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# *WATERFOWL DISTRIBUTION AND DIET ON THE MERSEY ESTUARY AND ADJACENT AREAS*

*A report from the British Trust for Ornithology to the Mersey Barrage Company*

*by*

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## *CONTENTS*

## LIST OF TABLES

## *LIST OF FIGURES*

### *Section 1*

*Section 2*

*<u>Section 3</u>*

## *EXECUTIVE SUMMARY*

*Four major objectives were set for the 1990/91 winter:*

I) *to more fully quantify the inherent variability of the distribution patterns of waterfowl within the Mersey in order to identify three types of site - those that are regularly used, those that are intermittently used, those that are never used.*

II) *to investigate the relationship between bird distributions and that of both invertebrate prey and seed availability in order to explain results under objective I.*

III) *to conduct further detailed studies of the night-time distribution of Teal and Pintail in order to refine estimations of the dependence of these species on the intertidal areas within the Mersey.*

IV) *to determine the diet of Teal and Pintail feeding both within and flighting out of the Mersey.*

*These objectives were met by the continued collection of field data both during the day and at night, by the day and night radio-tracking and observation of Teal and Pintail, and by the analysis of Pintail stomach contents. Environmental Resources Limited conducted a sampling programme of both the seeds and the invertebrates of the Mersey, after initial discussions with the British Trust for Ornithology as to the positioning of the sampling sites.*

*The report is presented in five sections:*

*- the first records the changes that have taken place in the numbers of waterfowl on the Mersey over the three years of low tide monitoring. The effect of the cold weather experienced*

*during the 1990/91 winter is stressed. The mudflats that are regularly, intermittently, and never important to the different waterfowl species are determined.*

*- the second section compares the day and night distributions of the feeding waterfowl. All species, with the exception of Wigeon and Pintail, showed some evidence of feeding more on the falling tide. This is linked to the cold weather during the 1990/91 winter which may reduce prey availability and so made it less profitable for some species to feed at night.*

*- the third section concentrates on the distribution of the radio-tracked Teal. The upper and lower estuary Teal populations seemed fairly discrete. Teal mainly used the mudflats, but the saltmarshes became more important at high tide. One inland site was heavily utilized before freezing in mid-winter. The marshes were used more during the cold period as these may have afforded some protection from the wind-chill. There was no evidence of Teal leaving the immediate vicinity of the Mersey estuary on a regular basis during the 1990/91 winter.*

*- the fourth section reports on the feeding ecology study of Teal and Pintail, using both stomach analyses and visual observations. Pintail were found to feed on Suaeda seeds at the inland site, but their stomachs also held Macoma and Cerastoderma remains from estuarine feeding. The intertidal mudflats were the most frequently used habitat and were particularly important on the falling tide and during cold periods when inland sites were frozen.*

*- the fifth section compares invertebrate densities in the Mersey Estuary to bird densities. Waterfowl were generally more numerous in areas with high densities of potential prey. When large numbers of birds were found in areas with low invertebrate densities this was thought to be related to the nature of invertebrate distributions making the sampling*

*technique inadequate. There was not a wide enough spread of data to allow accurate predictions of bird distributions according to invertebrate numbers.*

*Recommendations for further work include the continued ornithological monitoring of the estuary for a fourth winter. Further work on radio-tagged Pintail should be undertaken to fully determine their dependence on the intertidal mudflats of the Mersey, a few Teal should also be tagged to allow comparison with the 1990/91 data. Day and night visual observations of Pintail and Teal from the Mount Manisty high density site would allow the monitoring of saltmarsh and mudflat activity and distribution patterns. More data on invertebrate distributions and size classes would help determine why birds distribute themselves as they do, and possibly whether all feeding areas within the estuary are fully exploited. The invertebrate diet of the Mersey waterfowl could be determined using polygenic antibodies.*

## *GENERAL INTRODUCTION*

*A tidal barrier has been proposed for the Mersey Estuary. One of the potential impediments to large engineering projects like the Mersey Barrage is the effect they may have on the environment (Goss-Custard, 1987), and thus on large populations of wintering waterfowl. The Mersey is the eleventh most important site for wildfowl and the eighteenth most important site for waders in the United Kingdom (Kirby et al., 1990). The Mersey holds over 20,000 waterfowl in total, over 1% of the north-west European population of Shelduck, Teal and Pintail, and over 1% of the east Atlantic flyway population of Dunlin and Redshank. Thus the estuary qualifies as a candidate for the Ramsar Convention designation as an Internationally Important Wetland.*

*The proposed Mersey tidal barrage will generate power on the ebb tide. This would reduce the tidal range and the length of time for which the mudflats are exposed, as the energy yield is linked to the head of water on the landward side of the barrage. It is potentially economically viable to actively pump water on the flowing tide to increase the tidal head. This mode of operation is already used at La Rance, the one operational tidal barrage in Europe. This active pumping leads to increased flooding behind the barrage. The waters then take longer to fall than under natural conditions, an effect heightened when the barrage is generating electricity. The prolonged emptying time reduces the mudflat areas exposed at low tide and lessens available feeding time. A diminution of feeding area could lead to a decrease in waterfowl populations (Goss-Custard and Moser, 1988). This effect might be countered by an increase in the size of individual invertebrates (Kirby, 1987) as the post-barrage immersion times are increased allowing longer periods of feeding for the invertebrates. It is critical to be able to understand how the Mersey is used by birds so that the long term implications of the barrage can be assessed.*

*Estuaries are frequently associated with large bird populations in part because of very high numbers of invertebrates (Prater, 1981). In the context of the proposed Mersey tidal barrage it is important to know what prey the Mersey waterfowl are utilizing, and to what extent the potential prey resources are being exploited. The exploitation level of the invertebrate and plant material could be modified considerably, with potentially serious implications for the birds, as a result of the construction of the proposed barrage. Furthermore the effect of the tidal barrage on the invertebrates and plants will also affect the waterfowl indirectly.*

*To predict the impact of the barrage on the Mersey Estuary, long term monitoring has been required. The work carried out during 1990/91 constitutes the third consecutive winter of monitoring. The work over the three winters has aimed to determine year to year variability, the most regularly important intertidal areas, and waterfowl activity budgets. This has necessitated both diurnal and nocturnal observations as birds are known to feed at night (Dugan, 1981; Wood, 1983; Robert and McNeil, 1989). The work carried out during the 1990/91 winter also concentrated on two internationally important species, Teal and Pintail, the nocturnal distribution and feeding behaviour of which was poorly understood.*

*Long term studies of the year to year variability in the usage made of estuaries by waterfowl are uncommon. This type of study can be invaluable when it comes to assessing the impact of such incidents as the accidental Mersey oil spill of 1989 (Clark et al., 1990b). Furthermore frequent physical changes have occurred over three years in the intertidal areas due to the dynamic nature of the Mersey Estuary. The subsequent changes in waterfowl usage have led to an enhanced understanding of what constitutes preferred feeding and roosting areas. The winter of 1990/91 was characterised by a period of severe cold, from 13 January to the first ten days of February. This was the first* *time in three years that the effect of cold weather could be taken into account.*

*This third year of monitoring has resulted in three major advances in our knowledge of the Mersey ecosystem. The confidence that can be placed in predicting the most important intertidal areas for Mersey waterfowl, both during the day and at night, has been increased. Observations and radio-tracking have led to a better understanding of Teal distributions and Teal and Pintail feeding behaviour on the estuary. Finally the relationship between invertebrate and seed numbers and the waterfowl diet has been assessed.*

# ***SECTION 1***

## ***YEAR TO YEAR CHANGES IN THE NUMBERS OF WATERFOWL FEEDING ON THE MERSEY***

## *1.1 INTRODUCTION*

*The winter of 1990/91 provided a further opportunity to continue the monitoring of the waterfowl numbers using the Mersey Estuary and it's environs. Many seasons of observations must be carried out before the post-barrage bird populations can become more precisely predictable. These observations lead to an enhanced understanding of the variables that characterise the system. This winter was the first of the last three winters of intensive monitoring to have experienced extended periods of cold weather, the last two winters of 1988/89 and 1989/90 having been unusually mild (Clark et al., 1990a; Clark et al., 1990c). The 1990/91 winter was remarkable for the very large wader mortalities occurring on some estuaries of the east coast of Britain. For instance over half the wintering Redshank on the Wash died. Very hard weather conditions are known to lead to cold weather movements of some species (Prater, 1981; Baillie et al., 1986), thus waterfowl influxes onto the Mersey might have been expected this winter as birds tried to escape the harsher conditions prevailing in the east of Britain. The waterfowl counts carried out this winter enabled this possibility to be assessed. The changing physical conditions of the Mersey (eg sediment distribution) were noted and their effect on the changing wildfowl distribution considered.*

*The numbers of birds counted at high tide by the BoEE (Birds of Estuaries Enquiry) were compared to the previous winters' numbers. Both the high tide and low tide counts were used to investigate how bird numbers changed over the winter, especially in the context of the cold weather period. The low tide count data also added to the knowledge of feeding waterfowl distribution in the Mersey, the Alt and the North Wirral Shore. The distribution of the ducks and waders over the last three years was compared so as to allow the most important intertidal areas of the estuary to be determined. This is important in the context of the proposed tidal barrage, and fulfils Objective 1 of the Phase III Ornithological Studies.*

***The distribution of the birds at the all day sites was also quantified.***

## *1.2 DATA COLLECTION AND ANALYSIS*

*In continuing the last two years of ornithological study of the Mersey Estuary two types of counts were made during the 1990/91 winter. The extensive low tide counts covered the whole of the study area every two weeks, and the intensive counts were made at the three `all day' study sites at regular intervals. The high tide BoEE counts are carried out every month and are timed to coincide with spring tides when the waders congregate at discrete traditional roosting sites. This winter the two consecutive official count dates of 2 December and 20 January meant that there was a seven week count interval in mid-winter. During this period no high tide count data on changes in waterfowl numbers was available.*

### *1.2.1 Data Collection - Low Tide Counts*

*The total numbers and distribution of waterfowl using the Mersey and adjacent areas at low tide were assessed by experienced volunteers who carried out low tide counts of the whole area twice a month during the winters of 1988/89, 1989/90, and 1990/91. Figure 1.1.1 shows the 96 separate low tide count areas used to divide the study site into convenient units for counting and distributional analysis. These 96 areas were separated by such features as changes in substrate type, river channels, permanent features such as rock outcrops or large man-made features on the horizon. Whenever possible the numbering of the areas follows that used in previous years. Some parts of the Mersey which had been counted as several areas in previous winters, were counted as one this 1990/91 winter. Thus some areas defined in the previous winters had to be pooled to form new larger areas this winter. The 1989/90 areas 62, 63 and 64 (Figure 1.1.1 in Clark et al., 1990c) were pooled to become area 63 for this winter's analysis (Figure 1.1.1, this report), similarly areas 22, 23, and 24 became area 23. The low tide count area at Egremont (low tide count area 23* *in Figure 1.1.1) is considered part of the North Wirral Shore as it's wader populations move out to the North Wirral Shore when the Egremont foreshore is covered.*

*Seven comparable counts were carried out each winter, with most counts being performed within an hour of low tide and on the official count day (Table 2), although the availability of amateur counters meant that the low tide counts made of some areas were one or two days on either side of the official date. Some areas were not counted this winter, or else the data was not sent in by the counters (Figure 1.1.2).*

*As in the previous two winters specially designed low tide recording forms were used and returned to the British Trust for Ornithology headquarters for computerisation. Birds found feeding and roosting were recorded separately, and the weather conditions and any disturbance were also noted in an effort to take count reliability into account.*

*Counts made during the winter of 1988/89 were reported to ETSU (Clark et al., 1990a). The bird numbers for the winter of 1989/90 were used in a report also made to ETSU (Clark et al., 1990c), as well as in a document to the Mersey Oil Spill Project Advisory Group (MOSPAG), which was interested in the effects on waterfowl of the Mersey oil spill of August 1989 (Clark et al., 1990b).*

### *1.2.2 Data Collection - All Day Counts*

*Three Mersey sites were chosen for intensive counting during the hours of daylight. All day study sites at New Ferry (Figure 1.2.2.1), Stanlow (Figure 1.2.2.2) and Oglet (Figure 1.2.2.3) were counted every hour by the BTO staff from dawn to dusk. Counts were made at fortnightly intervals at Stanlow and Oglet and once a month at New Ferry. Each of these three all day study sites was divided into several all day count areas. These* *areas were smaller than the low tide count areas. This allowed the analysis of changes between winters in numbers and behaviour of feeding and roosting birds to be more precise. The dates of the counts were chosen to cover as much of the whole tidal cycle each month as possible (Table 3).*

### *1.2.3 Data Analysis - Low Tide Counts*

*The low tide count coverage of the whole area was good for the three winters, with on average 78% of all low tide count areas being counted on each count date. Some areas were missed through counters not being available on the required count dates, or for reasons of bad weather. The best available measure of low tide usage for each intertidal area is taken to be the average number of birds counted in the area over the count period.*

*The peak low tide counts are given for the three winters in Tables 4 and 5. For each species of waterfowl figures are presented which show the frequency of the birds on the various mudflats at low tide on the Alt, the North Wirral Shore, and the Mersey Estuary (eg Figure 1.3.1.1).*

*A further set of figures show which mudflats have been used by large numbers of birds over the three winters, 1988/89, 1989/90, and 1990/91 (eg Figure 1.3.1.2). For a mudflat or an area to have been considered important for a particular year it must have held on average at least two percent of the total numbers of a species censused on the Mersey Estuary during the low tide counts of that year. If a mudflat were to reach this 2% limit three winters out of three it would be considered regularly important. If the mudflat only held 2% of the wintering birds in two out of three years it would be taken to be frequently important. If 2% of the low tide population was reached only during one winter out of three the mudflat would be classed as infrequently important, and if never reaching* *this level it was not considered important. This fulfils Objective 1 of the Phase III Ornithological Studies relating to the Mersey Barrage, of quantifying the inherent variability of the distribution patterns of waterfowl within the Mersey.*

*The changes in the bird numbers over the winter are also represented (eg Figure 1.3.1.3). These numbers were collated from both the low tide counts and also the separately organised BoEE counts. These were also carried out by amateur counters, but the counts were made at high tide.*

*1.2.4 Data Analysis - All Day Counts*

*The all day usage values for each species of waterfowl feeding on each of the all day count mudflats were compared between the three years of data. Each usage value represents the total number of bird hours spent feeding on each of the intertidal areas, throughout the study area, and are calculated using:*

$$Usage = \sum_{t=-6}^{t=+5} (A \times B)$$

*Where:*

*t = hours from low tide*

*A = average number of birds feeding at time t when area is exposed*

*B = proportion of counts when area is exposed at time t.*

*The number of the most common bird species found in the Mersey Estuary and the percentage feeding at the all day sites were represented graphically in relation to the state of the tide (eg Figure 2.3.1.1). The distribution of the birds over the winter in the Stanlow and Oglet all day sites are also represented figuratively (eg Figures 2.3.1.2 and 2.3.1.3).*

## 1.3 RESULTS

*The peak low tide counts for the three winters are presented in Tables 4 and 5. The following species accounts summarise the results of analysis of both low tide and all day counts and assess changes in numbers and distribution of the birds between the three years.*

### 1.3.1 Shelduck

*Normally the highest counts of Shelduck recorded from the high tide BoEE counts in Britain are in January or February (Kirby et al., 1990). More Shelduck were counted on the Mersey this winter than in the last five winters at high tide. The peak BoEE count of 5,750 birds was in early December (Figure 1.3.1.1) and thereafter declined. It is thus possible that some birds did not stay on the Mersey, but continued on elsewhere since the winter was particularly cold. The Mersey remains internationally important for Shelduck with 1.4% of the W. European population (Table 1).*

*The peak winter low tide count of feeding and roosting Shelduck on the Mersey Estuary of 3,700 birds in 1990/91 was similar to that of 4,000 in 1989/90, but both these years were lower than the 5,000 birds in 1988/89 (Table 4). The much smaller numbers found on the Alt and North Wirral Shore also declined (Table 5).*

*The low tide distribution of feeding Shelduck in the area (Figure 1.3.1.2) was very similar to those of the last two years (Clark et al., 1990a; Clark et al., 1990c). The decline in the use made of area 58 near Runcorn Bridge continued (Figure 1.1.1). The decline in numbers on the Alt and on the North Wirral Shore was a reflection of the drop in low tide numbers noted above. The inner part of the Oglet and Stanlow Bays, Ince Marsh and the mixed mudflat and saltmarsh areas of*

*Frodsham Score held the greatest numbers of birds in the 1990/91 winter.*

*The most commonly used areas over the last three winters are very similar to those most frequented this winter (Figure 1.3.1.3). The mudflats most used by the Shelduck are generally found in the upper estuary on the areas with the greatest exposure times (Figures 1.2.2.1; 1.2.2.2; 1.2.2.3).*

*The feeding distribution of the Shelduck at the Stanlow all day site (Figure 2.3.1.2) this winter was similar to that of the two previous winters. At Oglet (Figure 2.3.1.3) the feeding birds were found in much the same areas as in the 1989/90 winter, but in greater numbers than in the 1988/89 winter.*

### *1.3.2 Wigeon*

*The BoEE peak count made this winter of 6950 Wigeon was the highest for three winters. However this bird dropped just below the 1% threshold for being Internationally Important, the Mersey now only being considered to hold regularly 0.9% of the N.W. European population (Table 1). International Importance is calculated using a five year moving average. The decline in the International Importance of the Mersey for Wigeon is due to this year's peak count of 6,950 birds replacing a peak count of 11,650 Wigeon made during the winter of 1985/86. The numbers of Wigeon recorded on the BoEE high tide count rose from November to their normal December peak (Kirby et al., 1990), thereafter declining steadily to late February, with numbers dropping rapidly in March as the birds migrated away from the estuary (Figure 1.3.2.1). The cold weather did not appear to displace the birds.*

*The low tide counts were more erratic, but showed the early December increase and the decline thereafter. The peak low tide count of 5,000 Wigeon was the highest count to be made over these last three winters of study (Table 4).*

*Wigeon were found concentrated in areas of Frodsham Score at low tide (Figure 1.3.2.2). They are grazers of vegetation and were much less dependent on the mudflats than on the saltmarsh. The birds were found feeding at the Stanlow all day site, with the greatest numbers found on the portion of the Ince Marsh near the Stanlow observation point (Figures 2.3.2.1 and 2.3.2.2).*

### *1.3.3 Teal*

*The BoEE count maximum of 10,300 birds in December is well within the range of numbers found in the last five winters (Kirby et al., 1990). The Mersey remains very important at the International level for Teal with 2.7% of the W. European population (Table 1). Teal numbers increased from November to December and then declined sharply to mid-January. A period of increase followed before the birds left the estuary from mid-February onwards (Figure 1.3.3.1). The sharp decline in numbers from mid-December is normal for the Mersey, and cannot be attributed to the weather as it was before the severe cold spell of January 1991.*

*The 7,000 Teal recorded on the Mersey Estuary during this winter's peak low tide count (Table 4) were fewer than last winter's 14,000, but greater than the peak 1988/89 winter count of 6,000. Teal are difficult to count at low tide as many can be out of view in channels and creeks. No Teal were recorded on the Alt and North Wirral Shore (Table 5).*

*The low tide distribution of feeding Teal in the area showed the majority of birds to be in Oglet Bay and Stanlow (Figure 1.3.3.2). The Mount Manisty and New Ferry areas were also important. The most commonly used areas over the last three winters were very similar to those most frequented this winter (Figure 1.3.3.3). The areas near Speke airport (76 and 77; Figure 1.1.1) were not counted this winter. The areas used by 2% or more of the feeding Teal each winter at low tide were 32,* *69 and 70. None of these is primarily salt-marsh, and area 32 is quite isolated from any major estuarine vegetation. This implies that Teal fed on an invertebrate diet during the day.*

*The feeding distribution of Teal at the Stanlow all day site this winter (Figure 2.3.3.2) was very similar to that of last winter, but with many more feeding birds than in the 1988/89 winter and less use being made of all day count areas 16 and 21. At Oglet the distribution of feeding birds was very similar this winter (Figure 2.3.3.3) to the last two winter areas, but again much higher numbers were found than during 1988/89 winter.*

### *1.3.4 Mallard*

*The 740 Mallard recorded on the Mersey Estuary during this winter's peak low tide count (Table 4) were fewer than last winter's 1360, and the 1988/89 winter's 870 birds. A further 310 Mallard were censused on the Alt and North Wirral Shore, again smaller numbers than the last two winters (Table 5).*

*The areas most important for the feeding Mallard were Stanlow and Oglet Bays, and the Mount Manisty area (Figure 1.3.4.1).*

### *1.3.5 Pintail*

*The BoEE count maximum of over 3,200 birds in October was the lowest recorded high tide count from the Mersey Estuary in the last five winters and was also two months earlier than the usual December peak (Kirby et al., 1990). This did not appear to be part of a trend as the Mersey Pintail numbers showed large fluctuations from year to year. The Mersey remained internationally important for Pintail with 8.4% of the W. European population (Table 1). The winter Pintail BoEE counts showed that numbers were highly variable with high numbers in December and February (Figure 1.3.5.1). The Pintail numbers showed an increase in the late February count before the birds* *left for their East European summering grounds. The decline from the December count to that of the end of January coincided with the beginning of the harsh weather. It is possible that the birds went further west to try to escape the severe weather.*

*Up to 1,300 Pintail were recorded on the Mersey Estuary during this winter's low tide counts (Table 4). This number was similar to the maximum low tide counts of 1,400 during the 1989/90 winter, and 1,200 during the 1988/89 winter. Only seven Pintail were counted on the Alt and North Wirral Shore (Table 5). The low tide counts registered fewer birds. In a similar fashion to Teal, Pintail will feed and roost in creeks and channels where they can be difficult to see, thus making low tide counts particularly difficult.*

*This winter (Figure 1.3.5.2) most Pintail were found feeding in Stanlow Bay, at New Ferry and also in areas 79, 80, and 84 (Figure 1.1.1). These areas are those that are considered frequently or regularly important (Figure 1.3.5.3). As for the other ducks, the Alt and the North Wirral Shore were hardly used.*

*All day counts showed that Pintail primarily used the eastern end of Stanlow Bay for feeding, this winter (Figure 2.3.4.2) as well as the two previous winters. Fewer Pintail were observed feeding at Oglet this winter than the last two (Figure 2.3.4.3), with rarely more than a hundred birds using a mudflat.*

### *1.3.6 Oystercatcher*

*The BoEE count maximum was only of 58 birds in March on the Mersey estuary. Only 18 Oystercatchers were recorded on the Mersey Estuary during this winter's peak low tide count, however a maximum of 4,100 Oystercatcher were recorded on the Alt and North Wirral Shore (Table 5). This continues the* *decline noticed in the previous winter which was attributed to changes in the sediments of Liverpool Bay (Clark et al., 1990c).*

*Oystercatchers recorded feeding during the low tide counts were mainly found on the North Wirral Shore and on the Alt (Figure 1.3.6.1), with very few birds being noted on the Mersey Estuary. This follows the pattern of the previous winters.*

### *1.3.7 Ringed Plover*

*The BoEE winter count maximum was of only 6 individuals, however 45 Ringed Plover were recorded on the Mersey Estuary during this winter's peak low tide count (Table 4). These were fewer than the 64 and 80 counted during the last two winters' low tide counts. Ringed Plover were also recorded in smaller numbers on the Alt and North Wirral Shore (Table 5).*

*Very few Ringed Plover were found at low tide, but those that were feeding preferred a part of New Ferry, and the central part of the North Wirral Shore (Figure 1.3.7.1).*

### *1.3.8 Golden Plover*

*The BoEE counts of the Alt and North Wirral Shore recorded a maximum of 280 birds (Table 5). In the Mersey Estuary the BoEE count maximum of 1730 birds in December (Table 5) tallies very well with the figure of 1750 Golden Plover recorded on the Mersey Estuary during this winter's peak low tide count (Table 4). This was higher than the previous two winters' low tide counts, but was not necessarily related to a severe weather influx. During the 1989/90 winter Golden Plovers were present in exceptionally high numbers in Britain (Kirby et al., 1990).*

*The low tide count distribution of Golden Plover revealed that one area, the Ince Marsh, was much preferred by feeding Golden Plover (Figure 1.3.8.1) with areas 76, 80 and 81 also used by a* *few feeding birds. Only odd birds fed on the Alt and the North Wirral Shore.*

### *1.3.9 Grey Plover*

*BoEE counts of Grey Plovers were exceptional in the 1990/91 winter with over 2,000 in December and February (Table 5). Large flocks of Grey Plovers do occasionally appear on estuaries for a few weeks, but their origin is unclear (Clark, 1989). Generally the majority of Grey Plover are considered to be highly site faithful between years (Townshend, 1981; Clark, 1989). These high numbers were not reflected in the low tide counts which only recorded 100-150 birds per count. Grey Plover feed well dispersed over the intertidal area and can be difficult to locate. It is, however, unlikely that 2,000 could be missed, and thus their feeding area must remain unclear. If large numbers of Grey Plovers winter on the Mersey in future it will be important to locate their feeding areas. This high BoEE count increases the National Importance of the Mersey Estuary, which is now considered to regularly hold 3.4% of the British population of this bird, up from a value of 1.4% the previous winter. Grey Plover numbers have generally been increasing in the country (Moser, 1988).*

*The numbers of Grey Plover recorded on the BoEE counts showed an increase from November to December, followed by a very sharp decline recorded in late January. Numbers peaked in February before the birds left for staging areas in the Waddensee before migrating to breeding grounds in the northern Soviet Union (Figure 1.3.9.1). The sharp decline in numbers recorded in late January may have been due to severe weather movements.*

*The maximum low tide count of Grey Plover on the Mersey Estuary was of 158 birds (Table 4). The greatest number of feeding Grey Plover at low tide were found on the Alt (Figure 1.3.9.2). This species also fed in smaller numbers on the North Wirral Shore,* *in Stanlow and Oglet Bays, as well as a few individuals in the Mount Manisty area (Figure 1.1.1).*

*The areas found to be regularly important over the last three winters are in Oglet Bay, Stanlow Bay and near Mount Manisty (Figure 1.3.9.3).*

*This winter the preferred areas at the Stanlow all day site were the outer mudflats in the bay (Figure 2.3.5.2). The Grey Plover feeding at Oglet Bay were found primarily on the more outer mudflats, areas associated with sandy mud (Figures 2.3.5.3; 1.2.2.3).*

### *1.3.10 Lapwing*

*The BoEE count maximum of 11,700 in December shows a continuing increase over the previous four years' peak high tide counts of the Mersey. Lapwing numbers increased nationally in 1989/90 (Kirby et al., 1990).*

*The 15,000 Lapwing recorded on the Mersey Estuary during this winter's peak low tide count (Table 4) continued a trend of increases in recorded low tide numbers over the last three winters. There was a decline in the smaller numbers of birds present on the Alt and North Wirral Shore (Table 5).*

*The Lapwing found feeding on the Mersey were concentrated on the Ince Marsh and the upper intertidal areas of Frodsham Score (Figure 1.3.10.1). Fewer birds fed in Oglet Bay. The majority of these birds were associated with saltmarsh and areas of mixed mudflat and vegetation. Many hundreds of Lapwing used the estuary as a roost.*

### *1.3.11 Knot*

*The BoEE count maximum of 870 birds in December shows an increase over the four previous years' peak high tide counts of* *the Mersey (Table 5). This is lower than the low tide count maximum because one of the important Knot roosts on the Mersey at New Ferry is not counted during the high tide counts.*

*The 1,800 Knot recorded on the Mersey Estuary during this winter's peak low tide count (Table 4) showed no great change from the 1,900 and 2,200 birds of the previous two winters. The 12,500 Knot found on the Alt and North Wirral Shore (Table 5) this winter showed very little change from last year, but were many fewer in number than those recorded during the winter of 1988/89.*

*The feeding Knot found in the Mersey Estuary were fairly evenly distributed in Stanlow, Oglet and New Ferry (Figure 1.3.11.1). A few birds also fed near Mount Manisty. This is the first winter with large Knot numbers at Stanlow. Greater numbers of Knot were found on the Alt and North Wirral Shore. The birds were fairly uniformly distributed on the Alt and found on the central sections of the North Wirral Shore.*

### *1.3.12 Sanderling*

*The Mersey Estuary held no Sanderling during either the low tide or high tide counts. The Sanderling on the Alt and North Wirral Shore were there in smaller numbers than in the previous two years (Table 5).*

*The low tide distribution of Sanderling was concentrated around the Alt (Figure 1.3.12.1), a pattern very similar to that of the 1988/89 winter.*

### *1.3.13 Dunlin*

*The BoEE count maximum of 52,000 birds in December is over twice as big as the next largest made during the previous five years and is the largest count ever made on the Mersey. This* *increases the National and International Importance of the Mersey Estuary for Dunlin (Table 1).*

*The peak low tide count of Dunlin recorded was of 33,000 on the Mersey Estuary (Table 4). This was a large increase over the previous two winters' counts of 13,000 and 14,000. The 3,400 Dunlin recorded from the Alt and North Wirral Shore showed a drop from the maximum numbers recorded the previous winter, back to the level of the 1988/89 winter (Table 5).*

*The numbers of Dunlin recorded during the BoEE counts increased from November to a December peak, staying steady to late January before declining sharply through February to March (Figure 1.3.9.1). It is interesting to note that the birds seem to stay on the estuary during the beginning of the period of cold weather in January. There were still 29,500 birds present in mid- February when the worst of the cold spell was over. The low tide count numbers being smaller than those recorded at high tide are a reflection of the large numbers of Dunlin present on Frodsham Score (Figure 1.1.1) which is difficult to count, as well as the relative likelihood of missing small birds which often use gullies and creeks when feeding.*

*These birds distributed themselves extensively in the Mersey Estuary (Figure 1.3.13.2). The highest concentrations were found in Stanlow Bay, Oglet Bay, Ince Marshes, and Frodsham Score. Small numbers of these birds were found in almost all the areas counted this year, except for sandy areas such as areas 38, 75, and 78 (Figure 1.1.1). Dunlin were also found in most areas of the Alt and North Wirral Shore.*

*The areas found to be regularly important over the last three winters are Stanlow Bay, Oglet Bay, and much of Frodsham Score (Figure 1.3.13.3). The areas that are less used tend to be associated with higher sand content (Figures 1.2.2.2 and 1.2.2.3). The Dunlin were found in all areas of Stanlow (Figure 2.3.6.2) during the day. All day count areas 23, 24 and 25* *continued to become more important compared to the last two winters. This was probably a reflection of their increasingly muddy substrate. The birds were found in all areas of Oglet Bay except for saltmarsh (Figure 2.3.6.3). The extensive all day count area 57, sandy in character, had low numbers for its area. Oglet Bay showed an increase in Dunlin numbers for the third consecutive winter: this is possibly just a reflection of the increased birds on the Mersey.*

### *1.3.14 Bar-tailed Godwit*

*The BoEE counts for the Mersey showed a peak of only 7 birds on the Mersey, but no Bar-tailed Godwit were counted at low-tide on the Mersey this last winter. The 6,100 Bar-tailed Godwit on the Internationally Important Alt and North Wirral Shore showed a continued slight decline in low tide count numbers recorded over the past three winters (Table 5).*

*These birds were widespread on the Alt and the North Wirral Shore at low tide (Figure 1.3.14.1).*

### *1.3.15 Black-tailed Godwit*

*The BoEE counts for the Mersey showed a March peak of 247 birds on the Mersey with 152 birds in February. This species has become nationally important for the first time this winter on the Mersey Estuary. These Mersey birds may be part of the Ribble population which seemed to be redistributing itself towards the Dee Estuary in the winter of 1989/90 (Kirby et al., 1990).*

*This winter's low tide maximum of 205 Black-tailed Godwit is much larger than the previous winter's 62 (Table 4) inferring that the Mersey is becoming more important for this species. Only 3 birds were recorded from the Alt and North Wirral Shore (Table 5). The birds arrived on the estuary in early December.*

*The low tide numbers fluctuated over the winter (Figure 1.3.15.1).*

*The Black-tailed Godwit were found uncommonly feeding on the North Wirral Shore and near Mount Manisty (Figure 1.3.15.2), and more regularly in Oglet Bay at low tide. A few birds were found to use all day sandy mud area 25 at Stanlow (Figure 2.3.7.2). Most parts of Oglet Bay were used by feeding birds (Figure 2.3.7.3). There are several possible reasons for this species concentrating in Oglet Bay. It is possible that this was the only suitable area for this species on the Mersey. Otherwise the small total numbers did not make it necessary for the Black-tailed Godwits to distribute themselves widely to make full use of feeding possibilities. Waders like to aggregate, forming as large a flock as possible to lessen the probability of an individual bird being taken by predators, which may have been the reason why Black-tailed Godwit concentrated in a relatively small area.*

### *1.3.16 Curlew*

*The BoEE count maximum of 1,800 Curlew in March is the highest for five years and led to an increase in the National Importance of the Mersey (Table 1).*

*The peak low tide count of 960 Curlew on the Mersey was less than the 1,300 birds found in the winter of 1989/90 and slightly more than the 870 birds recorded during the peak 1988/89 winter count (Table 4). The Alt and North Wirral Shore showed an increase in numbers over the previous year from 460 birds to 670 (Table 5).*

*The numbers of Curlew on the Mersey recorded during the BoEE counts are frequently lower than those of the low tide counts (Figure 1.3.16.1). This is due to many Curlew feeding away from the estuary in fields at high tide. The difference in the two counts was most noticeable in late January when the weather was* *at its most severe, this presumably leading to more birds attempting to increase their energy uptake by trying to feed in the fields adjacent to the Mersey.*

*Curlew distributed themselves widely on the Mersey Estuary at low tide (Figure 1.3.16.2). Unlike many other waders, this bird did use sandy areas and was even found on such outer sandbanks as area 78 (Figure 1.1.1). The greatest numbers were found in Oglet Bay, Stanlow, Frodsham and the sandy areas just west of the Runcorn Bridge, which were infrequently used by other species. The Alt and North Wirral Shore were also used extensively by feeding birds.*

*The Mersey Estuary was divided into 58 areas for the purposes of this study. Over the last three winters two percent or more of the Curlew used most areas of the inner estuary at least during one winter (Figure 1.3.16.3) showing the species to be widely distributed. The areas most regularly important were Stanlow Bay, Oglet Bay, the outer Frodsham Score mudflats and the areas just to the west of Runcorn Bridge  A similar widespread distribution of Curlew was found on the Severn Estuary (Clark, 1989).*

*Curlew utilised all of the Stanlow mudflats during the all day counts for feeding (Figure 2.3.8.2). Curlew used all day areas 23, 24 and 25 more this winter than past winters, this was similar to Dunlin. The all day site at Oglet Bay (Figure 2.3.8.3) was extensively used by feeding birds, but in greater numbers than those seen at Stanlow. The outer mudflats, 54, 56 and 66 were used by more birds this winter, than the previous two winters.*

### *1.3.17 Redshank*

*The peak BoEE count for the internationally important population of Redshank of 4,330 birds was similar to the previous year's high count (Table 1). However the peak low tide* *count on the Mersey recorded 6,460 Redshank (Table 4). This was a large increase over the previous two winters' low tide counts of 4,490 and 3,360. The 1,610 Redshank recorded from the Alt and North Wirral Shore represented a drop from the 2,070 recorded the previous winter and the 2,080 in the 1988/89 winter (Table 5).*

*The numbers of Redshank on the Mersey recorded during the BoEE counts increased slightly from November to peak in December, declined in January and showed an increase in February (Figure 1.3.17.1). The sharp decrease in numbers is also noted on the early January low tide count, with the increase in birds confirmed by the end of January low tide count (Figure 1.3.17.1). The frequently high low tide count values compared to those of the BoEE are a reflection of the difficulty in locating widespread roosts of Redshank and the number of birds that were feeding inland during the mid-winter cold period.*

*Feeding Redshank were found to be widely distributed in the Mersey Estuary and on the Alt and North Wirral Shore during the low tide counts in 1990/91 (Figure 1.3.17.2). In the Mersey Estuary the greatest numbers were found in Stanlow Bay, followed by Frodsham Score and Oglet Bay. Large densities were also found on the North Wirral Shore.*

*Over the last three winters, New Ferry, the Mount Manisty area, Stanlow Bay, and Oglet Bay form the most important areas for feeding Redshank inside the Mersey Estuary (Figure 1.3.17.3). Frodsham Score was only important during this 1990/91 winter. At the Stanlow all day site the Redshank were found in all areas (Figure 2.3.9.2), but only in small numbers on the Ince Bank saltmarsh and the sandy area number 18. There has been a trend for more birds to use Stanlow all day areas 23, 24 and 25 in the last two winters. As for Dunlin this is probably a reflection of these areas becoming muddier in character. At Oglet Redshank were recorded feeding in all areas during the day (Figure 2.3.9.3), but most of all in the inner, muddier,* *areas of the bay. The pattern of Redshank usage of Oglet Bay has hardly changed between the last three winters.*

*1.3.18 Turnstone*

*The BoEE counts for the Mersey did not record any birds on the Mersey during the winter. Only 24 Turnstone were counted at low tide in the Mersey Estuary this winter, numbers found during previous winters have also been very small (Table 4). The 551 birds on the internationally important Alt and North Wirral Shore were a slight drop from the numbers recorded the previous year (Table 5).*

*Turnstone were uncommonly seen feeding in the Mersey Estuary (Figure 1.3.18.1), but were more frequent on the Alt and especially the North Wirral Shore. The Egremont area held the greatest densities of this species (Figure 1.1.1).*

*1.3.19 Total birds*

*The most commonly used areas of the Mersey Estuary during the 1990/91 winter, by all species of feeding birds, were to be found in Stanlow Bay, Oglet Bay, the Ince Marshes and Frodsham Score (Figure 1.3.19.1). The sandbanks in the middle of the estuary, 38, 49, 56, 57, 78 (Figure 1.1.1) were the least used of the counted areas. The outer mudflats of the Alt were extensively used, as were the more central areas of the North Wirral Shore.*

*Over the last three winters Stanlow Bay, Oglet Bay, Ince Marsh and Frodsham Score have proved to be the most utilised areas of the Mersey estuary when total bird usage is considered (Figure 1.3.19.2).*

## *1.4 DISCUSSION*

*The 1990/91 winter was the first of the three winters of intensive monitoring of the waterfowl populations in Liverpool Bay that had a prolonged period of cold weather. Very hard weather conditions are known to lead to cold weather movements (Prater, 1981), thus waterfowl influxes onto the Mersey might have been expected this winter as birds tried to escape the harsher conditions prevailing in the east of Britain. There was very little evidence of this. Shelduck, Wigeon, Grey Plover, Dunlin, Black-tailed Godwit and Curlew numbers were high this winter, but the peak counts were mainly before the period of cold weather, or after in the case of Black-tailed Godwit.*

*Unlike parts of eastern England very little evidence was found of mortality induced by hard weather on the Mersey. A single Wigeon was recovered frozen in its roosting position and one dead Redshank was found at the end of January. However the numbers of most species did not show much evidence of fluctuations beyond what would normally be expected. Some Pintail may have left the Mersey Estuary during the cold period and returned afterwards. Pintail also declined in late December during the mild winter of 1988/89, but their numbers did not increase again. Grey Plover numbers also declined in late January at a time that suggested a move away from the hard weather. Two species, Dunlin and Curlew, declined in numbers at the time of the cold weather, but both species showed similar population decreases in the mild 1988/89 winter (Clark et al., 1990a). Redshank numbers declined more rapidly in early January than in the 1988/89 winter. The increase that followed in early February 1991 might have been due to birds from other areas arriving on the Mersey. It is possible that some Mersey birds left the estuary hoping to find better feeding conditions and that some of these or other birds returned. There is very little hard evidence of large changes in bird numbers caused by the weather. On the whole the birds on the Mersey stayed there, and survived climatic conditions that did not get as bad, in*

*January and February, as in some other parts of eastern Britain. Even during the sub-zero nights, the birds on the Mersey had a few hours of feeding time as the waters receded after high tide. For most of the warmer days the mudflats remained unfrozen.*

*Physical conditions on the Mersey were seen to have some of the expected effects on the distribution of birds (Clark, 1983; Ferns, 1983). Shelduck seemed to prefer areas with higher exposure times. Wigeon were not dependent on the mudflats, but mainly utilized the saltmarsh areas. Grey Plover and Curlew were seen feeding in areas with both sand and mud. Redshank preferred muddier areas. Dunlin numbers were lowest in sandy areas. Changes in sediment type can lead to changes in usage. This occurred in all day areas 24, 25 and 26 of Stanlow Bay which changed from sand towards a mud substrate over three years, leading to much increased use of these areas by Redshank, Curlew and Dunlin.*

*The use made of the estuary at low tide was found to be similar between the winters of 1988/89 and 1989/90 for the common species such as Dunlin, Redshank, Curlew, and Shelduck in the Mersey (Clark et al., 1990c). This was generally the case after three winters. There were some local changes in distribution; often these could be attributed to physical changes as above, or else to lower populations (eg Pintail in Oglet Bay). Shelduck, Wigeon and Teal distributions were very similar for all three winters. Grey Plover distributions stayed much the same between the three years. Dunlin, Redshank and Curlew distributions also did not vary much between years, and the variation could be explained in terms of sediment changes.*

*The areas of the estuary that were least important to the birds were generally the sandier outer mudflats such as areas 48, 49, 74, 75, 78, 80 and 81 (Figure 1.3.19.2), as well as most of the New Ferry area. The most regularly important areas were Stanlow, Oglet Bay and Frodsham Score, which are all primarily*

***muddy in character. Some species had preferences that did not quite fit into the above general observations. The Pintail regularly used areas 28, 79 and 80 that were not important for most other species. Area 48 and 49 were regularly important for Dunlin. At least 2% of the Curlew were found in each year in area 74, yet this was not an important area for other birds. Apart from these exceptions, the areas most important to the pooled birds are also, on the whole, those that are most used by all individual species.***

# *SECTION 2*

## *COMPARATIVE STUDIES OF DAY AND NIGHT DISTRIBUTION AND FEEDING OF THE MERSEY WATERFOWL*

## *2.1 INTRODUCTION*

*Monitoring the use made of the mudflats at night by waterfowl was continued for a second winter at the two most studied all day sites, Oglet and Stanlow. This was to further the understanding of the way that waterfowl increase their food intake by feeding at night on the Mersey. This is a regular phenomenon in some wader species such as Grey Plover (Dugan, 1981; Wood, 1983), and for some duck most of their feeding activity is carried out during the hours of darkness (Pirot, 1981; van Eerden, 1984).*

*In temperate climes birds are known to feed actively at night, presumably to make up for energy shortfalls during the day caused by high energy requirements and short daylight periods (Goss-Custard et al., 1977; Pienkowski, 1982), or else because invertebrate behaviour makes feeding more profitable at night. There is evidence to show that birds also feed at night in the tropics despite the weather being more clement and days never as short (Robert and McNeil, 1988). In both temperate and tropical conditions prey activity often increases at night and feeding conditions improve (Dugan, 1981). So whereas in some tropical conditions waders are known to feed at night because of their difficulty in obtaining enough food due to low invertebrate numbers (Englemoer et al., 1984), other work tends to show that the invertebrate activity patterns lead to this increased nocturnal feeding (Robert and McNeil, 1988). A further factor leading to night-time feeding is the lower predation risk and disturbance that feeding birds are subjected to (Owen et al., 1986).*

*Wader feeding strategies are as yet imperfectly understood. On the Mersey the understanding of the feeding effort made by the ducks and waders at night was much advanced by the work carried out during the 1989/90 winter (Clark et al., 1990c). The winter of 1990/91 has seen a continuation of this work, and the results are presented here. The nocturnal work has concentrated*

***on the Mersey itself, the area most likely to be affected by the building of the proposed tidal barrage.***

***Whenever reference is made to the 1988/89 winter the figures can be found in Clark et al. (1990a), while figures for the winter of 1989/90 can be found in Clark et al. (1990c).***

## *2.2 DATA COLLECTION AND ANALYSIS*

*Due to the smaller numbers of birds seen feeding at night the data presented here were only for the commonest species: Shelduck, Wigeon, Teal, Pintail, Grey Plover, Dunlin, Black-tailed Godwit, Curlew and Redshank.*

### *2.2.1 Data Collection*

*All night data were collected at two of the three all day sites, at Stanlow (Figure 1.2.2.2) and at Oglet (Figure 1.2.2.3). Each count took two hours to complete due to greater concentration required when using the image intensifier. Methodology changed for nocturnal counts at Oglet from the previous 1989/90 winter. For the majority of these counts the observer walked most of the length of the bay to compensate for the lower magnification of the visual aid, the circuit taking about two hours. Otherwise the method is as that of the all day counts (Section 1.2.2). Whenever the climatic conditions permitted the night counts were carried out immediately after the day-time counts and followed the all day count dates (Table 3).*

*The counts were carried out for this study using an image intensifier with either a catadiopteric Nikkor 500/f8 lens or a Nikkor 300/f4.5 lens. The lens used depended on the light conditions. Dark overcast nights made the 500mm lens more difficult to use due to its greater light attenuation, and often the mudflats were better counted with the lower magnification. The 500mm lens magnified the object just over nine times, the 300mm about 5.5 times. The telescopes used for the daytime counts magnified between 20 and 40 times. It was thus to be expected that the outer mudflats would not be counted as completely at night as during the periods of day-light.*

*Areas with dark, non-reflective substrata made nocturnal bird counts more difficult. Small, dark, roosting or infrequently moving birds were difficult to pick up at night. Shelduck were more easily seen than Dunlin. Counts made with the image intensifier were particularly good during moonlit nights. Similarly the eastern end of Stanlow was easier to count at night, because of the lights from the industrial complex reflecting on the mudflats. Night-time counts are still likely to be underestimates of the actual bird population present on the mudflats compared to counts carried out during the day. This is especially true for birds that were far from the observation point, on the outer mudflats. If there were large differences in the number of birds seen feeding on different nights this would lead to the variance shown for some species, a reflection of the two-hourly nature of the counts.*

### *2.2.2 Data Analysis*

*The night-time data were analyzed in the same way as the day-time data from the all day counts (Section 1.2.4). Both the numbers and the percentage feeding of the most common bird species found at night on the Mersey were represented graphically (eg Figure 2.3.1.1). The nocturnal distribution of the birds over the all day mudflats was mapped for both Oglet and Stanlow (eg Figures 2.3.1.2 and 2.3.1.3). The bird numbers and frequency of feeding at night were compared between the two winters of 1989/90 and 1990/91. The day-time numbers and feeding frequencies were compared between the winters of 1988/89 and 1990/91, as the data from the 1989/90 winter was analyzed differently (Clark et al., 1990c). Only very obvious differences in the day and night distributions of the birds were noted, as generally night-time counts were more likely to underestimate the actual bird population present on the mudflats than the day-time counts. This was due to the problems of visibility (Section 2.2.1).*

## *2.3 RESULTS*

### *2.3.1 Shelduck*

*During the day the majority of Shelduck were observed feeding, except at high tide (Figure 2.3.1.1). Generally 70 to 90 percent of birds fed for three or more hours either side of low tide, with a gradual decline as high tide approached. The decline in the proportion of feeding birds was disguised at Oglet because some Shelduck roosted away from the Bay and were not included in the analysis. Some of the few remaining birds continued feeding around the non-flooded margins of Oglet Bay. Between 5 and 6 hours before low tide there was little change in the proportion of feeding birds at both Oglet and Stanlow, however the number of birds in the area increased considerably. This may have been due to birds arriving from their roosts into the area and waiting for the mudflats to be cleared of water by the falling tides before feeding.*

*At night the number of birds feeding was much more variable. There were never as many birds feeding at night as during the day. This was at least partly due to birds on the outer mudflats being more difficult to count at low tide. On any one night the counts were carried out every two hours, and as there were very large differences in the number of birds seen feeding on different nights, this increased the amount of variance. At night the greater proportions of birds were seen feeding on the falling tides. This may have been due to the cold weather. The cold was particularly bitter at night and the mudflats froze up fairly rapidly. This not only reduced the activity of the invertebrates, but may also have made them burrow more deeply out of reach of feeding birds. By the time the tides started coming in the surface of the mudflats would have been frequently frozen leading to very poor feeding conditions.*

*The two winters of day-time data showed very similar patterns. The winter of 1988/89 was very similar to that of 1990/91. The* *numbers of Shelduck formed a plateau at low tide as did the proportion feeding, with a decline to high tide of both values. There was no evidence of greater day-time numbers or proportions of feeding Shelduck in the 1990/91 winter. This would have been expected if the birds were finding it difficult to fulfil their nutritional requirements due to the prolonged cold weather. Yet the number of Shelduck feeding at night was higher in 1990/91 than in 1989/90. In both winters feeding declined on the rising tide. It is possible that some of the birds increased their nocturnal feeding to make up for the inclement conditions.*

*Shelduck distributed themselves at night in a manner very similar to that found during the day, especially at Oglet (Figure 2.3.1.3), where the only difference was in the smaller number of birds. There was no evidence of a change in the day to night distribution at Stanlow either, if the difficulties of night observations are taken into account. The relative decline in usage made of areas 13, 14 and 20 (Figure 2.3.1.2) may be due to the further birds not being seen. During the day many of the birds using these areas are found in the western end of the bay. This were similar to the distributional changes found during the winter of 1989/90.*

*Summary: The majority of the Shelduck fed during most of the day with the exception of the high tide periods when the mudflats were covered. At night the Shelduck fed mainly on the falling tide due to the colder conditions that affected the availability of their prey. The numbers of birds feeding at night were lower, but distributed in a similar manner to that observed during the day.*

*2.3.2 Wigeon*

*During the winters of 1988/89 and 1989/90 no more than five Wigeon used either Stanlow or Oglet, being mainly concentrated on the Frodsham Score. 1990/91 saw larger Wigeon numbers using*

*Stanlow. Oglet was also used on one occasion, but there was not enough data to make any comments worthwhile. During the day less than fifty percent of the Wigeon at Stanlow were feeding (Figure 2.3.2.1). The majority were loafing or roosting. The proportion feeding was greater on the falling tide, when this largely vegetarian duck may well have been feeding on vegetation displaced from the saltmarshes. Many fewer Wigeon were seen at night, and very few were feeding.*

*During the day most Wigeon were found at the western end of the Ince Bank and on the all day area 25 (Figure 2.3.2.2). The creek areas 11 and 15 were also used, possibly much more widely than recorded (see Section 4.3.2) due to the difficulty of counting this area (pers. obs.). Very few birds were seen at night. The Wigeon are known to feed on the Ince Bank.*

*The cold 1990/91 winter was the first time in three years that Wigeon used Stanlow in numbers. It is possible that due to the bad feeding conditions caused by the prolonged cold period the birds had to use the estuary more than usual for feeding.*

### *2.3.3 Teal*

*During the day the numbers of Teal stayed fairly steady at Stanlow and Oglet (Figure 2.3.3.1). The lower numbers found towards high tide were due to the Teal roosting on the covered mudflats where they were not counted, or moving into the channels and creeks where they are very difficult to see. The decline at Stanlow towards low tide was not significant, as can be seen by the standard errors, but it was possible that some birds left Stanlow to roost at Oglet.*

*The proportion of feeding birds during the day varied between about 20 and 70 percent, with the lowest values at both sites being recorded around low-tide. At both sites the largest proportions of feeding birds were recorded at high tide, when total bird numbers were declining. This was due to Teal* *`disappearing' into the creeks and channels of the saltmarshes to feed (Section 4.3.2).*

*At night numbers were much smaller than during the day at both sites, being partly a reflection of the greater difficulty in seeing birds at night. At Stanlow a higher proportion of feeding birds was found at night than during the day. The birds fed more on the falling tide. The decline in the proportion feeding towards high tide was a reflection of the distance to the creeks making it impossible to see at night the birds that are known to feed in the creeks during the day. The birds were unable to feed on the mudflats when covered. The birds also fed more on the falling tide at Oglet.*

*In both winters the peak daytime numbers of Teal were counted at Oglet a few hours after low tide when many birds were using the area as a roost. The proportion of feeding birds was greatest around high tide. Many more Teal used Stanlow in 1990/91 than during the winter of 1988/89. The night data for the last two winters showed a similar high proportion of feeding birds at Stanlow with a decline towards high tide. The Oglet data showed that the proportion of feeding birds at night was higher and more continuous in the winter of 1989/90 than was the case this 1990/91 winter. This may be due to it having been warmer in the former 1989/90 winter, thus allowing birds to feed right through the tidal range.*

*The day-time and night-time distributions of the Teal at Stanlow (Figure 2.3.3.2) and at Oglet (Figure 2.3.3.3) showed no differences that could not be explained by the methodology (Section 2.2.1). Teal are small, brown, slow-moving duck, which are difficult to see at night. This would also apply to the differences noted in the 1989/90 winter.*

*<u>Summary</u>: Teal numbers stayed fairly constant during the day at both Stanlow and Oglet. Teal fed throughout the tidal cycle, though probably most of all at high tide when the creeks and*

*saltmarsh became available. At night Teal fed less on the rising tide, probably due to the cold conditions prevailing for part of the winter, but the birds were seen feeding actively both on the mudflats and in the creeks. There was no evidence of differences in the day- and night-time distributions of the birds.*

### *2.3.4 Pintail*

*Only a small number of Pintail were ever counted at Oglet. Stanlow was more important for the Mersey population. The Stanlow Pintail showed large apparent fluctuations with the tide (Figure 2.3.4.1), but the standard errors show these not to be significant. The large standard errors are due to the large variation in the numbers of birds using the area during different all day counts. This also explains the large oscillations that occur in feeding percentages. The Pintail seemed to feed most at mid tide and high tide in Stanlow Bay. As was also the case for Teal, the visible numbers of Pintail declined at high tide, this being due to their disappearing into the creeks near Mount Manisty where they fed extensively (see Section 4.3.2). The few Oglet birds seemed to mainly feed on the falling tide, but numbers increased towards high tide with the arrival of Pintail that did not appear to feed. These birds would probably feed in the saltmarsh at high tide, where they would be out of the view of the counters.*

