The breeding biology and population dynamics of shelduck (Tadorna tadorna L.) at Aberlady Bay.

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THE BREEDING BIOLOGY AND POPULATION DYNAMICS OF SHELDUCK (*TADORNA TADORNA* L.) AT ABERLADY BAY

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ABSTRACT

The breeding biology of shelduck at Aberlady Bay in 1976 is described in detail and possible factors affecting breeding success are discussed.

Factors affecting nest site selection were determined. Both parliament site and nest site tended to be as close as possible to a pair's feeding area within the bay, which was chosen in early spring.

Artificial nest boxes were used to study individual birds during the breeding season. The rhythm of egg production was irregular for all birds studied. The mean rate of egg production was 0.63 eggs day^{-1}, and clutch size 9.3 ± 2.4 eggs. Laying occurred between 15th April and 2nd July, the mean incubation period being 32.2 ± 1.2 days. Hatching success varied between 80-100%. There was little evidence of predation although there was some evidence of intraspecific disturbance and mechanisms by which it may occur are described.

Ducklings appeared on the bay from the end of May until the first week in July. Thirty-six broods were brought onto the bay and most ducklings were taken to a main nursery area.

Mechanisms leading to creching of ducklings are described. Creching was extensive, although mainly between ducklings of similar ages (and usually younger ducklings were involved). The largest creche observed contained 38 ducklings. Ducklings could be separated in the field into different age classes (I-IV). Mortality of Class I ducklings was found to be 81%. The first fledged duckling was seen on 16th July.

The distribution within the bay of invertebrate food items taken by shelduck was determined. The abundance of Hydrobia ulvae within the feeding ranges of breeding birds varied between 1-100+ dm^{-3}. Evidence

suggested that sediment type may be important in affecting food availability in different parts of the bay. The feeding areas of individual ducks during the breeding season moved each year, either into, out of, or within the bay. Movement of feeding areas into the bay, particularly onto muddy or wet areas, usually resulted in successful breeding (duck seen with ducklings). Pairs feeding further into the bay or on muddy areas bred earlier than other pairs. Early breeding was thought to be beneficial for the maintenance of the parent/duckling bond, and survival of ducklings.

Forty-two pairs were known to have bred between Musselburgh and North Berwick. The number of breeding pairs at Aberlady was thought to be restricted by competition for good feeding sites in the muddy or wetter areas of the bay, coupled with increased individual distance during the breeding season.

Production of offspring at Aberlady Bay was found to be inadequate for maintenance of its population of shelduck (mainly due to high duckling mortality) and immigration from other areas was thought to occur, especially from areas with low densities of shelduck where production per pair appeared to be higher.

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INTRODUCTION

1.1 INTRODUCTION

Recent work, much of it experimental, has demonstrated that spacing mechanisms in general and territorial behaviour in particular, can limit the density of populations (Watson and Moss 1970). This has been demonstrated for few bird species so far and the importance of spacing in waterfowl has received scant attention, apart from the work of McKinney (1965) and Patterson (1976).

The aim of my study was to examine in detail the breeding biology of individually marked shelduck at Aberlady Bay, East Lothian, Scotland. By doing so, the validity was to be examined of Jenkins et al. (1975) hypothesis relating the social status of shelduck to their breeding success. It was also intended to find whether the possible mechanisms for population regulation suggested by Williams (1973) for shelduck in the Ythan Estuary, were also true for Aberlady.

Shelducks (Tadorna tadorna L.) are dispersed around the coasts of Britain and Europe in a number of discrete populations (Atkinson-Willes 1963). Although shelduck are increasing on a national scale (Parslow 1967-68) long established populations may have reached a maximum sustainable number, offering opportunities for studying natural population processes in the Anatidae, on which until recently, there have been few long term studies.

The distribution of shelduck along the coast of the Firth of Forth has remained relatively constant for the last 40 years and a series of counts during the period 1961-71 over the whole of the firth, showed stability in numbers at all times of the year (Jenkins 1972). Shelduck are numerous around the Forth area on muddy estuaries and few shelduck are found on the mainly sandy or rocky areas between the estuaries. The main breeding areas are around Aberlady Bay, the River Almond, the River Tyne and the upper Forth between Grangemouth and Tulliallan (Jenkins et al. 1975). Shelduck found along the coast between North Berwick and Edinburgh during the breeding season, winter at Aberlady Bay along with its resident population and nearly all coastal breeders bring their ducklings to the bay (Jenkins et al. 1975).

Shelduck populations have previously been studied by Young (1964, 1965, 1970a,b) and Williams (1973) at the River Ythan, Hori (1964a,b, 1965, 1969) around the Isle of Sheppey in the Thames Estuary and Jenkins et al. (1975) at Aberlady Bay. Although the birds behaviour was similar in outline at all areas certain differences existed between the populations.

Both Aberlady Bay and the Ythan Estuary are much further north than Sheppey. Sheppey may support up to 1,800 shelduck during winter (Hori 1964), compared with between 110-140 at Aberlady (Jenkins et al. 1975) and 20-30 at the Ythan (Williams 1973). At Aberlady and Sheppey most shelducks return from their moult migration by midwinter, whereas at the Ythan they continue to arrive until April. At Sheppey the majority of breeding birds feed on freshwater fleets in grazed marshes and nest in hollow trees, haystacks and farm buildings in close proximity to man (Hori 1964). However at the Ythan, birds remain throughout the breeding season in the muddy estuary and nest mainly in rabbit burrows along the dunes (Patterson 1974).

1.2 THE ANNUAL CYCLE OF SHELDUCKS AT ABERLADY

Jenkins et al. summarised the annual cycle of shelduck at Aberlady as follows:

Most adults leave the bay in July and August and presumably moult with other European shelduck in the Heligoland Bight in West Germany (cf. Goethe 1957). The first birds return during September. Adults are usually seen in pairs throughout the year, except for a few unmated drakes. First year birds usually make up less than 5% of the population and are either paired with adults or remain solitary. Until early February, birds occur in one or more flocks, often on the sandy areas of the bay. From mid-February, these flocks gradually break up into scattered pairs in conjunction with an increase in display and aggression, especially between drakes. From April onwards these separate pairs occupy the whole of the muddy parts of Aberlady Bay at low tide and 1-3 pairs move up the Peffer Burn.

Areas where pairs were seen regularly at low tide were called territories by Jenkins et al. (1975). Such feeding areas were first termed territories by Hori (1964) who concluded that the high levels of aggression (both intersecific and intrasecific) displayed by the occupants, together with the repeated use of localised feeding areas, satisfied Nobles' (1939) definition of a territory as "any defended area". These areas at Aberlady contrasted with so called "neutral areas" on which birds had less narrowly defined feeding areas and where feeding in flocks still occured. In the early morning, from late February onwards, pairs left the bay to prospect for nest burrows mainly in Gullane Links and Dunes, but also in bale stacks up to 6 km inland. Copulation was recorded from early March to the end of May and eggs were laid from mid-April. While females were incubating the males usually remained on their territories. The first ducklings were seen from the end of May and fledged in about eight weeks.

1.3 SOCIAL ORGANISATION WITHIN SHELDUCK POPULATIONS

Jenkins et al. (1975) postulated that shelducks belonging to the population centred at Aberlady Bay, could be classified into different social groups. He distinguished birds present only in winter but not in spring (transients) from others which are present in spring, either all the time or mainly around high water (residents and commuters respectively). These classes could be further divided as follows:

(a) Transients into:-

(i) birds seen only 1-2 days in winter (January to March).

(ii) wintering birds seen 2-4 months from November to March, but not between April to July (the breeding season).

(b) Residents/Commuters into:-

(i) non-territorial birds seen in winter and also in spring, but thereafter usually only seen around high water or on neutral ground and not on territories.

(ii) territorial birds seen in winter and also in spring around low water on territories or on breeding areas as well as around high water.

Jenkins' main hypothesis about the regulation of numbers of shelducks on the bay was as follows:

(a) that the amount of mud in the bay is fairly constant and with it the number of feeding places.

(b) that there are daily peaks of availability of food when there is the right depth of water over food-rich mud, and only then can the birds feed really efficiently.

(c) that competition for feeding space at a good place at the main feeding time, sets a maximum to the number of resident birds in the bay, with competition occuring through aggressive interactions.

(d) that in January these interactions are at a relatively low level, usually strong enough to exclude potential colonists above a ceiling population, but allowing residents to feed on the rich mud area. From February onwards, interactions become more pronounced around feeding time so that at low water the less dominant birds are excluded from the mud.

(e) that at first these more submissive birds returned around high tide to feed on biologically poorer areas where competition for food was not so fierce. But as the aggressive level of the dominant residents continues to increase through March-April and these birds disperse in territories over the whole of the inner bay, including the silt as well as the mud, the submissive residents are eventually excluded from the silt as well. They are then confined to neutral areas or leave the bay altogether. Whether they stay may depend on whether alternative feeding areas are available.

This hypothesis requires the existence of a dominance hierarchy similar to Carrick's (1972) description of hierarchies in Royal Penguins (Eudyptes chrysolophus schlegeli Finsch) and silver gull (Larus notachollandiae Stephens). In these species the individuals that fed best also bred best and feeding dominance and an efficient time-energy budget were essential pre-determinants of breeding status and successful competition for good breeding sites. Changes in social position (i.e. from transient to non-territorial to breeder or vice versa) of an individual shelduck between (or within) years, should, therefore, be correlated with changes in the bird's (or its mate's) position in the dominance hierarchy.

Young (1964) suggested a classification of shelduck types on the Ythan Estuary during the breeding season, similar to that of Jenkins at Aberlady. He proposed the Ythan Population could be divided into two components:

(a) territorial pairs which occupied discrete and mutually exclusive areas of the intertidal zone (similar to b(ii) of Jenkins).

(b) a surplus flock excluded from the areas occupied by territorial pairs (similar to b(i) of Jenkins).

The numbers of pairs holding territories remained relatively constant from year to year in both the Ythan population (Young 1964, Williams 1973) and at Aberlady (Jenkins et al. 1975). Young claimed that if territory holders were removed, their vacated areas were quickly occupied by members of the surplus flock. His findings were criticised by Williams (1973) who said that Young had only shown this to occur during April, before all the possible territory sites could have been occupied (since some birds did not arrive until then). When Williams repeated this experiment during May there was no replacement of missing territorial pairs. Young also suggested the constancy in the number of territories was indicative of the Ythan Estuary being fully utilised by shelduck and concluded the breeding population was limited by territorial behaviour. However, Williams (1973) argued that territorial behaviour had not been shown to limit breeding output in the Ythan shelduck population and suggested the three main factors affecting output were nest failure, high duckling mortality and losses from fledging to the time of recruitment into the breeding population. To maintain the breeding population at its relatively constant level, he suggested that there must have been recruitment from birds reared elsewhere. Patterson (unpublished in Williams 1973) showed that first year birds and failed breeders prospected for nest burrows in the dunes and may induce desertion of nests.

A large proportion of shelducks may fail to breed or lose their eggs (Boase 1935) and the proportion of shelducks that breed is still controversial. Hori (1964) stated that all adults present during the breeding season attempted to breed. However, Young (1964), Williams (1973) and Jenkins et al. (1975) claimed that some adults, in the non-territorial flock, did not attempt to breed, though Tompa (unpublished in Williams 1973) disagreed.

To examine the validity of the above ideas, I studied the breeding behaviour and reproductive output of as many shelducks as possible on Aberlady Bay during the 1976 breeding season. Because many birds were individually colour-ringed, it was possible to trace their past history, their feeding sites on the bay, and in some cases their reproductive performance in previous years.

MATERIALS AND METHODS

2.1 STUDY AREA

Aberlady Bay (Figure I) is the tidal estuary of the Peffer Burn which flows north-west into the Firth of Forth, about 20 km east of Edinburgh. The estuary (Figure II) is 2.8 km long and up to 2.7 km wide. The upper estuary is muddy and holds some mussel (Mytilus edulis) beds, but near the sea the sediments are mostly sand. The inner shores are bounded by salt marsh, particularly on the north side where the marsh is extensive. To the west and east the coast is rocky or sandy with little mud. Roads and tracks run close to the shore along the entire length, so all parts of the area can be observed easily. On the north side of the estuary is Aberlady Nature Reserve, an area of dunes, salt marsh and calcareous grasslands. The dune system, on the seaward edge of the reserve, is composed of two major ridges running parallel to the coast from Gullane Point to the mouth of the estuary. The seaward edge of the dunes is mobile and sparsely covered with maram grass (Ammophilia arenaria). Towards the east this gradually changes to flat calcareous grasslands, with several stands of sea buckthorn (Hippophae rhamnoids). The whole reserve is completely separated from surrounding agricultural land by golf courses, which on the north side rise up on a ridge to 70 m above sea level. Rabbits (Oryctolagus cuniculus) were abundant in all areas and their burrows provided most of the shelduck nesting sites. Temporary and permanent pools occur in many of the dune valleys. To the east of the estuary lies mixed farmland which holds a few scattered pairs of nesting shelduck, especially at Drem Pools, two ponds dug for irrigation purposes.

2.2 COUNTS

Counts of the numbers of shelduck on the bay were made with a

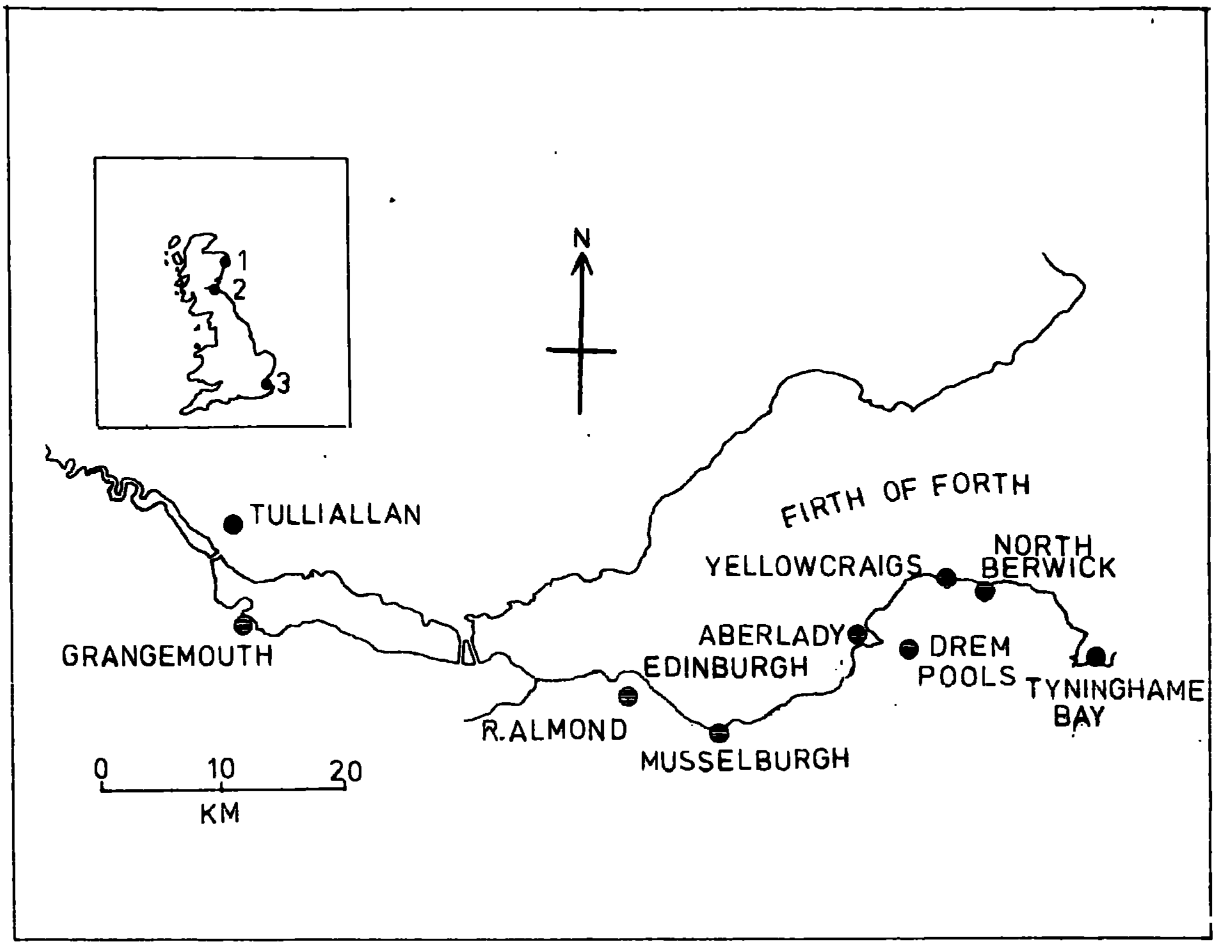

FIGURE I. The Firth of Forth (inset: places where research is being done on shelduck in England and Scotland. 1- R. Ythan, 2- Aberlady Bay, 3- Isle of Sheppey.)

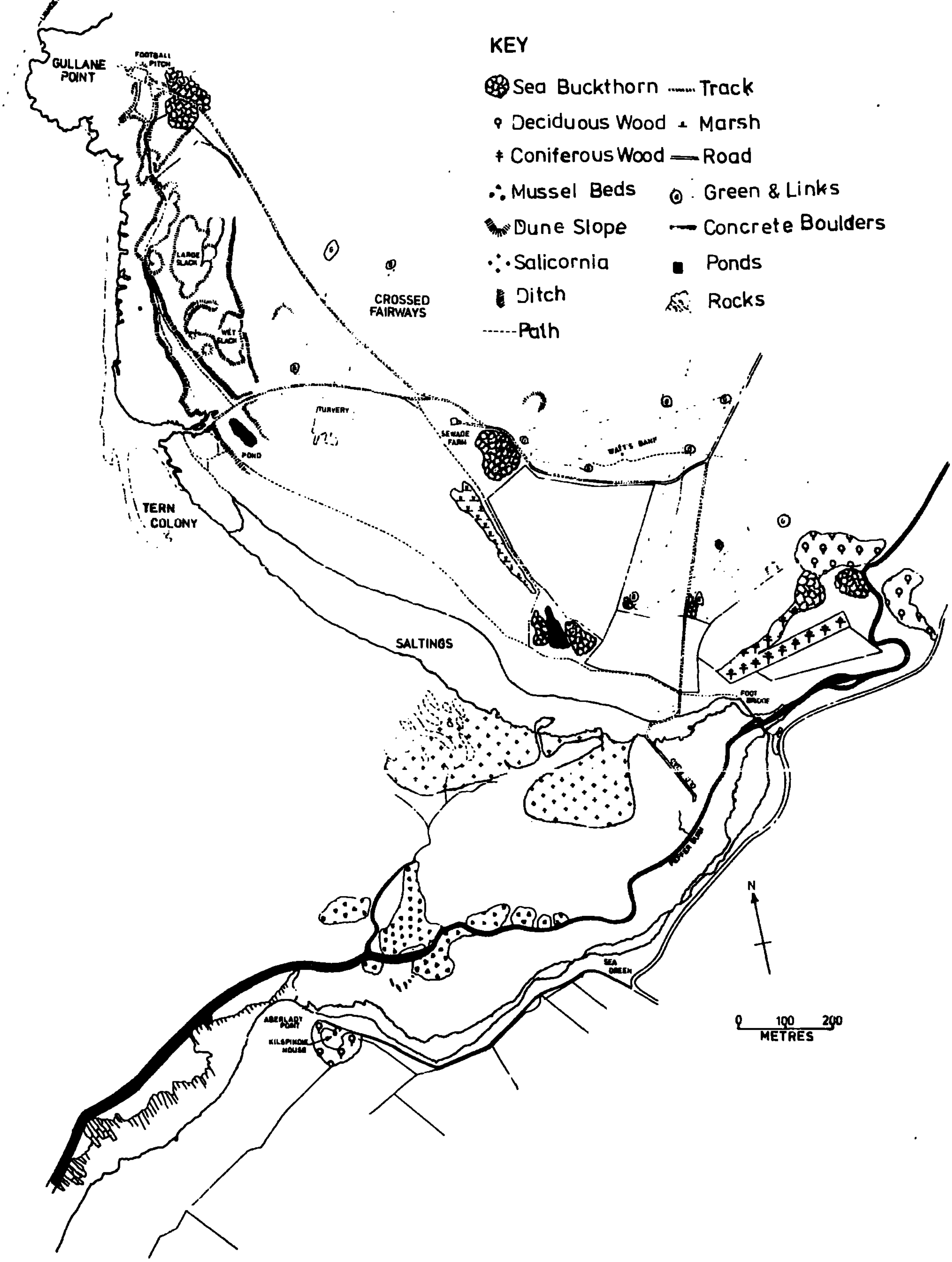

FIGURE II. Aberlady Bay

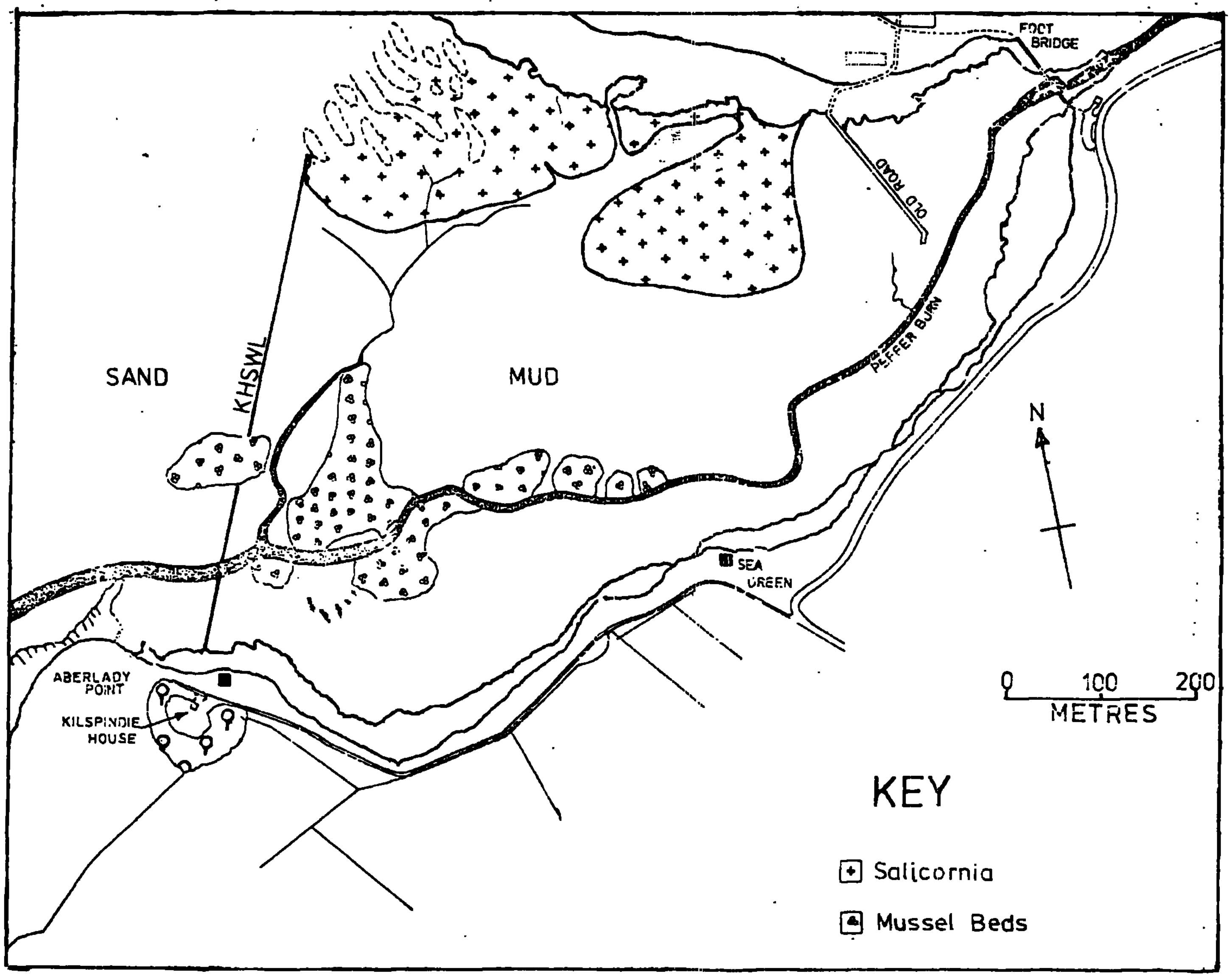

FIGURE III. Aberlady Bay, showing the Kilspindie House Sewage Works Line used to arbitrarily divide the bay into "mud" and "sandy" areas. Positions from where counts were made are also shown ( ).

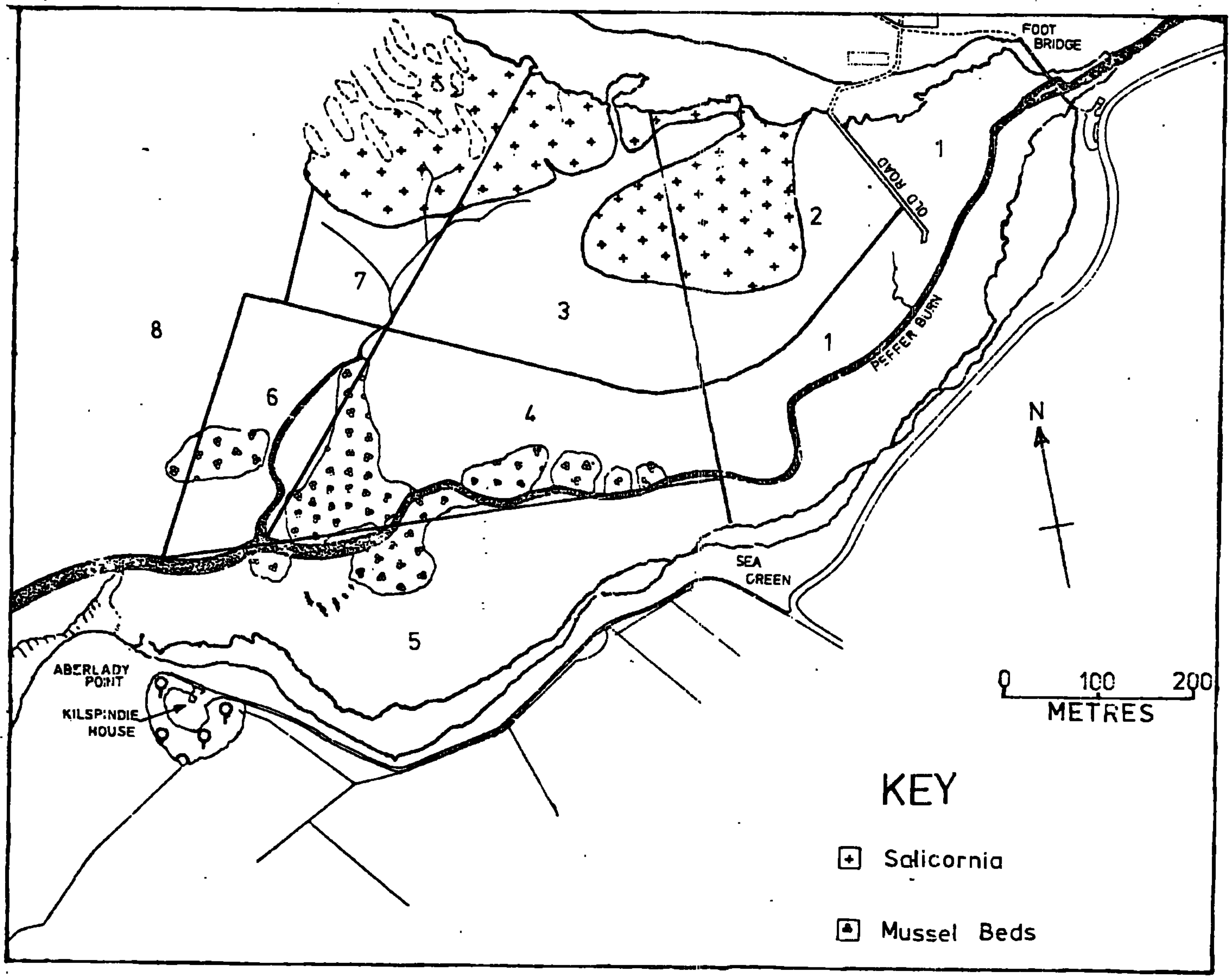

FIGURE IV. Aberlady Bay, showing the divisions of the bay used for detailed counts.

