 26 western European estuarine/embayment sites, consisting of 33 alignments, are identified tentatively as sites at most risk of development for power generation (Table 1.1, Figure 1.11).

TABLE 1.1

SUMMARY OF SITES STUDIED WITH U<= 7p/KWH & A MINIMUM WATER DEPTH >4M

BARRAGE LOCATION	$2M^2$ (m)	A (km2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £	U (p/KWh)	COMMENT
BRITAIN											
CAMEL ESTUARY	4.75	6.0	550	9.0	4.0	6	28	55	44	5.3+	
TAW/TORRIDGE ESTUARY	5.45	12.9	1125	11.0	4.0	15	90	165	-	4.6*	
SEVERN ESTUARY	7.0	520.0	16600	40.0	9.0	216	8640	17000	8657	3.6+	
WYE ESTUARY	9.6	2.0	275.0	16.3	4.0	3	35	73	-	4.8*	
BURRY INLET:											
Whiteford pt	5.55	43.6	3375	18.0	6.0	22	300	540	-	5.7*	
R.Loughor	3.6	2.4	246	5.3	2.8	4	5	15	14	7.0+	
MILFORD HAVEN (Lawrence Quay)	4.57	3.1	200	10.5	3	5	13	23	-	5.5*	
MENAI STRAITS	5.05	18.75	800	21.1	4.0	21	105	205	-	6.3*	
CONWY ESTUARY	5.2	5.5	200	13.0	4.0	6	34	60	50	6.0+	
MERSEY ESTUARY	6.45	70.0	1740	28.0	8.0	27	621	1200	652	4.5+	
WYRE ESTUARY (outer)	6.4	6.39	480	15.0	4.0	8	57	110		5.0*	
MORECAMBE BAY	6.3	350.0	16600	30.0	9.0	80	3040	5400	4521	5.8+	
WALNEY, PIEL & ROA ISLANDS	6.25	17.1	1688	17.6	6	10	195	275	-	5.9*	
DUDDON ESTUARY (outer)	5.6	19.85	2200	9.6	3.0	41	135	255	-	(3.6)*	
SOLWAY FIRTH	5.64	860.0	30000	28.0	9.0	180	5580	10050	9368	6.1+	
BARNIK POINT	5.8	44.7	2500	9.8	3.0	92	331	629	-	(3.7)*	
DEE ESTUARY (ABERDEEN)	2.6	8.3	140	9.5	3.0	12	17	25	21	5.97	DREDGED CHANNEL
MONTROSE BASIN	2.94	8.3	180	9.1	3.0	13	20.4	33.5	24	5.3	DREDGED CHANNEL
TAY ESTUARY:											
Tentsmuir pt	3.2	109.0	4800	13.8	5.0	67	317	522	480	6.7	
Broughty Castle	3.32	86.1	1400	18.9	7.0	27	259	440	330	5.9	
LANGSTONE HARBOUR	3.03	19.0	550	12.0	4.0	9	24	53	53	6.6+	
PORTSMOUTH HARBOUR	2.84	15.7	220	13.2	5.0	9	38	61	49	6.0	

* = Data presented in Binnie & Partners 1989 with Unit cost adjusted to January 1989 prices.
+ = Unpublished data provided by Binnie & Partners.

TABLE 1.1 (cont)

SUMMARY OF SITES STUDIED WITH U<= 7p/KWH & A MINIMUM WATER DEPTH >4M

BARRAGE LOCATION	$2M^2$ (m)	A (km2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £	U (p/KWh)	COMMENT
IRELAND											
CARLINGFORD LOUGH (entrance)	3.08	50.0	3600	7.7	3.0	83	136	221	165	5.8	
CARLINGFORD LOUGH (inner)	3.08	38.2	1700	7.1	9.0	7	103	167	86	4.7	DREDGED CHANNEL
WATERFORD HARBOUR (inner)	2.9	28.6	500	15.0	5.0	8	34	55	109	6.6	
GALWAY BAY (Aughinish Bay)	3.06	5.0	200	9.4	3.0	8	13	27	27	6.8	
MULROY BAY/BROAD WATER	2.4	26.5	250	14.2	5.0	13	47	66	61	6.7	
FRANCE											
RADE DE BREST (entrance)	4.08	160	1800	35.6	9.0	34	659	1215	1096	6.4	
RIVIERE D'ETEL	3.36	18.6	500	11.1	3.0	33	59	101	68	5.2	
GOLFE DU MORBIHAN (entrance)	3.06	116	1000	19.2	7.0	35	311	503	267	5.1	
ABER BENOIT	4.9	3.1	300	10.7	3.0	6	16	31	44	6.0	
BAIE DE MORLAIX	5.54	11.7	1900	14.0	3.0	24	70	145	255	7.0	
NETHERLANDS											
WESTERSCHELDE	3.48	326	4500	26.3	9.0	66	1097	1906	1264	6.1	

KEY TO SYMBOLS

$2M^2$	Mean tidal range	N	The number of turbines
A	The enclosed area of the basin	P	The total installed capacity of the generator
L	The length of the barrage	E	The average energy output
H	The max. depth of water along the barrage alignment	U	The unit cost of electricity from the barrage
D	Turbine diameter	C	The capital cost

Figure 1.11 Sites identified tentatively as ones at most risk of development for tidal power generation

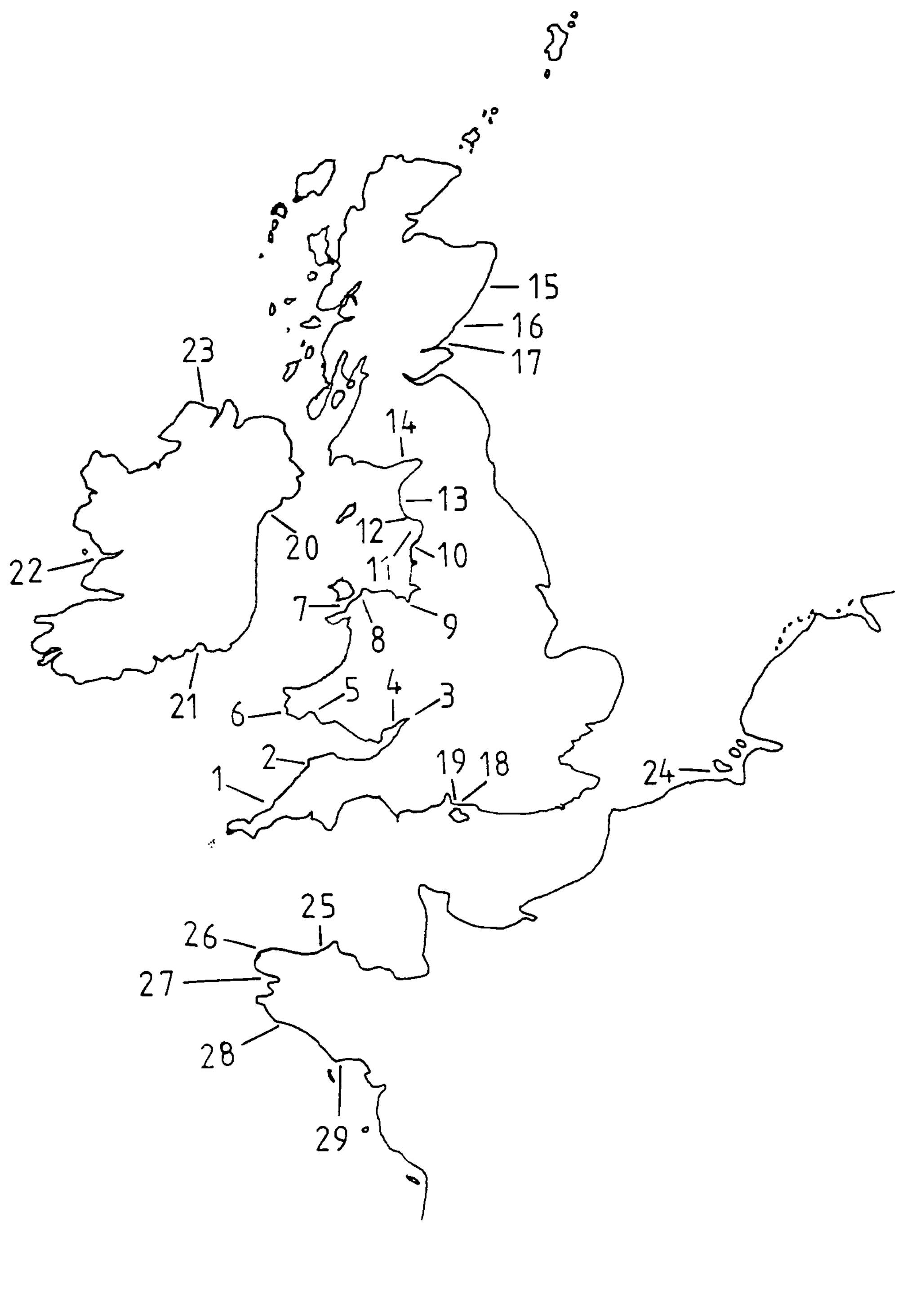


Figure 1.11 (cont.). Key to the estuary/embayment site numbers

1 Camel estuary
2 Taw/Torridge estuary
3 Severn estuary
4 Wye estuary
5 Burry Inlet
6 Milford Haven
7 Menai Straits
8 Conwy estuary
9 Mersey estuary
10 Wyre estuary
11 Morecambe Bay
12 Walney, Piel & Roa Island
13 Duddon estuary
14 Solway Firth
15 Dee estuary
16 Montrose Basin
17 Tay estuary
18 Langstone Harbour
19 Portsmouth Harbour
20 Carlingford Lough
21 Waterford Harbour
22 Aughinish Bay
23 Mulroy Bay
24 Westerschelde
25 Baie de Morlaix
26 Aber Benoit
27 Rade de Brest
28 Riviere d'Etel
29 Golfe du Morbihan

1.5 COSTING OF THE TIDAL POWER RESOURCE OF AN ESTUARY

In the foregoing site assessment, the basis for costing has been ebb-generation using the Parametric Method. This latter process estimates the value of assembling the main barrage components from a set of "building blocks" comprising turbine caissons, turbines, sluice caissons, embankments, ship locks and transmission (Baker 1986). Together with various contingency allowances, the costs are combined with likely construction programme costs to calculate the unit costs of electricity with a discount rate of 5%. The costing is inclusive of interest during construction, annual maintenance at 1% of mechanical and electrical plant costs, and 0.75% of civil costs, and complete replacement of all electrical and mechanical equipment after 40 years (ETSU & NORWEB 1989).

The Parametric Method's costing is within the accuracy that is realistically possible on the basis of the data available (ETSU & NORWEB 1989). Only a site specific study would provide more accurate cost estimates, a step obviously beyond the scope of this project.

The Parametric Method models for ebb-generation without pumping. The benefits of pumping differs with site. However, pumping and additional turbines often improves the energy output by 5-15% (R. Price pers comm.).

No attempt has been made within the costing analysis to accommodate the value of any non-energy benefits a barrage could bring in addition to power generation. This could take the form of a road/rail crossing, an amenity barrage and its associated developments, and/or improved coastal protection. The opportunity exists for the costs of such complementary developments to be discounted from the capital cost of the barrage. In addition, the creation of employment both directly and indirectly from the barrage, may, for example, entitle the Barrage Company to receive grant aid from the E.E.C. for initiating industrial regeneration in a depressed region.

1.6 SYNTHESIS AND OVERALL CONCLUSIONS

The physical characteristics shown by an estuary or embayment that may offer economical tidal power generation are:

- a macrotidal environment,
- a water depth along the barrage alignment of at least 4 metres, but not exceeding that practicable for barrage construction,
- the positioning of an alignment that provides an adequate compromise

between the cost inherent in the length of the barrage with its various components (turbines, sluices etc.) and its requirement to accommodate a tidal prism of sufficient magnitude.
- a seabed that provides adequate support for the barrage structure,
- a sediment loading in the inshore/estuarine waters that is low,
- a water current environment whose alteration by the alignment would not rearrange sedimentation patterns to the detriment of barrage operation.

Using the "desk-top" Parametric Method which is based upon relationships amongst three of the key physical characteristics, the present study has tentatively identified 26 barrage alignments in western Europe potentially offering economical tidal power generation. Prior to this study, 14 of the sites identified as potentially promising for tidal power generation (Table 1.2) have not been mentioned in the scientific literature. Heavy shipping usage of the waterways, environmental damage and the problem of large barrages being particularly controversial, are points that have been put forward as possible problem areas for three of the other alignments identified (ETSU & NORWEB 1989). Otherwise for all the remaining sites (all within the British Isles), recent studies by or on behalf of ETSU have produced no comments that would suggest that these sites are not worthy of further consideration (Table 1.2). In fact, at least six of the sites have been the subject of more detailed feasibility studies. All these observations would tend to reinforce the tentative conclusion of the present study, that the 14 previously "unknown" sites, together with the remaining 12, are most at risk of development for tidal power generation.

TABLE 1.2. A summary of the findings of other tidal power generating studies.

	SITE	REFERENCE
Sites for which no tidal power studies are known	Britain: Dee Estuary, Montrose Basin, Tay Estuary, Portsmouth Harbour Ireland: Carlingford Lough, Waterford Harbour, Aughinish Bay, Mulroy Bay. France: Rade de Brest, Riviere d'Etel, Golfe du Morbihan, Aber Benoit, Baie de Morlaix Netherlands: Westerschelde	
Sites for which studies have found circumstances for tidal power generation development favourable in regards to feasibility and costs.	Britain: Camel Estuary, Taw/Torridge Estuary, Wye Estuary, Burry Inlet (Whiteford Point), Milford Haven, Menai Straits, Wyre Estuary, Walney Is., Duddon Estuary, Barnik Point, Morecambe Bay, Solway Firth, Langstone Harbour.	Binnie & Partners 1989a ETSU & NORWEB 1989
Sites which have been the subject of a detailed feasibility study. All sites still remain possibilities for tidal power generation in the future.	Britain: Severn Estuary, Burry Inlet (R.Loughor) Conwy Estuary, Mersey Estuary.	Binnie & Partners 1989b DEn., CEGB & STPG 1989 Parkman 1988 T.H.Technology Ltd. 1990

CHAPTER II

AN INVENTORY OF PRESENT KNOWLEDGE OF THE NATURE CONSERVATION INTEREST OF WESTERN EUROPEAN COASTAL WETLANDS AT RISK FROM TIDAL POWER GENERATION DEVELOPMENTS

2.1 INTRODUCTION

Twenty six of western Europe's estuaries were identified in Chapter I as potentially fulfilling the physical and economic requirements for tidal power generation. For several of these locations, tidal barrage feasibility programmes are already in progress in association with environmental impact assessments (DEn, CEGB & STPG 1989). Consultants undertaking the assessments have invariably found limited data from which to work to document the current state of the sites' wildlife resources. Though such feasibility studies sometimes lead to limited fieldwork programmes, finances and time dictate that only very specific projects can be undertaken to assess any environmental impact. Birds are most frequently examined as they represent consumers rather than producers in the ecosystem and are comparatively easy to work upon. E.I.A.s for tidal power proposals have yet to assess with any accuracy the full impact of the proposed developments upon many other parts of the ecosystem. To begin such a thorough analysis, a knowledge of what data exist for each component of a site's ecosystem is an essential prerequisite. For many sites no one document provides such an overview. However, without it, ecologists cannot channel their efforts so effectively into projects that go towards establishing a thorough understanding of a site, in readiness for any future development.

For those sites identified in Chapter I as worthy of consideration on economic grounds for a tidal barrage, a provisional inventory of data relating to the natural resources of each site is presented in this section. The intention of the inventory is to make a statement of what types of information are available and where, or from whom. The inventory is undeniably incomplete. However, by publishing what data sources have been identified, this will hopefully emphasise to those whose work is omitted (unintentionally) that failure to disclose or publish the data they hold is not assisting conservation.

2.2 THE INVENTORY: ORIGIN & PRESENTATION OF DATA

The following inventory has been compiled through a review of the literature and enquiries to international, national and local organisations and to individuals who may have a knowledge of a site's fauna and flora. Enquiries were also made to substantiate what data bases, if any, exist that incorporate the sites under review. For the British sites, many relevant data have been collated very recently by the Nature Conservancy Council's (NCC) Chief Scientist Directorate Review Teams, notably the Estuaries Review Team; these data were made readily available. For the remainder of western Europe the presence of any data bank has been less readily ascertained, particularly in Eire. In many cases, relevant data are known or strongly suspected to exist; their extent and form are, however, not known. The organisations and persons to whom approaches were made and replies received are listed in the Acknowledgements.

For each site the inventory provides the following information, where known:

1. Site Details - Coordinates or Ordnance Survey Grid Reference (Britain),
   - County/Region,
   - Total Area (ha).

2. Conservation Status - The presence and numbers of reserves, statutory orders and international designations covering part or all of the site are listed. The designation initials (as used in the inventory) and references detailing each designation (where appropriate) are as follows:

   a) British site designations

   NCR - Nature Conservation Review Site; (Ratcliffe 1977)
   GCR - Geological Review Site; (Davidson 1991)
   SSSI(B) - Site of Special Scientific Interest (Biological); (NCC 1988)
   SSSI(G) - Site of Special Scientific Interest (Geological); (NCC 1988)
   NNR - National Nature Reserve; (Davidson 1991)
   LNR - Local Nature Reserve; (NCC 1989)
   RAMSAR - Ramsar site (Wetland of International Importance); (Davidson 1991)
   SPA - EEC Special Protection Areas; (Davidson 1991)
   AONB - Area of outstanding Natural Beauty; (Countryside Commission 1989)
   CWT - County Wildlife Trust Reserve
   SWT - Scottish Wildlife Trust Reserve

RSPB - Royal Society for the Protection of Birds Reserve
ESA - Environmentally Sensitive Area; (Davidson 1991)
WWT - Wildfowl and Wetlands Trust Reserve
NT - National Trust property; (Davidson 1991)

b) European site designations

RAMSAR - Ramsar site (Wetland of International Importance); (Davidson 1991)
SPA - EEC Special Protection Areas; (Davidson 1991)
ASI - Area of Scientific Interest (Eire); (Grimmett & Jones 1989)
ASSI - Area of Special Scientific Interest (Eire); (Grimmett & Jones 1989)
LNR - Landschappen Nature Reserve (Netherlands); (Grimmett & Jones 1989)
CHR - Coastal Hunting Reserve (France); (Grimmett & Jones 1989)
CR - Conventional Reserve (France); (Grimmett & Jones 1989)

Proposed Ramsar and SPA sites are given in parenthesis.

3. Habitats - The status and area (if relevant) of eight distinct habitat types at each site are given. A source of reference is provided that expands upon that basic information. The majority of these habitats in Britain are the subject of national surveys by the Nature Conservancy Council's Chief Scientist Directorate (NCC CSD). For a given habitat at a site the NCC CSD have attempted to document its component communities and their respective importance on a national scale.

4. Waterfowl - The status of our knowledge and sources of information are given for nine ornithological parameters:

a) Waterfowl Population Levels*
b) Shorebird feeding distribution
c) Shorebird roosting distribution
d) Wildfowl feeding distribution
e) Wildfowl roosting distribution
f) Importance of the site to waterfowl as a moulting site
g) Importance of the site to waterfowl as a spring staging post
h) Importance of the site to waterfowl as an autumn staging post
i) Importance of the site to waterfowl as a breeding site**

* Since 1969 the waterfowl populations of British estuaries have been monitored though the Birds of Estuaries Enquiry (BoEE) and National Wildfowl Counts (NWC). Nationally coordinated monthly counts of waterfowl, primarily from October to March, have been undertaken by volunteers on the majority of British estuaries including those identified as potential tidal power sites (Section I). These data are collated and analysed by the British Trust for Ornithology (waders; BoEE) and Wildfowl & Wetlands Trust (wildfowl; NWC) for site evaluation and population dynamics. Their findings are presented annually through the publication *Wader & Wildfowl Counts* (e.g. Kirby, Waters & Prys-Jones 1991). Enquiries in relation to bird numbers using particular British sites can be made to both the B.T.O. and W.W.T..

** The Nature Conservancy Council and Seabird Group have established and maintained a register documenting Britain and Ireland's breeding seabirds. Recently the Seabird Colony Register has been summarized in the publication *Status of Seabirds in Britain and Ireland* (Lloyd, Tasker & Partridge 1991). Enquiries about the Register should be directed to Seabird Colony Register, Nature Conservancy Council, Aberdeen, AB1 1XE.

5. Mammals - For each site considered, the current status and conservation importance of four species/groups of mammals (Otter *Lutra lutra*, Cetaceans, Grey Seal *Halichoerus grypus* & Common Seal *Phoca vitulina*) are tabulated together with a source of information. No other north western European mammals have been considered since none exhibit any dependence upon estuarine waters.

6. Amphibian - The Natterjack Toad *Bufo calamita* is the only north western European amphibian exhibiting any reliance upon coastal or estuarine environments. For each site considered, the current status and conservation importance of the Natterjack Toad, together with a source of information, are stated.

7. Fish - For each site considered, the current status and conservation importance of their fish species, where known, together with a source of information, are stated. A data base of rare British marine fishes is being developed that will be fully integrated with the Marine Nature Conservation Review (MNCR) of the Nature Conservancy Council (Swaby & Potts 1990). The limited availability of time in which to compile this inventory prevented the author from consulting this database. Enquiries in relation to this database should be directed to the MNCR, Nature Conservancy Council.

8. Marine communities - For each site considered, the presence and conservation

importance of their marine communities together with sources of information, are stated. The Nature Conservancy Council's Marine Nature Conservation Review (MNCR), in order to assess Britain's biological marine resources, has categorised the marine communities of Britain. Laffoley (1991) has extended into estuarine or reduced saline conditions, the marine communities categorization adopted by the MNCR.

9. Terrestrial Invertebrates - For each site considered, the current status and conservation importance of their terrestrial invertebrates, together with sources of information, are stated. Much British data are held by the Nature Conservancy Council's Invertebrate Site Regiser (ISR). Where applicable ISR site details have been included in the inventory.

10. Flora - For each site considered, the current status and conservation importance of the plant communities, together with sources of information, are stated.

Since the objective of the inventory is to summarize the types of information are available and where or from whom, no attempt has been made to reproduce any of the data listed which is readily available through the publications referenced or from the organisations stated. The site inventory tabulations include a question mark (?) where the existence of information relating to the respective entry is unsubstantiated.

2.3 SITE INVENTORY

The site inventory is presented in Appendix II

CHAPTER III

THE IMPACT OF A TIDAL POWER BARRAGE UPON THE ORNITHOLOGICAL IMPORTANCE OF A SITE

3.1 INTRODUCTION

The physical characteristics shown by an estuary or embayment that may offer economical tidal power generation were described in chapter I. Twenty six of western Europe's estuaries were subsequently identified as potentially fulfilling the physical and economic requirements for tidal power generation. The existence of information relating to their natural resources was shown, from compilation in chapter II of a provisional inventory, to be extremely variable between sites. The interpretation of these data and the acquistion of new data in relation to the threat posed by a tidal power barrage requires an understanding of the processes involved in its environmental impact. This is addressed initially in this chapter from a review of the current literature concentrating solely upon the ornithological impact.