*Less than five Pintail were seen feeding at night at Stanlow (Figure 2.3.4.1), but this is probably due to their preference for feeding areas far from the observation point, and thus out of useful range of the image-intensifier. Oglet Bay was little used by Pintail at night.*

*During the winter of 1988/89 fewer Pintail were recorded at Stanlow during the day-time than in the 1990/91 winter. Very few Pintail were seen feeding. More birds were seen at Oglet, but no clear pattern emerges of the birds' feeding patterns or* *movements. Too few birds fed at night to make any comparisons worthwhile.*

*No Pintail were seen to be feeding at night at Stanlow (Figure 2.3.4.2) and very few at Oglet (Figure 2.3.4.3). The birds seen at Stanlow during the day-time were mainly found near Mount Manisty, at the western end of the bay, and thus out of sight of the image intensifier. Oglet did appear to be less used at night than during the day by the few birds that used this area. The few birds present at night used mudflat 66 which was not used during the day.*

*The past winter of 1989/90 also recorded very few Pintail at Stanlow at night. More Pintail were seen feeding at night in Oglet Bay during the 1989/90 winter than during that of 1990/91. The numbers were still small.*

*Summary: Stanlow was more important for the Mersey population of Pintail than Oglet. The numbers seemed to stay fairly constant during the day at Stanlow and showed an increase of non-feeding birds at Oglet towards high tide. The Pintail fed most at mid-tide and high tide in Stanlow Bay. The Oglet Pintail seemed to mainly feed on the falling tide. Stanlow was used by more Pintail this winter compared to 1988/89. No Pintail were seen to be feeding at night at Stanlow and very few at Oglet.*

### 2.3.5 Grey Plover

*During the day numbers of Grey Plover at both Stanlow and Oglet (Figure 2.3.5.1) did not vary significantly, except towards high tide when the birds roosted in places where they were more difficult to see. At Oglet nearly all the birds fed four hours either side of low tide, only stopping when the mudflats became covered. At Stanlow the proportion of birds feeding declined from two hours after low tide onwards. Stanlow may have provided better feeding conditions allowing the birds to use* *slightly less of the tidal cycle. Otherwise the Stanlow Grey Plover may have fed on an invertebrate species which could burrow to escape prolonged periods of exposure and thus be less available on the rising tide. Very few Grey Plover were seen feeding at night at either Stanlow or Mount Manisty.*

*Stanlow and Oglet usage this winter was very similar to that of the 1988/89 winter, both in terms of birds present and proportion feeding. The same decline in feeding proportion on the falling tide was noted at Stanlow both winters. The Oglet birds feed fairly continuously on the available mudflats both winters. There were too few birds seen at night during the last two winters to make comparison worthwhile.*

*Very few birds were seen at night at either Stanlow (Figure 2.3.5.2) or Oglet (Figure 2.3.5.3).*

*Summary: Grey Plover fed intensively during the majority of the tidal cycle. Feeding conditions may have been better at Stanlow for this species which did not feed there for the whole of the rising tide, or else prey became less available making it less worthwhile for Grey Plover to feed. There was no evidence of differences in between-year usage of Stanlow and Oglet. Very few birds were seen feeding at night.*

### *2.3.6 Dunlin*

*During the day between 75 and 100% of Dunlin fed from five hours before to four hours after low tide at both Stanlow and Oglet (Figure 2.3.6.1). At both sites there was evidence of a decline in the proportion feeding on the rising tide. This was probably again due to the reduced availability of invertebrates after exposure to the cold air temperatures found during the 1990/91 winter. Dunlin numbers were lowest at high tide, as the birds left to roost at Frodsham. Both Stanlow and Oglet showed slight, though not significant, declines, in the number of*

*Dunlin present from low tide onwards. The birds may have left for their roost immediately after feeding.*

*The numbers of Dunlin seen at night were much smaller than those recorded during the day at both Stanlow and Oglet. At Stanlow the proportion of feeding birds declined with the falling tide on the one night count that revealed feeding Dunlin. This may have been due to invertebrate activity being lessened by exposure to the cold, or even the physical hardening of the mud during the very cold period (pers. obs.) making feeding difficult. At Oglet, Dunlin found at night were continuously feeding except towards high tide. The larger numbers counted toward high tide may just reflect the nearness of the birds to the observer at that period. There was no evidence of a decline in feeding on the falling tide at Oglet.*

*The two winters of 1988/89 and 1990/91 showed a similar Dunlin peak abundance towards low tide. Over 80% were feeding through the tidal cycle, except for the high tide period. There were very few Dunlin feeding at night during the 1989/90 winter at Stanlow. Oglet had similar numbers of Dunlin at night as in the day on the falling tide. These Dunlin were all feeding.*

*Fewer Dunlin were seen feeding at night than during the day in the winter of 1990/91. When the distances that can be accurately counted using the image intensifier are taken into account, there is no obvious difference between the day-time and night-time distributions of Dunlin at Stanlow (Figure 2.3.6.2), except for area 24 which is used for many bird hours during the day, but not at night. This mudflat is dark which makes counting small dark birds on it difficult. The same lack of notable difference in day-time and night-time distribution applies to Oglet (Figure 2.3.6.3). There are no obvious differences between the day and night count distribution at Stanlow during the 1989/90 winter. The distribution of Dunlin at Oglet during the 1989/90 winter does show more birds using area 63 at night than during the day and fewer using area 60.*

*This may be due to human and canine disturbance during the day near area 63, as many walkers take the footpath around the Hale lighthouse.*

*Summary: Dunlin fed intensively for most day-light hours except at high tide when the mudflats are covered. This was the case for the two comparable winters of study. During 1990/91 a decrease in feeding on the rising tide, probably due to the cold weather reducing invertebrate availability, was observed. Fewer Dunlin were seen at night than during the day. At Stanlow most night-feeding of Dunlin was on the falling tide. During the 1989/90 winter as many Dunlin fed at Oglet at night as during the day, all feeding on the falling tide. The day and night distribution of the birds was very similar, but with some areas being used more at night possibly through lesser disturbance.*

### *2.3.7 Black-tailed Godwit*

*The 1990/91 winter revealed significant numbers of Black-tailed Godwit using the Mersey Estuary. These were almost all concentrated in Oglet Bay. The small numbers explained the large fluctuations observed in the proportion of feeding birds (Figure 2.3.7.1). Bird numbers increased towards high tide, as birds known to be feeding in area 65 (figure 1.1.1) returned to Oglet to form a high tide roost. On very high tides the birds flew in the direction of Ince Marsh, probably to roost. Most birds fed during the falling tide, the proportion feeding declined on the rising tide with all birds roosting at high tide. Night feeding at Oglet was only witnessed during one count, toward high tide.*

*Very few Black-tailed Godwits were seen feeding during the day-time at Stanlow (Figure 2.3.7.2) and none at night. There were too few sightings of nocturnally feeding Black-tailed Godwits to make a comparison between the day and night distributions (Figure 2.3.7.3).*

## 2.3.8 Curlew

*The numbers of Curlew at Stanlow showed a steady decline from two hours after high tide (Figure 2.3.8.1). The proportion of feeding birds also showed a slight decline with the rising tide. This may be related to the cold leading to a decline in feeding efficiency, and thus the birds leaving. Curlew are known to find feeding difficult during cold winters (Clark, 1982). Some birds leave Stanlow to roost, leading to the gradual fall in numbers, others stay and roost on the mudflats. The numbers of Curlew at Oglet did not change significantly during the day, except at high tide when some birds left the area to roost or feed in the nearby fields. The proportion of feeding Curlew also declined with the rising tide, but from two hours after low tide.*

*At night at Stanlow, the number of Curlew showed an increase either side of low water. Rarely were there enough birds to make the calculation of a feeding percentage possible. Most Curlew at Stanlow were roosting out on the mudflats at night. The proportion of feeding birds showed a decline towards high tide. This was similar to the daytime feeding behaviour. The numbers of Curlew at Oglet were very variable at night.*

*The two winters of day-time data show that over 70% of the Curlew fed for three hours either side of low tide. The numbers of feeding Curlew declined towards high tide in both winters. At Stanlow birds were seen to feed for most of the available time during the winter of 1988/89, without the sharp decrease witnessed this winter. This implies that the decline in numbers of Curlew at Stanlow this winter may have been linked to the cold weather.*

*The two winters of night data at Stanlow showed opposing patterns. The 1990/91 winter data showed bird numbers increasing on the rising tide; the previous winter showed an increasing number of Curlew on the falling tide. Both winters* *showed that the majority of the Curlew were roosting at night. At Oglet high proportions of Curlew fed on the falling tide.*

*At Stanlow there were no major differences between the day- and night-time distributions on the mudflats (Figure 2.3.8.2) when distance from the observation point to the mudflat was taken into account. This was also the case at Oglet Bay (Figure 2.3.8.3). It might appear surprising to have seen so few birds on the more distant Oglet mudflats, but this is due to the cryptic coloration of Curlew and the dark mudflats found at Oglet. Nor was there any significant difference in the distribution of these birds during the winter of 1989/90 at either Oglet or Stanlow.*

*Summary: Curlew at Stanlow spent less time feeding than those at Oglet during the 1990/91 winter. Stanlow is more open to northerly winds and it's sediments may be more affected by the wind chill, leading to colder temperatures and the attendant less suitable feeding conditions. The birds fed less on the falling tides. Most Curlew seen at night were roosting out on the mudflats. The way the birds distributed themselves on the mudflats showed no change between night and day.*

### *2.3.9 Redshank*

*During the day Redshank numbers stayed fairly constant from four hours before to three hours after low tide at Stanlow (Figure 2.3.9.1). The smaller numbers before and after were due to roosting and feeding birds not being picked up in the saltmarsh vegetation. The pattern was roughly similar at Oglet with an added slight decline in numbers at low tide when some of the birds using the outer mudflats were out of view. Generally over 70% of the birds fed at all tidal states except for high tide when the mudflats were covered.*

*At night the numbers recorded were smaller than during the day, but at Oglet the numbers were comparable when the lessened* *visibility and magnification of the image intensifier is taken into account. The birds were feeding in similarly high proportions at night as in the day. There was also some evidence of a decline in the proportion feeding towards high tide.*

*At Stanlow the winters of 1988/89 and 1990/91 showed fairly similar usage patterns. The major difference was in the time spent feeding by the birds. The plateau of peak numbers lasted for four hours in the 1988/89 winter, but seven to eight hours in the 1990/91 winter. This may have been due to higher energy demands and the more difficult feeding conditions experienced by Redshank during the colder winter of 1990/91. This increased time spent feeding is not as clearly seen in Oglet Bay. Both winters showed day-time feeding to decrease towards high tide as the mudflats were flooded.*

*The two winters of night-time data showed that the Redshank fed extensively at night. There was often a decline in feeding birds on the rising tide.*

*Redshank seen at night at Stanlow were distributed in a similar way to those found during the day (Figure 2.3.9.2). This was also the case for the Oglet Redshank (Figure 2.3.9.3). Redshank was found to be the species whose day and night distribution patterns were most similar (Clark et al., 1990c) and this holds true for both the 1989/90 and 1990/91 winters.*

*Summary: Redshank numbers around low tide stayed fairly constant. The numbers declined at high tide as birds roosted in vegetation, out of view. Over 70% of the birds feed around low tide. Both winters many birds fed at night. Peak numbers of Redshank fed longer at Stanlow during the 1990/91 winter than in the winter of 1988/89, this possibly being due to the increased demands placed on the birds by a cold winter. The day-time and night-time distributions of Redshank remained the same for both winters.*

## 2.4 DISCUSSION

*The intensive field surveys of 1990/91 continued the work started in the 1989/90 winter which compared the difference in day and night distributions of ducks and waders on the Mersey. Whereas the winter of 1989/90 was mild this winter was much colder. This allowed a preliminary impression of the effects of cold weather to be formed.*

*Of the species looked at, all but Grey Plover, showed some behavioral changes that could be linked to the cold weather that occurred during the winter of 1990/91. Though Shelduck did not noticeably change their daytime feeding behaviour in response to the colder weather of this winter, they increased their feeding at night. Two other duck species, Wigeon and Pintail, that normally were found in Stanlow Bay in very small numbers, were far more numerous this winter and were seen feeding in the bay during the day. While Teal showed a decline in their normally favoured night feeding, numbers found actively feeding on the mudflats in the day-time were much greater than in previous winters. This may have been due to the colder conditions found at night preventing efficient foraging.*

*Almost all of the species showed some evidence of more active feeding on the falling tide. The exceptions were Pintail and Wigeon that were present in relatively small numbers. During the day Black-tailed Godwit, Grey Plover, Dunlin and Curlew, and at night Shelduck, Teal, Dunlin, Curlew and Redshank fed less actively on the rising tide. This tendency to feed on the falling tide was possibly linked to the water column being warmer on cold days than the ambient air temperature. The intertidal mudflats would be at their warmest when first exposed, resulting in the greatest invertebrate activity on the falling tide. More active invertebrates are more easily detected by the visually feeding waders. Ducks such as Teal and Shelduck, that find their food by sieving through the mud, will also be affected by the cold, in that their prey items will* *burrow more deeply to escape the worse effects of the cold temperature. Finally, in very cold conditions the mud of the estuary will actually freeze making it very difficult for the birds to physically insert their bills into the mud in the hunt for prey. This is more likely to happen on the rising tide when the mudflats have been exposed to the air temperature for longer.*

*There was some evidence of changed wader and duck feeding distributions from day to night as reported by other authors (Evans and Dugan, 1984). Dunlin made more use of an area of Oglet at night than during the day. One possible explanation for this is the disturbance that this area was subjected to by walkers during the day. Grey Plover were not seen feeding at night, possibly because this species feeds largely on the outer mudflats which would be difficult to see with the image intensifier. Wigeon were less common at night at Stanlow than during the day for this bird is known to feed extensively on the Ince Marshes at night (Clark et al., 1990c). Pintail were not seen at night in Stanlow, but their normal day-time haunts would be out of sight of the image intensifier.*

*Periods of very cold weather are very stressful to the birds, especially in the winter when day-length is short. At a time when the metabolic requirements of ducks and waders are increasing, due to the need to expend more energy to keep warm, daylength and food supplies are declining. The invertebrate numbers are lower through fish and avian predation in the autumn and early winter. Invertebrates also die as a result of the cold (Hauser, 1973; Rehfisch, 1989), though in the case of mussels and cockles this can lead to an easily accessible source of food. Furthermore as the invertebrates suffer from less profitable feeding conditions found during the winter they will become less nutritionally desirable with the loss of glycogen, lipids and proteins (Beukema and Bruin, 1979). Finally the invertebrates burrow more deeply to escape the cold and become less available (Reading and McGrorty, 1978).*

*Waterfowl can partially make up for increased metabolic requirements by night feeding, but the benefits of this can be limited by the attendant greater cold.*

*There were three different responses of the Mersey waterfowl to the cold winter. The Grey Plover did not noticeably change their behaviour. Teal, Wigeon and Pintail increased their diurnal feeding as compared to previous winters. Shelduck increased their nocturnal feeding. Almost all species fed more commonly on the falling tide.*

# *SECTION 3*

# *RADIO-TRACKING OF TEAL AND PINTAIL*

## *3.1 INTRODUCTION*

*The first two years of intensive monitoring of the Mersey waterfowl showed that substantial numbers of both Teal and Pintail used the estuary during the day. Yet only some of the Teal were located at night and very few Pintail. Objective 3 of the Phase III Ornithological Studies relating to the Mersey Barrage aimed at a better understanding of why these birds occur in such internationally important numbers on the Mersey. To satisfy this requirement a thorough knowledge of how the birds exploit the area over the whole twenty-four hour period was needed. Due to the difficulty of finding birds visually at night the most suitable solution was to catch and fit radio-transmitters to a small sample of these two duck species.*

*The data gained from the radio-tracking carried out during the whole winter lead to an improved understanding of the areas that are most frequently used by the Teal at night and how habitat use varies with seasonal climatic changes.*

## *3.2 DATA COLLECTION AND ANALYSIS*

### *3.2.1 Data collection*

*The ducks were caught by canon-netting. This requires a thorough knowledge of the area, of the behaviour of the birds, of the tides, and of the weather conditions. In total it took 34 man days spent in observation, in equipment preparation, in equipment transport, and waiting for the birds to be in such a position as to be catchable. The ducks had to be in an area the size of the net, 27m by 13m, directly in front of the canon-net to present a potential catch. The birds were more predictable at two of the non-tidal sites. The Mount Manisty area (Figure 1.1.1) which held the large majority of Pintail seen this winter was tidal and there the birds were sparse and patchily distributed. As the area's gradient was very small, a 10cm tidal difference could be crucial to the position of the birds from one day to the next. A day of high pressure was enough for the tide not to rise as far as expected and for the ducks to be out of range of the catching equipment. About ten days were spent trying to catch there. No birds were caught because of the weather, a net misfire (an occupational hazard, only three out of four of the net transporters carried to their normal distance), and slight changes in the position of the birds from one day to another.*

*The first ten Teal (Table 6) were caught at the Hale Duck Decoy, near Hale Head (Figure 3.2.1) on 23 November 1990. The next catch of four Teal (Table 6) was on the 5 January 1991 on the Bromborough Pool (Area J, Figure 3.2.1.). On the 3 of February 1991 five Pintail and four Teal were trapped, again on the Bromborough Pool, and had radio-transmitters fitted (Table 7).*

*The analysis did not cover the Pintail as there is evidence that three of the five birds had pulled off their transmitters within two to five days of being caught at Bromborough. Two* *radios were recovered, another radio emitted signals from an empty outer mudflat. The other two Pintail may also have pulled off their transmitters as these duck were not traced beyond the first day after catching.*

*There were no references found to radio-tracking of duck in an estuarine environment. It was thus initially decided to try three types of transmitter. The smallest one stage type had the advantage of weighing only 4g but it's range of 2km did not prove sufficient due to the large size of the estuary. The 6g two stage transmitter battery only lasted for two weeks. The heavier 10g two stage transmitters were ideal due to their transmitting distance being supposedly 5km (in fact one bird was picked up at a distance of 23km) with the battery lasting for over one month. A more powerful transmitter is invaluable in that in poor conditions the transmission range can be much reduced, for example by obstacles in the line of site, static interference from industry or climatic conditions (Kenward, 1987). After a trial using the three types of transmitter with the first group of birds, all subsequent birds were fitted with the heavier transmitters.*

*Tracking was conducted at least weekly from the 23 November 1990 to the 4 March 1991. Birds were tracked continuously for two high tide and two low tide periods over twenty-five hours. This allowed a comparison to be made of the distributional changes as they related to both tidal state and daylight. Whenever possible the readings were taken from elevated sites with uninterrupted views of the Mersey to give the best reception. The sites were situated in such a way that birds anywhere on the estuary would be within reception range (Figure 3.2.1). To drive around the Mersey, with stops for radio-tracking, took about three hours. Thus measurements taken at `high tide' were within one and a half hours of high tide. `Low tide' measurements were made within one and a half hours of low tide.*

*The position of the birds was plotted on maps of the estuary and a record was kept of how frequently they used the various sections of the estuary. On several occasions, both at night and during the day, attempts at finding radio-tagged birds were made further afield, on the Dee Estuary to the south and Blackpool to the North.*

### *3.2.2 Data analysis*

*For analytical purposes the estuary was divided into 12 sections lettered from A to L (Figure 3.2.1). These sections could easily be related to the low and high tide count areas. Birds were occasionally recorded just inland of the above sections. Two more sections were created, the area inland of A being called A' and the area inland of C being called C'.*

*The bird radio-tracking data were analyzed to try and elucidate whether:-*

- *i) the birds mixed within the estuary or were in separate populations.*
- *ii) the birds distributed themselves differently according to high or low tides, in the whole estuary or in certain habitats only.*
- *iii) the birds distributed themselves differently depending on the diurnal state, and whether certain habitats had a particular influence.*
- *iv) the birds distributed themselves differently according to date, this being related to the period of very cold weather.*

*The analysis was carried out using the Chi² or "goodness of fit" test, with every effort being made to keep expected frequencies above 5 (Fowler and Cohen, 1987; Sokal and Rohlf,* *1981). The $Chi^2$ test is normally used for completely independent observations. It could be argued that these radio-tracked birds did not select their roosting and feeding areas randomly each time, and that each individual showed preferences for particular roosting and feeding areas. In mathematical terms, this means that the individual bird movements were non-independent of each other. From the maps of the Teal movements (eg Figure 3.3.8) it can be seen that individuals did move around the estuary considerably and that the potential problem of non-independence may not be that serious. To overcome any possible influence of non-independent movements, only results showing a probability of less than or equal to 0.01 of having occurred by chance are taken as significant.*

## 3.3 RESULTS

*The attempts to find birds on the Dee Estuary to the south, and Blackpool to the north, did not lead to a single bird being traced outside of the inner Mersey. Nor were any birds tracked to the east of Runcorn Bridge (Figure 3.2.1; Figures 3.3.1 - 3.3.10). This suggests that no Teal left the proximity of the Mersey.*

### 3.3.1 Comparison of Teal caught at the Hale Duck Decoy and the Bromborough Pool.

*The Teal caught at the Hale Duck decoy found inland of the upper parts of the estuary, sections A to E for the purposes of this analysis (Figure 3.2.1), stayed in the upper estuary (Table 8). Teal caught on the Bromborough Pool, part of the lower estuary, were found predominantly in the lower estuary, sections F to L ($Chi^2 = 208.90$, d.f. = 1, $p < 0.001$).*

### *3.3.2 Comparison of Teal distribution according to high or low tides.*

*There is no evidence of the Teal changing their estuary usage between high and low tide (Chi² = 15.92, d.f. = 10, N.S.) when the expected occurrence of the birds is compared to the number of times the birds were actually recorded in each section (Table 9). When the usage made of the saltmarsh sections is contrasted to that made of the mudflat areas (Table 10) then a significant difference is found between the distribution of the birds at high and at low tides (Chi² = 7.51, d.f. = 1, $p < 0.01$). The reason for this difference is the increased usage made of the saltmarsh at high tide.*

### *3.3.3 Comparison of Teal distribution according to it being day or night.*

*There is a significant difference between the day-time and night-time distribution of Teal (Chi² = 37.06, d.f. = 11, $p < 0.001$) in the whole estuary (Table 11). The highest departures from expected values are from sections B and G (Figure 3.2.1). B, the M.S.C.C. sludge pool, is used much less than expected during the day (used 3 times instead of the expected 16), this probably due to disturbance and shooting (see Section 4.4 of this report). Section G is recorded as being used more during the day (14 times instead of the expected 8 times) than at night, this being at least partly due to the greater frequency of daytime readings being made at this site.*

*If section B is excluded from the analysis then no significant difference (Chi² = 15.56, d.f. = 10, p > N.S.) is found between the use made of the different sections by Teal at night or during the day (Table 12). If the same analysis is carried out just using the January to March radio-tracking data, so as to exclude the period that Teal were using the sludge pool (Table 13), again no significant change between day-time and night-time usage is noted (Chi² = 3.02, d.f. = 5, p > N.S.).*

### *3.3.4 Comparison of Teal distribution according to date-effect of the cold weather.*

*A straightforward comparison could not be made by dividing up the winter into three periods of about a month, as the catching site would have strongly biased the results (Section 3.3.1). Only three Hale-caught birds were recorded in January, thus it was not meaningful to compare the distribution of the Hale birds in December to that in January. These three birds were all found in the upper estuary, as would be expected from birds caught at Hale (Section 3.3.1).*

*It was possible to compare the distribution of the Bromborough-caught Teal between the dates of the 8 January to the 8 of February, and the 9 February to March (Table 14). The value of carrying out the analysis between those dates is that the period from the 8 January to the 8 February held most of the very cold weather, and that the next period was on the whole much milder. There was a significant change in the distribution of the two sets of birds between the two periods (Chi$^2$ = 18.07, d.f. = 5, $p < 0.005$). There is one area in particular that generates large chi-squared values, section J, the reclamation pool (Figure 3.2.1). More birds than expected (28 cf 18) were found there from the 9 February to March 1991. This was due to the reclamation pool being frequently frozen from the 13 January to early February, and thus unavailable to the ducks. It is likely that the cold weather of January was responsible for distributional changes of Teal. This effect may also have explained the higher than expected number (21 cf 15) of birds in the saltmarsh (Sections E and G; Figure 3.2.1) from the 8 January to the 8 February. It was possible that the birds found more shelter from the wind-chill there.*

## *3.4 DISCUSSION*

*The work on radio-tagged Teal addressed objective 3 of the Phase III ornithological studies, for Teal if not Pintail. The radio-tracking led to a much improved knowledge of the night-time distribution of Teal, and the use they make of the Mersey over the whole day.*

*The birds caught at the Hale Duck decoy near the Upper Estuary stayed in the Upper Estuary (Figures 3.3.1 to 3.3.5). The birds caught at the Bromborough Pool stayed in the Lower Estuary (Figures 3.3.6 to 3.3.10). There was very little mixing, suggesting separate discrete populations of Teal.*

*Teal distributed themselves differently at high and low tides in the saltmarshes and on the estuarine mudflats. They used the saltmarshes more frequently at high tide. They followed the line of the rising tide and moved into the many creeks leading into the saltmarshes (Sections 4.3.2 and 4.4). On the spring tides some of the Teal fed on the flooded marshes. Even so the majority of the Teal were still to be found over or next to the Mersey Estuary mudflats at high tide (Tables 9 and 10). Thus the mudflats are important to the birds at all stages of the tide.*

*Teal were found to be distributed differently at night and during the day in the estuary. The main reason for this change in distribution was due to the M.S.C.C. sludge pool being used much more than expected at night. When the MSCC sludge pool was excluded from the analysis, or when the analysis only included data from the period when the sludge pool was not being used, no difference in the day-time and night-time Teal distributions occurred. Thus the main cause of day-night variation in Teal distribution patterns was the M.S.C.C. sludge pool. This area was used intensively at night until the January cold spell which led to it freezing. One night in December all of the nine Teal fitted with transmitters were found to be on the sludge* *pool. Use of the sludge pool almost solely at night may be related to the closeness of a road and hunting pressure.*

*Teal distribution changed from the 8 January to the 8 February 1991 period to the 9 February to March period. This was probably due to the colder weather experienced during the January period. This stopped the birds from using section J, the reclamation pool, for feeding, after it completely froze over from 13 January. This effect is likely to have been linked to the higher than expected number of birds in the saltmarshes of Stanlow and Mount Manisty (sections E and G). The birds may have used the marsh creeks to shelter from the wind. Birds may also have fed in the saltmarsh creeks which being subject to a lesser wind-chill factor may have allowed feeding for longer on receding tides. The salt-marsh itself was frozen and unavailable for feeding. The movements of individual Teal confirm this. One Teal (Figure 3.3.7) was recorded in the Stanlow and Ince marshes during the cold period and then moved back to the Bromborough Pool after the weather became more clement in mid-February. Another Teal (Figure 3.3.10) similarly moved from the Mount Manisty marshes during the cold period, back to Bromborough after the weather warmed up. A third bird (Figure 3.3.8) stayed for the two months in the Stanlow and Mount Manisty marshes. This implies that the marshes could be used for feeding during the periods of thaw as well as during the colder periods.*

*The radio-tracking carried out during the 1990/91 winter showed that Teal on the Mersey Estuary did not act as a uniform population, but may have acted as partly independent populations. The mudflats were most important to the Teal at all states of the tide, thus indicating that invertebrates must form an important component of the diet of Teal. The marshes were used more during the high tide periods, when saltmarsh plant seeds are more available after being washed out by the tide. Apart from the usage made of the M.S.C.C. sludge pool there were no differences in day and night distributions of the*

*Teal. This sludge pool was used extensively at night by feeding birds (Section 4.4) until it froze over. Thereafter it was no longer used. The temporal change in Teal habitat usage can be related to changes in weather. The birds are forced away from the less saline open waters to the saltmarshes and estuary during the cold weather periods. The marshes are thought to act as protection from the cold as well as allowing feeding to continue for longer periods due to a reduction of the wind-chill factor on the feeding areas.*

*There was no evidence of Teal using areas outside of the immediate vicinity of the Mersey Estuary for feeding. All the radio-tracking carried out from the Dee Estuary up to Blackpool did not record a single radio-tagged Teal. This implies that the Mersey Estuary is essential to these birds. This is particularly the case during cold winters when all the non-saline waters freeze over particularly rapidly, thus making food unavailable.*

# *SECTION 4*

# *THE FEEDING ECOLOGY OF PINTAIL AND TEAL*

## *4.1 INTRODUCTION*

*Objective 3 of the 1990/91 winter was to determine the diet of Teal and Pintail both within and when flighting out of the Mersey. A three pronged approach was used. The first, radio-tracking to determine habitat choice, is covered in section 3 of this report. Pintail proved most difficult to catch and radio-track. To compensate for the lack of distribution data for these birds, with the help of the Frodsham Wildfowlers' Club, seven Pintail were collected and their stomach contents analyzed. Furthermore a particular emphasis was put on visual observations of feeding Teal and Pintail, the extensive effort at catching leading to many prolonged observation periods during the day in areas particularly favoured by the feeding birds. The third method of correlating bird numbers to potential diet items is covered in Section 5 of this report.*

*Stomach analyses can be used for a variety of purpose. Most commonly the determination of diet, but also, when larger numbers of birds are available, determination of habitat type and usage by relating the prey items to their source (Pirot, 1981). It is also possible to determine whether the bird has fed recently from the quantity of food found in the oesophagus and proventriculus rather than the stomach (Campredon et al., 1982). In this case the analysis was to confirm that Pintail were feeding in an area where they were frequently seen (M. Ellams, pers. comm.; pers. obs.).*

## *4.2 DATA COLLECTION AND ANALYSIS*

*Seven Pintail stomachs were obtained from the Frodsham Wildfowlers' Club in mid-December. The birds were shot at the Manchester Ship Canal Company sludge pool (SJ505785), but the exact circumstances of their deaths are not known. The birds may have been shot immediately upon flighting in from the estuary or after having had an opportunity to feed in the pool.*

*The stomachs were kept frozen until ready to be dissected. The contents of the oesophagus and proventriculus were kept separate from those of the stomach. Both were stored in 50% alcohol. A full oesophagus shows that the bird fed shortly before being collected.*

*The seeds of each type were identified to genus and then counted. The text used for the seed identification (Campredon et al., 1982) was too general to allow specific identification in most cases. Only two individual seeds were found that could not be identified down to genus. A record of the presence or absence of various types of grit was kept.*

## *4.3 RESULTS*

### *4.3.1 Stomach analysis*

*The data from the stomachs and oesophagi are pooled in Tables 15 and 16. Three of the Pintail had well filled stomachs, all of them with large numbers of Suaeda sp. seeds as well as a few seeds from other saltmarsh plants. These birds had seeds in their oesophagi and must have been feeding just before being shot.*

*The other birds were probably shot upon flighting in to the area at dusk, their stomachs holding very few seeds.*

*Most of the seeds found in the birds were of common saltmarsh plants. Salicornia sp., eg Glasswort is found on saltmarshes, mudflats and rarely inland on salty soils. Suaeda (maritima) or Annual Sea-blite is found in saltmarshes and seashores, on muddy soils, more rarely inland. Rumex sp., of the Dock family has a wide distribution ranging from fields to ponds and brackish waters. Polygonum (persicaria), a plant commonly called Redshank is found in fields, waste places and muddy soils by ponds. Potamogeton sp., of the Pondweed family are found in slow flowing waters. Zostera sp. or Sea-grass are found in coastal waters. Scirpus sp., a member of the Club-rushes which are found in damp or wet areas, often associated with brackish waters. Rubus (fruticosus), or Blackberry, is not a saltmarsh plant but can be found commonly on the eroding borders of the Mersey, from where fruit may have fallen onto the mudflats.*

*None of the birds held any organic animal remains. The only remains of animal origin being shells of the Baltic Tellin (Macoma balthica) and a cockle (Cerastoderma sp.) found in two of the ducks. These remnants of the shellfish diet of the Pintail form part of the grit used by the ducks to physically break up plant material. Other forms of grit included long-lasting quartz found in all birds, some small glass balls up to 3mm in diameter which are used in industrial processes, and also two pieces of steel shot.*

### *4.3.2 Visual feeding observations*

*The duck were observed feeding particularly frequently in Stanlow Bay, especially near Mount Manisty, in Oglet Bay, at New Ferry and also on the Bromborough Pool (Area 29 on Figure 1.1.1).*

*Stanlow Bay near Mount Manisty: as the tide rose the birds would converge towards the large inlet to the west of the Mount. Initially the birds would largely loaf near the* *saltmarsh or on the mudflats, but as the tide continued its rise the ducks would ring the water's edge. They would then move their bills from side to side in the water, presumably sieving seeds and/or invertebrates from the mud. Teal, Pintail, Mallard and Wigeon fed in this manner. On high tides the water would rise high enough to flood the marsh, the birds would then feed in the vegetated parts, before following the falling tide out. Pintail, Mallard and especially Teal would also sometimes continue feeding on the mudflats after the tide had receded.*

*Oglet Bay: the duck, mainly Teal, would spend most of their time loafing and roosting in the main channel. Their activity would increase as the tide rose. The birds would feed in a line following the rising waters, similarly to Mount Manisty. When the tides flooded the saltmarsh the ducks would be seen picking vegetation and seeds from the surface of the water. Teal would also often feed out on the open mudflats after the tide had receded, especially in areas 68 and 69 (Figure 1.1.1.). At night the ducks were observed forming a ring around the newly appearing mudflats in area 69, as the tide receded, and following the lengthening water's edge.*

*New Ferry: the Teal and Pintail would follow the receding waters as above, feeding in shallow water, rarely far from the water's edge out on the mudflats. The Teal and Mallard would occasionally upend. New Ferry only has a very small saltmarsh area which would not produce many seeds. Thus ducks feeding at New Ferry would be largely feeding on invertebrates.*

*Bromborough Pool: Teal and Pintail and a few Mallard would use this as a high water roost and as a feeding area. Frequently the numbers of Teal on the pool would far exceed those on the mudflats. The pool was vegetated with emerging plants such as Polygonum persicaria. The ducks would often be difficult to observe, hidden in the vegetation. The visible ones roosted or fed by dabbling or upending.*

## *4.4 DISCUSSION*

*The M.S.C.C. pool was brackish and flooded only to a few centimetres depth. Pintail feed preferentially in depths of less than 30 cm and Teal in very shallow waters, to a few centimetres depth (Cramp, 1977). The pool's vegetation comprised large amounts of the plants Suaeda sp., Polygonum persicaria and Aster tripolium. The latter is a plant associated with wet meadows on saline soil and saltmarshes. These plants produce seeds that are favoured by feeding duck (Campredon et al., 1982). This made the feeding conditions ideal for dabbling ducks as plants and seeds were easily available. This would explain the very large numbers of duck recorded by the Frodsham Wildfowlers' Club on a relatively small area. Counts have been made of up to 2000 Pintail flying into the MSCC sludge pool in early January 1991, and 4000-6000 Teal were counted in the winter of 1989/90 on the pool (M. Ellams, pers. comm.).*

*The vegetative contents found in the Pintail stomachs this winter were very similar to those found in a previous Mersey study (E.A.U., 1988), with Rubus sp., Aster sp., Suaeda sp. and Rumex sp. in common. That study based on fifteen birds found that the Pintail also fed for a small part on invertebrates. The only animal matter found in this study was of shell fragments of Macoma balthica and Cardium sp. These are part of the grit found in birds to help with their processing of food. These two molluscs are found in the Mersey, and their presence in the stomachs implies that the birds fed on these bivalves at some time before they were shot. The relative softness of the shell material means that it does not last in the stomachs as long as the hard quartz material, but may have been there for several days. It is not thought that the birds take the empty shells to use as grit (Campredon et al., 1982).*

*The birds collected this winter lead to an improved understanding of the relative importance of various diet items.*

*The Pintail fed predominantly on plant material which is commonly the case in autumn and winter (Cramp, 1977), but the shells were evidence of some animal component to their diet (Olney, 1965; E.A.U., 1988). The birds that had fed recently had obtained their plant material from the sludge pool. The birds that had animal shells must have fed on the Mersey Estuary or in a similar environment a short period before being collected.*

*Visual observations of feeding Pintail on the estuary were carried out in areas that were frequently not visible from the normal all day counting areas. This partly explains the previous lack of evidence as to where the birds were feeding during the day. Observations carried out in early December as part of the canon-netting programme showed up to 1200 Pintail (about equivalent to the peak low tide count for Pintail on the Mersey, Table 4) converge on to the main creek at the base of Mount Manisty in Stanlow Bay. These birds fed actively. These creeks may be particularly important during spring high tides and just after as seeds from the saltmarsh are washed out and vegetation becomes available to the ducks. After a high tide some of the birds would continue feeding in the marsh, others would follow the receding waters and feed out on the mudflats.*

*Teal also used the smaller creeks and channels in Stanlow Bay regularly. Due to the length and the steepness of the sides it is often difficult to get accurate counts of the birds, but in early December over a thousand birds used the Stanlow creek to feed actively. Furthermore the mudflats of Stanlow and Oglet were also used regularly on falling tides, the birds filtering mud. It is most likely that these birds fed on what was available, a mixture of seeds and invertebrates. Teal feed in variable fashions depending on the habitat, from being mainly nocturnal, depending on climatic conditions and day length, to mainly diurnal (Cramp, 1977).*

*Both these species have been observed feeding actively during the day. The reason that they only feed at night on the sludge pool may be due to the presence of a nearby road, occasional walkers, and shooting disturbance. This hypothesis is confirmed by the use the Teal make of the narrow channel in Area 70 (Figure 1.1.1) at night, but much more rarely during the day. Similar areas further out in Oglet Bay are used frequently during the day. The difference being that the channel in area 70 is close to a much used public footpath.*

*This winter was the first in the three years of ornithological studies carried out on the Mersey that had prolonged periods of cold. During the cold period this winter Teal in particular, but also Pintail, fed especially actively on falling tides during the day on the mudflats. The mudflats would freeze up after a few hours of exposure to the cold. This led to their being available for feeding only a few hours every tidal cycle. So whereas the ducks also fed on the falling tide in previous winters, these hours were particularly important during this winter's cold period when any inland sites away from the estuary that they could have otherwise used were completely frozen. Large numbers of Teal fed during the few hours of falling tide showed large Teal numbers (Figures 2.3.3.2 and 2.3.3.3) following the waters edge and sieving the mud to feed primarily on invertebrates. After exposure to the cold invertebrates bury more deeply and become inactive (eg Clark, 1983; Muus, 1967; Rehfisch, 1989), thus are much less available to the feeding birds.*

*This section shows that Pintail feeding on the sludge pool had a diet mainly consisting of seeds, as is likely to be the case for Teal using the same habitat, while birds feeding on the estuary would have a much greater invertebrate component to their diet. The mudflats form an important feeding area for ducks, especially during cold periods when potential inland sites are unavailable.*

# SECTION 5

# THE DISTRIBUTION OF WATERFOWL IN RELATION TO INVERTEBRATES

## 5.1 INTRODUCTION

*The building of the proposed tidal barrier on the Mersey will change the estuarine environment and is thus likely to affect the number of waterfowl that can feed on the intertidal mudflats. This is one of the major environmental issues relating to any barrage construction (Goss-Custard, 1987). Behind a barrage, the tidal range is reduced. This not only lessens the area of mudflats exposed at low tide, but also reduces the time that they are uncovered for feeding. A diminution of feeding area can lead to a fall in waterfowl populations (Goss-Custard and Moser, 1988). On the other hand, a reduction in tidal range may increase biological productivity through the more regulated nature of the post-barrage estuary (Kirby, 1987).*

*The very high numbers of euryhaline invertebrates often found in estuaries (Prater, 1981) lead to this habitat frequently being associated with large bird populations. In the context of the proposed Mersey barrage it is important to know what prey the Mersey bird populations are utilizing, and to what extent the potential prey resources are being exploited. The level of exploitation of the available invertebrates and plant matter could be modified considerably, with potentially serious implications for the birds, as a result of the construction of the proposed barrage. Thus the second objective of the Phase III ornithological studies relating to the Mersey Barrage was aimed at trying to elucidate the relationship between bird distributions and that of both the invertebrate prey and seed availability.*

## 5.2 DATA COLLECTION AND ANALYSIS

### 5.2.1 Data collection

*The invertebrate and seed sampling were carried out by Environmental Resources Limited (ERL). The areas to be sampled were chosen after joint consultation between ERL and the BTO. The sampling sites covered most areas and habitats of the Mersey where the birds were known to have fed in large numbers during previous winters, as well as some of the areas and habitats that were much less used by birds. Sampling sites included sandbanks, saltmarshes and their creeks, as well as estuarine mudflats.*

*Sampling of the mudflats concentrated on the all day study areas of New Ferry, Stanlow and Oglet, with some further samples being taken from the rest of the estuary. The number of samples taken was limited by the large physical handling time demanded by each sample.*

*A hovercraft was used to get to the sampling sites. Sampling was monthly. Quarterly, intensive surveys concentrated on the main bird feeding grounds and separated all the invertebrates, including oligochaetes, into species. The monthly extensive surveys covered more of the estuary, but oligochaetes and spionids were not identified down to species. Triplicate cores of 87cm$^2$ each and 20cm depth were taken from every site. During sample collection if certain areas showed signs of extensive bird usage, further samples were taken.*

*The core samples were both collected and sorted by ERL. The data received by the BTO consisted of peak invertebrate numbers per core, mean invertebrate numbers per core, and mean invertebrate numbers per square metre, but did not include size class information. The data covered the four winter months from November 1990 to February 1991.*

*A review of the literature was made to find out which of the Mersey invertebrates had been recorded prey of the more widespread and common waterfowl: Shelduck, Teal, Pintail, Grey Plover, Dunlin, Curlew and Redshank.*

### *5.2.2 Data analysis*

*To enable the data from the quarterly intensive and the monthly extensive surveys to be compared, some species, which were only distinguished in the quarterly surveys, were lumped into the less specific categories used in the monthly surveys. Thus the oligochaete species, Tubifex costatus, Tubificoides benedeni and Clittelio sp., were lumped together. The two species of Spionidae, Pygospio sp. and Streblospio sp. were lumped into the Spionid category. The common polychaete worm Nereis sp. and the more infrequently encountered polychaete Nephtys sp., were lumped into the Nereis category. Rarely recorded species, such as Manayunkia, Phyllodoce, and Capitella were not included in the analysis. Similarly, the seeds found in the core samples were not included in the analysis as their densities were very low and they were recorded from parts of the estuary for which no specific low tide counts were available (eg individual creeks). In total, there were nine species or categories of invertebrate used in the analysis: Abra, Macoma, Cerastoderma, Hydrobia, Corophium, Nereis, Spionidae, Oligochaeta and Nematoda.*

*In order to detect any associations between the invertebrate and feeding bird populations, the invertebrate density data from ERL was compared statistically with the equivalent low tide feeding bird count data (described in Section 1). The low tide bird counts were chosen as these covered the whole of the Mersey Estuary and were representative of feeding bird distributions. Only the more widespread and common species, Shelduck, Teal, Pintail, Grey Plover, Dunlin, Curlew and Redshank, were used in the analysis.*

*Regression analysis was used on the data treated in three different ways:-*

*i) from some sections, four or more monthly sets of triplicate cores were taken during the winter. The set of triplicate cores with most individuals of an invertebrate category was used to calculate the peak mean density of that category. The peak mean monthly density for each invertebrate category was then compared to the feeding bird densities in each section over the 1990/91 winter.*

*ii) the overall mean density of each invertebrate category, calculated by averaging the four months of invertebrate numbers data, was compared to the feeding bird densities in each section.*

*iii) the log transformed overall mean density of each invertebrate category, calculated by averaging and then logging the four months of data, was compared to the logged feeding bird densities in each section.*

*For the density of each bird species at low tide, a regression line was calculated for points relating to the densities of each of the invertebrate categories in the three above data treatments. To show that these points were distributed in a way that approximates a straight line, not only must the analysis of variance show that the points are not randomly distributed, but that the slope of the ensuing line differs significantly from zero. The extent to which the variance in the distribution of the birds was explained by the invertebrate densities was calculated using $R^2$ values.*

*A visual comparison was also made of the bird distribution and the invertebrate densities in an attempt to link the presence of potential prey items to feeding birds.*

## *5.3 RESULTS*

*The following dietary descriptions were compiled from Cramp and Simmons (1977 and 1982) and Goss-Custard (1989). For each section, the low tide waterfowl density data can be found in Table 19, the equivalent peak mean invertebrate density data can be found in Tables 17a/b, and the overall winter mean data can be found in Tables 18a/b. When stepwise multiple regression analysis gave high $R^2$ values, these values must be treated with some suspicion due to the possible bias introduced by a few outlying points.*

### *5.3.1 Shelduck*

*Shelduck have a mainly invertebrate diet. Molluscs such as Hydrobia, Cerastoderma and Macoma, crustaceans such as Corophium, Nereidae and other polychaetes, small oligochaetes and various insects are important components of the Shelduck diet.*

*The highest Shelduck densities found during the 1990/91 winter, in the low tide count sections for which invertebrate data are available, were from sections 31, 33 and especially 68 (Table 19, Figure 1.1.1). Section 68 had particularly high densities of Macoma, Nereis and oligochaetes (Tables 17a/b and 18a/b), all recognised prey of Shelduck. Section 33 held Macoma, Hydrobia, Corophium and a few oligochaetes, not in particularly high densities, but all potential prey. Section 31 had a poor fauna consisting of low oligochaete densities.*

*Regression analysis showed no statistically significant links between invertebrate densities and bird densities. Stepwise multiple regression analysis showed that Shelduck distributions were best explained by Cerastoderma, Macoma and Nereis peak mean densities ($R^2$=66.8%).*

### *5.3.2 Teal*

*This small duck is omnivorous. The diet of Teal varies widely with habitat, and includes Hydrobia ulvae, other molluscs, small crustaceans, oligochaetes and many insect larvae and adults as well as plant matter.*

*In 1990/91, the highest densities of Teal were found in sections 33, 43 and especially 68 (Table 19, Figure 1.1.1). Section 68 had the largest recorded densities of Macoma and Nereis, and amongst the highest oligochaete densities (Tables 17a/b and 18a/b), all potential prey for Teal. Section 43 had a varied fauna with very high Corophium numbers, a crustacean that is small enough for Teal to be able to handle. Section 33 did not have high invertebrate numbers, but held oligochaetes, Macoma, and Corophium, as did section 43.*

*Regression analysis showed no statistically significant links between invertebrate densities and bird densities. Stepwise multiple regression analysis linked Teal distributions to Cerastoderma, Macoma, Corophium and Nereis peak mean densities ($R^2$=73.5%).*

### *5.3.3 Pintail*

*Pintail are omnivorous birds which are known to include a large plant component in their diet as well as such invertebrates as Hydrobia, other molluscs, oligochaetes (Harrison and Grant, 1976), small crustaceans and many insects (see also Section 4.3.1).*

*Of the low tide sections for which invertebrate data were available, the highest Pintail densities were in sections 27 and 80 (Table 19, Figure 1.1.1). Section 27, part of the New Ferry all day count site, had eight of the nine major invertebrate categories and held particularly high densities of oligochaetes, as well as good Macoma and Hydrobia populations*

*(Tables 17a/b and 18a/b), the two molluscs recognised prey items of Pintail. Section 80 only supported an oligochaete fauna and the Pintail may have been feeding on these invertebrates. Sections 33 and 36 were also used by feeding Pintail. Section 33 had a fauna consisting of Macoma, Hydrobia, Corophium and oligochaetes. Section 36 held a varied fauna which included relatively high Macoma, Corophium and Nereis densities.*

*Regression analysis showed no statistically significant links between invertebrate densities and bird densities. Stepwise multiple regression showed that Pintail distributions were best explained by Cerastoderma, Nereis and oligochaete overall mean densities ($R^2$=58.8%).*

### *5.3.4 Grey Plover*

*A large element of the diet of Grey Plover includes polychaete worms such as Nereis, Nephtys, and Phyllodoce, the bivalve molluscs Macoma, Cerastoderma, as well as crustaceans and insects.*

*In 1990/91 the highest Grey Plover densities were found in sections 67 and 72 (Table 19, Figure 1.1.1). Section 67 held Abra, Macoma, Hydrobia, Nereis and oligochaetes (Tables 17a/b and 18a/b), all potential Grey Plover prey. Samples from section 72 held no invertebrates. Sections 31 and 68 showed the next highest Grey Plover feeding densities. Section 68 had the highest recorded densities of Macoma and Nereis, as well as large numbers of oligochaetes. Section 31 only had a few oligochaetes.*

*Regression analysis showed no statistically significant links between invertebrate densities and bird densities.*

## *5.3.5 Dunlin*

*Dunlin feed chiefly on invertebrates located by sight or touch. Major prey species include Hydrobia, Macoma, Cerastoderma, Corophium, Nereis, Oligochaeta and insects, as well as a few plant seeds.*

*In 1990/91 the highest densities of Dunlin were found in sections 27, 36, 67 and especially 68 (Table 19, Figure 1.1.1). Section 68 had the highest recorded Macoma and Nereis densities and high oligochaete numbers (Tables 17a/b and 18a/b), all major prey items of Dunlin. Section 27 held eight of the nine major invertebrate categories and was particularly rich in oligochaetes, while also holding good Macoma and Hydrobia numbers. Similarly section 36 also held a varied fauna which included relatively high Macoma, Corophium and Nereis densities. Section 67 held Abra, Macoma, Hydrobia, Nereis and oligochaetes.*

*Regression analysis showed no statistically significant links between invertebrate densities and bird densities. Stepwise multiple regression showed that Dunlin distributions were best explained by Cerastoderma, Macoma and Corophium overall mean densities ($R^2$=86.8%).*

## *5.3.6 Curlew*

*This is an omnivorous species which feeds principally on invertebrates. Major prey items included Macoma, Cerastoderma, Nereis, Nephtys, and the larger Oligochaeta such as Arenicola; Corophium and insects are less frequently found in stomach analyses.*

*Of the sections for which invertebrate data are available the highest densities of Curlew were in sections 47, 48, 67 and 68 (Table 19, Figure 1.1.1). Section 47 held a few Nereis, section 48 held few Corophium and both held oligochaetes, those in* *section 48 occurring at median densities (Tables 17a/b and 18a/b). Both Nereis and Corophium are potential Curlew prey, but their relatively small numbers would not seem to make either of these areas very attractive unless they were large individuals. Sections 67 and particularly 68 held Macoma and Nereis, both part of the Curlew diet.*

*Regression analysis showed no statistically significant links between invertebrate densities and bird densities.*

### *5.3.7 Redshank*

*Due to the large numbers of studies that have been made of Redshank, they are known to feed on a wide variety of prey items. Most typically, Redshank feed on a limited range of invertebrate prey including Corophium, Nereis, Nephtys, Hydrobia and Macoma, while Cerastoderma, Oligochaeta, and insects are less frequently recorded prey.*

*The highest densities of Redshank from sections sampled for invertebrates during the 1990/91 winter were found in sections 31, 33, 36 and 68 (Table 19, Figure 1.1.1). Section 31 had a poor fauna consisting of low oligochaete densities. Section 33, which had the highest Redshank densities, held Macoma, Hydrobia, Corophium and a few oligochaetes (Tables 17a/b and 18a/b) though in not particularly high densities. Section 36 held a varied fauna which included relatively high Macoma, Corophium and Nereis densities. Section 68 was particularly rich in Macoma, Nereis and oligochaetes.*

*Regression analysis showed no statistically significant links between invertebrate densities and bird densities. Stepwise multiple regression analysis showed that Redshank distributions were best explained by Macoma, Hydrobia and Nereis peak mean densities ($R^2$=44.3%).*

## 5.4 DISCUSSION

*Past studies have correlated potential prey species to bird numbers and have found some significant links between certain invertebrate species and waders (eg Goss-Custard, 1989). This study has also used regression analysis in an attempt to find similar relationships between the densities of invertebrate species and their wader predators. Whereas a few high $R^2$ values were obtained, where $R^2$ is an indication of the amount of variation in bird numbers explained by the invertebrate numbers, these were for non-significant regression lines. Often one or two paired high bird and invertebrate density outliers were enough to generate these high $R^2$ values. More data would be necessary for this type of analysis to lead to definitive conclusions. Furthermore the format of the data, raw invertebrate numbers, is not sufficient for this type of analysis, as can be demonstrated using Curlew as an example. Curlew are large waders. They select for individual invertebrates that are profitable, i.e. that have an energy to handling time ratio that is conducive to efficient feeding. For example, Curlew numbers can best be related to Nereis that are longer than 50mm (Goss-Custard, 1989). To compare Nereis densities of all size classes to Curlew densities is not ideal. The majority of Nereis in a population will be recruits from that year, small individuals of less than 20mm, of little energetic profit to Curlew. Thus Curlew may utilize areas with small nereid densities, but where the individuals are large. This may apply to section 47 which had high Curlew densities, but low Nereis densities. Redshank also are known to select large Corophium when these are present in such densities as to allow choice (Goss-Custard, 1977a and 1977b). Regression analyses carried out using size class information of the invertebrates might well have met with more success.*

*Direct comparisons of the data on bird densities with invertebrate numbers showed that the birds fed mostly in areas with potential prey, as would be expected.*