15-60x telescope and 10 x 50 binoculars from the positions shown in Figure III. There was little chance of ommissions or duplications because birds were not flushed and because nearly all parts of the bay could be seen within a few minutes. Counts were usually done twice on each occasion and varied by not more than 10%. Numbers on the "mud" and "sand" were counted separately using an arbitrary dividing line between Kilspindie House and the sewage plant on the nature reserve (Figure III). More detailed counts of the number of shelduck in different parts of the bay were made using the areas shown in Figure IV. All counts were made within two hours of low water and during the afternoon, as some birds tended to remain in the dunes until late morning if not disturbed.

Aberlady was a popular place for bird watching at weekends but not much disturbed during the week. Disturbance caused the birds to move about within the bay. Consequently, weekend counts are omitted from analysis of the dispersion of birds within the bay.

After the end of May, when the first ducklings were brought onto the bay, counts were made of their numbers each day. Ducklings were also divided into the following age classes:

CLASS I	Downy, newly hatched ducklings, down patterns bright and distinct.
CLASS II	Down colour fading and patterns becoming less distinct. First feathers appear.
CLASS III	Face loses down cover. Predominantly feathered but incapable of flight.
CLASS IV	Young able to fly.

This classification is based on that used by Williams (1973) and is equivalent to his Classes I, II and III, IV, V respectively. His Classes II and III were amalgamated to form Class II in this study, because I found I could not separate them reliably, due partly to

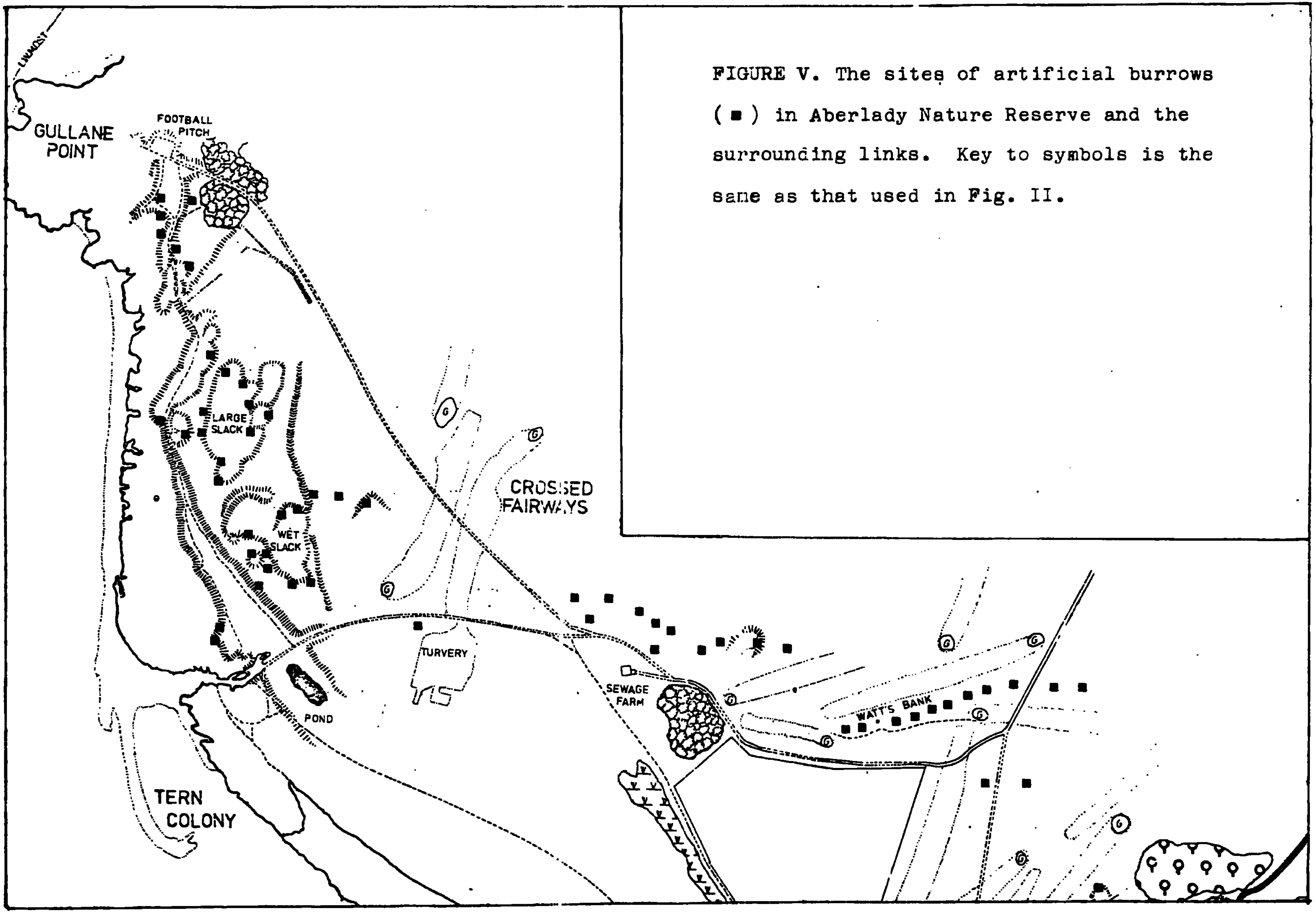

FIGURE V. The sites of artificial burrows (■) in Aberlady Nature Reserve and the surrounding links. Key to symbols is the same as that used in Fig. II.

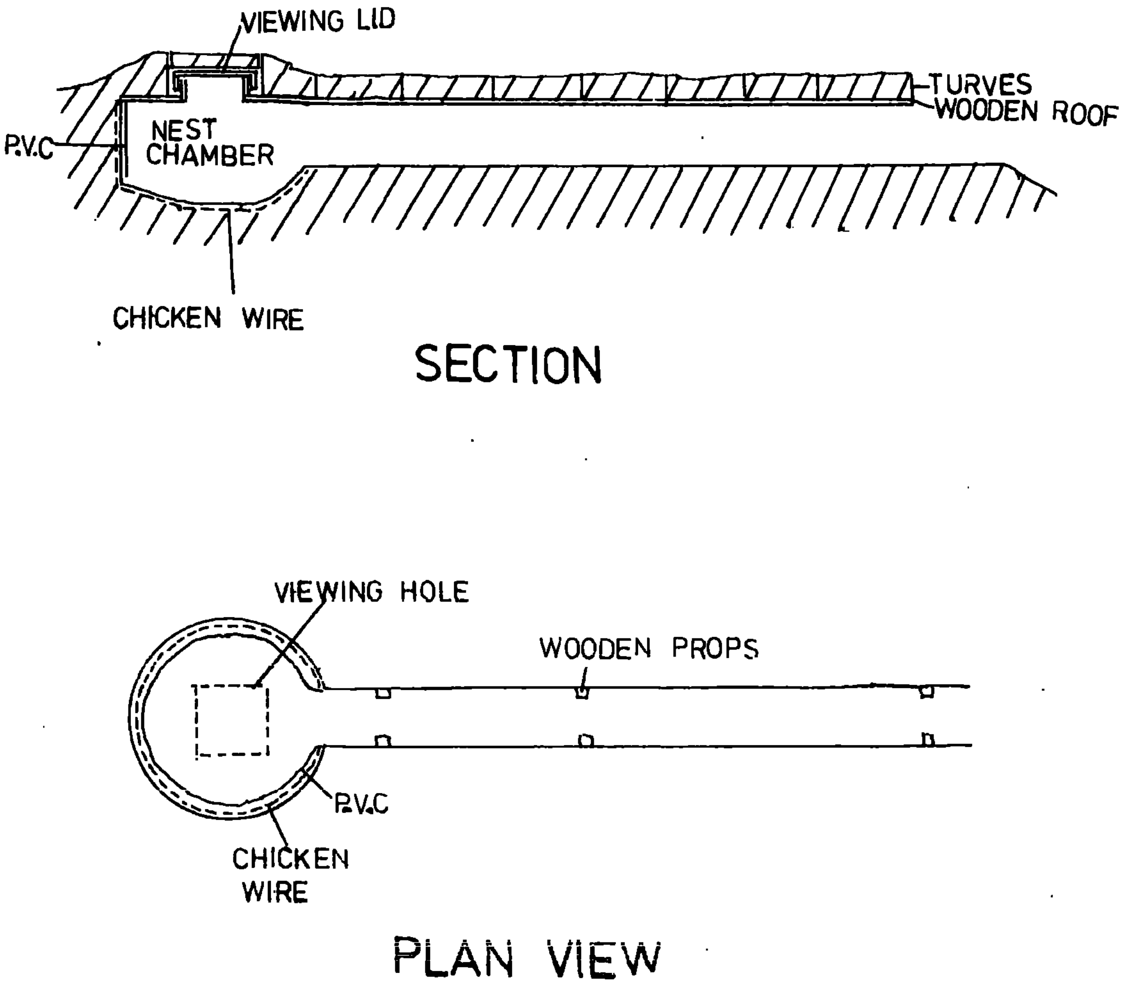

FIGURE VI. The design of artificial burrows.

inexperience and partly to poor visability during hot weather.

2.3 MARKING BIRDS

To enable identification of individual birds a proportion of the population had been colour-ringed. Some adults had been ringed as ducklings before fledging, others caught in early spring. (Ducklings were caught <u>en masse</u> in July, after they had been herded into an area surrounded by rabbit nets).

2.4 STUDY OF SHELDUCK BEHAVIOUR

When colour-ringed birds were identified, their position and activity were recorded on a map of the bay. Plotting was aided by a 100 x 100 m^2 grid staked out on the bay. Similar data were available from previous years.

The feeding ranges of individual pairs of shelduck were determined by plotting the location of the pair within two hours of high water on a map. The outermost points of the range were then connected forming a polygon, whose area was said to be the range of that pair.

Observations of nesting behaviour were made using a 15-60x telescope, either from the natural cover of the dunes or from a portable hide. Sixty-one artificial nest burrows were placed in the study area (Figure V). Figure VI shows the general design of the artificial burrows, though there was some variability between boxes, e.g. the entrance did not always lead directly to the nest chamber. Boxes were checked regularly for the onset of laying when the following information was collected:

1. Time of laying (date and time during day).
2. Weight, length and maximum breadth of each egg.
3. Identity of laying duck.
4. General activities associated with nest building.
5. Length of incubation.

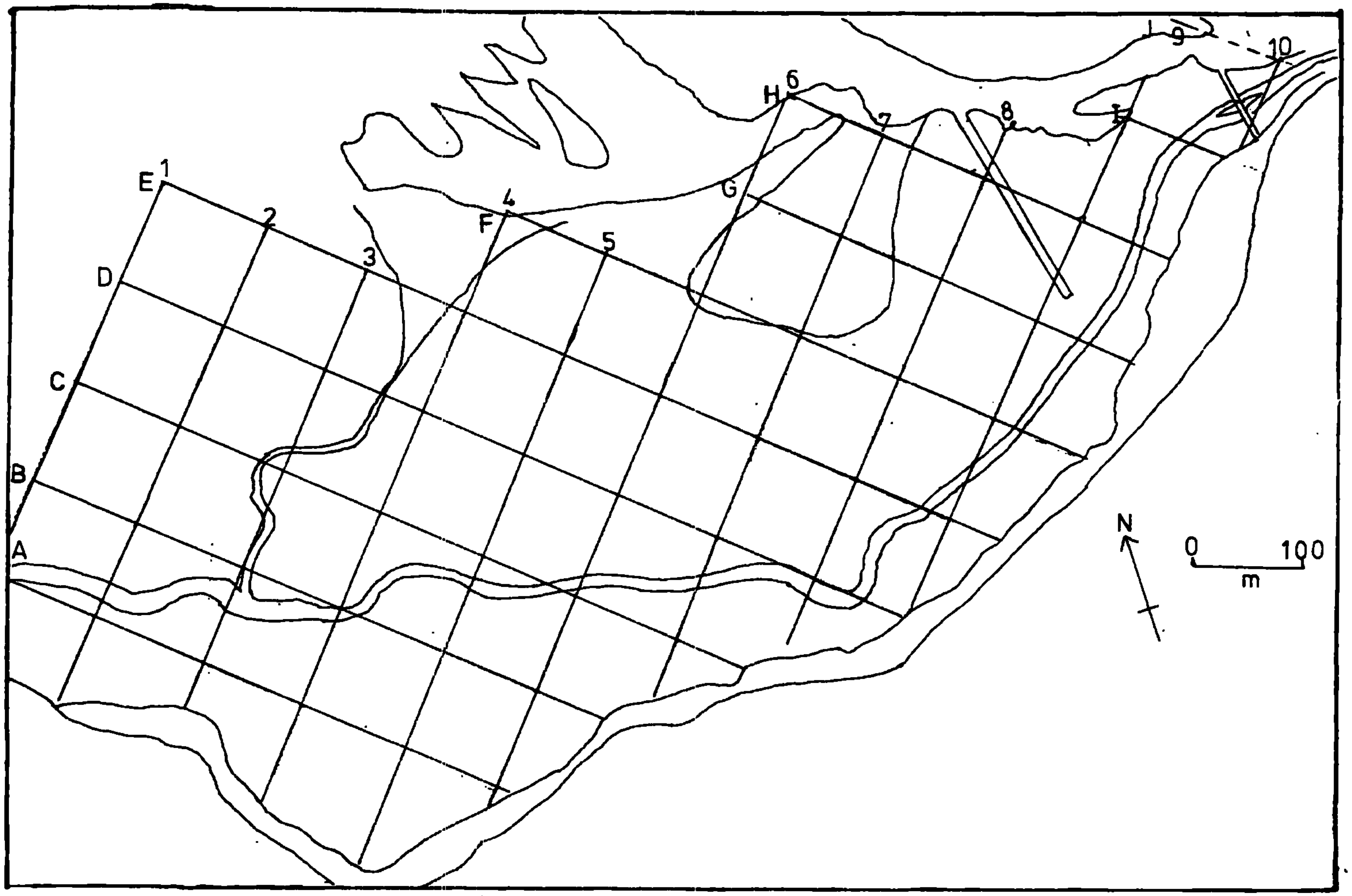

FIGURE VIII. Grid system used in sampling invertebrates in Aberlady Bay.

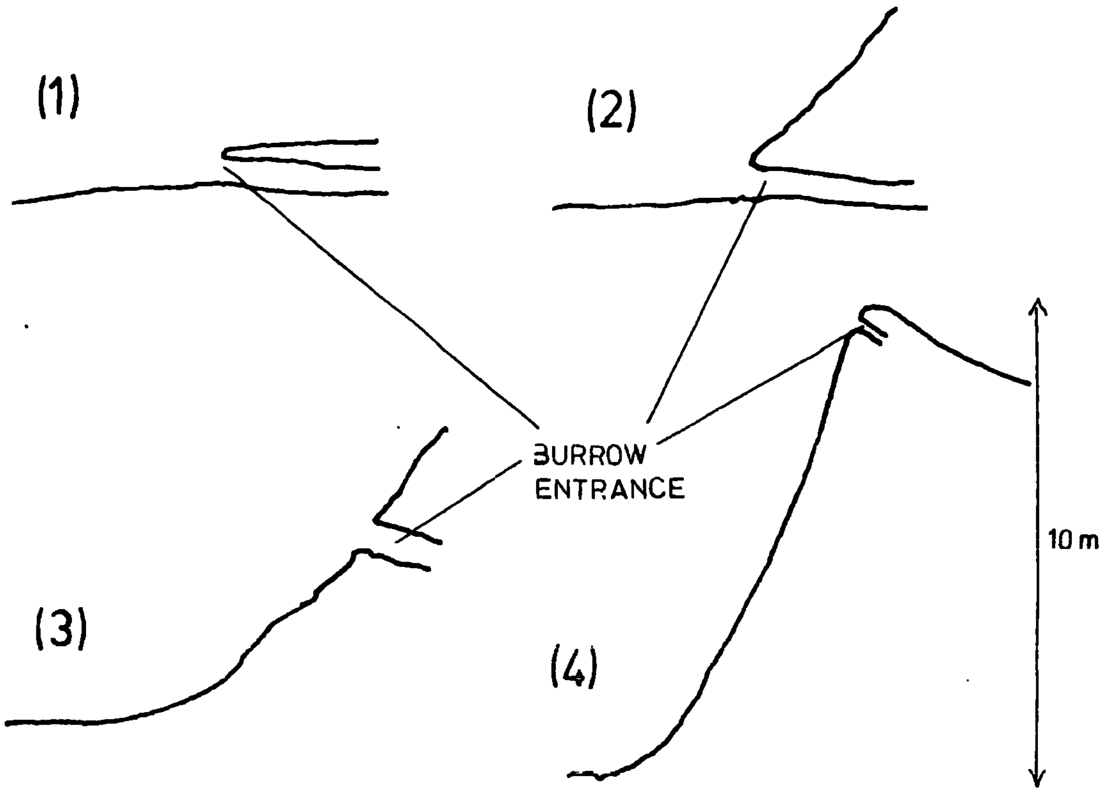

FIGURE VII. Grades of slope (1-4) surrounding natural nest entrances.

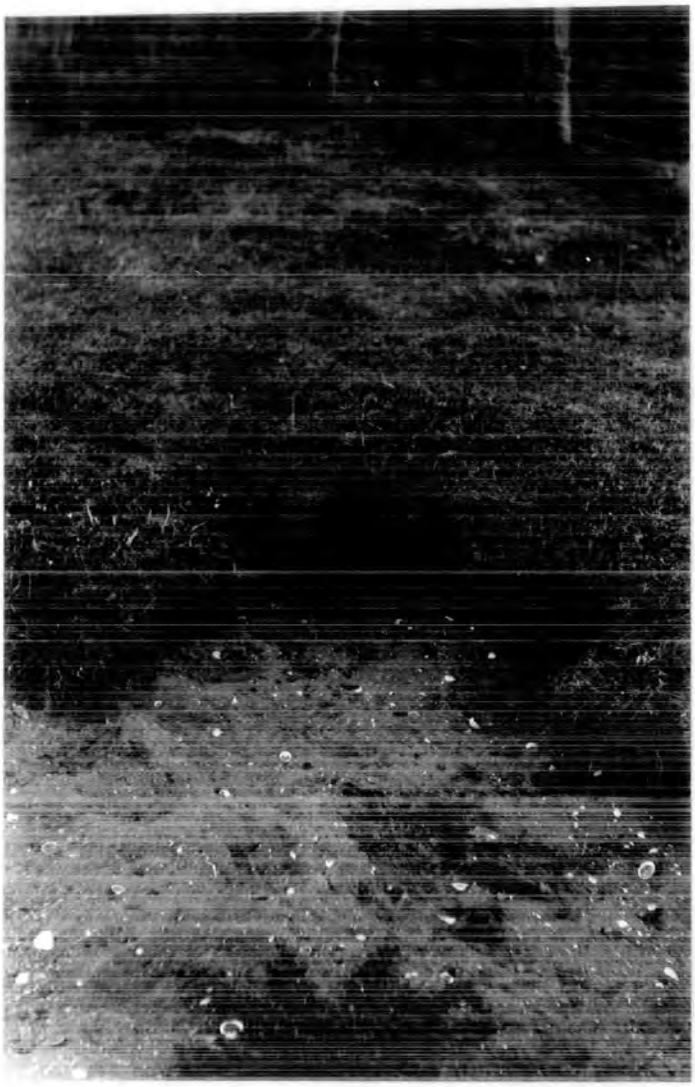

PLATE I. Cover value around natural nest entrance Grade +.

PLATE II. Cover value around natural nest entrance Grade ++.

PLATE III. Cover value around natural nest entrance Grade +++.

6. Hatching success and the amount of time spent in the nest by ducklings before being taken to the bay.

Natural nests were found by continuous observation, watching for males escorting females back to the nest burrow. The presence of down or webbed foot marks at a burrow entrance also indicated a nest burrow in use, though it was not positively identified as such unless a female was seen to enter, preferably more than once.

2.5 NEST SITE SELECTION

Once found, nest sites were compared to identify possible factors influencing nest site selection. These were as follows:

1. Aspect
   (a) Direction faced by burrow entrance
   (b) The degree of slope surrounding the burrow (Figure VII).
   (c) General cover i.e. was it a ridged area where the birds could disappear from view before entering the burrow?
2. Description of burrow
   (a) Amount of cover around nest entrance. This was graded from + to +++ (Plates I-III).
   (b) General dimensions of the burrow.
   (c) Number of possible entrances.
3. Distance of nest from feeding area.

2.6 FOOD AVAILABILITY

Shelduck are known to eat a variety of invertebrates including <u>Hydrobia ulvae</u> (Olney 1965). The distributions of invertebrates were assessed on the bay by means of a 100 x 100 m grid sampling system, shown in Figure VIII. Two 1 km^3 samples were taken at each point of the grid. Samples were then sieved using a 1 mm mesh sieve and the animals so retained were returned to the laboratory for sorting and counting.

NESTING

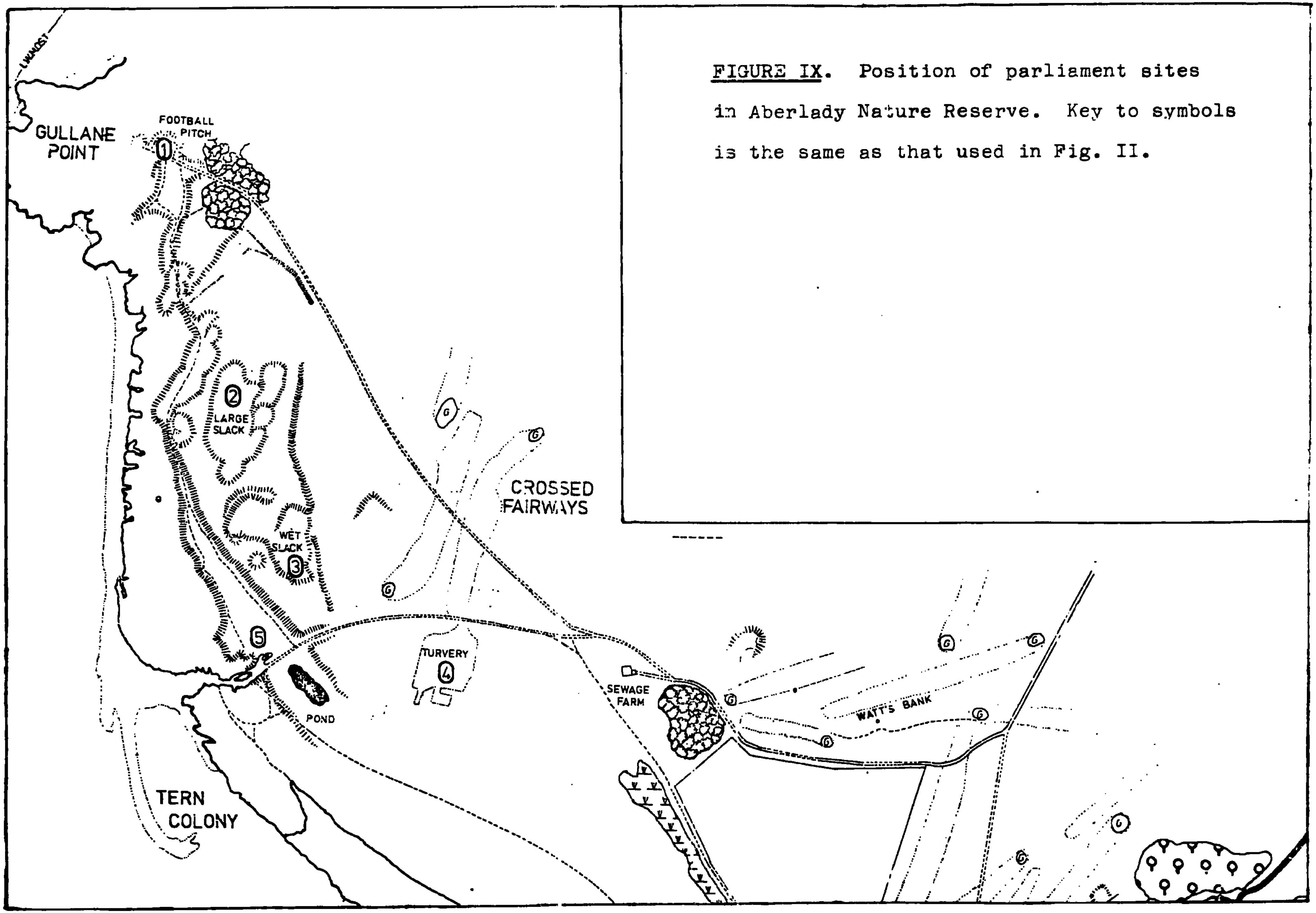

FIGURE IX. Position of parliament sites in Aberlady Nature Reserve. Key to symbols is the same as that used in Fig. II.

TABLE I. Parliament sites at which known birds were seen. Where shelduck were seen at more than one site * marks their main parliament site.

Bird No.	Parliament Site 1	2	3	4	5
823				+	
827					+
840		+			
875					+
877			+ *	+	
879		+ *	+		
882			+		
893/967			+		
898			+		
809/904		+ *	+		
911			+		
925	+				
928		+			
929	+				
952			+		
957	+				
309		+			

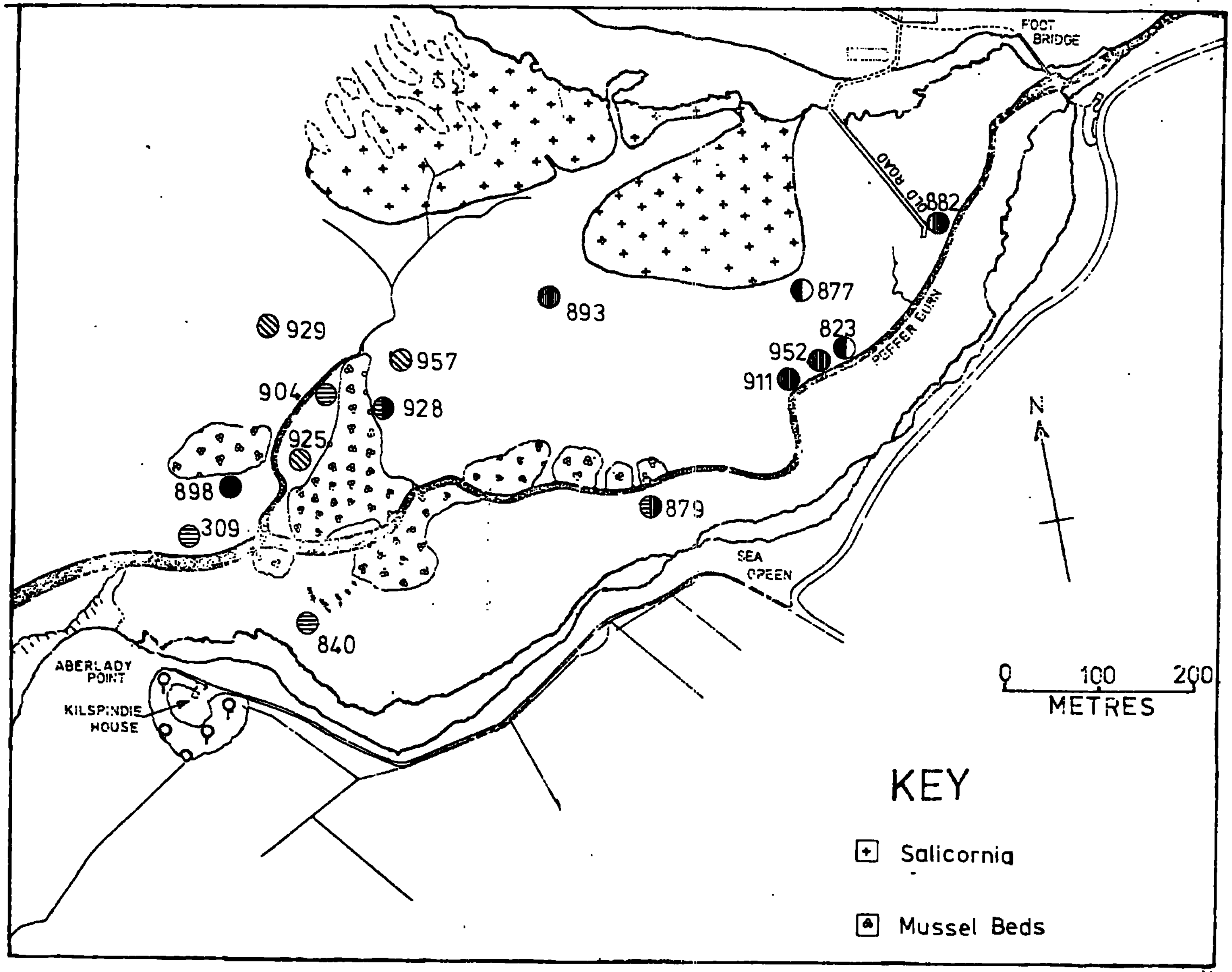

FIGURE X. The position of different shelduck feeding areas, showing which parliament site they were seen at.