In accordance with European Economic Community law, developments such as a tidal barrage within a member state requires an Environmental Impact Assessment (E.I.A.) to be undertaken prior to any construction. In evaluating our ability to make a tidal power E.I.A. this chapter continues by examining those ornithological E.I.A.'s, past and present, undertaken in relation to tidal power within Britain. This point is emphasised further when the chapter concludes with an ornithological E.I.A. upon a given estuary utilising solely the data available.

3.2 THE ORNITHOLOGICAL IMPACT OF TIDAL POWER BARRAGES: AN OVERVIEW

The tidal curve of an estuary is the principal physical characteristic that will be altered by installation of a tidal power barrage. Ebb generation, with or without pumping (the operational procedure incorporated by most feasibility studies (chapter 1.2)), modifies the natural tidal curve landward of the alignment so that (figure 3.1):

i. the low tide level is raised to that of mean sea level;
ii. the fall in water level on the ebb tide is significantly slower;

iii. the low water period is shortened;
iv. peak high water will have a standing period of 2-3 hours;
v. the levels of high spring tides will be reduced.

Western Europe's estuaries extend over approximately 1,895,000 ha (Davidson et al. 1991), and support a very significant proportion of the 3.2 million waders (Smit & Piersma 1989) and 17.5 million wildfowl (Pirot, Laursen, Madsen & Monval 1989) that winter in the region. Feasibility studies of the Severn and Mersey barrages predict the loss of more than 40% of the intertidal flats currently present (DEn et al 1989; Parkman 1988). The most significant bird community in size and importance within almost all western European estuaries is that dependant upon the food resources of these soft sediment intertidal areas. What impact therefore will the loss of these intertidal flats have upon the bird community? Before discussing this point, a general summary is necessary detailing what determines the distribution of birds across vast expanses of intertidal flats.

3.2.1 BIRDS AND MUDFLATS

Estuaries, though consisting of a mosaic of habitats comparatively simple in structure, are biologically very productive. The overall density and biomass of invertebrates that inhabit the intertidal flats are very high e.g. for the polychaete *Nereis diversicolor*: $5000/m^2$, $14g/m^2$ (Plymouth Marine Laboratory 1989). This abundant supply of invertebrates throughout much of the year is the attractive force for a large number of waterfowl species that use estuaries outside the breeding season. A smaller number of species use the algae and grasses of the intertidal flats and saltmarshes for food. Both the spatial and temporal distribution of birds within an estuary is largely influenced by the density and availability of their food. Even the roost sites used by shorebirds at high water, the period when food is in general unavailable to them, are located as near to the low tide foraging grounds as practicable, in order to conserve energy.

Apart from in very shallow water close to the tide edge, the vast majority of shorebirds are able to forage only on exposed intertidal flats. Upon tidal exposure and drying of the surrounding sediments, many invertebrates burrow down into the flats and thereby become unavailable to avian predators. When foraging for invertebrates, the majority of waders and wildfowl are therefore distributed close to the tide edge or other damp areas. In other words, the importance of a specific area to foraging birds varies with time during the tidal cycle. Those areas favoured most at a given time will generally be those that provide birds with the greatest food intake rate, thus increasing the probability of the individual attaining its daily energy requirement in the total period available for foraging. Several factors, of which many affect energy expenditure, modify the food distribution/bird distribution correlation, e.g. species substrate preference, nearness of roosts, disturbance.

A 40% loss of the Mersey's intertidal area post-barrage (Parkman 1988) does not necessarily imply a similiar reduction in the total bird population or that of any particular species, as was found after loss of intertidal area on the Tees estuary (Evans & Pienkowski 1983). The magnitude of the loss is determined in part by the usage individual birds make of the areas lost. However, whether these potential losses can be accommodated by the remaining food resources or by changes in social structure of the bird community will affect the outcome. Consideration is given in the next section to the immediate impact upon species with a variety of foraging strategies of the permanent inundation of a proportion of their feeding grounds

3.2.2 THE MODIFIED TIDAL CYCLE: ITS IMMEDIATE IMPACT UPON BIRDS

The feeding strategies of waders can be categorized into territorial and non-territorial. Which is adopted depends upon species and in some cases individuals within a species. Territorial birds defend a fixed area, normally a feeding area, from conspecifics, whether other territorial holders or non-territorial birds. A barrage would obviously directly submerge territories at present occupied below mid tide level, i.e. birds would be actively displaced. The density of birds feeding on the remaining intertidal flats would in consequence need to increase for the estuary population to be maintained.

In general, waders and wildfowl adopting non-territorial feeding strategies follow closely the tide edge as it moves across the intertidal areas. The lower tidal amplitude of a post-barrage environment reduces the area transversed by the tide edge on the ebb and flood. For the larger waders in particular, a greater proportion of birds feed on the ebb as opposed to the flood tide (pers. obs., Pienkowski 1973). Because the water depth drops more slowly as a consequence of the reduction in overall amplitude, the time taken for the tide edge to cross a particular zone on the shore increases. This means that birds following the tide edge will spend longer in that zone and so deplete the food supplies at a faster rate. If spread evenly along the tide edge, the density of birds would not be expected to change as a result of the change in tidal amplitude. However, the densities of concentrations of non territorial birds both along specific food-rich regions of the tide edge and those exploiting other largely damp areas, are considered likely to increase. The post-barrage tidal curve is likely to reduce the preferred feeding areas the tide edge previously transversed and thereby concentrate more birds in those remaining 'hotspots'.

In addition to the impact of a barrage upon the spatial distribution of feeding birds is the impact on potential feeding time. The high water period upstream of an alignment is prolonged by a tidal power barrage. The degree of prolongment will vary with locality depending upon distance from the barrage and the sites hydrology and bathymetry. Overall though, the remaining intertidal areas will be available to foraging birds for a shorter time period. In consequence, post-barrage birds will be confronted with a shorter time period in which to forage amongst a greater density of individuals whilst still maintaining an adequate food intake rate from the reduced food resources.

A point will be reached when an individual cannot achieve its required daily food intake rate and therefore it will lose condition. The mechanisms by which this is brought about require understanding before a population's response to an altered environment can be predicted.

3.2.3 BIRD DENSITY: ITS EFFECTS ON AN INDIVIDUALS FOOD INTAKE RATE

There are two ways in which an increase in bird density might cause food intake rate to decline - depletion and interference (Goss-Custard 1980).

a) Depletion

The depletion of a food resource by foraging birds reduces their intake rate since this is related to prey densities. Reproduction and growth of intertidal invertebrates is largely restricted to the summer period, though it may continue into the autumn in those estuaries in the south and west of western Europe. In general therefore, the invertebrate populations that sustain the large assemblages of wintering waterfowl is a diminishing resource that is only replenished by reproduction of the populations remaining after the birds' departure. The rate at which the resource is depleted is greatest where it is initially abundant since this is where the birds generally prefer to forage. In such areas waders may deplete the standing crop of invertebrates by as much as 25-40% within a winter period. Consequently over the winter, a wader's food intake rate may decline by between 5-30%, depending on the initial density of the food and the wader species considered (Goss-Custard 1980). Any further increase in an area's wintering bird density will result in the additional depletion of food supplies with the possibility of more significant decline in feeding rate. Thus the impact of a tidal power barrage may well make it more difficult for birds to feed fast enough to maintain daily energy balance.

The depletion of winter food resources and impact of the consequential reduction of intake rate is just as applicable to herbivorous birds as it is to the invertebrate feeders e.g. van Eerden 1984. As with invertebrates, plant growth is restricted largely to the summer season, so the winter resource to foraging wildfowl is a finite one.

b) Interference

The greater the density of a population the more likely feeding rates will be influenced directly by interference between individuals within the population. The mechanisms by which interference may operate within feeding waterfowl are:

i) Encounters over food: The degree to which individuals attempt to displace or rob conspecifics of food items varies between species. Its frequency, however, has been shown to increase with that of bird density in several species. The consequence is to reduce the average food intake rate of the species (e.g. Goss-Custard 1987).

ii) Kleptoparasitism: Food located, by waders in particular, may be stolen from them by gulls, corvids, and occasionally waders of a different species. The relationship between the density of foraging birds and the likelihood of an individual being subjected to kleptoparasitism is little understood in estuarine species (but see Barnard & Thompson 1985 for inland studies on gulls and plovers). However, the greater the frequency of kleptoparasitism upon an individual the lower its overall intake rate. In one study, the frequency of kleptoparasitism by gulls, *Larus* spp., on individual Oystercatchers *Haematopus ostralegus* increased as wader density increased (Goss-Custard 1980).

iii) Disturbance in searching: If birds take a path when foraging which allows them to maximize encounter rates with food items (Goss-Custard 1980), deviations from it that are forced by the close approach of neighbours potentially reduces food intake rate. The frequency with which the paths of birds meet theoretically increases with density. Therefore the time devoted to avoiding collisions with near neighbours and any loss of food intake resulting from the deviation will reduce the overall food intake rate as bird density rises. The individual may also become more aware of food piracy directed towards it from near neighbours. In response, the proportion of time devoted to vigilance may increase to the detriment of the food intake rate.

iv) Depression of prey availability: The vibrations caused by an approaching bird induces many invertebrate prey to attempt to evade the predator through either burrowing or withdrawing into their shells. As the density of foraging birds increases the probability of an invertebrate re-emerging after evasion of one bird but in time for the arrival of a second, will decrease. Thus the availability of prey and as a consequence the food intake rate of an individual will decline.

As the density of birds increases within a foraging area, a point will be reached when the mechanisms described above will lower the food intake rate of an individual below that able to sustain daily requirements. This is exacerbated by reduced foraging time, the consequences of which are discussed next.

Variability is known to exist amongst foraging individuals in their reactions to increases in density of conspecifics and to decreases in foraging time. An understanding of this is a prerequisite to determining their impact upon the distribution and survival of an estuary's bird populations.

3.2.4. REDUCTION IN FORAGING TIME: ITS CONSEQUENCES UPON BIRDS

For a given area, a reduction in feeding time may require a bird to intensify its foraging activity in order to maintain overall food consumption. Whether a bird is able to do so is dependant upon whether it has already reached the optimum foraging rate in terms of physical ability and prey availability. Studies of the reclamation of intertidal land suggest that many waders and wildfowl may not have the ability to compensate for lost feeding time in western European estuaries. The decrease in at least two wader species numbers after the reclamation of 60% of the Tees estuary intertidal mudflats was considered the direct result of the shorter time for which intertidal areas are now exposed (Evans 1978). This was also assumed to be the reason behind a 60%+ decline in 13 waterfowl species' migrant populations on a reclaimed area and adjacent mudflats on the Danish Waddensea (Laursen, Gram & Alberto 1983). The mechanisms by which birds respond to a loss in feeding time is comparable to that of increased density (chapter 3.2.3). Fewer areas may be able to provide the required quantity of food within the shortened time period, thus competition between birds intensifies. Within a fixed time period intensification of foraging by birds will increase the extent of prey depletion. The consequence is that though a barrage may not physically remove significant areas of intertidal land, the time with which waterfowl can utilize the resource may be too limited. Hence the availability of feeding areas is in effect reduced. In fact the impact of reduced feeding time is likely to be greater in proportion than loss of a feeding area. The possibility exists where despite retention of extensive areas of intertidal flats upstream of a barrage, an insufficient period of availability would not sustain a bird population comparable to such an area with a longer period of exposure.

3.2.5 SUSCEPTIBILITY OF INDIVIDUALS TO COMPETITION FOR FOOD RESOURCES AND ITS INFLUENCE UPON DISTRIBUTION AND SURVIVAL WITHIN A SPECIES

The food intake rates of immature birds often do not initially match those of adults this may in part be the result of inexperience e.g. van der Have et al. 1984. Social dominance of adults over immatures puts this latter age class at further disadvantage when foraging. Adult birds are more likely to win conflicts with an immature bird over a prey item or a feeding site e.g. Goss-Custard & Durell 1984. For waders in particular, such inequalities between age groups are strongly reflected in the distribution of the two groups within an estuary while feeding e.g. van der Have et al. 1984. When many wader species begin to arrive at their wintering grounds for example, they often occupy first the feeding areas where they can obtain the highest food intake rates. Competition intensifies as more birds return and occupy these few "preferred" areas. Sub-dominant or young birds consequently may settle in other areas to increase their survival chances. On "preferred" feeding areas a ceiling density may be reached beyond which no further birds settle; the carrying capacity of that area. In contrast, numbers of birds in the less "preferred" areas continue to rise as more birds arrive until such areas may also reach carrying capacity. Sub-dominant or young birds in these less preferred areas may meet lower bird densities, and therefore lower competiton. Removal of feeding areas, regardless of their preference ranking, would place immature birds at greater risk of failing to attain an adequate daily food intake rate to fulfil their requirements.

Unlike waders and duck, juvenile geese and swans remain within family parties with their parents throughout their first winter. Recent studies suggest that social dominance amongst feeding geese is related to the structure of the family parties. The presence of juveniles, and the greater their number, the better the foraging areas the family group is able to commandeer (Lambeck 1990). Single birds regardless of age, are apparently low in the social hierarchy that determines distribution on the feeding grounds. This suggests that any goose that starves through the loss of feeding grounds is most likely to be a relatively young bird, as the breeding success of individuals increases with age and experience.

Within a species, age may not be the only attribute which affects the susceptibility of the individual to the effects of bird density. A morphological feature may differ between the sexes or divide two or more sub-populations of a species so that each obtains a better food intake rate from different habitats. In a given habitat the different sexes or sub-populations may differ in their success at obtaining food e.g.Clark 1989, Smith 1975, Townshend 1981. Clark (1983, 1989) suggests that the difference in bill lengths found between the feeding populations of Dunlin *Calidris alpina* on four sites on the Severn estuary may be related to differences in prey types or substrates available. If true, by removing the preferred intertidal area of one sub-population, a barrage will put those individuals within the estuary at a disadvantage. Their food intake rate elsewhere might be lower than that obtainable by their conspecifics. In consequence such birds would be less able to suceed in the interspecific competition that could develop or intensify with the removal of some intertidal areas. Furthermore, Clark (1990) has suggested that the populations of some species within an estuary may be ascribed to sub-populations from a discrete part of the respective species breeding range. No convincing evidence for this hypothesis is shown from data published to date.

The important point of the above observations is that a species population is not homogeneous across its range. A tidal barrage scheme is likely to affect the breeding populations of or sizes within, a species unevenly, with the possibility of a significant impact upon birds from only certain discrete areas within the species' breeding range.

3.2.6 BIRD POPULATIONS OF OTHER ESTUARIES

The carrying capacity (chapter 3.2.5) can be defined (Goss-Custard 1985) as the number of birds above which a rise in bird density would be accompanied by an increase in mortality. This may develop because competition for resources intensifies, as described above, or vulnerability to disease or predation increases. For some species, studies suggest that birds arriving first at an estuary occupy the most "preferred" areas i.e. those in which food intake rate is highest. Whether an estuary as a whole is at or near carrying capacity for a species, either before or after barrage construction, cannot be satisfactorily proven at present although Moser (1988) has shown that some British estuaries are now "full" of Grey Plovers *Pluvialis squatarola* whereas others are not. However, it is assumed that in such a scenario any additional birds will seek out suitable and available feeding grounds in a nearby estuary upon which to settle. Thus the impact of a tidal power barrage upon birds may not be confined to those of the estuary in which the barrage is to be constructed.

An estuary may be incorporated into a species survival strategy to provide resources for:
a) moulting birds,
b) a wintering population,
c) passage migrants (for a brief refuelling stop),
d) supporting the species population in cold weather or other circumstances that necessitate feeding areas.

An individual bird may rely upon a suite of estuaries to fulfill each one of these functions. Thus, denying a bird access to one of those estuaries will potentially affect populations in the other estuaries.

For each of the functions of an estuary, the carrying capacity will differ in relation to the duration for which, and rate at which, the species requires its finite resource. An estuary caters for a suite of species differing in their use of the site both in time and in their requirements. Therefore the idea of an overall carrying capacity of an estuary's for birds subsumes a complex of carrying capacity limits which alter with time and environmental factors such as temperature. Caution is particularly required when considering the carrying capacity of those estuaries that provide species with resources only in adverse weather. It is essential that such sites contain the food resources needed by a population when necessary for survival. Such resources will be available but not actively utilized for much of the time. Removal of such a site or the need for it to support an additional population e.g. as a result of the potential impact of a tidal power development elsewhere, will endanger the long term survival of the original population using it.

Many estuaries identified as potential tidal power sites are areas that provide "reserve" resources for many waterfowl in winter e.g. Severn estuary. The macrotidal environment that characterises tidal power sites generally keeps the intertidal areas of such estuaries free of snow and ice during severe weather. At such times many waterfowl seek refuge at these sites by migrating from the southern North Sea estuaries e.g. Waddensea and the Wash, where cold weather may severely reduce food availability (Townshend 1981, Owen et al. 1986). This ability of an estuary to accommodate cold weather migrants when necessary is very likely to be reduced by a tidal power barrage.

To summarize, the impact upon bird populations of a tidal power barrage is likely to extend far beyond that of the estuary under consideration. The actual response is largely dictated by the degree to which the barrage alters the resources available to adequately sustain the bird populations that currently exist.

3.2.7 INTERSPECIFIC COMPETITION

A change in density of a species or time available for foraging cannot be considered for that species in isolation. For two species utilizing identical food resources, regardless of whether their respective times of foraging differ, the density of prey available to each will obviously be influenced by the overall extent of prey depletion (chapter 3.2.3). Furthermore, the intensification in interference between individuals that may result from an increase in population density, is not restricted to one species, regardless of diet (chapter 3.2.3). Most of the different mechanisms of interference are as applicable between species as they are within one. For example an invertebrate species is unlikely to be able to differentiate between the vibrations caused by a bird walking nearby whether of a species that will or will not prey upon it. Thus the increased density of one bird species on an intertidal flat may depress the availability of invertebrate prey to another, thus potentially reducing that species rate of food intake. Competition between species is therefore likely to be one mechanism by which intertidal reclamation affects estuarine bird populations. Evans (1978) suggested that interaction between species explained part of the alteration in species composition that resulted after the loss of 60% of intertidal land to reclamation at Teesmouth.

3.2.8 DIFFERENTIAL IMPACT UPON NOCTURNAL AND DIURNAL FORAGING

Nocturnal foraging of waterfowl species may differ from that by day in several respects:

i. The intertidal areas used by an individual may differ by day and night e.g. Evans 1984, Clark et al. 1991b,
ii. The method of foraging used by an individual e.g. Robert & McNeil 1989,
iii. The prey taken e.g. Robert & McNeil 1989,
iv. The extent and period of foraging e.g. Zwarts et al. 1991, Clark et al. 1991b,
v. Food intake rate e.g. Pienkowski 1983,
vi. The proportion of the daily net energy intake provided by the diurnal foraging period at different times of year (Dugan 1981, Pienkowski 1982b).

Studies of wintering Redshank *Tringa totanus* and Curlew Sandpiper *Calidris ferruginea* (Goss-Custard 1969, Puttick 1984) suggest that nocturnal foraging is used to allow the individual to fulfill any shortfall in the daily energy intake from diurnal feeding. This is not true for all waders in temperate latitudes where in winter both daylength and prey availability are reduced. For at least some prey species, their activity and availability in fact increases during the hours of darkness (Pienkowski et al. 1981). This increased prey availability in the long nights of winter, apparently offsets any difficulty some waders have in detecting prey at night. The major part of their energy requirements may be met by nocturnal foraging e.g. Grey Plover, Ringed Plover (Pienkowski 1982, Wood 1983). For such species nocturnal feeding may in fact be preferable to foraging diurnally (Dugan 1981). The importance of night feeding within a species, may vary, however, according to the individual's use of foraging space, i.e. whether territorial or non-territorial (Townshend et al. 1984).

For many herbivorous wildfowl (e.g. Wigeon, Teal), the extent to which they forage at night and by day is apparently related to the level of disturbance on the feeding grounds (Owen et al. 1986). An abundance of diurnal avian predators (Tamisier 1974) or disturbance by hunting in general leads to feeding within the periods of darkness when the presumed risks of disturbance and predation are lessened (Owen et al. 1986).

The existence of differing foraging strategies between night and day suggests that the nature of the competition between feeding birds (chapter 3.2.5, 3.2.7) and impact upon prey availability (chapter 3.2.3) differ between the two periods. Thus the extent of the impact of a tidal power barrage upon foraging birds at night and day is likely to differ.

3.2.9 POST-BARRAGE SEDIMENTATION

So far in this discussion the underlying assumption has been that other than an alteration in the tidal cycle and accompanying loss of intertidal areas in time and space, a bird's environment remains unaltered after barrage construction. However, the barrage's alteration to the hydrology of the estuary will lead to redistribution of sediments including those of the remaining intertidal areas. In consequence a bird's choice of foraging area amongst those remaining may alter, influencing the overall impact of a barrage.

Despite extensive modelling of the hydrology and sedimentology post-barrage of the Severn estuary, we still lack an adequate understanding of sediment dynamics to enable us to predict the sediment regime to a satisfactory level of confidence (DEn, CEGB, STPG 1989). At present only a general description can be made of the predicted physical environment, post-barrage. A more precise statement would lack sufficient supporting evidence at present. In compiling this section of the overview, studies funded by the Energy Technology Support Unit (ETSU) have been consulted (Plymouth Marine Laboratory 1989, Ravensrodd Consultants Ltd. 1989, Gray et al. 1989). A summation of these has been given by the Severn Tidal Power Group (1989).

A tidal power barrage reduces the tidal prism (chapter 1.2) of an estuary and thereby the dynamic state of the water column. With an overall reduction in water currents upstream of the barrage, turbidity will decrease and many fine sediment particles previously mobilized by the tide will settle out. The mixing of fine particles into sand substrates is considered likely, making the former sandier intertidal substrates finer and more stable. Certain species of intertidal invertebrates actually feed on, as opposed to only anchoring within, the substrate. The organic content of sediments is therefore an important regulator of invertebrate distribution and abundance. Generally an inverse relationship exists between sediment grain size and organic content, a reflection of the surface area to volume of the particles. Predictive studies of the Severn barrage suggest that those intertidal areas to be permanently inundated i.e. the lower flats, are least rich organically. For at least the Severn, the upper foreshore substrate is richer organically than that of the lower foreshore. This is paralleled by the biomass of intertidal invertebrates the two areas support i.e. the upper foreshore holds the greater biomass density.