*The three sections most used by Shelduck held oligochaete populations, and two of the sections held Macoma and Corophium, all part of the Shelduck diet. Goss-Custard (1989) similarly found correlations between Shelduck densities and Nereis, Tubificidae and Corophium densities. This study has found Shelduck distributions to be best explained by Cerastoderma, Macoma and Nereis peak mean densities.*

*Teal densities were highest in three sections that held Macoma, Corophium, and oligochaetes. Teal distributions can be best explained by Cerastoderma, Macoma, Corophium and Nereis peak mean densities.*

*The highest feeding Pintail densities were found in four sections that all held oligochaetes, and three of which held Macoma, Hydrobia and Corophium. Macoma shells were found in the stomachs of Mersey Pintail (Section 4.3.1) and this bivalve is very likely to form part of their diet. Yet the density of feeding Pintail is best modelled by Cerastoderma, Nereis and oligochaete overall mean densities.*

*Grey Plover densities were high in two sections with either a small oligochaete density or no invertebrates at all, as recorded from the core samples. The other two sections with high Grey Plover densities had Macoma, Nereis and oligochaetes in common, of which oligochaetes and Nereis densities were found to be correlated with Grey Plover numbers by Goss-Custard (1989).*

*Dunlin densities were highest in four sections with a wide variety of fauna, holding at least five of the possible nine faunal categories present, and all with Macoma, Nereis and oligochaetes. These four sections are all predominantly of muddy substrates. Dunlin feeding distributions are best modelled by Cerastoderma, Macoma and Corophium overall mean densities. Goss-Custard (1989) found Dunlin numbers to correlate best with Nereis numbers, and that only a small part* *of the numerical variation in Dunlin numbers could be explained by a multiple regression that included Nereis and cirratulid worms.*

*The section with the highest densities of feeding Curlew had Abra, Macoma and Nereis as well as the ubiquitous oligochaetes. Another section favoured by Curlew had high Macoma and Nereis densities. Two of the highest feeding densities of Curlew were found in sections with a limited fauna of oligochaetes and either Corophium or Nereis. Goss-Custard (1989) only found correlations between Curlew densities and Nereis over 50mm in length on the Severn.*

*The highest Redshank densities were found in one section which only had very low oligochaete numbers, and in another three sections which held Macoma, Corophium and oligochaetes. Redshank distributions are best modelled by Macoma, Hydrobia and Nereis peak densities. Goss-Custard (1989) found Redshank numbers to correlate best with Nereis (10-50mm in length), Corophium and oligochaetes, and that only Nereis and Corophium significantly helped explain the variation in Redshank numbers in a multiple regression analysis.*

*Some bird species were found in high densities in areas where the core sampling had shown few invertebrates to be present (similarly to Goss-Custard, 1989). Such was the case for Grey Plover which fed in relatively high densities in a section (72) which sampling had shown to have no invertebrates (Table 17a/b; 18a/b). There are several possible explanations for this phenomenon. It is possible that sampling missed clumped invertebrate populations that the birds are more efficient at detecting. It is also possible that the Grey Plover would be feeding on large, rare prey, such as Arenicola or big Nereis, that could be missed by small area core samples. Curlew have been seen feeding on blennies and Great Black Backed Gulls on small flounders left behind by the Mersey tide (pers. obs.), neither of these two `rare' vertebrate species having been* *recorded from the mud samples. Lastly there are other factors apart from prey densities, such as substrate type, which can attract birds to an area. Dunlin, for example, seem to prefer the muddier areas of the Mersey, though whether this is due to sediment or the possible higher productivity and more varied fauna of muddy areas, is more uncertain.*

*Generally waders and possibly ducks can utilize most prey items of manageable size. The lack of significant links between invertebrates and birds may have been partly due to the relatively small number of invertebrate samples taken at each site, due to the limits in available processing time, leading to an inaccurate estimation of the invertebrate numbers in each area. This is quite possible as the data show large variations in numbers of invertebrates counted per sample, as well as large differences between the monthly means of even the commoner species.*

*The very uncertain link between invertebrate numbers and bird densities could imply very tenuously that the Mersey is not presently being used to it's carrying capacity. If there were as many waterfowl on the estuary as it could support, i.e. if the estuary's carrying capacity for waterfowl had been reached, the distribution of waterfowl ought to approximate invertebrate distributions. The lack of any significant correlations between invertebrate and bird densities, as far as can be ascertained from insufficient data, points to this not being the case. It is important to remember that such an analysis is complicated by some invertebrates not being available to the feeding birds (Reading and McGrorty, 1978), or else not being sampled efficiently by the corer. Furthermore large invertebrates can bury themselves out of reach of the sampler, Nereis, for example, having been found at depths of up to 60cm (Muus, 1967).*

*Further work on the Mersey waterfowl diet could be concentrated in two specific areas. Polygenic antibodies could be used to* *determine what the various bird species are feeding on, using either shot specimens or else faecal samples. This test is based on the reaction of antibodies (normally produced in a rabbit or horse) to an allergen. When a rabbit is inoculated with an allergen, such as Nereis, it will produce antibodies to the allergen, Nereis in this case. These antibodies are then removed in the rabbit plasma. The plasma from the Nereis sensitised rabbit is then added to a faecal or gut sample. If the bird providing the gut or faecal sample has fed on Nereis, in this example, there will be a positive coagulatory response. Once the antibodies to the allergens have been produced a large number of samples can rapidly be tested. The antibodies in this case would be for the major invertebrate species found in the Mersey. The advantage of this test is that it can detect even minute quantities of oligochaetes, which are often not a recognised prey of many bird species simply because they are digested rapidly and cannot be easily seen in gut and faecal samples.*

*More practically, the collection of more invertebrate and seed data would lead to a better understanding of the link between waterfowl distributions and their prey. The data should include both density and size class information. From this it might be possible to determine if the carrying capacity of the Mersey has been reached. If the carrying capacity were not to have been reached this would have obvious implications for the feasibility of the Mersey barrage, since a decline in feeding time and area might still allow the present bird populations to survive on the estuary.*

## *Recommendations for Further Work*

### *1. Continued ornithological monitoring of the Mersey*

*Monitoring should be continued on the same basis as in the past years, leading to a fuller understanding of the factors responsible for the long and short term changes in waterfowl distribution. The Mersey, the Alt and the North Wirral shores should be covered by extensive low tide counts. Intensive all day coverage of Stanlow and Oglet should be continued. This would provide a fourth year of detailed data from which the within and between year variability of the whole system can be assessed.*

### *2. Monitoring individual movement patterns Pintail (and Teal)*

*Despite three winters of study it is still uncertain why the Mersey is so important for Pintail. Individual Pintail should be radiotagged and then tracked to assess the dependence of these birds on the intertidal flats of the Mersey. Past observations having suggested that there may be some movement between the Mersey and the Dee, the latter estuary would be closely monitored. A small sample of Teal, inevitably caught at the same time as the Pintail, should also be fit with radio-transmitters to allow between year comparison of movements.*

### *3. Monitoring the activity and distribution of Pintail (and Teal)*

*Mount Manisty has large concentrations of Pintail and Teal. The reasons for this area being so important for the Mersey ducks is as yet not fully understood. Day and night visual observations of Pintail and Teal made at Mount Manisty would allow an assessment to be made of whether the birds are using the area to feed on the intertidal flats, to feed on the saltmarsh, or are simply using the area to roost.*

*4. Continued monitoring of the Mersey invertebrate populations*

*During the 1990/91 winter the baseline was established for invertebrate and seed numbers on the Mersey. Improved siting of samples and further sampling could lead to better predictions being made of the relation between waterfowl and their prey. It might then be possible to determine if the feeding areas of the Mersey are fully utilized by waterfowl, a very important factor in the context of the proposed tidal barrage. Seed and invertebrate sampling might also help explain the large duck concentrations near Mount Manisty (recommendation 3 above). The invertebrate diet of Mersey waterfowl could be confirmed using polygenic antibodies.*

*5. Long term trends in Mersey waterfowl populations*

*The re-analysis of all existing data from BTO studies and other previous work regarding long term trends in Mersey populations is proposed, in conjunction with an assessment of waterfowl densities on other estuaries with tidal regimes similar to the post-barrage Mersey. This should lead to predictions of likely post-barrage bird numbers with reference to the predicted sediment and tidal regimes in the post-barrage estuary. The use of mitigation measures should be assessed.*

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| Species | Av. Peak Winter Count (Nov.- Mar.) | % of British population | % of European population* |
|---|---|---|---|
| SHELDUCK *Tadorna tadorna* | 3394 | 4.5 | 1.4 |
| WIGEON *Anas penelope* | 6716 | 2.7 | 0.9 |
| TEAL *Anas crecca* | 10685 | 10.7 | 2.7 |
| MALLARD *Anas platyrhynchos* | 1217 | 0.2 | <0.1 |
| PINTAIL *Anas acuta* | 5908 | 23.6 | 8.4 |
| RINGED PLOVER *Pluvialis hiaticula* | 26 | 0.1 | 0.1 |
| GOLDEN PLOVER *Pluvialis apricaria* | 727 | 0.4 | 0.1 |
| GREY PLOVER *Pluvialis squatarola* | 710 | 3.4 | 0.5 |
| LAPWING *Vanellus vanellus* | 4852 | 0.5 | 0.2 |
| KNOT *Calidris canutus* | 316 | 0.1 | 0.1 |
| DUNLIN *Calidris alpina* | 23928 | 5.6 | 1.7 |
| BLACK-TAILED GODWIT *Limosa limosa* | 65 | 1.3 | 0.1 |
| CURLEW *Numenius arquata* | 1443 | 1.6 | 0.4 |
| REDSHANK *Tringa totanus* | 3824 | 5.1 | 2.6 |

* For wildfowl, percentages are of Western European population, for waders percentages are of East Atlantic Flyway population.

Table 1 — The National and International Importance of the Mersey for Waterfowl, 1986/87-1990/91.

| COUNT | EARLIEST DATE | OFFICIAL DATE | LATEST DATE |
|---|---|---|---|
| 1 | 22/11/90 | 25/11/90 | 27/11/90 |
| 2 | 6/12/90 | 9/12/90 | 11/12/90 |
| 3 | 20/12/90 | 23/12/90 | 25/12/90 |
| 4 | 3/ 1/91 | 6/ 1/91 | 8/ 1/91 |
| 5 | 24/ 1/91 | 27/ 1/91 | 29/ 1/91 |
| 6 | 7/ 2/91 | 10/ 2/91 | 12/ 2/91 |
| 7 | 21/ 2/91 | 24/ 2/91 | 26/ 2/91 |

*Table 2* Dates of Low Tide Counts, Winter 1990/91.

| COUNT | DATE | | |
|---|---|---|---|
| | NEW FERRY | STANLOW | OGLET |
| 1 | 9/11/90 | 22/11/90 | 13/11/90 |
| 2 | 19/12/90 | 11/12/90 | 4/12/90 |
| 3 | | 10/ 1/91 | 7/ 1/91 |
| 4 | 24/ 1/91 | 15/ 1/91 | 17/ 1/91 |
| 5 | | 8/ 2/91 | 5/ 2/91 |
| 6 | | 13/ 2/91 | 12/ 2/91 |
| 7 | | 20/ 2/91 | 22/ 2/91 |
| 8 | 28/ 2/91 | 5/ 3/91 | 26/ 2/91 |
| 9 | 19/ 3/91 | 13/ 3/91 | 12/ 3/91 |

*Table 3* Dates of All Day Counts, Winter 1990/91.

| | 1990/1991 | | 1989/1990 | | 1988/1989 | |
|---|---|---|---|---|---|---|
| | Feeding | Roosting | Feeding | Roosting | Feeding | Roosting |
| SHELDUCK | 3013 | 654 | 3500 | 540 | 4517 | 465 |
| WIGEON | 3254 | 1721 | 22 | 2912 | 567 | 3190 |
| TEAL | 2592 | 4424 | 5079 | 9169 | 3992 | 1917 |
| MALLARD | 407 | 331 | 548 | 813 | 260 | 612 |
| PINTAIL | 111 | 1205 | 555 | 858 | 380 | 850 |
| RINGED PLOVER | 38 | 7 | 59 | 5 | 77 | 3 |
| GOLDEN PLOVER | 1100 | 649 | 27 | 1405 | 23 | 468 |
| GREY PLOVER | 74 | 84 | 138 | 52 | 131 | 13 |
| LAPWING | 7029 | 8364 | 1021 | 5624 | 1446 | 227 |
| KNOT | 1789 | 20 | 1541 | 321 | 2110 | 124 |
| DUNLIN | 32656 | 458 | 8563 | 4357 | 12886 | 1333 |
| BLACK-TAILED GODWIT | 32 | 173 | 22 | 40 | 0 | 6 |
| BAR-TAILED GODWIT | 0 | 0 | 7 | 0 | 0 | 0 |
| CURLEW | 938 | 28 | 972 | 328 | 813 | 66 |
| REDSHANK | 6400 | 61 | 3907 | 580 | 3259 | 100 |
| TURNSTONE | 24 | 0 | 30 | 0 | 12 | 0 |

*Table 4* Peak winter low tide counts on the Mersey Estuary, winters 1988/89 to 1990/91.

| | 1990/1991 | | 1989/1990 | | 1988/1989 | |
|---|---|---|---|---|---|---|
| | Feeding | Roosting | Feeding | Roosting | Feeding | Roosting |
| SHELDUCK | 55 | 12 | 158 | 148 | 175 | 55 |
| WIGEON | 0 | 19 | 0 | 0 | 0 | 0 |
| TEAL | 0 | 0 | 0 | 0 | 0 | 2 |
| MALLARD | 15 | 297 | 53 | 406 | 210 | 220 |
| PINTAIL | 0 | 7 | 0 | 0 | 0 | 2 |
| OYSTERCATCHER | 3409 | 682 | 4175 | 2358 | 12713 | 1656 |
| RINGED PLOVER | 28 | 0 | 166 | 22 | 56 | 111 |
| GOLDEN PLOVER | 6 | 275 | 10 | 700 | 3 | 85 |
| GREY PLOVER | 650 | 0 | 534 | 0 | 362 | 0 |
| LAPWING | 0 | 666 | 220 | 1350 | 300 | 750 |
| KNOT | 3502 | 9000 | 5494 | 6259 | 27234 | 21062 |
| SANDERLING | 295 | 0 | 851 | 0 | 465 | 0 |
| DUNLIN | 3427 | 0 | 6744 | 45 | 3320 | 30 |
| BLACK-TAILED GODWIT | 3 | 0 | 0 | 0 | 21 | 0 |
| BAR-TAILED GODWIT | 6138 | 0 | 6193 | 520 | 7592 | 250 |
| CURLEW | 174 | 498 | 336 | 128 | 289 | 30 |
| REDSHANK | 1617 | 0 | 1920 | 150 | 1915 | 165 |
| TURNSTONE | 551 | 0 | 745 | 53 | 403 | 0 |

Table 5 Peak winter low tide counts on the Alt and North Wirral Shore, winters 1988/89 to 1990/91.

| Species | Date | Ring Number | Sex | Wing length (mm) | Weight (g) | Transmitter no., type and anticipated range |
|---|---|---|---|---|---|---|
| Teal | 23.11.90 | ER39064 | 4_ | 181 | 300 | 209 1 Stage 2km |
| Teal | | ER39065 | 4_ | 184 | 360 | 260 2 Stage 2km |
| Teal | | ER39066 | 4_ | 186 | 340 | 290 2 Stage 5km |
| Teal | | ER39067 | 3_ | 187 | 355 | 283 2 Stage 5km |
| Teal | | ER39068 | 3_ | 185 | 305 | 242 2 Stage 2km |
| Teal | | ER39069 | 4_ | 186 | 390 | 320 2 Stage 5km |
| Teal | | ER39071 | 4_ | 184 | 310 | 309 2 Stage 5km |
| Teal | | ER39072 | 3_ | 179 | 305 | 221 1 Stage 2km |
| Teal | | ER39073 | 3_ | 176 | 310 | 229 1 Stage 2km |
| Teal | | ER39074 | 4_ | 192 | 395 | 302 2 Stage 5km |
| Teal | 5. 1.91 | EK56929 | 6_ | 182 | 410 | 218 2 Stage 5km |
| Teal | | EK56931 | 5_ | 179 | 320 | 231 2 Stage 5km |
| Teal | | EK56932 | 5_ | 188 | 375 | 248 2 Stage 5km |
| Teal | | EK56933 | 6_ | 196 | 400 | 241 2 Stage 5km |

Table 6 Teal caught on the 23rd of November 1990 at the Hale Duck decoy, and on the 5th of January 1991 at Bromborough Pool, for the purposes of radio-tracking.

| Species | Date | Ring Number | Sex | Wing length (mm) | Weight (g) | Transmitter no., type and anticipated range |
|---|---|---|---|---|---|---|
| Teal | 3. 2.91 | EN28404 | 6_ | 174 | 350 | 350 2 Stage 5km |
| Teal | | EN28407 | 6_ | 191 | 375 | 280 2 Stage 5km |
| Teal | | EN28420 | 6_ | 191 | 385 | 259 2 Stage 5km |
| Teal | | EN28446 | 5_ | 191 | 340 | 274 2 Stage 5km |
| Pintail | | FA17044 | 4_ | 250 | 940 | 297 2 Stage 5km |
| Pintail | | FA17045 | 4_ | 274 | 1010 | 335 2 Stage 5km |
| Pintail | | FA17046 | 4_ | 262 | 810 | 289 2 Stage 5km |
| Pintail | | FA17047 | 4_ | 262 | 970 | 308 2 Stage 5km |
| Pintail | | FA17048 | 4_ | 278 | 1040 | 323 2 Stage 5km |

Table 7 Teal and Pintail caught on the 3rd of February 1991 at Bromborough Pool, for the purposes of radio-tracking.

| Sections | Hale birds | Bromborough birds | Hale | Brom. |
|---|---|---|---|---|
| | Observed | Observed | Chi² | Chi² |
| Upper Estuary (Sections A-E) | 156 | 33 | 49.84 | 44.62 |
| Lower Estuary (Sections F-L) | 7 | 149 | 60.36 | 54.08 |

Total Chi² = 208.90, d.f. = 1, p < 0.001

Table 8 Hale and Bromborough caught birds - frequency in upper and lower estuary.

| Sections | High tide birds | Low tide birds | High Tide | Low Tide |
|---|---|---|---|---|
| | Observed | Observed | Chi² | Chi² |
| A + A' | 19 | 19 | 0.13 | 0.11 |
| B | 12 | 22 | 0.86 | 0.73 |
| C + C' | 36 | 31 | 0.85 | 0.73 |
| D | 19 | 19 | 0.13 | 0.11 |
| E | 6 | 6 | 0.04 | 0.03 |
| F | 14 | 20 | 0.18 | 0.15 |
| G | 12 | 5 | 2.22 | 1.89 |
| H | 5 | 7 | 0.05 | 0.04 |
| I | 8 | 17 | 1.08 | 0.92 |
| J | 21 | 19 | 0.36 | 0.30 |
| K+L | 7 | 21 | 2.70 | 2.31 |

Total Chi² = 15.92, d.f. = 10, 0.05 < p

Table 9 Comparison of Teal high and low tide usage of the Mersey Estuary.

| Sections | High tide birds | Low tide birds | High Tide | Low Tide |
|---|---|---|---|---|
| | Observed | Observed | Chi² | Chi² |
| A' + E + G (saltmarsh areas) | 26 | 13 | 3.59 | 3.07 |
| Other sections (mudflat areas) | 133 | 173 | 0.46 | 0.39 |

Total Chi² = 7.51, d.f. = 1, $p < 0.01$

Table 10 Comparison of Teal distribution at high and low tide in the estuary and the surrounding salt-marsh.

| Sections | Day birds | Night birds | Day | Night |
|---|---|---|---|---|
| | Observed | Observed | Chi² | Chi² |
| A | 16 | 12 | 0.70 | 0.60 |
| A' | 5 | 5 | 0.03 | 0.02 |
| B | 3 | 31 | 10.34 | 8.94 |
| C + C' | 31 | 36 | 0.00 | 0.00 |
| D | 21 | 17 | 0.65 | 0.56 |
| E | 3 | 9 | 1.18 | 1.03 |
| F | 18 | 16 | 0.31 | 0.27 |
| G | 14 | 3 | 4.75 | 4.15 |
| H | 8 | 4 | 1.07 | 0.92 |
| I | 11 | 14 | 0.03 | 0.03 |
| J | 20 | 20 | 0.11 | 0.09 |
| K+L | 10 | 18 | 0.68 | 0.60 |

Total Chi² = 37.06, d.f. = 11, $p < 0.001$

Table 11 Comparison of day- and night-time distribution of Teal on the Mersey Estuary.

| Sections | Day birds | Night birds | Day | Night |
|---|---|---|---|---|
| | Observed | Observed | Chi² | Chi² |
| A | 16 | 12 | 0.24 | 0.25 |
| A' | 5 | 5 | 0.00 | 0.00 |
| C + C' | 31 | 36 | 0.24 | 0.24 |
| D | 21 | 17 | 0.17 | 0.18 |
| E | 3 | 9 | 1.55 | 1.58 |
| F | 18 | 16 | 0.04 | 0.04 |
| G | 14 | 3 | 3.42 | 3.49 |
| H | 8 | 4 | 0.62 | 0.63 |
| I | 11 | 14 | 0.21 | 0.21 |
| J | 20 | 20 | 0.00 | 0.00 |
| K+L | 10 | 18 | 1.21 | 1.24 |

Total $Chi^2 = 15.56$, d.f. = 10, $p > 0.05$

Table 12 Comparison of day- and night-time distribution of Teal on the Mersey Estuary, excluding the M.S.C.C. sludge pool data.

| *Sections* | *Day birds* | *Night birds* | *High Tide* | *Low Tide* |
|---|---|---|---|---|
| | *Observed* | *Observed* | *Chi²* | *Chi²* |
| *A - D* | *11* | *15* | *0.14* | *0.13* |
| *E + G* | *16* | *12* | *0.57* | *0.51* |
| *F* | *15* | *16* | *0.01* | *0.01* |
| *H + I* | *17* | *18* | *0.01* | *0.01* |
| *J* | *20* | *20* | *0.06* | *0.05* |
| *K + L* | *10* | *18* | *0.80* | *0.72* |

*Total Chi² = 3.02, d.f. = 5, p > 0.05*

*__Table 13__ Comparison of day- and night-time distribution of Teal on the Mersey Estuary from January to March 1991, dates chosen to exclude the M.S.C.C. sludge pool data.*

| | *Dates of bird-tracking* | | | |
|---|---|---|---|---|
| | *Jan.8 to Feb.8* | *Feb.9 to March* | *Jan.8 to Feb.8* | *Feb.9 to March* |
| *Sections* | *Obs.* | *Obs.* | *Chi²* | *Chi²* |
| *A - D (Upper Estuary)* | *14* | *8* | *0.30* | *0.37* |
| *E + G* | *21* | *7* | *2.05* | *2.50* |
| *F* | *18* | *13* | *0.06* | *0.07* |
| *H + I* | *22* | *11* | *0.83* | *1.01* |
| *J* | *12* | *28* | *4.53* | *5.53* |
| *K + L* | *13* | *15* | *0.37* | *0.45* |

*Total Chi² = 18.07, d.f. = 5, p < 0.005*

*__Table 14__ The distribution of the Bromborough-caught Teal on the Mersey Estuary between November to December 1990 compared to between the 8th of January to the 8th of February 1991.*

| Pintail | Seed numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Suaeda | Rubus | Scirpus | Potamogeton | Zostera | Polygonum | Rumex | Salicornia |
| 1 | 915 | 2 | | | 5 | | 1 | 1 |
| 2 | 1 | | | | | | | |
| 3 | | | | 1 | | 2 | | |
| 4 | 1500 | | | | | | | |
| 5 | | 1 | | | 7 | | | |
| 6 | | 3 | | | 4 | | | |
| 7 | 1000 | | 1 | 2 | | | | |

Table 15 Stomach contents of Pintail shot at the MSCC sludge pool.

| Pintail | Grit | | | | | |
|---|---|---|---|---|---|---|
| | Quartz | <u>Macoma balthica</u> | <u>Cerastoderma</u> sp. | Coal particles | Glass balls | Shot |
| 1 | * | | | * | | * |
| 2 | * | * | | | | * |
| 3 | * | | | | * | |
| 4 | * | | | * | | |
| 5 | * | | | * | | |
| 6 | * | | * | * | * | |
| 7 | * | | | | * | * |

* Present in stomach

*<u>Table 16</u>* *Types of grit found in Pintail shot at the MSCC sludge pool.*

| Section (LT) | Peak Mean Invertebrate Densities (numbers/m²) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Abra* | *Macoma* | *Cerasto-derma* | *Hydrobia* | *Corophium* | *Nereis* | Spionidae | Oligo-chaeta | Nematoda |
| 27 | 0 | 1386 | 347 | 1271 | 1617 | 404 | 347 | 41492 | 154 |
| 30 | 0 | 231 | 0 | 0 | 0 | 0 | 0 | 1502 | 116 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 116 | 0 |
| 33 | 0 | 231 | 0 | 231 | 462 | 0 | 0 | 4389 | 0 |
| 34 | 0 | 116 | 0 | 0 | 116 | 0 | 0 | 1502 | 0 |
| 36 | 0 | 1098 | 346 | 116 | 7623 | 752 | 347 | 15708 | 116 |
| 38 | 578 | 0 | 0 | 0 | 0 | 347 | 0 | 12359 | 0 |
| 40 | 0 | 174 | 0 | 462 | 4679 | 1043 | 231 | 12014 | 0 |
| 43 | 0 | 579 | 0 | 39 | 10519 | 1503 | 348 | 3735 | 0 |
| 47 | 0 | 0 | 0 | 0 | 0 | 348 | 0 | 1041 | 0 |
| 48 | 0 | 0 | 0 | 0 | 115 | 0 | 0 | 17551 | 0 |
| 53 | 0 | 0 | 0 | 0 | 693 | 0 | 0 | 45517 | 0 |
| 54 | 0 | 231 | 0 | 0 | 462 | 1155 | 0 | 12367 | 0 |
| 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30023 | 115 |

Table 17a  Peak mean invertebrate densities found in some low tide sections of the Mersey. Data supplied by Environmental Resources Limited.

| Section (LT) | Peak Mean Invertebrate Densities (numbers/m²) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | <u>Abra</u> | <u>Macoma</u> | <u>Cerasto-derma</u> | <u>Hydrobia</u> | <u>Corophium</u> | <u>Nereis</u> | Spionidae | Oligo-chaeta | Nematoda |
| 58 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 1617 | 0 |
| 59 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 231 | 0 |
| 67 | 117 | 924 | 0 | 231 | 0 | 1386 | 0 | 10743 | 0 |
| 68 | 0 | 3351 | 0 | 0 | 693 | 4389 | 348 | 31023 | 0 |
| 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 73 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 462 | 0 |
| 76 | 0 | 347 | 0 | 0 | 0 | 116 | 0 | 462 | 0 |
| 78 | 0 | 347 | 0 | 0 | 116 | 809 | 0 | 1040 | 0 |
| 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10857 | 0 |

Table 17b Peak mean invertebrate densities found in some low tide sections of the Mersey. Data supplied by Environmental Resources Limited.

| Section (LT) | November 1990 to February 1991 Mean Invertebrate Densities (numbers/m²) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Abra* | *Macoma* | *Cerasto-derma* | *Hydrobia* | *Corophium* | *Nereis* | Spionidae | Oligo-chaeta | Nematoda |
| 27 | 0 | 196 | 68 | 390 | 204 | 60 | 67 | 16265 | 16 |
| 30 | 0 | 231 | 0 | 0 | 0 | 0 | 0 | 1502 | 116 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 58 | 0 |
| 33 | 0 | 116 | 0 | 116 | 289 | 0 | 0 | 2888 | 0 |
| 34 | 0 | 58 | 0 | 0 | 58 | 0 | 0 | 867 | 0 |
| 36 | 0 | 448 | 87 | 43 | 3638 | 448 | 145 | 8056 | 29 |
| 38 | 289 | 0 | 0 | 0 | 0 | 174 | 0 | 6180 | 0 |
| 40 | 0 | 102 | 0 | 116 | 1237 | 280 | 96 | 5372 | 0 |
| 43 | 0 | 241 | 0 | 10 | 3838 | 658 | 106 | 2398 | 0 |
| 47 | 0 | 0 | 0 | 0 | 0 | 116 | 0 | 260 | 0 |
| 48 | 0 | 0 | 0 | 0 | 29 | 0 | 0 | 4446 | 0 |
| 53 | 0 | 0 | 0 | 0 | 99 | 0 | 0 | 10560 | 0 |
| 54 | 0 | 77 | 0 | 0 | 154 | 411 | 0 | 4430 | 0 |
| 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7506 | 29 |

Table 18a  Mean invertebrate densities found in some low tide sections of the Mersey - winter 1990/91. Data supplied by Environmental Resources Limited.

| Section (LT) | November 1990 to February 1991 Mean Invertebrate Densities (numbers/m²) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Abra* | *Macoma* | *Cerasto-derma* | *Hydrobia* | *Corophium* | *Nereis* | Spionidae | Oligo-chaeta | Nematoda |
| 58 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 539 | 0 |
| 59 | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 77 | 0 |
| 67 | 29 | 289 | 0 | 58 | 0 | 404 | 0 | 3408 | 0 |
| 68 | 0 | 838 | 0 | 0 | 231 | 1165 | 116 | 12405 | 0 |
| 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 73 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 231 | 0 |
| 76 | 0 | 174 | 0 | 0 | 0 | 58 | 0 | 289 | 0 |
| 78 | 0 | 58 | 0 | 0 | 7 | 58 | 0 | 152 | 0 |
| 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8200 | 0 |

Table 18b Mean invertebrate densities found in some low tide sections of the Mersey - winter 1990/91. Data supplied by Environmental Resources Limited.

| Section (LT) | Bird Densities (nos./hectare) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SU | T | PT | GV | DN | CU | RK |
| 27 | 0.13 | 0.00 | 0.57 | 0.00 | 9.97 | 0.17 | 3.00 |
| 30 | 0.26 | 0.24 | 0.00 | 0.05 | 7.53 | 0.05 | 0.45 |
| 31 | 1.87 | 0.33 | 0.00 | 0.13 | 3.00 | 0.07 | 2.80 |
| 33 | 1.42 | 2.77 | 0.23 | 0.00 | 0.81 | 0.04 | 5.19 |
| 34 | 0.02 | 0.67 | 0.13 | 0.00 | 1.00 | 0.11 | 0.50 |
| 36 | 0.28 | 0.19 | 0.35 | 0.01 | 14.99 | 0.10 | 3.21 |
| 38 | 0.02 | 0.00 | 0.00 | 0.04 | 0.00 | 0.06 | 0.07 |
| 40 | 0.08 | 0.00 | 0.00 | 0.02 | 3.96 | 0.18 | 0.39 |
| 43 | 0.35 | 2.04 | 0.00 | 0.00 | 1.05 | 0.05 | 0.87 |
| 47 | 0.58 | 0.32 | 0.00 | 0.00 | 0.63 | 0.41 | 0.09 |
| 48 | 0.00 | 0.27 | 0.08 | 0.00 | 0.00 | 0.48 | 0.00 |
| 53 | 0.54 | 0.10 | 0.00 | 0.00 | 0.78 | 0.15 | 1.59 |
| 54 | 0.27 | 0.00 | 0.00 | 0.00 | 0.89 | 0.19 | 0.10 |
| 56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 |
| 58 | 0.02 | 0.03 | 0.00 | 0.00 | 0.02 | 0.21 | 0.02 |
| 59 | 0.01 | 0.36 | 0.00 | 0.00 | 1.21 | 0.27 | 0.01 |
| 60 | 0.07 | 0.10 | 0.00 | 0.00 | 0.04 | 0.07 | 0.00 |
| 67 | 0.53 | 0.32 | 0.00 | 0.21 | 11.79 | 0.70 | 0.85 |
| 68 | 4.04 | 4.15 | 0.00 | 0.09 | 22.78 | 0.41 | 3.43 |
| 72 | 0.47 | 0.00 | 0.00 | 0.19 | 5.00 | 0.22 | 0.20 |
| 73 | 0.05 | 0.00 | 0.00 | 0.01 | 1.31 | 0.18 | 0.00 |
| 76 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| 80 | 0.46 | 0.12 | 0.56 | 0.00 | 4.85 | 0.02 | 0.73 |

Table 19 Bird densities calculated from the low tide counts of the Mersey - winter 1990/91.

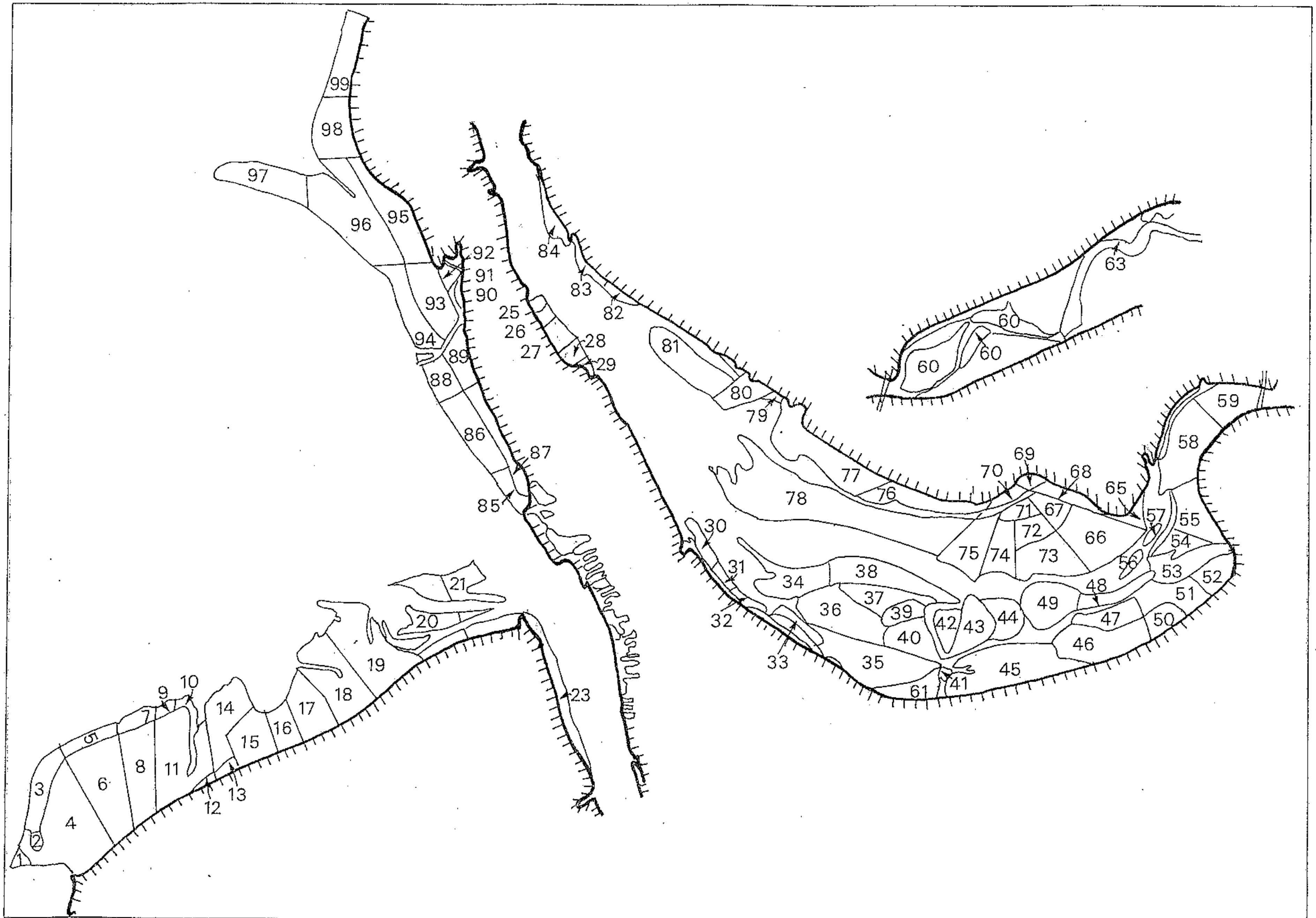



Figure 1.1.1 The locations of the 96 intertidal areas which were surveyed regularly during the 1988/89 to 1990/91 winters.

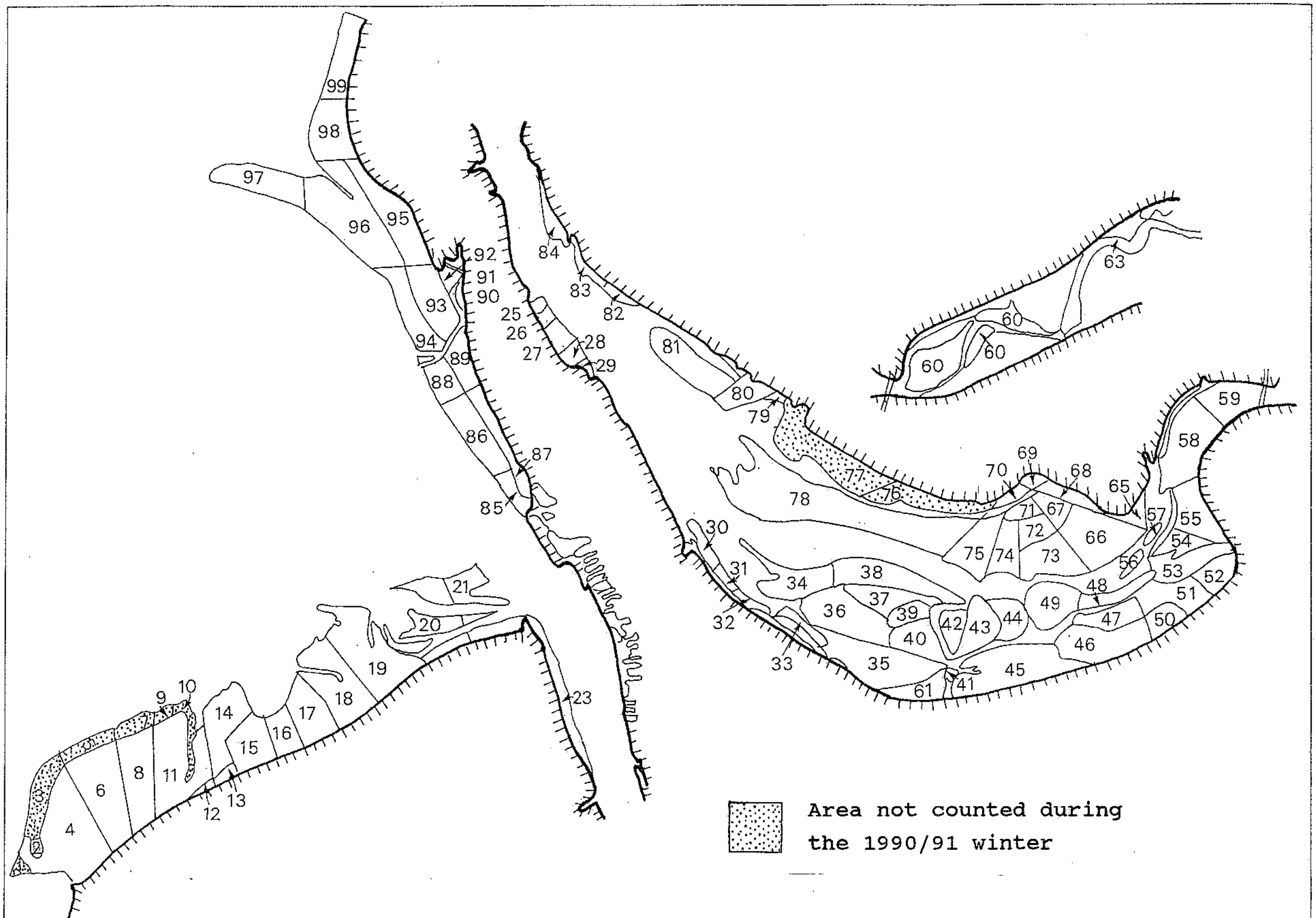



Figure 1.1.2 Intertidal areas for which data was not available during the 1990/91 winter.

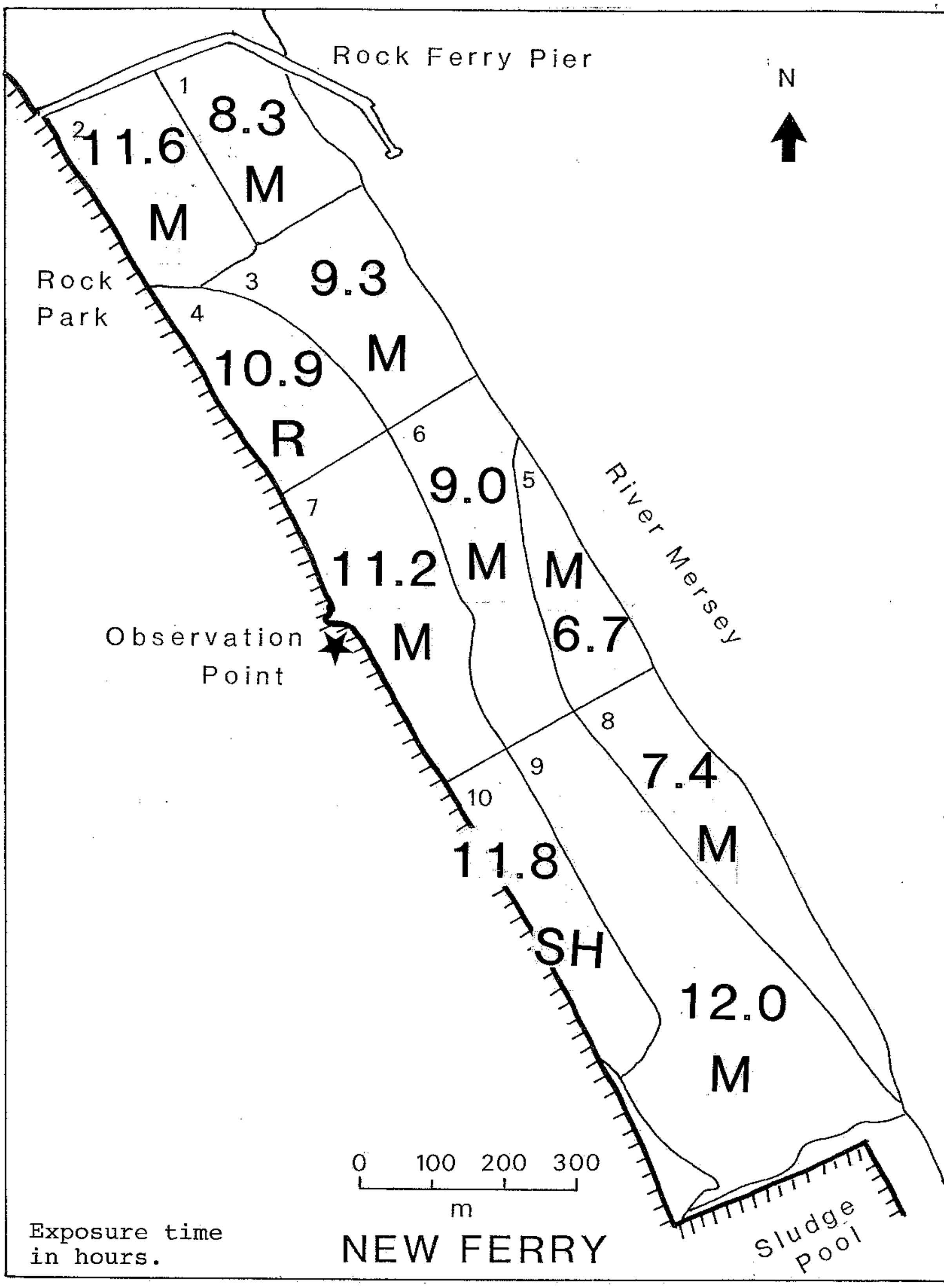



Figure 1.2.2.1 The New Ferry all day study site. The average exposure time in winter is given together with the main substrate type for each intertidal area.
(M = Mud, R = Rock, SH = Shingle)

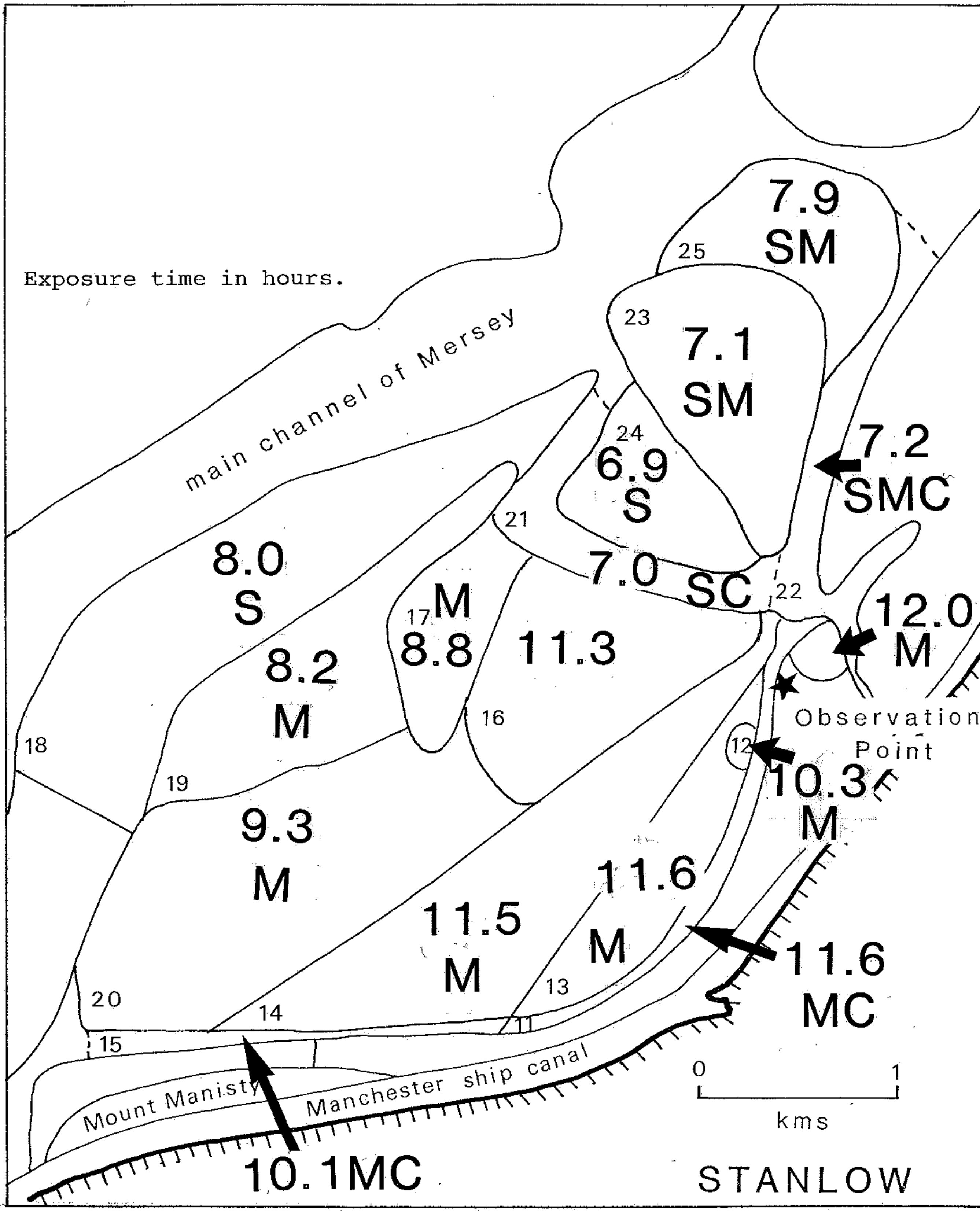



Figure 1.2.2.2 The Stanlow all day study site. The average exposure time in winter is given together with the main substrate type for each intertidal area.

(C = Channel, M = Mud, S = Sand, SM = Mixed sand and mud)

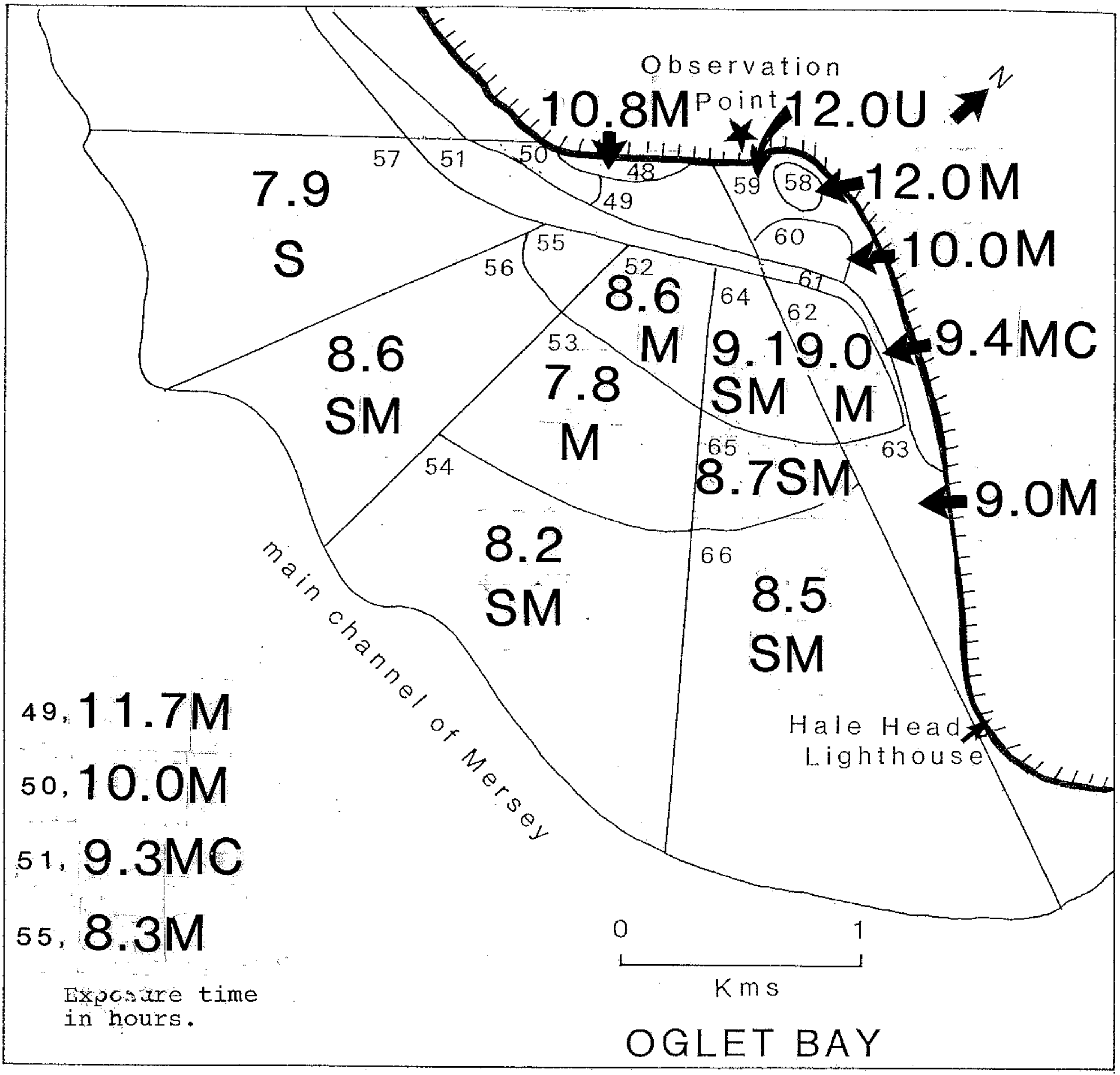



Figure 1.2.2.3 The Oglet Bay all day study site. The average exposure time in winter is given together with the main substrate type for each intertidal area.