Site 1 ⊘ , Site 2 ⊜

Site 3 ● , Site 4 ○

The position of these parliament sites are shown in Fig. IX.

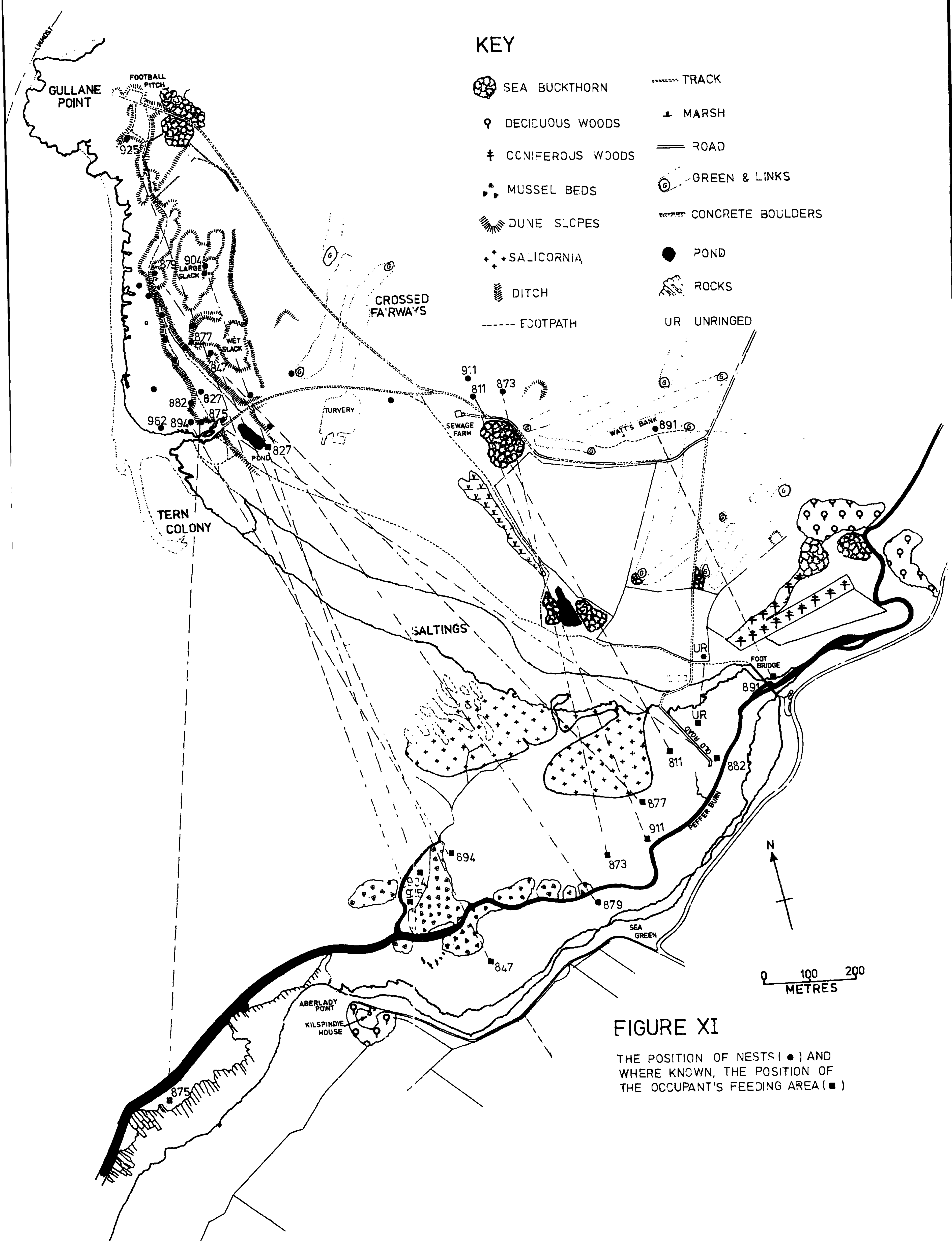

FIGURE XI

THE POSITION OF NESTS (●) AND WHERE KNOWN, THE POSITION OF THE OCCUPANT'S FEEDING AREA (■)

3.1 HOW DO SHELDUCKS CHOOSE THEIR NEST SITE

From late February onwards pairs of shelduck leave the bay early in the morning to prospect for nest burrows, mainly in Gullane Links and Dunes (Jenkins et al. 1975). My observations in the dunes from mid-April to mid-May showed birds to congregate regularly in groups of up to 17 in certain places. Young (1970) called similar groups, found in the Sands of Forvie, 'parliaments'. Their distribution at Aberlady is shown in Figure II. Birds were seen in other areas but usually in smaller numbers. Prospecting for nest sites was seen to occur either in groups, where birds would sometimes 'queue up' to inspect a possible nest site, or in single pairs.

Birds were seen regularly at the same parliament site and the occurrence of particular birds are shown in Table I. Further comparison shows that birds seen at the same parliament site had feeding areas near to each other in the bay (Figure X). Also, in general, birds seen at parliament sites in the southern part of the dunes or east of this area fed further into the bay than birds found in the northern part of the dunes. Birds also nested near their parliament site, distances varying between 43 and 1,298 m with a mean of 122±72 m.

The regular use of a parliament site by an individual bird has also been observed by Hori (1964) at the Isle of Sheppey and Young (1970) at the Ythan Estuary. Hori called his groups of birds 'communes' and claimed that the association between groups of pairs could persist throughout incubation. Also, as at Aberlady, Hori stated that pairs forming each 'commune' had neighbouring feeding areas.

Figure XI shows the position of nests in the study area and where known the position of their owner's feeding area in the bay (or elsewhere). This suggests that the position of the feeding area in the bay affects the choice of nesting area, the further out in the bay a bird feeds,

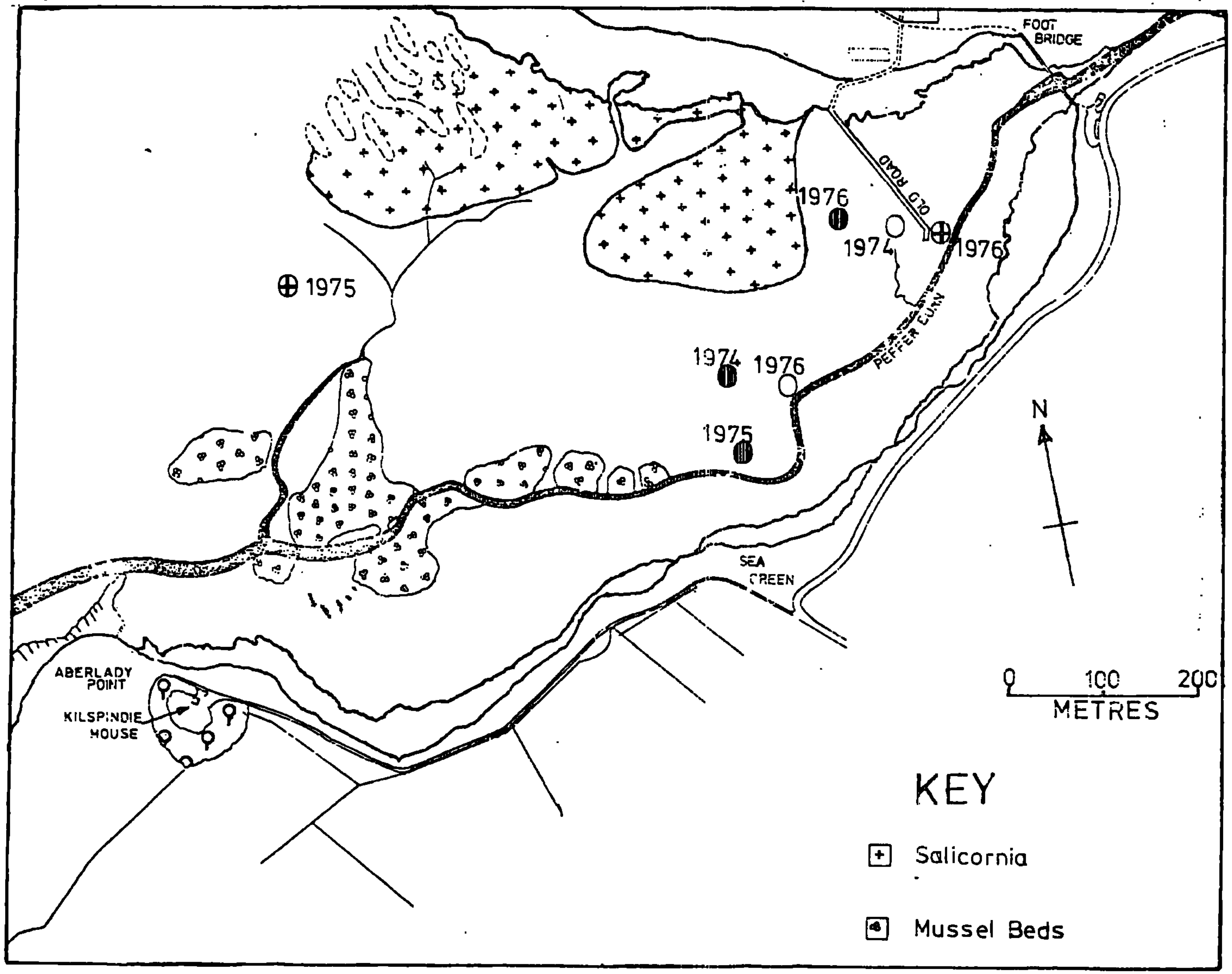

FIGURE XII. The position of different birds feeding areas between 1974-1976. Bird no. 811 ⬤, bird no. 882 ⊕, bird no. 911 ○.

TABLE II. Distance of pairs' feeding areas from their nest.

	Bird No.	Dist. from nest (m)	$\bar{x}$	Total $\bar{x}$
RIGHT OF SEA GREEN	873	1212		
	811	1056		
	877	1732		
	891	762	1151±412	
	911	1368		
	882	1732		
	UR	199		
				1473±310
LEFT OF SEA GREEN	847	1818		
	875	1818		
	879	2078	1848±234	
	894	1368		
	809/904	1801		
	925	2208		

the more likely it is to nest in the dunes. This results in birds feeding well into the bay having shorter distances to travel between nest and feeding area (Table II). As the position of a pairs parliament site appears to affect their choice of nest site the above effect may be secondary.

Williams (1973) suggested intraspecific disturbance at nest sites may be an important factor controlling the number of successful breeding birds at the Ythan. If this shown to be an important factor at Aberlady, then birds nesting in the dunes would probably be at a disadvantage, as the majority of shelduck moving inland during the morning collect in this area and disturbance would seem more likely to occur here than elsewhere. It would appear, therefore, that the position of feeding areas may have often important consequences for a pair of breeding shelduck apart from the amount of food available.

3.2 DOES A CHANGE IN FEEDING AREA BETWEEN YEARS RESULT IN A CHANGE OF NEST SITE?

By using unpublished data from Armstrong (1974) and Sutherland, Court and Wood (p.com) it is possible to show the position of feeding area and nest site for pairs of shelduck in different years. Bird no. 811 has nested near the sewage works for the last three years and comparison with the pair's feeding area during this period shows that although it moved slightly each year the general position of the bird in the bay has not changed (Figure XII).

Bird no. 911 nested in Watt's Bank in 1974 and fed near the old road (Figure XII), whereas in 1976 it fed near Sea Green and nested near the sewage works. Therefore, as would be expected from the hypothesis put forward in Section 3.1, a movement of feeding area towards the mouth of the bay resulted in a movement of nest site towards the dunes.

Bird no. 811, by nesting in the same area for three years, could merely be showing a high degree of nest site fidelity, rather than maintaining nest position in relation to its feeding area. Hori (1969) showed remarkable examples of nest site fidelity by shelduck at the Isle of Sheppey, and work on other hole nesting ducks has shown similar tendencies (Siren 1957; Eskins 1961; Bellrose et al. 1964).

Bird no. 882's feeding area was near the mouth of the bay in 1975 and is presumed not to have bred (Court and Wood p.com). In 1976 this pair's feeding area had moved much further into the bay (Figure XII). However, they nested in the dunes rather than east of Crossed Fairways as would have been expected. Similarly bird no. 877 attempted to breed (unsuccessfully) in 1976 and chose a nest site in the dunes, though the pairs feeding area was well up the bay (Figure XI). However, this bird was seen prospecting east of the Wet Slack suggesting some attempt had been made to nest outside the dune system.

Jenkins et al. (1975) showed evidence for a shortage of nest sites east of Crossed Fairways but not in the dunes. It is possible, therefore, that some intraspecific competition for nest sites may have occurred east of Crossed Fairways, and as inexperienced breeders, both 877 and 882 failed to establish nests in this area.

Data are sparse at present and more information concerning feeding areas and nest sites are required, especially for birds that move their feeding areas between years.

3.3 WHAT IS WRONG WITH THE BOXES?

During the breeding season in 1976 only 4 out of the 61 artificial nest burrows were used. To try to identify possible reasons for the

TABLE III. Description of natural nest sites.

Direction faced by nest	Surrounding slope	Ridged or Flat area	Cover of nest entrance	Dist. of nest chamber from entrance	Ht. of nest chamber (cm)	Depth of soil above (cm)	Surrounding vegetation	Sand at entrance ?	No. of entrances
SW	1	F	+	1.2	20	20	G	+	2
W	1	F	++	2.4			G	+	2
NE	1	R	++				M	+	2
N	2	R	+++	1.7	20	10	G	+	>2
NW	1	R	+++	1.7	25	20	G	-	>2
SE	2	R	+++	1.4	30	25	G/M	+	2
SW	2	R	++	1.4	35	30	G/M	+	>2
SE	2	R	++	1.4			G/M	+	2
SE	2	R	+++				M/G	+	
ENE	2	R	+++	1.7			M/G	+	2
ENE	2	R	+++				V. mixed	+	
ENE	2	R	+				M/G	+	
S	4	R	++	1.9			M/G	+	3
SE	3	R	++	>1.0			M/G	+	2
E	3	R	++	>1.0			M/G	+	2
SE	4	R	++				M/G	+	2
SW	3	R	+				M/G	+	
ENE	2	R	+++				V. mixed	+	
E	2	R	+++				M	+	2
N	1	F	+				G	+	2
NE	3	R	++				M/G		

F- Flat; R- Ridged; G- Grass; M- Marram.

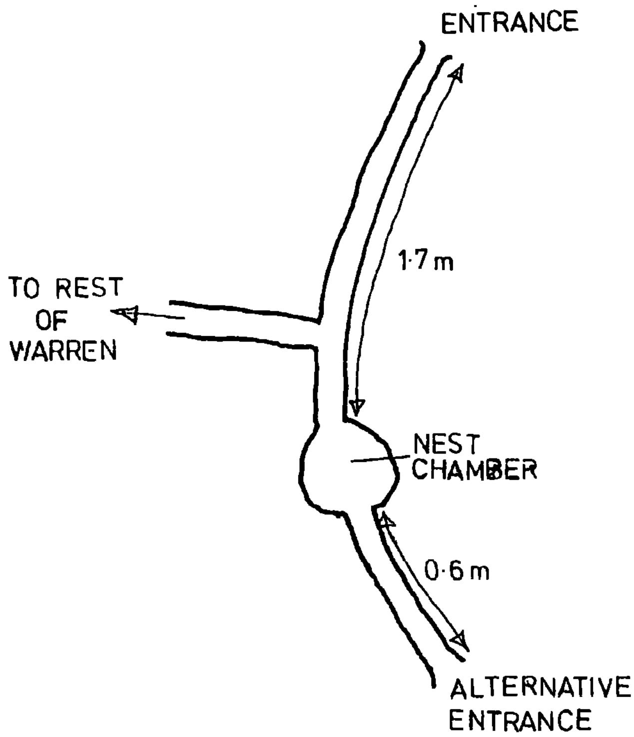

FIGURE XlII. A plan view of one of the natural nests found at Aberlady in 1976.

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sparse use, data were collected from natural nest sites to discover possible factors affecting nest site selection. These are summarised in Table III.

Most natural nests were found in Gullane Dunes and Links, and only one inland (in a haystack). By nesting in the dunes most birds had some cover while approaching the nest, since they could fly behind a dune ridge, before reaching the nest entrance. The amount of cover around the nest entrance also seemed important, 80% of natural nest entrances having cover values of ++ or +++ (see Plates I-III). In an extreme case, one bird used a burrow well covered by a wild rose bush (Rosaceae sp.) and brambles (Rubus fructiocosus). Another bird preferred a dense cover of Rosebay (Chamnaenon agustifolium). 76% of nest burrows were on some degree of slope (Grades 2-3 in Figure VII), some birds nesting near the top of dune ridges (approximately 10 m high). However most rabbit burrows occurred on slopes. Ease of entry could be an important factor in nest site selection, females sometimes flying into the burrow on their return.

During observations of natural nests it was found that shelduck generally used only one entrance. Two entrances used by bird no. 827 were later shown to join just underneath the surface. On closer examination of nest burrows, most were found to have two tunnels leading from the nest chamber and usually more than one possible exit (Figure XIII). In 33% of natural nests the alternative exit was found to be a small opening not large enough for a shelduck to pass through, though feathers were found around some, indicating a shelduck had possibly attempted to use one to leave the burrow.

71% of nest entrances faced within the first 180^{o} of the compass between north and south (the direction of the bay from the nest) and may indicate a possible preferance for an easterly facing exit.

(No data are available on the direction faced by rabbit burrows).

Nest chambers were always more than a metre from the nest entrance, the farthest being 2.4 m. Depth of soil over the chamber was usually greater than 20 cm and probably significantly deeper in burrows entering a slope. (Collapse of burrows while digging them out prevented measurement of most nest chambers and some burrows were too deep to dig out without damaging the dune flora). The vegetation surrounding the nest site was usually a mixture of maram and grass (57% of burrows). No nests were found in the flatter more exposed areas of the dunes dominated by lichens and mosses. Sand was found at burrow entrances in all but one case and may help the bird to identify the position of the nest from the air.

Nest boxes did not satisfy most of the criteria that seem to be required for a good nest site. General cover was good only for the boxes in the dunes. However, local cover in all the boxes was poor, only 10 out of the 61 boxes having nest entrance cover values greater than +, and 4 out of these 10 had nests in them. Perhaps the most important feature missing from the nest boxes was the complexity of the tunnel system leading to the nest chamber. This could be in terms of the number of entrances to the system as a whole, though this seems unlikely as birds were only seen to use one entrance and some of the alternative entrances were too small for shelduck to pass through. Hori (1964) suggested that incubating females used an escape tunnel to hide in when danger threatened. Various observations at natural nests and nest boxes at Aberlady supported this theory. One female (the mate of bird no. 873) was extremely timid and flew out of the nest merely at the approach of a human observer. However, in a different box where rabbits had dug out a new tunnel leading from the entrance tunnel, the female there (no. 811) was difficult to disturb, usually

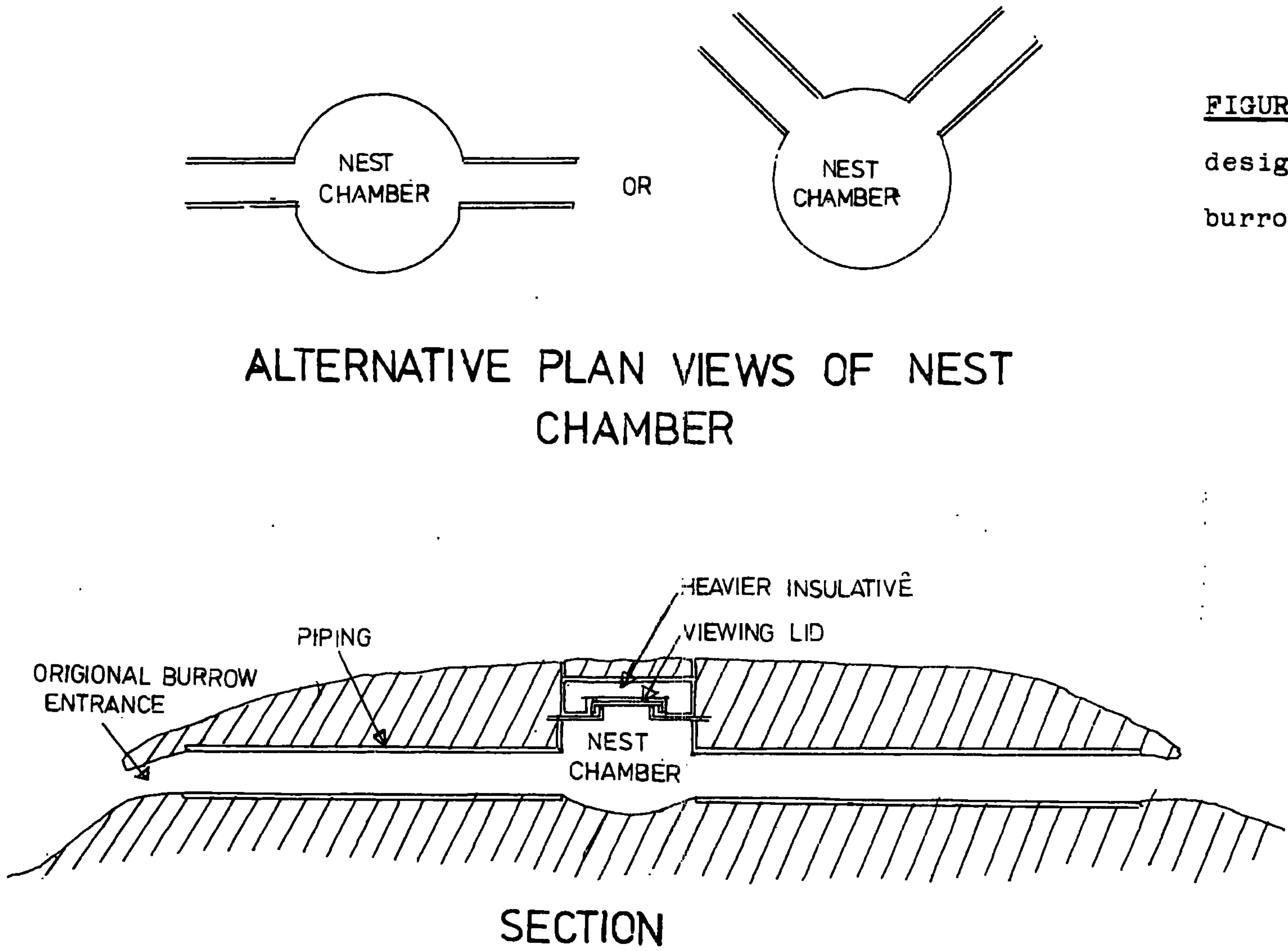


FIGURE XIIIa. Suggested new design for an artificial nest burrow.

hiding in the tunnel while the eggs were being inspected. Birds in natural nests were rarely frightened off the nests, except in two cases. Both these birds had very simple tunnel systems leading to their nest chamber, one just being a straight tunnel with the nest chamber in it.

Another possible factor affecting choice of nest site is the depth of the chamber below the surface, usually being greater than 20 cm in natural nests. The boxes are at most 20 cm below the surface, resulting in poor 'insulation' from outside disturbance, both from the weather and physical disturbance. After heavy rain water probably leaked into the nest chamber.

A major problem in building artificial burrows is the damage caused by rabbits outside the breeding season. Their new tunnels leading off the artificial burrows may result in shelduck using these and finding a natural nest chamber rather than the artificial one. To help to prevent this, nest boxes were lined with chicken wire and P.V.C. or roofing felt, all of which may make the nest boxes too unatural.

A new nest box should be designed incorporating the following features:

1. At least two exits from the nest chamber
2. To be as deep as possible (though still shallow enough to reach for the eggs!)
3. To build them around old nests leaving as much of the old burrow as possible, especially the nest entrance

Figure XIIIa shows a possible new design for an artificial nest burrow. The tunnel could be constructed with earthenware piping which would be more "burrow-like", as well as being less susceptible to collapse and allowing growth of the sward over the top of it to make it more natural. (The turves tended to dry out on top of the wooden boxes and even if replaced, still created an unatural appearance). The nest chamber should be left as natural as possible and where possible should be the original chamber. To counteract any possibility of rabbit damage the tunnel entrances could be sealed and only opened from February to July (the breeding season).

LAYING, INCUBATION AND HATCHING

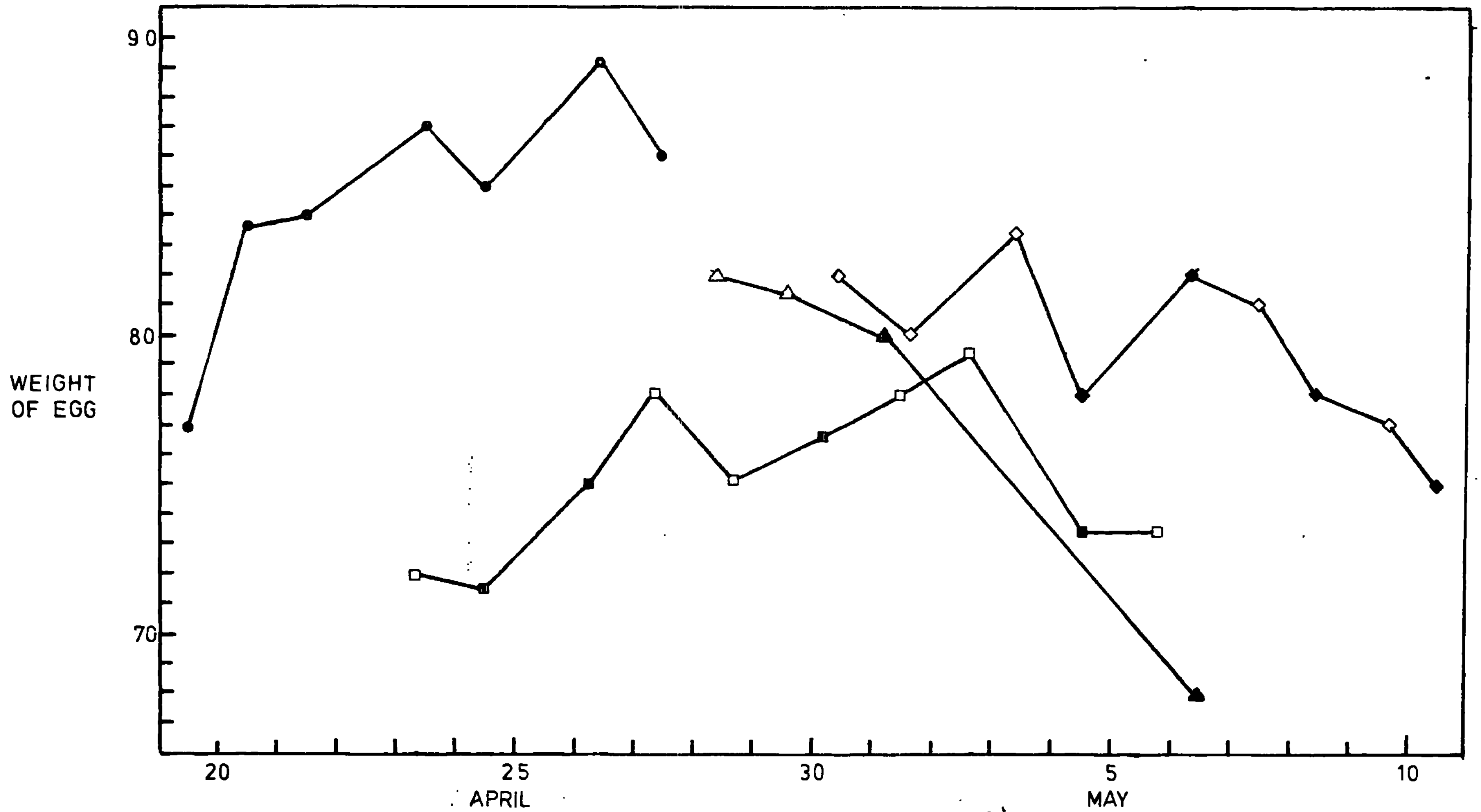


FIGURE XIV. The weight, date and time of day laid for eggs of shelduck using nest boxes at Aberlady in 1976. Shaded symbols represent estimated times of laying. (Bird no.811 □, bird no. 873's mate ○, bird no.891 ◇, bird no.911 △ .)