Whether the overall balance between erosion and accretion, together with their respective zonation, will significantly alter the extent of the remaining intertidal areas post-barrage is unclear for any estuary. If accretion in the Severn estuary becomes greater post-barrage, it is envisaged that more organically enriched fine sediments will accumulate in the upper foreshore, potentially enhancing this zone biologically.

The change that will take place post-barrage in intertidal sediment distribution is in part dictated by the prevailing wave and current climates. Predictions suggest that only close to an alignment would the wave climate decline significantly. Over much of the area upstream of a barrage the wave climate would be unchanged (Parkman 1988, Severn Tidal Power Group 1989). However the rate of retreat of the tide edge over the intertidal areas during the slower ebb tide will be reduced. In addition, upstream of a tidal power barrage alignment, wave action around the shoreline would be restricted to a narrower zone; because the tidal range is reduced post-barrage. Therefore the effect of wave action upon the sediment distribution of the intertidal area may increase. Furthermore any change in the shape of the intertidal zone would affect the wave run-up and hence its impact upon the sediments.

Intertidal invertebrate distribution within an estuary is known to be strongly influenced by the physical characteristics of the sediment and water column. Any change imposed upon either the sedimentology or hydrology of the estuary will consequently affect the distribution and abundance of the intertidal invertebrates. With the deposition of finer sediment particles post-barrage, the intertidal invertebrate community upstream of the alignment may diversify and increase in abundance unless salinity is markedly reduced. Higher levels of the intertidal zone will be submerged more regularly with the invertebrate community altering in response.

A reduction in the concentration of suspended sediment particles in the water column will increase the depth of an estuary's euphotic zone post-barrage. Together with greater sediment stability and reduced salinity amplitude, this will allow a general increase in the species diversity, standing crop and productivity of an estuary's plant community. More primary production provides more resources for a larger invertebrate community. The diversity and abundance of the intertidal invertebrates are not the only parameters liable to alter in a post-barrage invertebrate community. Substrate stability also influences the size distribution of certain intertidal invertebrates through disturbance-related mortality. A less dynamic estuary post-barrage may lessen such mortality, thus increasing longevity with a concomitant shift in size distribution towards larger individuals (Plymouth Marine Laboratory 1989).

The post-barrage algal and plant communities may, however, reduce the availability to birds of invertebrates in some of those intertidal areas remaining. With improved water clarity, there exists the potential for algal blooms to increase in occurrence, species diversity and vigour. Where the green macro-algae *Enteromorpha* spp. bloom in the summer months, the intertidal flats can be smothered by its mats, which reduces the availability of the underlying prey to many bird species (Nicholls et al. 1981). Open mudflat areas may also be lost to feeding birds post-barrage through the encroachment of salt-marsh. Where present, the cord grass *Spartina anglica* would be expected to extend down shore in a post-barrage environment, the extent dependent upon the erosive properties of the new wave regime.

The presence of the invertebrates themselves directly influences the surrounding sedimentary environment through bioturbation. This leaves sediments less well sorted, potentially a substrate stabilizing action as mud particles packed amongst those of a sandy substrate decreases the chances of erosion. Bioturbation also increases water ventilation through the sediment thus influencing the sediment/water exchange process and the oxygenation of the sediment. The exact magnitude and importance of bioturbation in a post-barrage environment is unknown, even for the best studied sites e.g. the Severn estuary.

The consequences upon birds of these changes in the sedimentation pattern post-barrage are several. Increased sediment stability may influence the distribution of at least some species whose foraging is known to be influenced by substrate firmness e.g. *Calidris* species (Gerritsen & Heerzik 1985). Any increase in invertebrate diversity, biomass and size classes as a consequence of the sediment modifications, will provide a greater food resource for birds. The composition and size of the bird populations that can be supported will obviously depend upon the availability and composition of the foods and the interaction between individual birds, points discussed previously in relation to an area's carrying capacity.

Clearly a tidal power barrage will modify to differing degrees the hydrology, sediments and invertebrate communities of the remaining intertidal areas. Precisely to what extent the above processes would alter this habitat is not known for any given site. Recent studies orientated particularly around the proposed Severn Barrage, have progressed our understanding of an estuary's physical and biological reaction to a tidal power barrage substantially. However, this knowledge has only allowed us to understand the mechanism, in many cases superficially, and possible direction by which physical and biological changes may take place post-barrage, for a given estuary. After the barrage has been built, an unknown period of time (possibly years) will elapse before the biological and physical components of a post-barrage era are fully re-adjusted to the conditions imposed.

3.2.10 ROOST SITES

When waterfowl are unable to feed because of inundation of their intertidal feeding grounds, i.e. at high water, birds congregate on land (waders) and/or water (wildfowl) in discrete groups numbering at times tens of thousands. Communal roosting may confer advantages to the individuals in terms of a more favourable microclimate energetically, a means of gaining foraging information from others and protection against predators (Ydenberg & Th. Prins 1984). These roosts are generally close to the feeding grounds, thus reducing the energy expenditure required in travel between the two. Foreshore habitats e.g. saltmarsh, shingle banks and beaches, are the most frequently used sites for wader roosts. However, within these habitats, the selection of a roost site on a given day is modified by factors such as the tidal height, vulnerability to predators, disturbance in general and degree of shelter they offer from the weather. When very high tides inundate much of the foreshore, adjacent fields are often used for roosting. If suitably undisturbed roosts are not available on very high tides, as at a few localities e.g. the Cheshire Dee, waders are forced to roost on the wing for as long as three hours (Hale 1980). This obviously entails a significant energy expenditure beyond that for ground roosting; its occurrence in a period of severe winter weather could put the birds at a serious disadvantage energetically.

Behind the tidal barrage, an increased erosive force acting upon the foreshore habitats is expected, due to the prolonged period of high water and insignificant reduction in the wave climate except in close proximity to the alignment (Severn Tidal Power Group 1989). This would dictate the extent of any *Spartina* marsh encroachment (Institute of Terrestrial Ecology 1989) down the shore profile, post-barrage, and thus the availability of one habitat frequently utilised by roosting waterfowl. Whether a post-barrage environment is conducive to expansion of other saltmarsh communities is unclear. However, a reduced tidal influence may not be sufficient to maintain a number of typical saltmarsh plants, with the subsequent loss of the more mature and diverse upper saltmarsh (Mitchell et al. 1981). As a consequence, such land is likely to prove attractive for agricultural usage. The availability of other foreshore habitats will likewise be subject to the erosive forces of the prolonged high water period modifying their profile. As the possibility exists of a reduction in habitats offering potential roost sites, consideration is needed of the potential impact upon the roosting bird community.

Any factor that alters the quality of a roost site will in turn influence the energy requirements of a bird roosting there. Birds at those sites with shorter flights from roost to foraging-site, a more advantageous microclimate and a lesser degree of disturbance will survive better in periods of stress such as cold weather or food shortage. Overall, the quality of a roost within an estuary may in fact modify the distribution and numbers of waterfowl in its catchment area beyond that determined by food availability (Furness 1973). Thus any impact from a tidal barrage upon the saltmarsh and other foreshore habitats which alters the quality and availability of potential roost sites may modify the carrying capacity of the estuary.

In common with foraging (chapter 3.2.5), social dominance within several bird species e.g. age and sex related, has been shown to spatially distribute individuals within and between roosts (Ydenberg & Th. Prins 1984, Swennen 1984). The more subordinate birds are forced to roost at the edge of roosts where exposure to the weather is greatest (and so too may predation). The best roost positions and sites are occupied by the most dominant individuals. Observations of the arrival of one species at a roost leading to displacement of another within the roost (pers obs.) would suggest dominance may well both be an inter- and intraspecific phenomenon. As between species, sub-species of a species will at times use different roost sites e.g. the passage versus wintering populations of Dunlin and Sanderling at Teesmouth, England (pers obs, Cooper 1987), for reasons not yet understood. These observations therefore suggest that any reduction in roost site quantity and quality can be considered likely to fall unevenly upon individual birds.

Finally, the locality of roosts may also vary with time, apparently independent of any other physical factor (pers obs.). The occupation of differing roost sites between night and day may well relate to a difference in potential predators and their visibility on approach to the birds at such times.

3.2.11 SALTMARSH, FORAGING WILDFOWL AND BREEDING WADERS

Many herbivorous wildfowl graze extensively upon the saltmarsh vegetation whilst for others the seeds of the plants are an important food resource. Post-barrage inundation of the upper saltmarsh and salting pastures will cease as the tidal range upstream of the alignment is reduced. As a consequence a smaller quantity of seed will be flushed from the saltmarsh vegetation on to the intertidal flats where seedeating wildfowl forage, by dabbling. Furthermore the floral composition of the higher saltmarsh and saltings is likely to alter as the reduced tidal influence may be insufficient to maintain the saltmarsh species and thus the vegetation's seed production. Though a reduced tidal range is to the detriment of seed eating wildfowl, the cessation of flooding and elimination of saltmarsh species would allow better control of grazing stock on the saltings, to the benefit of grazing wildfowl (Owen 1977).

The extent of saltmarsh, other than *Spartina* (Severn Tidal Power Group 1989), would seem likely to contract post-barrage; the extended period of high water will erode the seaward edge whilst a loss of upper saltmarsh would follow reduced tidal inundation. As a major habitat for many breeding waders, a loss in saltmarsh area could lead to a reduction in the number of breeding territories. This may be compensated to some degree by the actions of increased water level in the coastal fields of a post-barrage environment. With the low tide level upstream of the barrage raised to mean sea level, the sluices that currently allow water runoff from the coastal fields at low tide will be unable to function post-barrage. Controlled flooding and drainage of such land could be used to recreate coastal wet meadows that will benefit breeding as well as wintering waterfowl.

3.2.12 DIVING BIRDS

The majority of estuarine impact assessments have concentrated with good reason upon the commonest estuarine bird community, that of the intertidal mudflats. However many macrotidal estuaries support significant wildfowl populations that forage within the subtidal and inundated intertidal areas of an estuary. Such birds dive in order to forage for fish, invertebrates and plant material, utilizing sight for location of food. Therefore improved water clarity post-barrage (chapter 3.2.9) may well be expected to increase the success with which such species forage and therefore the population the estuary may support. Furthermore any increase in the biological productivity and diversity of the estuary (chapter 3.2.9) may lead to an increase in the food resource of diving birds. With reduced water velocity post-barrage, the energetic cost involved in obtaining this food through counteracting any water currents will be lessened.

The possibility exists that diving birds will be sucked through a barrage turbine, an event that is likely to result in death. Injury could result through either haemorrhaging or the shearing forces of the water tearing the bird apart as it does with fish (Davies 1984). The currents surrounding an active turbine are liable to be too great to attract subtidally foraging birds. Those birds that do venture within the immediate environment of the turbines will be lucky to escape the suction forces of the turbine. Such a highly dynamic environment is unlikely to support a significant food resource for diving waterfowl.

Overall a deleterious impact upon diving waterfowl from a tidal power barrage is considered unlikely. Any positive impact would largely depend upon the biological productivity of the post-barrage environment and its availability to foraging diving birds.

3.2.13 THE IMPACT OF BARRAGE CONSTRUCTION WORK

The immediate impact of any construction work is its intrusion through sight and sound upon the local environment. Most studies that have attempted to quantify disturbance have examined recreational activities e.g. Ward 1990. Audio- and in particular visual disturbance is unlikely to exist beyond 1000 metres and probably less than 500 metres from the construction site. With time, birds will largely habituate to disturbance emanating from an adjacent area when they recognise the activities as not predatory in nature. On the beaches of Teesmouth vehicles can often be driven repeatedly within 5 metres of flocks of waders, terns and gulls, which only take action to move to the side of the oncoming vehicle when "death" is imminent. From experience, birds have no reason to see vehicles as active predators, thus many birds include road side verges within their feeding territory.

In those areas whose usage by birds is impeded by disturbance, the consequences upon the birds are identical to its removal (see above). The displaced individuals will add to the density of birds utilizing those areas "remaining". Increased competition for food resources or roost sites may lead to a detrimental influence falling, unevenly, upon the estuary's bird population. Due to the restricted area involved, any ornithological impact of disturbance would be less damaging overall than the consequences of operating the barrage. Restricting the most damaging phases of construction work to periods of the year when the site is of lesser ornithological importance will reduce its immediate impact.

Current construction technology suggests the use of caissons together with embankments as the basic components of a tidal power barrage (Dept. of Energy et al. 1989). The sequence of caisson installation and embankment construction allows control to be exercised over any adverse environmental impact such work may cause. It is envisaged that during construction of the Severn barrage the total discharge of each tidal cycle will not be significantly reduced (Severn Tidal Power Group 1989). The allowance of free water flow through turbines and sluices situated in the water will minimise the flow obstruction. However with a constrained water passage, velocities must increase in some locations along the alignment. Erosion of sediments in these areas would result and consequently increased particle suspension in the vicinity of such sites (Severn Tidal Power Group 1989). Dredging for caisson foundations, shipping access etc. would also disturb the sediments within the construction area. With time, deposition of the eroded material would occur in sheltered waters, including perhaps the site of origin, once the current velocity subsides. The velocity and direction of water currents for the Severn barrage is expected to be altered little beyond 2-3km from the alignment (Severn Tidal Power Group 1989).

Any mobilisation of sediments and compositional changes in the sediments of the intertidal flats will alter the latter's invertebrate communities (chapter 3.2.9). However, the optimum invertebrate communities associated with a given substrate may not be reached before conditions change again as the barrage is brought into operation. The birds will respond to such changes largely according to the availability of their intertidal food supply (chapter 3.2.9). Rapid alteration in a bird's feeding environment, as may occur within 3 km of the barrage, would be too fast initially for a bird to adapt sufficiently to allow it to respond in any way other than a detrimental one. This is in part a reflection of the rate at which invertebrates are themselves able to adapt to new conditions within their immediate environment.

Severn Barrage feasibility studies suggest that the sluices and turbines of the barrage can be used to minimise the impact environmentally of the transition between an uncontrolled estuary and that utilised for power generation (Severn Tidal Power Group 1989). However, the optimum transitional programme in terms of rate of transition, time of year and sluice/turbine use has yet to be studied in detailed for the impact to be assessed. Two observations illustrate just how vulnerable birds may be to the control of the tidal regime behind the completed alignment prior to the barrages commissioning. In 1984 a storm surge barrier in the Oosterschelde, the Netherlands, was closed for three tidal cycles. During this period only the upper parts of the intertidal area were exposed and furthermore for the entire duration of the closure. Despite a much reduced intake rate, Oystercatchers continued to show a tidal pattern in foraging (Meire 1989). Observations suggested the Oystercatchers were already foraging at their maximum rate prior to the barriers closure. Theoretically therefore a longer period of closure may well have led to birds eventually exhausting their energy reserves with death following. This was the observed outcome for a significant proportion of the Oystercatchers roosting on Texel, The Netherlands, when in

1976 their feeding grounds were covered by ice for several days, thus unavailable (Swennen & Duiven 1983). During this period the Oystercatchers remained at their high tide roosts throughout the day. However, the cold spell itself was not the primary cause of the Oystercatcher fatality, only a contributing factor. The two months prior to the cold spell strong westerly winds prevented the feeding grounds from being exposed or allowed only the exposure of a small area for a very short time during 30 tides (out of 52). Thus during that period the birds had a restricted opportunity to forage on the tidal flats and drew upon their energy reserves many times prior to the cold spell.

3.3 TIDAL POWER ENVIRONMENTAL IMPACT ASSESSMENTS; AN EVALUATION OF PAST AND PRESENT ORNITHOLOGICAL STUDIES IN BRITAIN

For 50 years the Severn estuary (figure 1.11) has been a major focus of attention in Britian as a site suitable for tidal power generation. A succession of E.I.A.'s have been commissioned that clearly illustrate the development of such studies, from crude attempts at describing the present ornithological interest to predictive modelling of the post-barrage situation. It is probably correct to say that no other man-made developments in an estuarine environment have taken the concept of an EIA so far, though we are still well short of satisfactorily answering the questions it poses. This becomes evident as the different stages of tidal power E.I.A.'s, commissioned on the Severn and elsewhere, are considered.

3.3.1. THE ORNITHOLOGICAL IMPORTANCE OF A SITE

Before any evaluation of the impact of a development can be attempted, the present status of a site requires describing. The Birds of Estuaries Enquiry database (chapter 2) has been a major source of information used for tidal power EIA's to assess an estuary's numerical importance in both the national and international context e.g. Andrews (1975), Binnie & Partners (1989b), Parkman (1988), T.H.Technology Ltd. (1990). BoEE count data provide a snap-shot of the birds using an estuary on a given day, identifying key wintering and passage sites. However, it provides no method of calculating population turnover at the site to allow an estimation of the total number of birds dependant upon the site in a season. For example, the Teesmouth BoEE counts of Shelduck in winter 1978/79 peaked at 2100 birds (Marchant 1981) whereas in fact over 4200 individuals used the site that winter (Evans 1984) as established by colour-marking of samples of trapped birds. The addition of often random counts from Bird Reports and other sources only improves the portrayal of daily maxima e.g. Ward (1989). What may not be apparent from daily maxima counts is when the cumulative number of birds using a site represents a significant proportion of the species population in conservation terms. Furthermore the importance of a site is not necessarily in proportion to the time an individual spends at that location. Whilst on spring passage (April-June) many waders stop over en route at an estuary for only a few days to accumulate additional food reserves. Whether the individual is able to supplement its food reserves sufficiently may strongly influence the individuals chances of reaching the breeding grounds and its success once there.

No EIA yet published has attempted to quantify the turnover of an estuary's bird population, a task for which a completely satisfactory method has yet to be devised (Evans 1984). As migrants generally arrive and depart from an estuary in waves, summation of the fluctuations in a species' daily numbers provide a broad indication of the size of the passage population. However a more satisfactory measurement of the turnover can be ascertained through monitoring the change in proportion of marked to unmarked birds with time (Evans 1984). The success of this approach is obviously dependant upon the capture and marking of a substantial proportion of the birds present early in the migration period.

The vast majority of birds that use an estuary are not residents but visitors for part of the year. Identifying the origins and destinations of migrants has only recently been addressed in a tidal power EIA. An analysis of the national ringing scheme database and the literature has allowed the recognition of those sub-species of each species that utilise the Mersey and Severn estuaries, and which may be under threat if a tidal power barrage was to be built (Clark 1989, Clark et al. 1991a). Without such an analysis, separation between many sub-species from either the different times at which each respectively uses a site or plumage characteristics visible during field observations is impossible. Identification of sub-species defines further the importance of an estuary to a species, one of many steps that would increase the confidence with which a post-barrage predictive model may be used.

Whole estuary counts, such as those collated by the BoEE, can only present an estuary's importance to a proportion of a species. The impact of a tidal power barrage upon a bird population is unlikely to result from the estuary's removal as a whole. The various parts of an estuary therefore need to be evaluated as to their respective ornithological importance. Initially, Ferns (1977) described the low tide distribution of wintering waders and Shelduck on the Severn in broad terms using the BoEE data and local knowledge, in particular of the BoEE counters. Later, Ferns (1980) combined data from Mudge (1979) with that of his own original observations of low tide wader distribution on seven sites comprising 75% of the intertidal area. However the categorization of each site in terms of physical and biological characteristics was very broad. In the most recent studies of the Severn (Clark

1989, 1990) and Mersey (Clark et al. 1991a, 1991b), this approach was refined so that the entire estuary was counted at monthly intervals over 2 winter seasons, the intertidal areas being subdivided into 169 and 99 count areas respectively.

Low tide counts over-estimate the importance of the lower tidal flats for some species within a tidal cycle (Clark 1990). Foraging at mid tide or higher levels of intertidal flats may in fact be of greater importance to the survival of, e.g. Grey Plovers. However, the incorporation in an EIA study of hourly distributional counts through the tidal cycle (e.g. Ward 1989) will not necessarily reflect the overall importance of an area to a foraging bird. The proportion of the total food intake an area provides in a tidal cycle is of prime importance to a bird, a variable not necessarily described adequately by time spent foraging in that area.

All distributional studies of foraging waterfowl in relation to tidal power barrages have concentrated upon the winter season (October-March). The usage of an estuary in spring and autumn also requires addressing. At these seasons, not only a greater proportion of a species' population may be reliant upon an estuary, but their preferred feeding areas within it may differ substantially from those of the species' winter population (pers. obs.).

Both the temporal and spatial distribution of many foraging waterfowl species differ between night and day (Evans & Dugan 1984, Owen et al. 1986, Pienkowski 1981). Only on the Mersey estuary have night time distributional studies of foraging birds been undertaken in relation to a tidal barrage (Clark et al. 1991b). Using an image intensifier, counts were made in two localities for a limited time period (one hour before to two hours after low tide). Although this corresponded to the time at which the majority of birds fed diurnally, comparatively few birds were found foraging nocturnally at such tidal times. Thus daylight observations cannot necessarily be extrapolated to predict activity within the hours of darkness; separate observations are required. This comment applies equally to roost site utilization in the hours of darkness. Nevertheless, there are an increasing number of studies of nocturnal behaviour of shorebirds in estuaries not yet proposed for tidal barrages.

In order to model the foraging rate and success of a bird in the present and post-barrage situation, it is necessary to understand the factors that determine the food intake rate and how this influences the distribution of foraging birds. A general overview of the subject was presented in chapter 3.1. Initially on the Severn Ferns et al. (1984) related wader distribution to their respective positions from the tide edge. Since then, studies have considerably furthered our understanding of why birds are distributed as they are across the

Severn estuary. In general, the relationships identified between the physical and biological characteristics of the intertidal flats and the density of birds they support apply equally to estuaries other than the Severn. However, Evans & Dugan (1984) compared the relationship at two estuarine sites (Firth of Forth and the Suffolk/Essex estuaries complex) between the densities of Curlew *Numenius arquata* and of its prey *Nereis diversicolor*. At a given prey density, a difference was observed between Curlew densities in the two areas of a magnitude far exceeding that predicted from differences in the environmental variables known to influence prey availability. Thus before quantitative extrapolation can be made of bird densities from one estuary to another, a much fuller understanding is required of the relationship within and between the biological and physical components of an estuary.

The distribution of roost sites in relation to feeding grounds influences the daily net energy expenditure of an individual and thus its survival (chapter 3.2.10). Little consideration has been given by tidal power EIA's to this point. However, unless this component of the energy budget is evaluated for the existing situation, the impact from a tidal power barrage will be less easily predicted. The utilisation of a roost site by birds on a given date is related to the high water height, weather conditions and susceptibility to predation. With fixed values for the former two parameters, the resultant roost site distribution has been observed to differ with the time of day and not only apparently as a description of the hours of light or darkness (author pers obs.). Furthermore the sub-population of species involved may also influence the choice of roosts occupied (chapter 3.2.10).