(C = Channel, M = Mud, SM = Mixed sand and mud, U = Ungrazed saltmarsh)

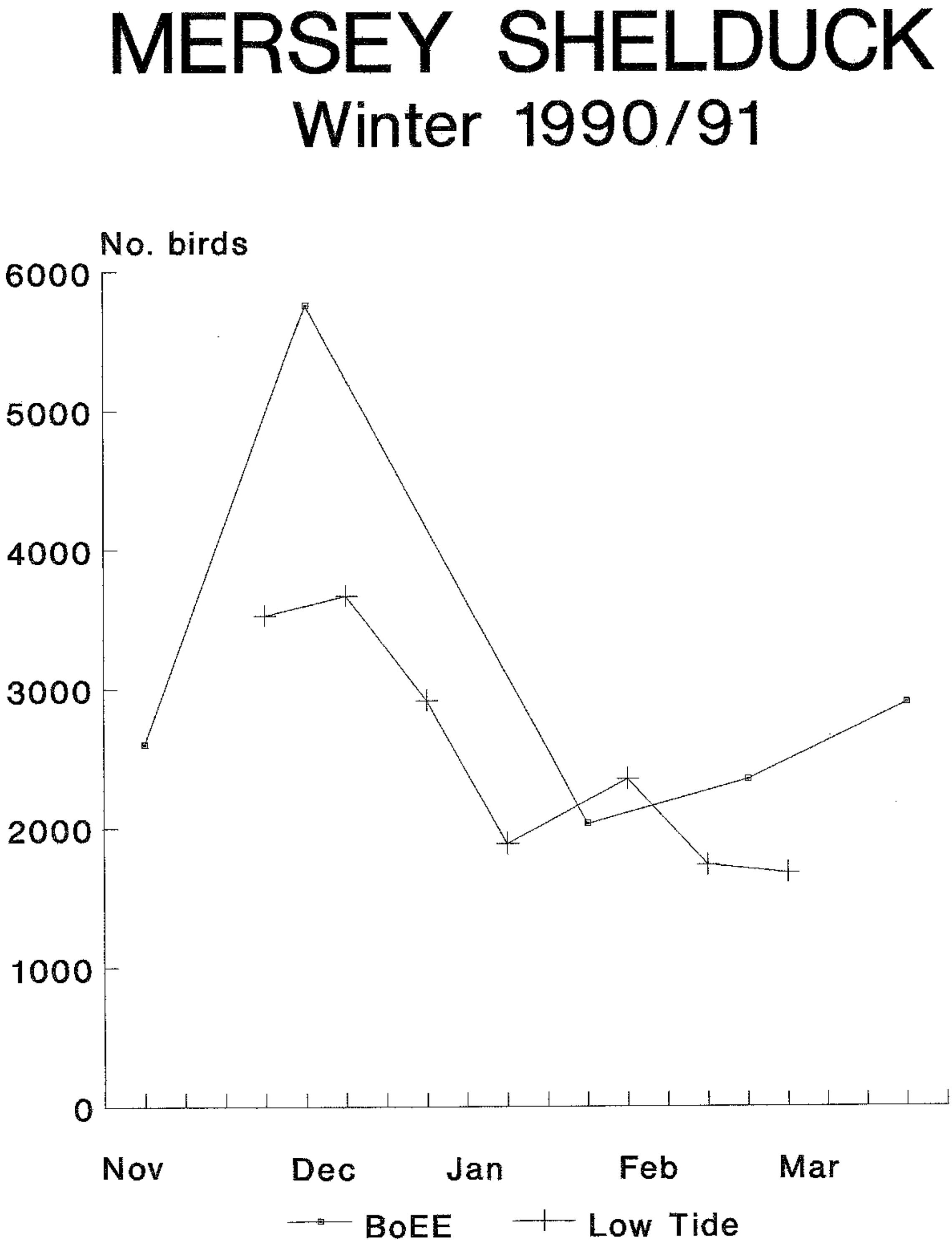



Figure 1.3.1.1 High tide (BoEE) and low tide counts of Shelduck during the 1990/91 winter.

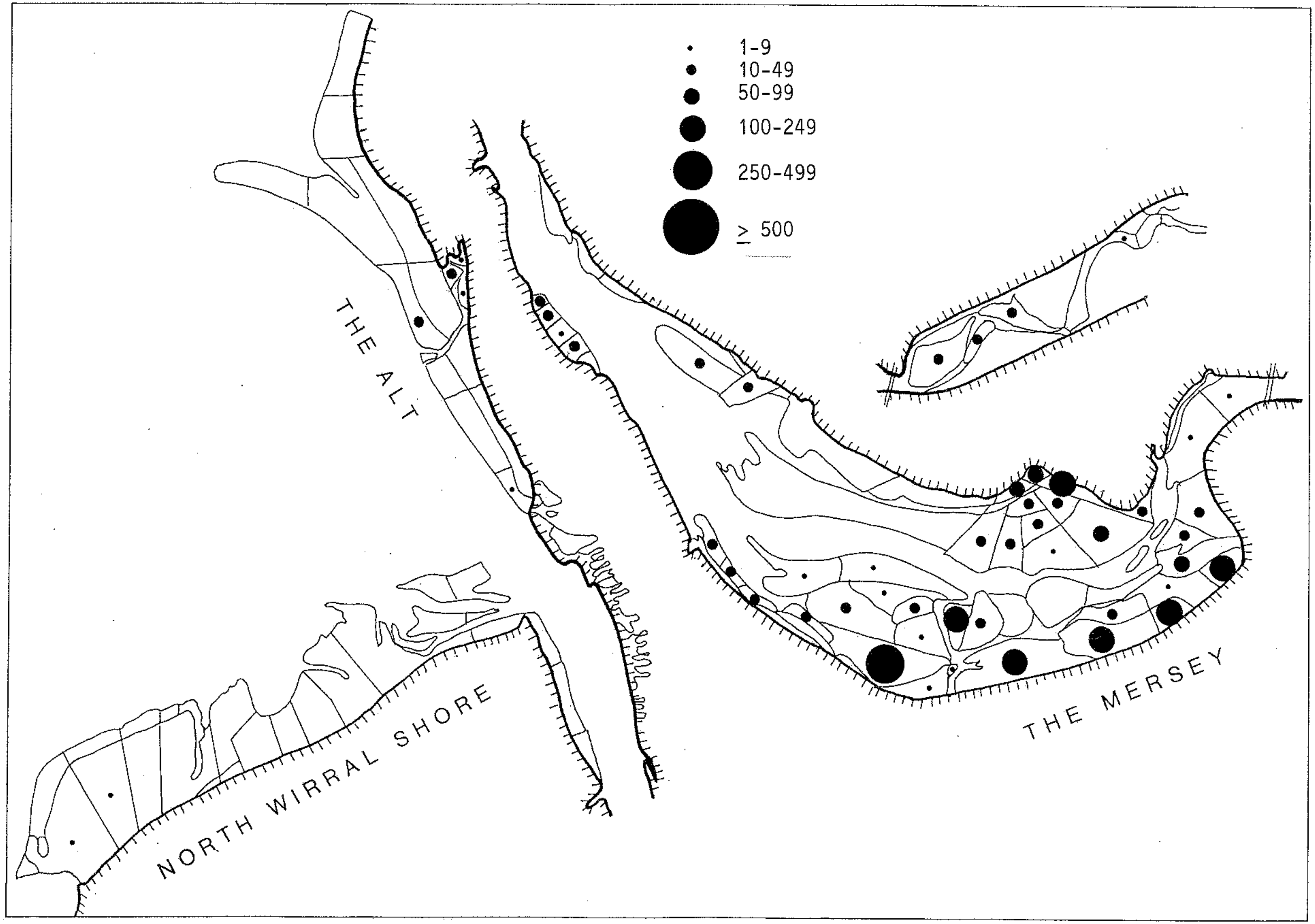



Figure 1.3.1.2 The average number of Shelduck feeding at low tide on each intertidal area during the 1990/91 winter.

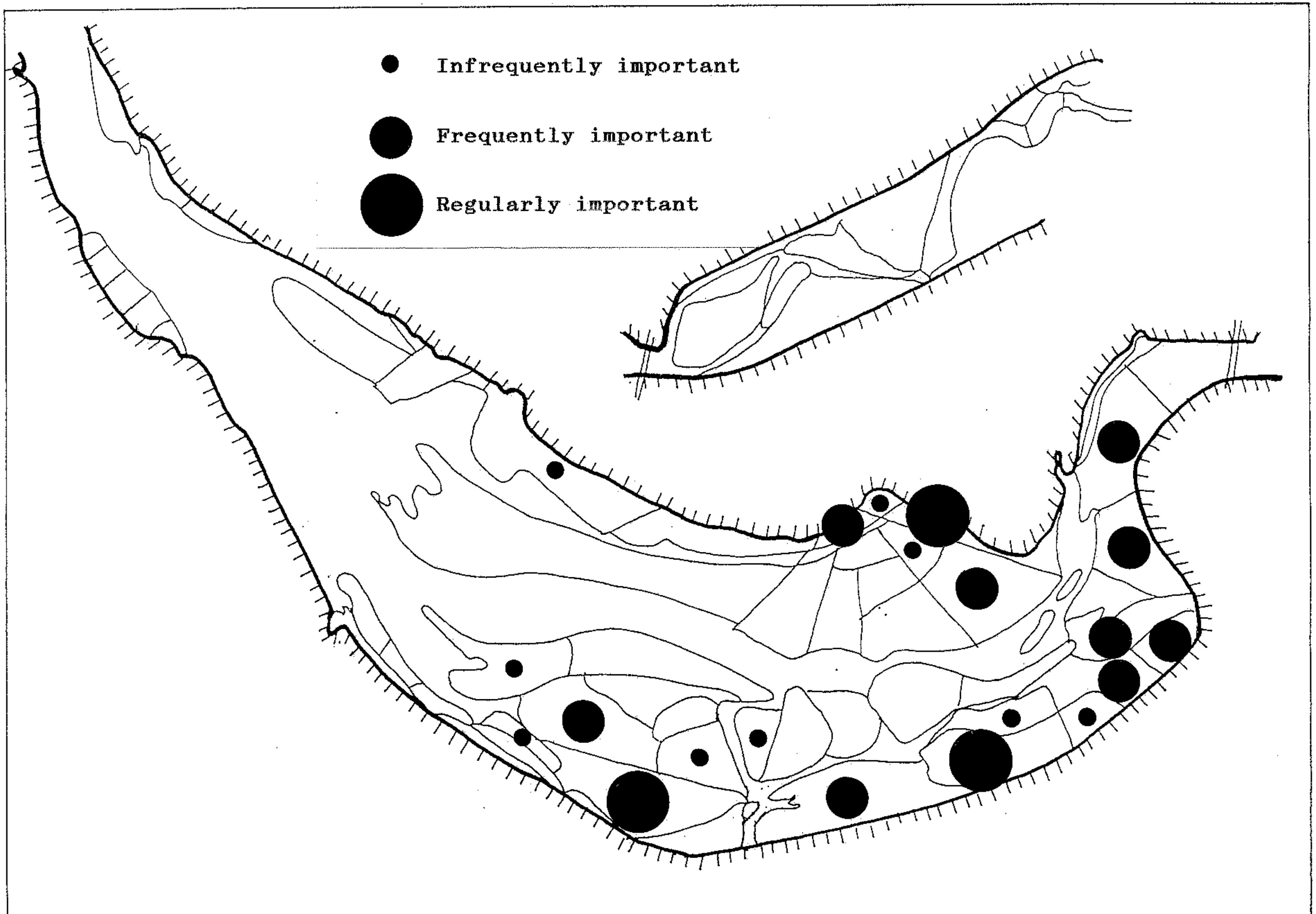



Figure 1.3.1.3 The relative importance of intertidal areas for feeding Shelduck in the winters 1988/89 to 1990/91.

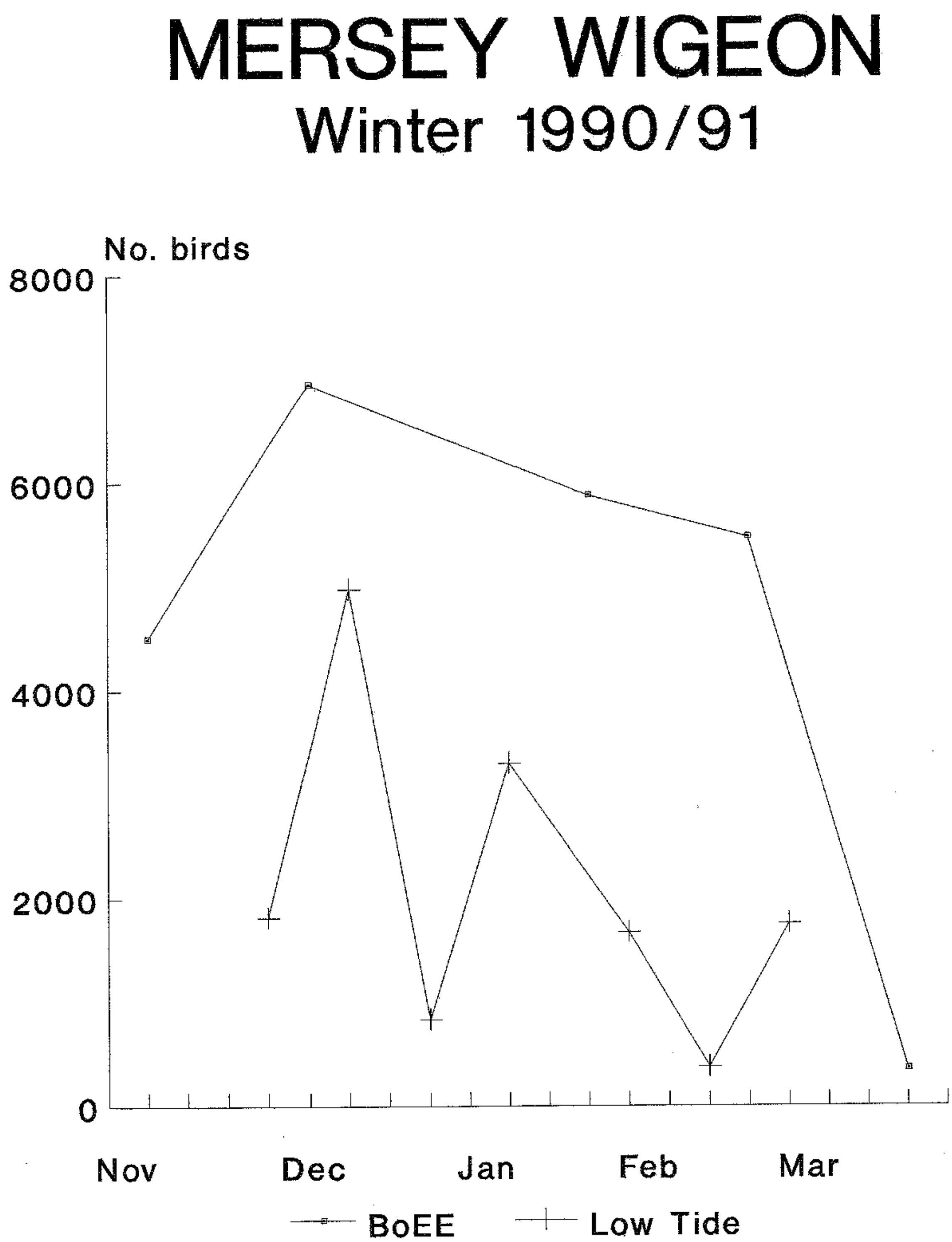



Figure 1.3.2.1 High tide (BoEE) and low tide counts of Wigeon during the 1990/91 winter.

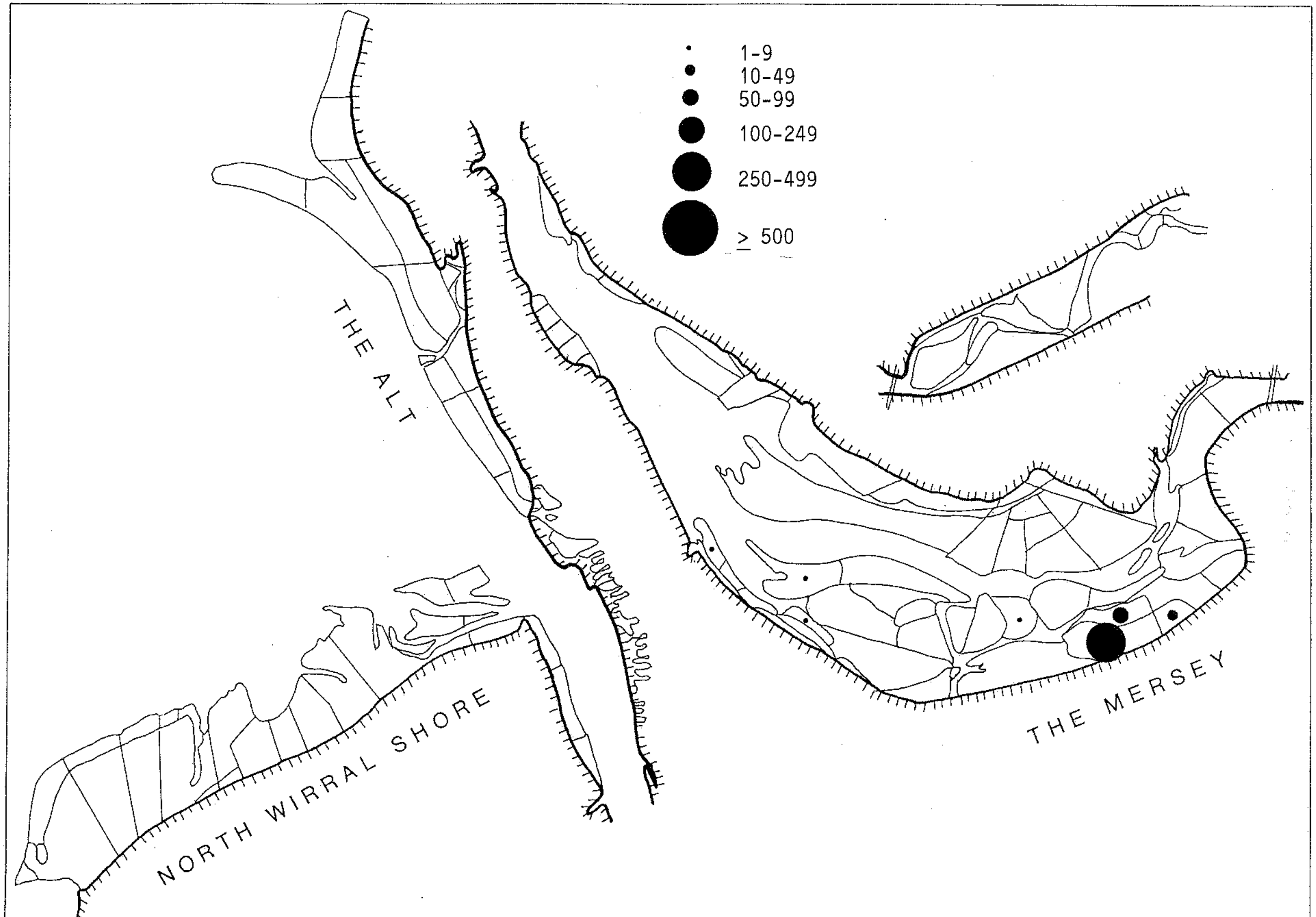



Figure 1.3.2.2 The average number of Wigeon feeding at low tide on each intertidal area during the 1990/91 winter.

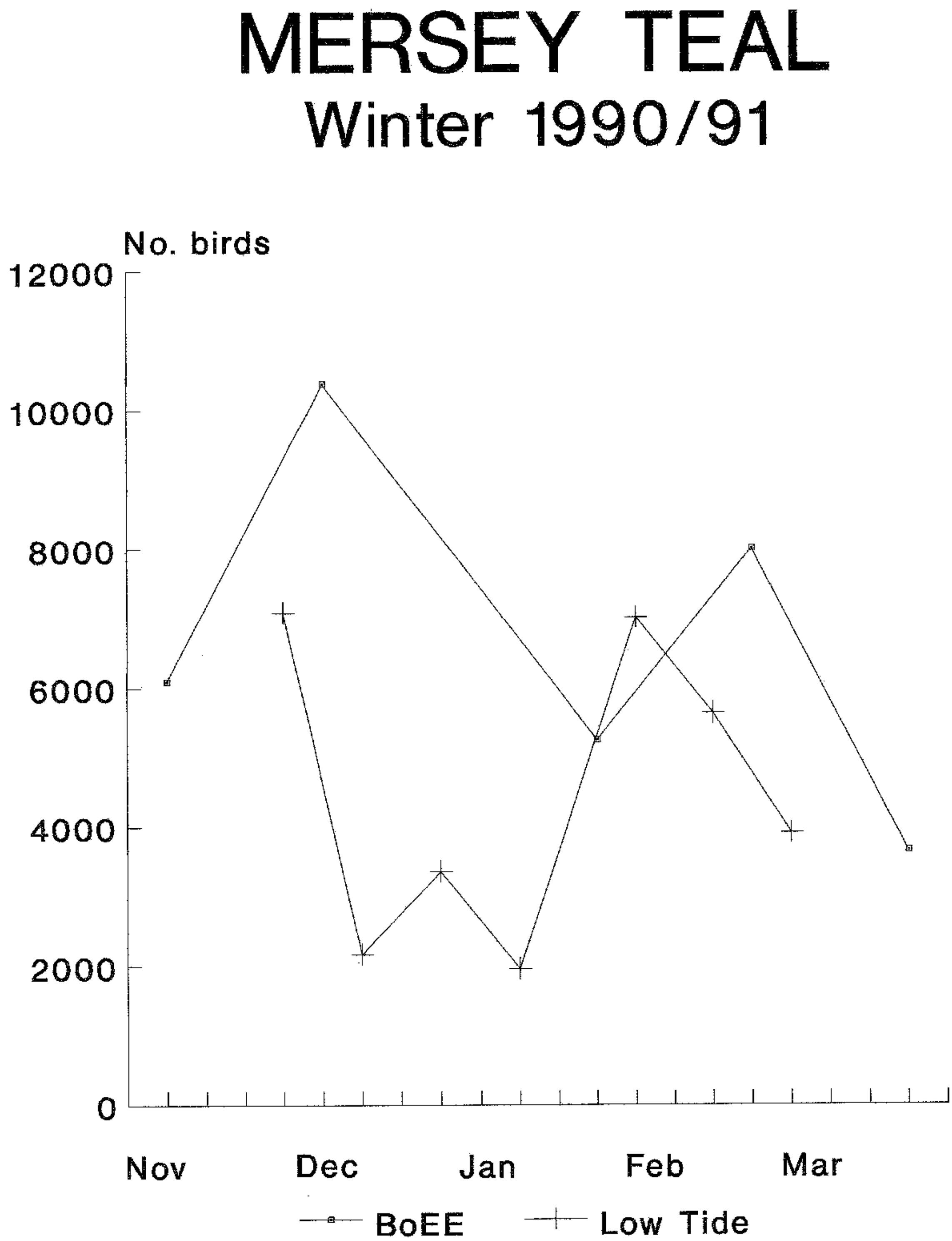



Figure 1.3.3.1 High tide (BoEE) and low tide counts of Teal during the 1990/91 winter.

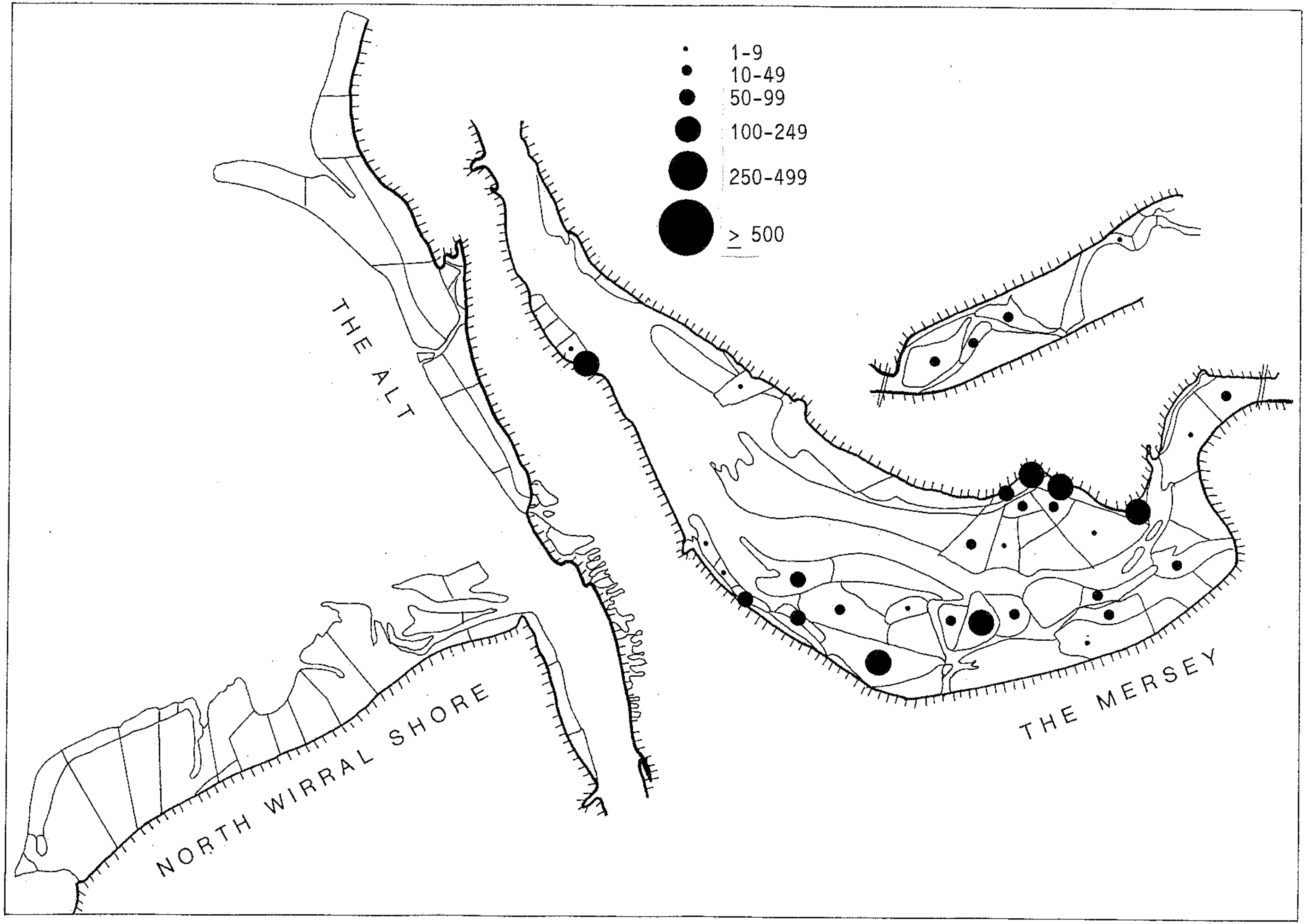



Figure 1.3.3.2 The average number of Teal feeding at low tide on each intertidal area during the 1990/91 winter.

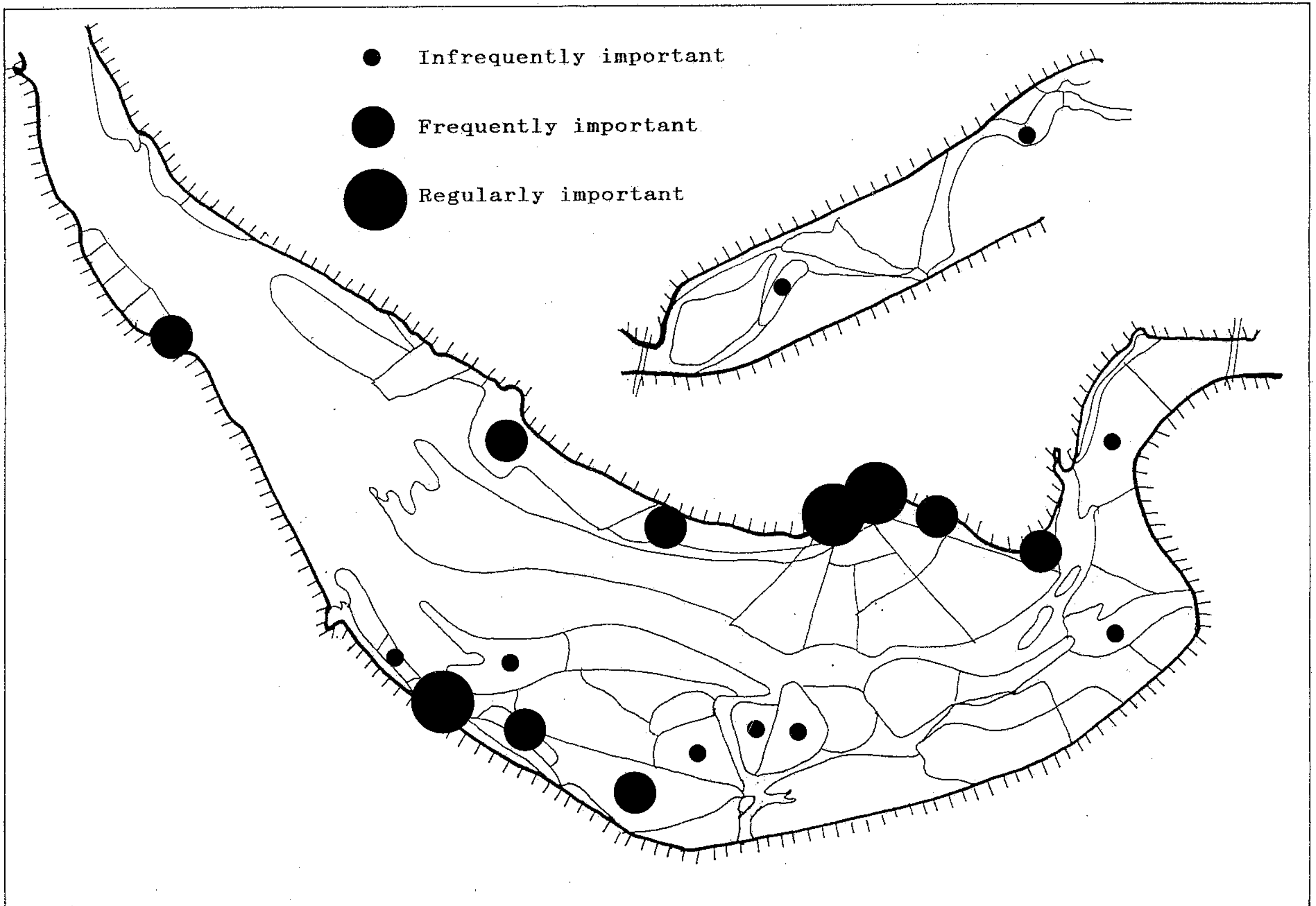



Figure 1.3.3.3 The relative importance of intertidal areas for feeding Teal in the winters 1988/89 to 1990/91.

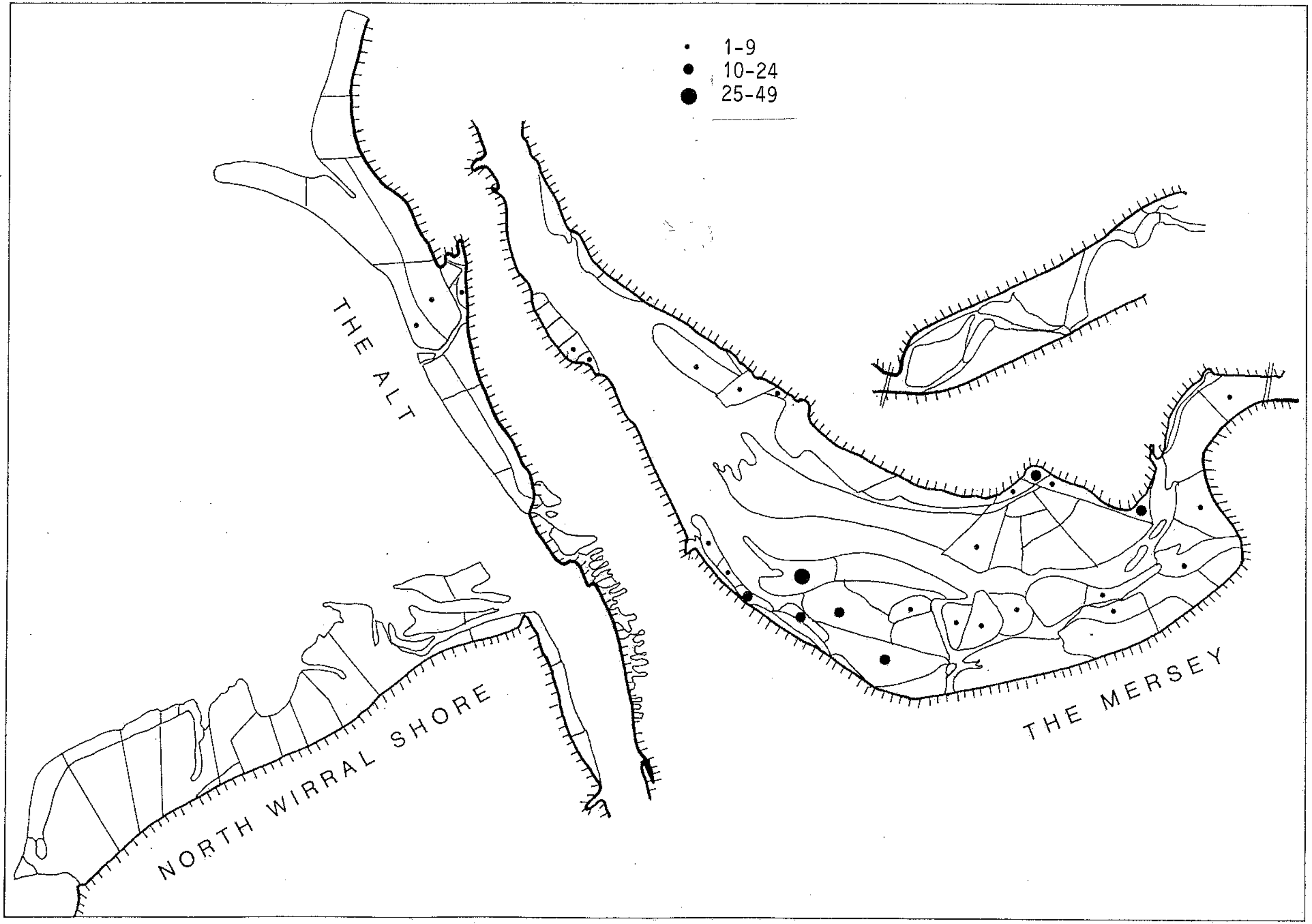



Figure 1.3.4.1 The average number of Mallard feeding at low tide on each intertidal area during the 1990/91 winter.

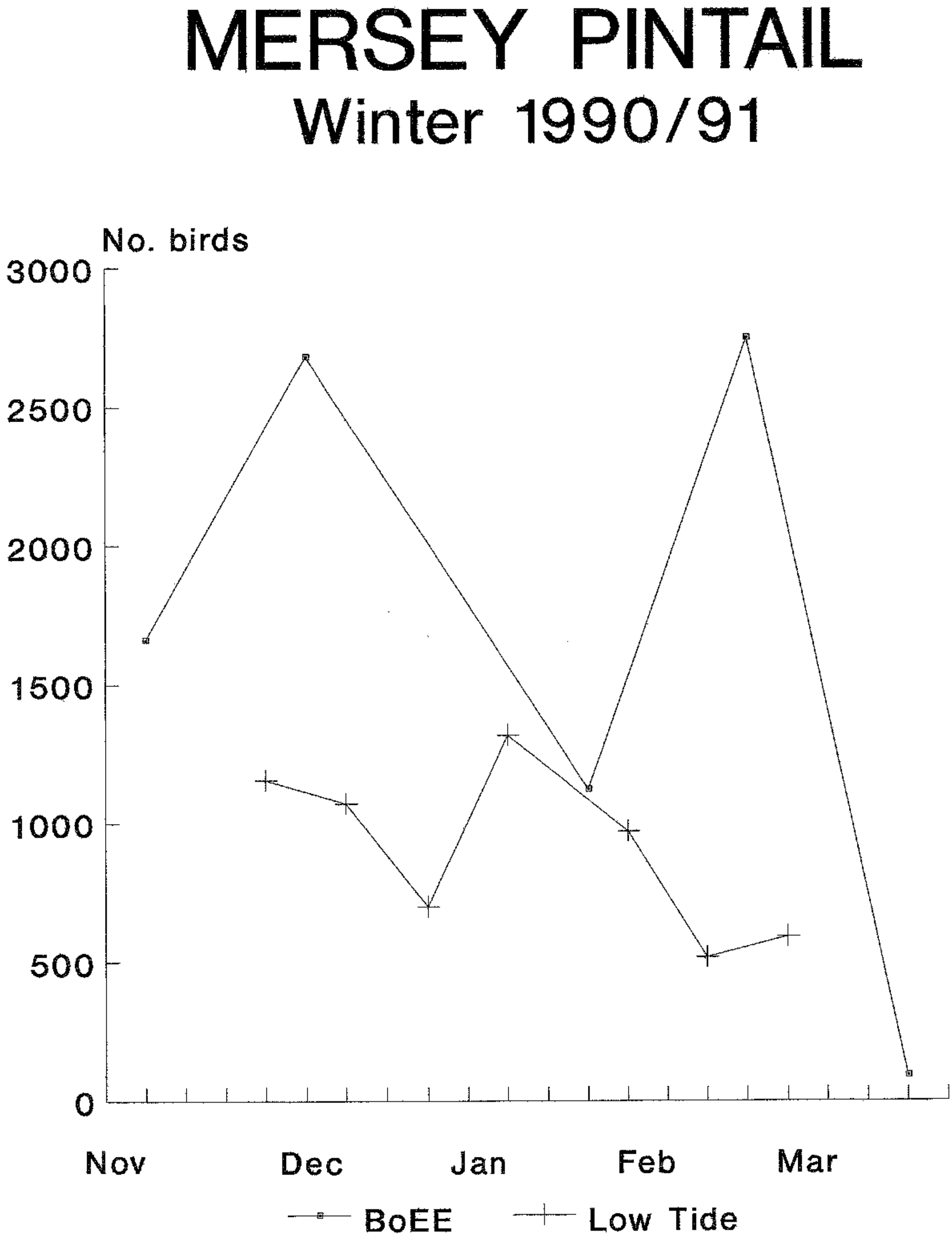



Figure 1.3.5.1 High tide (BoEE) and low tide counts of Pintail during the 1990/91 winter.

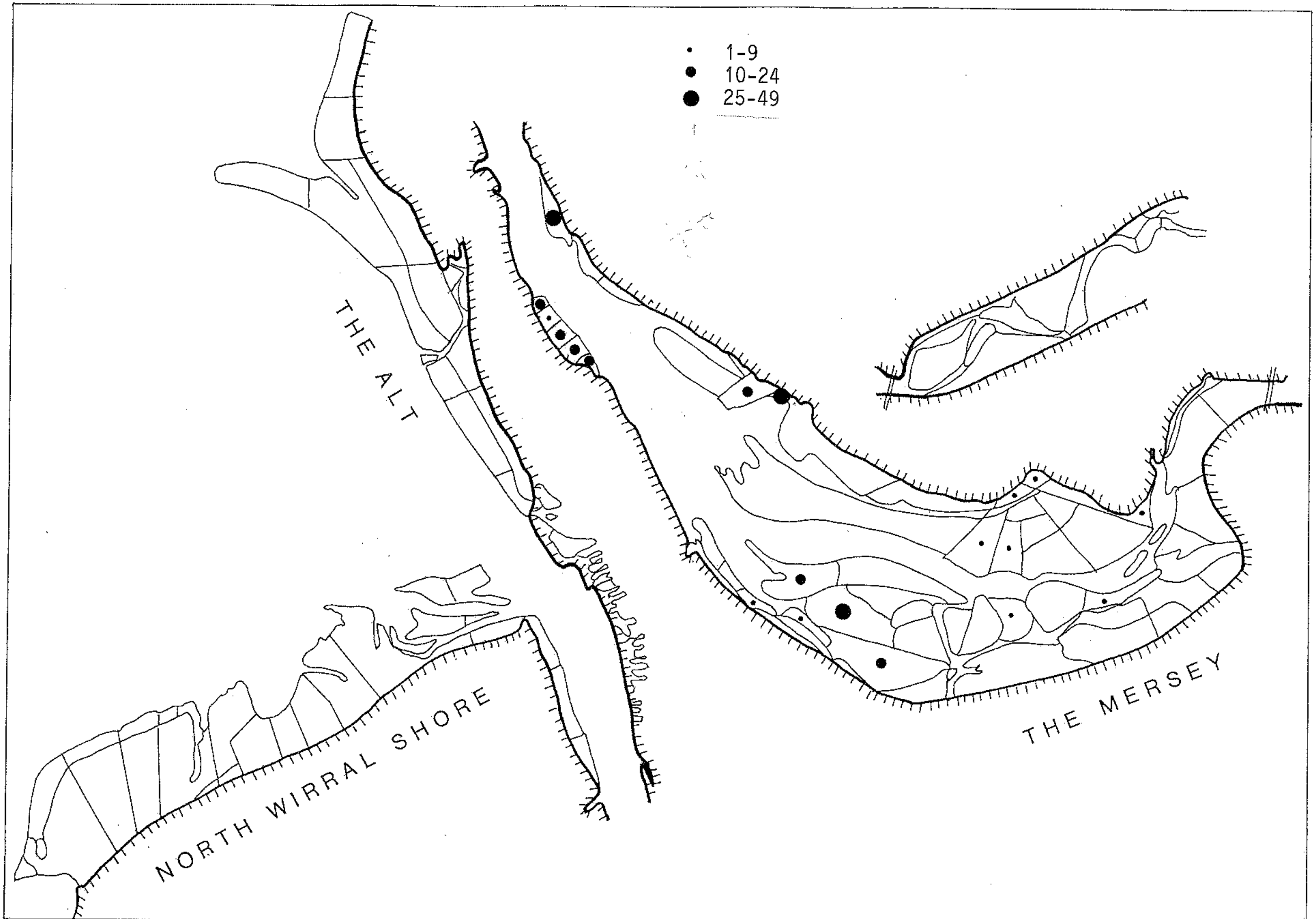



Figure 1.3.5.2 The average number of Pintail feeding at low tide on each intertidal area during the 1990/91 winter.

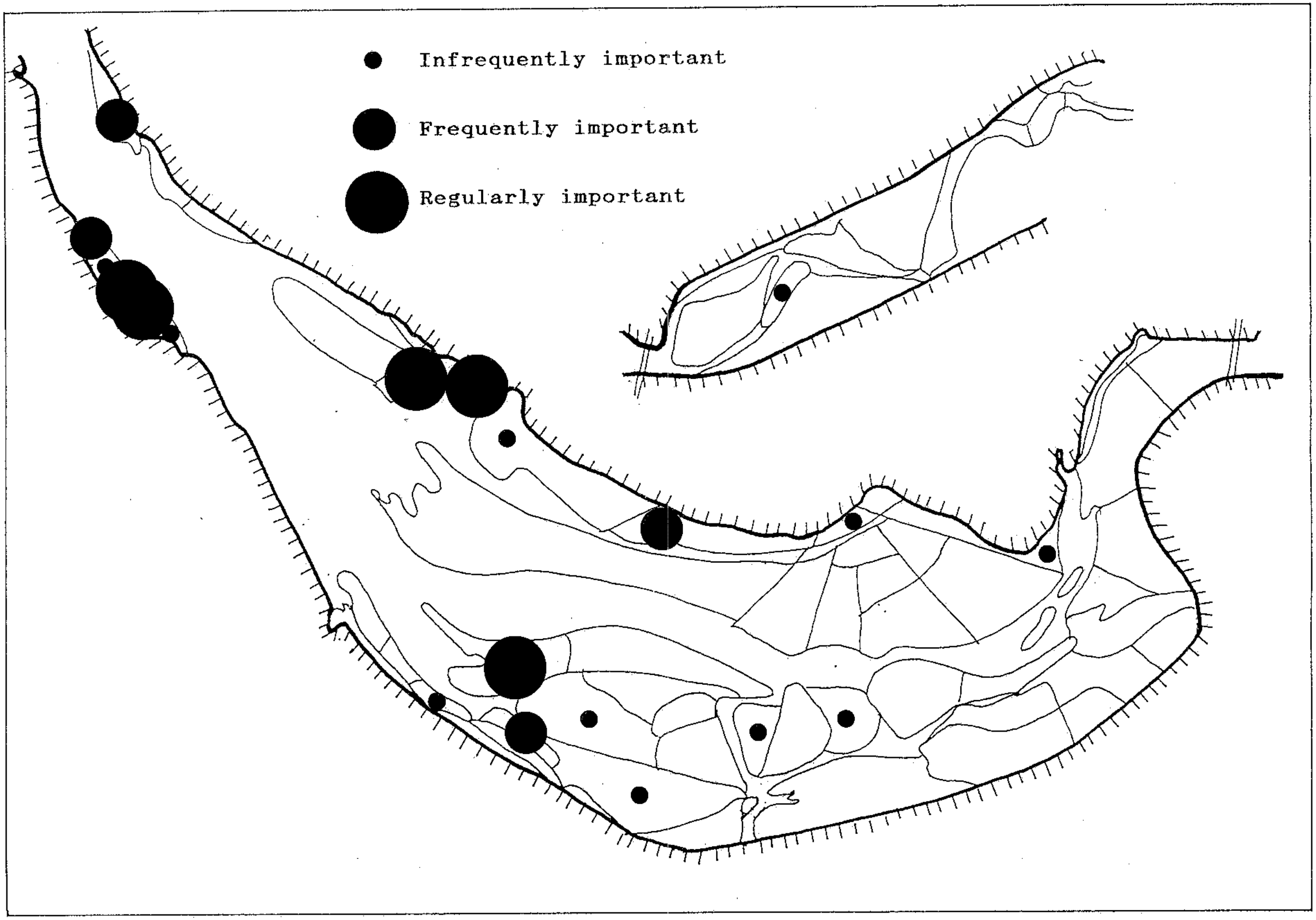



Figure 1.3.5.3 The relative importance of intertidal areas for feeding Pintail in the winters 1988/89 to 1990/91.

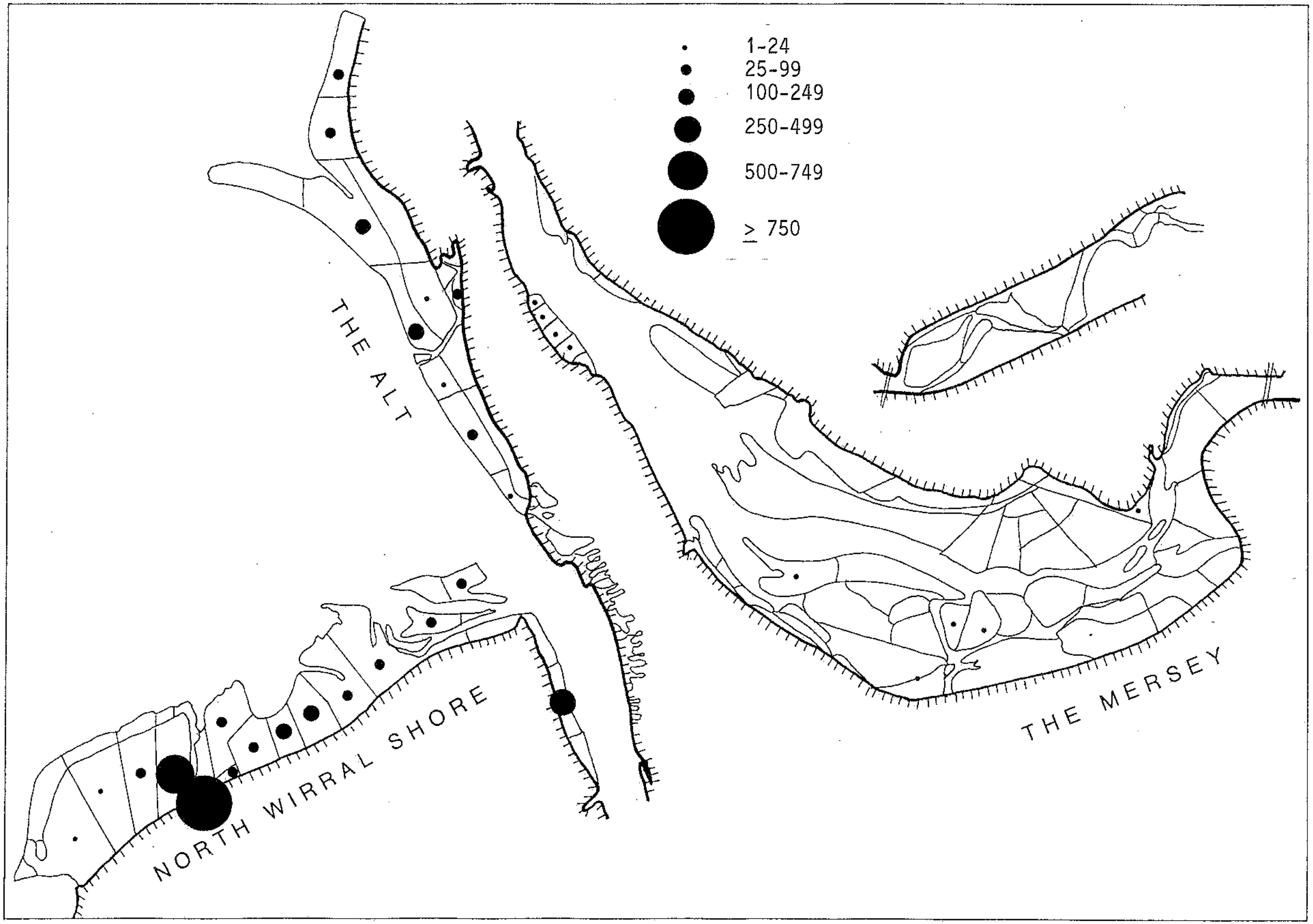



Figure 1.3.6.1 The average number of Oystercatcher feeding at low tide on each intertidal area during the 1990/91 winter.

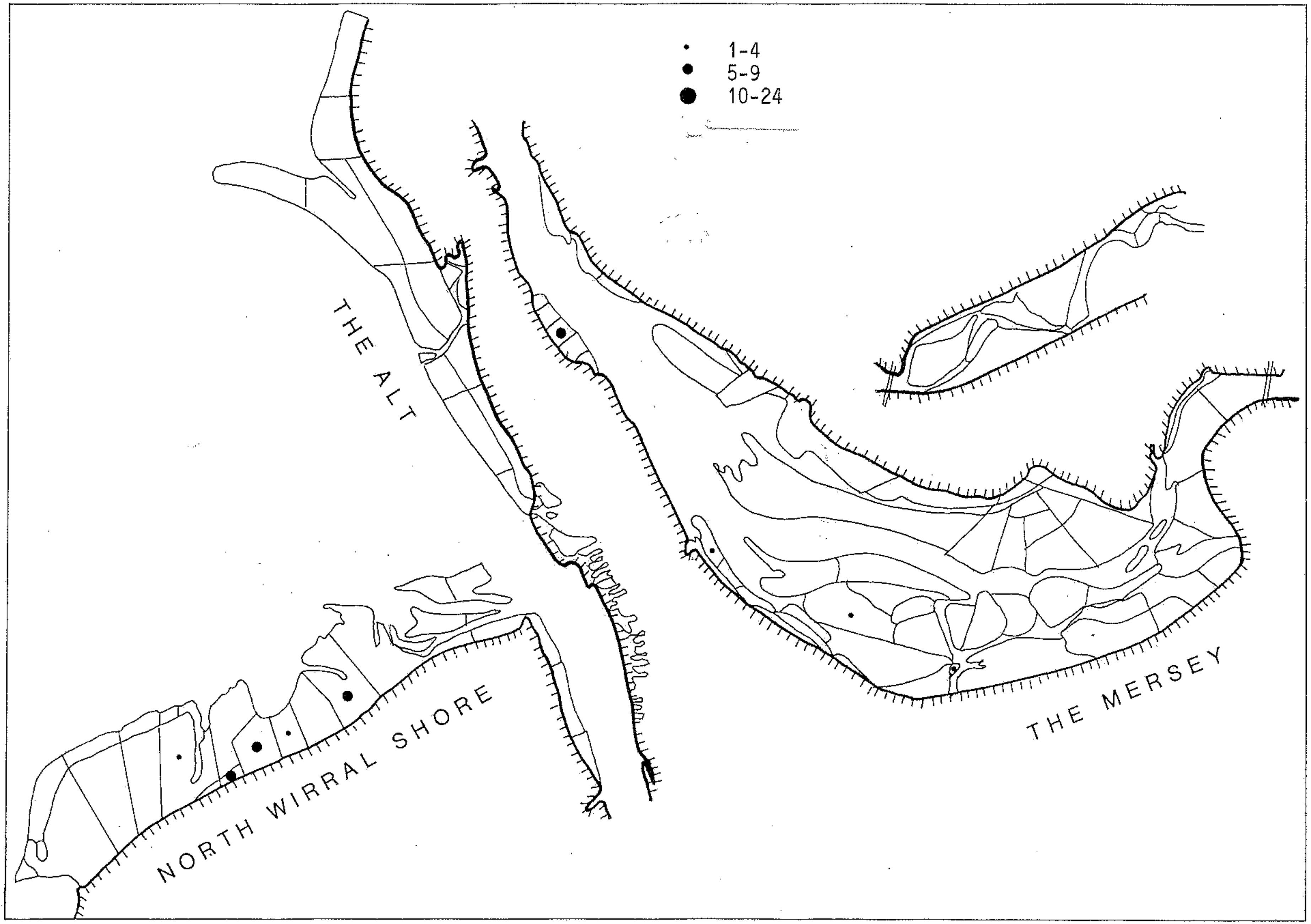



Figure 1.3.7.1 The average number of Ringed Plover feeding at low tide on each intertidal area during the 1990/91 winter.