4.1 THE LAYING PERIOD

Only four shelduck used the artificial nest burrows during the study (possible reasons for this were discussed in the previous chapter).

Figure XIV shows the patterns of egg laying for each of the four birds in the nest boxes. The mean rate of egg production for the four birds was 0.63 eggs d^{-1}, but the intervals between laying were irregular for all the birds. Some shelduck managed to lay eggs on three consecutive days and one for five. However observations of the time of day when each egg was laid shows the probability of a laying rhythm greater than 24 h egg^{-1}. For example, the 6th, 7th and 8th eggs of bird no. 811 were laid sometime between first light and 0700 h, 1100 h and 1618 h respectively, giving a time interval of 29 h. By laying the sixth egg early in the morning, the bird was able to lay on three consecutive days but had to miss the next day, probably prefering not to lay at night (no birds were seen to lay later than 1900 h). 75% of eggs laid after a day was missed were heavier than the previous egg. Also 73% of eggs laid on the day immediately following were lighter than the previous one. This suggests that an interval of greater than 29 h between eggs enabled the female to produce a larger egg, possibly with more yolk, which would be an important factor for the survival of ducklings between hatching and taking in their first food (Kear 1964).

The most unusual laying pattern was that of bird no. 911. This bird followed the expected rhythm for the first three days but then failed to lay an egg for a further six days. No eggs were laid then for four days. However, between 11th May and 15th May, three more eggs were laid and the bird started to incubate. On the days this female failed to lay (2nd-6th May and 7th-11th May) she was seen at her feeding area and was extremely gravid and it was not known if the female laid in another nest during this period. It was also not known if she laid the final four eggs of the clutch, although this would seem likely as she incubated the clutch. When observed laying the second egg of her clutch, she was seen to enter the wrong burrow, remaining there for three minutes before emerging and eventually finding the correct one. This mistake may have resulted from the lack of sand outside her burrow entrance to help her to identify it from the air (see Section 3.3 for further discussion of this idea).

In all four boxes the first eggs were laid on bare sand and covered with a few pieces of dead moss or marram grass. The female started to cover eggs with down, two or three days before completion of the clutch. All clutches had a complete downy cover before the final egg was laid. Time spent in the box while laying varied between 25-75 min, females spending longer in the boxes as the clutch neared completion. This may be linked in part to down stripping. Weidman (1956) reported similar behaviour in mallards and suggested that slight warming may be needed for earlier eggs and a difference in the rate of development of early and late eggs may occur. This supported by Laughlin (pers. comm.) who found eggs in a mallard's clutch to be at different stages of incubation.

Hori (1964) stated that shelduck at Sheppey laid one egg each day, only failing to do so due to disturbance. This is unlikely to be the case at Aberlady where the bird that showed the best continuity of egg laying was nearest to a possible source of disturbance. (The possible effects of food availability will be discussed in a later chapter).

4.2 CLUTCH SIZE

Clutch size (two in natural nests, four in boxes) varied between seven and fifteen giving a mean value of 9.3±2.4. Jenkins et al. (1975) obtained a mean value of 11.7 for the period 1967 to 1973 at Aberlady and Hori (1964) determined an average clutch size of 10.1 (1962-63).

Nest parasitism, both intra and interspecific, is widespread in Anatids (Weller 1964). Hori (1964) was the first to report this for shelduck. Multiple nests on Sheppey contained between 14 and 25 eggs and represented 14% of known nests. Hori concluded that clutches of over 12 eggs were probably mixed. If this is assumed to be the case for Aberlady as well, then the mean clutch size for this study becomes 8.2±1.1 and for Jenkins' study it would be 9.7. Hori stated that, "a prospecting female will examine an incomplete clutch minutely and the attraction of such a nest appears to be considerable". The highest densities of birds at Aberlady were seen in the dunes and therefore nest parasitism would seem more likely to occur in this area. Jenkins et al. (1975) included clutches from the dunes when determining his value for mean clutch size (11.7). This may explain the difference between his value and that found for this study where the value was determined only from nests outside the dune area.

An alternative explanation for the occurrence of nest parasitism is a shortage of available nest sites. However this is unlikely to be true for Aberlady where Jenkins et al. (1975) showed a shortage to be likely only outside the dune system where few of the shelduck nested. Patterson (1974) working at the Ythan Estuary (a similar area to Aberlady), concluded the occurrence of nest parasitism there was low.

4.3 LAYING DATES

Except for nests in boxes, the date on which the first egg of a clutch was laid, was determined by backdating from the appearance of the broods on the bay, incorporating information on length of incubation etc.

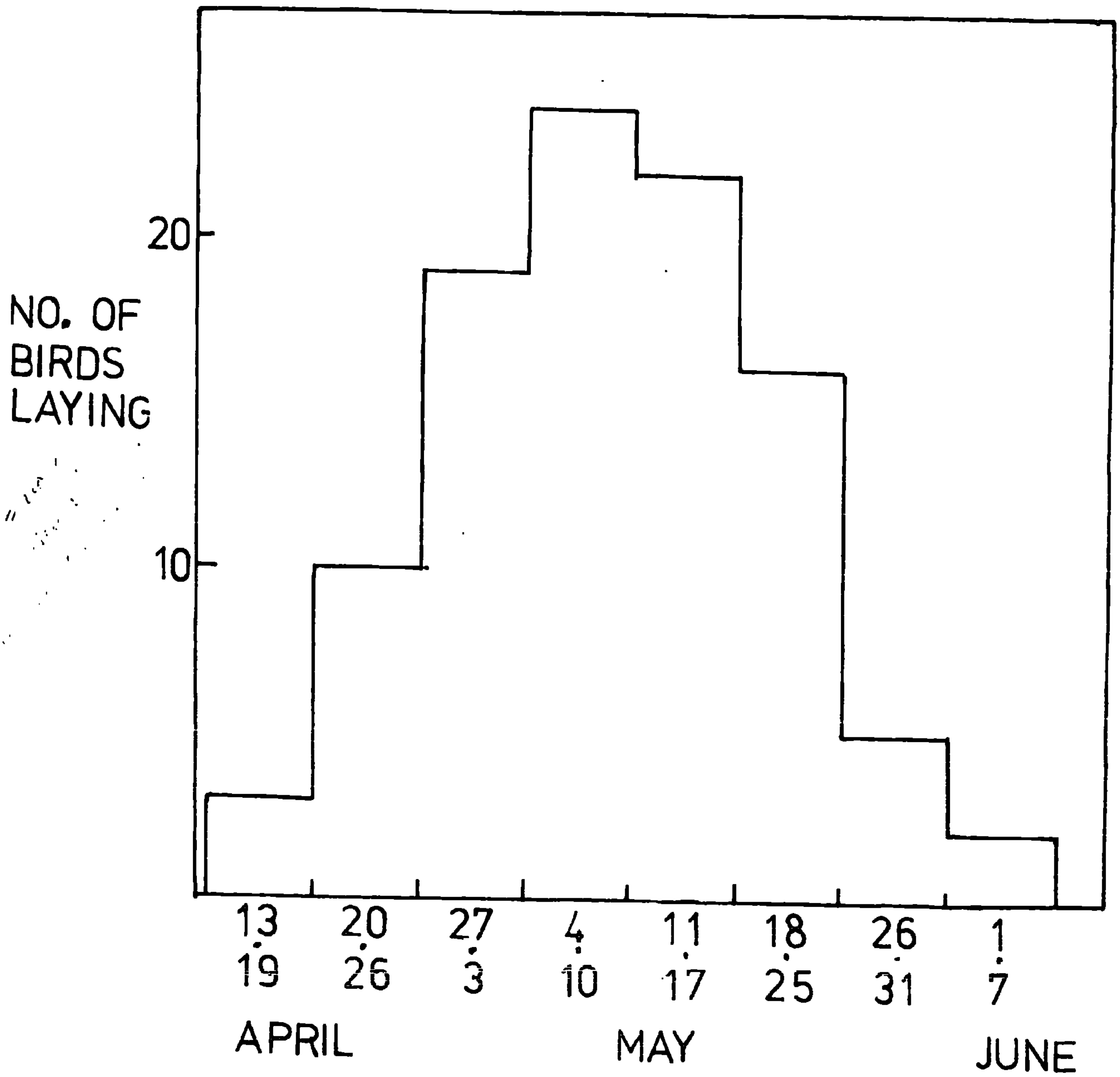


FIGURE XV. Number of shelduck laying between April and June, 1976, at Aberlady Bay. (Estimated by back-dating.)

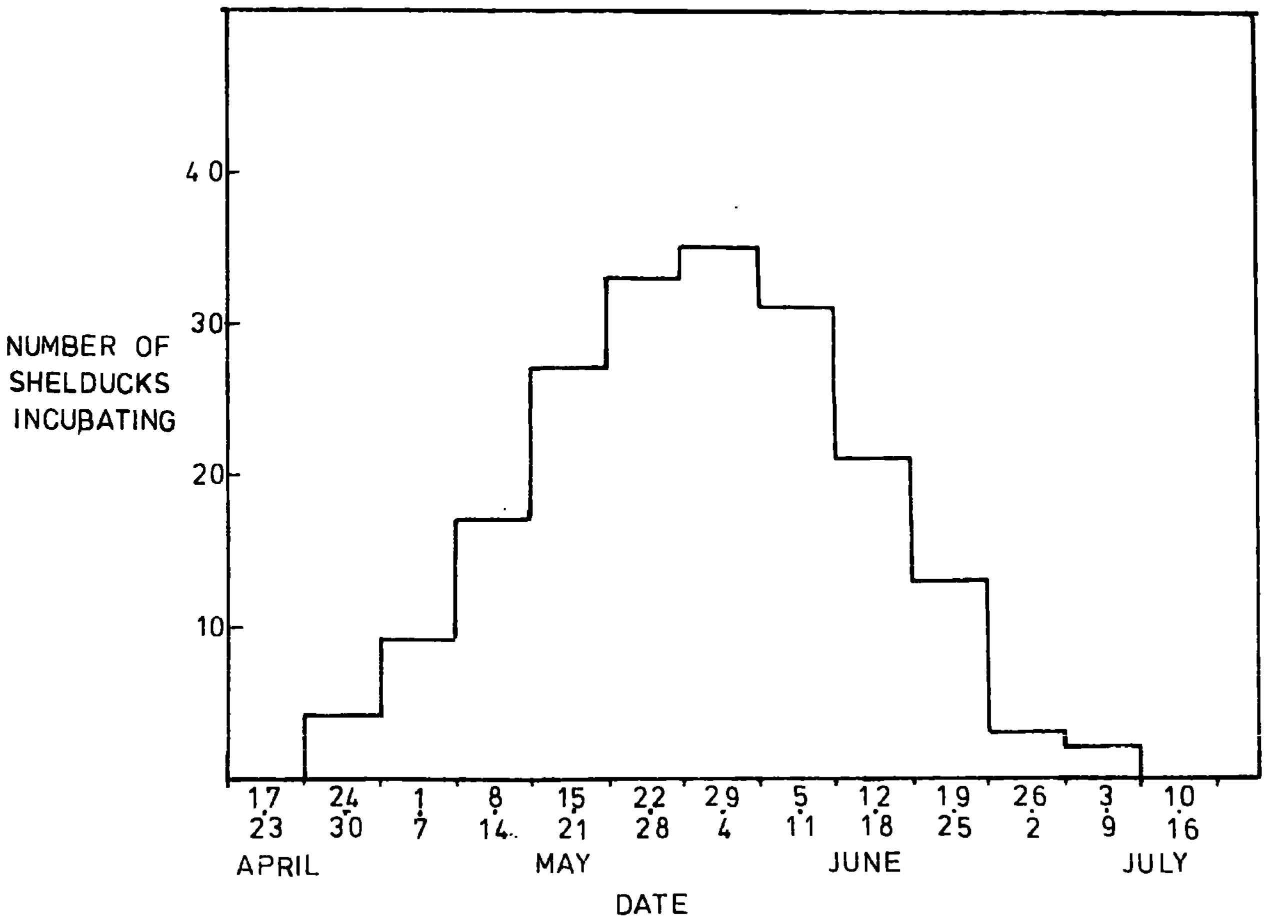


FIGURE XVI. Number of shelduck incubating between April and July, 1976, at Aberlady Bay. (Derived by backdating from the time of arrival of broods on the bay.)

determined during this study. There are several errors inherent in this method; young may not have been seen on the day they left the nest and the laying dates of successful pairs, estimated from the dates of appearance of their broods, may have differed from those of pairs that lost their eggs.

The first egg was alid about the 15th April and 50% of the females had completed their clutches by the second week in May (Figure XV). Laying continued until the 1st June. Hori (1964) found a laying period between 25th April and 19th June (1961-63) with the peak in laying in the second week in May. Patterson (1974) at the Ythan found a span of laying between 20th April and 12th June (1962-64). In all years at the Ythan and Sheppey laying tended to tail off slowly, whereas at Aberlady it appears to be relatively abrupt. At the Ythan this could be due to late arrivals of some pairs whereas at Aberlady all breeding pairs are present in March.

4.4 INCUBATION

The first bird started incubation on the 28th April and the last stopped on the 2nd July. Most shelduck were incubating during the first week in June (Figure XVI). The incubation period gave a mean value of 32.2 days (four observations). This compares with 28.1 days given by Hori (1964) for shelduck at the Isle of Sheppey. Incubation at Sheppey usually did not start until the first week in May and continued to the third week in July, peaking during the second and third week in June (Hori 1964).

During incubation ducks usually left the nest of their own accord (12 observations) although they were always escorted back to their nests by the drake. Ducks were seen to leave in response to calls from the drakes on only two occasions. Kingman and Leader (p.com) failed to witness this at all during all-day watches over the dunes, which supports my observations. When a drake called a female off the nest it circled low around the nest entrance and then on once occasion flew around waiting for the female to appear, and on the other, landed nearby in the West Slack. Some drakes seemed to wait at places other than their territory for females to leave the nest. Drake no. 904 was seen to wait for periods of up to 45 min in the West Slack. Eventually the female would arrive and they would fly down to the bay to feed. This drake was also seen to return to the Wet Slack after escorting the female to the nest. Throughout laying and incubation the female always flew off first with the male following her e.g., when leaving their feeding area to return to the nest.

4.5 HATCHING

The hatching period lasted for two days in all the boxes. Once all the eggs had hatched the ducklings remained in the nest for 24 h before being taken down to the bay. Hatching success varied from 80% to 100%. There was only one piece of direct evidence for desertion. This concerned bird no. 877 and his mate who were identified as having a nest in the dunes. One morning a group of seven shelduck were seen to show great interest in this nest site, some birds looking down the burrow, others (two females) actually entering it. (Unfortunately none of these birds were ringed). During this period the drake was at the nest entrance and sometimes tolerated the behaviour of the other birds, although on other occasions showed aggression either by posture or flying at the other birds. This pair were never seen with ducklings and no evidence for hatching was found at the nest sites. They were therefore presumed to have deserted for some reason, but whether it was due to the type of social interaction described above or to other factors is not known.

Examination of unhatched eggs showed the eggs to have either no

TABLE IV. Information on deserted eggs.

Bird No.	No. Unhatched	Stage of Development		
		No sign	Mid	Late
811	2	1(9)		1(3)
874	3			3
882	1			1
891	1	1(9)		
-	1			1
-	1	1		
-	6	6		

Numbers in brackets are the number of the egg in the clutch i.e., (3)= 3rd egg.

signs of development or to be very well developed; no eggs were found at intermediate stages of development. Details of the stages of egg development for deserted eggs are given in Table IV.

Kear (1964) showed that in mallard ducklings their only source of nourishment, during the period after hatching and before they fed, was the remains of their yolk. This is absorbed into the body just before hatching and then gradually released into the gut. The occurrence of deserted well-developed eggs could be explained by delayed hatching of these eggs for some reason, which resulted in the female leaving them in the nest when she took the hatched ducklings down to the bay.

Bird no. 911's 100% hatching success was remarkable, considering the time taken to lay the clutch (three of the eggs being left on damp sand for two weeks). Resistance to chilling has not been recorded for shelduck, but Matthews (1954) showed the eggs of many shearwaters to be resistant to chilling at all stages of development.

Only one predated nest was found, 9 out of the 15 eggs having been eaten. Weasels (Mustela nivalis), stoats (M. erminea) and the brown rat (Rattus norvegicus) were all common on the reserve, each one being the potential predator.

4.6 DEPARTURE FROM THE NEST

Ducklings were taken down to the bay by the parents early in the morning. Times ranged from 0400 h to 0940 h. Departure of the ducklings from the nest was seen on three occasions. In two of the cases the female left the box and went down to the bay to collect the drake. On arrival at the nest site the pair landed some distance away (50-200 m). The female then approached and entered the nest box, eventually bringing the ducklings out and joining the drake who by this time had moved to within 30 m of the burrow. The ducklings were then taken down to the bay by the most direct route. The third pair seen leaving the nest with their ducklings, although showing similar behaviour overall, demonstrated aspects of behaviour not seen in the other pairs. The female of this pair was particularly nervous, always very easily disturbed. On the expected day of departure by the ducklings from the nest, a watch was started at first light. By 0530 h no ducklings had been seen and the box was approached to see if ducklings could be heard within. Before reaching the box the female flew out, apparently disturbed, and went to the bay. She returned a few minutes later with two other females and a drake. These birds showed great interest in the box, looking down the entrance and also entering, whether the female was in there or not. The female, whose box this was, wandered in and out of the box quite frequently while the other shelduck were present. Three more shelduck arrived, two females and a drake (no. 873 the mate of the owner of the box), and also showed interest in the box. At this point a group of ten eiders walked towards the box and joined the group of shelduck around it, though only remained there a few minutes before flying away. This was followed a few minutes later by the departure of the shelduck around the box. Between 0730 h and 0800 h the female left the nest on several occasions to fetch her mate from the bay, who returned briefly with her to the nest each time but soon went back to the bay, a behaviour similar to that used during incubation. At 0830 h she made one of these journeys to the bay returning to the nest with her mate and another strange pair of shelduck (a male and a female). When they landed at the nest there was some aggression between the two drakes, followed by no. 873 walking away from the nest. The two drakes, and the strange female, then returned to the bay. The female who owned the nest then made further attempts to bring her mate to the nest site but each time the drake soon returned to the bay. Eventually at 0940 h the female took the ducklings to the bay by herself and met her mate in the saltings. Unfortunately the response of the male to the first sight of the brood was not seen. Two of the females that visited the nest during this behaviour were colour-ringed, and both were known to feed near the mout of the estuary and were thought to be non-breeders. The significance of these visits is not clear. However high tide was at 0645 h that morning and it seems likely that the visit of the female to the main shelduck roosting area in the saltings in search of her mate resulted in birds following her back to the nest site. Whether this was accidental or for other reasons it demonstrates a possible mechanism by which intraspecific interference could develop, one which might apply at any time during the breeding season.

4.7 NUMBER OF SHELDUCK PAIRS BREEDING

A total of 36 broods were brought onto Aberlady Bay in 1976. The parents of six of these broods were not resident in the bay i.e., they were not seen feeding in any part of the bay before arrival with their ducklings. Of the remainder, ten pairs were known to have fed both in the bay and nested in the nature reserve and eight were known to have fed in the bay and presumed to have nested in the nature reserve. The remaining twelve comprised unringed birds of unknown status (though one unringed pair were known to have nested successfully in the nature reserve and fed in the bay). In addition to these birds two pairs were known to have fed in the bay and nested in the reserve but were never seen with ducklings (though remains of hatched eggs were found at one of these nest sites). Another pair nested successfully in the dunes but took their ducklings to Musselburgh. Three other pairs were also believed to have attempted to breed (drake seen alone on their feeding area or the female was seen to be gravid). This gives a total of 42 breeding birds (39 of these with direct evidence of nesting) between North Berwick and

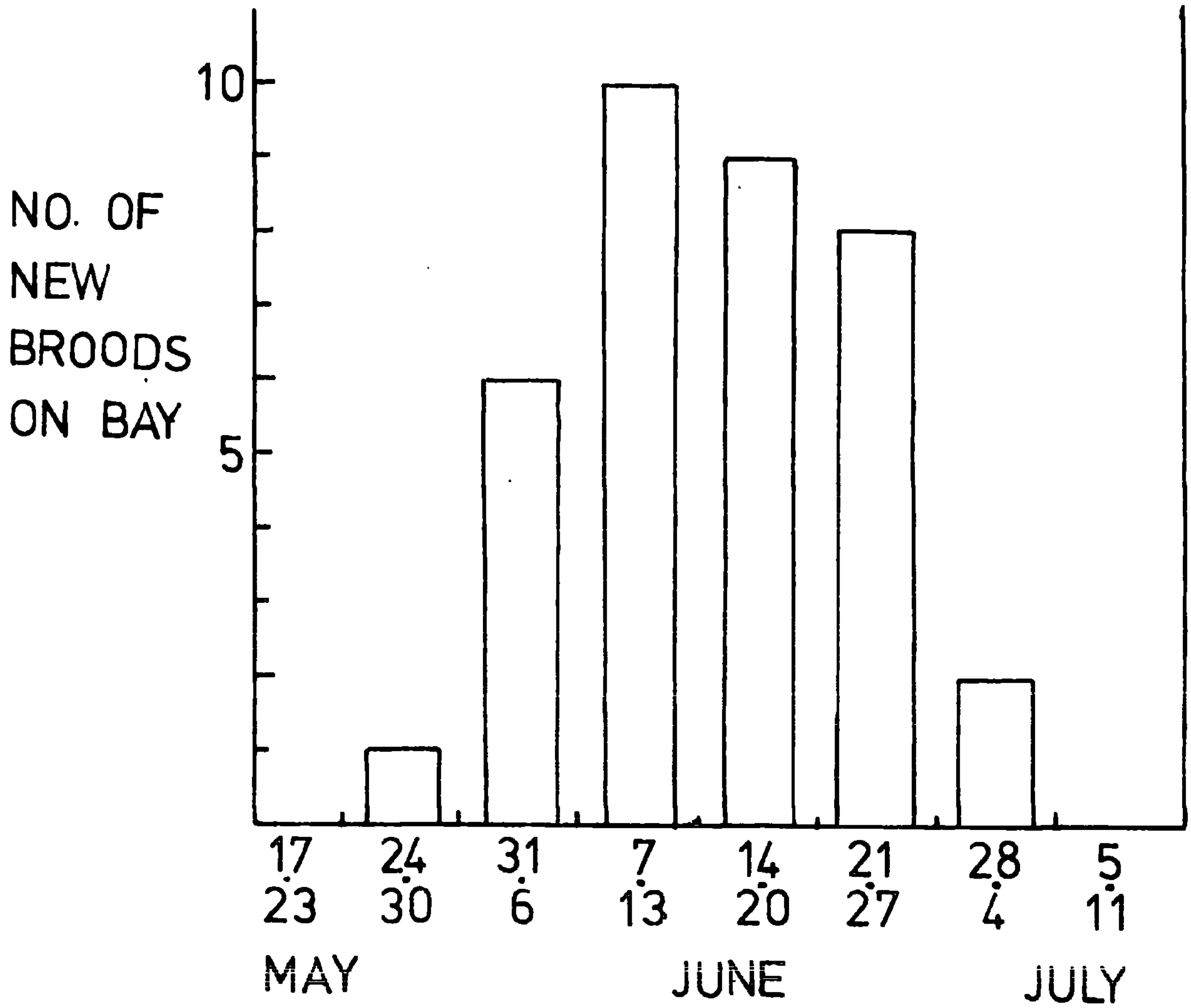
Musselburgh. This is probably a minimum estimate as birds with ducklings along the coast may not have been seen and other pairs may have attempted to breed but failed to hatch their clutch.

Only one ringed shelduck (bird no. 851) was seen inland with her mate at Drem pools. One nest was found inland in a haystack near Gullane, although it is not known if this belonged to bird no. 851. Another ringed pair (female no. 827) had a feeding area during incubation in the small pond near the tern colony (Figure XI).

Pairs that were known to breed successfully all fed inland of the Kilspindie House-Sewage Works line. However, three of these pairs did feed at sometimes during incubation to the seaward site of this line (although they also fed in more muddy areas of the bay). This would suggest that pairs may be able to breed if they fed on the seaward side of the Kilspindie line (at least for part of the time).

Thirty-six broods on the bay is a much higher figure than that seen by Jenkins _et al._ (1975) between 1967 and 1973, his highest figure being 18 broods seen in 1969.

BROODS



<u>FIGURE XVII</u>. Number of new broods arriving on Aberlady Bay between May and July in 1976.

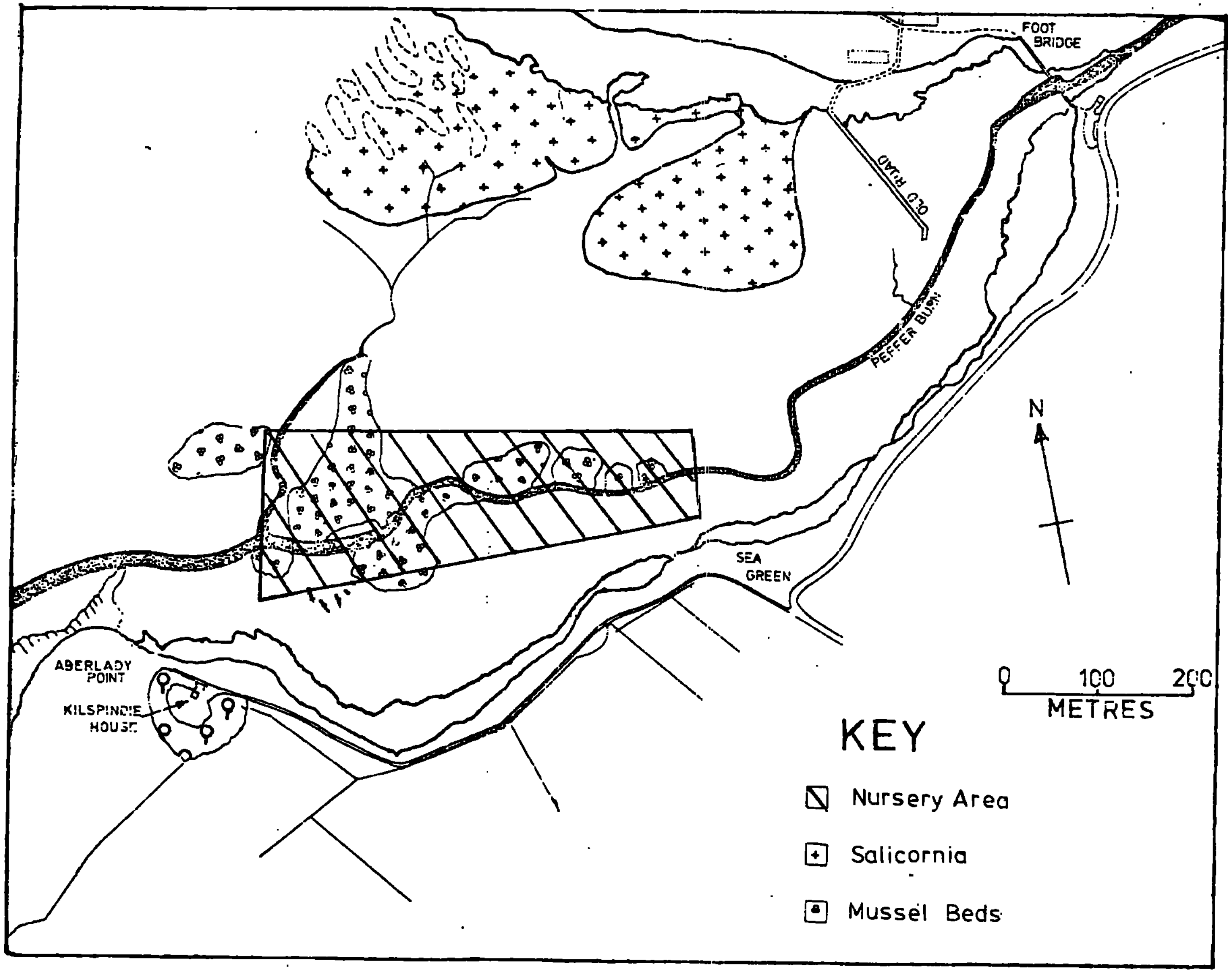


FIGURE XVIII. Position of main duckling nursery area on Aberlady Bay in 1976.