Future tidal power EIA's for an estuary should assess the existing importance of the estuary to waterfowl through:

i. distributional counts of foraging waterfowl throughout the tidal cycle for the entire estuary, both by night and in the daytime,
ii. measurement of the foraging time in a given area and the observed food intake rate for each species,
iii. evaluation of the size, distribution and utilization of roost sites.
iv. determination of the quantitative relationship between the physical and biological components of the intertidal flats and the bird community they support.

3.3.2 THE POST-BARRAGE ENVIRONMENT AND THE BIRD COMMUNITY IT IS ABLE TO SUPPORT

Ferns et al. (1984) were the first to make quantitative predictions as to the loss of shorebirds that may result from a tidal power barrage on the Severn. However, they made the assumption that the physical and biological characteristics of the remaining intertidal flats would remain unaltered post-barrage; this is known to be unlikely (chapter 3.2.9).

The only serious predictive work subsequently has been by NERC & Ravensrodd Consultants Ltd. (1989), the objective of which was the development of a mathematical model for predicting the densities of shorebirds after a tidal energy barrage is built. The relationships between physical environmental variables, macrobenthic invertebrate densities and shorebird densities were established by measurements at forty sites in the Severn estuary and five other S.W.British estuaries. The sites were selected to span the range of post-barrage environments expected in the Severn estuary. A critical inference from the analysis was that any post-barrage reduction in feeding time would be unlikely to affect bird density significantly. Therefore it was concluded that bird densities could be predicted from post-barrage densities of their invertebrate prey. The models predicted that with the exception of Dunlin, a doubling of invertebrate density would be required in the existing feeding areas in order to maintain present bird numbers on the Severn. In principle this could be achieved (NERC & Ravensrodd Consultants Ltd. 1989). The Dunlin numbers would according to the model only be sustained with a 5-6 fold increase in invertebrate densities.

Is it true that a reduction in foraging time does not affect bird density significantly (ITE 1989)? Poole Harbour is one of the two estuaries upon which their conclusion was based. There, the intertidal exposure time is shortest but the densities of foraging birds were comparable with those in other estuaries in S.W.Britain. At times, substantial numbers of waders in Poole Harbour are known to seek additional feeding time on damp grassland at high water (Ward 1989, Goss-Custard & Durell 1983, Collins 1986). This factor was disregarded in the predictive analysis. Poole Harbour may well support wader populations at similiar densities to populations at sites with longer intertidal exposure only because high tide foraging in fields is possible and profitable for individuals unable to meet daily requirements from the estuary alone. Thus the Institute of Terrestrial Ecology's analysis may not have detected the impact from reduced intertidal feeding time. Future modelling of estuarine shorebird communities should clearly evaluate the importance of any potential high water feeding to a species population (see also Davidson & Evans 1987).

The Institute of Terrestrial Ecology's study did succeed in determining that the modelling of densities of shorebirds post-barrage is feasible. However, quantitative predictions of post-barrage invertebrate densities on the Severn could not be made with present knowledge, yet these are an important component of any model predicting the bird density. Much work is still needed in understanding the relationships between the physical variables, macrobenthic invertebrates and shorebirds before a quantitative predictive model can be used with any confidence (NERC & Ravensrodd Consultants Ltd. 1989). The realism of the model will obviously be greatly improved when it is expanded beyond reliance on the daylight foraging of the wintering populations, to include noctural foraging, subpopulations present at other times, etc..

Clark's (1989) methodology in assessing the potential ornithological impact of a tidal barrage on the Severn, and later the Mersey (Clark et al 1991a), proved to be controversial amongst ornithologists. BoEE data was used to evaluate the capacity of adjacent estuaries to absorb any waders displaced from either the Severn or Mersey estuaries. This involved the calculation of a correlation index between peak winter counts for a given estuary and a National index derived from the peak winter counts of all estuaries counted in Britain (Clark 1989). However, peak winter counts may give a false impression of the size of the wintering population an estuary may support through the entire winter period. If the peak winter count results from a temporary large influx of a species, it will, perhaps incorrectly, be assumed in Clark's (1989) methodology to be the size of population that the estuary can sustain throughout the winter. Furthermore, these occasional influxes may be of a species that utilises the estuary only as an overspill at the end of a flyway or as a temporary refuge in hard weather (chapter 3.2.6).

Tubbs (1991) identified in Moser's (1988) use of a similiar methodology applied only to Grey Plover, that a BoEE count of certain estuaries at high water may include birds feeding on adjacent estuaries. For such sites, an error is brought into the analysis, since the low water bird density is the most likely determinant of an estuary's carrying capacity.

Even from our current limited understanding of the complexities of the intertidal bird communities, the methodology used by Clark (1989) treats the carrying capacity concept too simply. Any use of a methodology involving the carrying capacity concept requires caution as it is unlikely to be a stable parameter through time, varying within and between years. The carrying capacity differs, for example, in relation to prey abundance, the population size and time period for which a predatory species utilises a site, and the feeding strategies adopted by individuals e.g. territorial or not. As discussed in a previous chapter (chapter 3.2.5), an estuary's waterfowl population is not a uniform body but composed of sub-populations differing in social hierarchy and morphology. The response of various sub-populations of a species to a tidal barrage will differ, with any displaced birds interacting with adjacent estuaries' sub-populations to differing degrees. However, for an individual species, Clark's (1989) model assumes that the population of each estuary is identical in its ability to forage amongst the different intertidal habitats that the species occupies throughout its whole estuarine range. Clark (1983) himself has suggested that within certain species, sub-populations exist that are morphologically adapted to optimize foraging in specific intertidal habitats. Therefore the extent of the resources in an adjacent estuary available to displaced birds may in fact differ for each species sub-population.

The subjects of roosting, moulting and breeding of birds in a post-barrage environment have not been seriously considered in EIA studies. This is because these activities are largely dependant upon the adequacy of an estuary to sustain a bird population through adequate food resources. Thus EIA studies have concentrated upon feeding ecology. The sites at which species roost and breed on the estuary are influenced by the extent and quality of shoreline habitat e.g. saltmarsh, shingle, sand-dunes, coastal wetlands. Studies beyond those summarized by STPG (1989) are necessary to predict the effect of the altered tidal regime in a post-barrage environment upon the coastal vegetation of any estuary. Until the structure and distribution of the coastal vegetation is predictable with confidence, evaluating the impact of barrage construction upon breeding and roosting birds can be no more than superficial. Before this, however, studies can progress that evaluate the existing importance of the estuary in situ to breeding and roosting birds (chapter 3.3.1) whilst also identifying the criteria that describe those sites preferred most by each species within the estuary under consideration.

3.4. A DESK STUDY OF THE ORNITHOLOGICAL IMPLICATIONS OF TIDAL POWER GENERATION AT A WESTERN EUROPEAN ESTUARY: AN EXAMPLE OF OUR CURRENT KNOWLEDGE AND ITS LIMITATIONS.

So far a general appraisal has been given of the ornithological impact of tidal power generation (chapter 3.2) and an assessment made of the tidal power EIA studies undertaken to date (chapter 3.3). This information will now be drawn upon together with the biological information identified in chapter 2, to consider what can be said at present of the ornithological impact of a tidal power barrage upon a given estuary. From those estuaries with tidal power potential (chapter 1) and for which no previous tidal power EIA exists, the Burry Inlet is selected for treatment. The limits of such an assessment and recommendations for furthering an EIA will be discussed.

3.4.1. The Study Site

Situated on the South Wales coast of the Bristol channel (Figure 1.11), the Burry Inlet is an estuary of contrasting shorelines; the northern shore dominanted by the conurbations of Burry Port and Llanelli, and the southern shore largely rural (Figure 3.1). The only natural habitats remaining on the heavily industralized north shore are the dune system of Pembrey Burrows at the western end and the saltmarsh at Tir Morfa. Part of a dune complex, Whiteford Burrows, dominates the southern shore at the estuary entrance. This shoreline otherwise is an extensive area of grazed saltmarsh behind which lies agricultural land. 6552.5 ha of intertidal sand and mud flats extend across the 9524 ha estuary (Davidson et al. 1991). The area supports an important cockle fishery. Mussel beds or scars are another dominant feature of the intertidal areas. The most notable scars are located off Tir Morfa and the north-west edge of Whiteford Burrow. The estuary includes the tidal reaches of its main tribuary, the Loughor, which is comparatively narrow and fringed by areas of saltmarsh. The Burry Inlet's 2188 ha of saltmarsh is both the largest in Wales and of national importance (Burd 1989, Ratcliffe 1977). The physical and biological characteristics of the estuary together with man's influence on the system, is discussed in a Symposium volume edited by Nelson-Smith & Bridges (1977) to which the reader is referred for further background information.

The Burry Inlet is currently protected by means of three SSSI's, a National Nature Reserve and the recent establishment at Tir Morfa of a Wildfowl and Wetlands Trust Centre (Figure 3.1). The Burry Inlet has also been proposed officially as a Ramsar site and Special Protection Area under the European Community Directive.

3.4.2. Data and Methods

Our knowledge of the estuarine bird community of the Burry Inlet (Appendix II) is neither as extensive as that of a few European estuaries e.g. the Severn estuary, nor as limited as that of Aber Benoit, France about which we know very little. The abundance and distribution of waterfowl on the Burry Inlet was the subject of a recent report (Prys-Jones et al. 1989) providing a baseline of information upon which more detailed studies could be built upon when necessary. The observations made of waterfowl distribution at low tide were from only one winter period; November 1987- March 1988 (see chapter 3.3.1). An earlier assessment of the site's ornithological interests was included within a Symposium in 1976 (Prater 1977). Both documents together with the Birds of Estuaries Enquiry and National Wildfowl Counts (chapter 2), are the main sources of information found for consultation for the EIA which follows. Additional site information relating to the birds'

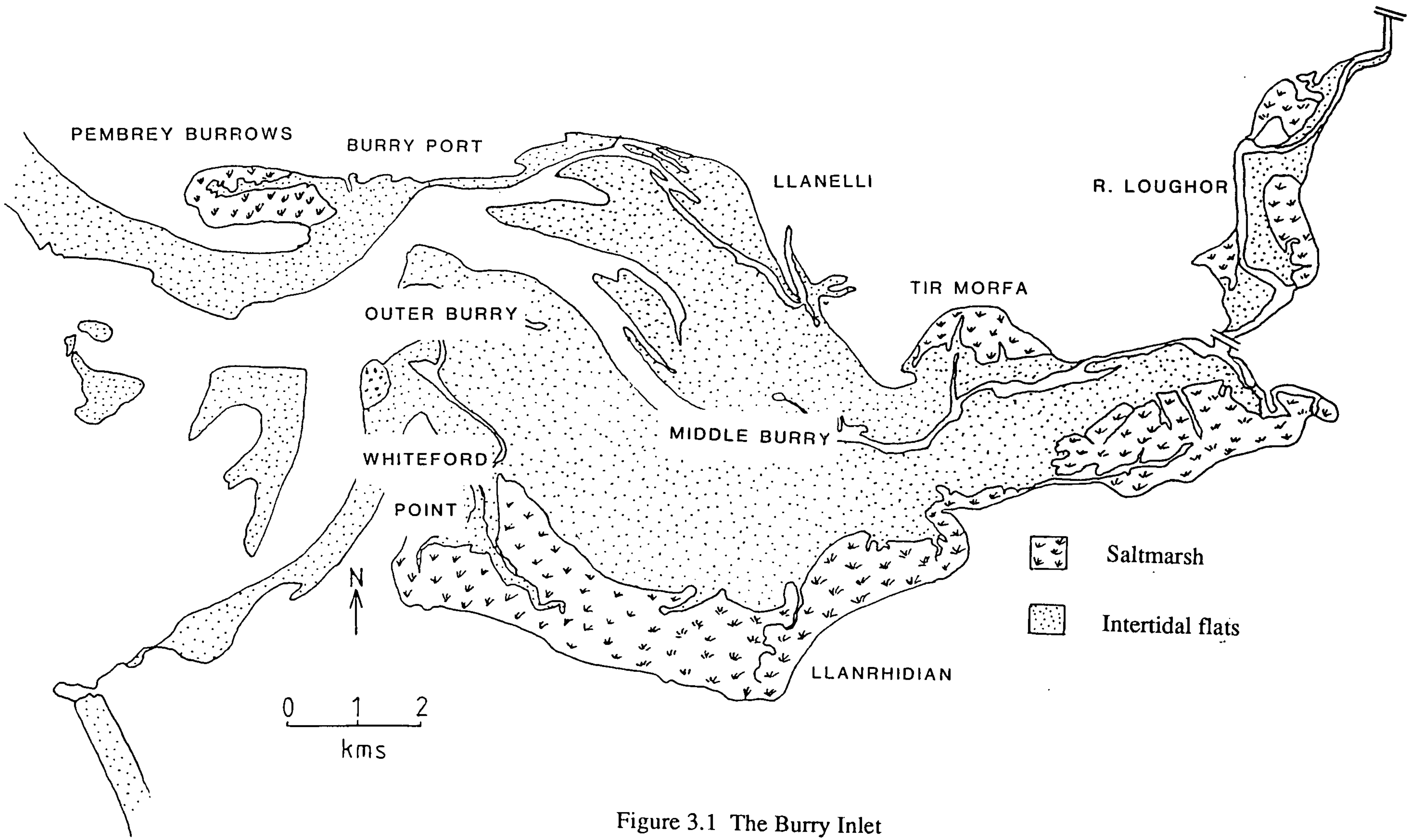


Figure 3.1 The Burry Inlet

present environment was provided by papers in the Symposium volume edited by Nelson-Smith & Bridges (1977) together with other texts referenced in the respective Site Inventory entry (Appendix II).

Utilizing the above information the approach taken in the EIA consisted of three steps:
i assessment of the usage and importance of the Burry Inlet to waterfowl: Prys-Jones et al. (1989) provides an overview of the seasonal and annual trends of waterfowl numbers on the Burry Inlet, as shown by BoEE/NWC data, whilst waterfowl site usage in winter at both low and high water periods was documented by Prater (1977) and Prys-Jones et al. (1989). No attempt has been made to replicate any of these data other than to summarize their findings. Data from the five most recent years of BoEE/NWC counts (1985/86-89/90) have been used to provide estimates of the current waterfowl population levels on the Burry Inlet during winter (November-March) and passage (April-June, July-October). With these data the importance of the Burry Inlet to waterfowl species at both a national and international level was assessed using the generally accepted 1% criterion (Kirby et al. 1990).
ii The prediction from current knowledge of the likely distribution and abundance of waterfowl post-barrage. Models of the post-barrage situation for ebb-generation tidal power sites in general suggest that low water level of the impounded water will be equivalent to present day mid tide levels (Dept. of Energy et al. 1989). Admiralty navigation chart No.1167 was used in this study to determine the reduction, post-barrage, in the present intertidal area of the Burry Inlet with the assumption that no accretion or erosion will alter the present sediment distribution post-barrage; (the validity of this is given consideration). Given the known distribution of waterfowl at present as identified in the previous step, the situation post-barrage is assessed and consideration given to what further predictions can realistically be proposed regarding the impact upon waterfowl of a Burry Inlet barrage during and after construction.
iii The identification of information lacking but required with which to make a full EIA of a tidal barrage on the Burry Inlet.

As mentioned previously, the EIA was limited to what could be ascertained from a desk study based upon the ornithological literature and data on the Burry Inlet known to the author. No attempt was made to consult scientists in the fields of hydrology, sedimentation and engineering in specific regard to an EIA. Such additional information was not deemed necessary to illustrate the inadequacies that may exist in our ornithological knowledge of a given European estuary (identified as a potential tidal power generation site) to enable the construction of a detailed and realistic EIA.

3.4.2. The present usage by and importance to waterfowl of the Burry Inlet

A measure of the importance to waterfowl of the Burry Inlet in winter and periods of passage is provided by BoEE/NWC data (tables 3.1, 3.2 & 3.3). Only since 1987/8 has BoEE/NWC coverage of the Burry Inlet been complete, prior to which only the southern shore was counted. The Burry Inlet supports wintering populations that qualify for national and international importance for 7 and 2 species respectively. On considering the average peak spring and autumn counts of waders, the Burry Inlet becomes of international and national importance to one further species, the Whimbrel *Numenius phaeopus* (Table 3.1). As the site regularly supports over 20000 wintering waterfowl (average peak winter total for all species = 30939; 1985/86-1989/90) the Burry Inlet qualifies as a Ramsar site (Kirby et al. 1990) for which it has been officially proposed. Prys-Jones et al. (1989) summarised the annual trend in the peak winter counts on the Burry Inlet and concluded that the Burry Inlet had retained or even increased its importance for wintering waterfowl between 1968-88.

The distribution and importance of breeding estuarine birds, either past or present, other than seabirds (Lloyd et al. 1991) and Ringed Plover (Prater 1989), is not documented. The New Breeding Bird Atlas (BTO pers. comm.) and its predecessor (Sharrock 1976) is unlikely to yield more information than the presence and possible abundance of a species within the two $10km^2$ squares encompassing the estuary.

The winter distribution of the individual waterfowl species at high water was documented by Prys-Jones et al. (1989) from an analysis of BoEE data and fieldwork during the winter of 1987/88. A summary of the major wader and wildfowl roosts, identified by Prys-Jones et al. (1989) with additional information from Prater (1977, 1981), together their respective usage on neap and spring tides, is illustrated in figure 3.2. These studies identify the saltmarsh along the entire southern shore as being of major signifiance for roosting birds, with the largest consistent roosts between Whiteford point and Llanrhidian. The only major waterfowl roost on the north shore at Tir Morfa may well become increasingly important with the establishment there of the Wildfowl & Wetlands Trust Centre. The usage of each roost site is dependant upon the tide height at high water. A proportion of the Burry Inlet's waterfowl utilise roosts at the adjacent estuaries of the Gwendraeth, Tywi and Tef (Prater 1977), a point not mentioned by Prys-Jones et al. (1989)

From a single winter season's fieldwork (1987/88) Prys-Jones provides the only detailed account of wildfowl and wader species feeding distribution. Localities identified as particularly noteworthy for their large assemblages of feeding waterfowl through low tide

Table 3.1 Average peak winter (November-March) counts of waders on the Burry Inlet, 1985/86 - 1989/90, in relation to qualifying levels for National and International importance

	Average peak winter count, 1985/86 - 89/90	Qualifying level for National Importance+	Qualifying level for International Importance++
Oystercatcher	18001**	2800	9000
Lapwing	1804	2200	3500
Ringed Plover	165	230	500
Grey Plover	739*	210	1500
Golden Plover	1787	2000	10000
Turnstone	528*	450	700
Common Snipe	58	?	10000
Jack Snipe	1	?	?
Curlew	1530*	910	3500
Black-tailed Godwit	17	50	700
Bar-tailed Godwit	400	610	1000
Green Sandpiper	4	?	?
Common Sandpiper	2	?	?
Redshank	914*	750	1500
Spotted Redshank	2	(2)	500
Greenshank	2	(4)	500
Knot	5037**	2200	3500
Dunlin	6163*	4300	14000
Sanderling	86	140	1000
Total wader population:		10000	

NB + : 1% of British wintering population, with 50 birds as a minimum qualifying level (from Kirby et al 1990)
++: 1% of west European population for waders (from Kirby et al 1990)
* : population of species exceeds qualifying level for National Importance
** : population of species exceeds qualifying level for International Importance

Table 3.2 Average peak spring and autumn counts of waders on the Burry Inlet, 1985/86 - 1989/90, in relation to qualifying levels for National and International importance

	Average peak spring count, 1985/86 - 89/90	Average peak autumn count, 1985/86 - 89/90	Qualifying level for National Importance+	Qualifying level for International Importance++
Oystercatcher	3789*	13778**	2800	9000
Lapwing	50	553	2200	3500
Ringed Plover	47	159	300	500
Grey Plover	68	339*	210	1500
Golden Plover	52	366	2000	10000
Turnstone	189	713**	450	700
Common Snipe	4	20	?	10000
Jack Snipe	0	0	?	?
Curlew	468	2930*	910	3500
Whimbrel	144*	104*	50	700
Black-tailed Godwit	17	37	50	700
Bar-tailed Godwit	59	232	610	1000
Green Sandpiper	1	8	?	?
Common Sandpiper	2	13	?	?
Redshank	151	1189	1200	1500
Spotted Redshank	1	9	(2)	500
Greenshank	5	34	(4)	500
Knot	31	408	2200	3500
Dunlin	1105	1209	2000	14000
Sanderling	20	72	300	1000
Total wader population:		10000		

NB + : 1% of British wintering population, with 50 birds as a minimum qualifying level (from Kirby et al 1990)
++: 1% of west European population for waders (from Kirby et al 1990)
* : population of species exceeds qualifying level for National Importance
** : population of species exceeds qualifying level for International Importance

Table 3.3 Average peak annual counts of wildfowl on the Burry Inlet, 1985/86 - 1989/90, in relation to qualifying levels for National and International importance.