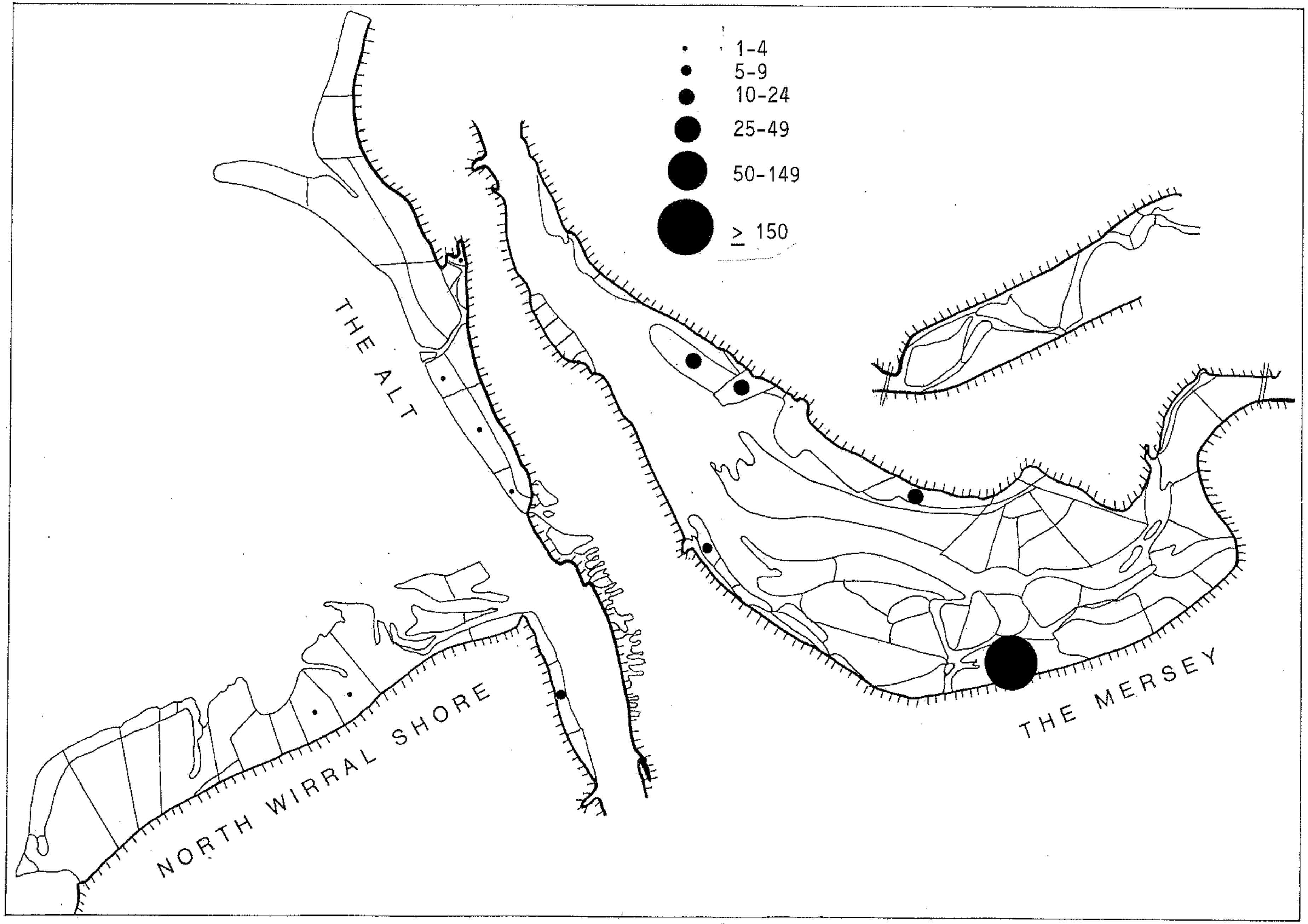



Figure 1.3.8.1 The average number of Golden Plover feeding at low tide on each intertidal area during the 1990/91 winter.

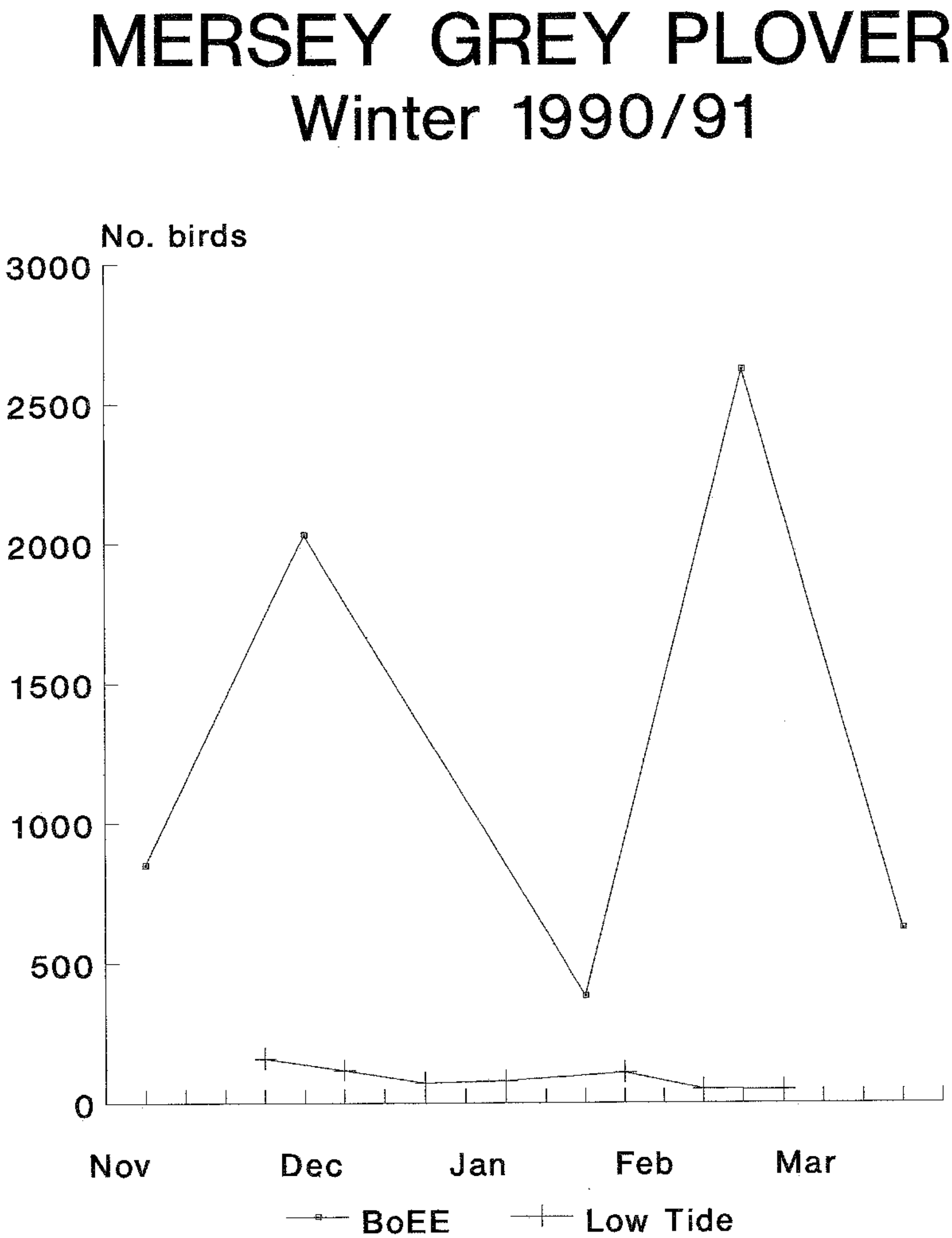



Figure 1.3.9.1 High tide (BoEE) and low tide counts of Grey Plover during the 1990/91 winter.

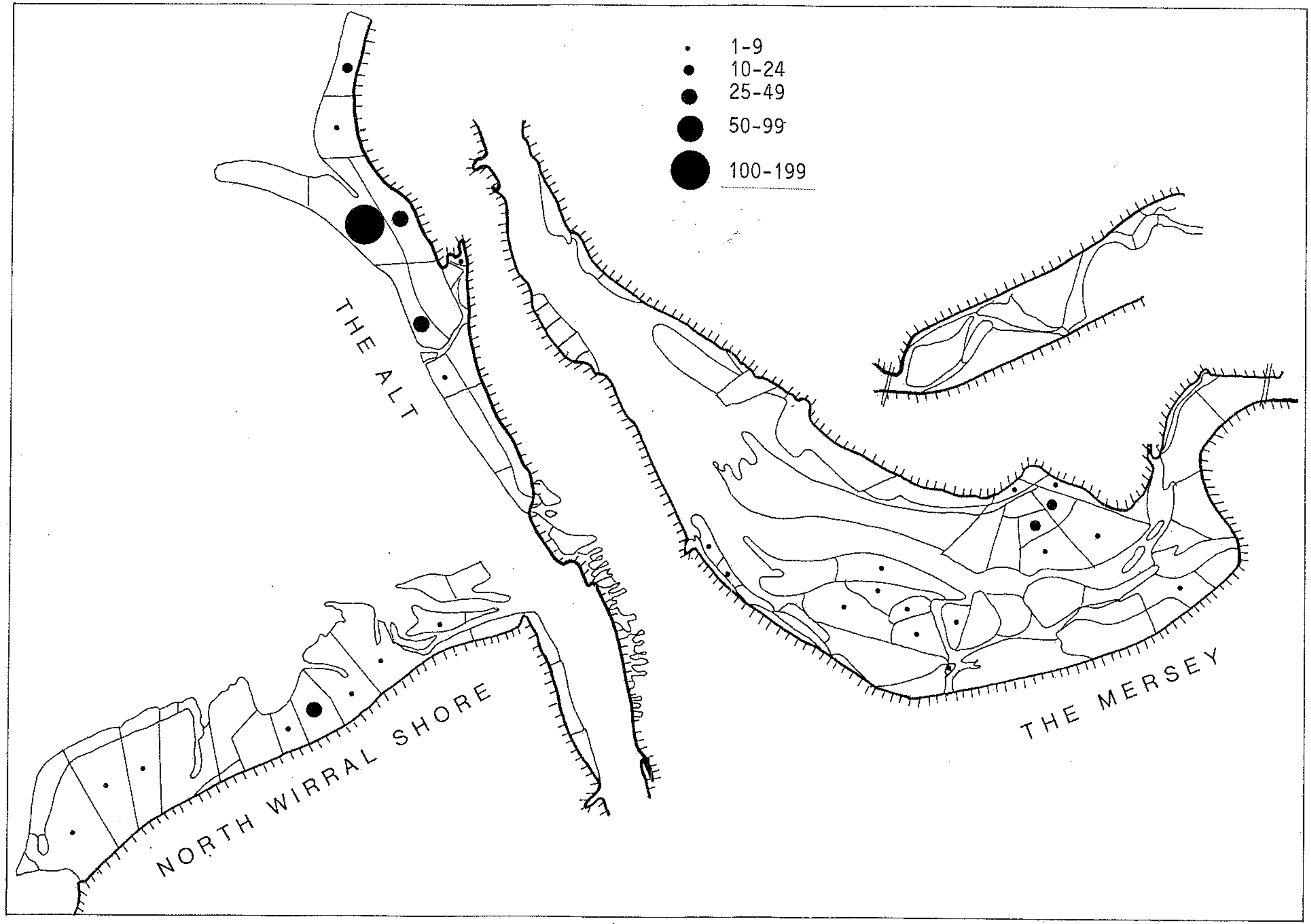



Figure 1.3.9.2 The average number of Grey Plover feeding at low tide on each intertidal area during the 1990/91 winter.

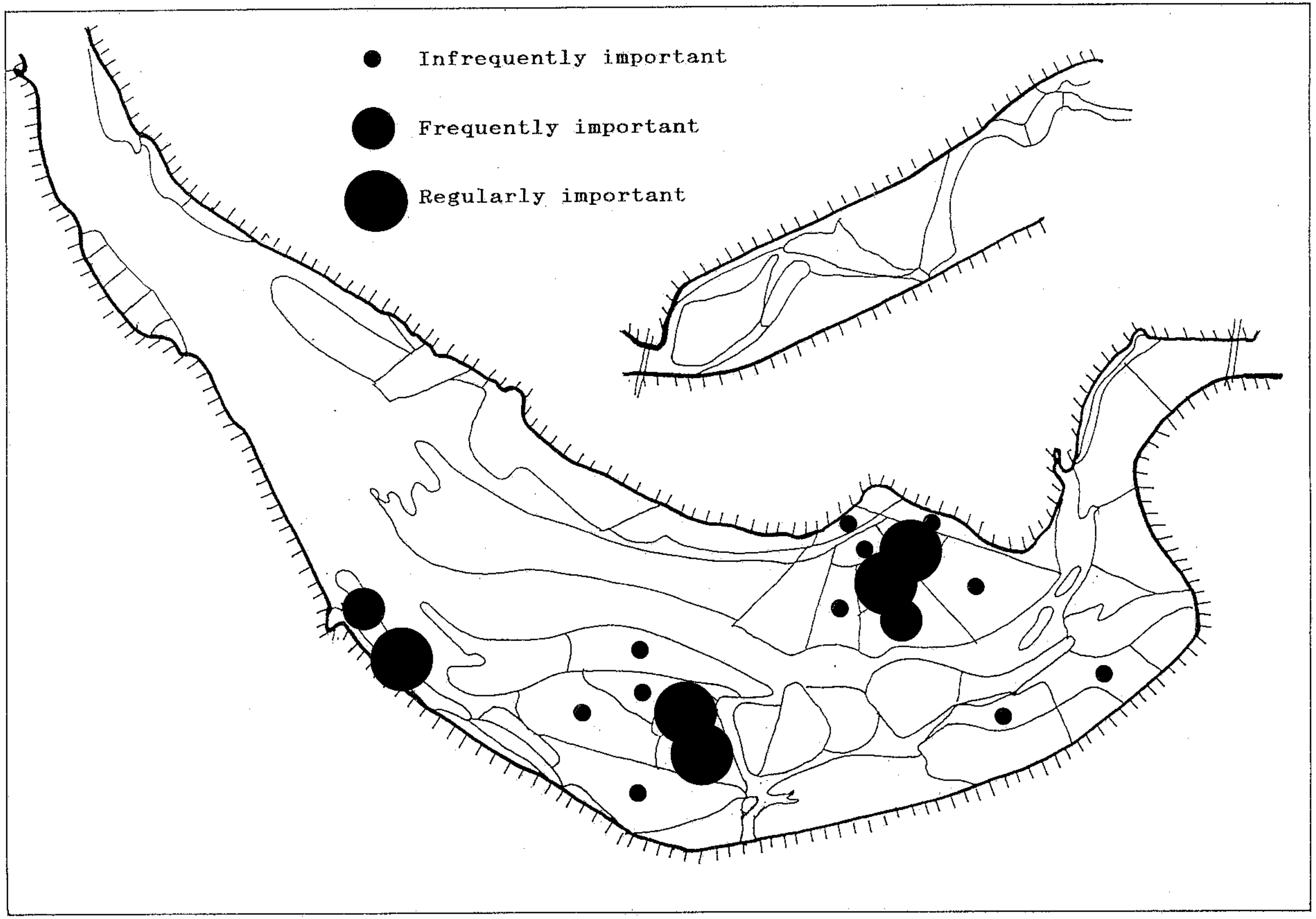



Figure 1.3.9.3 The relative importance of intertidal areas for feeding Grey Plover in the winters 1988/89 to 1990/91.

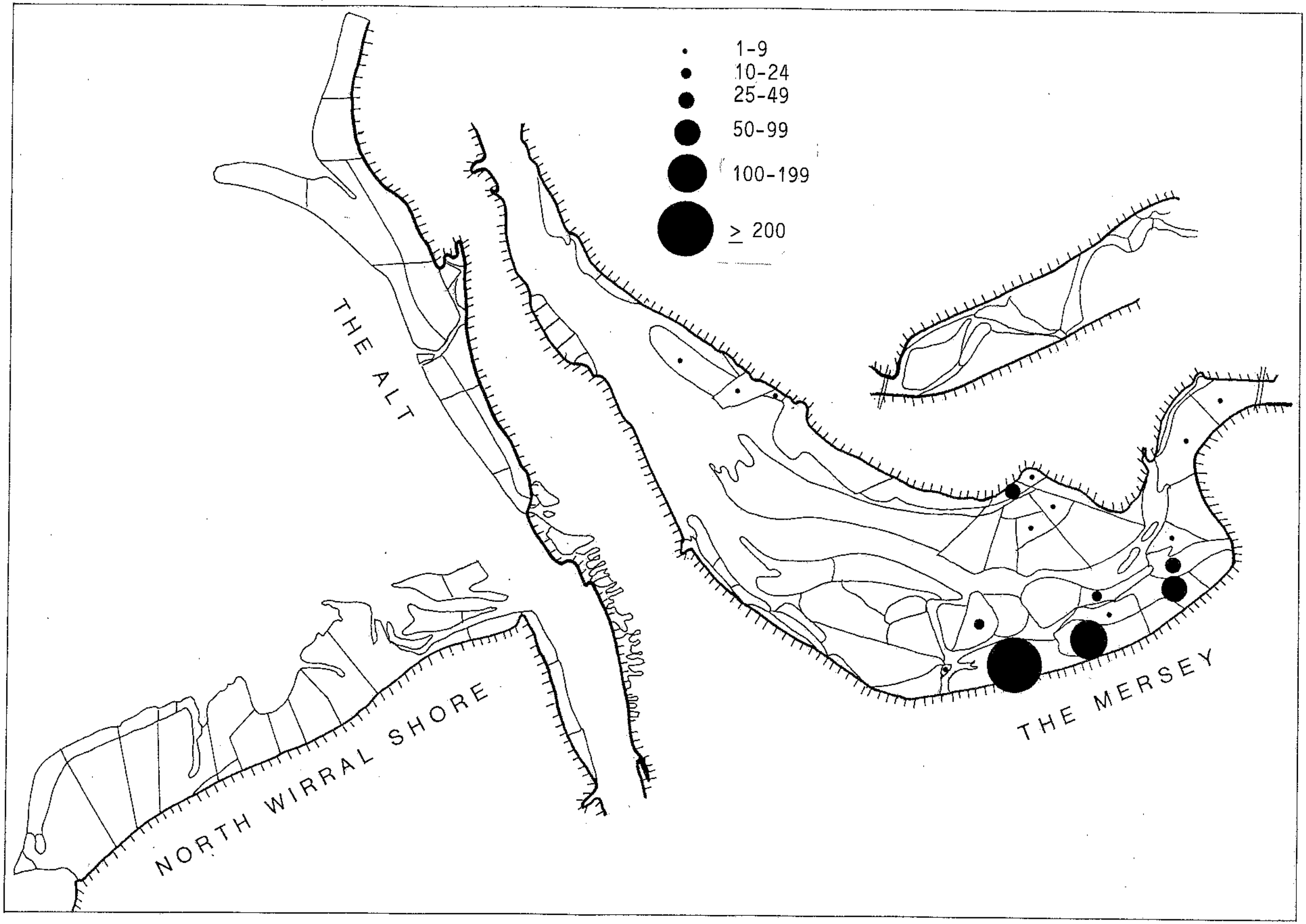



Figure 1.3.10.1 The average number of Lapwing feeding at low tide on each intertidal area during the 1990/91 winter.

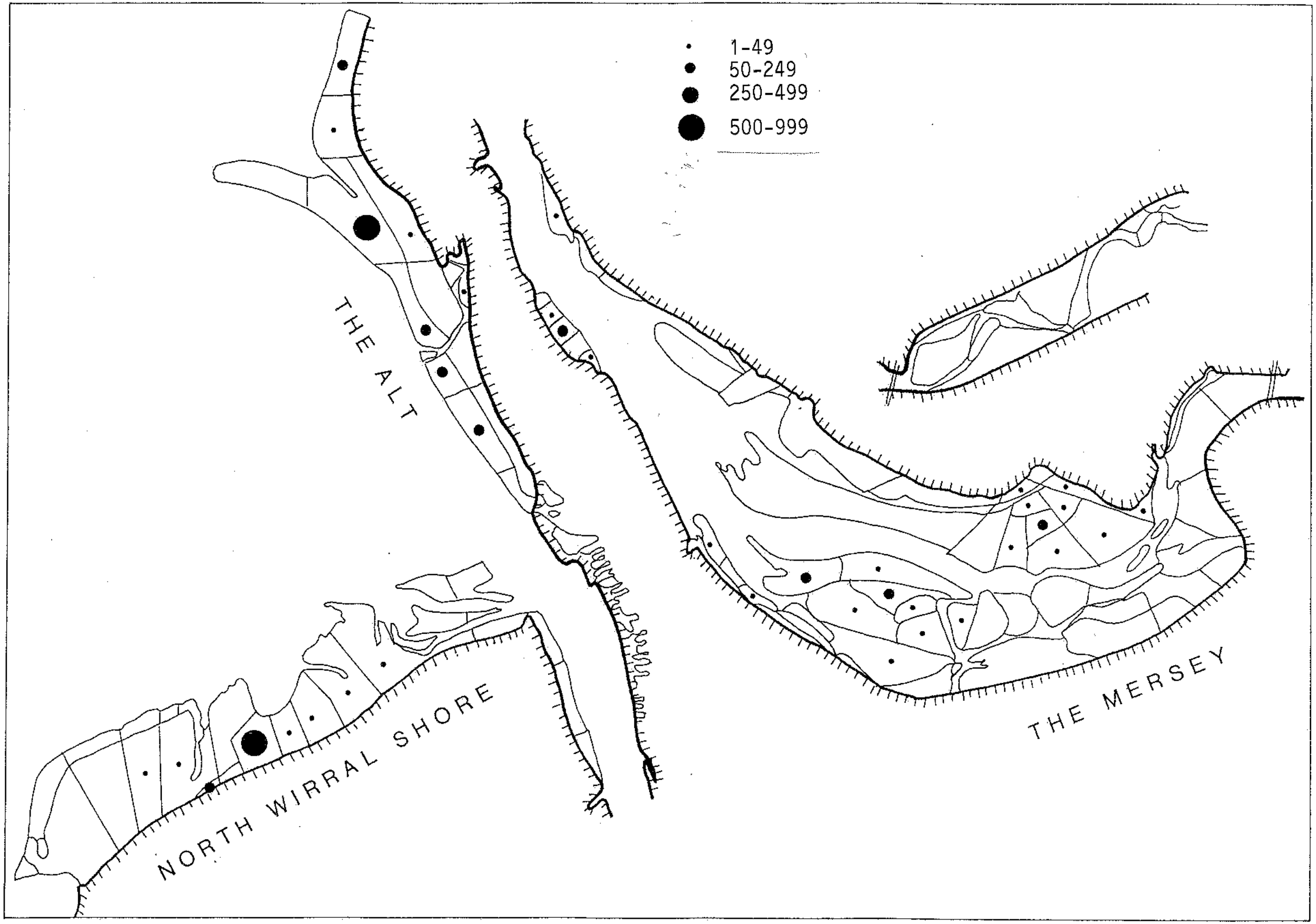



Figure 1.3.11.1 The average number of Knot feeding at low tide on each intertidal area during the 1990/91 winter.

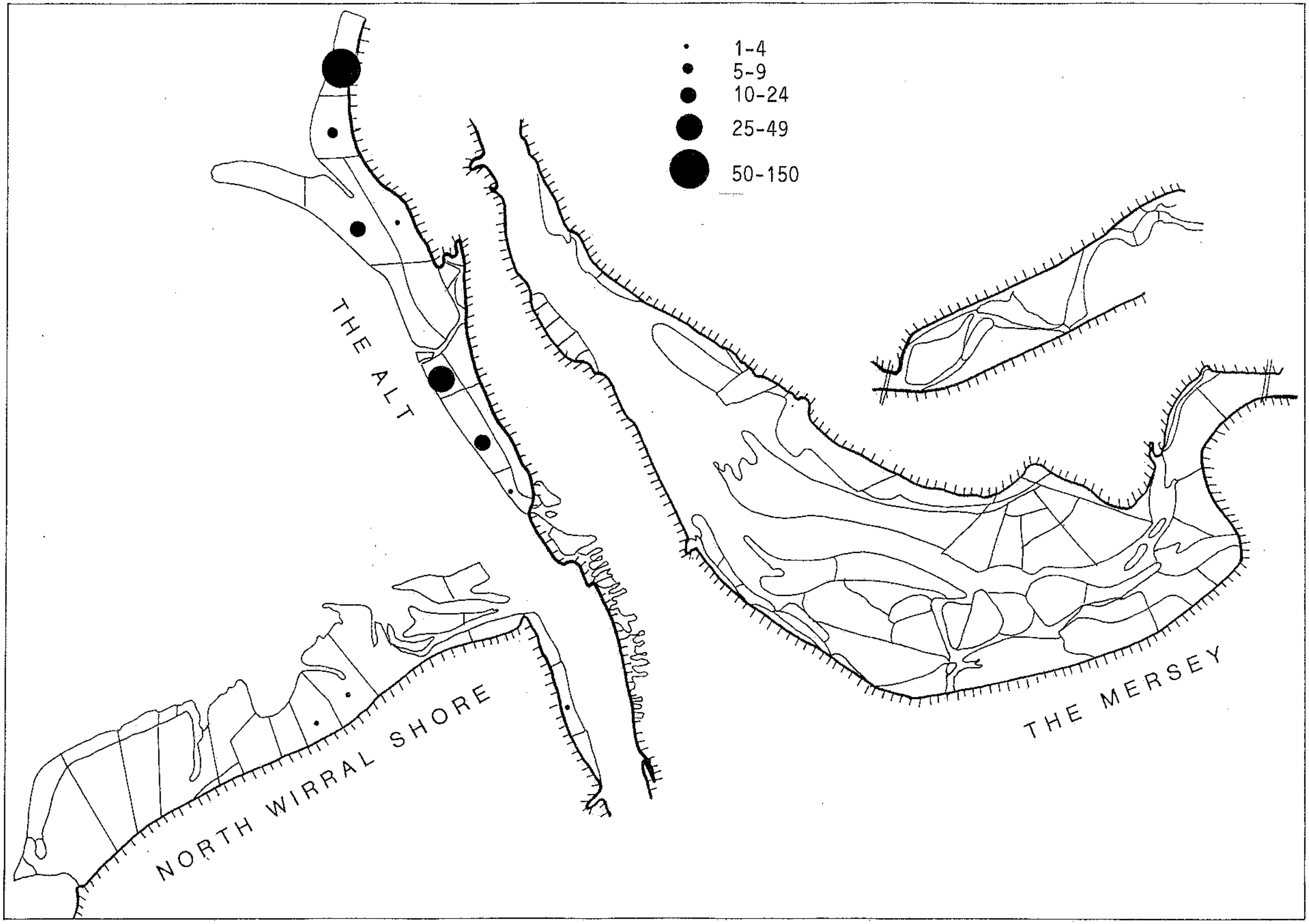



Figure 1.3.12.1 The average number of Sanderling feeding at low tide on each intertidal area during the 1990/91 winter.

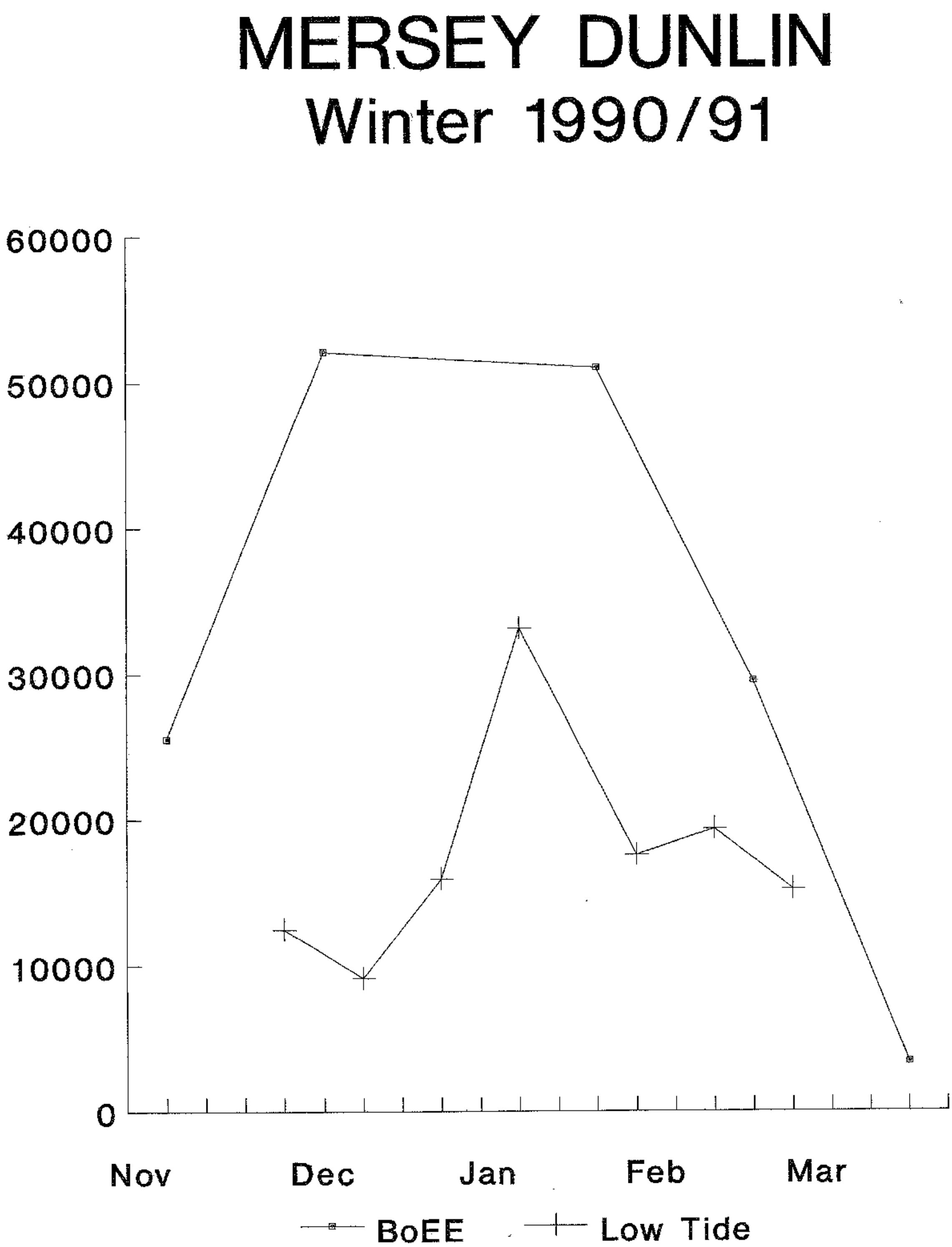



Figure 1.3.13.1 High tide (BoEE) and low tide counts of Dunlin during the 1990/91 winter.

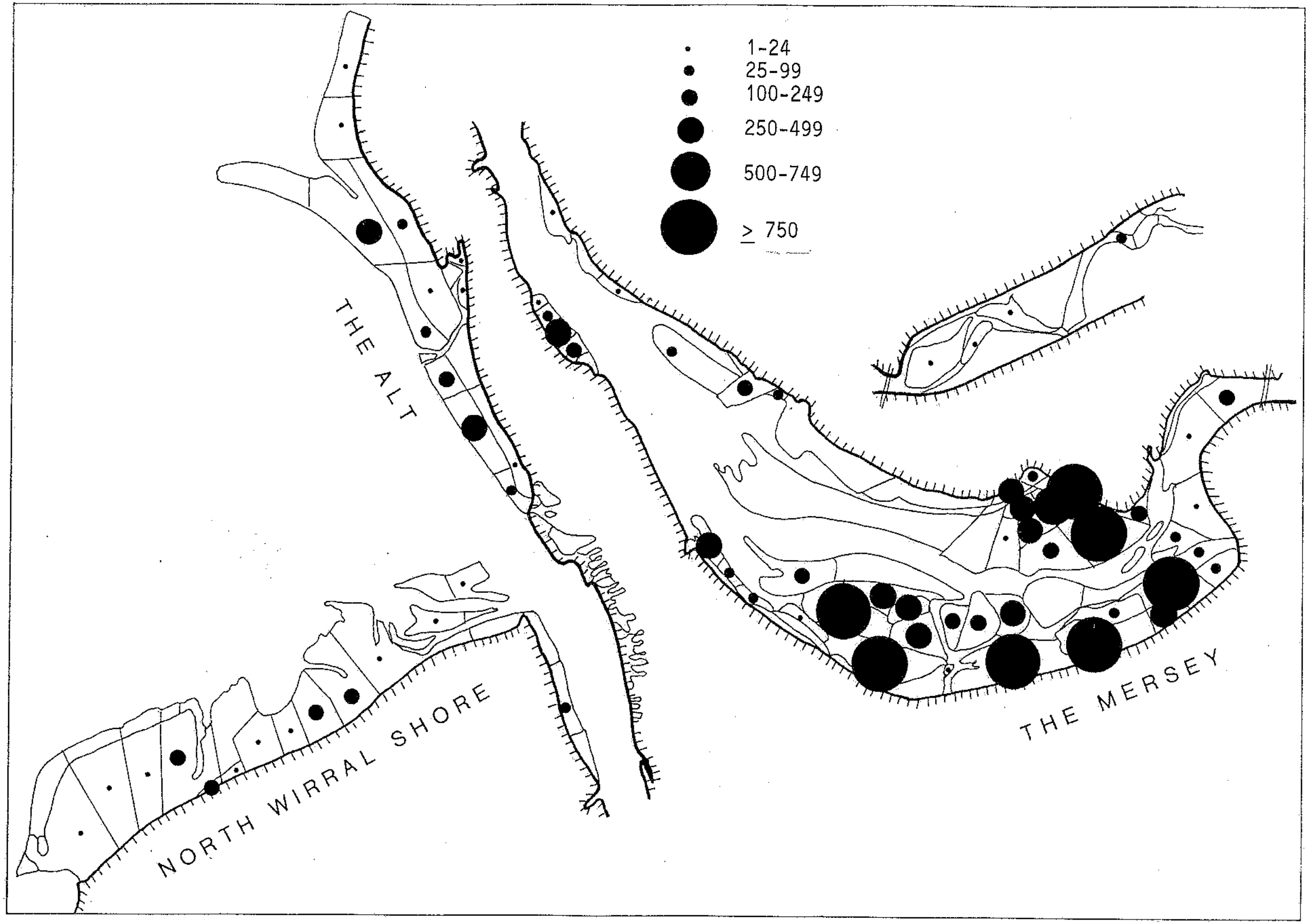



Figure 1.3.13.2 The average number of Dunlin feeding at low tide on each intertidal area during the 1990/91 winter.

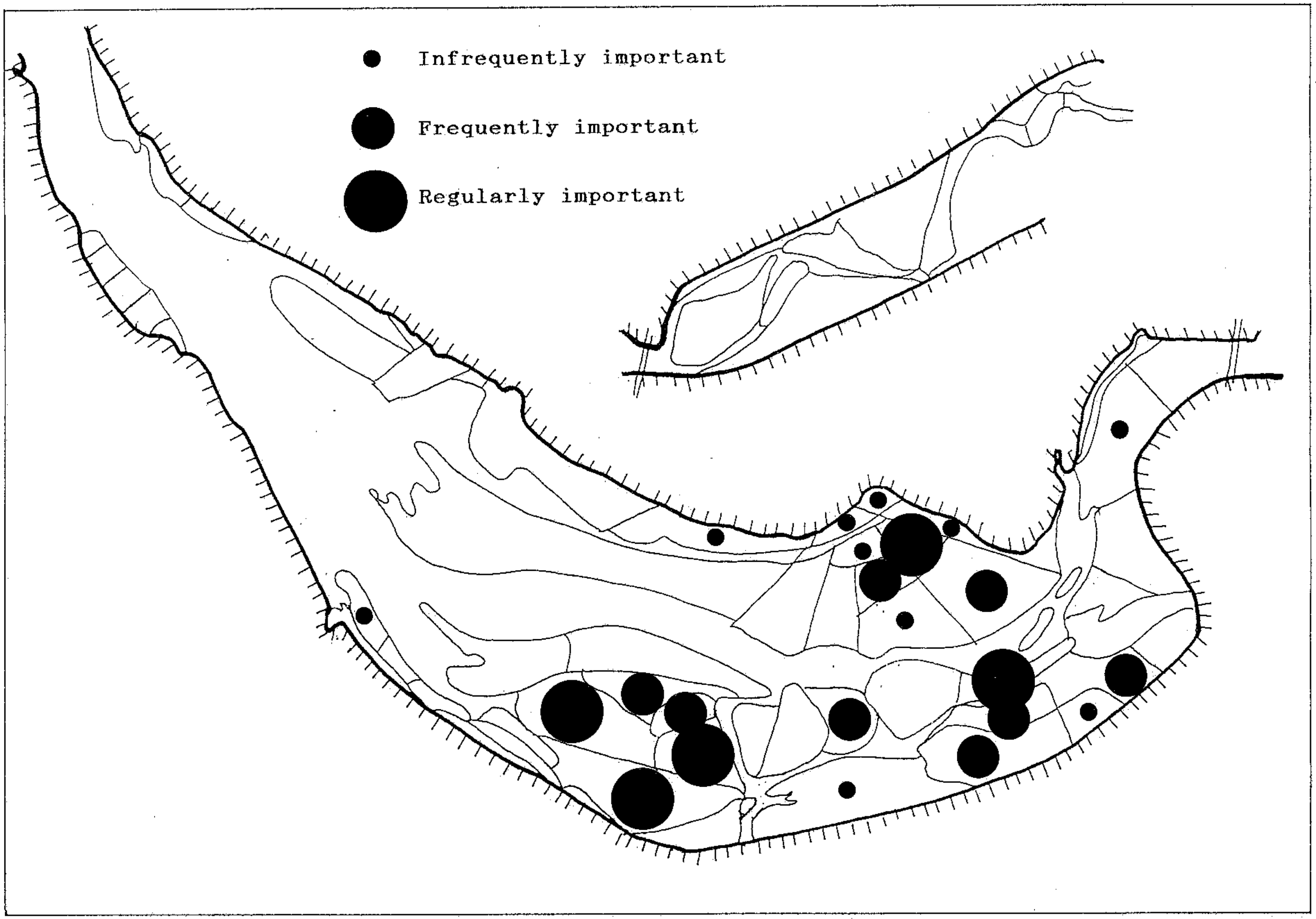



Figure 1.3.13.3 The relative importance of intertidal areas for feeding Dunlin in the winters 1988/89 to 1990/91.

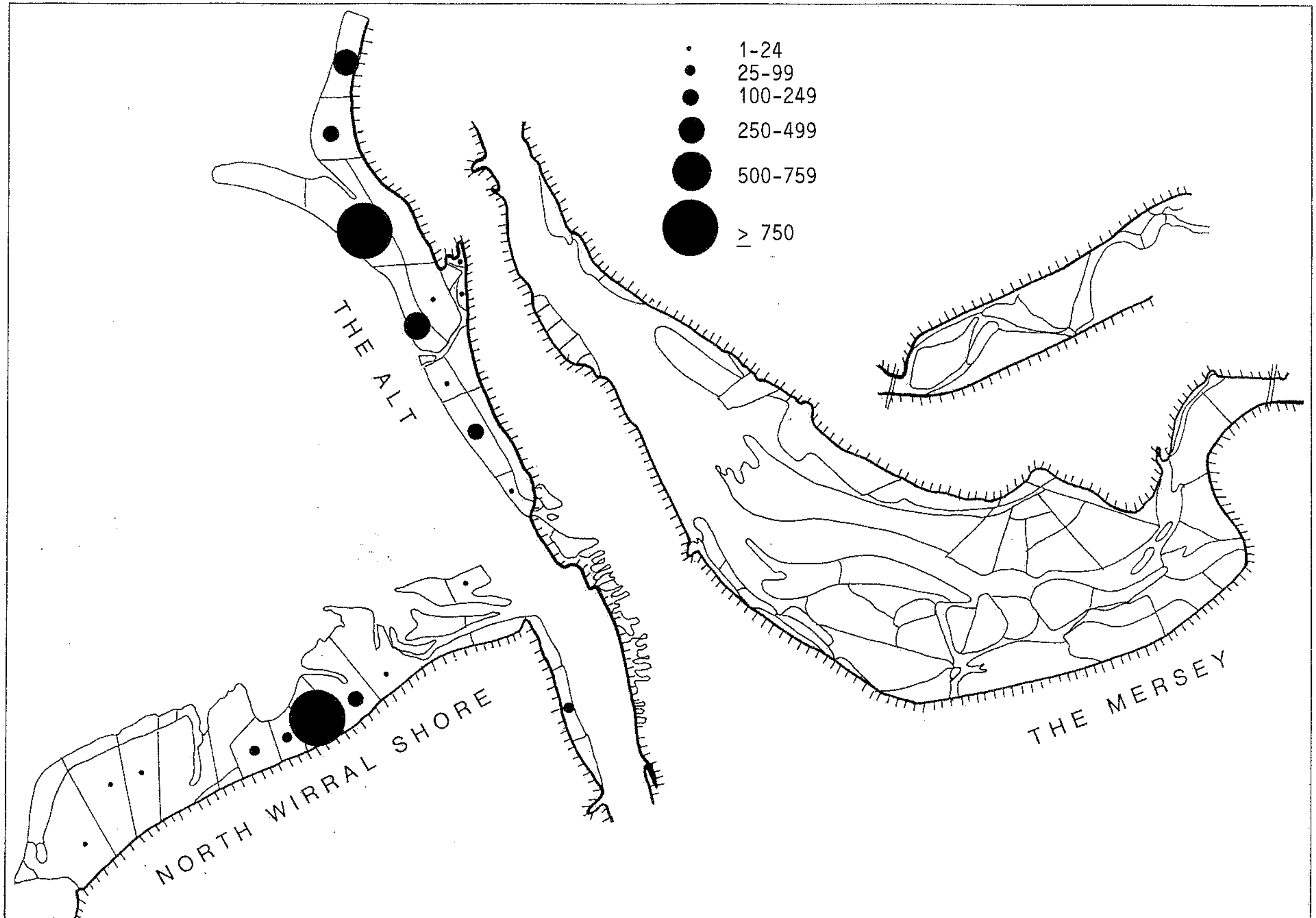



Figure 1.3.14.1 The average number of Bar-tailed Godwit feeding at low tide on each intertidal area during the 1990/91 winter.

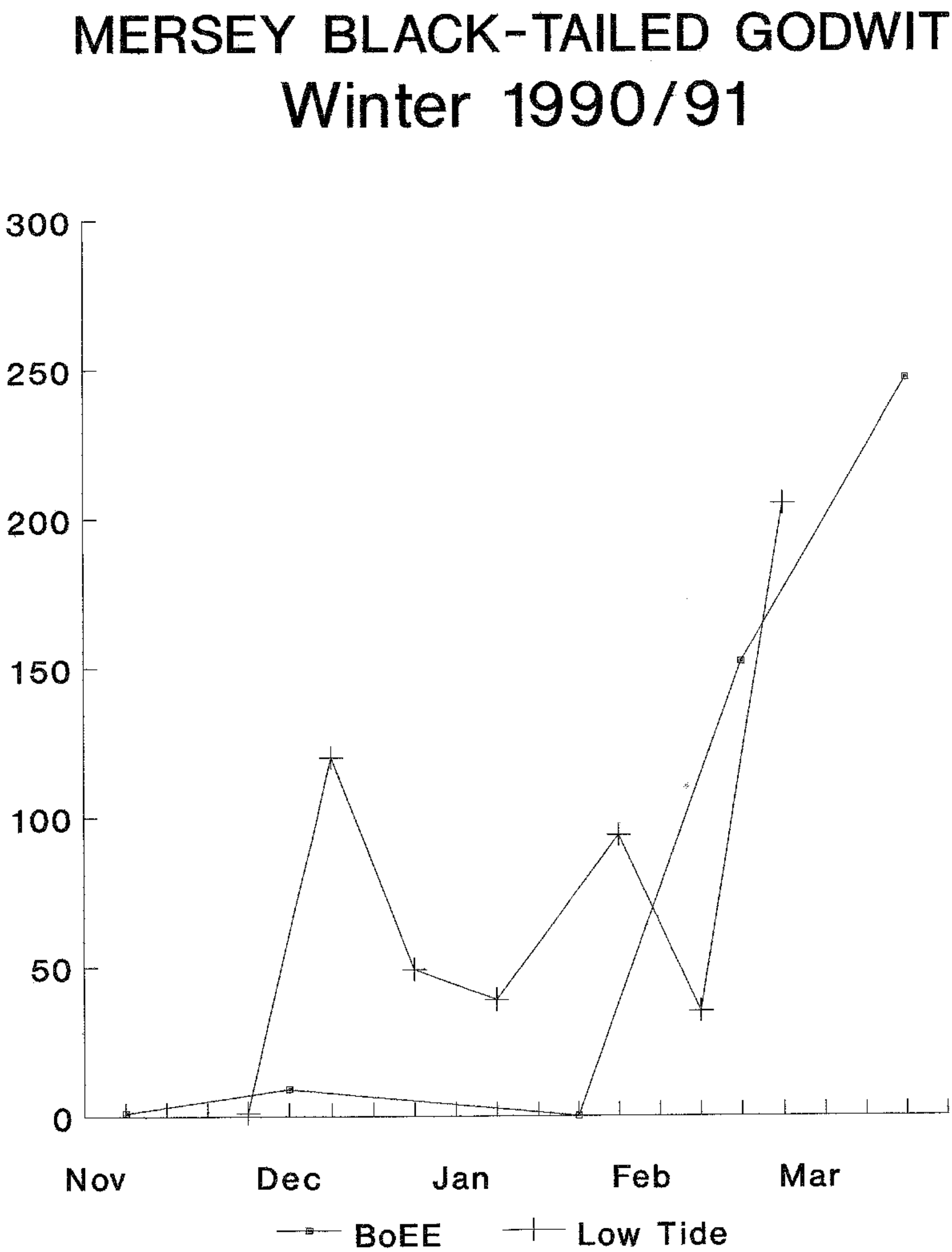



Figure 1.3.15.1 High tide (BoEE) and low tide counts of Black-tailed Godwit during the 1990/91 winter.

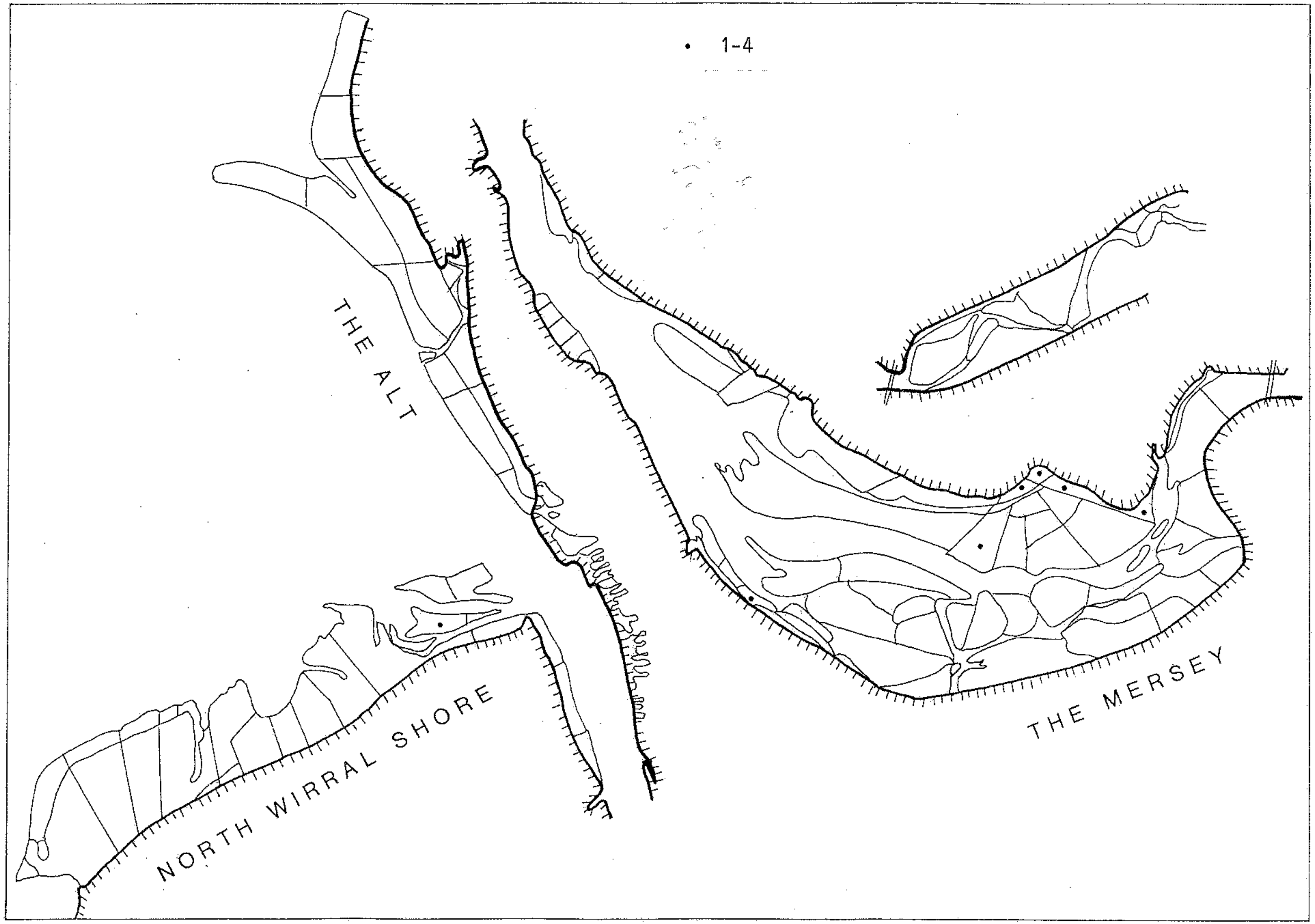



Figure 1.3.15.2 The average number of Black-tailed Godwit feeding at low tide on each intertidal area during the 1990/91 winter.

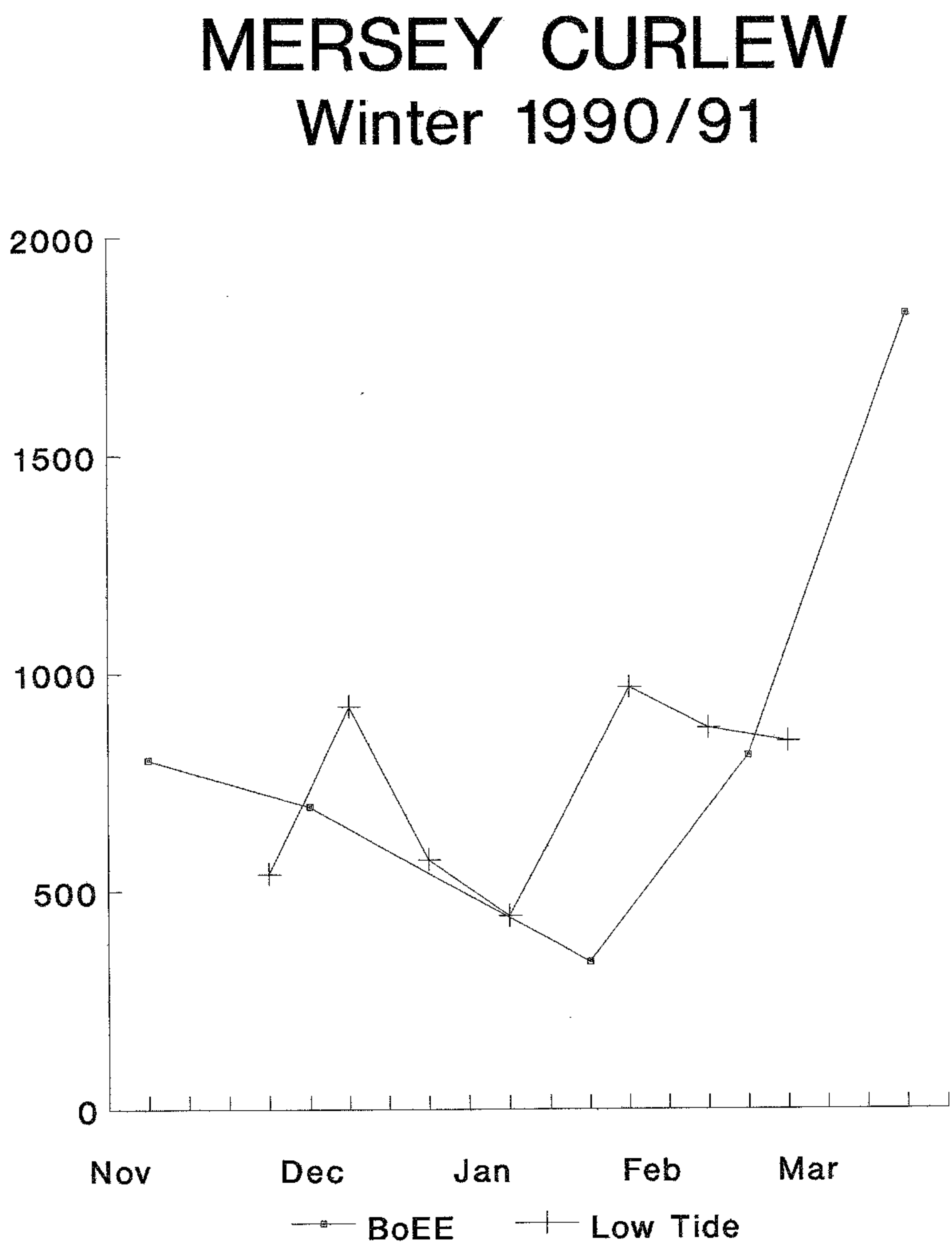



Figure 1.3.16.1 High tide (BoEE) and low tide counts of Curlew during the 1990/91 winter.