5.1 TIMING OF APPEARANCE

The first broods were seen on the bay at the end of May, and by mid-June 50% of known broods had been brought to the bay (Figure XVII). The first brood consisted of only two ducklings, their parents having fed during laying and incubation on a small pond near the tern colony. The latest date on which a newly hatched brood was seen was the 4th July.

Hatching dates are recorded in several British studies (Staton 1945; Gilham and Holmes 1950; Coombes 1950; South and Butler 1955; Hori 1964, 1969; Williams 1973) and are similar to those found for Aberlady.

5.2 NURSERY AREAS

From the nests ducklings were taken down to the bay usually by the most direct route, although a female with a nest near the football pitch (Figure XI) took her brood along the beach on the seaward side of the dunes and then into the bay. The most remarkable journey was that of a pair with a nest by the tern colony. This pair were never seen feeding in the bay during this study. However, remains of eggs outside the burrow entrance showed their eggs had hatched and the pair were finally seen at Musselburgh with nine ducklings. If these were their ducklings this would have entailed a journey of at least 10 km along the coast.

Once on the bay 86% of the broods (30 out of 36) were seen at some time near the mussel beds along the Peffer Burn (Figure XVIII) which appeared to be the main nursery area, although broods were seen on occasion in every part of the bay while the tide was out. At high tide broods collected in the salting on the north side of the bay although one or two broods remained below Kilspindie House.

Two broods, on arrival on the bay, were taken up the Peffer Burn to an area with plenty of cover for the ducklings, above the foot-bridge. The first brood's parents had had a feeding area in the main part of the bay during laying and incubation, but their brood remained in the area above the foot-bridge until the second pair, whose feeding area during incubation was also in this region, brought their brood down to the burn. After five days the second pair also took their brood into the main part of the bay. Only two pairs kept their broods within 100 m of their previous feeding area. Both these pairs eventually lost their ducklings, either through mortality or to another pair. One of these pairs fed beyond Ailsjindie Point and so away from the other broods, whereas the other fed by the old road, further into the bay in an area where a few other broods were taken.

All the areas where ducklings were taken were easily viewed and very prone to disturbance. Generally broods were not disturbed by people on the edge of the bay. However, as soon as movement was made onto the bay (only a few metres) adult shelduck looking after broods would lead them away in the opposite direction. Such reactions were seen over distances of 300 m. If surprised, ducklings dived under water or scattered in the saltings. The reaction of the adults varied. Males in particular, vigourously defended the brood against other shelduck and were also seen to attack eider (Somateria mollissima), mallard (Anas platyrhyncos) and potential predators such as the Herring gull (Larus argentatus) and the black-headed gull (Larus ridibundus).

At the first signs of trouble the female called the ducklings to her using a rapid "ak-ak-ak" call. If disturbed by people the male would circle around the area whistling lowdly. Both adults would also feign injury, a common feature in Anatids (Hebard 1959). This behaviour was never seen when broods were attacked by gulls. In this case the male would chase the gull and the female gather her ducklings around her. Also on one occasion a drake was seen to push under water a duckling that was already diving to escape.

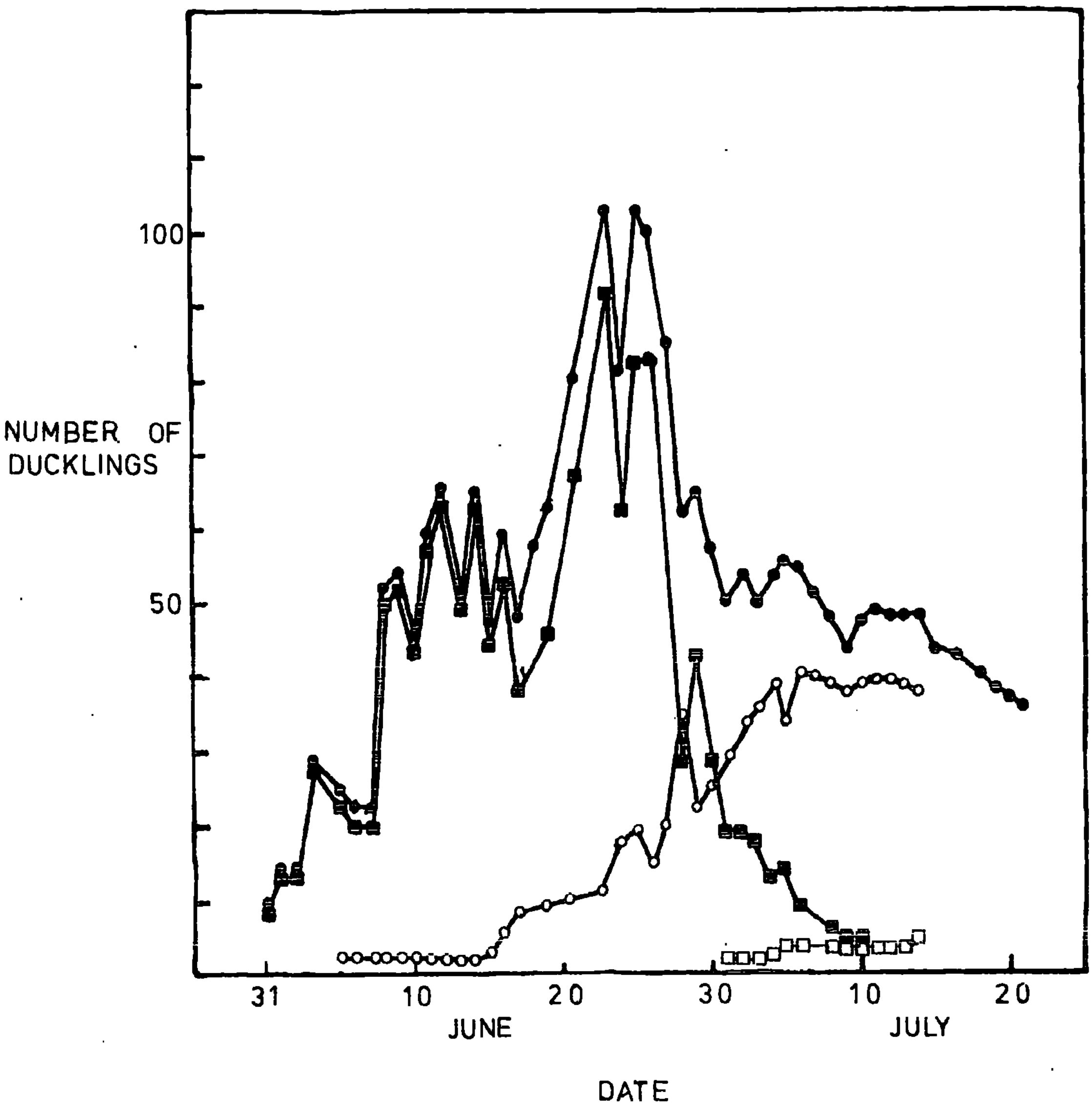


FIGURE XIX. The number of ducklings of different age classes (I-IV) seen on Aberlady Bay between May and July 1976. (Class I , Class II , Class III , total number of ducklings ( ) is also shown.)

5.3 AGE AND GROWTH

The development of ducklings was followed by observing successive stages in development of their plumage. Figure XIX shows the occurrence of the different age classes of ducklings on the bay from the end of May. Numbers of Class I ducklings reached a maximum in the fourth week in June and had almost all died or reached the next age class by the second week in July. Class II ducklings were first seen in the first week of June and were probably at a maximum in the second week in June when the first Class III ducklings could be identified. Only one fledged duckling was seen and that was on the 16th July.

Due to creche formation and the lack of distinctive markings of ducklings it was impossible to follow individual ducklings throughout their development. Only one pair was thought to have maintained parental care of their ducklings through to fledging. These were the first ducklings on the bay and were always slightly older than the rest of the broods. This pair of ducklings took at least 31 days to reach Class III in their development. This compares favourably with the results of Williams (1973) who found this period of development to take 39 days at the Ythan. At Sheppey, Hori (1964) did not observe Class II ducklings until the third week in June as a result of the later hatching date there.

5.4 CRECHING

Some pairs of shelduck cared for groups of ducklings of two or more different ages. This mixture of young is termed creching and is an uncommon feature of water fowl biology (Gorman and Milne 1972).

Creching was most obvious when the brood contained ducklings of different sizes, although this was seen in only 8% (24 out of 307) of observations on broods. Many of the amalgamations between broods involved ducklings of the same size. Extensive creching has been reported for some shelduck populations (Hori 1964, 1969; Boase 1951) with as many as 100 ducklings in a creche. The largest creche at Aberlady was of 38 ducklings.

5.5 HOW CRECHING OCCURRED

Parents were seen not only to defend their broods but an area around them. The position of the main nursery area in the centre of the bay resulted in frequent interactions between pairs. Broods frequently swam up and down the Peffer Burn which runs through the nursery area. When swimming towards each other, broods sometimes coalesced to form groups of up to 42 ducklings. If aggression occurred between two sets of parents with ducklings, this helped to cause interchange of broods during the resulting melee. However, exchange of ducklings was sometimes much more subtle. For example, if a brood was sitting on the mussel beds when a different brood swam by, mutual attraction between the ducklings caused some of the sitting brood to join the other. Sometimes parents would lose just a few ducklings, other times all of them. When feeding on the mudflats, ducklings sometimes strayed up to 50 m from their parents and when two broods were close enough some exchange could take place. Such exchange of ducklings was seen 13 times. Eleven of these transfers were seen to occur in the nursery area along the Peffer Burn. Disturbances from people may also lead to creching if different broods move into the same area. Williams (1973) stated that the nursery areas at the Ythan were in quite isolated areas away from disturbances. At Aberlady no part of the bay is secluded, except in the Peffer Burn above the foot-bridge. Usually at least one brood is reared there annually (Jenkins pers. comm.). However, except for two broods kept there for a few days when first brought onto the bay, no ducklings were reared in this area in 1976. Although parts of the coast line from North Berwick to Musselburgh are more secluded than Aberlady, pairs from these areas generally bring their ducklings into Aberlady Bay, (Jenkins et al. 1975), probably due to unsuitable feeding substrates for ducklings along the coast.

The mutual attraction between ducklings was not always greater than that for their parents. Once three ducklings were seen to join another brood in the burn and swim up to 10 m from the rest of their brood, before turning and rejoining them.

5.6 BEHAVIOUR OF ACCOMPANYING PARENTS

When pairs lost some or even all of their ducklings to other broods they usually moved away without apparent distress. Once a female was seen to try to keep her ducklings separate from those of another brood, but she failed. Two interesting pieces of behaviour were seen in two females two or three days after they had lost their broods. Bird no. 891 was seen to fly across to another female who had a brood of 15 ducklings. No. 891 showed aggressive behaviour towards this female and wandered through her brood. She eventually "separated" 11 ducklings for herself, leaving four with the other female. Another female (no. 928), three days after losing her brood, was seen accompanying an unringed pair with their ducklings, though she did not gain a new brood.

The occurrence of creches of very mixed ages was rare. In such groups one or both adults would attack those ducklings obviously of a different age from the others (nine observations). Those ducklings caught were pecked, often quite viciously, on the wings, head and neck and forcibly immersed under water or smothered in the mud.

As ducklings became older it was more frequent to see them without accompanying adults (86% of lone ducklings were Class II or older). Three of the attacks described above were on older ducklings that were attempting to join a brood and on none of these occasions were their attempts successful. One duckling was continuously attacked for at least 15 min. As with other ducklings that were attracted to broods it tried to evade attack and remain in the group. However, it was eventually seen to leave the brood wet, muddy and exhausted, to rest in the saltings. This duckling (which was ringed) was never seen again and is presumed to have died.

5.7 AGE AT WHICH CRECHING OCCURRED

All of the ducklings seen to be transfered between broods were of age Class I. Transfer may also have occurred in older ducklings, but evidence suggests they joined broods from unattended groups of vice versa. For example, bird no. 840 brooded the majority of older ducklings during late June and early July, and during July the numbers in her brood varied in relation to the numbers of birds in a small unattended creche, possibly indicating transfer between the two. Creching also seemed to occur immediately a brood reached the bay. Bird no. 925 was seen early in the morning taking her eight ducklings down to the bay. However, the first time the brood was seen on the bay in the nursery area, it contained 27 ducklings.

Creching at Aberlady was extensive and the crowding together of broods within a relatively small area together with disturbance were probably important factors affecting the extent of creching.

5.8 SURVIVAL VALUE OF CRECHING

The amalgamation of young into large groups or creches has been described for a number of unrelated species of birds, including penguins (Stonehouse 1953; Sladen 1958), pelicans (Brown and Urban 1969), terns (Dirksen 1932) and ducks (Koskimies 1955; Kear 1970; Gorman and Milne 1972) and a number of suggestions have been made to explain the habit. Penguin creches may conserve heat and replace parental brooding, while in pelicans, creching may protect the young from extremes of body

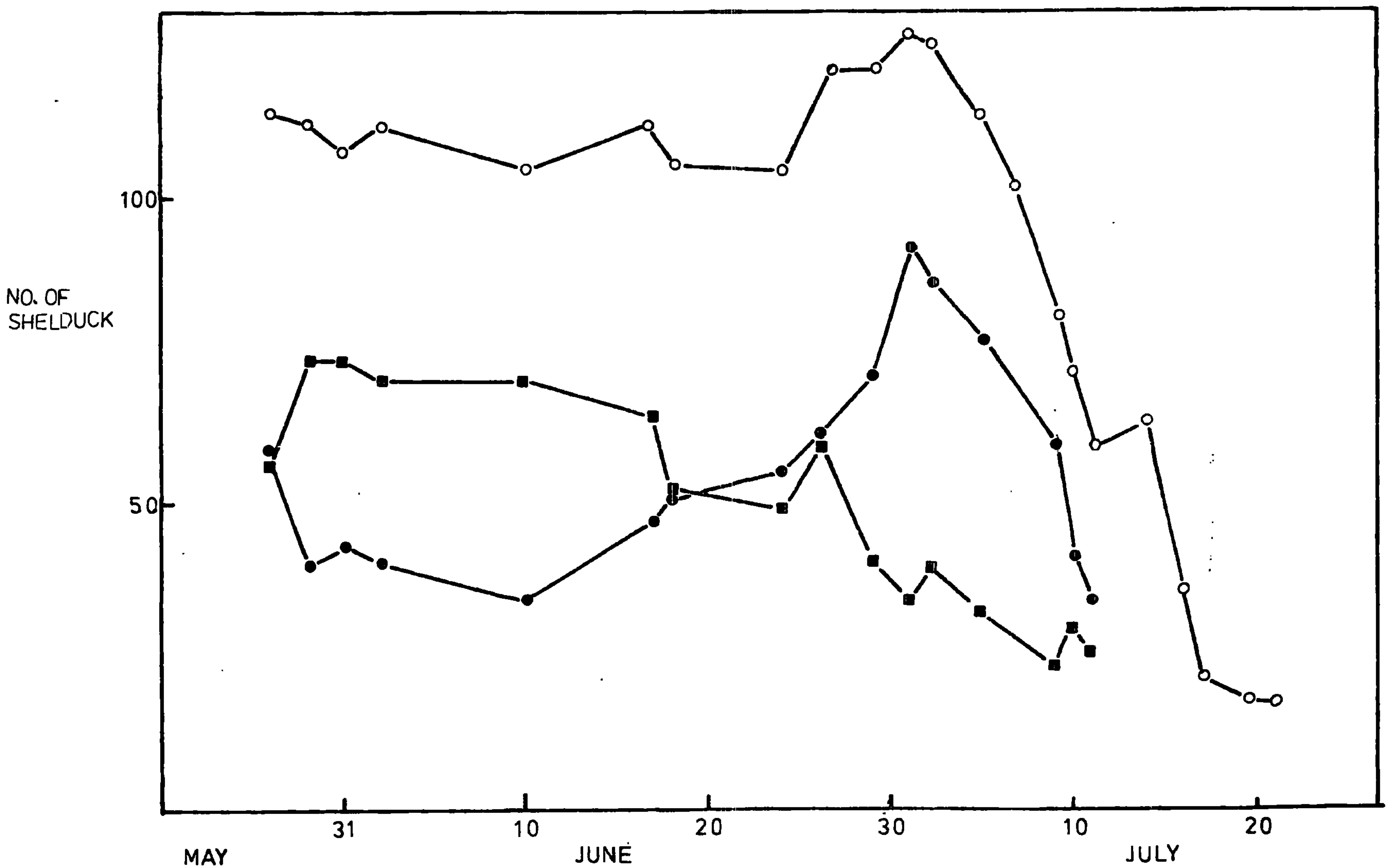


FIGURE XX. Counts of shelduck in different areas of Aberlady Bay between May and July 1976. (Total number of shelduck in bay o, number of shelduck in areas 1-5 ■, number in areas 6-8 ●. Areas 1-8 are defined in Fig. IV.

TABLE V cont.

Date	931	928	920	UR	925	893	UR	UR
23/6	20	12						
24/6	23		9			9		
25/6	14	33	9			7		
26/6	5	38	9	10		2		
27/6	3	5	4	7	27			
28/6	4	16		6	16	3		
29/6		9		1	18	2		
30/6		6		2	11			
1/7		7			7	6		
2/7		9			8	6		
3/7		9			12			
4/7		5			8		6	9
5/7		6			4		4	9
6/7					11		1	9
9/7					11			6
10/7					11			5
11/7					11			6
12/7					11			5
13/7					11			5
14/7					11			5
15/7					11			5
16/7					6			5
17/7					7			5
19/7					4			4
21/7					1			2

TABLE V cont.

Date	Bird No.													
	UR	852	961	889	UR	930	WW	809	UR	894	UR	911	UR	UR
14/6	8	9	6											
15/6		8	8	4										
16/6		7	18	4	6	5								
17/6		2	22	4	6	3	7							
18/6		3	4	4	6	1								
19/6		4	0	4	6	1	11	2						
20/6				4	6	0	0		12					
21/6		0		4	5				8	9	16	4		
22/6			2	4	5				8	7	6	3	15	3
23/6				4	5				8	3	9		15	
24/6				4	5				8	6	13			
25/6				4	5				8	1	14			
26/6				4					6	0	4			
27/6				4	5									
28/6				4	5									
29/6				4	5									
30/6				4	5									
1/7				4	5									
2/7				4	5									
3/7				4	8									
4/7					7									
5/7					7									
6/7					7									
9/7					7									
10/7					7									
11/7					7									
12/7					7									
13/7					7									
14/7					7									
15/7					7									
16/7					7									
17/7					7									
19/7					7									
21/7					7									

TABLE V . Number of ducklings in broods.

Date	Bird No. 827	851	828	873	823	924	840	811	UR	879	UR	UR	882	891
31/5	2		6											
1/6	2	6	6											
2/6	2	6	6											
3/6	2	8	6	7										
6/6	2		5		13									
7/6	2		2			5	11							
8/6	2						14	8	9	9				
9/6	2						11	8	9	15	8			
10/6	2						12	8		6	15			
11/6	2						22	8		6	5	18		
12/6	2						11			0	5	16	20	8
13/6	2						11	0				10	19	9
14/6	2						7	10				10	4	12
15/6	2						8	0					5	12
16/6	2						7	0					0	11
17/6	2						0	1					0	6
18/6	2						24							15
19/6	2						7	4						15
20/6	2							0						10
21/6	2						9							13
22/6	2						10							18
23/6	2						14							11
24/6	2						12							8
25/6	2						12							7
26/6	2						14							13
27/6	2						10							0
28/6	2						10							
29/6	2						9							
30/6	2						13							
1/7	2						13							
2/7	2						11							
3/7	2						13							
4/7	2						16							
5/7	2						19							
6/7	2						21							
9/7	2						15							
10/7	2						19							
11/7	2						18							
12/7	2						15							
13/7	2						17							
14/7	2						15							
15/7	2						16							
16/7	2						16							
17/7	2						14							
19/7	2						16							
21/7	2						21							

temperature. Many suggestions refer to protection from predators. Lack (1947) considered a tightly packed group of young would be more easily defended. Kear (1970) believed creching to reduce aireal predation - many eyes seeing better than one. Gorman and Milne (1972) showed creching to be correlated with the spatial separation of adult and duckling foods. Hori (1964b) suggested that creching in shelduck was more frequent late in the breeding season, allowing parents who had lost broods to regain condition for migration. This theory is examined in the nest section.

5.9 FATE OF BROOD OWNERS

Only 9 out of 36 pairs bringing broods onto the bay were seen with ducklings for more than a 10 day period (see Table V). Seven of these birds were ringed and out of these six were known to have bred at least three times before. Of the 16 other ringed birds only one had bred 3 times before, 5 twice, 4 once and for the rest there was no record of successful breeding. This suggests breeding experience may be important in affecting the number of days a pair kept ducklings.

Figure XX shows counts of birds on the landward and seaward sides of the tributary joining the Peffer Burn opposite Kilspindie House from the end of May to July, as well as the total number of birds in the bay. This suggests a movement of birds from the "mud" onto the sandy area. The rise in numbers on the sand may be due in part to coastal breeders remaining after bringing their ducklings to the bay. The rise in the total numbers of birds in the bay also suggests this. However, 13 out of 18 breeding pairs who fed east of the tributary during laying and incubation were seen feeding at sometimes left of the tributary after losing their ducklings. Only two pairs were seen to do so before hatching of their ducklings. This indicates some changes in feeding area after breeding.

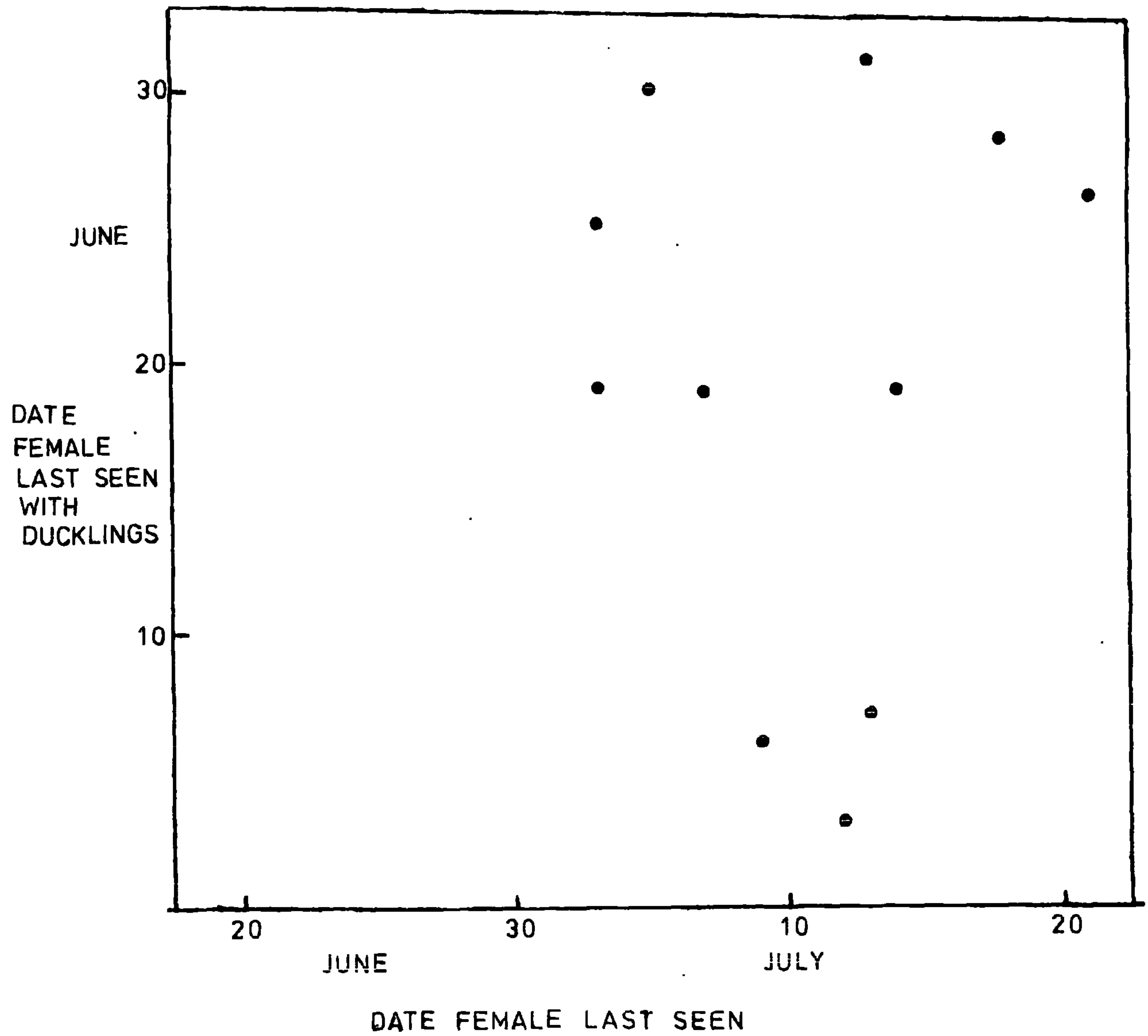


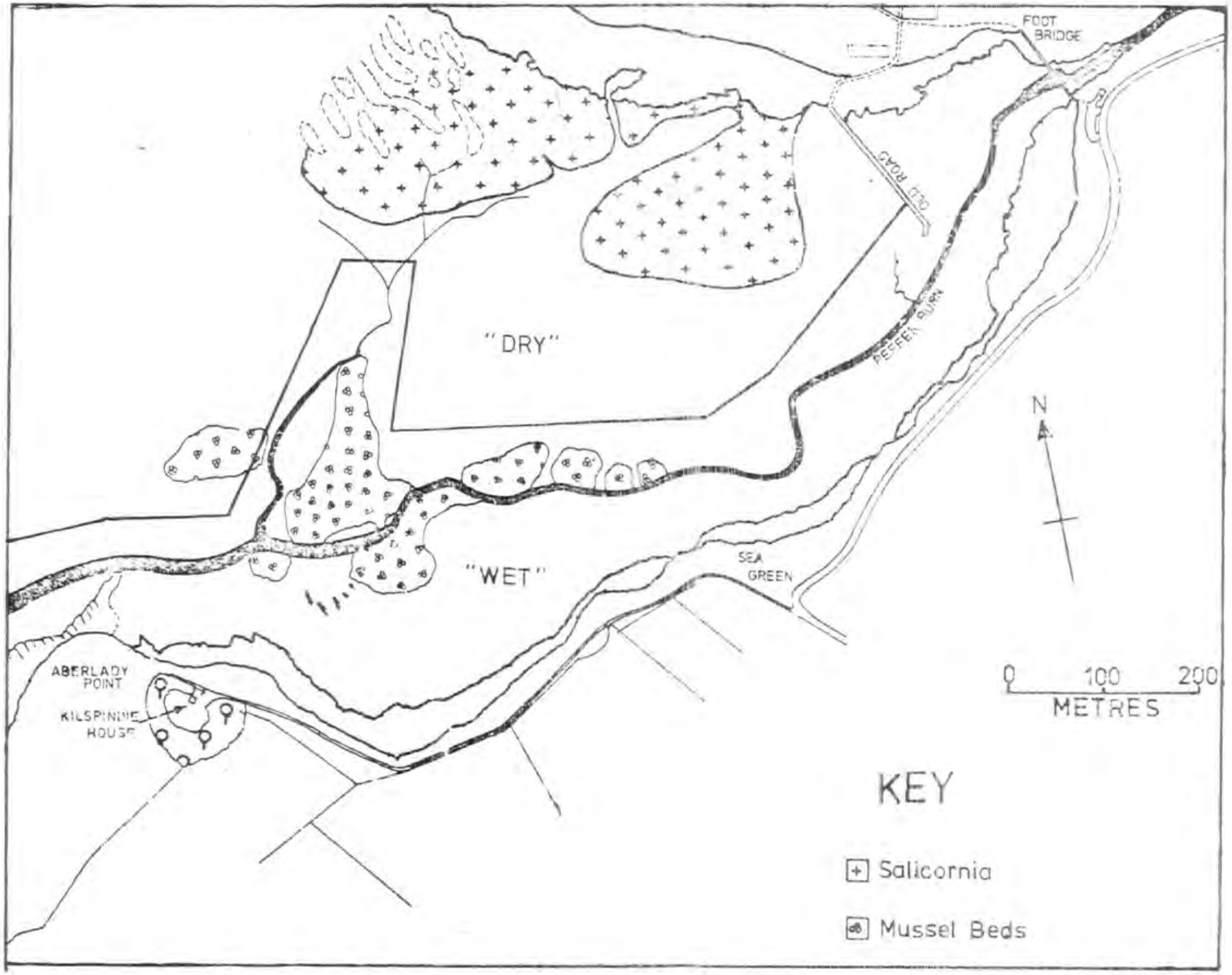
FIGURE XXI. Relationship between the date female shelducks at Aberlady Bay were last seen with ducklings and the date they were last seen on the bay (approximate time of migration).