	Average peak annual count, 1985/86 - 89/90	Qualifying level for National Importance+	Qualifying level for International Importance++
Brent Goose (dark-bellied)	773	900	1700
Shelduck	1505 *	750	2500
Wigeon	6399 *	2500	7500
Teal	1082 *	1000	4000
Mallard	401	5000	50000
Pintail	1878 **	250	700
Shovelor	235 *	90	400
Eider	147	700	20000
Red-Breasted Merganser	19	100	1000
Total wildfowl:	12465		

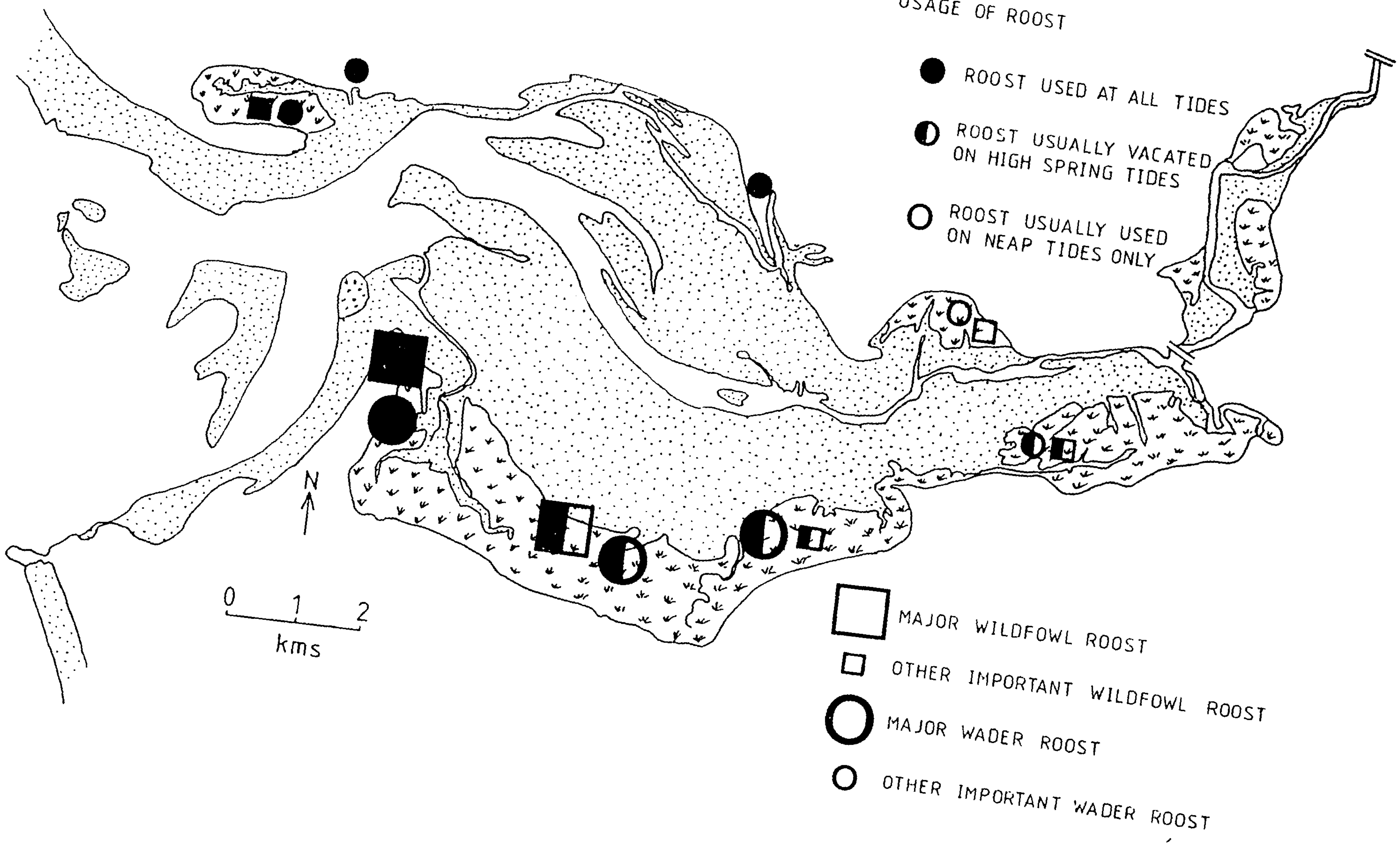
NB + : 1% of British population, with 50 birds as a minimum qualifying level (from Kirby et al 1990)

++ : 1% of north-west European population for wildfowl

* : population of species exceeds qualifying level for National Importance

** : population of species exceeds qualifying level for International Importance

Figure 3.2 The principal roosts used by waders and wildfowl in the Burry Inlet



were the mussel scars off Tir Morfa and to the north west edge of Whiteford Burrows. Otherwise the intertidal mud and sand flats as a whole provide an extensive low water feeding area with major concentrations of waders across the Middle Burry, Outer Burry (south) and mudflats adjacent to Tir Morfa. Wildfowl are largely concentrated across the intertidal areas of the south side of the estuary.

From studies of other estuaries (NERC & Ravensrodd Consultants Ltd. 1989) the distribution of waders is apparently correlated only indirectly with that of the sediments, through the invertebrate communities the latter supports. The relationship between sediment distribution and bird distribution has not been described for the Burry Inlet. However, Banister & Poopetch (1977) have described part of such a relationship by correlating sediments and invertebrate distributions for certain areas of the estuary.

In common with other E.I.A. related work (Clark 1989, Clark et al. 1990, Ward 1989), the possibility exists of identifying the origins and migration of waterfowl that use the Burry Inlet from an analysis of the ringing data base (held by the B.T.O.) and the literature. Such an analysis may establish not only whether the Burry Inlet population of a species originates from a discrete area of the breeding range but in addition the existence of a distinct sub-population of individuals e.g. males, juveniles. The importance of this in relation to interpreting the impact of a tidal power barrage was considered in chapter 3.2.5..

3.3.4 Prediction of waterfowl distribution and abundance post-barrage

The principal effects landward of a tidal barrage on the Burry Inlet will be a rise in the mean sea level ,low water occurring at the present mid tide height (4.8m), and the slowing of water currents with the reduction in the tidal range of the estuary. Hence the dynamic nature of the estuary's physical environment would be lessened. No studies have yet shown that the estuary's topography will alter post-barrage. It can therefore be considered that after barrage construction, the Burry Inlet would retain an intertidal topography similiar to that currently lying above mid tide level (Figure 3.3). 41% of the intertidal area lies below mid tide level for 80% of the estuary's total area (that west of 4^{o} 09'W, the extent of Admiralty Chart bathymetric data). Superimposing the above intertidal profile upon the low tide bird distribution of Prys-Jones et al. (1989) would suggest, for example, the removal of the feeding grounds for over 1% of the East Atlantic flyway Oystercatcher population (1%=900 birds; Smit & Piersma 1989). However, two assumptions which are unlikely to be true (chapter 3.2) are included in the above model:

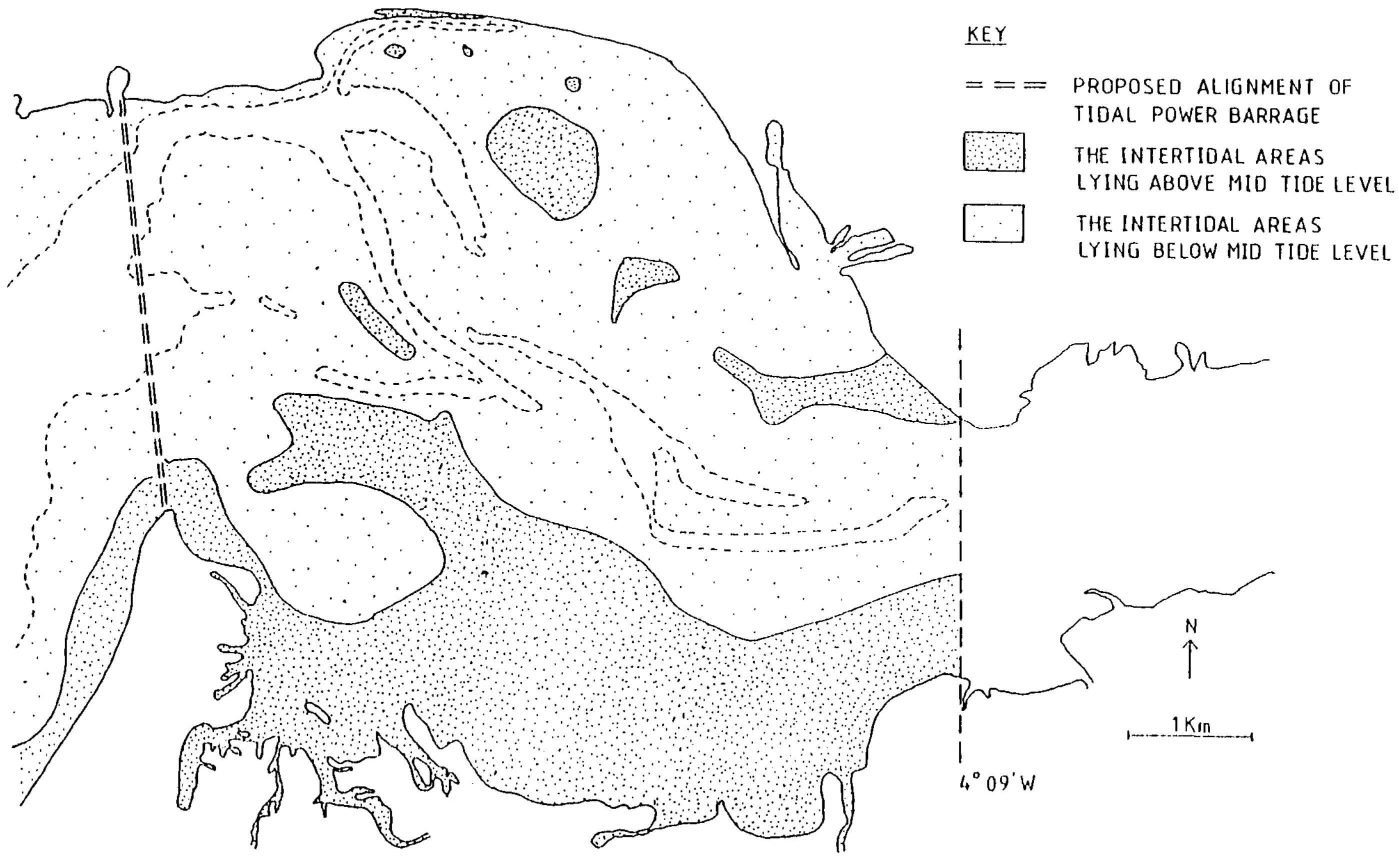


Figure 3.3 The distribution of intertidal areas with and without a tidal power barrage across the Burry Inlet

a) that the importance to feeding birds of the intertidal areas below mid tide as assesssed by Prys-Jones et al. (1989) remain unaltered during their respective periods of exposure,
b) that the invertebrate and plant communities present in the intertidal areas above mid tide level remain unaltered post-barrage.

Though the post-barrage intertidal topography may not significantly differ from the mid tide profile, the sediment characteristics are liable to alter. The plant and invertebrate communities will in turn respond to these environmental changes and influence the ornithological components of the intertidal areas (chapter 3.2). The sediments, hydrology and invertebrates of the Burry Inlet have been the subject of studies by Banister & Poopetel (1977) and Moore (1977). These data together with those of Prys-Jones et al. (1989) do not improve the predictions possible from the bird database alone. As recorded earlier, despite extensive hydrological and sediment studies, attempts at modelling the post-barrage estuary of the Severn has yet to provide a satisfactory predictive model that can be used with any confidence (Dept. of Energy et al. 1989). The prediction of any changes to the upstream waterfowl populations from the influence of a tidal barrage upon the Burry Inlet intertidal areas is at best a crude assessment.

A 0.5m raising of low water is predicted at Barry if the Severn barrage is built 8km upstream. A similiar though perhaps smaller influence from a Burry Inlet barrage upon tides immediately seaward of the alignment would be expected. The vast majority of mussel scars off Whiteford Burrows lie 2 metres above low water, so their permanent submergence post-barrage is considered unlikely. However, a loss in feeding time would result, the detrimental consequences of which upon the bird population are comparable in effect to the removal of an intertidal feeding area (section 3.1.4). The close proximity of the barrage structure itself to the scars (within 1000 metres) may also reduce the quality of the scars as a feeding site e.g. because of a greater risk of attack from avian predators. 400+ Brent Geese *Branta bernicla*, 4-600 Oystercatchers and 250+ Turnstone *Arenaria interpres* that forage at present on the scars which would lie seaward of a barrage would find the latter structure an obstacle in their flight to roost within the estuary. Inadequacies in our knowledge of the processess other than food supply in determining site quality do not enable any quantification to be made of the influence of an imposing barrage upon foraging birds. However, virtually all of those intertidal areas liable to be available that currently support major concentrations of waterfowl, excluding Whiteford Scars, are beyond 1000 metres from the barrage, a distance considered the maximum zone of potential disturbance (visual or audio). For those mussel scars in close proximity to the barrage during construction, both physical damage and blockage of the mussels' filter feeding system from increased turbidity are additional threats to the bird populations that they support. Further impact from barrage construction work cannot be specifically identified for the Burry Inlet until a construction plan is known. Possible implications regarding estuaries in general are considered in section 3.2.13.

Some waders and wildfowl vacate the Burry Inlet at high tide to roost on the adjacent estuaries of the Gwendraeth, Tywi and Tef (Prater 1977). A lack of adequate roost sites within the Burry Inlet may make this movement greatest at high spring tides. The lower high tide levels of a post-barrage environment will increase the availability of roost sites within the vicinity of feeding sites, hence reducing the energy expenditure incurred in flights to roosts. However, the degree to which the high water limit falls is dependant upon the pumping regime adopted by the barrage operators. Within 1000 metres of the alignment's southern landfall lies a major waterfowl roost along Whiteford Point's east side. This roost regularly exceeds 5000+ birds (Prater 1977). It is envisaged that the period of most disturbance (visual and audio) of this roost and the adjacent feeding areas e.g. Whiteford mussel scars, would be during the barrage's construction phase. Recommendation as to the timing of the various construction phases would include the segregation of the most potentially disturbing activities to waterfowl to the summer, when the abundance and importance of waterfowl populations is least. During the barrage's operational life, the level of disturbance placed upon the waterfowl roost is likely to be minimal, assuming that the level of human activities in the vicinity of the southern landfall differs little from that of the present. Overall, with the exception of Whiteford Point, the construction and operation of a tidal power barrage is unlikely to damage, but may well enhance, the availability of suitable roost sites within the Burry Inlet.

Without establishing the status and distribution of breeding waterfowl within the Burry Inlet at present (3.4.3), it is not possible to quantify any post-barrage impact. A general description, applicable to most estuaries, is all that can be given of foreshore habitat changes and their consequences (3.2.11.).

3.4.5. The environmental impact assessment: Recommendations for further work.

For an ornithological E.I.A. of tidal power generation in the Burry Inlet, or any other given site, to fulfil its named objective, it needs to have addressed at least the following points:

i) The importance to, abundance of and site usage by waterfowl populations of the estuary,
ii) The estuary's post-barrage environment, in particular in terms of the intertidal sediments and invertebrates,

which will be essential knowledge in predicting,

iii) The abundance and distribution of waterfowl in the post-barrage environment,

iv) The impact of the barrage upon the pre-barrage status of the waterfowl populations, i.e. national and international importance.

The above E.I.A., though conducted from the desk over a short time period, illustrates how poorly we can predict the ornithological impact of a tidal power barrage upon an average estuary in terms of the available physical and biological data. Only the present importance of the site to waterfowl populations is anyway near to being satisfactorily answered. Data lacking at present that would be needed to provide a complete appraisal of a tidal power barrage environmental impact in the Burry Inlet are discussed below.

Birds of Estuaries Enquiry data provides a reasonable assessment of the importance of the Burry Inlet to waterfowl within the limitations of the methodology (Prater 1981). One such limitation is that no assessment is possible from BoEE data of the turnover of individuals using the site. Ways of substantiating the existence of passage would be to examine to what extent variability exists between daily counts. The greater the occurrence and degree of variability implies a larger overall passage migrant population through the site. Quantification of the extent of turnover in a population can be more accurately assessed through dye marking individuals within an estuary's population (section 3.3.1). An analysis of ringing recoveries and a literature review will identify the origins and migration of an area's waterfowl furthering the data substantiating the site's importance.

Prys-Jones et al. (1989) provided the initial steps in describing the distribution of Burry Inlet's waterfowl at high and low water. An E.I.A. would ideally need to further this work to encompass the complete year and all stages of the tidal cycle. The importance of an area to a species is however determined not only by the number of birds present at any one time (chapter 3.2). The proportion of each individual's daily food consumption obtained within a tidal cycle from an intertidal area will also determine the latter's importance to a species. The combination of such parameters, which need to be ascertained for both day and night, periods in which a species' activity may differ (chapter 3.1.8), will allow quantification of the importance of an area to waterfowl.

In the above E.I.A., no prediction of the post-barrage intertidal area was possible beyond the crude assumption that the topography would be that of those intertidal flats currently above mid-tide level. Any improvement in the prediction would necessitate detailed modelling of the Burry Inlet's hydrodynamics and sedimentology, post-barrage. Such a predictive model has yet to reach a satisfactory level of development even for the Severn estuary (DEn, CEGB & STPG 1989). Physical variables that such a model requires include turbidity, sediment stability, grain size, factors that influence the quantity and quality of the invertebrate and plant communities of an intertidal area (chapter 3.2). These communities in turn largely determine the bird populations they can support. Before post-barrage predictive models can be formulated for any specific estuary much basic research is still needed to examine the general interactions between the different components of an estuary's biological and physical intertidal environment.

Once the two scenarios are modelled i.e. an estuary with and without a barrage, an assessment can then be quantified of the alteration in the Burry Inlet bird community through construction of a barrage. For reasons discussed previously (chapter 3.2), a satisfactory level of confidence in the prediction necessitates consideration of the fate of those individuals displaced by the barrage and the impact of their actions upon the respective species populations as a whole.

In conclusion, current literature and data allows only a statement of the Burry Inlets waterfowl populations in terms of its present day importance, abundance and distribution across the estuary. Breeding birds are poorly documented for E.I.A. purposes. The predicted impact of a tidal power barrage across the Burry Inlet cannot be based solely upon these data if it is to withstand biological scrutiny. Much research is necessary in the fields of hydrology, sedimentology and the ecology of the intertidal zone before any prediction can be made for the Burry Inlet or probably most western European estuaries at present. Whether any amelioration of the impact of a barrage is possible is very much dependant upon the outcome from the predictive modelling of the post-barrage environment

3.5 CONCLUSION

In determining how the biological importance of a site may be altered by tidal power generation, a prerequisite is knowledge of its natural resources. Such data that is available is largely very limited. This is evident from bringing together the results of the site inventory (chapter 2) with the requirements of the ornithological component of an E.I.A., as identified in this chapter. In particular, insufficient information exists specifically identifying why and to what extent a given site is of importance to a species. Furthermore, data of within site usage by individual species are invariably lacking or inadequate. Such detailed data are however a necessity for a comprehensive E.I.A..

This chapter examined the impact of a tidal barrage upon one biological component of an estuarine system, waterfowl. In doing, so detailed consideration was shown to be necessary of other components, both physical and biological. Though an estuary as a habitat is comparatively simple in structure, modelling the impact of a development within that habitat is extremely complex. This is due to the complexity of interactions between and within each component of the system. An E.I.A. can only be successful in its objective if when focusing upon one biological component it has addressed all relevant interactions with other components. Before that is feasible however, we require a clearer understanding of what are the interactions and their magnitude within an estuary.

Irrespective of site, much research is clearly still necessary to increase the confidence with which the post-barrage hydrology and sediment regime of an estuary can be described. Not until this has reached a satisfactory level can predictions with similar degrees of confidence be made of the ecosystem post-barrage. Meanwhile ecologists need to continue disentangling the complexities of survivorship and population regulation for individual species. How and where the latter process occurs is of obvious importance when considering that a development may alter one of the parameters controlling a species population.

At least until all the above points are satisfactorily addressed can we attempt to predict with any confidence the impact of a tidal power barrage.

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APPENDIX I

THE SITES STUDIED

SUMMARY OF SITES STUDIED IN BRITAIN

*<4.0m

BARRAGE LOCATION	$2M_2$ (m)	A (km^2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £M	U (p/KWh)	COMMENTS
LOCH FYNE	2.32	176.0	3300	186.0	9.0	26	293	403	24255	77.8	
LOCH LINNHE	2.26	153.0	3800	107.2	9.0	22	241	327	10957	54.9	
LOCH LEVEN	2.26	8.6	200	10.3	3.0	11	13	18	31	9.0	
WEST LOCH TARBERT	2.62	12.7	1000	20.1	9.0	2	25	39	287	18.8	RANGE TO LOW
LOCH SUNART	2.46	36.9	700	57.5	9.0	6	71	104	1261	27.9	
LOCH NEVIS	2.7	29.6	1300	124.8	9.0	5	65	100	6898	69.0	
LOCH HOURN	2.7	25.0	1600	171.8	9.0	4	52	80	13317	108.7	
LOCH CARRON	3.08	16.4	440	20.4	8.0	4	47	76	164	9.8	
LOCH CRERAN	2.26	14.7	500	30.2	9.0	2	22	64	342	24.4	
LOCH TORRIDON (entrance)	3.02	57.0	5400	126.2	9.0	10	145	235	17938	74.4	
LOCH TORRIDON (inner)	3.02	28.9	800	104.2	9.0	5	72	118	3704	41.8	
LOCH EWE	2.98	39.1	2100	54.1	9.0	7	100	162	2418	29.1	
LOCH GAIRLOCH	3.02	13.76	2700	67.2	9.0	3	44	71	4086	62.6	
LITTLE LOCH BROOM	3.0	21.1	900	67.2	9.0	4	58	93	1941	34.1	
LOCH LAXFORD	2.64	9.7	1100	53.7	9.0	2	26	39	1536	52.2	
LOCH INCHARD (entrance)	2.8	3.8	1550	37.8	9.0	1	14	21	1091	61.7	
LOCH INCHARD (inner)	2.8	3.0	800	26.8	9.0	1	14	21	391	44.2	
KYLE OF DURNESS	2.86	13.0	220								LACK OF DETAIL
LOCH ERIBOLL	2.86	17.6	1200	59.0	9.0	3	41	66	1904	39.4	
KYLE OF TONGUE	2.86	12.9	200								LACK OF DETAIL
LOCH FLEET	2.32	6.6	250	7.1	3.0*	9	11	16	21	8.0	SHALLOW AT LOW TIDE
DORNOCH FIRTH	2.32	57.3	3300	11.6	4.0	42	93	128	283	11.1	
INVER BAY	2.32	1.9	700								LACK OF DETAIL BUT SHALLOW AT LOW TDE
FINDHORN BAY	2.32	6.2	300	7.1	3.0*	8	10	14	24	9.0	SHALLOW AT LOW TIDE
TARBART NESS - BURGHEAD	2.32	692.7	24000	60.1	9.0	12	135	186	14550	30.4	
INVERNESS FIRTH	2.5	85.3	4300	42.4	9.0	13	157	232	2644	27.5	
BEAULY FIRTH	2.78	24.2	3000	17.1	6.0	9	54	85	481	16.7	
MUNLOCHY BAY	2.64	2.4	800	7.63	3.0*	4	6	9	55	17.1	SHALLOW AT LOW TIDE