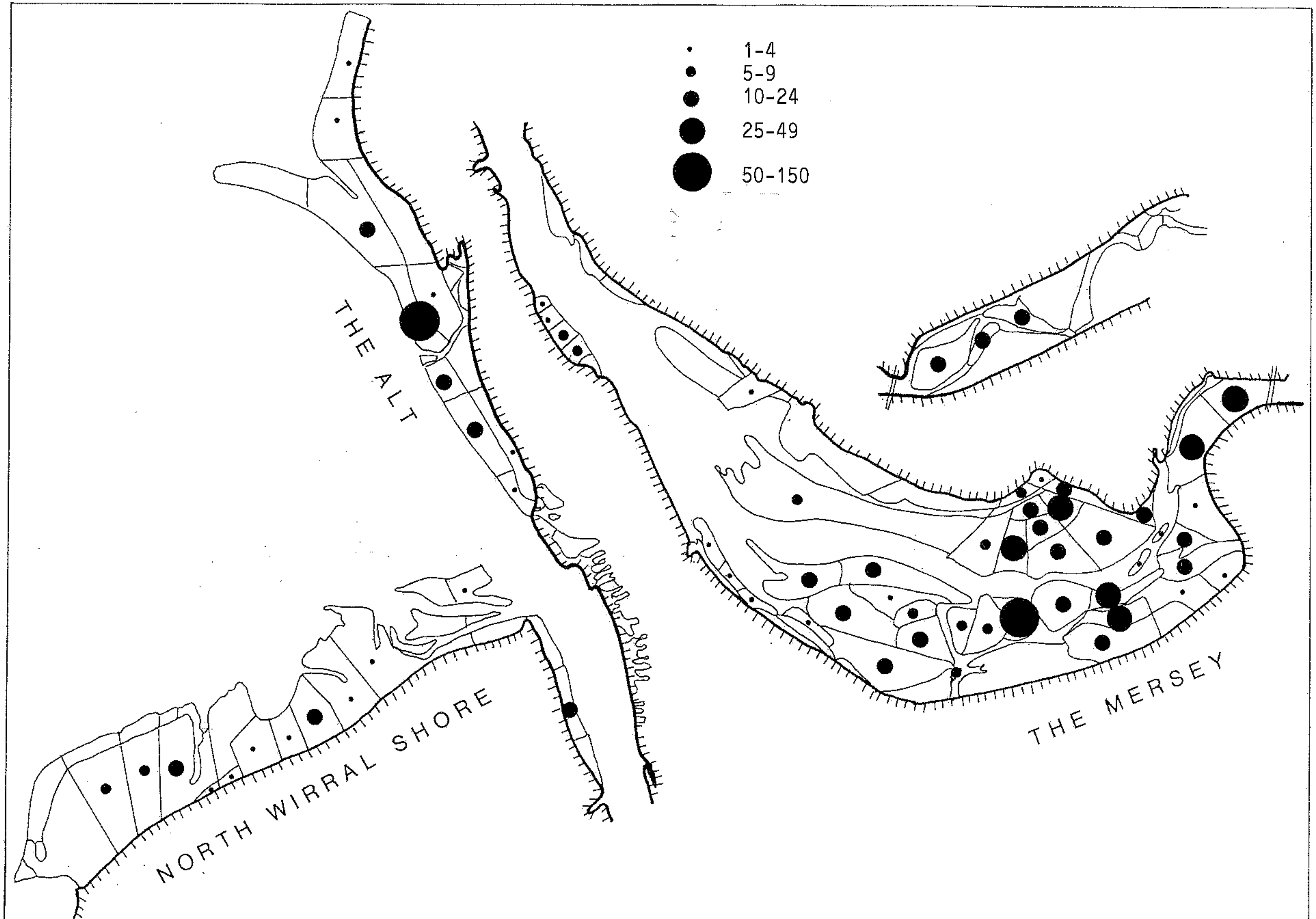



Figure 1.3.16.2 The average number of Curlew feeding at low tide on each intertidal area during the 1990/91 winter.

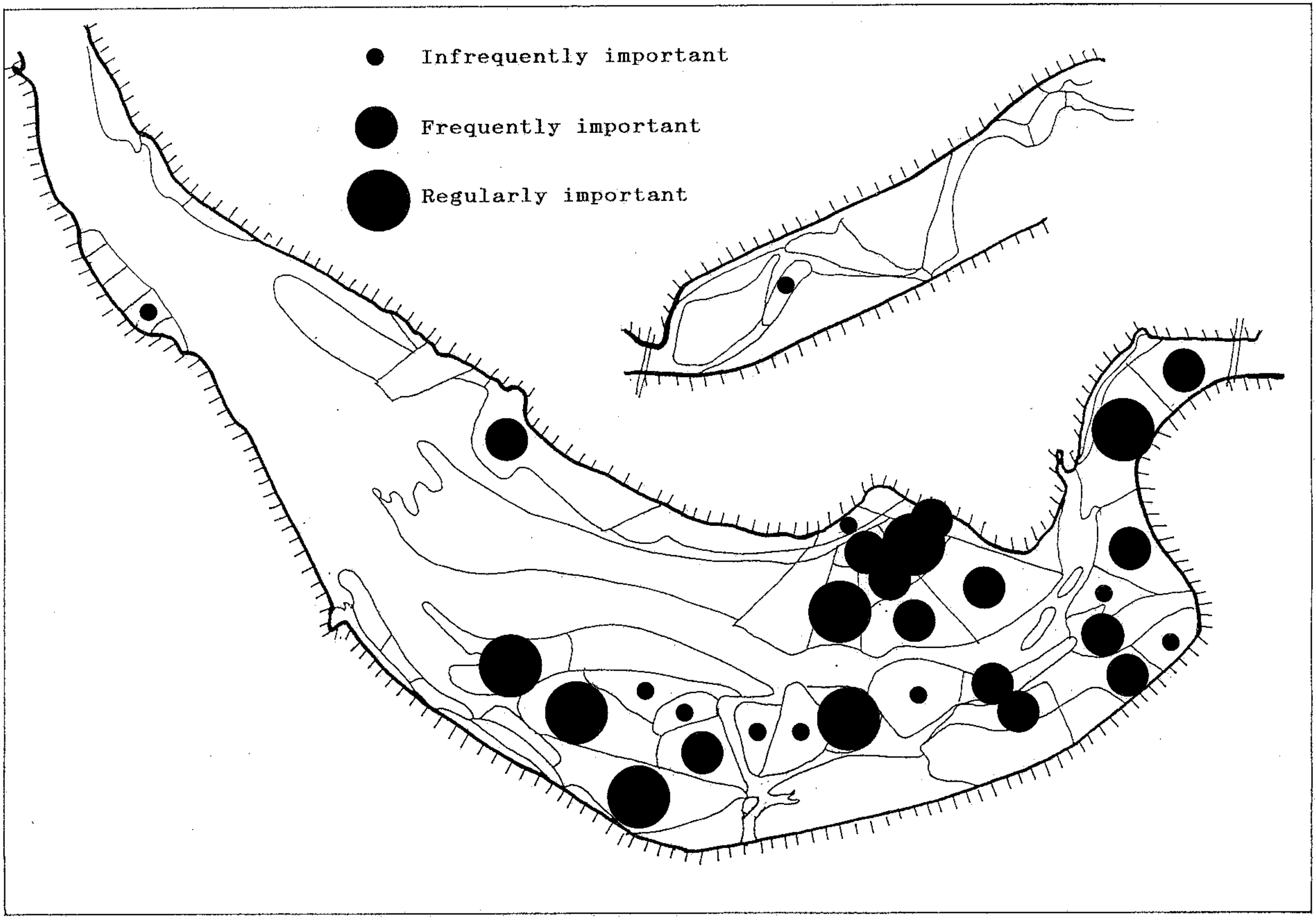



Figure 1.3.16.3 The relative importance of intertidal areas for feeding Curlew in the winters 1988/89 to 1990/91.

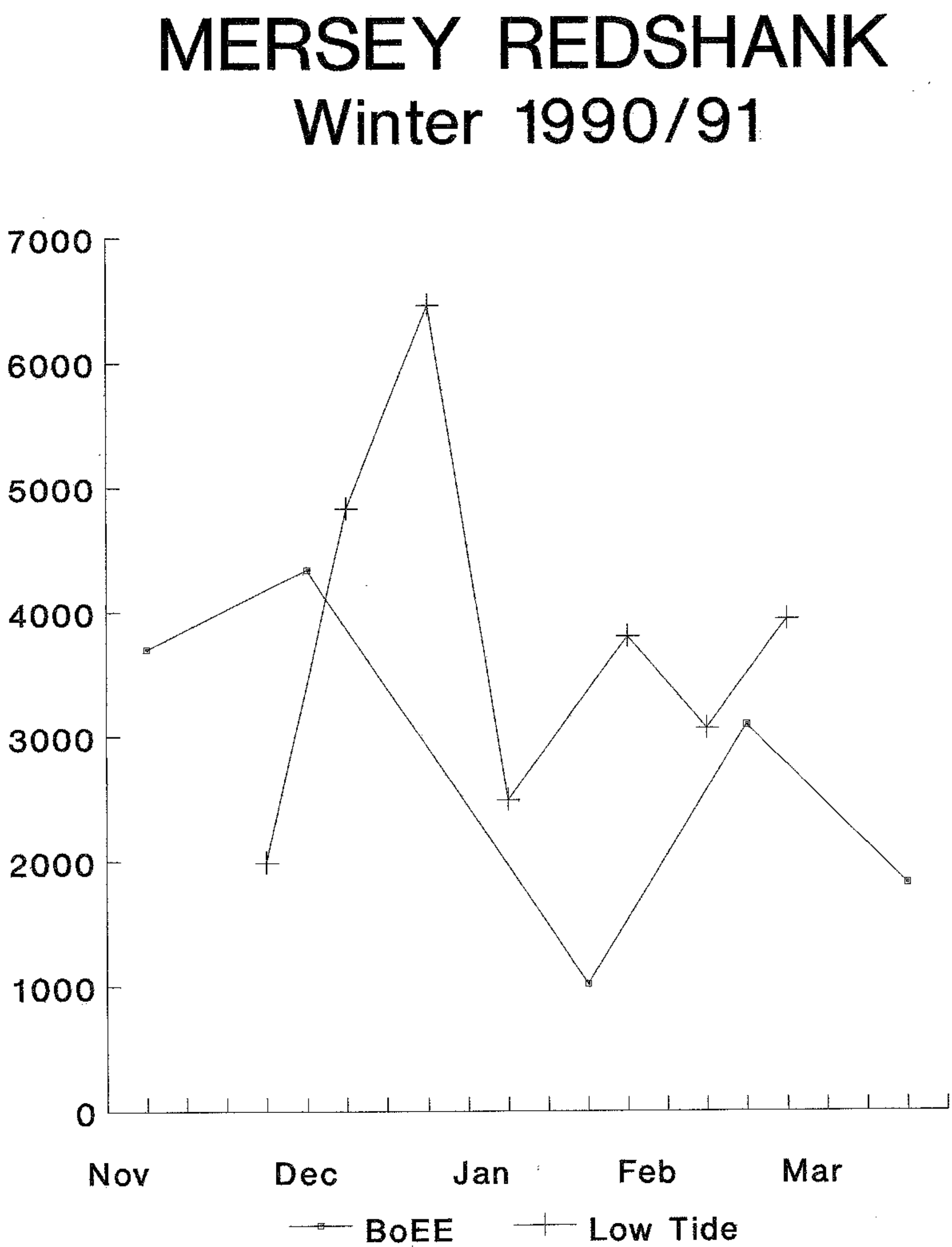



Figure 1.3.17.1 High tide (BoEE) and low tide counts of Redshank during the 1990/91 winter.

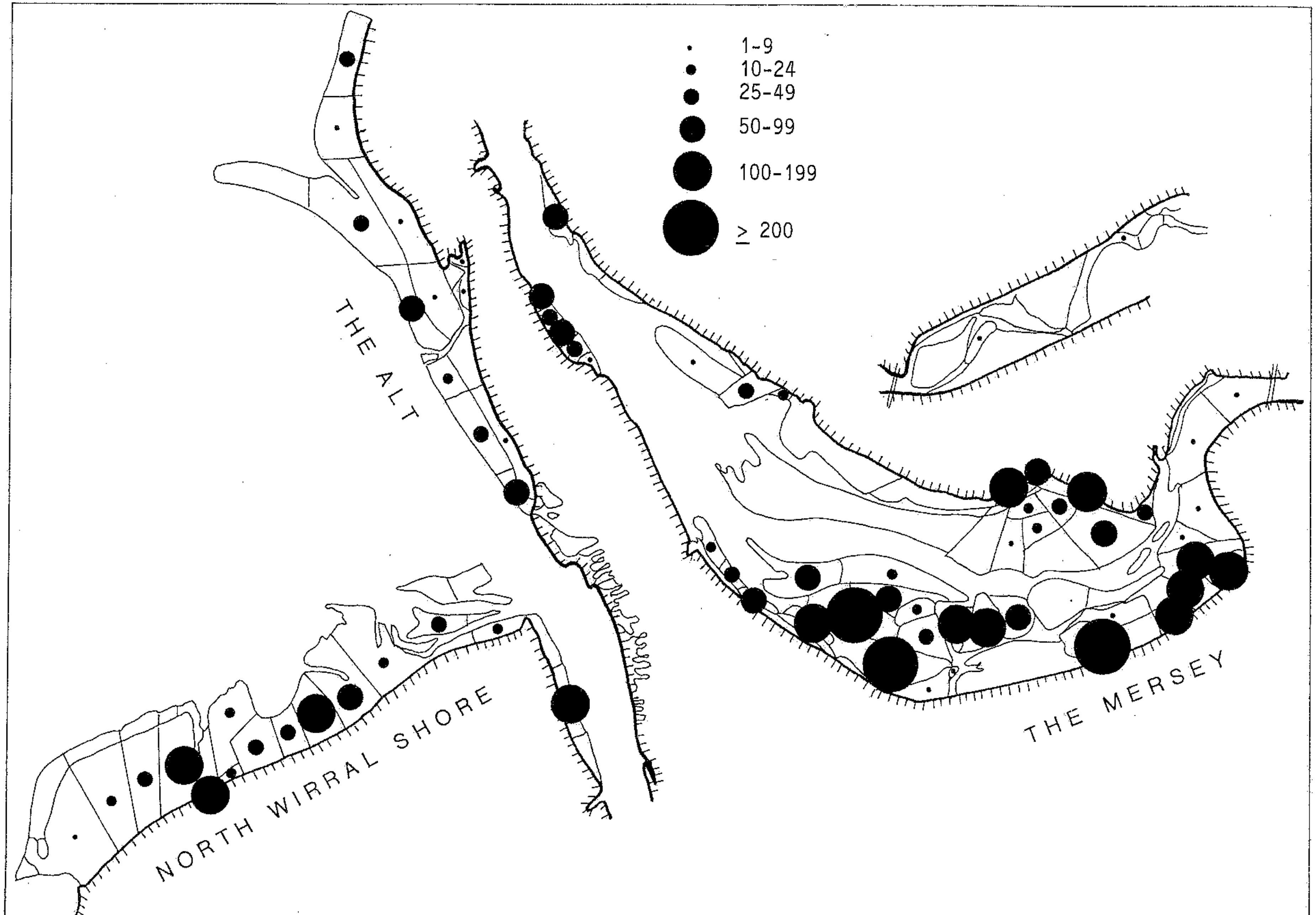



Figure 1.3.17.2 The average number of Redshank feeding at low tide on each intertidal area during the 1990/91 winter.

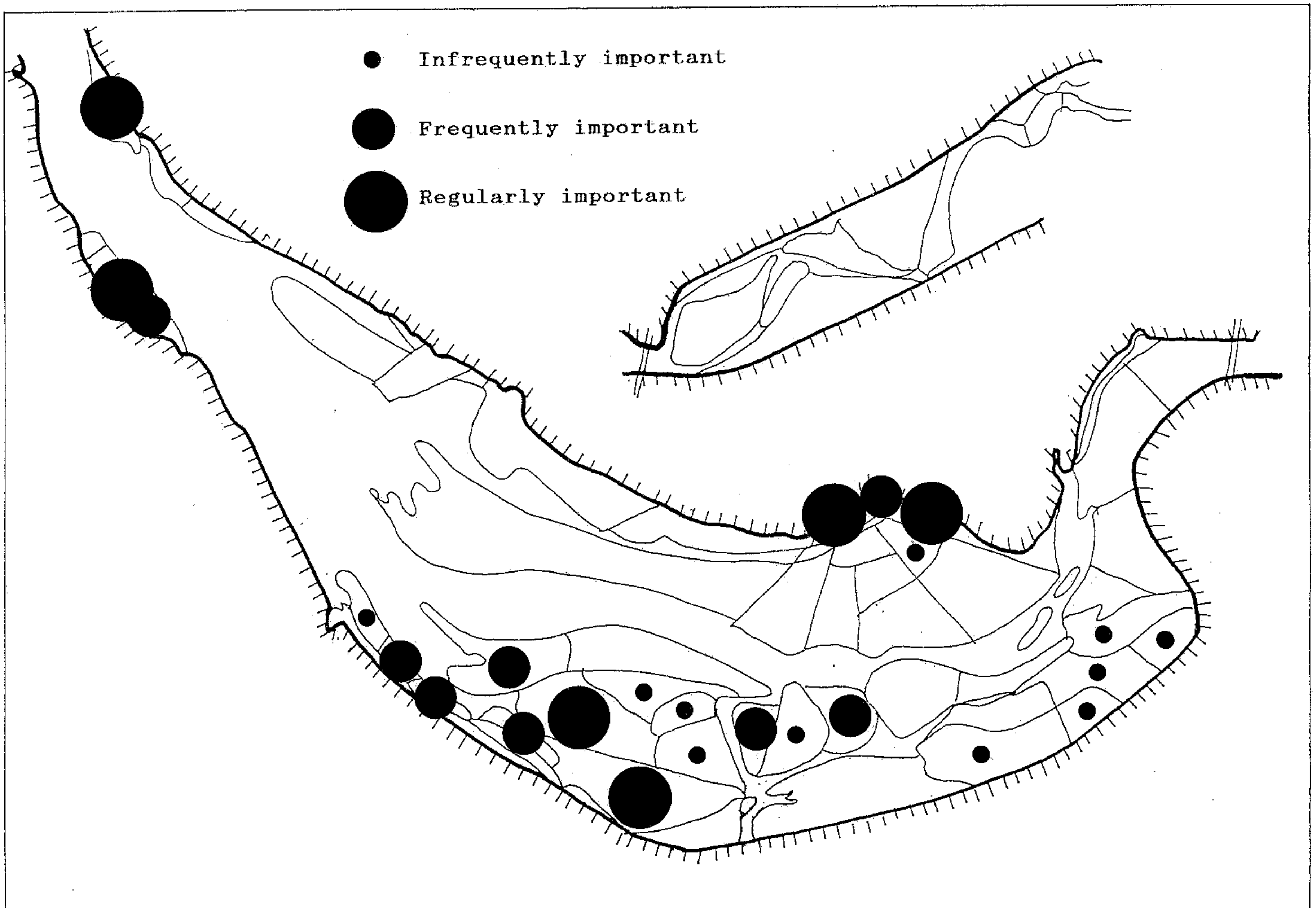



Figure 1.3.17.3 The relative importance of intertidal areas for feeding Redshank in the winters 1988/89 to 1990/91.

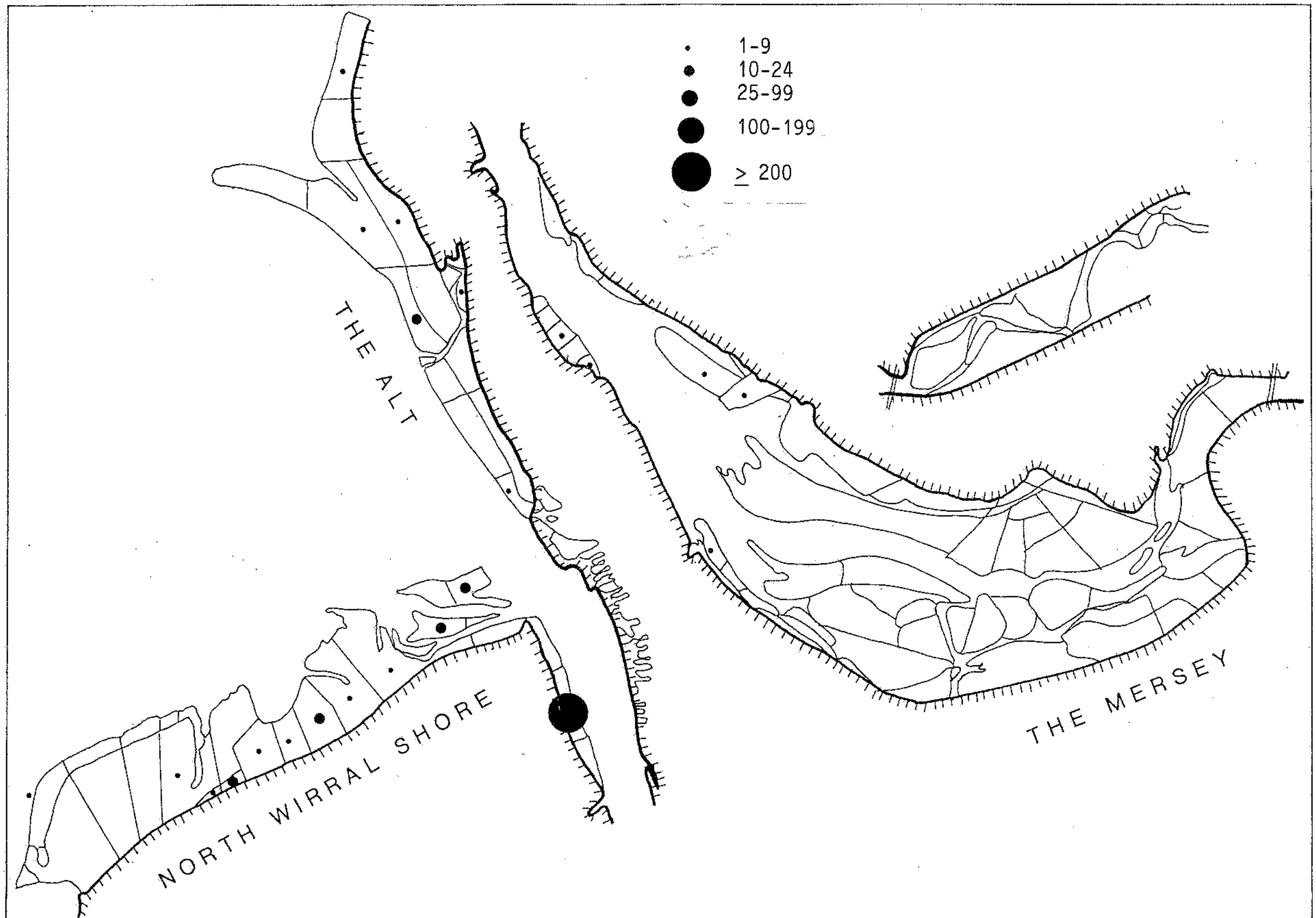



Figure 1.3.18.1 The average number of Turnstone feeding at low tide on each intertidal area during the 1990/91 winter.

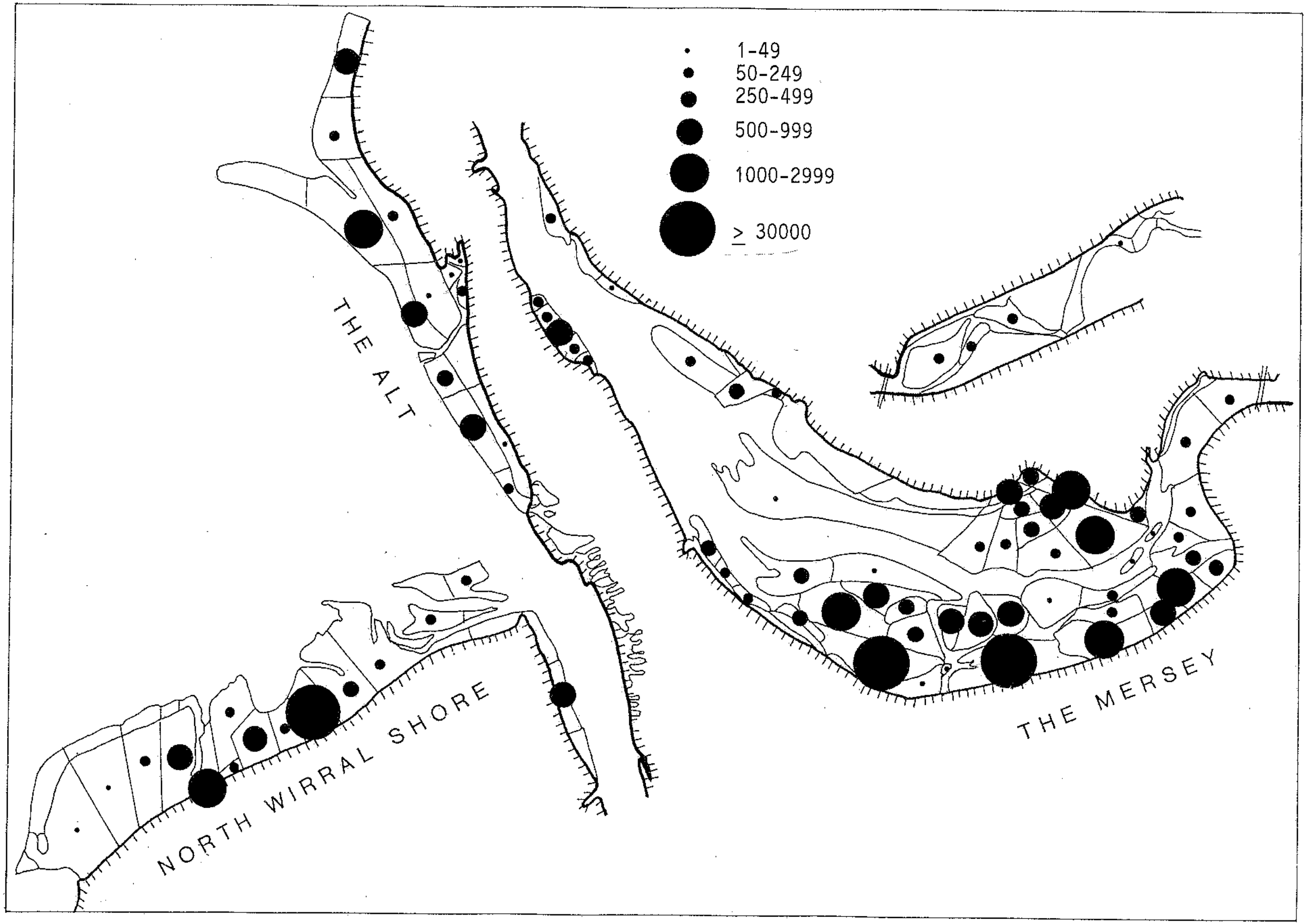



Figure 1.3.19.1 The average number of feeding birds of all species at low tide on each intertidal area during the 1990/91 winter.

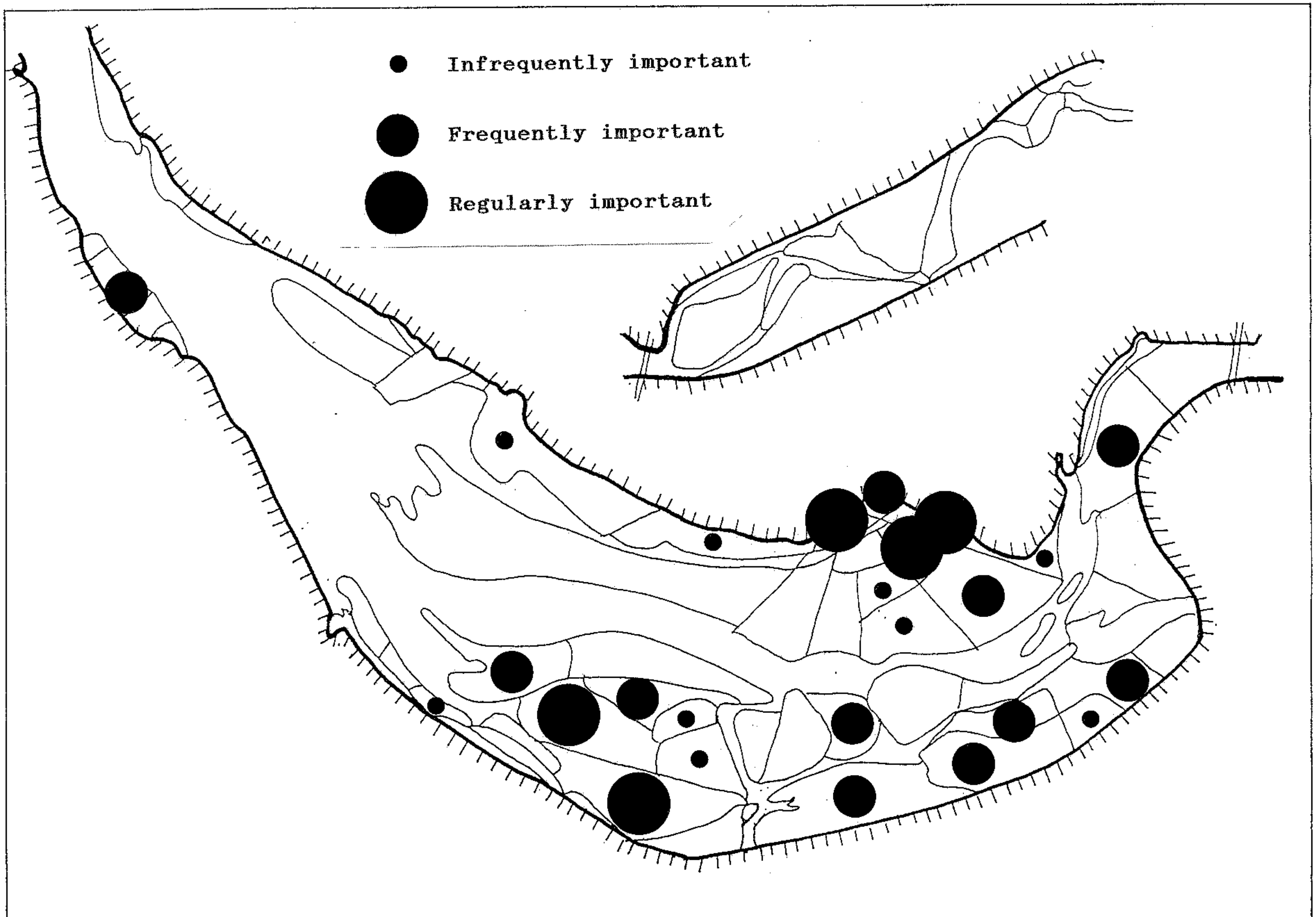



Figure 1.3.19.2 The relative importance of intertidal areas for feeding birds of all species in the winters 1988/89 to 1990/91.

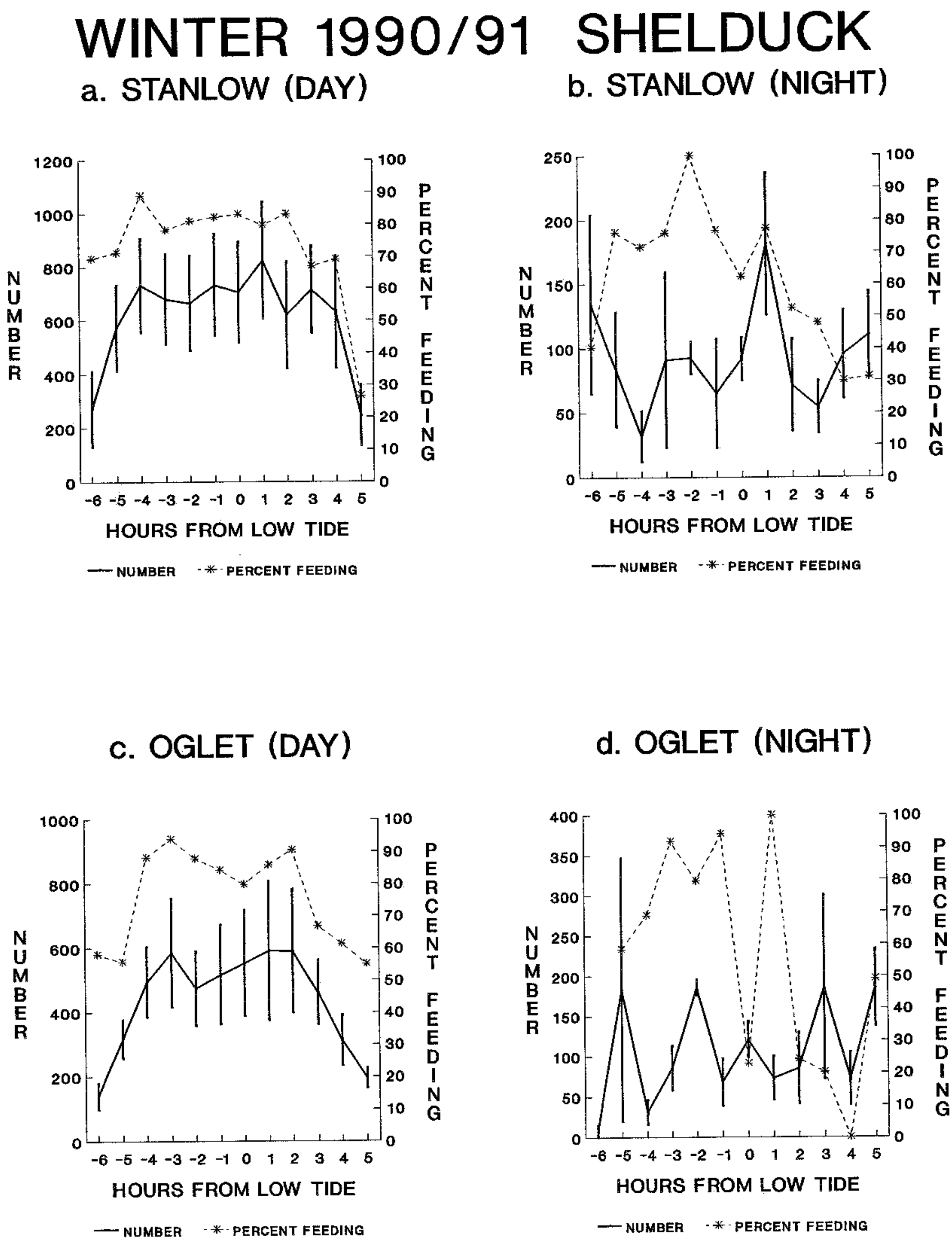



Figure 2.3.1.1 The number of Shelduck present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.

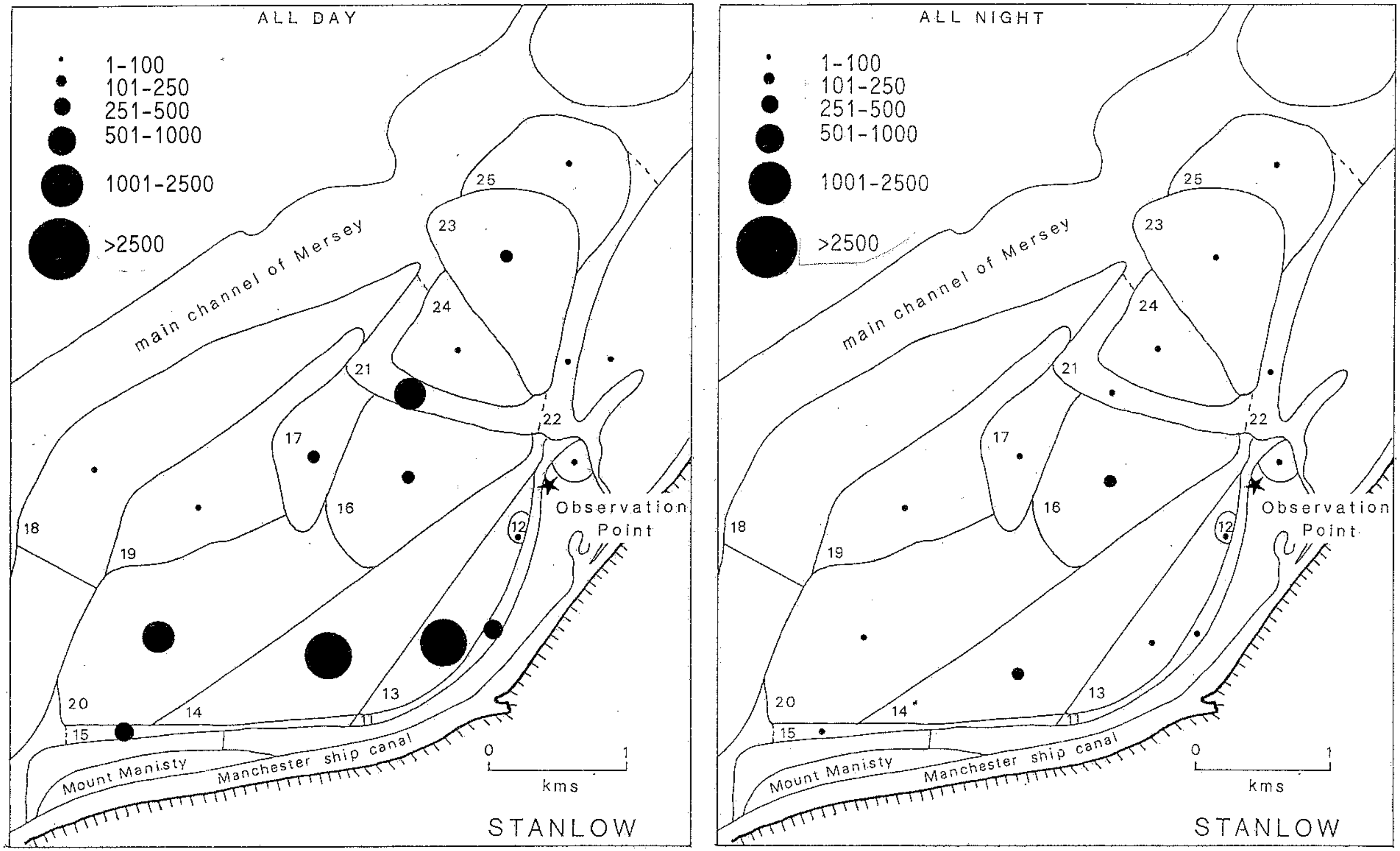



Figure 2.3.1.2 The number of bird hours per tidal cycle of feeding Shelduck on each intertidal area at Stanlow during the day and at night - winter 1990/91.

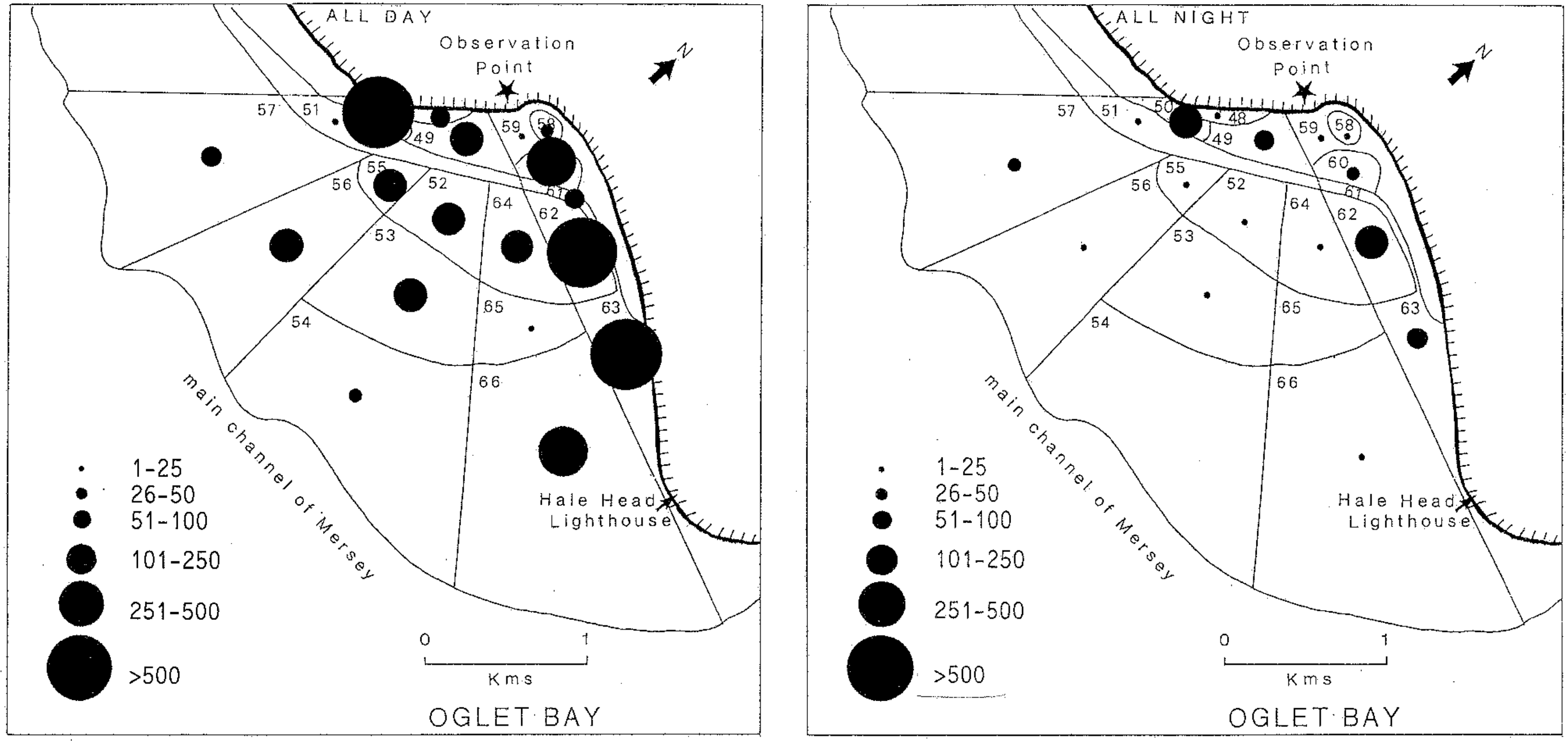



Figure 2.3.1.3 The number of bird hours per tidal cycle of feeding Shelduck on each intertidal area at Oglet Bay during the day and at night - winter 1990/91.

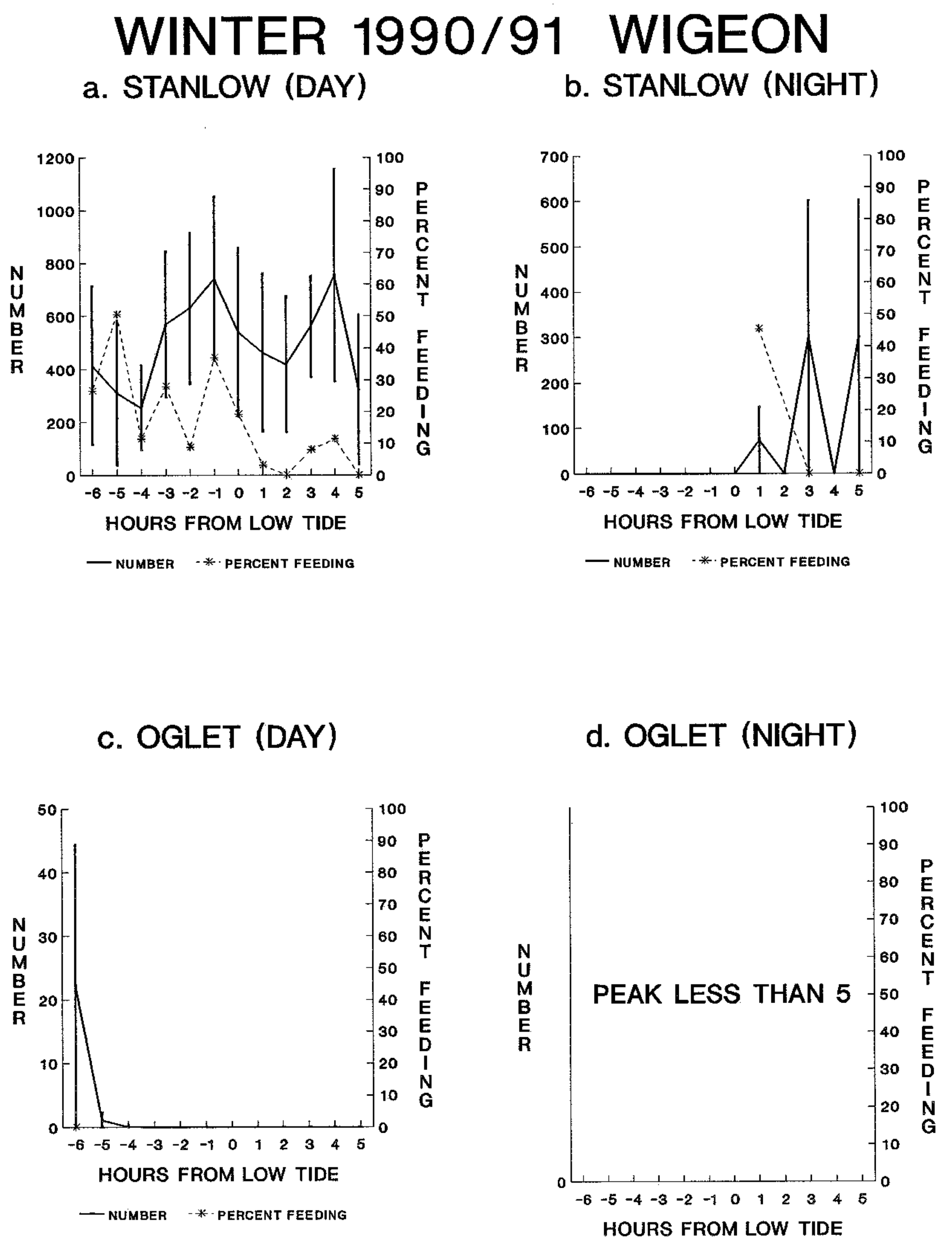



Figure 2.3.2.1 The number of Wigeon present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.

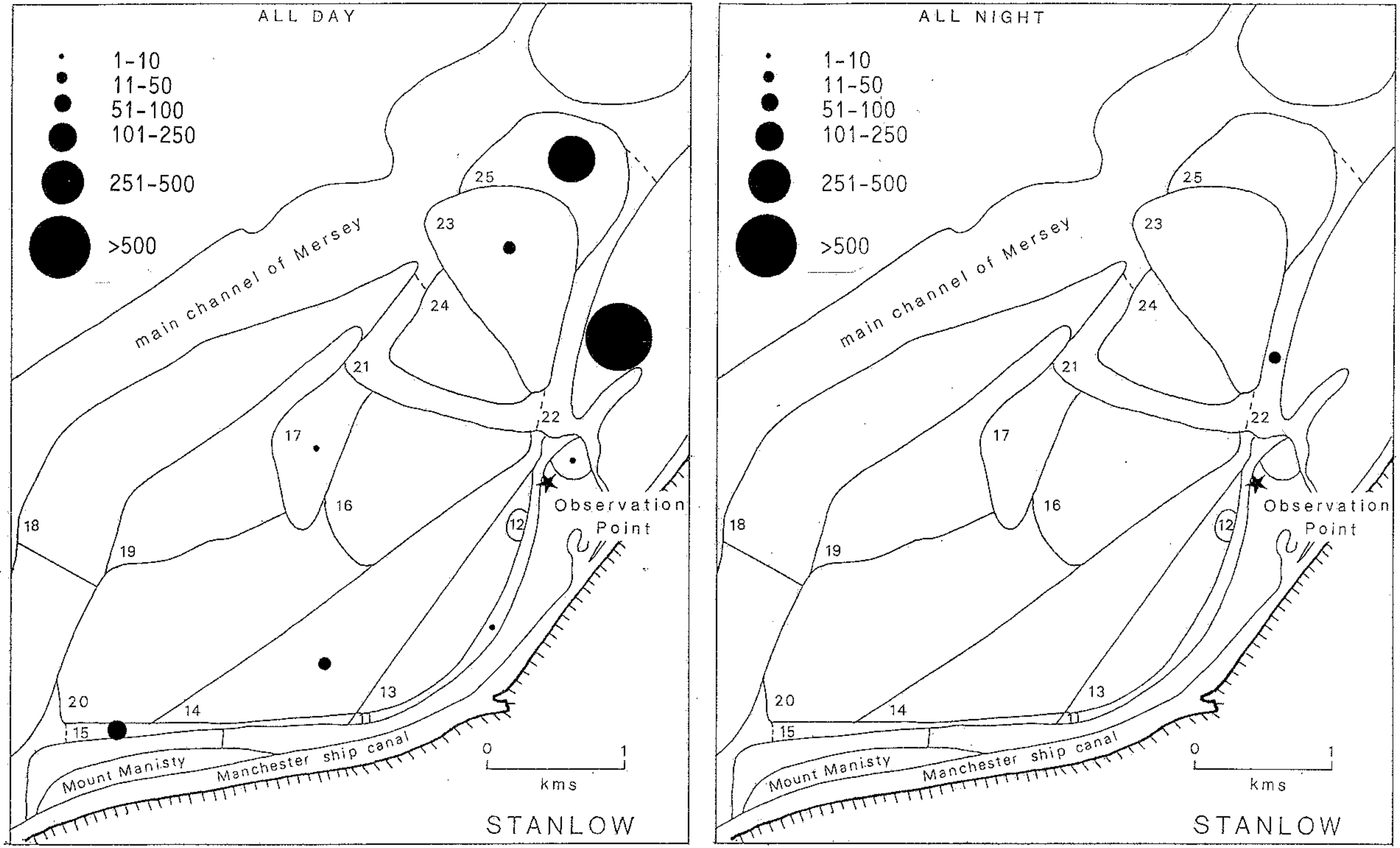



Figure 2.3.2.2 The number of bird hours per tidal cycle of feeding Wigeon on each intertidal area at Stanlow during the day and at night - winter 1990/91.

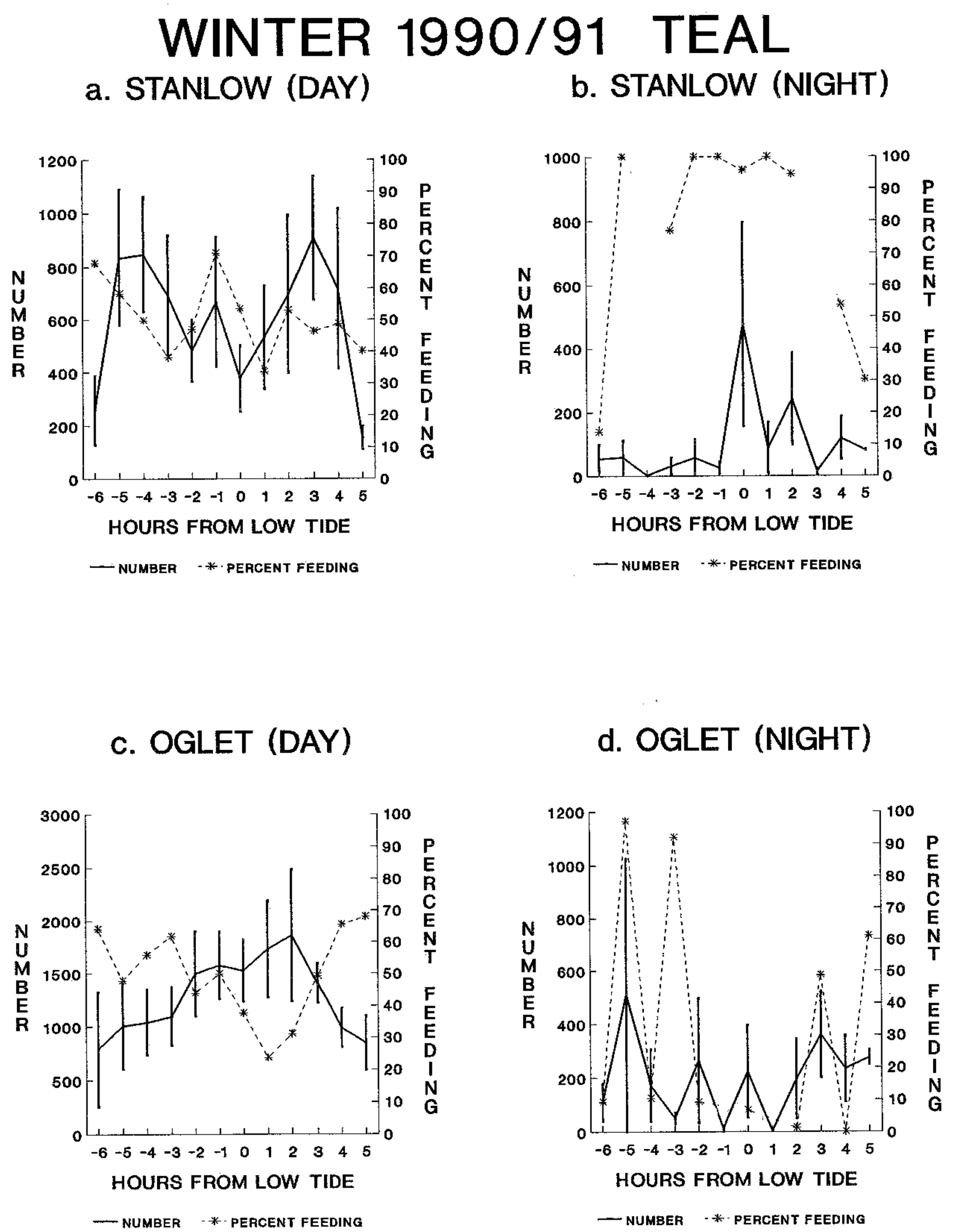



Figure 2.3.3.1 The number of Teal present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.