Figure XXI shows the date the female was last seen with ducklings against the date she was last seen (assuming this is an approximation to the time of migration). The time of losing their broods does not appear to affect the time of migration for the majority of birds (although obviously birds having broods during the main period of departure of the Aberlady population will remain longer)! Thus it would appear that by losing their ducklings through predation or creching the parents were able to migrate with the main flock, but the length of time pairs kept ducklings was a function of breeding experience, rather than time of hatching. Williams showed that the shelduck at the Ythan that remained with a brood for long periods had an equal probability of returning to breed the following year, compared with pairs that lost their ducklings early in the season.

5.10 DUCKLING SURVIVAL AND MORTALITY

The journey from the nest to the nursery area usually involved a distance of 1 km or more. Estimates of mortality incurred during this journey could be deduced by calculating the mean brood size on leaving the burrow (7.1), and subtracting from this the mean brood size when the birds were first seen on the bay (5.7). This gives an estimated mortality of 21%. This may be too high because one of the birds with ducklings disappeared on the way down to the bay but was seen two days later with a very mixed brood. This made it impossible to know whether any of her ducklings survived.

Because of creching it was impossible to follow individual ducklings on a day to day basis. Mortality was therefore estimated in relation to plumage class. As the study finished before the ducklings all fledged, it was only possible to calculate the mortality of Class I ducklings. 81% of the ducklings brought onto the bay died before reaching Class II. Williams (1973) showed 30-70% mortality of ducklings at the Ythan before they reached Class II.



<u>FIGURE XXIa</u>. Arbitrarily defined "wet/muddy" and "dry/sandy" areas in Aberlady Bay.

The death of duckling was rarely seen, most simply disappeared and only two bodies were found. Thus it was difficult to identify the causes of mortality. Only herring gulls were seen to take ducklings (seven observations). All these ducklings were Class I even though it was common to see groups of older ducklings sitting unattended. All except one of the ducklings seen to be taken by gulls had strayed from their parents when feeding, enabling the gull to take them before they could gather around the female.

Weather could be an important factor in duckling mortality. Koskimies (1955) refering to the very high mortality in a Finnish maratime population of the Velvet Scoter (Melanitta fusca), stated the heaviest mortality was during bad weather. The hot summer at Aberlady in 1976 may have caused the mud to dry out quickly after the tide receded which could have affected food availability for the ducklings (see Chapter 6 for further discussion on food availability).

Predators appear to be the major source of duckling mortality at Aberlady and besides herring gulls, greater black-headed gulls (Larus marinus) and herons (Ardea cinerea) were also reported to have taken ducklings. Herring gulls are numerous around the Firth of Forth and have been on the increase in recent years (Duncan pers. comm.) which can only increase the possibility of predation by gulls.

5.11 FEEDING AREAS OF BROODS

Subjectively, younger broods were thought to feed mainly on the muddy or wetter areas of the bay, only feeding further afield when older. To test this hypothesis the feeding positions of Class I ducklings and ducklings older than this were plotted on a map. The number of sightings in each of two arbitrarily defined areas (Figure XXIV) representing muddy and/or wet areas and sandy and/or dry areas were compared. Significantly more Class I ducklings fed in the "wet" area than in the dry (χ^2 = 8.91, 0.01)p)0.001 with 1 df.). Ducklings were seen sifting mud at all ages and it is possible that Class I ducklings could only cope with the finer or wetter substrates. Densities of free living oligochaetes were high where Class I ducklings fed (see Chapter 6) and may be an important food source for young ducklings.

FOOD AVAILABILITY

6.1 IS FOOD AVAILABILITY AN IMPORTANT FACTOR FOR BREEDING SHELDUCK AT ABERLADY?

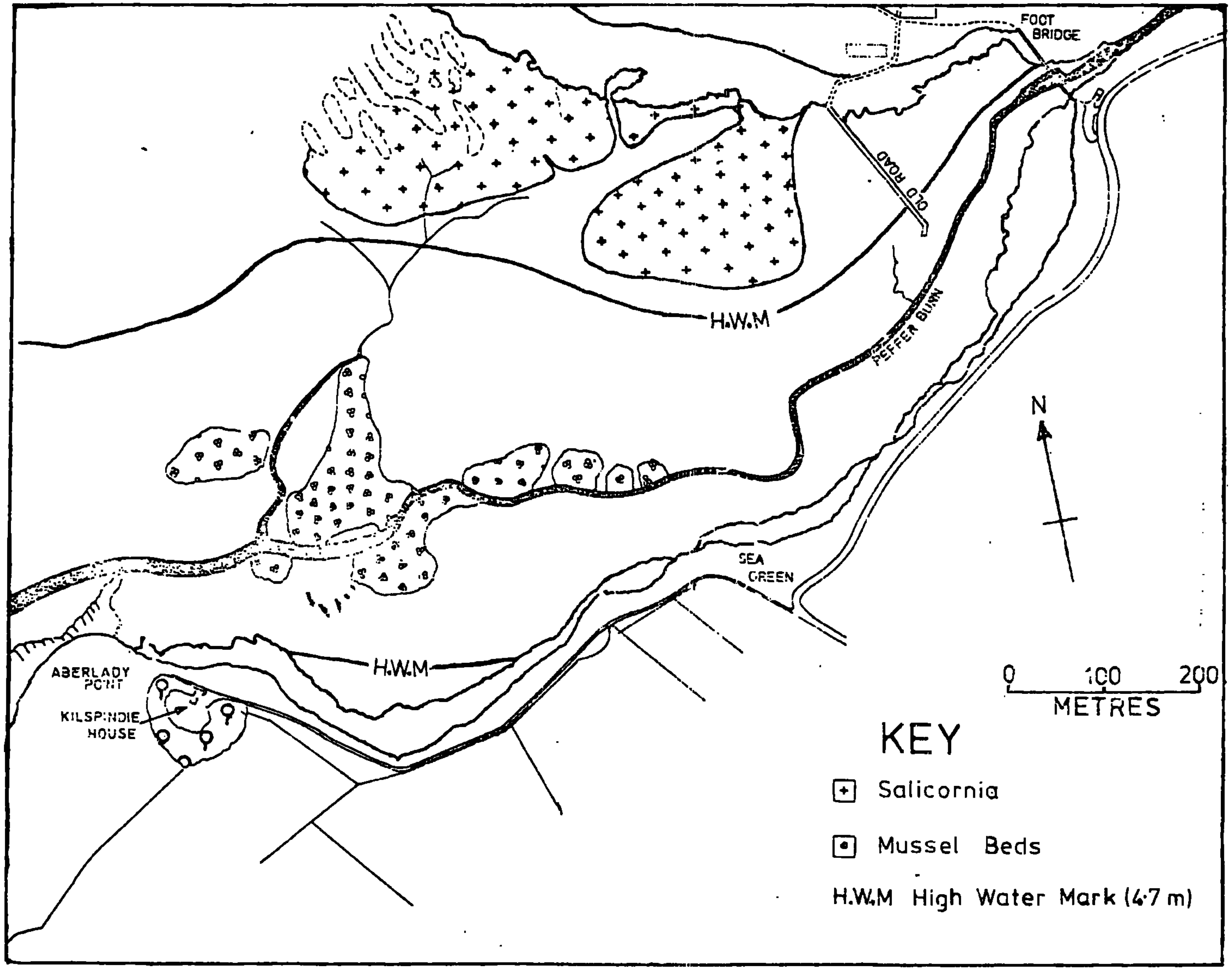
Various workers have assumed Hydrobia ulvae to predominate in the shelduck diet (Cambell 1947; Goethe 1961; Olney 1965; Bryant et al. 1975). Olney (1965) in a detailed analysis of shelduck gut contents found three other important food items, Macoma balthica, Corophium volutator and Nereis diversicolor. The behaviour of H. ulvae, C. volutator and Nereis is complicated. Newell (1960) showed that as the tide ebbs Hydrobia emerge from underneath the surface of the mud and feed on detritus. Towards low tide they burrow underneath the surface and remain there until the tide starts to come in, when they re-emerge and float in with the tide, finally sinking down on the ebb tide at approximately the same place they started the cycle. Vader (1964) showed that burrowing was greater in the summer months, desiccation being the major factor controlling the number of snails burrowing at low tide. In very muddy places the animals remained on the surface, burrowing being greatest where the surface dried and desiccation was maximal e.g., on sandy areas during summer.

Corophium and Nereis also show similar reactions to fluctuations in water level. Both remain in their burrows while the tide is out, though on immersion immediately come to the surface.

Because shelduck usually feed at the surface the behaviour of its major food sources must effect their availability during the tidal cycle. Four types of feeding activity were seen at Aberlady:

1. Scything on the mud surface
2. Scything in shallow water < 10 cm
3. Head dipping and dabbling in deeper water 10-25 cm
4. Upending in deeper waters

The sediments at Aberlady vary from sand to very soft mud presumably affecting the behaviour of invertebrates as described by



<u>FIGURE XXII</u>. High Water Mark for a 4.7 m tide at Aberlady Bay in 1976.

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Vader (1964). The distribution of invertebrates is probably further complicated by the occurrence of small pools and drainage channels in the area north of the Peffer Burn. Tide height would also affect the invertebrate distribution in some parts of the bay. Figure XXII shows the high water mark for a 4.7 m tide. This leaves large areas of the bay to the north of the Peffer Burn uncovered and would presumably affect the distribution and availability of invertebrates through desiccation (c.f. Vader 1964). The first date of laying for shelduck at Aberlady coincided with the spring equinox with tides up to 6 m, covering the whole bay. However, during April and May (when all laying occurred and incubation started) high tides were as low as 4.7 m on three occasions which would affect food availability for birds feeding in the uncovered areas.

6.2 DISTRIBUTION OF INVERTEBRATES AT ABERLADY BAY

Figure XXIII shows the numbers of _Hydrobia_ _ulvae_ dm^{-3} in different parts of the bay, numbers varying from 0-190 _Hydrobia_ dm^{-3}. _H._ _ulvae_ were present in all parts of the bay, except for a small area opposite Kilspindie House. Generally, numbers were highest in the wetter muddier areas. However, it must be remembered that the samples collected in this study include _H._ _ulvae_ from underneath the surface and may not indicate the numbers of _H._ _ulvae_ available to shelduck, within the limits of their different feeding methods. Most areas had more than 0.3 _Hydrobia_ dm^{-3} said by Young (1970) to be the lowest number suitable for the feeding area of breeding shelduck at the Ythan Estuary.

Figure XIV shows the distribution of a tube building spionid. This was found in the surface layers and may be taken by shelduck. Generally its distribution was complementary to that of _H._ _ulvae_, found in highest numbers where _H._ _ulvae_ was less common.

The distribution of _Nereis_ spp. is shown in Figure XXV. _Nereis_

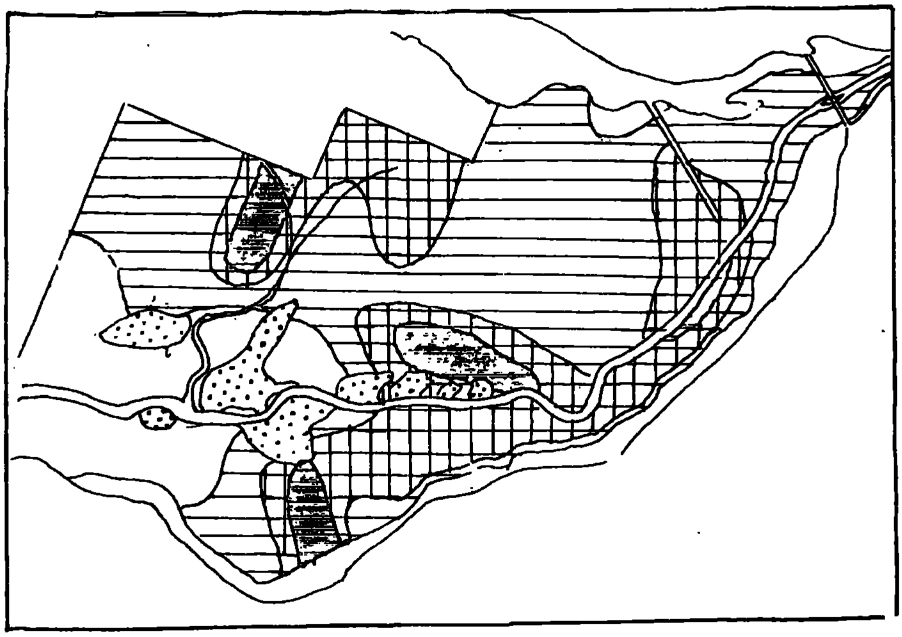

FIGURE XXIII. Distribution of <u>Hydrobia</u> <u>ulvae</u> at Aberlady Bay in 1976

>100 animals 2 dm^{-3}

50-100 "

10-50 "

10 "

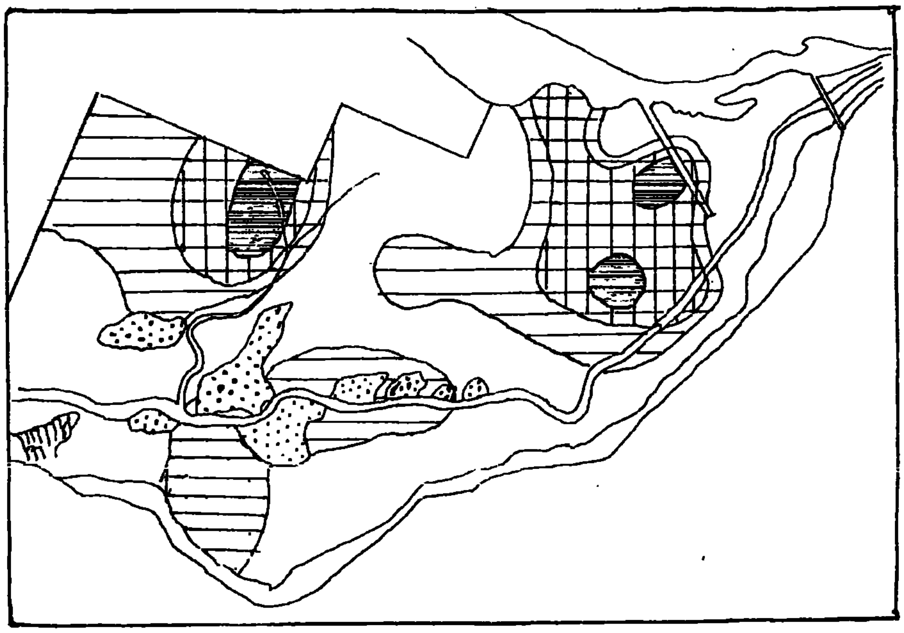

FIGURE XXIV. Distribution of a tube building Spionid worm at Aberlady Bay in 1976.

>200 animals 2 dm^{-3}

100-200 "

50-100 "

50 "

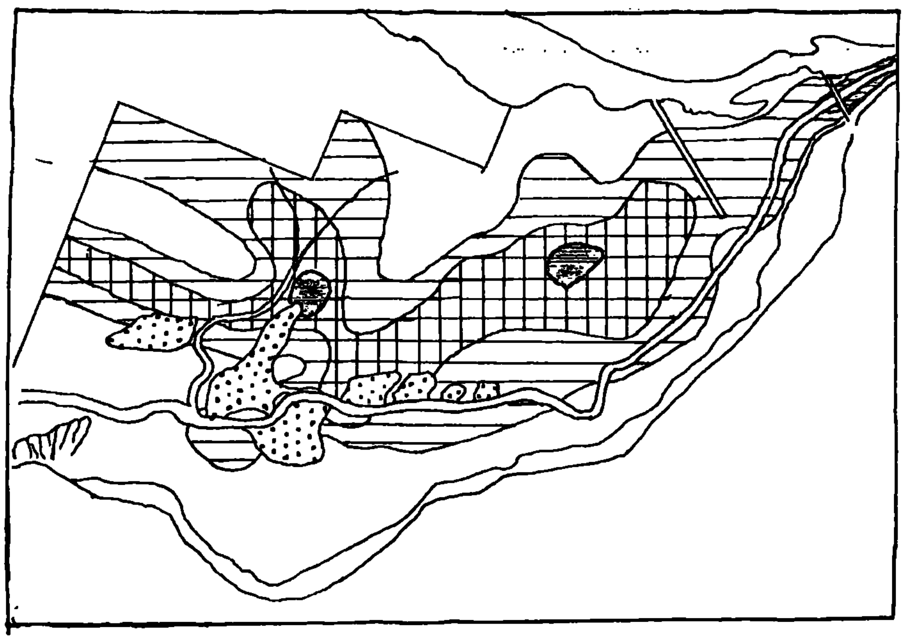

FIGURE XXV. Distribution of <u>Nereis</u> <u>diversicolor</u> at Aberlady Bay in 1976.

>20 animals 2 dm^{-3}

10-20 "

5-10 "

5 "

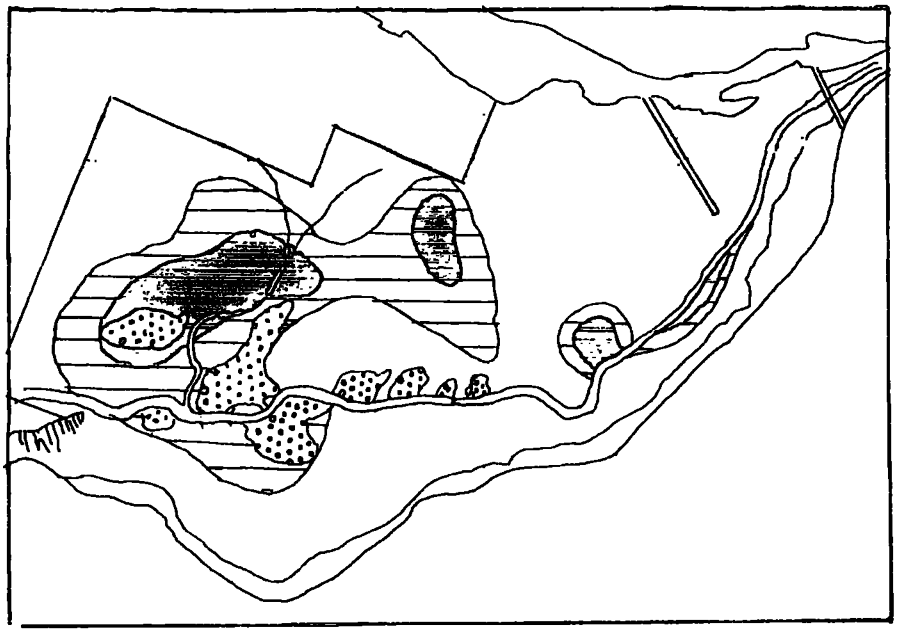

FIGURE XXVI. Distribution of *Macoma balthica* at Aberlady Bay in 1976.

>4 animals 2 dm^{-3}

1-4 animals 2 dm^{-3}

<1 animal 2 dm^{-3}

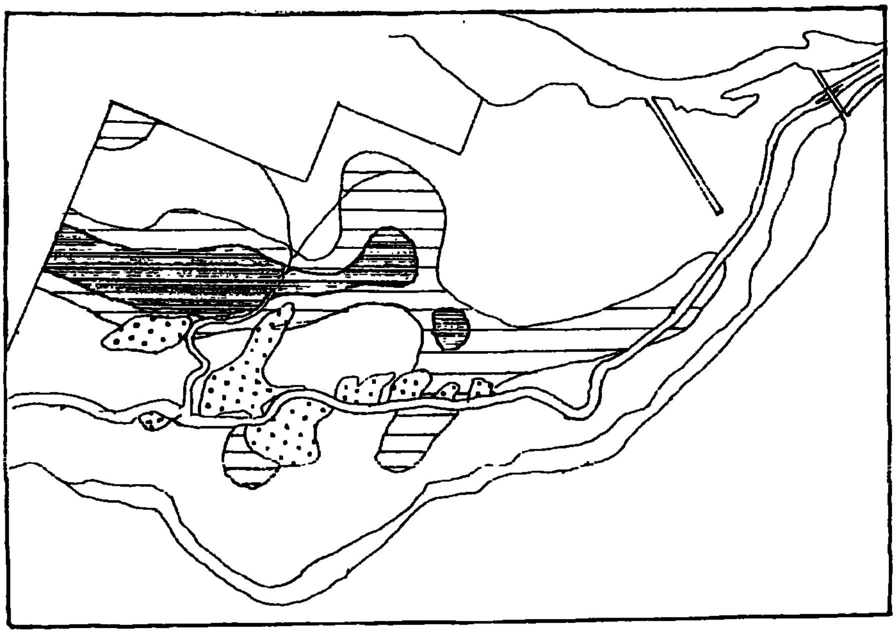

FIGURE XXVII. Distribution of *Cardium edule* at Aberlady Bay in 1976.

>10 animals 2 dm^{-3}

2-10 animals 2 dm^{-3}

<2 animals 2 dm^{-3}

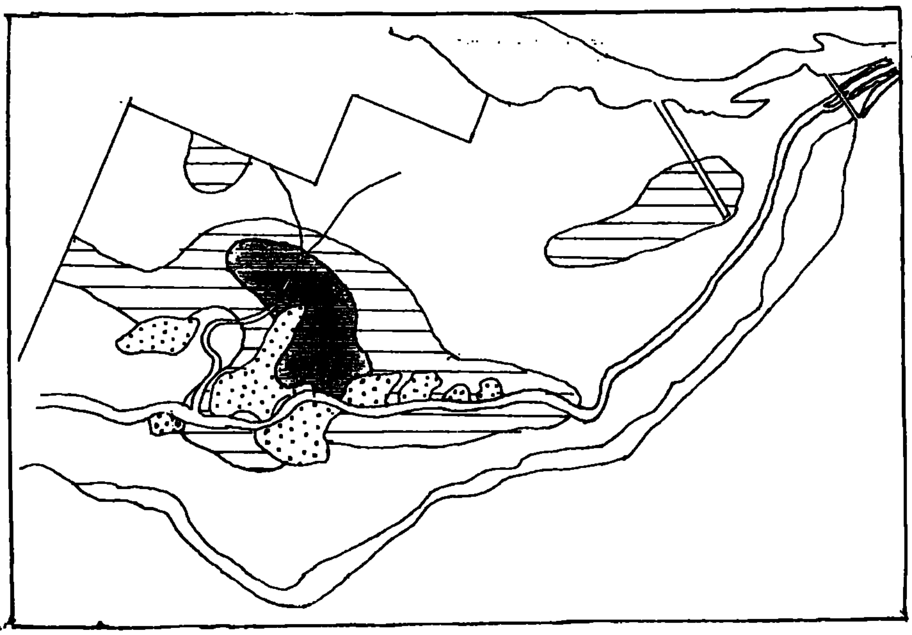

FIGURE XXVIII. Distribution of various oligochaetes at Aberlady Bay in 1976,

>30 animals 2 dm^{-3}

10-30 animals 2 dm^{-3}

<10 animals 2 dm^{-3}

73

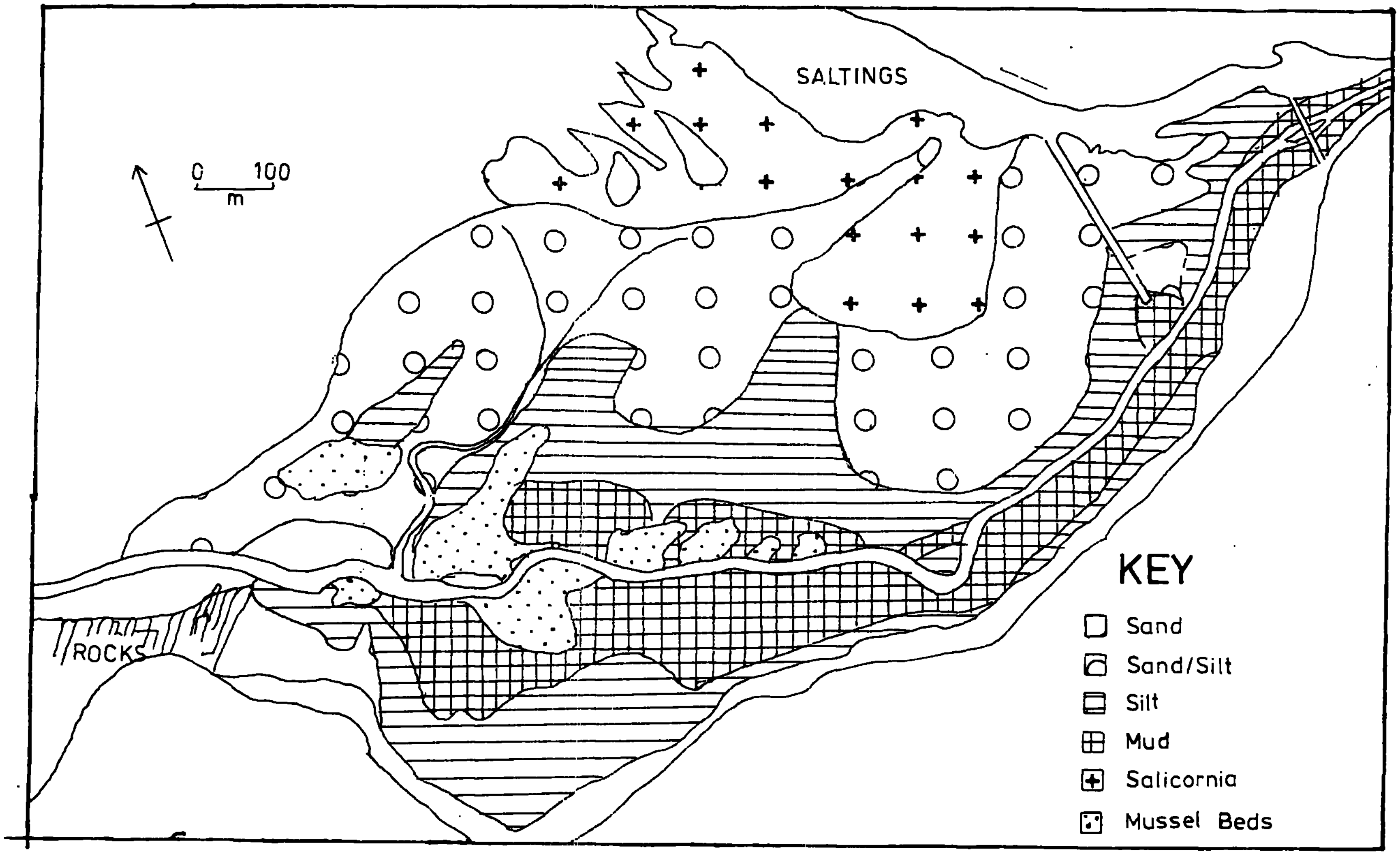

FIGURE XXIX. Distribution of different sediment types at Aberlady Bay (courtesy of Armstrong 1974).