SUMMARY OF SITES STUDIED IN BRITAIN

*<4.0m

BARRAGE LOCATION	$2M_2$ (m)	A (km^2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £M	U (p/KWh)	COMMENTS
YTHAN ESTUARY	2.43	2.7	300	-							LACK OF DETAIL
DEE ESTUARY	2.6	8.3	140	9.5	3.0	12	17	25	21	5.97	DREDGED CHANNEL
MONTROSE BASIN	2.94	8.3	180	9.1	3.0	13	20.4	33.5	24	5.3	DREDGED CHANNEL
TAY ESTUARY(Tentsmuir pt)	3.2	109.0	4800	13.8	5.0	67	317	522	480	6.7	
TAY ESTUARY(Broughty Castle)	3.32	86.1	1400	18.9	7.0	27	259	440	330	5.9	
EDEN ESTUARY	3.16	5.6	1000	-							LACK OF DETAIL
FIRTH OF FORTH (outer)	3.34	672.4	12400	55.4	9.0	130	2076	3543	8274	13.0	
FIRTH OF FORTH (inner)	3.56	181.7	8000	48.8	9.0	37	629	1102	5042	16.7	
TWEED ESTUARY	3.2	2.08	600	8.22	3.0*	4	7	11	50	13.2	SHALLOW AT LOW TIDE
TYNE ESTUARY(outer)	3.18	8.0	1000	12.9	4.0	8	24	40	142	12.1	DREDGED CHANNEL
TYNE ESTUARY(inner)	3.18	7.1	300	12.9	4.0	7	21	35	60	8.2	DREDGED CHANNEL
WEAR ESTUARY	3.14	2.08	400	11.8	4.0	2	6	10	64	15.4	DREDGED CHANNEL
TEES ESTUARY (outer)	3.38	12.2	1700	18.6	7.0	4	663	67	369	15.3	DREDGED CHANNEL
TEES ESTUARY (inner)	3.38	5.3	600	18.6	7.0	2	20	34	176	15.3	DREDGED CHANNEL
ORWELL ESTUARY	2.66	11.5	800	10.0	3.0	17	24	37	82	9.9	
STOUR ESTUARY	2.66	16.1	1000	11.4	4.0	13	33	50	117	10.2	DREDGED CHANNEL
LANDGUARD FORT	2.66	34.0	1900	14.4	5.0	18	71	109	267	11.1	DREDGED CHANNEL
COLNE ESTUARY	3.28	7.8	800	11.6	3.0	13	23	38	103	10.0	
BLACKWATER ESTUARY	3.38	33.7	1800	16.4	6.0	15	108	77	315	8.7	
CROUCH/ROACH ESTUARY	3.74	20.8	800	17.8	6.0	10	79	140	201	7.5	
LITTLEHAMPTON HARBOUR	3.94	2.1	40	9.0	3.0*	4	8	15	MW	3.9	SHALLOW AT LOW TIDE
ADUR ESTUARY	4.24	1.6	200	9.6	3.0*	3	7	13	28	7.7	DREDGED CHANNEL
CHICHESTER HARBOUR	2.98	29.5	1400	29.9	9.0	5	72	116	692	16.8	
PORTSMOUTH HARBOUR	2.84	15.7	220	13.2	5.0	9	38	61	49	6.0	DREDGED CHANNEL
SOUTHAMPTON WATER	2.6	30.0	2000	20.1	8.0	6	60	90	468	16.5	
HAMBLE ESTUARY	2.68	2.4	400	9.3	3.0	4	6	9	44	14.9	
MEDINA ESTUARY	2.38	1.52	150	7.1	3.0*	2	3	4	14	12.6	SHALLOW AT LOW TIDE

SUMMARY OF SITES STUDIED IN IRELAND

*<4.0m

BARRAGE LOCATION	$2M_2$ (m)	A (km^2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £M	U (p/KWh)	COMMENTS
CARLINGFORD LOUGH (entrance)	3.08	50.0	3600	7.7	3.0	83	136	221	165	5.8	
CARLINGFORD LOUGH (inner)	3.08	38.2	1700	7.1	9.0	7	103	167	86	4.7	DREDGED CHANNEL
DUNDRUM	3.1				3.0						LACK OF DETAIL
DUNDALK	3.08	3.27	330	7.7	3.0*	5	8	13	29	8.5	SHALLOW AT LOW TIDE
BOYNE ESTUARY	2.92	2.72	120	7.6	3.0*	4	6	10	MW	6.8	SHALLOW AT LOW TIDE
MALAHIDE INLET	2.92	5.44	440	7.1	3.0	9	14	23	32	7.6	
WATERFORD HARBOUR (entrance)	2.9	75.6	4800	19.9	8.0	9	99	159	848	12.5	
WATERFORD HARBOUR (inner)	2.9	28.6	500	15.0	5.0	8	34	55	109	6.6	
BLACKWATER ESTUARY	2.88	10.1	640								LACK OF DETAIL BUT SHALLOW AT LOW TIDE
CORK Hbr. (entrance)	2.86	58.0	1000	31.7	9.0	10	138	220	603	12.0	
CORK Hbr. (Lough Mahon)	2.86	16.2	300	20.9	8.0	4	44	70	129	9.7	
CORK Hbr. (East passage)	2.86	9.0	240	15.0	5.0	5	21	34	64	8.9	
OYSTER HAVEN	2.64	2.9	420	11.7	4.0	2	5	8	65	17.1	
KINSALE (Chroohoge Pt)	2.64	8.3	2700	15.1	6.0	3	17	26	368	25.9	
KINSALE (Blockhouse Pt)	2.64	6.5	340	15.5	6.0	2	11	17	87	13.6	
COURTMACSHERRY	2.5	7.3	1400	7.3	3.0*	10	13	20	77	13.1	SHALLOW AT LOW TIDE
CLONAKILTY	2.5	3.9	1200	7.3	3.0*	5	7	10	69	16.6	SHALLOW AT LOW TIDE
GLANDORE	2.36	2.3	600	11.9	4.0	2	5	6	87	26.4	
CASTLE HAVEN	2.36	2.4	600	15.0	6.0	1	5	7	125	31.3	
BALTIMORE HARBOUR	2.28	9.0	650	27.0	9.0	1	11	15	342	30.3	
DINGLE BAY (entrance)	2.34	446	18000	64.2	9.0	28	318	440	13381	35.1	
DINGLE BAY (Inch pt)	2.34	58.5	2200	12.8	5.0	28	98	136	247	10.1	
SMERWICK HARBOUR	2.34	11.2	2500	45.2	9.0	2	23	31	2027	68.7	
TRALEE BAY	2.81	95.5	8300	14.1	5.0	54	225	359	727	10.8	
BRANDON BAY	2.81	44	7200	28.8	9.0	8	108	172	2016	27.1	
SHANNON ESTUARY (Kilcredaun Pt)	3.28	336.0	3200	39.4	9.0	64	1004	1689	1920	8.2	
SHANNON ESTUARY (Poulnasherry)	3.28	5.5	300	8.4	3.0*	9	16	26	31	6.3	SHALLOW AT LOW TIDE

SUMMARY OF SITES STUDIED IN IRELAND

*<4.0m

BARRAGE LOCATION	$2M_2$ (m)	A (km^2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £M	U (p/KWh)	COMMENTS
SHANNON ESTAURY (Ardmore Pt)	3.28	226.0	2400	31.9	9.0	43	675	1135	1118	7.3	
LISCANNOR BAY	3.17	27.0	5500	37.3	9.0	5	76	125	2541	32.7	
GALWAY BAY (entrance)	3.06	253	10000	33.2	9.0	47	690	1117	3161	13.5	
GALWAY BAY (Kinvarra Bay)	3.06	5.9	900	8.2	3.0	10	16	26	66	10.0	
GALWAY BAY (Aughinish Bay)	3.06	5.0	200	9.4	3.0	8	13	21	27	6.8	
BERTRAGHBOY BAY	2.8	246	900	24.6	9.0	4	54	86	370	15.3	
KILLARY HARBOUR	2.54	9.7	650	44.5	9.0	2	25	37	782	38.3	
BALLYNAKILL HARBOUR	2.54	9.7	1400	16.8	7.0	3	22	33	273	21.9	
CLEW BAY (incl. Clare Is.)	2.42	c276	8800	44.3	9.0	42	492	702	4601	22.7	
BLACKSOD BAY (north part)	2.3	91.5	4600	18.9	9.0	13	145	198	759	15.4	
BLACKSOD BAY (all)	2.3	222	7200	32.1	9.0	31	346	473	2397	19.0	
SLIGO HARBOUR	2.39	15.8	860	9.1	3.0	21	27	38	75	9.7	
DRUMCLIFF BAY	2.39	7.5	700	7.3	3.0*	10	13	18	47	10.8	SHALLOW AT LOW TIDE
SHEEPS HAVEN	2.4	36.1	4500	27.2	9.0	5	58	82	1333	30.2	
MULROY BAY/BROAD WATER	2.4	26.5	250	14.2	5.0	13	47	66	61	6.7	
LOCH SWILLY	2.5	104.4	2300	22.8	9.0	16	193	286	631	11.4	

SUMMARY OF SITES STUDIED IN GERMANY/NETHERLANDS

*<4.0m

BARRAGE LOCATION	$2M_2$ (m)	A (km^2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £M	U (p/KWh)	COMMENTS
ELBE	2.68	c450	15500	19.4	8.0	93	949	1456	1828	ca9.2	DREDGED CHANNEL
WESER (Bremerhaven)	3.04	c128	1700	15.8	8.0	30	346	560	285	ca5.1	DREDGED CHANNEL
WESER (Wremen)	3.04	c224	10300								DREDGED CHANNEL
JADEBUSEN	3.08	c160	4400	28.4	9.0	30	443	718	1407	ca10.6	DREDGED - 17.8m
EMS (Knock - Oterdum)	2.7	129	3500	12.0	4.0	107	275	423	310	6.3	DREDGED CHANNEL
EMS (Hamswehrum to P.station)	2.7	220	8500	12.6	4.0	182	468	719	624	7.1	DREDGED - 8.8m
WESTERSCHELDE	3.48	326	4500	26.3	9.0	66	1097	1906	1264	6.1	

SUMMARY OF SITES STUDIED IN FRANCE

*<4.0m

BARRAGE LOCATION	$2M_2$ (m)	A (km2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £M	U (p/KWh)	COMMENTS
ESTUAIRE DE L'SIENNE	5.24	69.5	3300	11.0	3.0*	143	394	802	261	2.8	SHALLOW AT LOW TIDE
RADE DE BREST:											
Entrance	4.08	160	1800	35.6	9.0	34	659	1215	1096	6.4	
R. L'Elorn	4.08	7.1	600	20.6	8.0	2	31	32	208	11.4	
Estuaire de l'Aulne	4.08	94	3600	25.6	9.0	20	388	715	1037	8.0	
BAIE DE DOUARNENEZ	4.04	234	8800	40.5	9.0	49	941	1728	3985	11.1	
ESTUAIRE DE L'ODET:											
Entrance	3.06	10.2	1100	8.4	3.0	17	28	45	80	8.5	
Inner estuary	3.06	9.4	300	8.2	3.0*	16	26	42	30	5.3	SHALLOW AT LOW TIDE
RIVIERE D'ETEL	3.36	18.6	500	11.1	3.0	33	59	101	68	5.2	
LORIENT:											
Port Louis	3.24	15.7	700	28.4	3.0	27	47	78	392	14.8	
Pointe de Gavres	3.24	23.7	2200	14.4	5.0	15	72	120	296	10.5	
GOLFE DU MORBIHAN (entrance)	3.06	116	1000	19.2	7.0	35	311	503	267	5.1	
RIVERE D'AURAY	3.17	10.8	1200	22.4	9.0	2	30	50	389	18.1	
RIVIERE DE CRAC'H	3.36	4.2	700	12.9	4.0	4	13	22	110	13.4	
LA VILAINE (entrance)	3.5	21.5	4300	8.8	3.0*	39	72	126	227	8.6	SHALLOW AT LOW TIDE
LE CROISIC	3.18	5.5	400	8.3	3.0*	9	15	25	37	7.3	SHALLOW AT LOW TIDE
ESTUAIRE DA LOIRE:											
St Nazaire	3.5	24	1840	18.0	6.0	11	82	142	370	10.6	DREDGED CHANNEL
Pte de Saint-Gildas	3.5	185	11600	18.0	6.0	84	634	1085	1334	8.1	DREDGED CHANNEL
LA PENZE RIVIERE:											
Entrance	5.54	5.5	2000	15.1	4.0	6	31	64	298	10.8	
Inner estuary	5.54	2.5	800	12.5	3.0	5	15	30	115	9.5	
ABER WRAC'H	4.9	2.8	400	12.4	3.0	6	16	31	69	7.9	
ENERZ TERIH Is./ ABER WRAC'H	4.9	5.2	1200	13.4	3.0	10	26	51	172	9.5	
ILE GARO/ABER BENOIT	4.9	4.3	1400	9.6	3.0	9	23	46	115	8.5	SHALLOW AT LOW TIDE
L'ABER BENOIT	4.9	3.1	300	10.7	3.0	6	16	31	44	6.0	

SUMMARY OF SITES STUDIED IN FRANCE

*<4.0km

BARRAGE LOCATION	$2M_2$ (m)	A (km2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £M	U (p/KWh)	COMMENTS
R.VIRE & R.CARENTAN BAY	4.4	28.3	7000	10.0	3.0*	56	130	246	172	7.5	SHALLOW AT LOW TIDE
ILE D'ER/LA PETITE ILE/ ESTUAIRE DU JAUDY	5.99	5.8	3440	28.2	9.0	1	28	60	1174	20.1	
ESTUAIRE DU JAUDY (entrance)	6.28	3.7	700	18	5.0	3	27	59	186	8.8	
ILE DE BREHAT/ILE S.MODE/ ESTUAIRE DU TRIEUX EMBAYMENT	6.72	30	6200	40.2	9.0	7	221	497	3108	14.0	
ESTUAIRE DU TRIEUX	6.5	7.2	900	25.8	9.0	2	61	133	399	9.3	
BAIE DE MORLAIX	5.54	11.7	1900	14.0	3.0	24	70	145	255	7.0	
BAIE DE BOURGNEUF	3.64	320	13000	33.0	9.0	65	1128	1985	3737	10.5	
LA GIRONDE (Pte de Vallieres)	3.1	392	5000	37.1	9.0	73	1084	1757	2361	9.2	
BASSIN D'ARCACHON:											
Cap Ferret - Pte D'Arcachon	2.82	169	8000	13.8	7.0	49	402	641	686	7.9	
Cap Ferret - narrowest pt	2.82	152	3200	19.5	9.0	27	366	584	619	7.9	
PERTUIS BRETON	3.38	353	13100	36.6	9.0	69	1115	1920	4429	12.2	
PERTUIS D'ANTIOCHE (Pt Chassiron - St Marie de Re)	3.48	486	18400	39.7	9.0	98	1629	2830	6325	12.3	
PERTUIS DE MAUMUSON	3.31	36									LACK OF DETAIL <6.1m AT MLWS
L'ADOUR FLEUNE	2.54	2.5	170	17.5	7.0	1	7	11	64	19.3	

SUMMARY OF SITES STUDIED IN SPAIN & PORTUGAL

*<4.0m

BARRAGE LOCATION	$2M_2$ (m)	A (km^2)	L (m)	H (m)	D (m)	N	P (MW)	E (GWh)	C £M	U (p/KWh)	COMMENTS
RIA DE EL FERROL DEL CAUDILLO	2.36	21.1	420	26.4	9.0	3	34	48	242	15.9	
RIA DE LA CORUNA	2.34	17.9	2900	31.3	9.0	3	34	47	1235	42.1	
RIA DE CAMARINAS	2.34	16	2200	22.3+	9.0	2	23	31	590	29.7+	LACK OF DETAIL
RIA DE CORME Y LAGE	2.34	25.6	4800	29.2	9.0	4	45	63	1562	40.3	
RIO DE MERA	2.42	19.2	1800	-	-						LACK OF DETAIL
RIA DEL BARQUERO	2.42	3.2	950	8.6	3.0	4	5	7	74	20.0	
RIA DE CEDEIRA	2.36	5.12	950	14.4	6.0	2	10	14	163	25.1	
RIO DE SOLIA	2.64	25.6	2660	22.6	9.0	4	51	78	689	21.4	
RIA DE SANTONA	2.63	21.8	500	14.9	6.0	8	45	69	108	8.7	
RIA DE SUANCES	2.64	4.48	640	7.7	3.0	7	10	15	47	11.9	
RIO SELLA	2.56	2.6	180	7.5	3.0*	4	6	8	18	9.7	SHALLOW AT LOW TIDE
RIA DE VILLAVICIOSA	2.56	3.2	c200	-	-						LACK OF DETAIL
RIO NALON	2.48	7.0	150	7.4	3.0*	10	13	20	15	5.9	SHALLOW AT LOW TIDE
RIO DE NAVIA	2.44	2.6	160	-	-						LACK OF DETAIL
RIA DE RIBADEO	2.42	10.9	900	18.3	7.0	3	21	30	229	20.3	
RIA DE LA MASMA		3.8	c600	-	-						LACK OF DETAIL
RIA DE VIVERA	2.42	12.2	1900	27.3	9.0	2	23	33	739	36.0	
RIA DE MUROS (entrance)	2.22	85.1	5700	45.2	9.0	12	129	203	3549	39.5	
RIA DE MUROS (inner)	2.22	20.5	2150	14.2	6.0	6	29	45	285	19.5	
RIA DE AROSA (outer)	2.22	254	7700	61.2	9.0	35	378	592	7075	34.8	
RIA DE AROSA (inner)	2.22	61.4	4000	26.2	9.0	8	1439	135	1158	24.8	
RIO TEJO	2.3	269	200	33.3	9.0	38	424	579	210	11.1	
RIA DE CORCUBION	2.28	5.1	1600	30.3	9.0	1	11	15	382	74.6	
RIA DE AVILES	2.48	2.4	170	14.5	6.0	1	5	8	47	17.4	
RIO MUNDACA	2.62		270	2.6+	-	-					
RIA OYARZAN	2.62	1.0	200	22.6+	9.0	1	13	19	110	38.4	
BAIE DE FONTARABIE (Ria de Bidassoa)	2.64	2.2	320	5.14	3.0*	3	4	7	16	12.5	

APPENDIX II

THE SITE INVENTORY

SITE: CAMEL ESTUARY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SW945739	CORNWALL	839

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.		5	4	3			

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.		1					1

	Other site designations
no.	7

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	49.47		Burd 1989
Sand Dune	Present			NCC 1986a
Shingle	Present			Doody & Davidson 1991
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Present	560.53		Doody & Davidson 1991
Rocky Shores	Absent			Doody & Davidson 1991
Saline Lagoons/Ponds	Present			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	229		Doody & Davidson 1991
Marine Habitats	Present		Regional Importance	Gill & Mercer 1989

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Known Known	 Akers 1987 Akers 1987
Wildfowl: feeding distribution roosting distribution	 Known Known	 Akers 1987 Akers 1987
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC
Importance as a breeding site	Known	Chown 1987 NCC Seabird Colony Register Allport et al 1986 Prater 1989 Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Recorded upstream of tidal limits		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably rare visitor	No significance	D.Thompson, S.M.R.U.,pers. comm.
Grey Seal	Exact status unknown; probably an occasional visitor	No significance	D.Thompson, S.M.R.U., pers. comm.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D.Thompson, S.M.R.U. pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Sea Bass	Juveniles common	Major nursery	Laffoley 1991 B.R.Letts, in litt.
Salmon, Trout	Abundant with spawning grounds upstream	Estuary supports a valuable salmonid fishery and thriving rod fishery on river	B.R.Letts, in litt.
Flatfish spp., Herring, Pollack, Mackeral	Scarce		B.R.Letts.
Mullet	Common		B.R.Letts

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Clean Sand Community Beds of the European Oyster *Ostrea edulis* Exposed Sand community Beds of the Edible Mussel *Mytilus edulis* Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	Exposed rocky shore community Moderately exposed rocky shore community Exposed rock community Current swept rocky shore community Variable salinity rock community Variable, but mainly reduced, salinity rocky shore community Reduced salinity rocky shore community
Conservation Importance:	Regional importance
Source of information:	Laffoley 1991 Gill & Mercer 1989

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
Little Petherick	May merit national or regional importance; further survey work required.		Invertebrate Site Register
Rock Dunes SSSI	Regional importance?	Of particular note is the large Mollusc community with a number of characteristic dune species	NCC 1986a

g) FLORA

Community	Conservation Importance	Source of information
Lower saltmarshes, tidal flats, creek	Nationally scarce species -one	NCC 1986a
Shingle	Nationally rare species - one	NCC 1986b
Rocks	Nationally rare species - one	Doody & Davidson 1991
Dunes and dune slacks	Nationally rare/scarce species - four Locally rare species - one Of international value for its large population of very local species. 375 flowering species	NCC 1986a Ratcliffe 1977
Sea cliffs	Nationally rare species - one	Doody & Davidson 1991
Coastal grassland	Locally rare species - one	NCC 1986a

SITE: TAW/TORRIDGE ESTUARY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SS470310	Devon	1592.5

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	2	7	5	6	1		

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)	1		1			1

	Other site designations
no.	6

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	239.78		Burd 1989
Sand Dune	Present		Nationally Important	Doody &Davidson 1991
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Present	907.72		Ratcliffe 1977
Rocky Shore	Present			Doody & Davidson 1991
Saline Pond	Present		Recommended for conservation	Sheader 1989
Saline Lagoon	Absent			Barnes 1989
Subtidal Habitat	Present	445		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Unknown Unknown	 R.J.Wolton, (NCC ARO), pers. comm.
Wildfowl: feeding distribution roosting distribution	 Unknown Unknown	 R.J.Wolton, (NCC ARO), pers. comm.
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC
Importance as a breeding site	Knowledge incomplete	Seabird Colony Register Allport et al 1986 Prater 1989 Sitters 1988

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present in recent years		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably rare visitor	No significance	D. Thompson, SMRU pers. comm.
Grey Seal	Exact status unknown; Pupping sites along adjacent coastline	?	D. Thompson, SMRU pers. comm.. Gubbay 1988.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Salmon, Sea Trout, Bass, Pollock, Coid, Dab, Grey Mullet, Eel.	Main species known which are those caught.	?	N.J.Townsend, in litt.
Sea Bass	Nursery grounds	Major nursery	Laffoley 1991

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Exposed Sand community Beds of the Edible Mussel *Mytilus edulis* Variable or reduced salinity mud community Reduced salinity mud community
Communities recorded that exist on hard substrata:	Exposed rocky shore community Moderately exposed rocky shore community *Sabellaria* reef community Current swept rocky shore community Variable salinity rocky shore community Variable salinity rock community Variable, but mainly reduced, salinity rocky shore community Variable, but mainly reduced salinity rock community Reduced salinity rocky shore community
Conservation Importance:	
Source of information:	Laffoley 1991 Little 1990

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
Braunton Burrows NNR	National importance		Invertebrate Site Register
Northam Burrows	Regional importance	Nationally rare woodlouse *Armadillidium album*,nationally scarce Portland Moth *Ochropleura praecox* and Squashbug *Arenocoris falleni*	NCC 1988a Invertebrate Site Register
Taw/Torridge Estuary	Regional importance		Invertebrate Site Register
Knowl Water & Saltpill Duckpond	Unknown		Invertebrate Site Register

g) FLORA

Community	Conservation Importance	Source of information
Lower saltmarshes, tidal flats, creek	Nationally scarce species - one	NCC 1988a
Waste places, open areas, sandy shores	Nationally scarce species - one	NCC 1988a
Rocks	Nationally rare species - one	Doody & Davidson 1991
Dunes and dune slacks	Nationally rare species - one Nationally scarce species - eleven Over 60 Lichen species recorded	Doody & Davidson 1991 NCC 1988a
Sea cliffs	Nationally rare species - one	Doody & Davidson 1991
Coastal grassland	Nationally scarce species - two	NCC 1986c

SITE: SEVERN ESTUARY (incl. Wye estuary), U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
ST4080	Avon, Glos., Somerset, Gwent, S.Glamorgan	55684