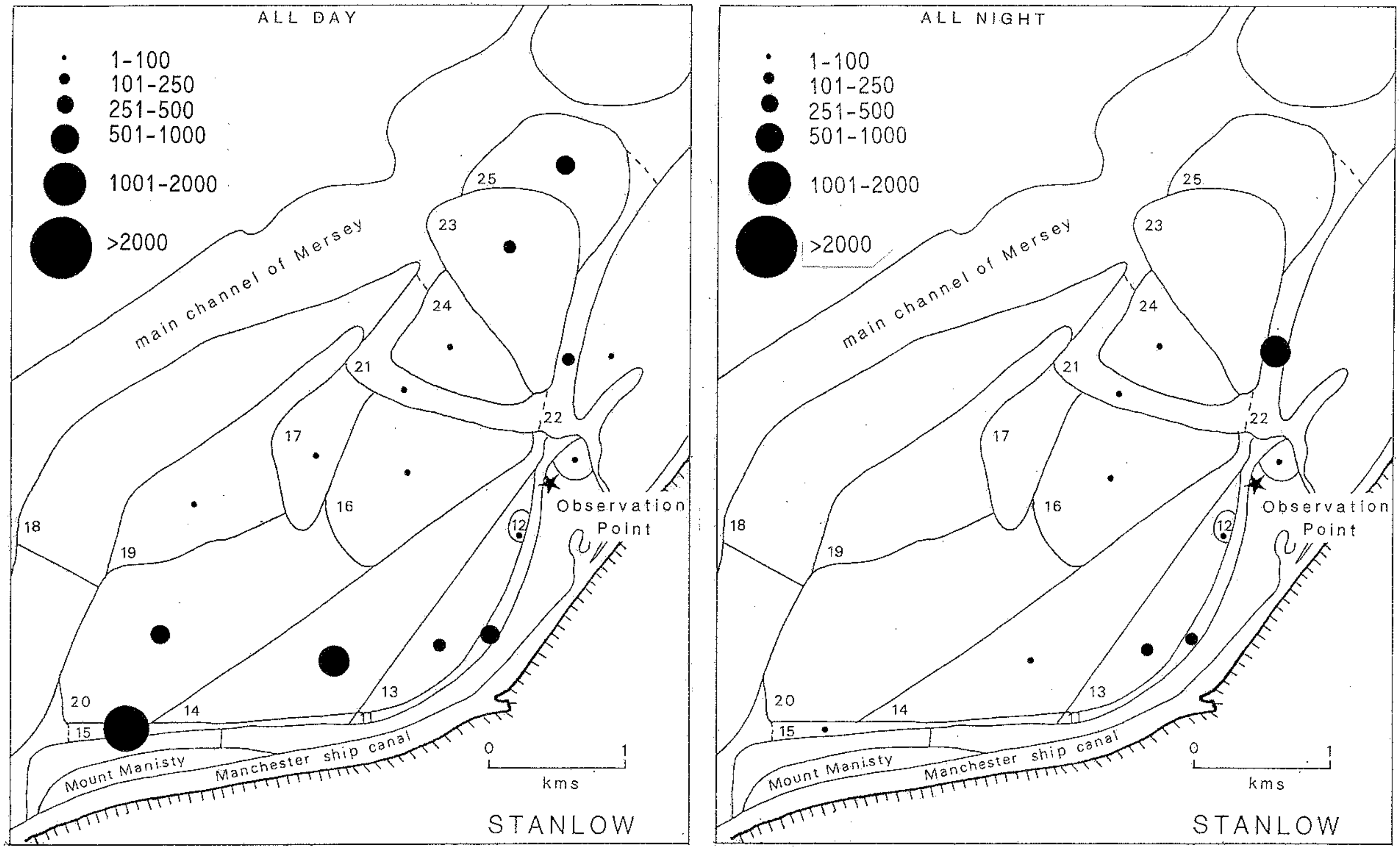



Figure 2.3.3.2 The number of bird hours per tidal cycle of feeding Teal on each intertidal area at Stanlow during the day and at night - winter 1990/91.

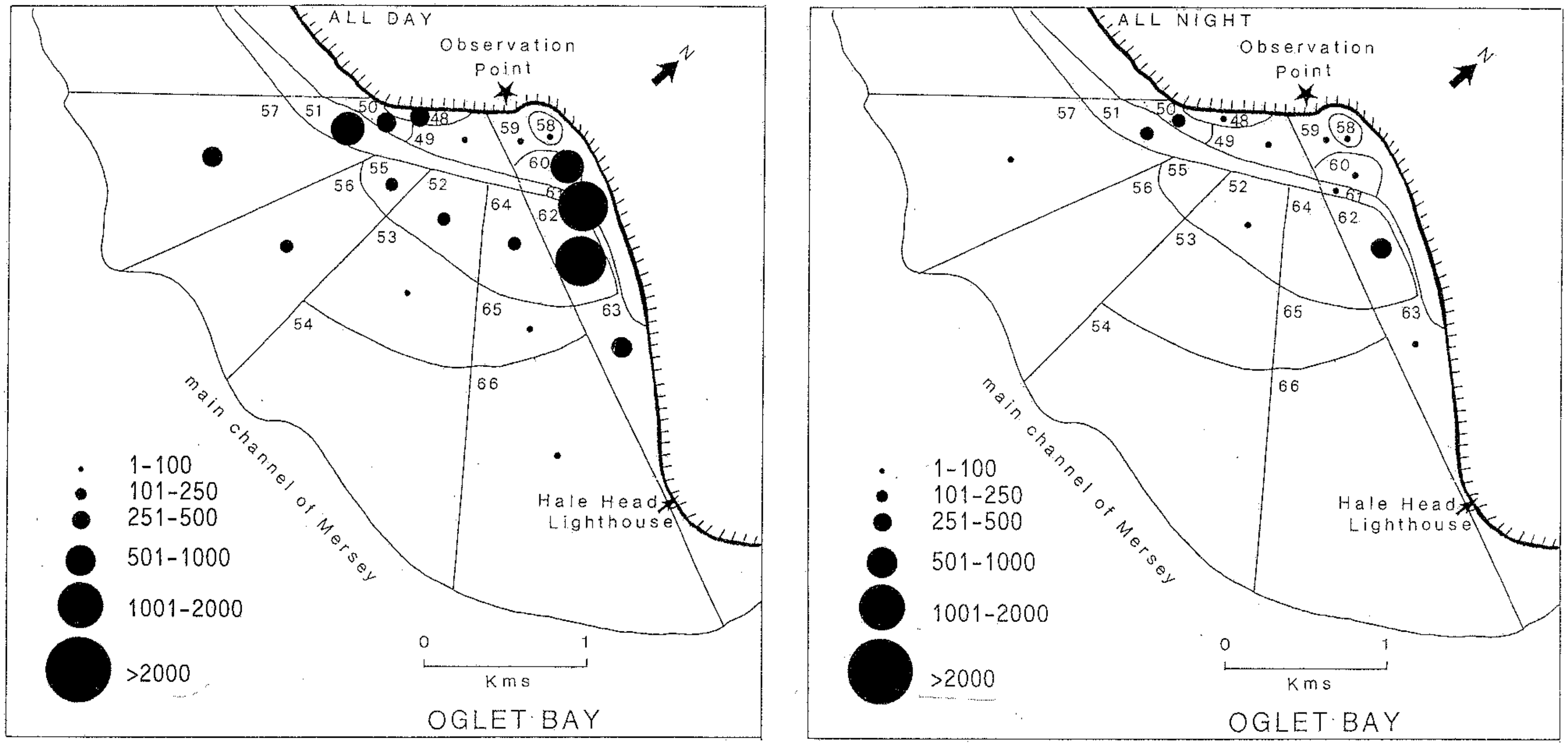



Figure 2.3.3.3 The number of bird hours per tidal cycle of feeding Teal on each intertidal area at Oglet Bay during the day and at night - winter 1990/91.

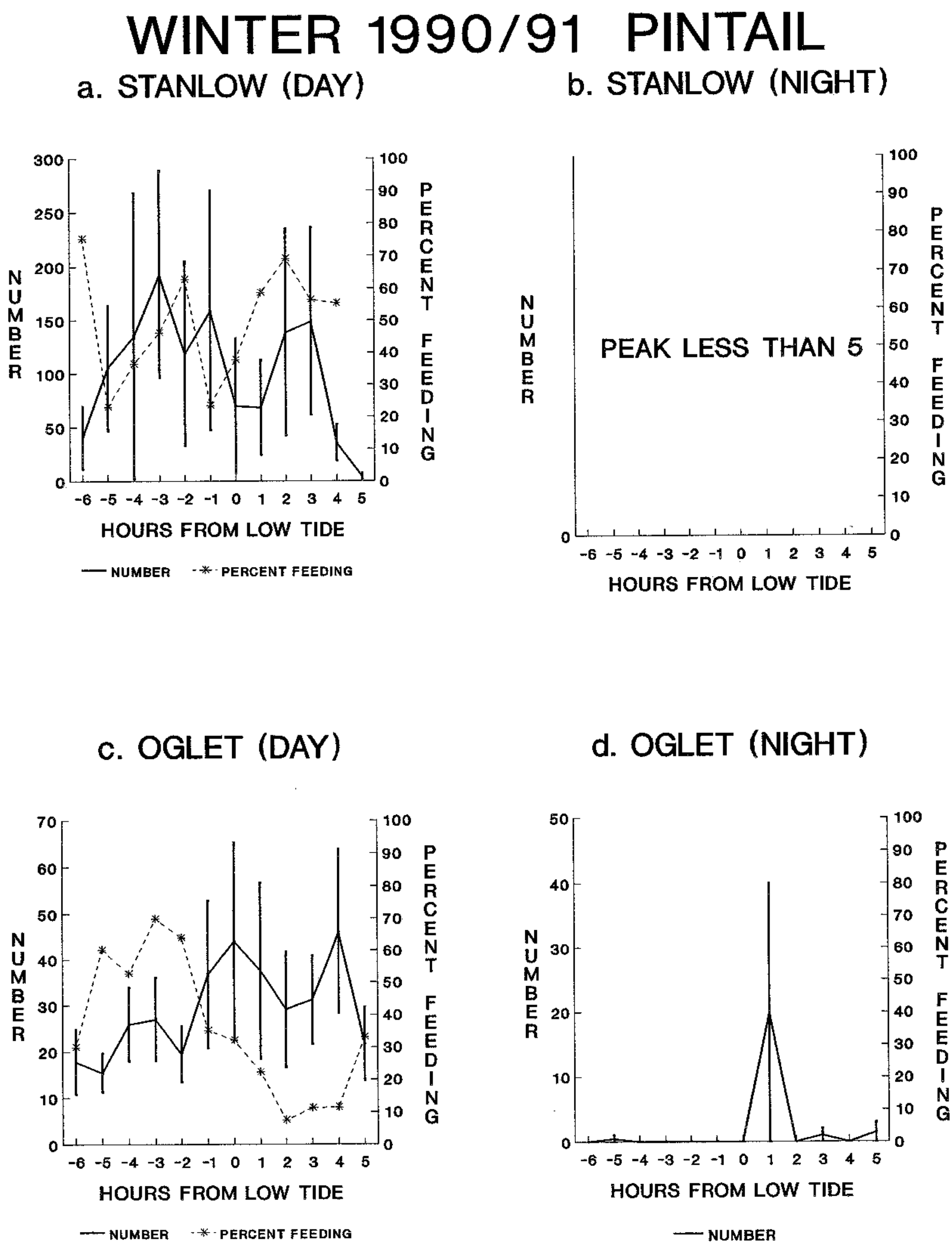



Figure 2.3.4.1 The number of Pintail present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.

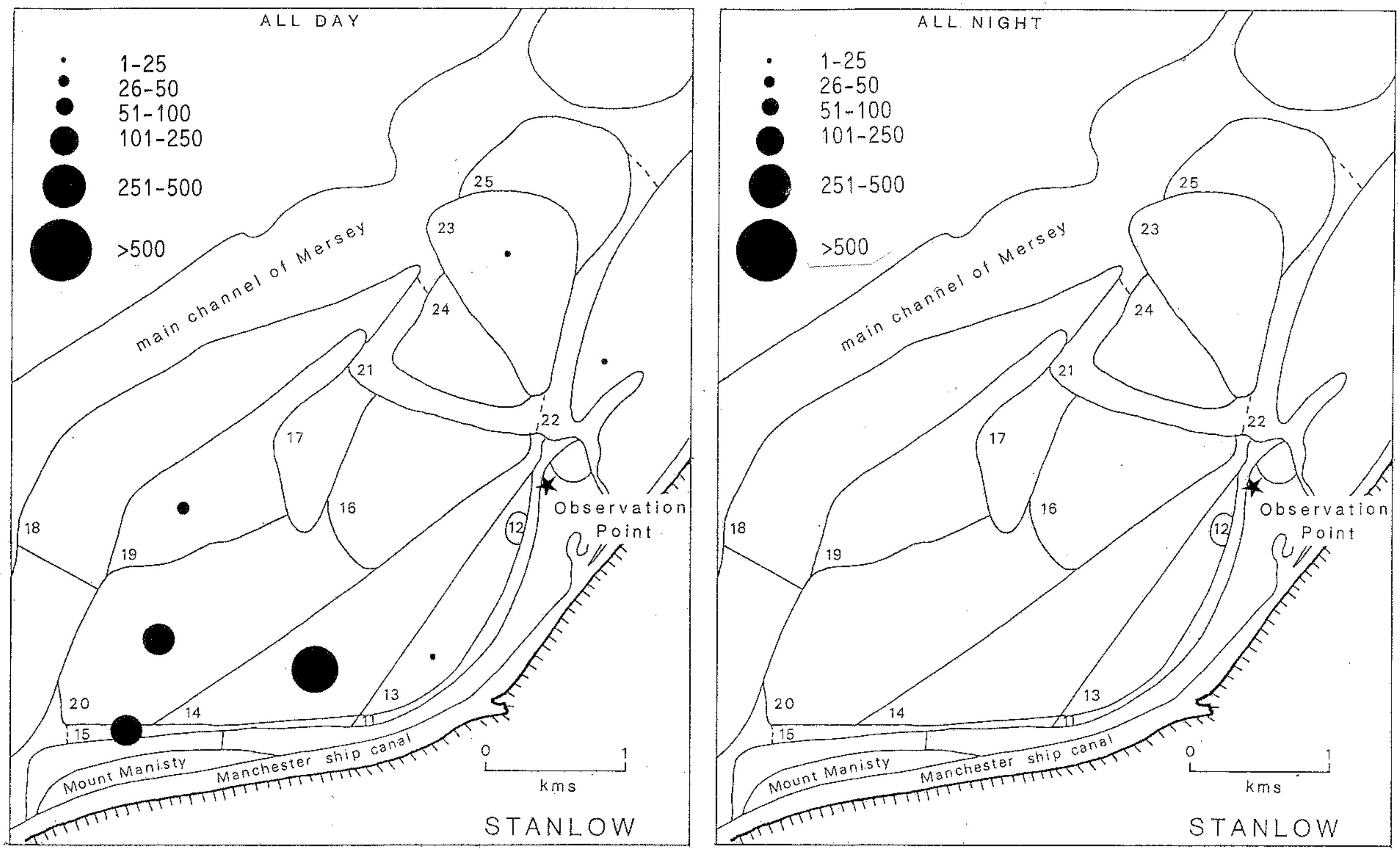



Figure 2.3.4.2 The number of bird hours per tidal cycle of feeding Pintail on each intertidal area at Stanlow during the day and at night - winter 1990/91.

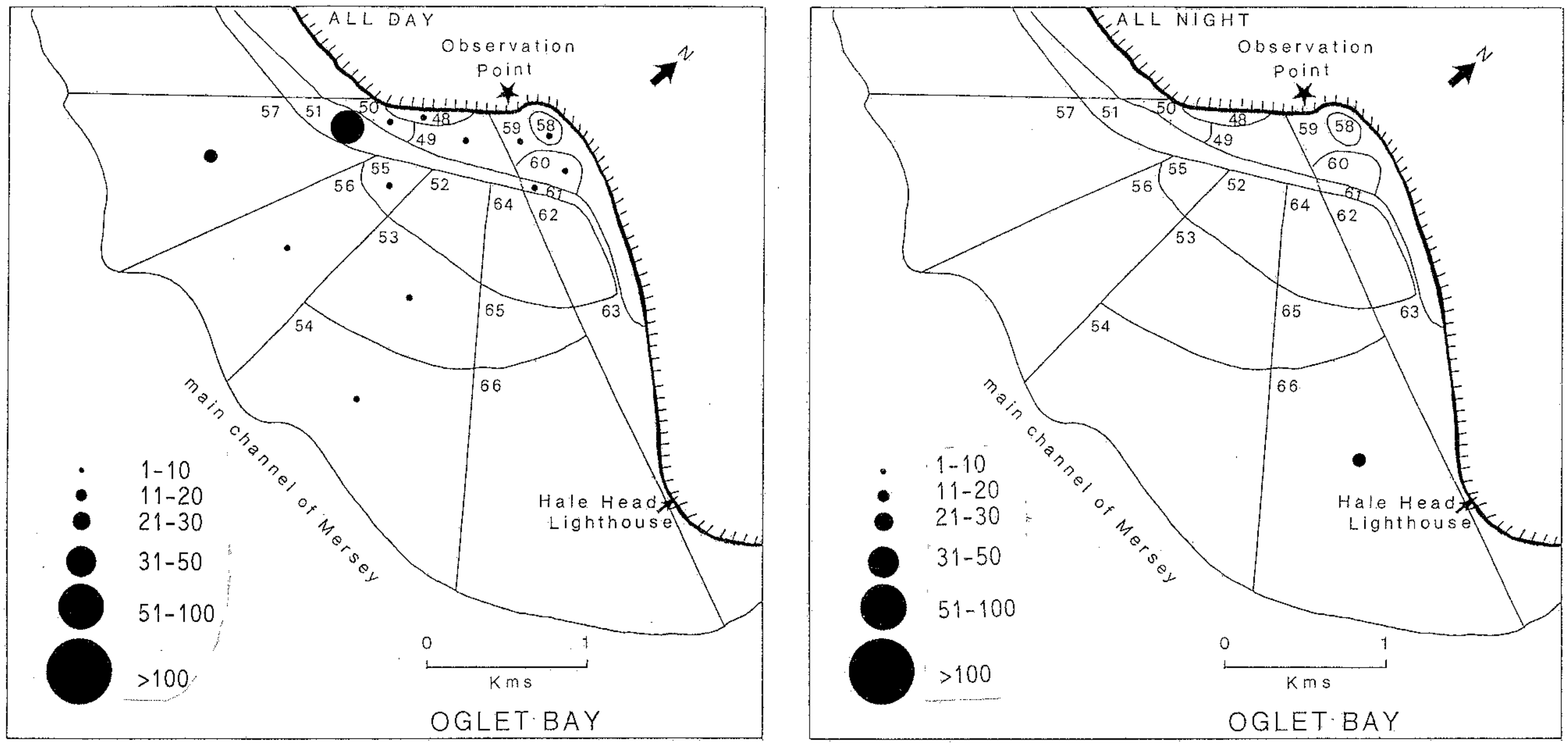



Figure 2.3.4.3 The number of bird hours per tidal cycle of feeding Pintail on each intertidal area at Oglet Bay during the day and at night - winter 1990/91.

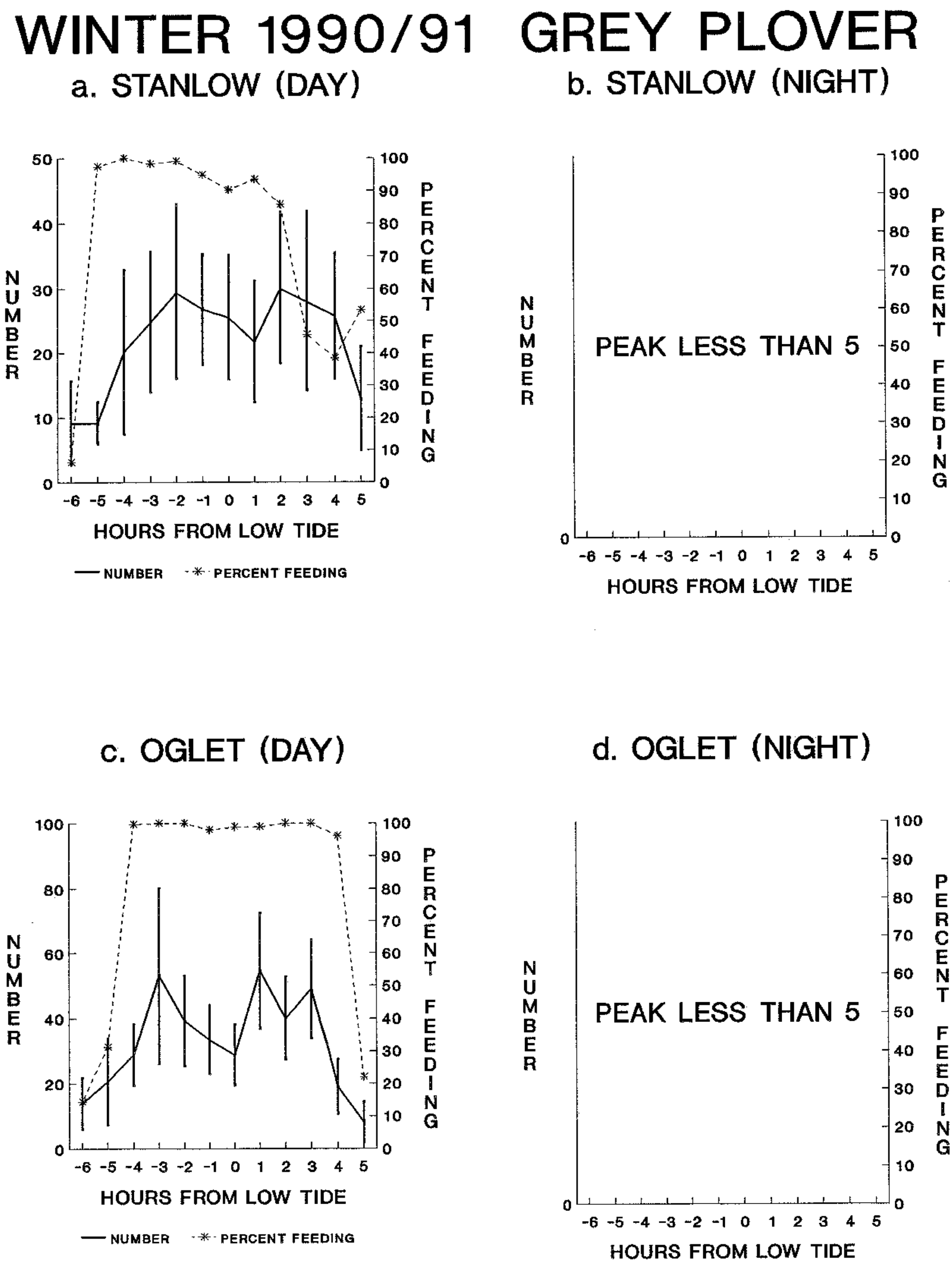



Figure 2.3.5.1 The number of Grey Plover present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.

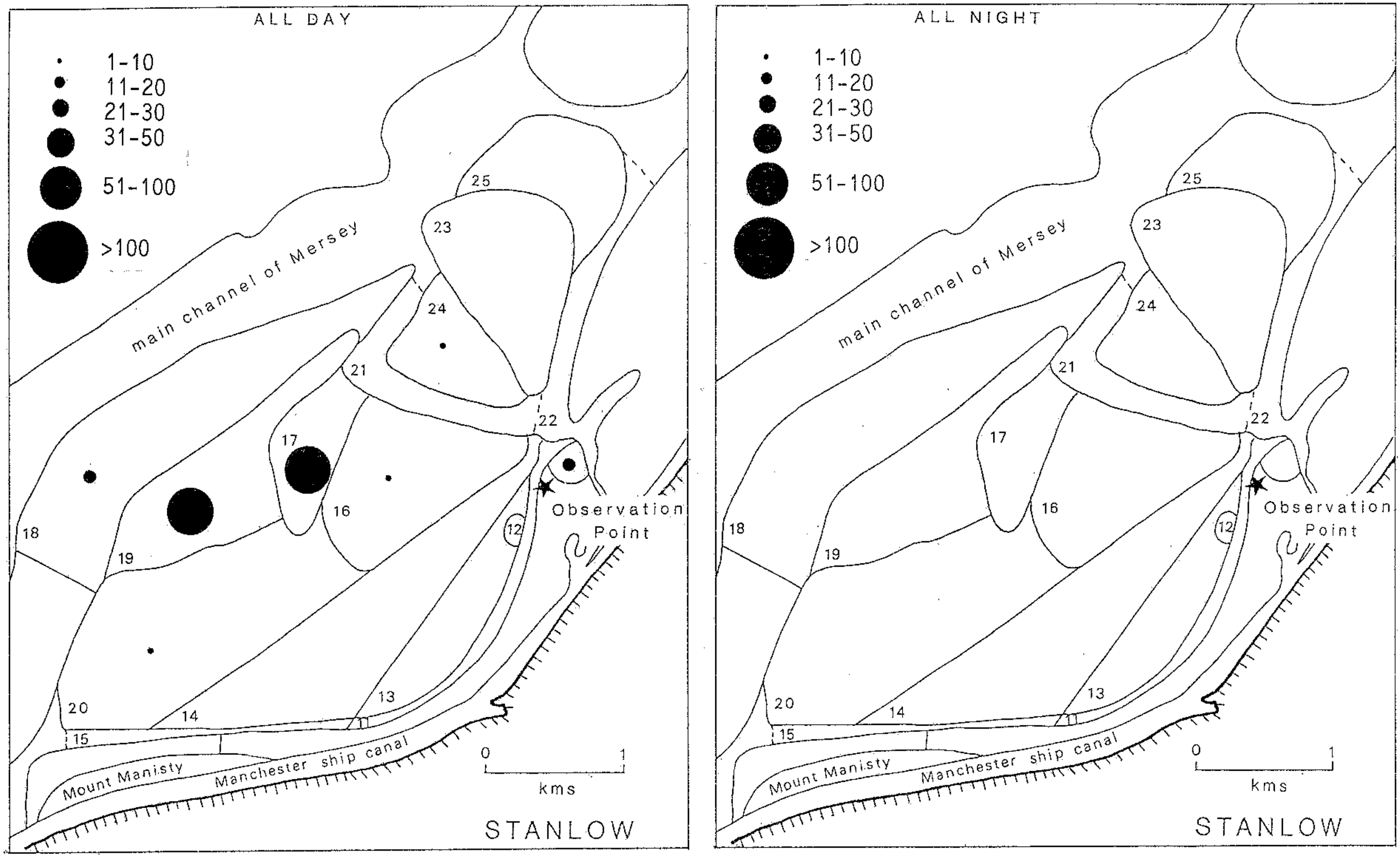



Figure 2.3.5.2 The number of bird hours per tidal cycle of feeding Grey Plover on each intertidal area at Stanlow during the day and at night - winter 1990/91.

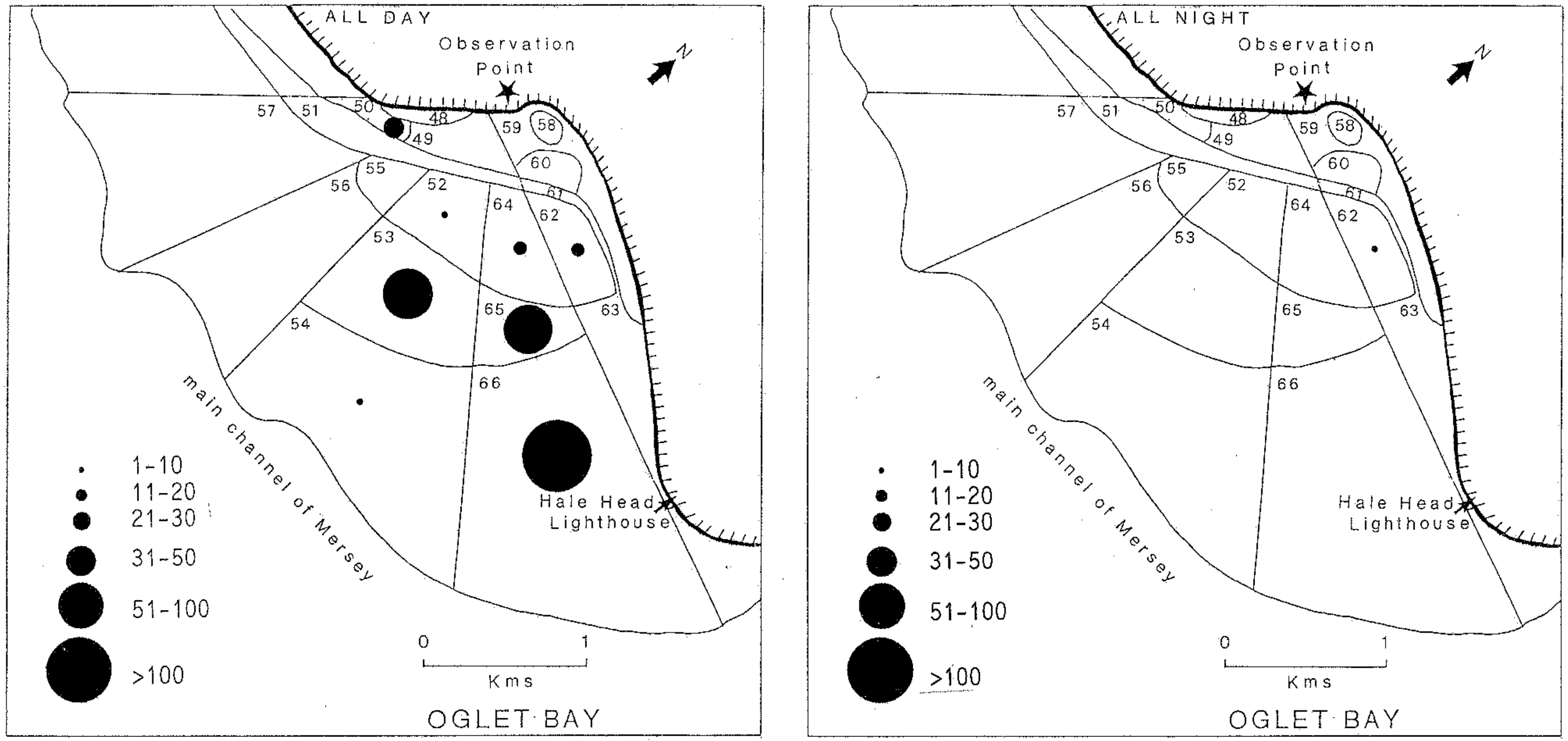



Figure 2.3.5.3 The number of bird hours per tidal cycle of feeding Grey Plover on each intertidal area at Oglet Bay during the day and at night - winter 1990/91.

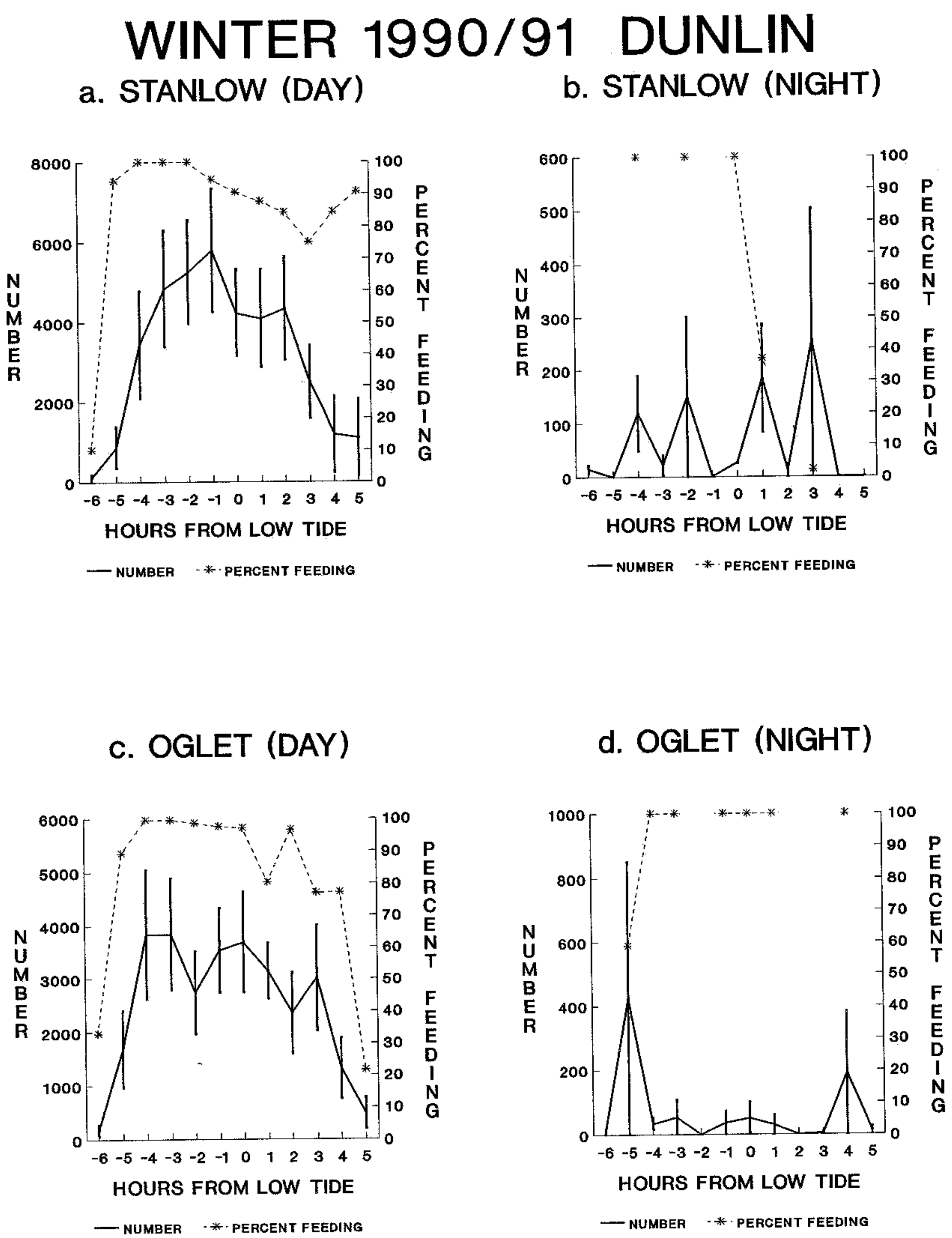



Figure 2.3.6.1 The number of Dunlin present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.

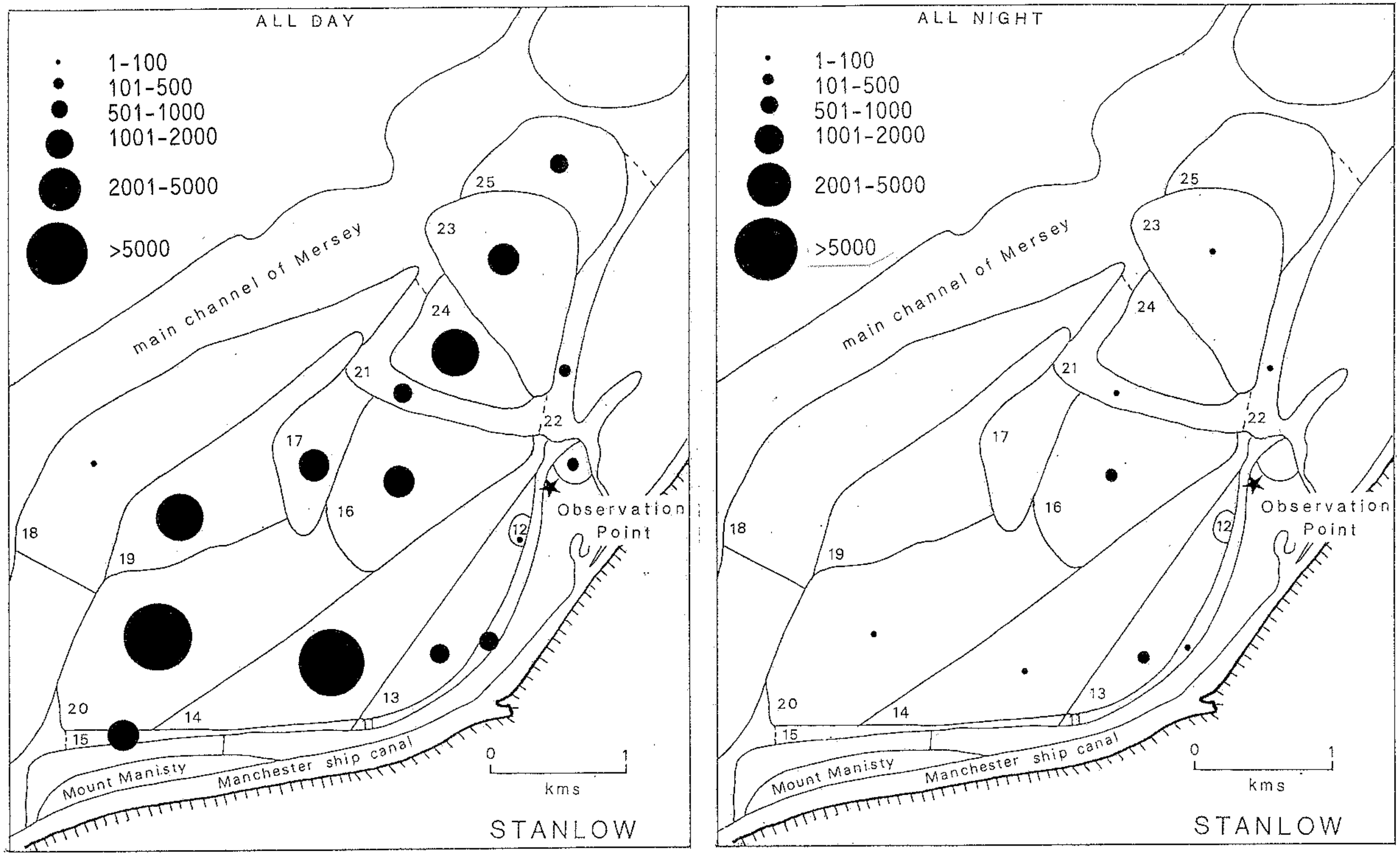



Figure 2.3.6.2 The number of bird hours per tidal cycle of feeding Dunlin on each intertidal area at Stanlow during the day and at night - winter 1990/91.

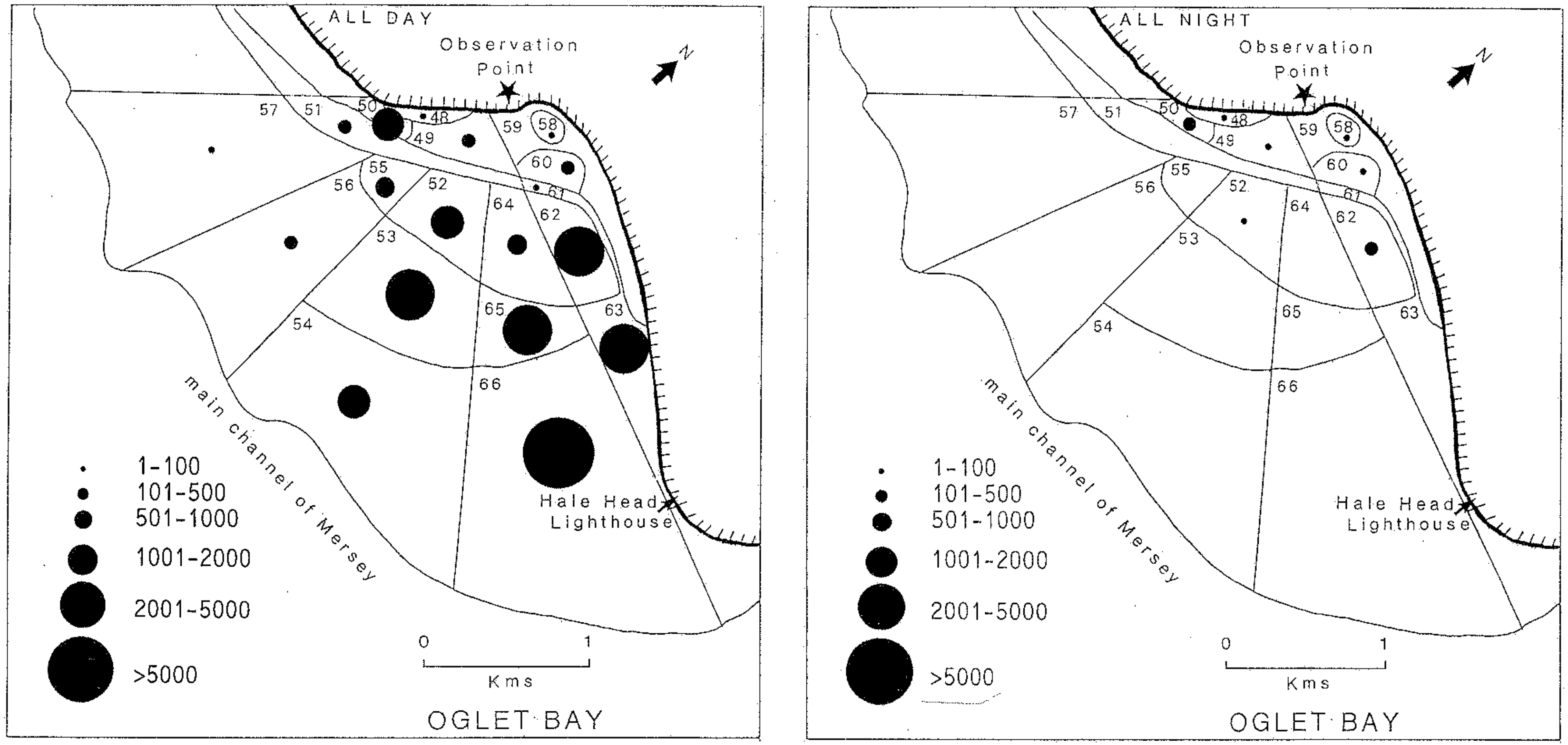



Figure 2.3.6.3 The number of bird hours per tidal cycle of feeding Dunlin on each intertidal area at Oglet Bay during the day and at night - winter 1990/91.

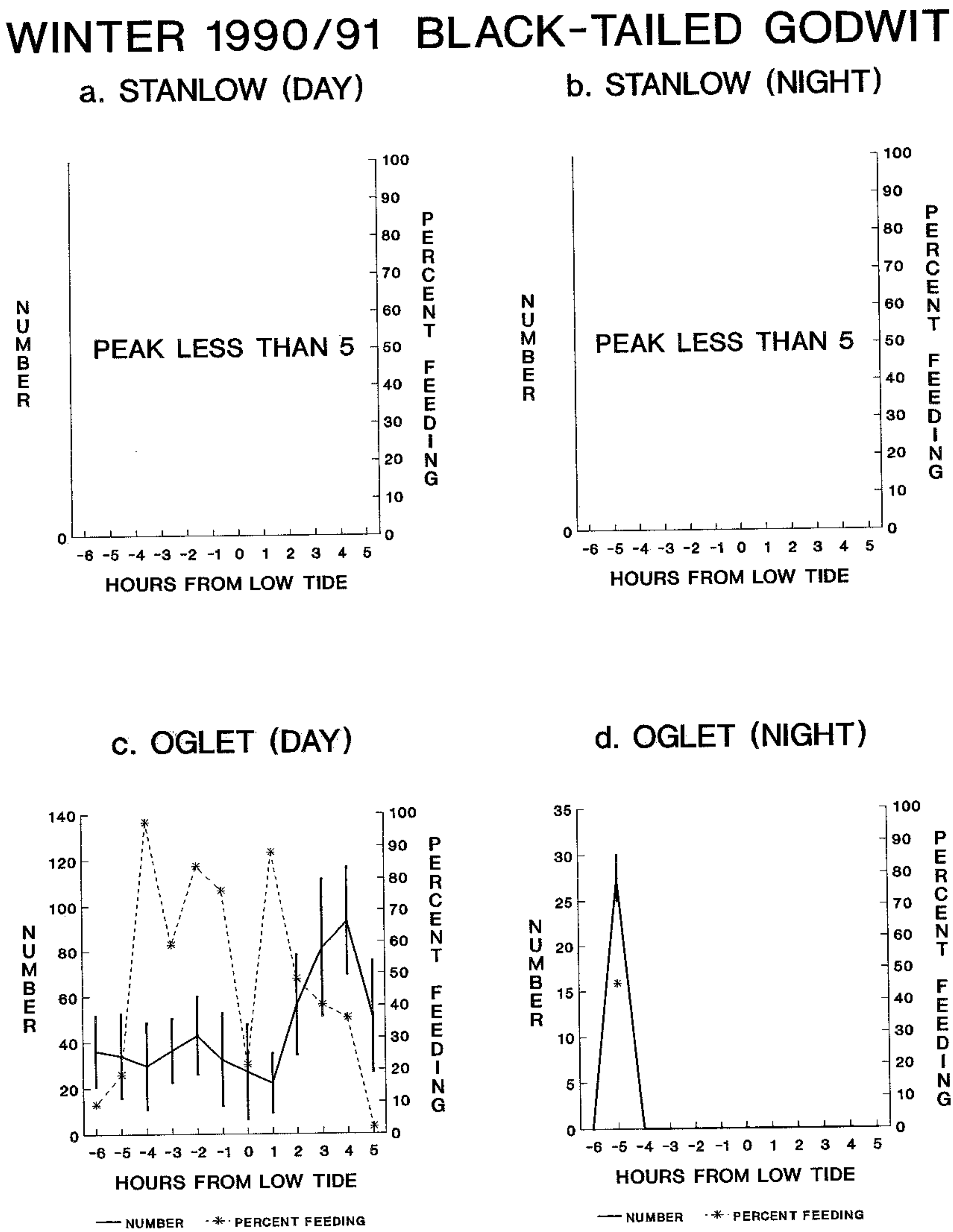



Figure 2.3.7.1 The number of Black-tailed Godwit present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.

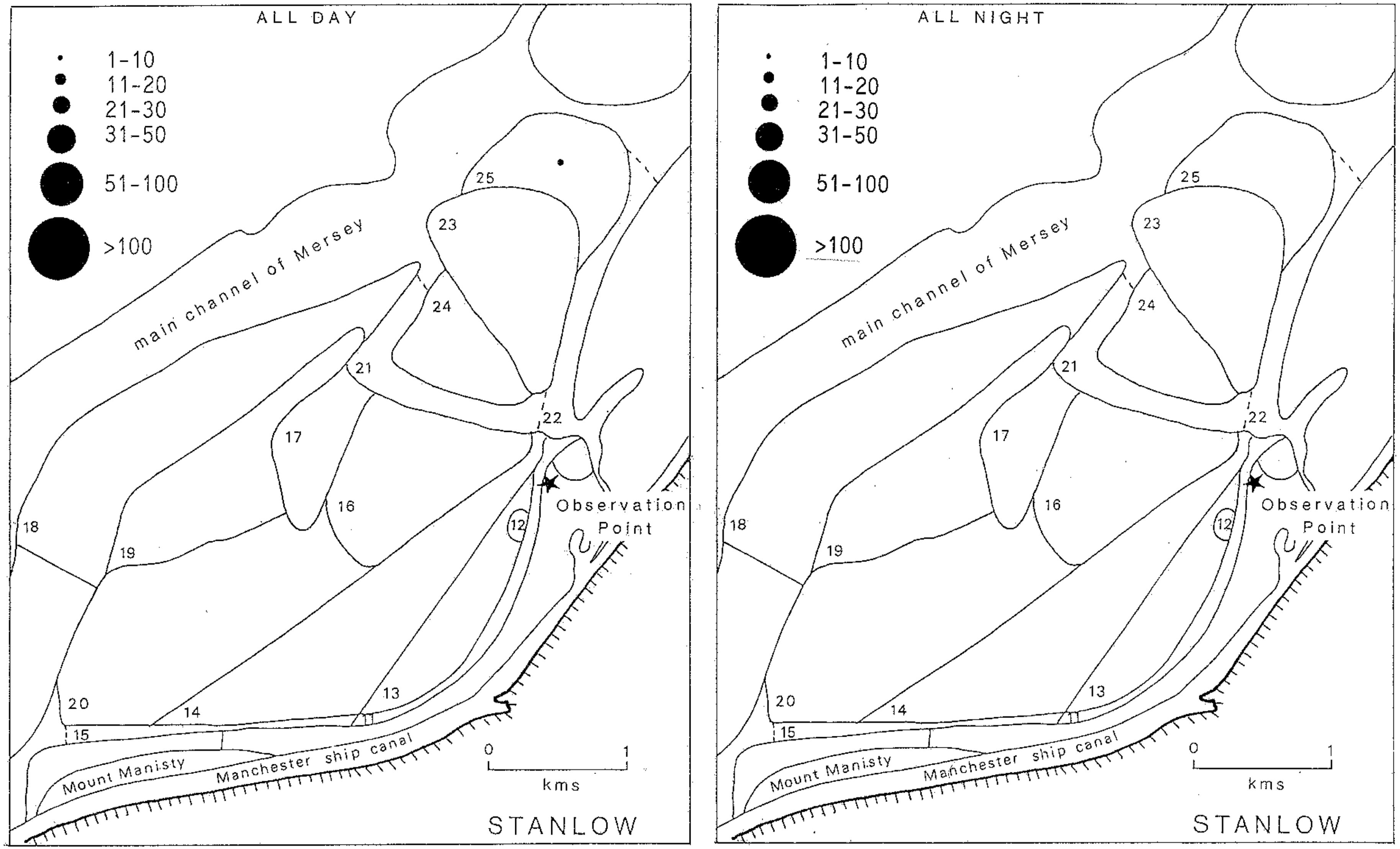



Figure 2.3.7.2 The number of bird hours per tidal cycle of feeding Black-tailed Godwit on each intertidal area at Stanlow during the day and at night - winter 1990/91.

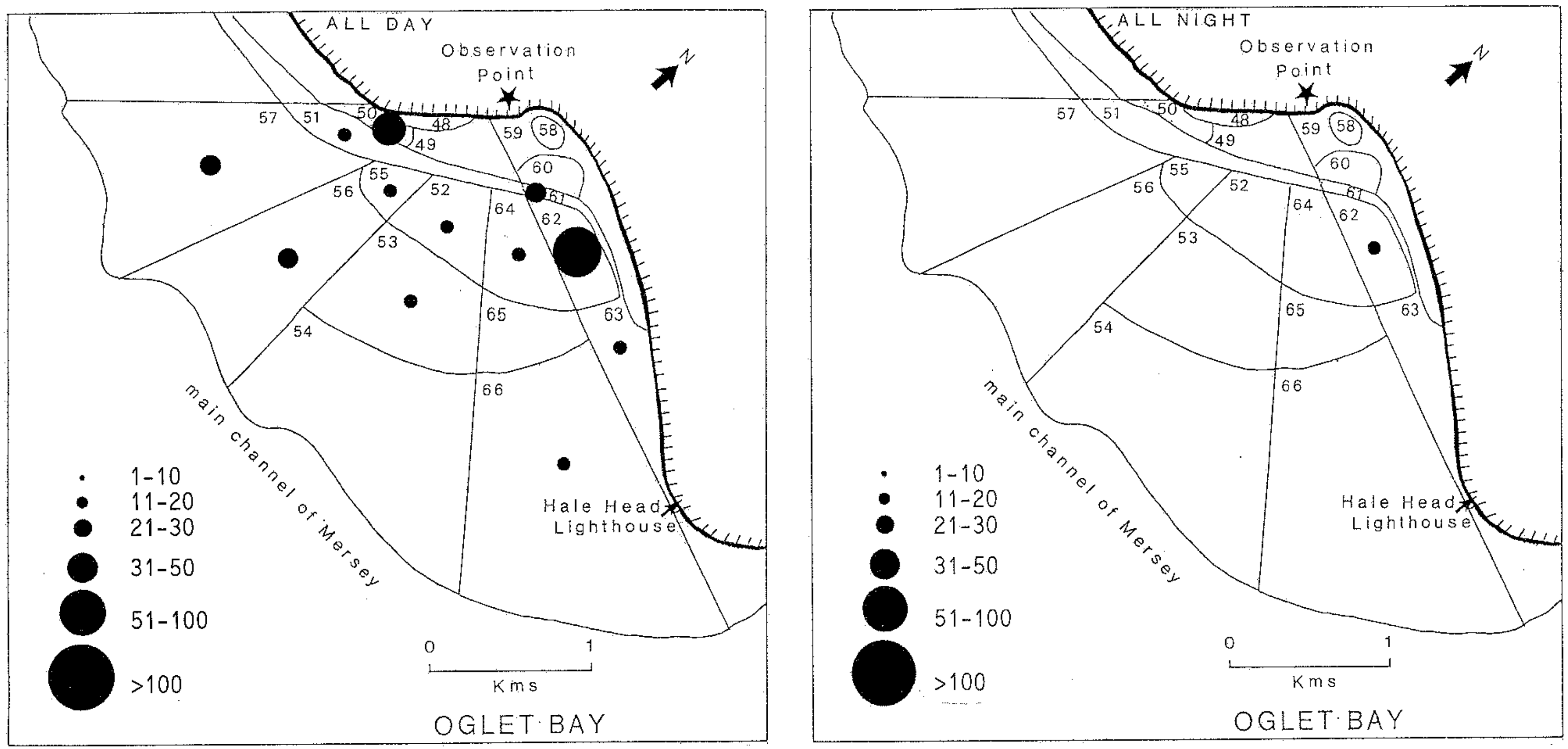



Figure 2.3.7.3 The number of bird hours per tidal cycle of feeding Black-tailed Godwit on each intertidal area at Oglet Bay during the day and at night - winter 1990/91.