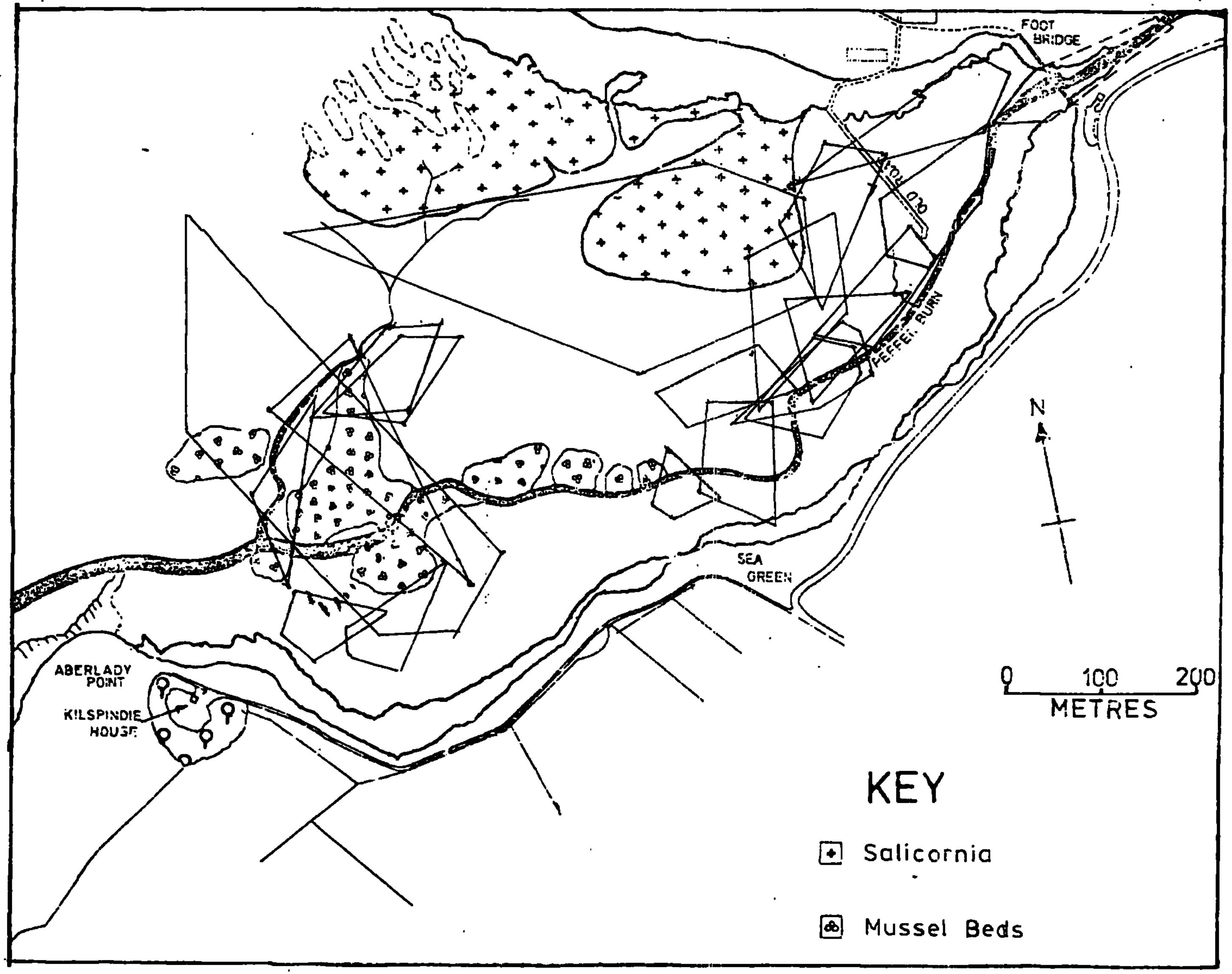

FIGURE XXX. The position of breeding pairs' feeding areas between mid-April and the end of May in 1976.

was widely distributed over the whole bay although densest in the Peffer Burn above the foot-bridge.

The distributions in Aberlady Bay of Macoma balthica and Cardium edule are shown in Figures XXVI and XXVII respectively. Both these bivalves were commonest in the central area of the bay and infrequent east of Sea Green.

Figure XXVIII shows the distribution of various oligochaetes at Aberlady. They are at their densest around the mussel beds in the central area of the bay and as Class I ducklings fed in this area these oligochaetes may be an important food source. Oligochaetes were also common in the Peffer Burn above the foot-bridge.

Other invertebrates, found in smaller numbers, included Corophium volutator, Bathyporeia pelagica, Scrabicularia plana, Arenicola marina and various beetle larvae. Details of the distributions of all these species are given in Table I in the Appendix.

Details of the distribution of different sediment types at Aberlady Bay are shown in Figure XXIX.

6.3 DISTRIBUTION OF FEEDING AREAS OF BREEDING BIRDS

Breeding birds include those pairs seen with ducklings, known to own a nest, or of which the drake had been seen alone on their feeding area. Breeding birds' feeding areas during April and May are shown in Figure XXX. No relationship is apparent between the position of the feeding area of such birds and the numbers of Hydrobia which ranged from 1- 100 Hydrobia dm^{-3}.

Various workers have shown selective feeding by female ducks for higher quality food during the breeding season; Serie (1976) and Dwyer (1974) on gadwalls (Anas strepera), and Krapu (1974) on pintails (Anas acuta). Assuming shelduck that successfully breed (are seen with ducklings) feed on areas with suitable food available, why do birds fail to breed

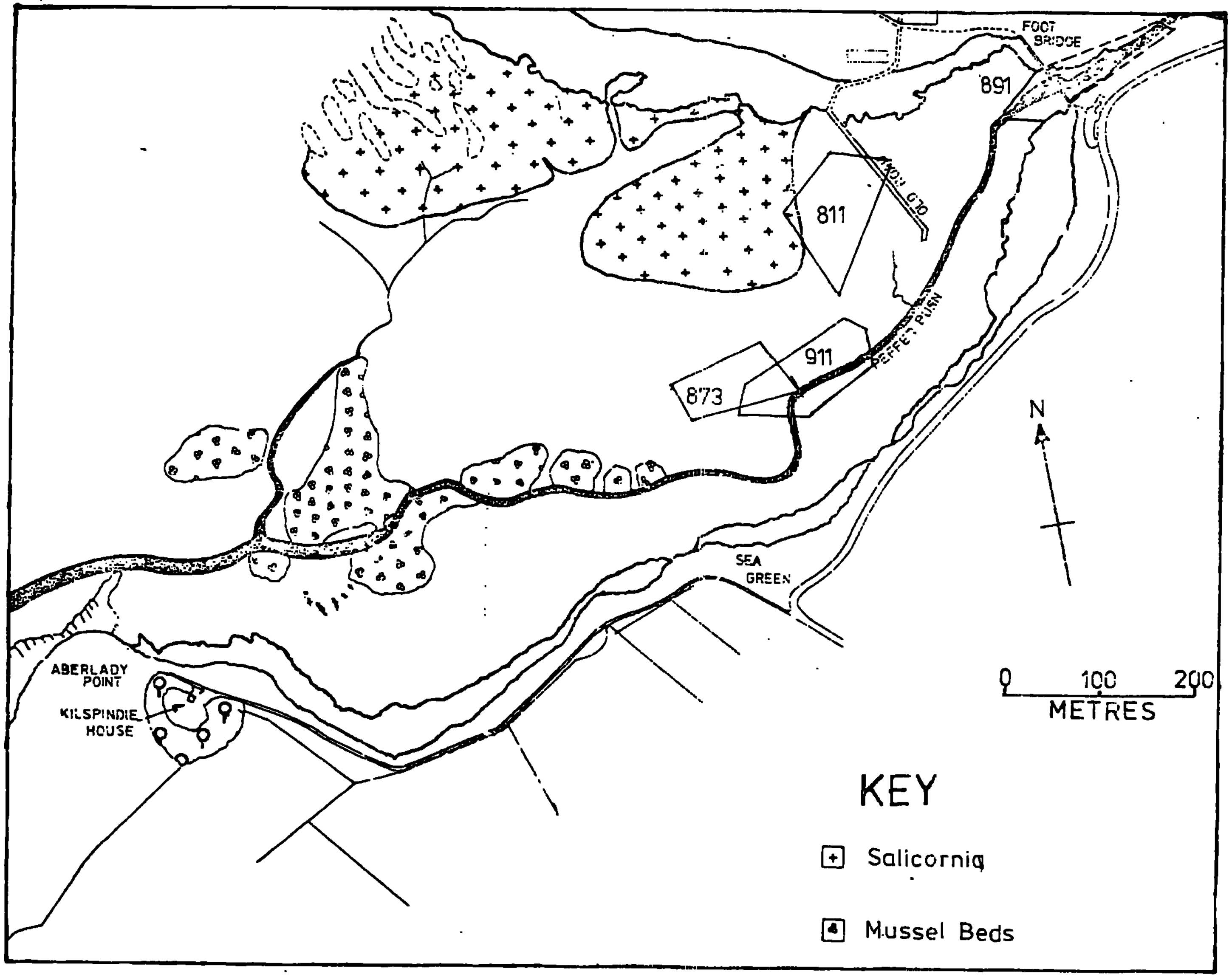

FIGURE XXXVI. The feeding areas (April-May incl.) of shelduck using artificial burrows in 1976.

successfully that feed on the north area of the bay, where food availability (in terms of Hydrobia dm^{-3}) is average for the whole bay? The feeding ranges of some of the breeding birds overlapped in this area, but usually included wetter of more muddy areas within their range as well. It is possible that the feeding areas are poorer to the north of the bay, food availability being affected by these sandier substrates drying out more rapidly as the tide recedes. This could explain the large feeding ranges of birds seen in this area, as the birds have to search for a more favourable feeding area during low tide. Examination of the egg production in shelduck at Aberlady showed it to be much more irregular than suggested by workers on other shelduck populations (Hori 1964; Patterson 1974). The feeding area of the four shelduck that used nest boxes are shown in Figure XXXVI and the description of their feeding sediments and egg production figures are summarized in Table VI. All four birds fed in areas with high numbers of H. ulvae (c.f. Young 1970), although the richest feeding area was probably the soft mud up the Peffer Burn above the foot-bridge where no. 891 fed. The sediments were also softest here and it was probably easiest here for a bird to gain an adequate food supply. Bengtson (1971) showed a correlation between increased clutch size and increased food supply for eight species of duck in Lake Myvatn in Sweden. However, Lack (1967) suggested ducks would postpone laying if food was in short supply. The mean clutch size for the three birds in the main part of the bay (8.0) was lower than that for bird no. 891 above the foot-bridge, although the three birds in the bay started laying before no. 891. For all birds an interval greater than 29 h between eggs nearly always resulted in a heavier egg being produced, which would suggest that by feeding longer the female was able to produce a larger egg. Also eggs produced 29 h after the previous one we e often lighter. The best rate of egg production

TABLE VI. Sediment types and rates of egg production for four shelduck.

Bird No.	Sediment	Onset of Laying	Egg Production eggs d^{-1}	Clutch size	Mean egg wt. (g)
811	S/S	23/4/76	1.3	10	75.2
873	S/S	19/4/76	1.3	7	84.0
891	SM	30/4/76	1.2	9	79.5
911	S	28/4/76	2.8	7	77.6

(S/S= Silt/Sand; S=Sand; SM= Soft Mud)

TABLE VII. Egg production by bird no. 811 from 1974-76. (Data for 1974 and 1975 are from Armstrong (1974) and Sutherland (pers. comm.) respectively.)

Year	Sediment	Clutch Size	Mean Volume of egg (cm^2)	Onset of laying
1974	S/S	10	73.1$\pm$1.2	1/5/74
1975	S	14	74.5$\pm$ 1.6	23/4/75
1976	S/S	10	75.8$\pm$ 1.2	23/4/76

(S/S= Silt/Sand; S= Silt)

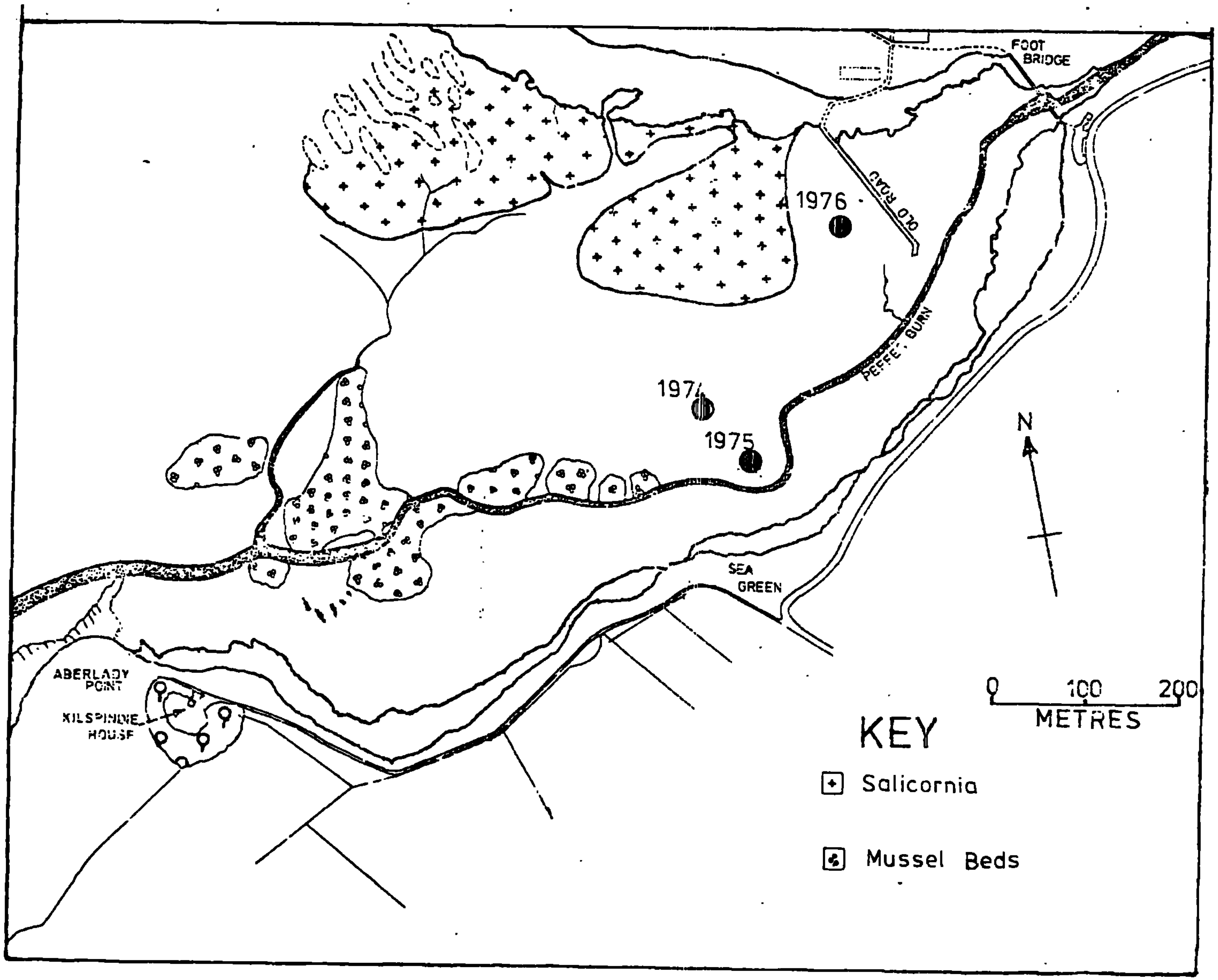

FIGURE XXXVII. The position of bird no. 811's feeding area during the breeding seasonsbetween 1974-76.

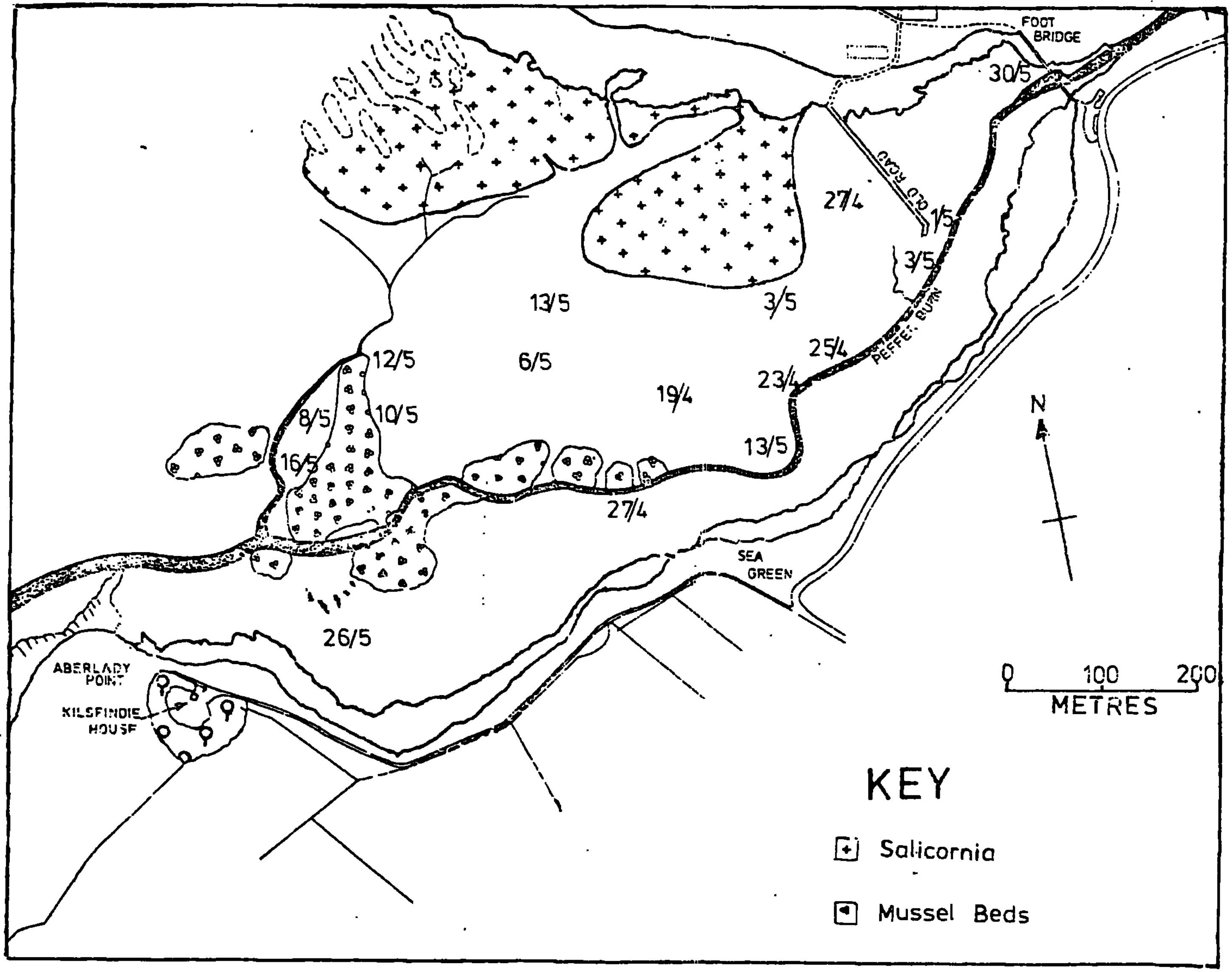

FIGURE XXXI. Dates of the onset of laying for selduck feeding in different parts of the bay.

was achieved by bird no. 891 feeding in the rich sediments above the foot-bridge. However, bird no. 891 only produced the second heaviest clutch and bred later than the other three pairs.

The most complete data for a single bird is that for bird no. 811 whose eggs have been measured for the last three years (Armstrong 1974; Sutherland pers. comm.). Her feeding areas in each of these years is also known (Figure XXVII). Unfortunately only the dimensions but not the weight of the eggs are available for 1974 and 1975, so the volume of the eggs (in all years) was calculated using the formula suggested by Preston (1974):

$$v = 0.5128\ LB^2$$

where:-

v = volume (cm^3)

L = length (cm)

B = maximum breadth (cm)

Available data for bird no. 811 is shown in Table VII. Although egg volumes were not significantly different between years (0.10 p 0.05), the bird produced more eggs with a heavier mean weight in 1975 when feeding on a muddy rich substrate, than in 1974 when she was feeding in sandier substrates. Also the earliest date for the onset of laying was in 1975 and the latest was in 1974 when she fed on the sandiest area.

Figure XXXI shows the dates for the onset of laying by the birds feeding in different areas in the bay, calculated where not known, from the date their broods were first seen on the bay. This suggests that birds feeding in the muddier areas of the bay started laying before the other birds. However, the birds occupying these areas may simply have set up their feeding ranges before the other birds. Although it is possible as Lack (1967) suggested, that poorer feeding areas resulted in the postponement of the onset of laying.

Although the above results suggest differences in food availability may be affecting the breeding potential of shelduck at Aberlady, further information is required on the following:

1. The laying rhythm of shelduck. Is it normally internally programmed at less than 1 egg day^{-1} and/or does it vary with food availability?

2. The feeding behaviour of birds in different substrate areas e.g., how much time is spent searching for food and what techniques are used to find it. Can this be correllated to substrate type?

FINAL DISCUSSION

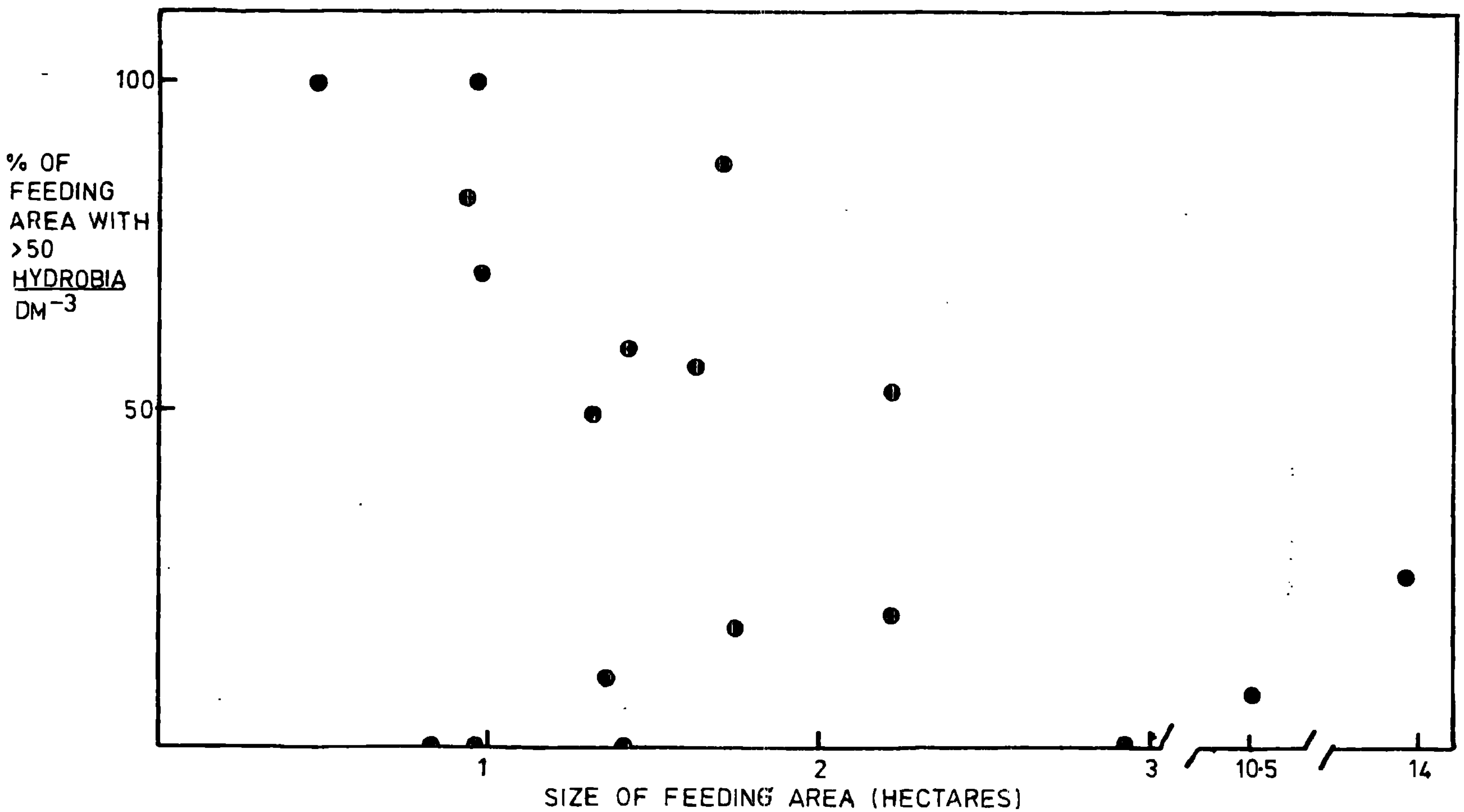

FIGURE XXXII. The relationship between the size of breeding shelducks' feeding areas and the percentage of that area with >50 Hydrobia dm^{-3}.

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7.1 THE SOCIAL ORGANISATION OF SHELDUCK AT ABERLADY

Since Howard (1920) and Altum (in Mayr 1935) formulated the first comprehensive theories on territories, many definitions of territory have been proposed (Lack and Lack 1933; Crawford 1939; Noble 1939; Tinbergen 1939; Nice 1941; Hinde 1956). Examination of the feeding ranges of pairs of shelduck during the breeding season suggests that they do not conform to two widely accepted definitions of territories namely defended areas (Noble 1939) or mutually exclusive areas (Pitelka 1959). Although aggression was seen to occur between neighbouring pairs of shelduck, pairs were never seen defending a rigid boundary around their feeding area. The extent of the area covered by individual pairs varied enormously (0.5 - 13.9 hectares). Known breeding pairs (male seen alone on the pair's feeding area, nest found, or seen with ducklings) had both large and small feeding ranges, although the majority (13 out of 18) had feeding ranges of less than two hectares. Pairs with large feeding areas certainly did not defend such areas continuously, since other pairs took their place when they moved away. Consequently to call the feeding ranges of breeding birds "territories" would seem to infer too much.

Why do the majority of breeding birds have small feeding ranges? Comparison of the positions of the feeding areas of breeding pairs of shelduck and the distribution of Hydrobia ulvae within the bay (in 1976) showed that feeding ranges of breeding birds occurred in areas of the bay with numbers of H. ulvae ranging from 1-100 dm^{-3} (see Section 6.3). When the size of the feeding area is plotted against the percentage of that area including densities of H. ulvae greater than 50 dm^{-3} (Figure XXXII) no clear relationship is apparent between the two, pairs feeding in small ranges sometimes having low numbers of H. ulvae throughout their range. (This assumes H. ulvae is the main food item of shelduck and whether shelduck fed on other invertebrates in areas where numbers of H. ulvae

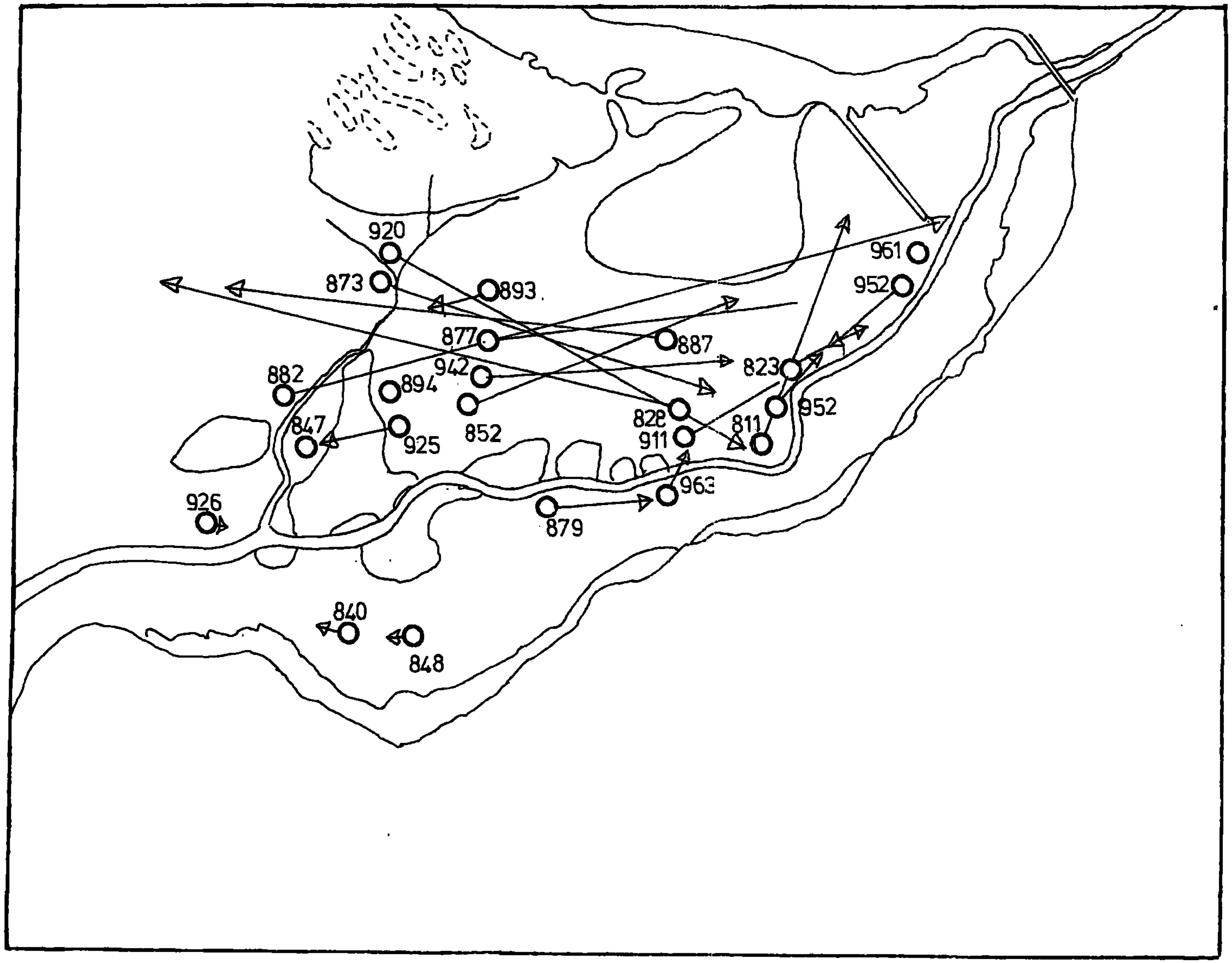


FIGURE XXXIVb. The position of feeding areas for different shelduck during April and May (pers. comm. Court, Wood Sutherland) in 1975.