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	4	23	18	10	2		(1)

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)	1	4			1	1

	Other site designations
no.	2

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	933	National importance (New grounds, Slimbridge)	Burd 1989 Ratcliffe 1977
Sand Dune	Absent			Doody & Davidson 1991
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Present		National importance	Doody & Davidson 1991
Intertidal Flats	Present	15957	National importance	Ratcliffe 1977
Rocky Shore	Present			Doody & Davidson 1991
Saline Lagoon/Ponds	Present			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	38794		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Known Known	 Clark 1989, 1990 Clark 1989, 1990
Wildfowl: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Clark 1989, 1990 Clark 1989, 1990
Importance as a moulting site	Knowledge incomplete	Jones 1989
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC
Importance as a breeding site	Knowledge incomplete	Seabird Colony Register Allport et al 1986 Prater 1989 Sharrock 1976 Tyler et al 1987

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present in recent years		Strachan, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably rare visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm. Gubbay 1988
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
100 species of fish and 20 species of prawn recorded			Henderson 1989 Henderson & Holmes 1989
Common Shrimp	Abundant	Major component of the local food web	Henderson & Holmes 1987
Dab, Sole, Flounder	Nursery grounds	?	Henderson & Holmes 1991
Whiting, Sprat, Sand Goby, Sea-snail	The four most abundant fish species in the estuary	Nursery grounds	Henderson & Holmes 1989, 1990.
Sea Bass	Nursery grounds		Holmes & Henderson 1990
Twaite Shad	Present	Vulnerable (IUCN cateogory of threat)	Laffoley 1991 NCC 1989a
Allis Shad	Present	Rare (IUCN cateogory of threat)	Laffoley 1991 NCC 1989a

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Clean Sand Community Gravel or Shell Gravel Community Exposed Sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	*Sabellaria* reef community
Conservation Importance:	National Importance
Source of information:	Laffoley 1991
Further macrobenthic fauna information:	University of Bristol 1988 Warwick et al 1989 Lovell & Mettam 1981

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
Wye Valley & Gwent Levels	National Importance	Gwent levels: 19 Red Data Book species & 94 Nationally scarce species recorded. Records held by the ISR	Invertebrate Site Register
Stroat, Brean Down & Berrow Dunes	Regional Importance		
Sedbury Marsh, Hinckley, Streat & Nailsea Moor	May merit national or regional importance; further survey work required.		
Severn Beach & Caldicot Pill	Local Importance		
Wentlooge Level & Lavernock Point	Unknown		

g) FLORA

Community	Conservation Importance	Source of information
Lower saltmarshes, tidal flats, creek	Nationally rare species - one Nationally scarce species - one	Doody & Davidson 1991 NCC 1989a
Mid and upper saltmarsh	Nationally rare species - one Nationally scarce species - three	
Rocks	Nationally rare species - one	
Coastal grassland	Nationally rare species - one Nationally scarce species - one	

SITE: BURRY INLET, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SS4897	Dyfed, West Glamorgan	9524

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	2	2	4	1	2		(1)

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)						2

	Other site designations
no.	3

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	2187.49	National Importance (Burry Inlet)	Burd 1989 Ratcliffe 1977
Sand Dune	Present		National Importance (Pembrey Burrows & Whiteford)	Ratcliffe 1977
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)				Bibby & Lunn 1982
Grazing Marsh	Present			Doody & Davidson 1991
Intertidal Flats	Present	4365.01	National Importance	Ratcliffe 1977
Rocky Shore	Absent			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	2972.3		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution	Known	Prys-Jones, Howells & Kirby 1989
roosting distribution	Known	Prys-Jones, Howells & Kirby 1989
Wildfowl: feeding distribution	Known	Prys-Jones, Howells & Kirby 1989
roosting distribution	Known	Prys-Jones, Howells & Kirby 1989
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	Prys-Jones, Howells & Kirby 1989
Importance as a autumn staging site	Knowledge incomplete	Prys-Jones, Howells & Kirby 1989
Importance as a breeding site	Knowledge incomplete	Seabird Colony Register Prater 1989 Allport et al 1986 Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Absent		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably rare visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm. Gubbay 1988
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Sea Bass	Nursery grounds	Major nursery	Laffoley 1991

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Clean Sand Community Exposed Sand community Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	Exposed rocky shore community Sheltered rocky shore community Variable salinity rocky shore community Variable, but mainly reduced, salinity rocky shore community
Conservation Importance:	National Importance
Source of information:	Laffoley 1991 Moore 1989

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
Cwm Ivy Marsh & Llanrhidian Marsh	May merit national or regional importance; further survey work required.	Records held by ISR	Invertebrate Site Register
Whiteford Burrows	Regional Importance	146 Arachnida, 130 Coleoptera recorded.	Ratcliffe 1977

g) FLORA

Community	Conservation Importance	Source of information
Mid and upper saltmarsh	Nationally scarce species - two species	NCC 1989b Doody & Davidson 1991
Dunes and dune slacks	Nationally rare species - one species Over 250 flowering species	Doody & Davidson 1991 Ratcliffe 1977

SITE: MILFORD HAVEN, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SM9403	Dyfed	5447.5

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.		3	9	1			

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)		3				2

	Other site designations
no.	4

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	358.3		Burd 1989
Sand Dune	Absent			Doody & Davidson 1991
Shingle	Present			Randell et al 1990
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Present			Doody & Davidson 1991
Intertidal Flats	Present	1351.7		Doody & Davidson 1991
Rocky Shore	Present			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	3737.5		Doody &Davidson 1991
Marine Habitats	Present			Doody &Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Known Known	 Prys-Jones 1989 Prys-Jones 1989
Wildfowl: feeding distribution roosting distribution	 Known Known	 Prys-Jones 1989 Prys-Jones 1989
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	Prys-Jones 1989
Importance as a autumn staging site	Knowledge incomplete	Prys-Jones 1989
Importance as a breeding site	Knowledge incomplete	Prater 1989 Seabird Colony Register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present in recent years		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably rare visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; Probably forages in the estuary regularly. Pupping occurs along the adjacent coastline	?	D. Thompson, SMRU, pers. comm. Gubbay 1988
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Sea Bass		Major nursery	Estuaries Review Team unpubl.

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Clean Sand Community Sand or Muddy Sand Community Maerl Community Exposed Sand community Current swept sand community Muddy gravel community Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	Exposed rocky shore community Moderately exposed rocky shore community Sheltered rocky shore community Exposed rock community Sheltered rock community Hydroid/Bryozoan Turf community Beds of the Slipper Limpet *Crepidula fornicata* Artifical substrata community Variable salinity rocky shore community Variable salinity rock community Variable, but mainly reduced, salinity rocky shore community Reduced salinity rock community
Conservation Importance:	National Importance
Source of information:	Little & Hiscock 1987 Laffoley 1991

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
Angle Bay & Village, Dale Point, Bentlass Saltmarsh, Pwllcrochan, Carew Saltmarsh, Cosheston Creek, Cresswell Creek & Eastern Cleddau	Unknown	Records held by ISR	Invertebrate Site Register
West Williamston	May merit national or regional importance; further survey work required.		

g) FLORA

Community	Conservation Importance	Source of information
All communities	Unknown	

SITE: MENAI STRAITS, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SH	Gwynedd	?

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	1		3+	1+	1+	1+	

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)		1+				

	Other site designations
no.	

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	192.46	National Importance	Burd 1989 Ratcliffe 1977
Sand Dune	Present		National Importance (Newborough Warren)	Ratcliffe 1977
Shingle	Present			Estuaries Review Team pers. comm
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Present		National importance	Ratcliffe 1977
Rocky Shore	Absent			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present			Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Dare & Schofield 1976 Prater 1981 Dare & Schofield 1976 Prater 1981
Wildfowl: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Dare & Schofield 1976 Prater 1981 Dare & Schofield 1976 Prater 1981
Importance as a moulting site	Knowledge incomplete	Dare & Schofield 1976 Kew & Stanyard 1979-80 Moss in press Prater 1981
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC Kew & Stanyard 1979-80 Moss in press
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC Kew & Stanyard 1979-80 Moss in press
Importance as a breeding site	Knowledge incomplete	Prater 1989 Kew & Stanyard 1979-80 Moss in press Seabird Colony Register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Recorded upstream of tidal limits		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably rare visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably a regular visitor	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded:	No information located by NCC's Estuaries Review Team to identify communities present. An account of the littoral fauna of the Anglesey coast of the Menai Straits documented by Jackson (1940) Menai Strait sublittoral survey by Lumb (1983) The invertebrate macrofauna of Lavan Sands was surveyed by Eagle et al (1974)
Conservation Importance:	National Importance; Proposed Marine Nature Reserve
Source of information:	Gubbay 1988 Laffoley 1991 MNCR

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
Newborough Warren Beaumaris Shore & Foryd Bay	National Importance Not known	Records held by ISR	Invertebrate Site Register

g) FLORA

Community	Conservation Importance	Source of information
Dunes and dune slacks	Nationally rare species - one	Doody & Davidson 1991

SITE: CONWY ESTUARY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SH7976	Gwynedd	1493.7

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	1		2			1	

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.				2			

	Other site designations
no.	1

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	105.25		Burd 1989
Sand Dune	Absent			Doody & Davidson 1991
Shingle	Present - (small area)			Estuaries Review Team per comm.
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Present	975.65		Doody & Davidson 1991
Rocky Shore	Absent			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	412.8		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Thorburn & Rees 1978 Thorburn & Rees 1978
Wildfowl: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Thorburn & Rees 1978 Thorburn & Rees 1978
Importance as a moulting site	Unknown	Kew & Stanyard 1979-80 Moss in press
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC Kew & Stanyard 1979-80 Moss in press
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC Kew & Stanyard 1979-80 Moss in press
Importance as a breeding site	Knowledge incomplete	Prater 1989 Kew & Stanyard 1979-80 Moss in press Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present upstream of tidal limit		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably a regular visitor	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Bass	Present	Bass conservation area since 1990	T.H.Technology 1990
Flounder, Mullet, Plaice, Sand Goby, Sand Eels	Present		
Salmon	Smolt leaving estuary = 30,000 - 50,000 Fish returning to breed = 3.000 - 5,000	The population supports a significant salmonid fishery	
Sea Trout	Smolt leaving estuary = 15,000 - 25,000 Fish returning to breed = 1,500 - 2,5000	The population supports a significant salmonid fishery	

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Beds of the Edible Mussel *Mytilus edulis* Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	None
Conservation Importance:	
Source of information:	Laffoley 1991 MNCR

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
Llandudno Junction Saltmarsh	Not known	Records held by ISR	Invertebrate site register
Morfa Conwy	May merit national or regional importance; further survey work required.	Two species of Red Data Book moths present	

g) FLORA

Community	Conservation Importance	Source of information
Coastal grassland	Nationally rare species - one	Doody & Davidson 1991

SITE: MERSEY ESTUARY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SJ4180	Merseyside, Cheshire	8914

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	1		1				(1)

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)		4				

	Other site designations
no.	9

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	1048.39	National Importance	Burd 1989 Ratcliffe 1977
Sand Dune	Absent			Doody & Davidson 1991
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Present			Doody & Davidson 1991
Intertidal Flats	Present	4559.11	National Importance	Ratcliffe 1977
Rocky Shore	Present			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	3306.5		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Known Known	 Clark et al 1991a & b EAU 1988 Clark et al 1991a & b EAU 1988
Wildfowl: feeding distribution roosting distribution	 Known Known	 Clark et al 1991a & b EAU 1988 Clark et al 1991a & b EAU 1988
Importance as a moulting site	Knowledge incomplete	Clark et al 1991a Thomason & Norman 1990
Importance as a spring staging site	Knowledge incomplete	Clark et al 1991a Thomason & Norman 1990
Importance as a autumn staging site	Knowledge incomplete	Clark et al 1991a Thomason & Norman 1990
Importance as a breeding site	Knowledge incomplete	Cheshire & Wirral Ornithological Society 1991 Prater 1989 Seabird colony register Sharrock 1976 Thomason & Norman 1990

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	No recent records		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably a regular visitor	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Doody & Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
All species	Inner estuary: A total of 31 marine, estuarine and migratory fish have been recorded since 1976, but the majority of these only occur very occasionally, and then usually as single specimens. A poor nursey area for the commerically exploited flatfish species. The goby is the only species to spawn within the estuary. Whole estuary: species list stands at 51.	Inner estuary: Four species (Sand Goby, Herring, Sprat, and Whiting) occur regularly every year and are the only ones which can be said to be common in the inner estuary Outer estuary: Part of the nursery grounds for the main, commerically exploited fish stocks of the Irish Sea: plaice, Dab, Sole, Whiting and Sprat.	Holland 1989 Dempsey 1989

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Beds of the Horse Mussel *Modiolus modiolus* Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	Variable salinity rocky shore community
Conservation Importance:	
Source of information:	Carter 1985 Laffoley 1991 MNCR Pugh Thomas 1980 Invertebrate surveys of the Mersey Estuary reviewed by: Holland 1989

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
			No information

g) FLORA

Community	Conservation Importance	Source of information
Mid and upper saltmarsh	Nationally scarce species - one	NCC 1985a

SITE: WYRE ESTUARY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SD 345 480	Lancashire	639

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	1		1				

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.			1				

	Other site designations
no.	1

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	293.63	National Importance (in combination with the whole of Morecambe Bay)	Burd 1989 Ratcliffe 1977
Sand Dune	?			
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	?			
Intertidal Flats	Present		National Importance	Ratcliffe 1977
Rocky Shore	?			
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present			
Marine Habitats	Present			

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution	Knowledge incomplete	Prater 1972, 1981 Rankin 1990 Water Resources Board 1972
roosting distribution	Knowledge incomplete	Prater 1972, 1981 Rankin 1990 Water Resources Board 1972
Wildfowl: feeding distribution	Knowledge incomplete	Prater 1972, 1981 Rankin 1990 Water Resources Board 1972
roosting distribution	Knowledge incomplete	Prater 1972, 1981 Rankin 1990 Water Resources Board 1972
Importance as a moulting site	Knowledge incomplete	Wilson 1973
Importance as a spring staging site	Knowledge incomplete	Wilson 1973
Importance as a autumn staging site	Knowledge incomplete	Wilson 1973
Importance as a breeding site	Knowledge incomplete	Allport et al 1986 Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present on the non tidal reaches?		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded	Treated as a subsite of Morecambe Bay by Laffoley (1991) - see Morecambe Bay Invertebrates sampled by Rankin 1991
Conservation Importance:	
Source of information:	Laffoley 1991 MNCR

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
Wyre Estuary			No data held by the Invertebrate Site Register

g) FLORA

Community	Conservation Importance	Source of information
Rocks	Nationally scarce species - one	Davidson et al 1991

<u>SITE</u>: MORECAMBE BAY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SD360700	Cumbria, Lancashire	44872.5

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	5	5	11	5	1		(1)

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)	1	1	2			2

	Other site designations
no.	6

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	3,253	National Importance	Burd 1989 Ratcliffe 1977
Sand Dune	Present			Doody & Davidson 1991
Shingle	Present			Randell et al 1990
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Present			Doody & Davidson 1991
Intertidal Flats	Present	30,496	National Importance	Ratcliffe 1977
Rocky Shore	Present			Doody & Davidson 1991
Saline Lagoon/Ponds	Present			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	11123.5		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird:		
feeding distribution	Knowledge incomplete	Prater 1971, 1981 Water Resources Board 1972
roosting distribution	Knowledge incomplete	Prater 1971, 1981 Water Resources Board 1972
Wildfowl:		
feeding distribution	Knowledge incomplete	Water Resources Board 1972
roosting distribution	Knowledge incomplete	Prater 1981
Importance as a moulting site	Knowledge incomplete	Wilson 1973
Importance as a spring staging site	Knowledge incomplete	Wilson 1973
Importance as a autumn staging site	Knowledge incomplete	Wilson 1973
Importance as a breeding site	Knowledge incomplete	Allport et al 1986 Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Recorded upstream of tidal limits		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably a regular visitor	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Present	National Importance	Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Sea Bass	Nursery grounds	Major Nursery	Laffoley 1991

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Beds of the Edible Mussel *Mytilus edulis* Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	None
Conservation Importance:	
Source of information:	Laffoley 1991 MNCR

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
Morecambe Bay	Regional Importance Atleast eight nationally scarce species	Records held by ISR	Invertebrate Site Register NCC 1990a
South Walney	Regional Importance		

g) FLORA

Community	Conservation Importance	Source of information
Lower saltmarshes, tidal flats, creek	Nationally scarce species - two	NCC 1984a, 1986d, 1990a, 1990b. Radley 1987 Randell et al 1990
Mid and upper saltmarsh	Nationally scarce species - one	
Shingle	Nationally scarce species - two South Walney has one of the richest shingle beach flora in Britain	
Waste places, open areas, sandy shores	Nationally scarce species - two	
Rocks	Nationally scarce species - two	
Dunes and dune slacks	Nationally scarce species - three South Walney supports some interesting nitrophilous species but the botanical interest is otherwise limited.	

SITE: WALNEY, PIEL & ROA ISLAND, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SD2265	Cumbria	1710

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	1		1	1			

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.			2				

	Other site designations
no.	

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	241.46	National Importance (as part of Morecambe Bay)	Burd 1989 Ratcliffe 1977
Sand Dune	Present			Doody & Davidson 1991
Shingle	Present			NCC 1986d
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Absent			NCC 1986d
Intertidal Flats	Present		National Importance (as part of Morecambe Bay)	Ratcliffe 1977
Rocky Shore	Absent			NCC 1986d
Saline Lagoon/Ponds	Present			NCC 1986d
Subtidal Habitat	Present			Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Prater 1971? Water Resources Board 1972 Prater 1981 T.Cleeves pers comm.
Wildfowl: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Water Resources Board 1972 Prater 1981 T.Cleeves pers comm.
Importance as a moulting site	Knowledge incomplete	Wilson 1973 T.Cleeves pers comm.
Importance as a spring staging site	Knowledge incomplete	Wilson 1973
Importance as a autumn staging site	Knowledge incomplete	Wilson 1973
Importance as a breeding site	Knowledge incomplete	Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	No recent records		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers comm.
Grey Seal	Exact status unknown; probably a regular visitor	No significance	D. Thompson, SMRU, pers comm.
Cetaceans	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	?		

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded	Treated as a subsite of Morecambe Bay by Davidson et al (1991) - see Morecambe Bay
Conservation Importance:	
Source of information:	Davidson et al 1991 MNCR

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
South Walney	Regional Importance	Records held by ISR	Invertebrate Site Register

g) FLORA

Community	Conservation Importance	Source of information
Lower saltmarshes, tidal flats, creek	Nationally scarce species - two	NCC 1986d Randell et al 1990 Radley 1987
Mid and upper saltmarsh	Nationally scarce species - one	
Shingle	Nationally scarce species - two One of the richest shingle beach flora in Britain	
Dunes and dune slacks	Nationally scarce species - two South Walney supports some interesting nitrophilous species but the botanical interest is otherwise limited.	

SITE: DUDDON ESTUARY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SD200800	Cumbria	6091.8

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	2	1	5	1			(1)

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)		1	1			1

	Other site designations
no.	1

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	488.22		Burd 1989
Sand Dune	Present		National Importance	Ratcliffe 1977
Shingle	Present		National Importance	Ratcliffe 1977
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Present			Doody & Davidson 1991
Intertidal Flats	Present	4567.58	National importance	Ratcliffe 1977
Rocky Shore	Absent			Doody & Davidson 1991
Saline Lagoon/Ponds	Present			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	1036		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. <u>FAUNA & FLORA</u>

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution	Unknown	
roosting distribution	Unknown	
Wildfowl: feeding distribution	Unknown	
roosting distribution	Unknown	
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC
Importance as a breeding site	Knowledge incomplete	Allport et al 1986 Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	No recent records		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers comm.
Grey Seal	Exact status unknown; probably a regular visitor	No significance	D. Thompson, SMRU, pers comm.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Breeding colonies	National Importance	Doody & Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Exposed Sand community Beds of the Edible Mussel *Mytilus edulis* Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	Moderately exposed rocky shore community Current -exposed sheltered rocky shore community
Conservation Importance:	
Source of information:	Laffoley 1991 MNCR

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
Haverigg Haws, Hodbarrow lagoon and Askam Ponds & Mines	May merit national or regional importance; further survey work required.	Records held by ISR	Invertebrate Site Register
Sandscale Haws and Duddon Moss	Regional Importance		
Summer Hill and Dunnerholme Quarry	Unknown		

g) FLORA

Community	Conservation Importance	Source of information
Dunes and dune slacks	Nationally rare species - one	Doody & Davidson 1991

SITE: SOLWAY FIRTH (of which BARNIK POINT barrage alignment is a subsite of), U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
NY160610	Cumbria, Dumfries & Galloway	42056

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	1	7	2	1	1		1(1)

	SPA	AONB	SWT	RSPB	ESA	WWT	NT
no.	(1)	1	2			1	1

	Other site designations
no.	2

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	2,925	National Importance	Burd 1989 Ratcliffe 1977
Sand Dune	Absent			Doody & Davidson 1990
Shingle	Absent			Doody & Davidson 1990
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Present			Doody & Davidson 1991
Intertidal Flats	Present	24625	National Importance	Ratcliffe 1977
Rocky Shore	Present			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	14506		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution roosting distribution	 Known Known	 Moser 1984 Moser 1984
Wildfowl: feeding distribution roosting distribution	 Known Known	 Moser 1984 Moser 1984
Importance as a moulting site	Knowledge incomplete	F.Mawby in litt. Moser 1984
Importance as a spring staging site	Knowledge incomplete	F.Mawby in litt. Moser & Carrier 1983 Prys-Jones pers. comm.
Importance as a autumn staging site	Knowledge incomplete	F.Mawby in litt. Moser 1984
Importance as a breeding site	Known	Allport et al 1986 F.Mawby in litt. Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present in recent years		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; though the species does occur but "in surprizingly small numbers"	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; though known to be a regular visitor	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Several breeding colonies representing over 10% of the British population	National Importance	NCC 1988b

d) FISH

Species	Current Status	Conservation Importance	Source of information
Salmon, Sea Trout	Common with major spawning grounds upstream. Both species support major fisheries	National Importance	R. Gardiner, SOAFD pers. comm.
Smelt *Osmerus eperlanus*	Relatively abundant		J. Hislop, SOAFD, in litt.

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Clean Sand Community Gravel or Shell Gravel Community Beds of the Horse Mussel *Modiolus modiolus* Muddy "offshore" sand community
Communities recorded that exist on hard substrata:	*Sabellaria* reef community Hydroid/Bryozoan Turf community
Conservation Importance:	In regards to fisheries, considerable quantities of Brown Shrimps *Crangon crangon* and Cockles *Cerastoderma edule* are taken; both species breed in the area.
Source of information:	J. Hislop in litt. Laffoley 1991 MNCR Perkins 1973

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
Upper Solway Flats & Marshes	Regional Importance	Records held by the ISR	Invertebrate Site Register

g) FLORA

Community	Conservation Importance	Source of information
Waste places, open areas, sandy shores	Nationally scarce species - one, a British endemic.	Doody & Davidson 1991

SITE: DEE ESTUARY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
NJ9405	Grampian	96.5

1. CONSERVATION STATUS

	site designations
no.	none

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Absent			Burd 1989
Sand Dune	Absent			Doody & Davidson 1991
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	Absent			
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Absent	6.9		Doody & Davidson 1991
Rocky Shore	Present			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	89.6		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution	Knowledge incomplete	Bell 1989
roosting distribution	Knowledge incomplete	Bell 1989
Wildfowl: feeding distribution	Knowledge incomplete	Bell 1989
roosting distribution	Knowledge incomplete	Bell 1989
Importance as a moulting site	Unknown	Unknown
Importance as a spring staging site	Knowledge incomplete	Bell 1989
Importance as a autumn staging site	Knowledge incomplete	Bell 1989
Importance as a breeding site	Knowledge incomplete	Buckland et al 1990 Seabird Colony Register

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present in recent years		Davidson & Laffoley 1991
Common Seal	Animals regularly forage in the estuary	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Animals regularly forage in the estuary	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Very rare visitor within the estuary. Porpoises, in particular, are present offshore.	No significance	

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Salmon, Sea Trout	Common with major spawning grounds upstream. Both species support important fisheries	National Importance	R. Gardiner, SOAFD, pers. comm.

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	None
Conservation Importance:	
Source of information:	Laffoley 1991 Eleftheriou 1964 MNCR

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			No information located

g) FLORA

Community	Conservation Importance	Source of information
All communities	Not known/not recorded	

SITE: MONTROSE BASIN, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
NO693577	Angus	841.5

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	1	3	1	1		1	(1)

	SPA	AONB	SWT	RSPB	ESA	WWT	NT
no.	(1)						

	Other site designations
no.	

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	58.01		Burd 1989
Sand Dune	Absent			Doody & Davidson 1991
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	?			
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Present	681.39		Doody & Davidson 1991
Rocky Shore	Absent			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	102.1		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. <u>FAUNA & FLORA</u>

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution	Unknown	
roosting distribution	Known to bird ringers but not documented	Summers et al 1988
Wildfowl: feeding distribution	Unknown	
roosting distribution	Unknown	
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC
Importance as a autumn staging site	Knowledge incomplete	BOEE/NWC
Importance as a breeding site	Knowledge incomplete	Allport et al 1986 Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present		Green & Green 1987
Common Seal	Common Seals occasionally visit the Basin which probably had a greater importance in the past as a Seal haul-out site		D. Thompson, SMRU, pers. comm.
Grey Seal	Grey Seals occasionally visit the Basin which probably had a greater importance in the past as a Seal haul-out site		D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown, though probably a rare visitor of which the Porpoise is most likely.		

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Salmon, Sea Trout	Common with major spawning grounds upstream. Both species support important fisheries.	National Importance	R. Gardiner, SOAFD, pers. comm. D.A. Dunkley, SOAFD, in litt.

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Exposed Sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	None
Conservation Importance:	Not Known/not recorded
Source of information:	Davidson et al 1991 MNCR McLusky & Roddie1982 Milligan 1984

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			No records held by the Invertebrate Site Register

g) FLORA

Community	Conservation Importance	Source of information
All communities	Not known/not recorded	

SITE: TAY ESTUARY, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
NO3527	North east Fife, Angus, Dundee, Perth & Kinross	12128.1

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.	3	3	5	3	1	1	(1)

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	(1)						

	Other site designations
no.	1

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	499.27	National Importance	Burd 1989 Ratcliffe 1977
Sand Dune	Present		National Importance	Ratcliffe 1977
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	Present		National Importance?	Bibby & Lunn 1982
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Present	5084.03	National Importance	Ratcliffe 1977
Rocky Shore	Absent			Doody & Davidson 1991
Saline Lagoon/Ponds	Absent			Barnes 1989 Sheader 1989
Subtidal Habitat	Present	6544.8		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution	Knowledge incomplete and not documented	B.Lynch in litt. N.Taylor pers. comm.
roosting distribution	Known but not documented	B.Lynch in litt. N.Taylor pers. comm.
Wildfowl: feeding distribution	Knowledge incomplete and not documented	N.Taylor pers. comm. Pounder 1976
roosting distribution	Knowledge incomplete with little documentation	N.Taylor pers. comm. Pounder 1971, 1974 Newton et al 1973
Importance as a moulting site	Knowledge incomplete	Pounder 1974
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC
Importance as a breeding site	Knowledge incomplete	Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Recorded in recent years		Green & Green 1987
Common Seal	August 1990 SMRU counted approx. 500. The vast majority are situated at the estuaries outer reaches	National Importance	D. Thompson pers. comm.
Grey Seal	August 1990 SMRU counted approx. 800. The vast majority are situated at the estuaries outer reaches	National Importance	D. Thompson pers. comm.
Cetaceans	Exact status unknown; probably an occasional visitor.		

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Salmon, Sea Trout	Common with important spawning grounds upstream. Both species support important fisheries.	National Importance	R. Gardiner, SOAFD, pers. comm.
Smelt	One of the few areas in Scotland where there was (and possibly still is) a fishery for smelt. The population of smelt appears to be only one of two in Scotland		J. Hislop, SOAFD, in litt. Maitland & Smith 1987
Plaice, Dab	The areas of sandy substrate are nurseries for plaice and dab.		J. Hislop, SOAFD, in litt.
All species	The diversity of the fish community, especially the estuarine component is one of the most outstanding biological features of the River Tay	The river Tay holds twenty species of considerable interest in terms of conservation	Maitland & Smith 1987 Maitland 1984

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Beds of the Common Mussel *Mytilus edulis* Beds of *Zostera spp.* Variable or reduced salinity mud community
ommunities recorded that exist on hard substrata:	Sheltered rocky shore community Variable, but mainly reduced, salinity rocky shore community
Conservation Importance:	Not known/not recorded
Source of information:	Laffoley 1991 MNCR

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
Earshall Muir Tayport, Errol Marshes and Tayport-Tentsmuir coast Barry Links	National Importance May merit national or regional importance; further survey work required. Regional Importance	Records held in the ISR	Invertebrate Site Register NCC 1983

g) FLORA

Community	Conservation Importance	Source of information
Dunes	Over 400 species of flowering plant recorded	Ratcliffe 1977

SITE: LANGSTONE HARBOUR, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SU700030	Hampshire	1924.6

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.			1			1	1

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.	1		1				

	Other site designations
no.	1

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	100.28	National Importance	Burd 1989 Ratcliffe 1977
Sand Dune	Absent			Doody & Davidson 1991
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	Present			Bibby & Lunn 1982
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Present	1412.72	National Importance	Ratcliffe 1977
Rocky Shore	Absent			Doody & Davidson 1991
Saline Lagoon/Ponds	Present		Recommended for conservation	Barnes 1989 Sheader 1989
Subtidal Habitat	Present	411.6		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution	Known	Tubbs & Tubbs 1980
roosting distribution	Known	Tubbs & Tubbs 1980
Wildfowl: feeding distribution	Knowledge incomplete	Tubbs & Tubbs 1980
roosting distribution	Knowledge incomplete	Tubbs & Tubbs 1980
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	Tubbs 1977
Importance as a autumn staging site	Knowledge incomplete	Tubbs 1977
Importance as a breeding site	Knowledge incomplete	Allport et al 1986 Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	No recent records		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
60 species of fish recorded	See reference, however, both diversity and abundance of fish have seriously declined since the late 1970's	Local importance as a nursery ground for atleast 14 species. Major Sea Bass nursery	Culley & Palmer 1978 Reay & Culley 1980 M.Culley in litt. Laffoley 1991
Oysters	Some oyster dredging occurs but the fishery is heavily overexploited. Now represents only a very small part of the Solent fishery.		S.Cunningham in litt.

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Beds of the European Oyster *Ostrea edulis* Exposed Sand community Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	None
Conservation Importance:	Not Known/Not recorded
Source of information:	Laffoley 1991 MNCR Portsmouth Polytechnic 1976

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
Langstone Harbour	Unknown	Records held by the ISR	Invertebrate Site Register

g) FLORA

Community	Conservation Importance	Source of information
Lower saltmarshes, tidal flats, creek	Nationally scarce species - two	Doody & Davidson 1991 NCC 1985b
Shingle	Nationally rare species - one which is a British endemic	
Coastal grassland	The grassland flora is espicially rich for reclaimed silt, and includes over 50 species of grasses.	

SITE: PORTSMOUTH HARBOUR, U.K.

SITE DETAILS:

O.S. Grid Reference	County	Total Area (ha)
SU620035	Hampshire	1593.1

1. CONSERVATION STATUS

	NCR	GCR	SSSI(B)	SSSI(G)	NNR	LNR	RAMSAR
no.			1				

	SPA	AONB	CWT	RSPB	ESA	WWT	NT
no.			1				

	Other site designations
no.	1

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	181.15		Burd 1989
Sand Dune	Absent			Doody & Davidson 1991
Shingle	Absent			Doody & Davidson 1991
Reedbed (>2ha)	Absent			Bibby & Lunn 1982
Grazing Marsh	Absent			Doody & Davidson 1991
Intertidal Flats	Present	782.75		Doody & Davidson 1991
Rocky Shore	Absent			Doody & Davidson 1991
Saline Lagoon/Ponds	Present		Strongly recommended for conservation	Barnes 1989 Sheader 1989
Subtidal Habitat	Present	629.2		Doody & Davidson 1991
Marine Habitats	Present			Doody & Davidson 1991

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Shorebird: feeding distribution	Unknown	
roosting distribution	Unknown	
Wildfowl: feeding distribution	Unknown	
roosting distribution	Unknown	
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC
Importance as a breeding site	Knowledge incomplete	Allport et al 1986? Prater 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	No recent records		Strachen, Birks, Chanin & Jefferies 1991
Common Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm.
Grey Seal	Exact status unknown; probably an occasional visitor	No significance	D. Thompson, SMRU, pers. comm.
Cetaceans	Exact status unknown; probably a rare visitor	No significance	D. Thompson, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Davidson 1991

d) FISH

Species	Current Status	Conservation Importance	Source of information
Sea Bass	Nursery grounds	Major nursery	Laffoley 1991

e) MARINE COMMUNITIES

Communities recorded that exist on soft substrata:	Beds of the European Oyster *Ostrea edulis* Beds of *Zostera* species Normal or variable salinity muddy sand community Variable or reduced salinity mud community
Communities recorded that exist on hard substrata:	None
Conservation Importance:	Not known/Not recorded
Source of information:	Laffoley 1991 MNCR Tubbs 1975

f) TERRESTRIAL INVERTEBRATES

Site	Conservation Importance	Comments	Source of information
		No records held by ISR	Invertebrate Site Register

g) FLORA

Community	Conservation Importance	Source of information
All communities	The flora includes about 30 species with narrow habitat tolerances or of decided rarity in Britain, including populations of five species of orchid and at least one extreme rarity.	NCC 1985c

<u>SITE</u>: CARLINGFORD LOUGH, EIRE/U.K..

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
54 04 N 06 12W	Co. Louth (Eire) Co. Down (UK)	3662

1. <u>CONSERVATION STATUS</u>

	NNR	ASSI	ASI	AONB	RAMSAR	SPA	RSPB
no.			1	1			1

	Other site designations
no.	

2. <u>HABITATS</u>

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	?			
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	Present			Grimmett & Jones 1989
Rocky Shore	?			
Saline Lagoon/Ponds	?			
Subtidal Habitat				
Marine Habitats	Present			

3. <u>FAUNA & FLORA</u>

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	Birds of Estuaries Enquiry Hutchinson 1979 IWRB Moser & Prys-Jones 1988
Shorebird: feeding distribution roosting distribution	 Unknown Unknown	
Wildfowl: feeding distribution roosting distribution	 Unknown Unknown	
Importance as a moulting site	Unknown	
Importance as a spring staging site	Knowledge incomplete	BoEE/NWC
Importance as a autumn staging site	Knowledge incomplete	BoEE/NWC
Importance as a breeding site	Knowledge incomplete	Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present		Chapman & Chapman 1982
Common Seal	Exact status unknown		D.Thompsom, SMRU, pers. comm.
Grey Seal	Exact status unknown		D.Thompsom, SMRU, pers. comm.
Cetaceans	Exact status unknown		D.Thompsom, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Frazer 1983

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

SITE: WATERFORD HARBOUR, EIRE.

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
52 10N 6 57W	Co. Waterford	7560

1. CONSERVATION STATUS

	Site designations
no.	?

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	100		Dijkema 1984
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	?			
Rocky Shore	?			
Saline Lagoon/Ponds	?			
Subtidal Habitat	?			
Marine Habitats	Present			

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	Hutchinson 1979 IWRB
Shorebird: feeding distribution roosting distribution	Unknown Unknown	
Wildfowl: feeding distribution roosting distribution	Unknown Unknown	
Importance as a moulting site	Unknown	
Importance as a spring staging site	Unknown	
Importance as a autumn staging site	Unknown	
Importance as a breeding site	Incomplete Knolwedge	Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	?		
Common Seal	Exact status unknown		D.Thompsom, SMRU, pers. comm.
Grey Seal	Exact status unknown		D.Thompsom, SMRU, pers. comm.
Cetaceans	Exact status unknown		D.Thompsom, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Frazer 1983

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

SITE AUGINISH BAY (part of Galway Bay), EIRE.

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
53 16N 9 03W	Co. Galway	500

1. CONSERVATION STATUS

	Site designations
no.	?

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	?			
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	?			
Rocky Shore	?			
Saline Lagoon/Ponds	?			
Subtidal Habitat	?			
Marine Habitats	Present			

3. <u>FAUNA & FLORA</u>

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	Hutchinson 1979 IWRB
Shorebird: feeding distribution roosting distribution	Unknown Unknown	
Wildfowl: feeding distribution roosting distribution	Unknown Unknown	
Importance as a moulting site	Unknown	
Importance as a spring staging site	Unknown	
Importance as a autumn staging site	Unknown	
Importance as a breeding site	Incomplete Knolwedge	Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present		Chapman & Chapman 1982
Common Seal	Exact status unknown		D.Thompsom, SMRU, pers. comm.
Grey Seal	Exact status unknown		D.Thompsom, SMRU, pers. comm.
Cetaceans	Exact status unknown		D.Thompsom, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Frazer 1983

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

SITE MULROY BAY, EIRE

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
55 15N 7 46W	Co. Donegal	2650

1. CONSERVATION STATUS

	Site designations
no.	?

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	?		Dijkema 1984
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	?			
Rocky Shore	?			
Saline Lagoon/Ponds	?			
Subtidal Habitat	?			
Marine Habitats	Present			

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	Hutchinson 1979 IWRB
Shorebird: feeding distribution roosting distribution	 Unknown Unknown	
Wildfowl: feeding distribution roosting distribution	 Unknown Unknown	
Importance as a moulting site	Unknown	
Importance as a spring staging site	Unknown	
Importance as a autumn staging site	Unknown	
Importance as a breeding site	Incomplete Knowledge	Grimmett & Jones 1989 Seabird colony register Sharrock 1976

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Present		Chapman & Chapman 1982
Common Seal	Exact status unknown		D.Thompsom, SMRU, pers. comm.
Grey Seal	Exact status unknown		D.Thompsom, SMRU, pers. comm.
Cetaceans	Exact status unknown		D.Thompsom, SMRU, pers. comm.

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		Frazer 1983

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

SITE RADE DE MORLAIX, FRANCE

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
48 41N 03 55W	Bretagne	1170

1. CONSERVATION STATUS

	Site designations
no.	?

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	300		Dijkema 1984
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	Present			Grimmett & Jones 1989
Rocky Shore	Present			Grimmett & Jones 1898
Saline Lagoon/Ponds	?			
Subtidal Habitat	?			
Marine Habitats	Present			

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	Grimmett & Jones 1989 IWRB Maheo 1986, 1987, 1988
Shorebird: feeding distribution roosting distribution	 ? ?	
Wildfowl: feeding distribution roosting distribution	 ? ?	
Importance as a moulting site	?	
Importance as a spring staging site	?	
Importance as a autumn staging site	?	
Importance as a breeding site	Knowledge incomplete	Grimmett & Jones 1989

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	?		
Common Seal	?		
Grey Seal	?		
Cetaceans	?		

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	?	?	

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

<u>SITE</u> ABER BENOIT, FRANCE

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
48 35N 4 35W	Bretagne	310

1. <u>CONSERVATION STATUS</u>

	Site designations
no.	?

2. <u>HABITATS</u>

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	?			
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	?			
Rocky Shore	?			
Saline Lagoon/Ponds	?			
Subtidal Habitat	?			
Marine Habitats	Present			

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	?	
Shorebird: feeding distribution roosting distribution	 ? ?	
Wildfowl: feeding distribution roosting distribution	 ? ?	
Importance as a moulting site	?	
Importance as a spring staging site	?	
Importance as a autumn staging site	?	
Importance as a breeding site	?	

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	?		
Common Seal	?		
Grey Seal	?		
Cetaceans	?		

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	?	?	

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?	?	

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

SITE RADE DE BREST, FRANCE

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
48 18N 04 23W	Bretagne	16,000

1. CONSERVATION STATUS

	CHR	Other site designations
no.	1	

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	1050		Dijkema 1984
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	Present			Grimmett & Jones 1989
Rocky Shore	Present			Grimmett & Jones 1989
Saline Lagoon/Ponds	?			
Subtidal Habitat	?			
Marine Habitats	Present			

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	Grimmett & Jones 1989 IWRB Maheo 1986, 1987.
Shorebird: feeding distribution roosting distribution	 ? ?	
Wildfowl: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Servat 1983 Servat 1983
Importance as a moulting site	?	
Importance as a spring staging site	?	
Importance as a autumn staging site	?	
Importance as a breeding site	Knowledge incomplete	Grimmett & Jones 1989

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	?		
Common Seal	?		
Grey Seal	?		
Cetaceans	?		

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	?		

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?		

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

<u>SITE</u> RIVIERE D'ETEL, FRANCE

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
47 35N 3 11W	Bretagne	1860

1. CONSERVATION STATUS

	Site designations
no.	?

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	400		Dijkema 1984
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	?			
Rocky Shore	?			
Saline Lagoon/Ponds	?			
Subtidal Habitat	?			
Marine Habitats	Present			

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	IWRB Maheo 1986, 1987.
Shorebird: feeding distribution roosting distribution	 ? ?	
Wildfowl: feeding distribution roosting distribution	 ? ?	
Importance as a moulting site	?	
Importance as a spring staging site	?	
Importance as a autumn staging site	?	
Importance as a breeding site	?	

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	?		
Common Seal	?		
Grey Seal	?		
Cetaceans	?		

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	?		

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?		

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

SITE GOLFE DU MORBIHAN, FRANCE

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
47 34N 02 46W	Bretagne	11,600

1. CONSERVATION STATUS

	CHR	CR	Other site designations
no.	1	1	

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	300		Dijkema 1984
Sand Dune	?			
Shingle	?			
Reedbed	?			
Grazing Marsh	?			
Intertidal Flats	Present			Grimmett & Jones 1989
Rocky Shore	Present			Grimmett & Jones 1989
Saline Lagoon/Ponds	Present			Grimmett & Jones 1989
Subtidal Habitat	?			
Marine Habitats	Present			

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	Evans & Grieg 1985 Grimmett & Jones 1989 IWRB Maheo 1986, 1987, 1988
Shorebird: feeding distribution roosting distribution	 ? ?	
Wildfowl: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 Servat 1983 Servat 1983
Importance as a moulting site	?	
Importance as a spring staging site	?	
Importance as a autumn staging site	?	
Importance as a breeding site	?	Evans & Grieg 1985 Grimmett & Jones 1989

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	?		
Common Seal	?		
Grey Seal	?		
Cetaceans	?		

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	?		

d) FISH

Species	Current Status	Conservation Importance	Source of information
	?		

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

SITE WESTERSCHELDE, NETHERLANDS

SITE DETAILS:

Co-ordinates	Region	Total Area (ha)
51 24N 03 50E	Zeeland	31,900

1. CONSERVATION STATUS

	RAMSAR	SPA	L	Other site designations
no.	1	1	2	1+

2. HABITATS

Habitat	Present/ Absent	Area (ha)	Conservation Importance	Source of information
Saltmarsh	Present	2750	?	Dijkema 1984
Sand Dune	Absent			P. Meire in litt.
Shingle	Absent			P. Meire in litt.
Reedbed	Present			P. Meire in litt
Grazing Marsh	Present			P. Meire in litt
Intertidal Flats	Present	?	?	Grimmett & Jones 1989
Rocky Shore	Absent			P. Meire in litt
Saline Lagoon/Ponds	Absent			P. Meire in litt
Subtidal Habitat	Present			P. Meire in litt
Marine Habitats	Present	?	?	P. Meire in litt

3. FAUNA & FLORA

a) BIRDS:

	Known/ Unknown	Source of Information
Waterfowl population levels	Knowledge incomplete	Evans & Grieg 1985 Grimmett & Jones 1989 IWRB Stuart et al 1990
Shorebird: feeding distribution roosting distribution	 Knowledge incomplete Known	 P. Meire in litt. P. Meire in litt.
Wildfowl: feeding distribution roosting distribution	 Knowledge incomplete Knowledge incomplete	 P. Meire in litt. P. Meire in litt.
Importance as a moulting site	Knowledge incomplete	P. Meire in litt.
Importance as a spring staging site	Known	P. Meire in litt.
Importance as a autumn staging site	Known	P. Meire in litt
Importance as a breeding site	Knowledge incomplete	Evans & Grieg 1985 Grimmett & Jones 1989 P.L.Meininger unpublished (Leewis 1984)

b) MAMMALS

Species	Current Status	Conservation Importance	Source of information
Otter	Absent		P. Meire in litt.
Common Seal	Reported very rarely		P. Meire in litt.
Grey Seal	Reported very rarely		P. Meire in litt.
Cetaceans	?		

c) AMPHIBIAN

Species	Current Status	Conservation Importance	Source of information
Natterjack Toad	Absent		P. Meire in litt.

d) FISH

Species	Current Status	Conservation Importance	Source of information
Sand Gobies	Winter density of 27/1000m^2	?	Meire et al 1989
Flatfish	Nursery		P. Meire in litt.

e) MARINE COMMUNITIES

Communities recorded	?
Conservation Importance:	?
Source of information:	?

f) TERRESTRIAL INVERTEBRATES

Sites	Conservation Importance	Comments	Source of information
			?

g) FLORA

Community	Conservation Importance	Source of information
All communities	?	?

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