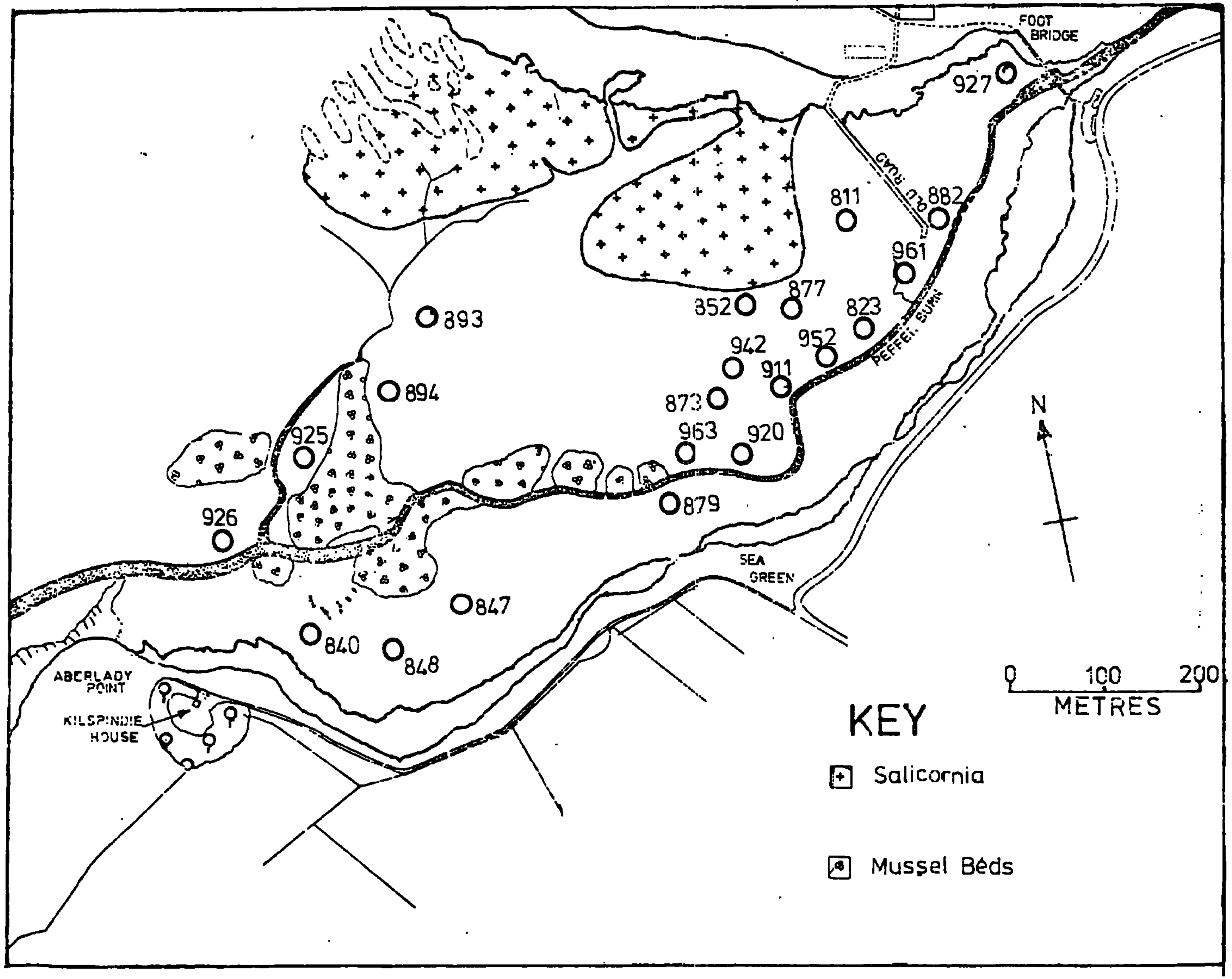
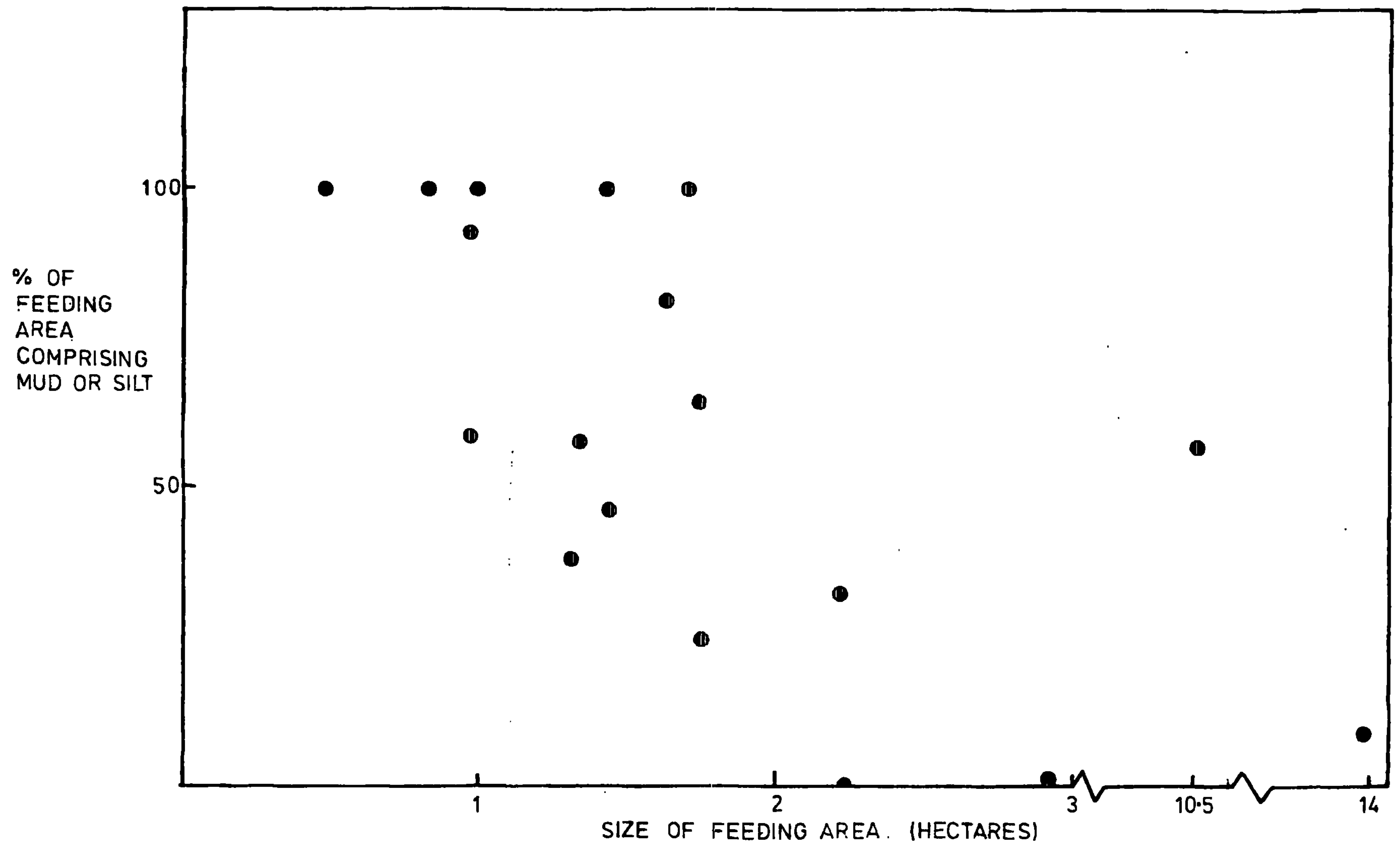


FIGURE XXXIVc. The position of feeding areas for different shelduck during April and May in 1976.



<u>FIGURE XXXIII</u>. The relationship between the size of breeding shelducks' feeding areas and the percentage of that area comprising mud or silt.

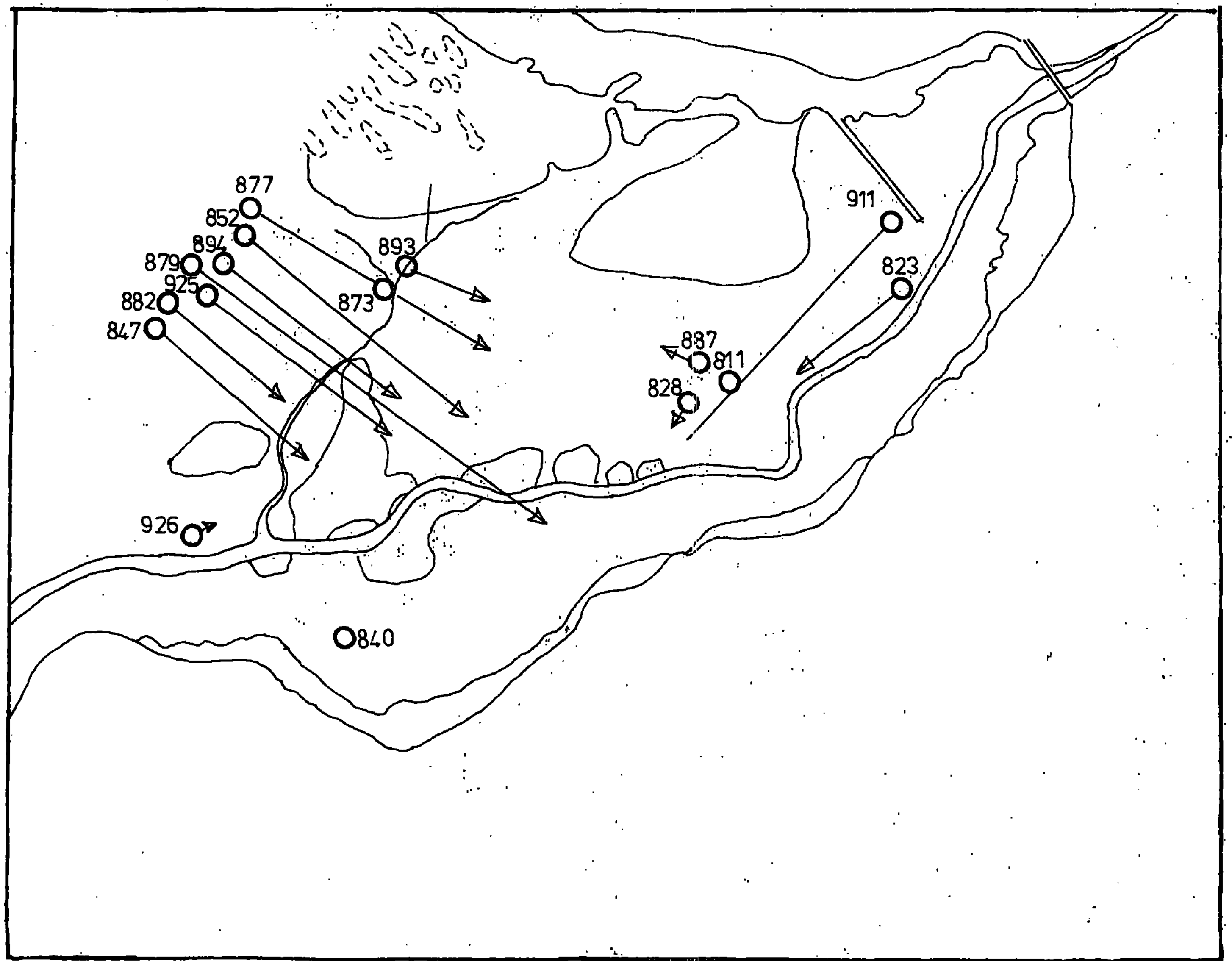


FIGURE XXXIV a. The position of feeding areas for different shelduck during April and May in 1974 (Armstrong 1974).

are low is not known). However, if the size of the feeding range is plotted against the percentage of that range represented by mud or silt (as defined in Figure XXIX) then it is apparent that the larger feeding ranges are usually associated with sandier sediments (Figure XXXIII). This may be related to differences in food availability. The sandy parts of the bay may be poorer feeding areas than the muddy areas. This could be due to rapid drying of the substrate after the tide recedes, causing burrowing of shelduck food items underneath the surface of the feeding substrate (as described in Chapter 6). Consequently, pairs feeding on sandy areas would need to travel further afield in search of more muddy or wet areas where food might be available at low tide. Birds whose feeding area was north of the Peffer Burn (in the sandy part of the bay) were seen to wander between small ponds and drainage channels in this area.

Barry (1962) found that if brant (Branta bernicla hrota) were unable to find suitable feeding areas during the nesting period then atresia of the ovarian occurred resulting in smaller clutches or non-nesting. A similar system if occurring in shelduck, could explain in part, breeding and non-breeding in different parts of the bay. Birds that fed on more sandy substrates would have to spend more time 'searching' for food, compared with pairs feeding on muddy areas, and would not be able to build up sufficient reserves for egg laying or incubation. However, in 1976, after shelduck lost their ducklings they tended to feed in the more sandy areas of the bay during the period before their migration. This suggests that sandy sediments may be good feeding areas, enabling shelduck to build up their fat reserves before migration.

Figure XXXIV a-c shows changes in the position of pairs feeding areas between 1974 and 1976. This shows a progressive movement of pairs'

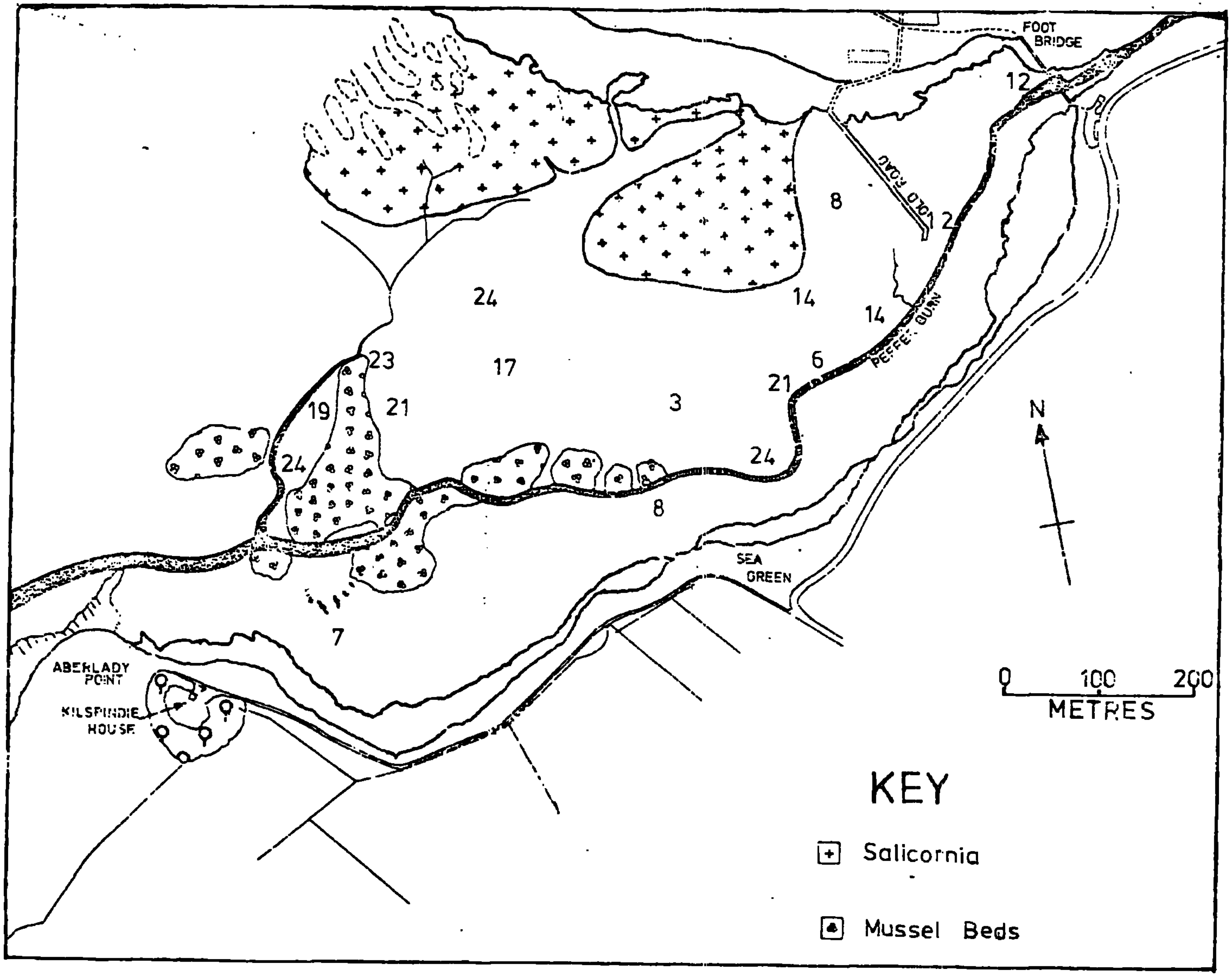


FIGURE XXXV. Dates of (in June) arrival of broods onto Aberlady Bay for shelduck feeding in different parts of the bay.

feeding areas from the mouth of the estuary into the main part of the bay. There were also movements within the bay and out of the bay. The movement of feeding areas into the wetter muddy parts of the bay was usually accompanied by successful breeding (an asterisk marks those birds which are known to have bred). This suggests again the apparent importance of the wet muddy areas of the bay. Although pairs moved their feeding areas up the bay between 1974 and 1976, some remained in the same area e.g., bird no. 840 which bred successfully (seen with ducklings) in at least two years out of the three. However, other birds moved their feeding ranges and still bred successfully (e.g., bird no. 811), although usually they remained in the muddy part of the bay. Therefore successful breeding associated with feeding in certain areas of the bay did not necessarily result in a maintenance of that feeding range in the following year. Could it be beneficial for pairs of shelduck to move further into the bay to feed, as would appear to be the trend in Figure XXXIV a-c? Examination of the date of arrival of broods on the bay (Figure XXXV) shows that generally pairs feeding further into the bay, or in muddy areas, brought their ducklings onto the bay before pairs that fed further out in the bay north of the Peffer Burn. This may have been because the first pairs to separate from the pre-breeding flocks in February fed in the muddy areas. However, if pairs the first to separate from the pre-breeding flock fed either in the muddy or the sandy areas of the bay, then pairs feeding further into the bay may have bred first because food availability being greater in these muddy areas, allowed the onset of laying sooner (cf. Lack 1967).

Shelduck feeding further into Aberlady Bay have been shown to nest usually outside the dune system, and east of Crossed Fairways (see Section 3.1). This study has shown possible mechanisms of intraspecific disturbance (Sections 4.5 and 4.6) and as most birds congregate in the dunes during the morning, disturbance at nest sites would seem most likely to occur in the dunes. This would infer that pairs feeding further into the bay may be more likely to be successful breeders. So, by moving their feeding area further into the bay pairs could not only be less prone to intraspecific disturbance but able to produce ducklings earlier. But is it an advantage to produce the dirst broods on the bay?

Heavy duckling mortality has been reported for several species of duck other than shelduck (Koskimies 1955; Beard 1964; Hilden 1964; Milne 1965). Jenkins et al. (1975) showed that the average production of young per adult tended to be lower at high shelduck densities than at low densities. He also showed that at Aberlady Bay an increase in the numbers of shelduck there from 1950 to 1973 coincided with decreased duckling production. Unfortunately my study finished before it was possible to determine the number of ducklings fledged. However, it was no more than 33 which for a population of 120 adults is equivalent to at most 0.27 fledged ducklings per adult, this may be compared with 4.5 fledged ducklings at Musselburgh (from one pair). I can confirm that low production at high densities of shelduck is not due to low egg production or hatching success (since 366 ducklings were brought onto the bay at Aberlady in 1976) but to high duckling mortality (81% of Class I ducklings died before reaching Class II in 1976). I suggest that high mortality is caused by the large numbers of shelduck (with or without ducklings) present in one area, resulting in frequent interactions between pairs. This in turn leads to creching or opportunistic predation of ducklings by gulls during fights between adults. It would seem that creching may not be as advantageous for ducklings at Aberlady than might be thought. Even though creches of up to 38 ducklings were seen at Aberlady, more than onepair of adults caring for a creche was only seen once. As ducklings stray from their parents while feeding, the larger the number of ducklings there were in a creche the easier it would be for gulls to take a duckling before the female could gather them around her. Therefore, if a pair bring their ducklings onto the bay earlier than most, the likelihood of creching would be less, as fewer broods would be present. Consequently, the chances of the ducklings surviving Class I (where most mortality occurs) may be greater (the smaller brood allowing better care of the ducklings by their own parents). Experimental analysis of following reactions in ducklings have shown the young to become 'imprinted' or 'conditioned' to a moving object when up to 24 h old (Fabricius and Boyd 1954). One hole-nesting species, the wood duck (*Aix sponsa*), can be imprinted to specific calls in the absence of visual stimulation. However, the shelduck follows the requirement for visual stimulation, characteristic of ducks with open nests (Klopfer 1959). Therefore shelduck bringing their brood onto the bay before many other broods are present, may allow more effective imprinting between the parents and ducklings to take place before the parent duckling bond could be broken by creching.

In previous years 1-2 broods were reared in an area of dense cover around the Peffer Burn above the foot-bridge (Jenkins pers. comm.). Two pairs (in 1976) initially took their broods to this area for several days before taking them onto the main part of the bay. One of these pairs had their feeding area in this region and the other pair fed high up in the bay. Therefore, by feeding further into the bay, pairs probably have a (prospective) good and isolated nursery area for ducklings.

It would, therefore, seem advantageous in many ways for pairs to move their feeding areas further into the bay onto more muddy areas. From Figure XXXIV this is a gradual process involving yearly reassessments of the position of pairs in the bay. This system could be maintained by a

TABLE VIII. Number of adult shelduck seen east of the Kilspindie House Sewage Works Line in March (April in 1973 and May in 1976) - mid June. All data except 1976 is from Jenkins *et al*. (1975).

	? 61		YEAR					
	1976	1968	1969	1970	1971	1972	1973	1976
$\bar{x}$	75	83	70	68	77	85	81	79
$S\bar{x}$	-	-	7.6	2.8	2.9	3.3	1.5	4.5

dominance hierachy with the older more experienced birds feeding in the "best" areas and being able to maintain their positions there, preventing other pairs encroaching onto their area.

The position of different pairs' parliament sites may also reflect this dominance hierachy, each pair selecting a site near to their feeding area and preventing other pairs landing there. Even though shelduck were tolerant of each other at parliaments, outbursts of aggression occurred between pairs. On one occasion three pairs were seen prospecting in a group near a parliament site. However, when another pair attempted to join them they were not allowed to (unfortunately it was not possible to see if any of these pairs were ringed).

7.2 CAN THE ABERLADY POPULATION BE SELF-MAINTAINED?

It is possible that the number of breeding pairs present each year is limited by competition between pairs for a good feeding site. The number of birds involved in this competition is probably limited by increased individual distance apparent in the breeding season. Various evidence supports this:

1. The numbers of birds east of the Kilspindie House Sewage Works line (KHSWL) where breeding pairs fed has remained relatively constant since 1967 (Table VIII).
2. Flocks of shelduck were only seen west of the KHSWL line or in the saltings.
3. Feeding ranges overlap.

However, whether the numbers of birds is at a maximum is not clear.

Assuming an annual mortality of 20% for adult shelduck (Boyd 1963), the population of 120 adult shelducks at Aberlady requires 24 shelducks to reach breeding age each year. At most 33 ducklings could have fledged at Aberlady 1976. However, an estimate of losses between fledging and arrival at the bay as an adult (deduced from ducklings ringed in previous years) is 62% which would lower the potential numbers of ducklings surviving to adulthood to 13, below that needed for maintenance of the Aberlady population. This would infer that immigration from other populations is required to maintain the Aberlady population. However, Aberlady is just part of a larger population present in the Firth of Forth and whether ducklings that fledged but did not return to the bay, died or just went elsewhere is not known. If production of ducklings is insufficient to maintain the numbers of shelduck at Aberlady then there must be areas where production exceeds mortality. This would seem likely to occur in smaller populations where densities were less e.g., at Musselburgh where one pair was seen with nine ducklings near fledging.

Reasons for shelduck nesting inland are not clear. Both birds seen feeding inland commenced laying early in the season but were not seen feeding in the bay during this period and it is not known if they did so before this. It is possible that opportunistic feeding in pools inland allowed these pairs to breed earlier free from any competition that birds might experience on the bay.

7.3 ABERLADY'S FUTURE

Aberlady Bay is actively silting up after once being a port. A main sewer used to flow into the bay creating suitable conditions for <u>Hydrobia ulvae</u> which eats bacteria, thriving on some kinds of organic pollution. However, this sewer has been redirected into the Firth of Forth, probably making the bay more sandy (locals told stories of people getting stuck in the mud but now this would only be likely to occur above the foot-bridge in the Peffer Burn). This silting of the bay may be detremental for shelduck e.g., the rise in ground level on the north side of the Peffer Burn may result in this area being covered by the tide less frequently, affecting the invertebrate population found there. Sediments should be checked every few years as this could be a major factor affecting this population.

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Shelduck parliaments. *Ardea* 58: 125-130.

APPENDIX

1·1 TABLE I. Number of invertebrates in mud samples (animals 2 dm^{-3})

Sampling Position	Species				
	Hydrobia ulvae	Nereis diversicolor	Spionid Worms	Macoma balthica	Cardium edule
B1	-	3	3	1	-
C1	-	12	20	1	63
D1	31	3	68	-	3
E1	24	7	50	-	6
A2	-	-	9	-	1
B2	-	1	3	4	-
C2	25	11	57	5	16
D2	88	2	131	2	7
E2	65	-	135	2	3
A3	17	1	87	-	-
B3	3	17	112	3	-
C3	3	10	15	4	4
D3	334	5	200	9	16
E3	230	13	243	2	3
A4	52	3	106	-	-
B4	42	4	47	5	18
C4	1	1	23	1	2
D4	33	25	10	6	13
E4	1		10	1	3
F4	128	7	18	-	5
A5	264	2	26	-	-
B5	239	2	17	-	3
C5	-	15	100	-	2
D5	191	7	32	-	-
E5	102	4	53	3	17
F5	134	3	10	6	6
B6	83	4	17	4	5
C6	173	6		10	7
D6	329	10	12	2	6
E6	29	16	48	4	2
F6	7	3	9	-	-
G6	21	5	28	-	-
H6	23	4	185	-	-
C7	128	2	5	-	2
D7	248	8	9	2	8
E7	67		96	-	-
F7	77	20	141	1	1
G7	59	4	192	2	-
H7	1	1	10	-	-
D8	137	2	7	1	2
E8	44	10	81	16	20
F8	52	15	161	-	-
G8	98	15	149	-	-
H8	110	7	230	-	3
F9	216	8	166	6	8
G9	194	2	10	-	-
H9	40	6	36	-	-
I9	79	7	10	-	-
J10	27	40	29	-	-

TABLE I cont.

Sampling Position	Species: Scrabicularia plana	Arenicola marina	Corophium volutator	Bathyporeia pelagica	Oligo-chaetes
B1					5
C1					15
D1				+	-
E1					5
A2					-
B2					6
C2					20
D2					4
E2					19
A3					-
B3					27
C3	1				3
D3					41
E3					3
A4		1			-
B4	2				28
C4					81
D4	3				99
E4					4
F4					3
A5					2
B5	2				1
C5					40
D5					17
E5					3
F5					5
B6					6
C6	3				20
D6					-
E6					9
F6					3
G6					-
H6					24
C7					3
D7					-
E7					6
F7					31
G7		1			-
H7					-
D8	1				13
E8					1
F8					1
G8					4
H8		1			20
F9		1	+		8
G9					2
H9					10
I9					-
J10			+		19