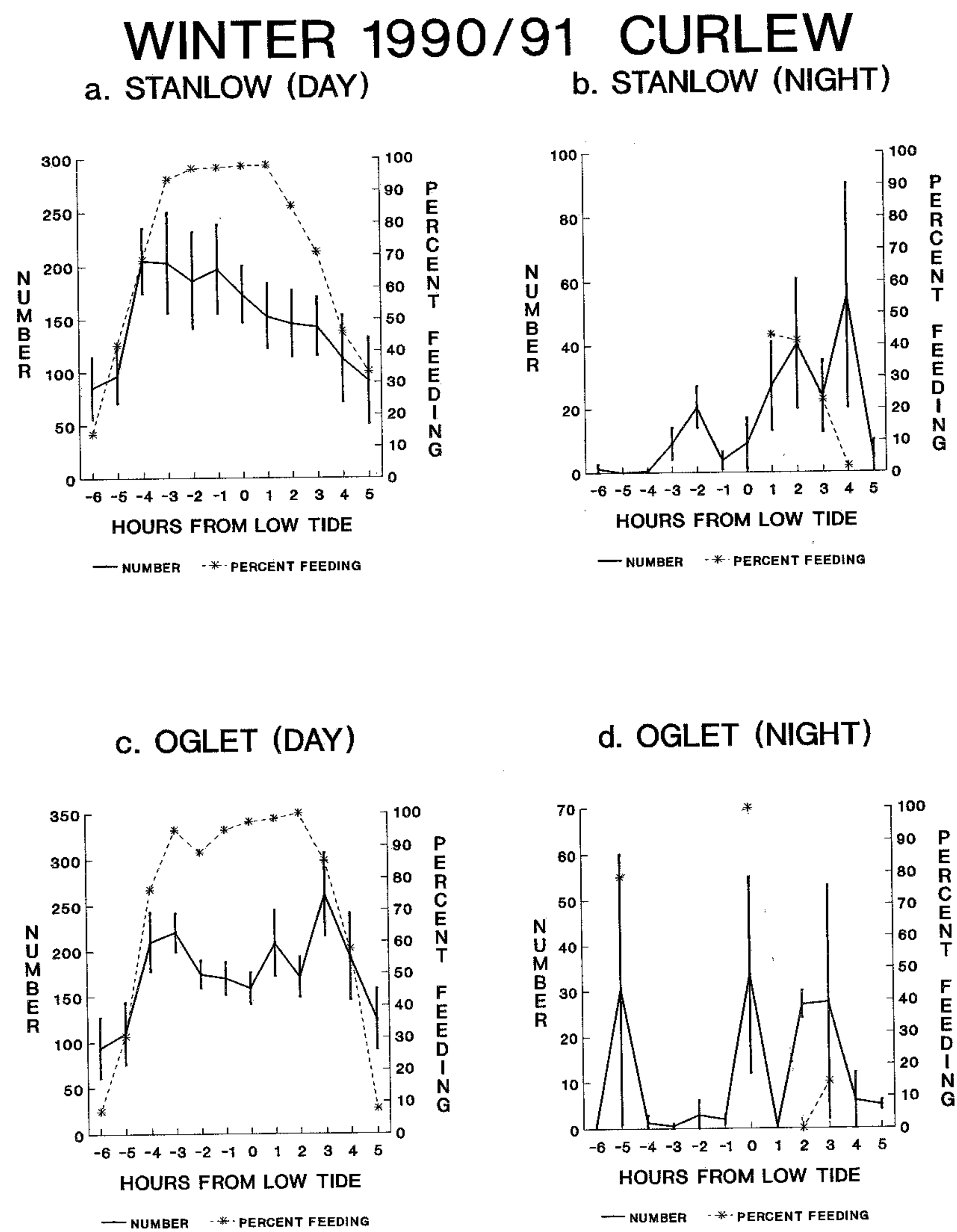
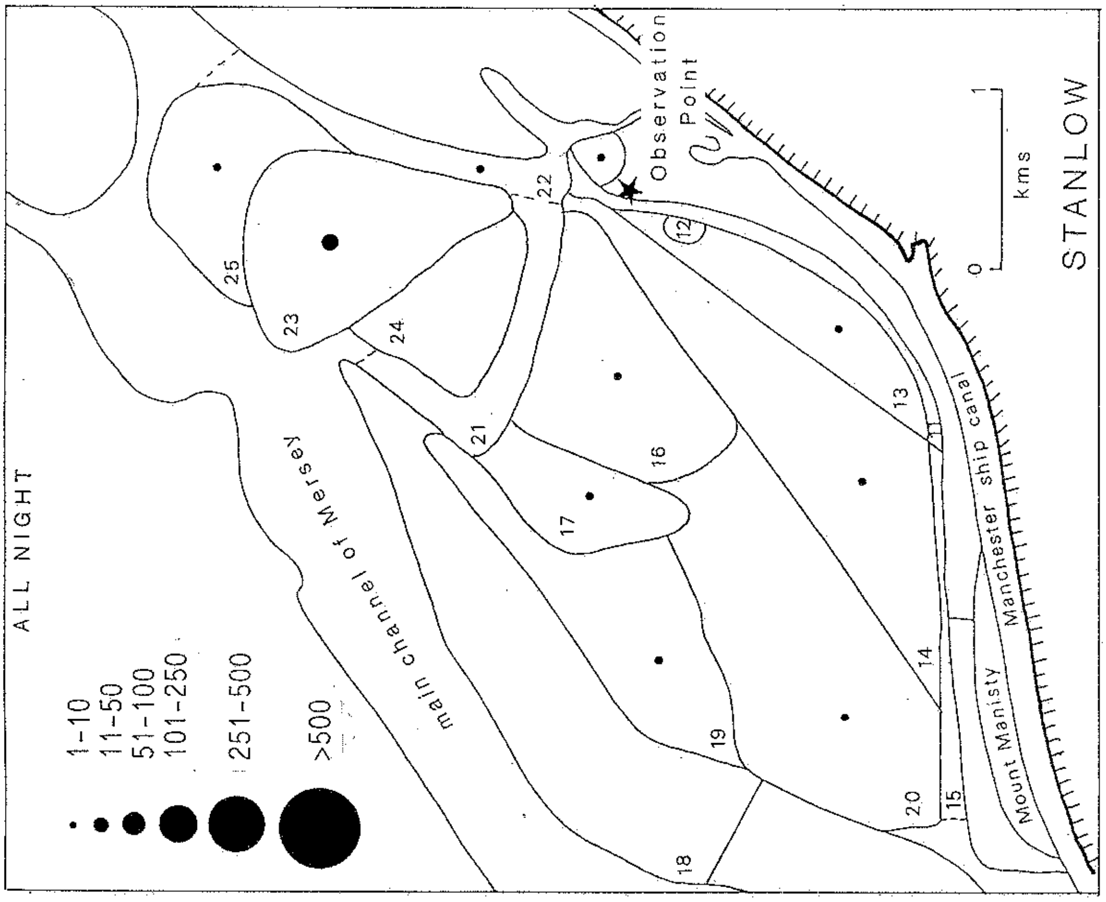



Figure 2.3.8.1 The number of Curlew present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.


ALL NIGHT
1-10
11-50
51-100
101-250
251-500
>500
main channel of Mersey
Observation Point
0
1
kms
STANLOW
Manchester ship canal
Mount Manisty
12
13
14
15
16
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18
19
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21
22
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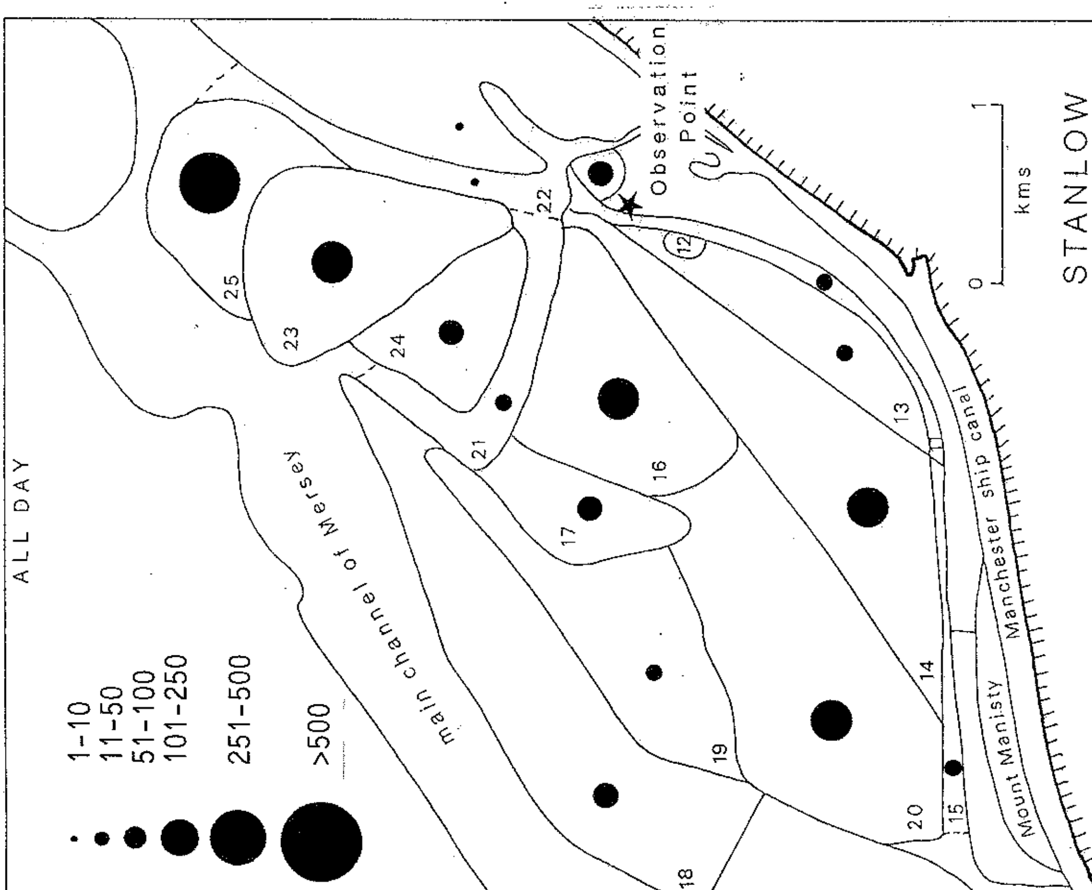
24
25


ALL DAY
1-10
11-50
51-100
101-250
251-500
>500
main channel of Mersey
Observation Point
0
1
kms
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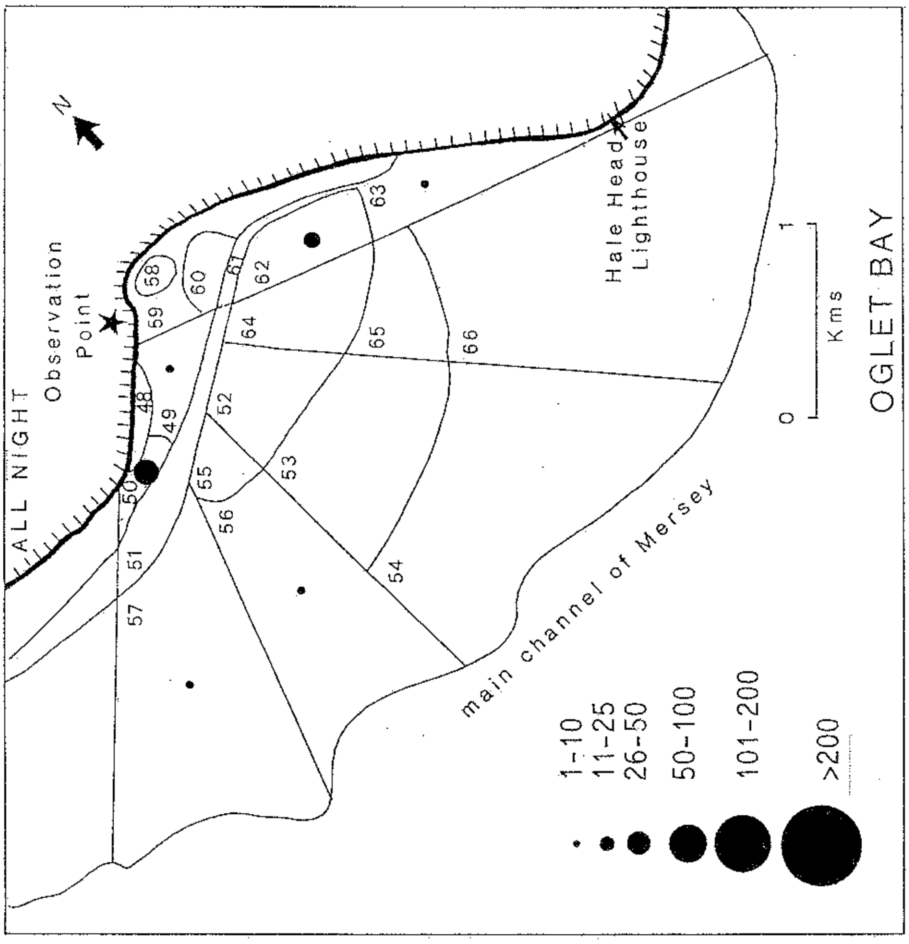
ALL NIGHT
Observation Point
Hale Head Lighthouse
main channel of Mersey
OGLET BAY
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Kms
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49
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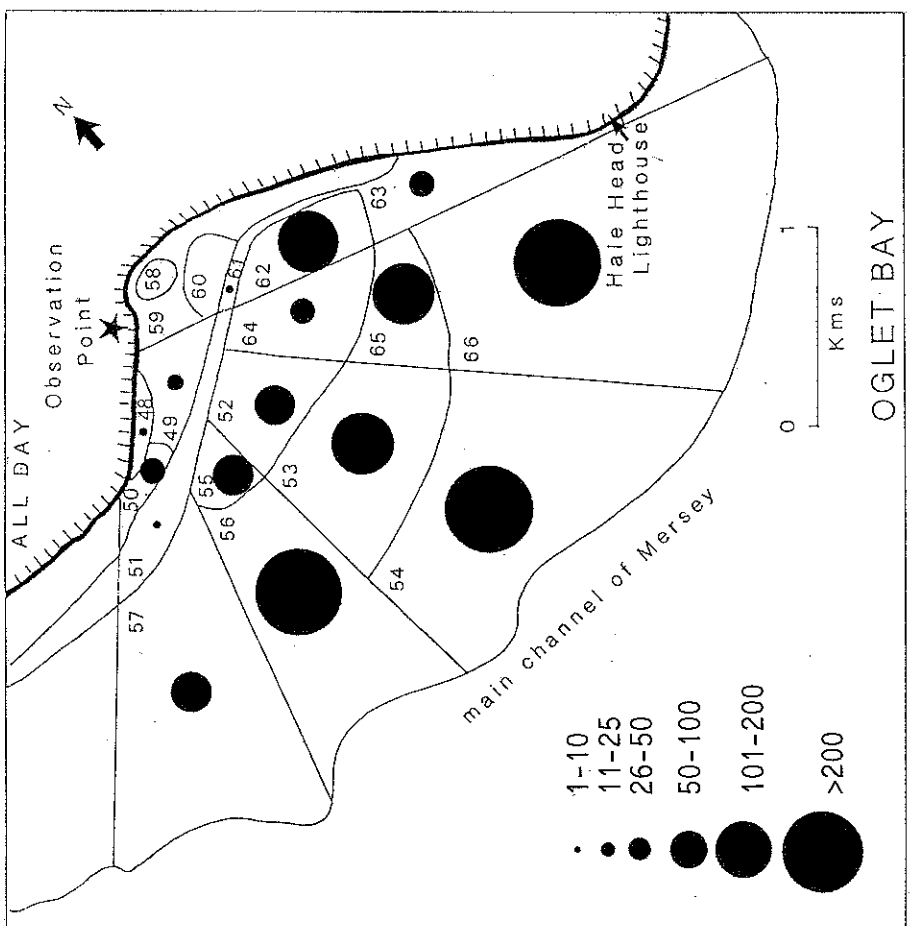
50-100
101-200
>200


ALL DAY
Observation Point
Hale Head Lighthouse
main channel of Mersey
OGLET BAY
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50-100
101-200
>200

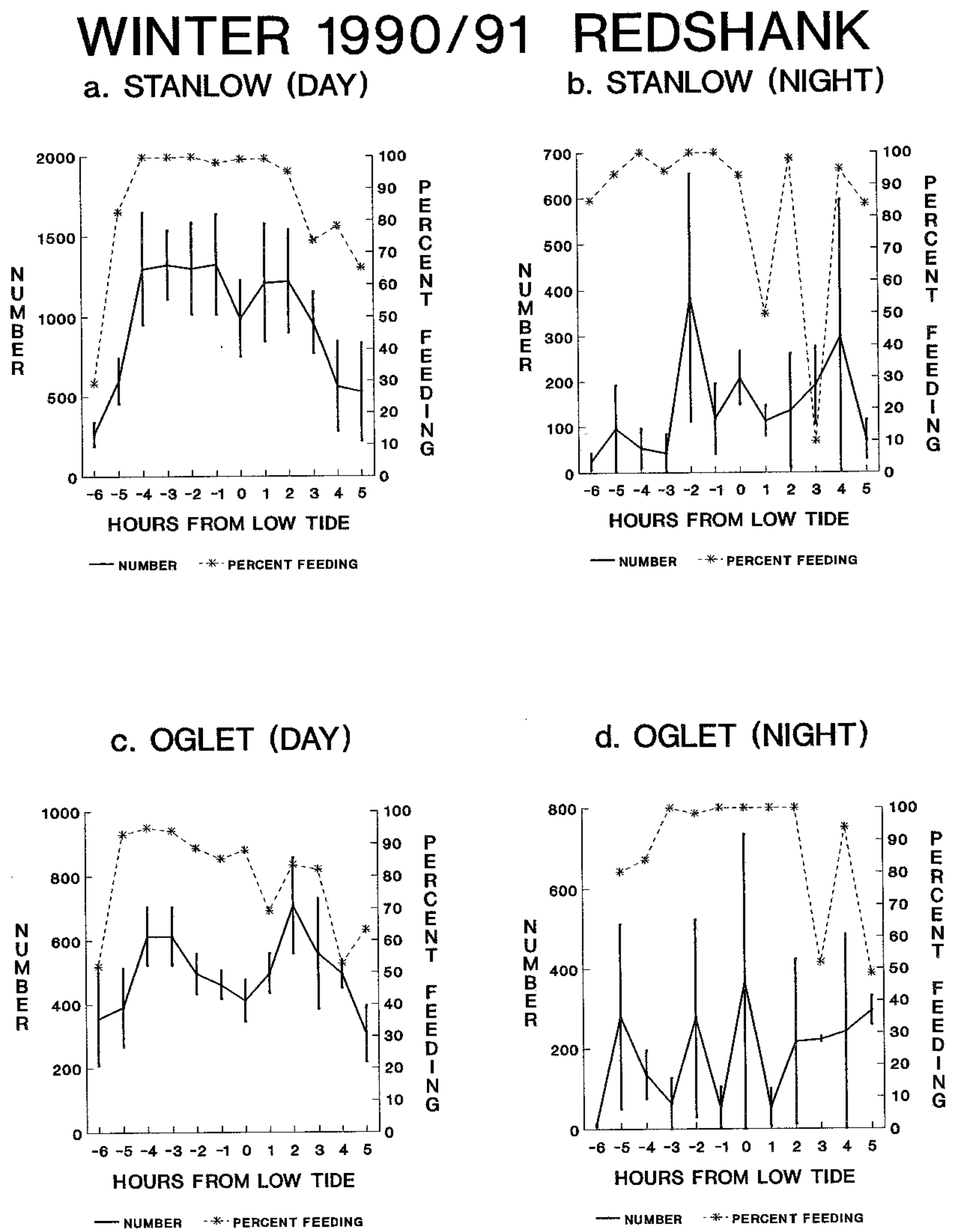


Figure 2.3.9.1 The number of Redshank present and the percentage feeding on the all day study sites, both during the day and at night, during the 1990/91 winter.

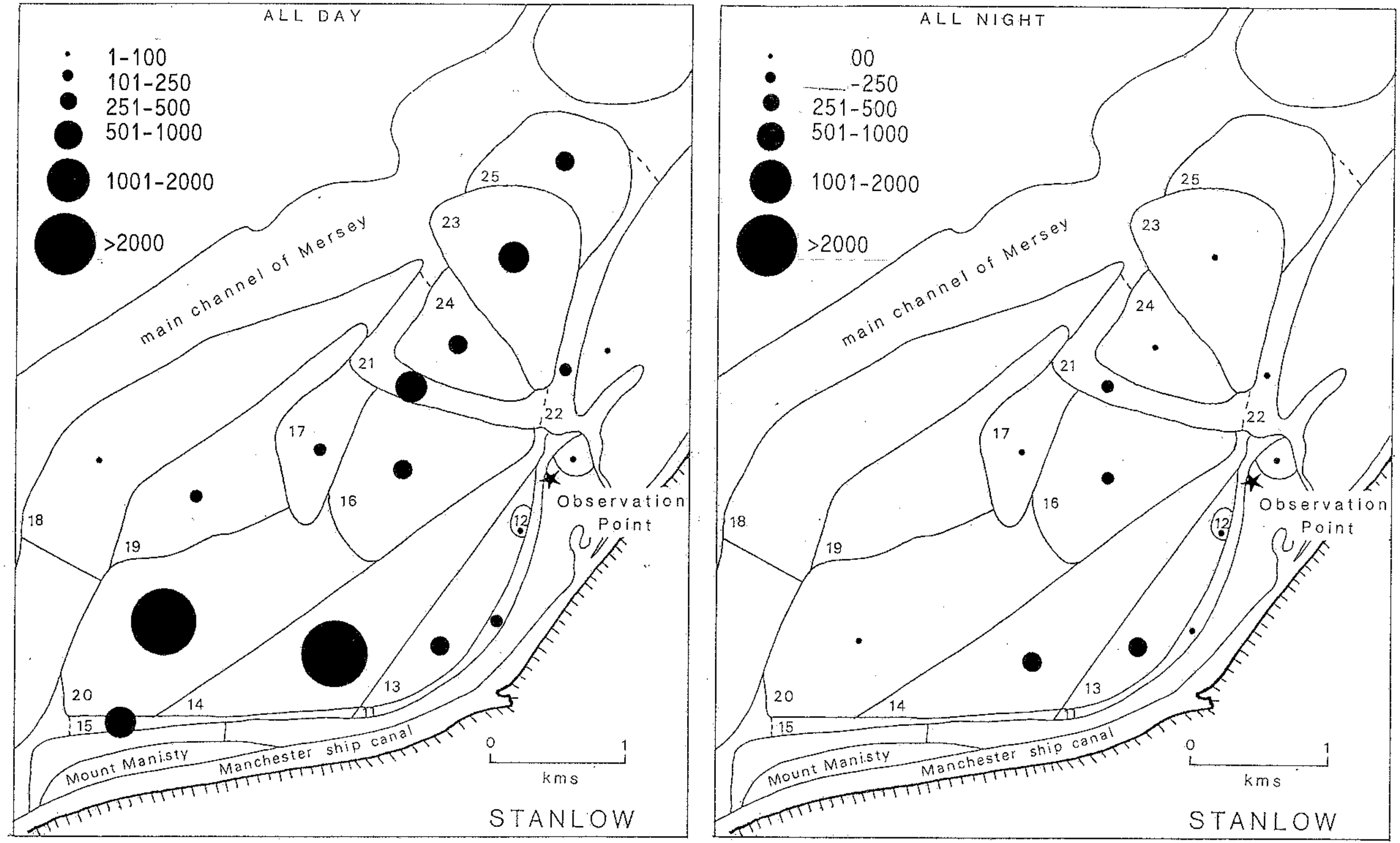


Figure 2.3.9.2 The number of bird hours per tidal cycle of feeding Redshank on each intertidal area at Stanlow during the day and at night - winter 1990/91.

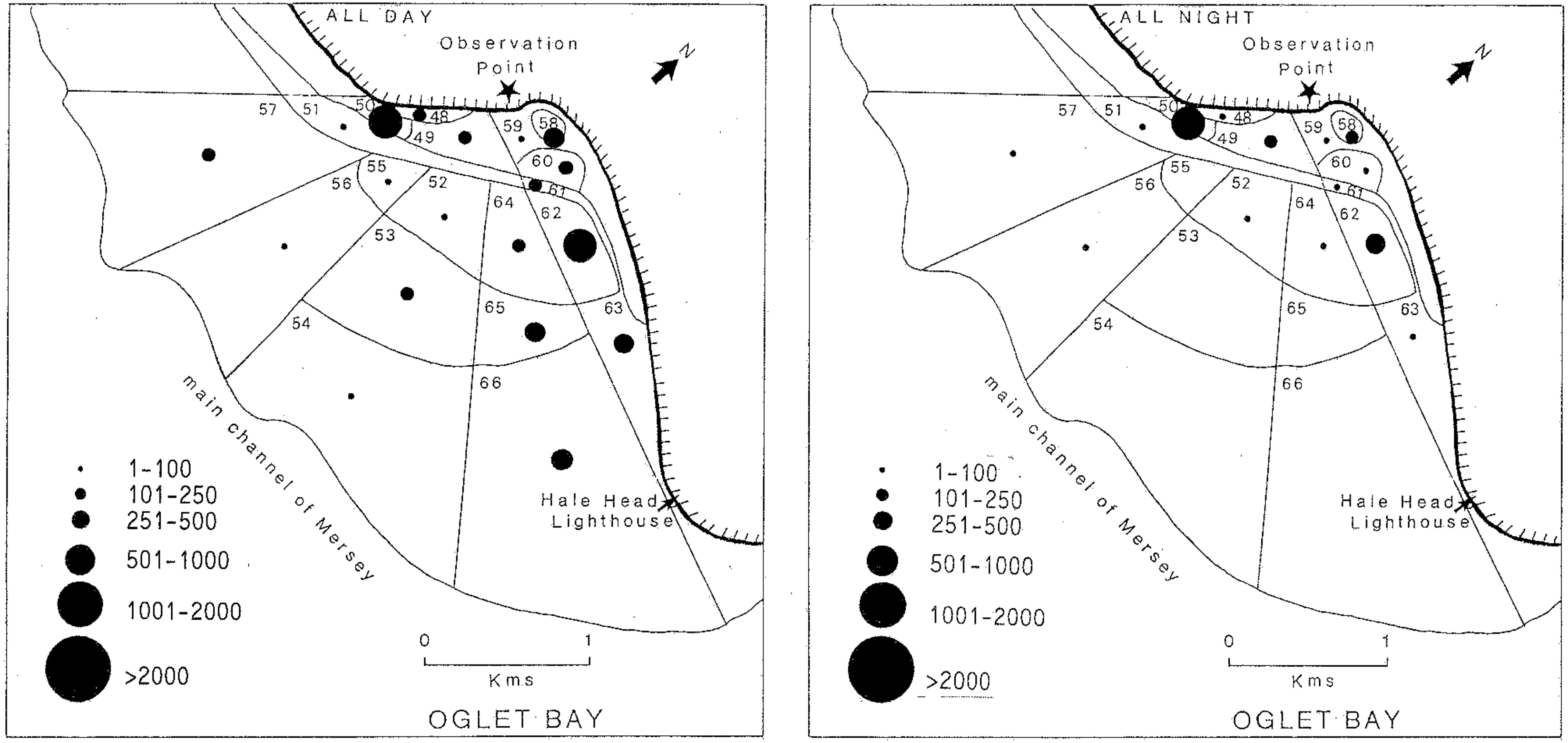


Figure 2.3.9.3 The number of bird hours per tidal cycle of feeding Redshank on each intertidal area at Oglet Bay during the day and at night - winter 1990/91.

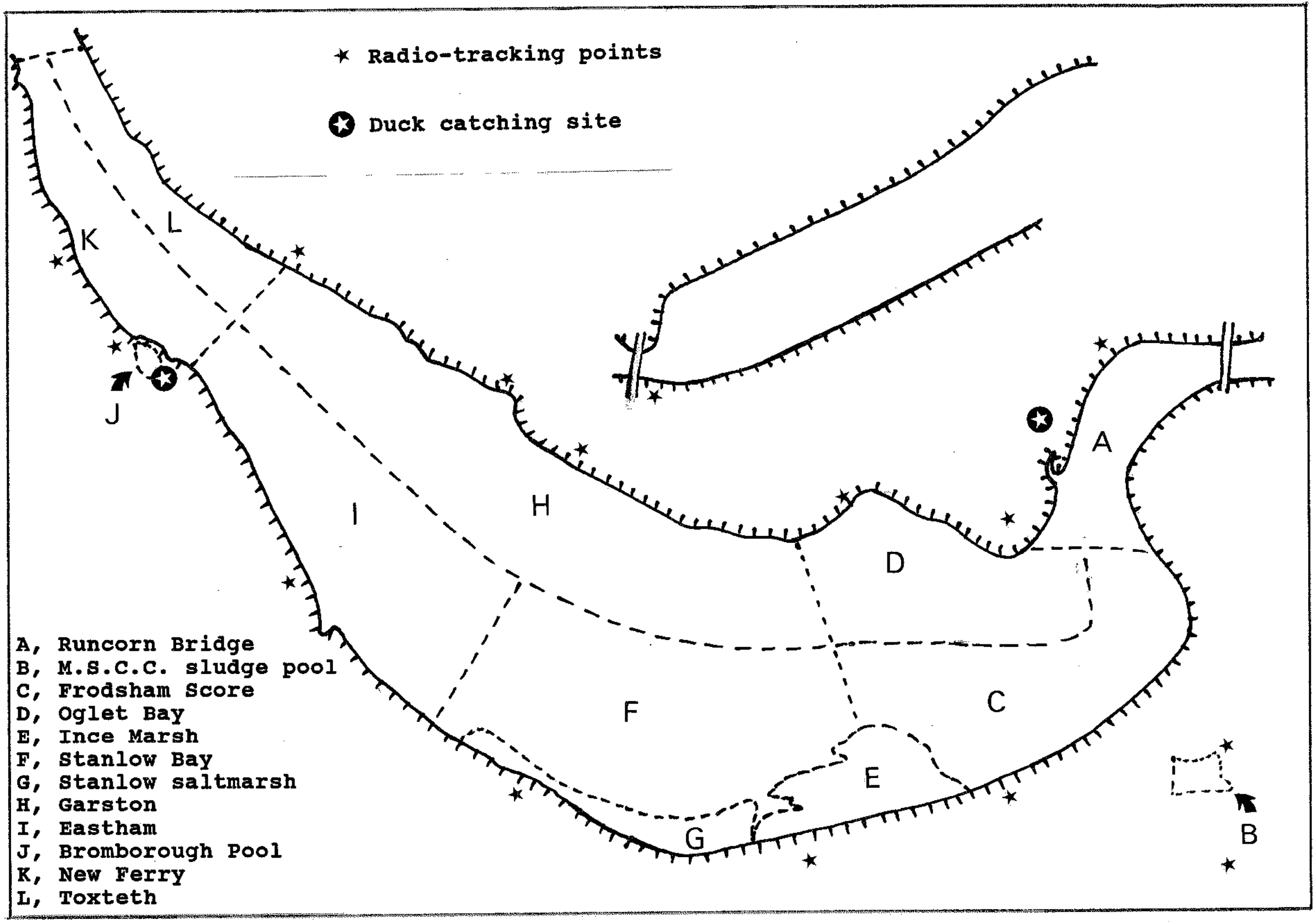


Figure 3.2.1 The location of the duck catching sites, the radio-tracking points, and the estuary divisions used in the analysis.

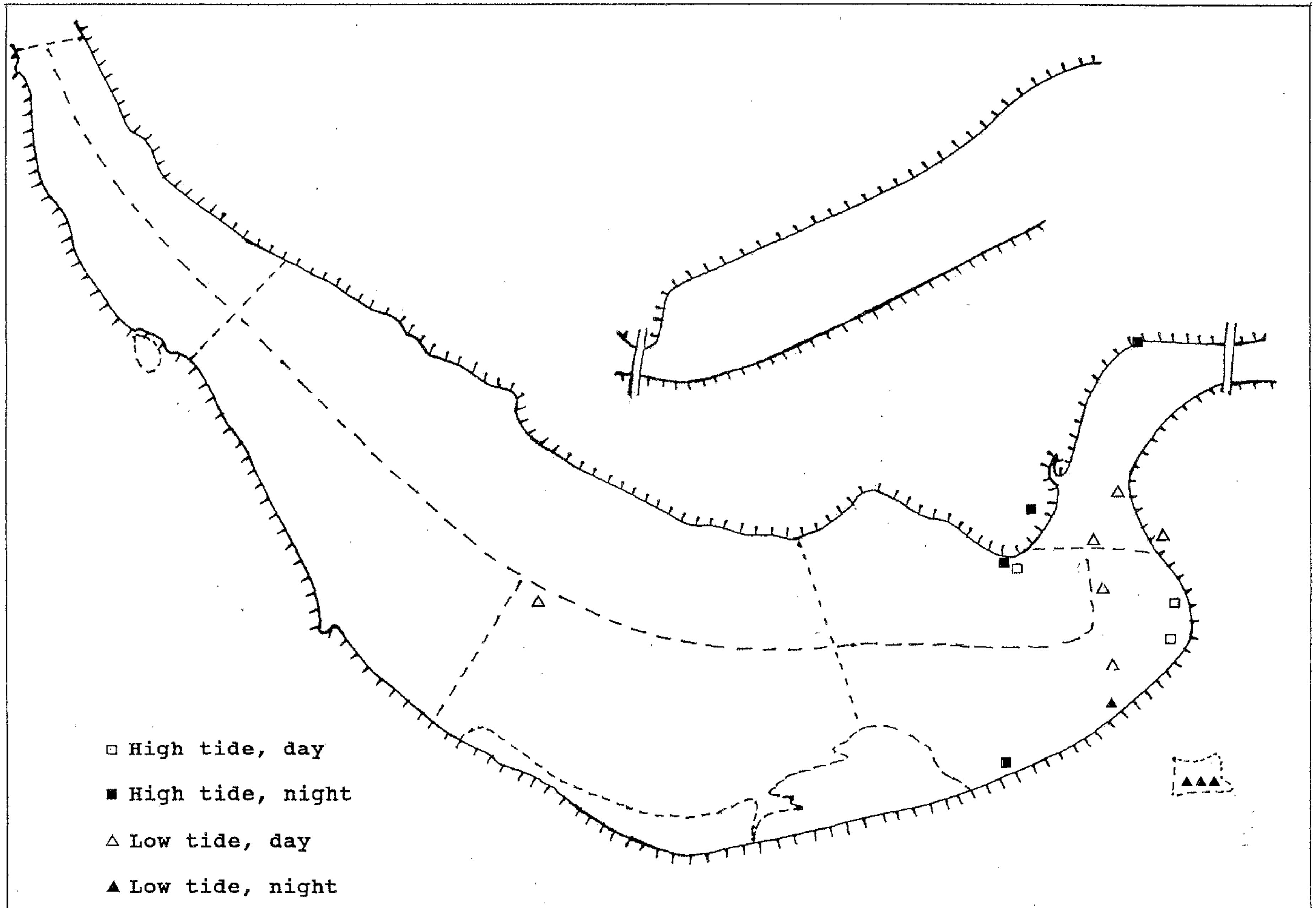


Figure 3.3.1 Movements of an adult male Teal, caught at Hale, from 25 November to 19 December 1990.

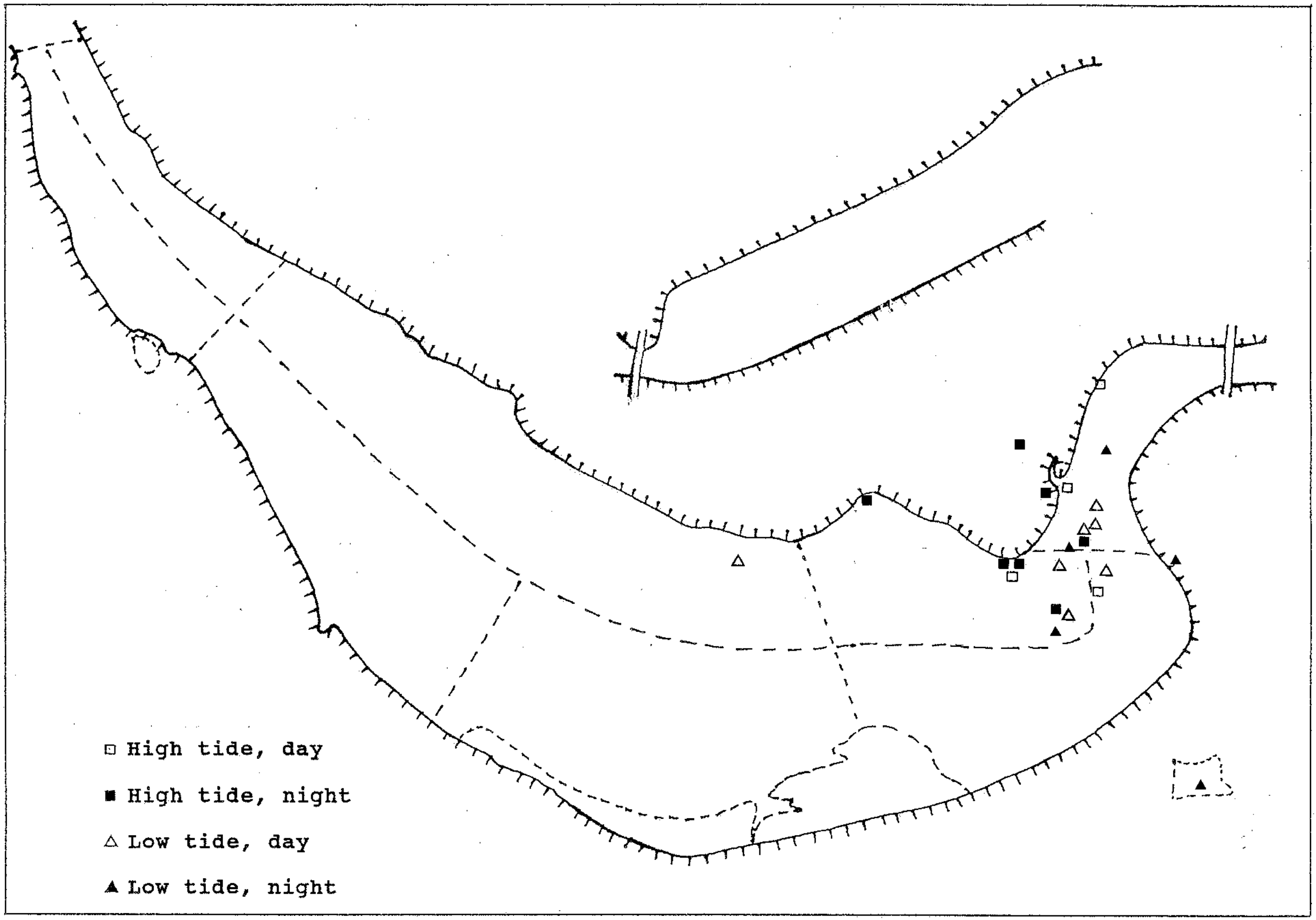


Figure 3.3.2 Movements of an adult female Teal, caught at Hale, from 25 November to 19 December 1990.

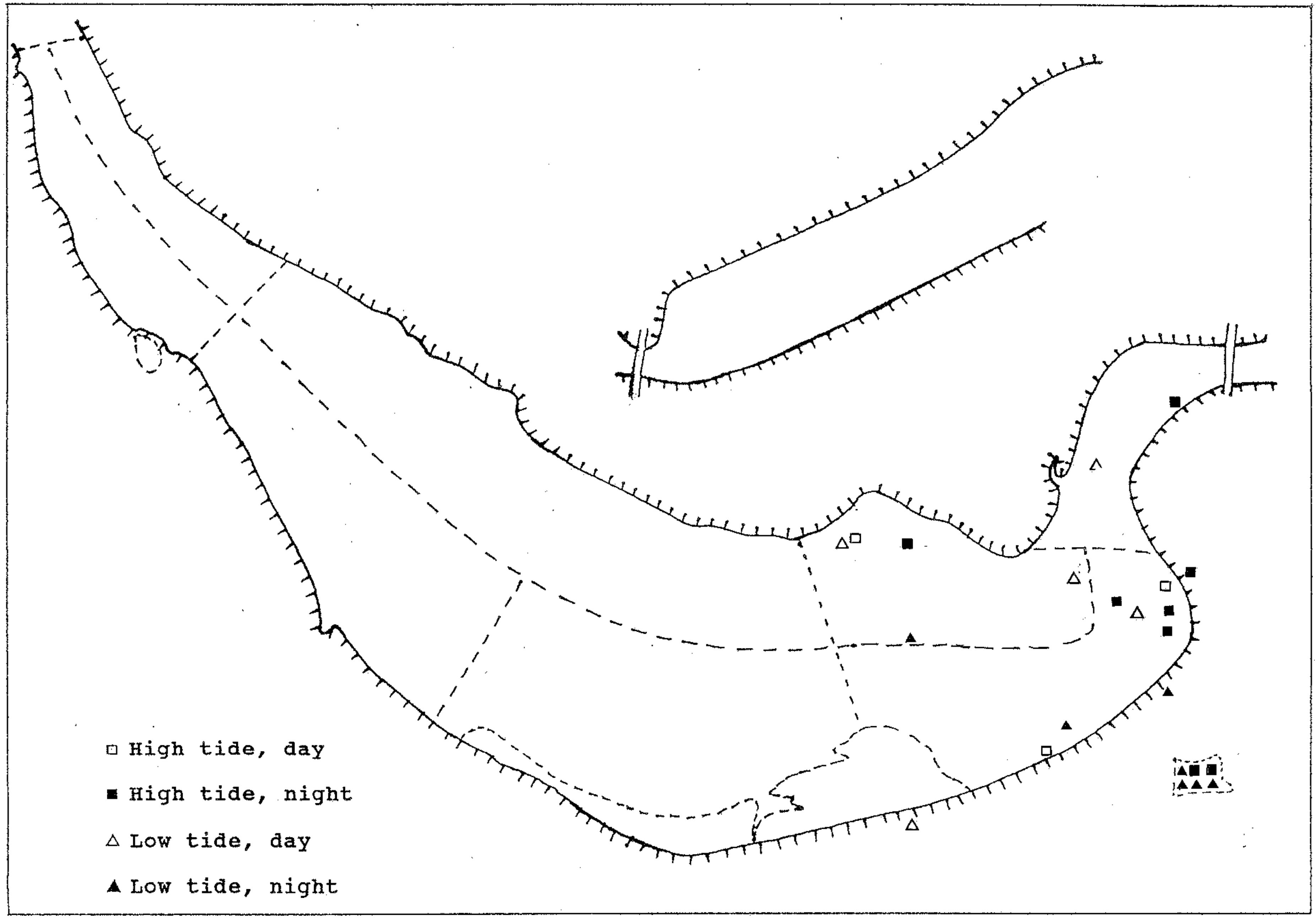


Figure 3.3.3 Movements of an adult female Teal, caught at Hale, from 23 November to 7 December 1990.

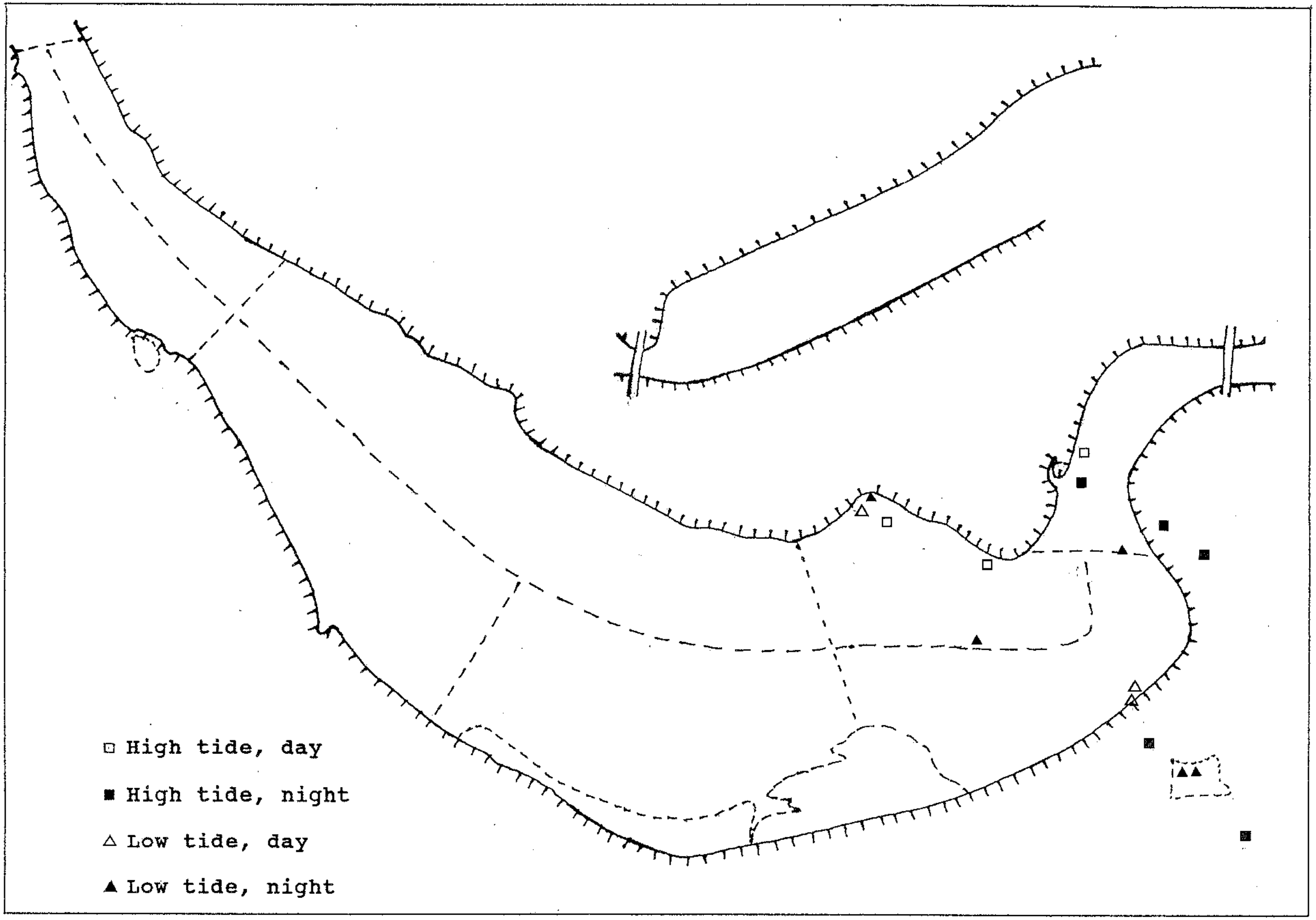


Figure 3.3.4 Movements of an adult male Teal, caught at Hale, from 23 November 1990 to 8 January 1991.

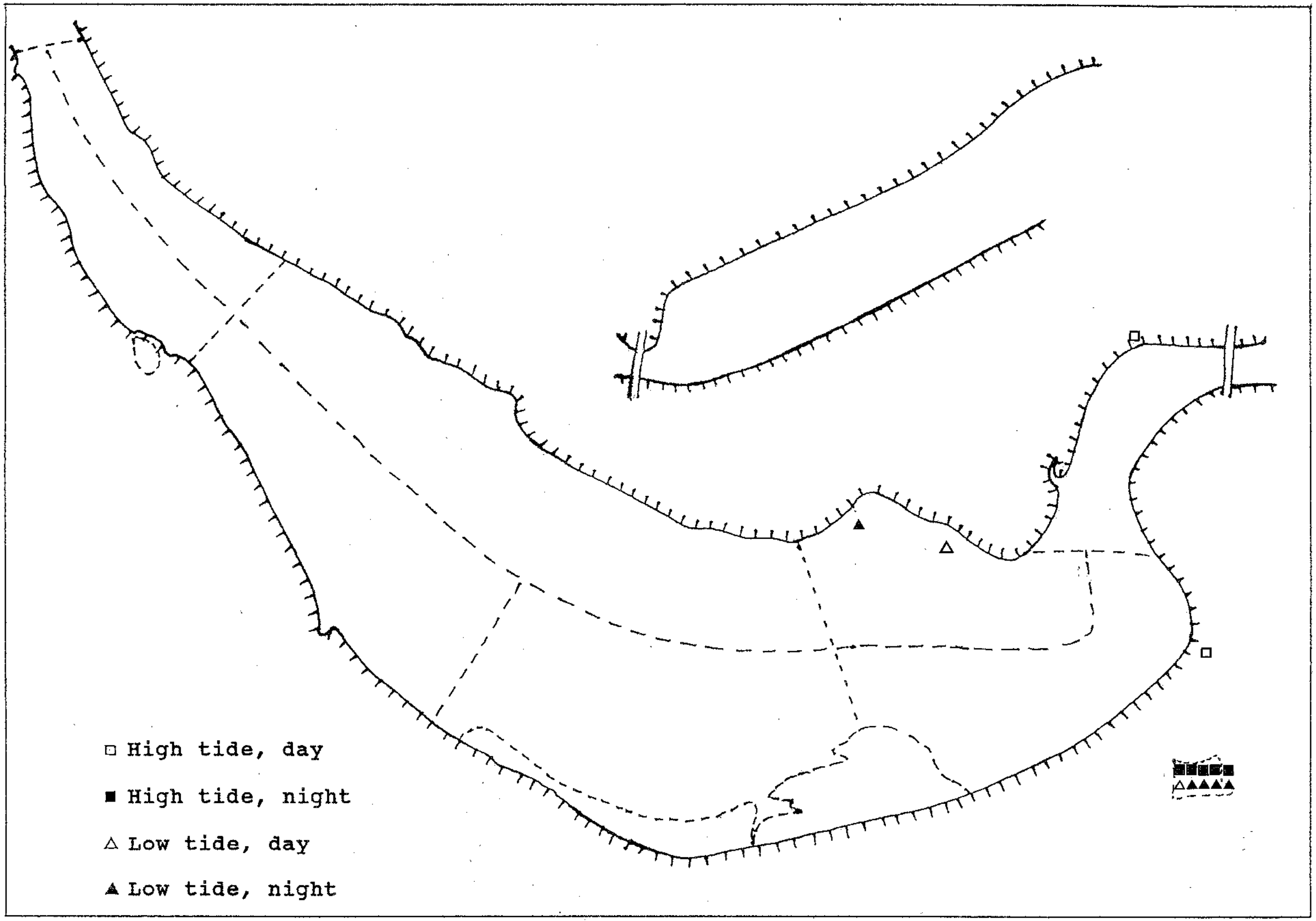


Figure 3.3.5 Movements of a juvenile female Teal, caught at Hale, from 23 November 1990 to 25 January 1991.

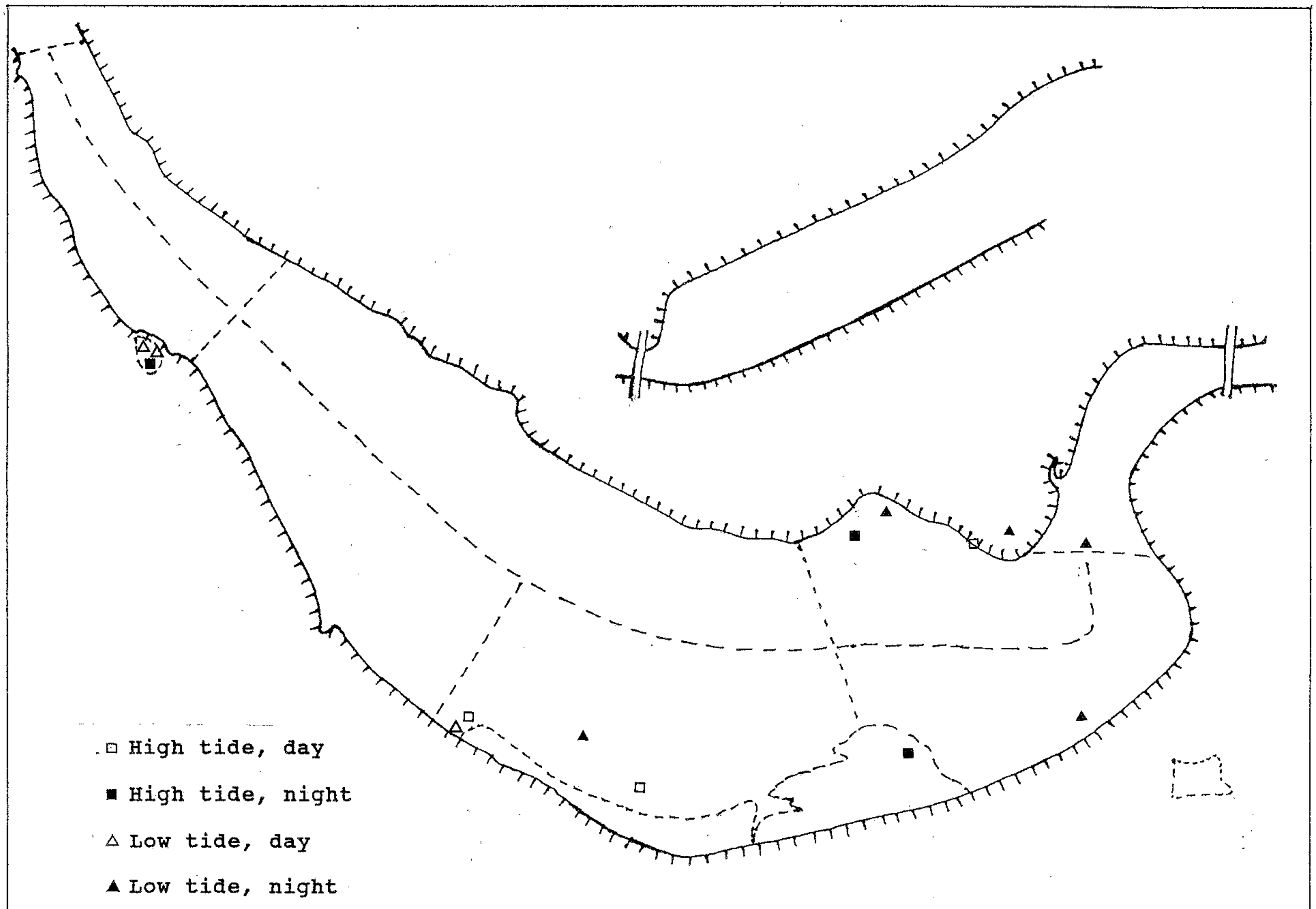


Figure 3.3.6 Movements of an adult female Teal, caught at Bromborough, from 8 January to 4 March 1991.

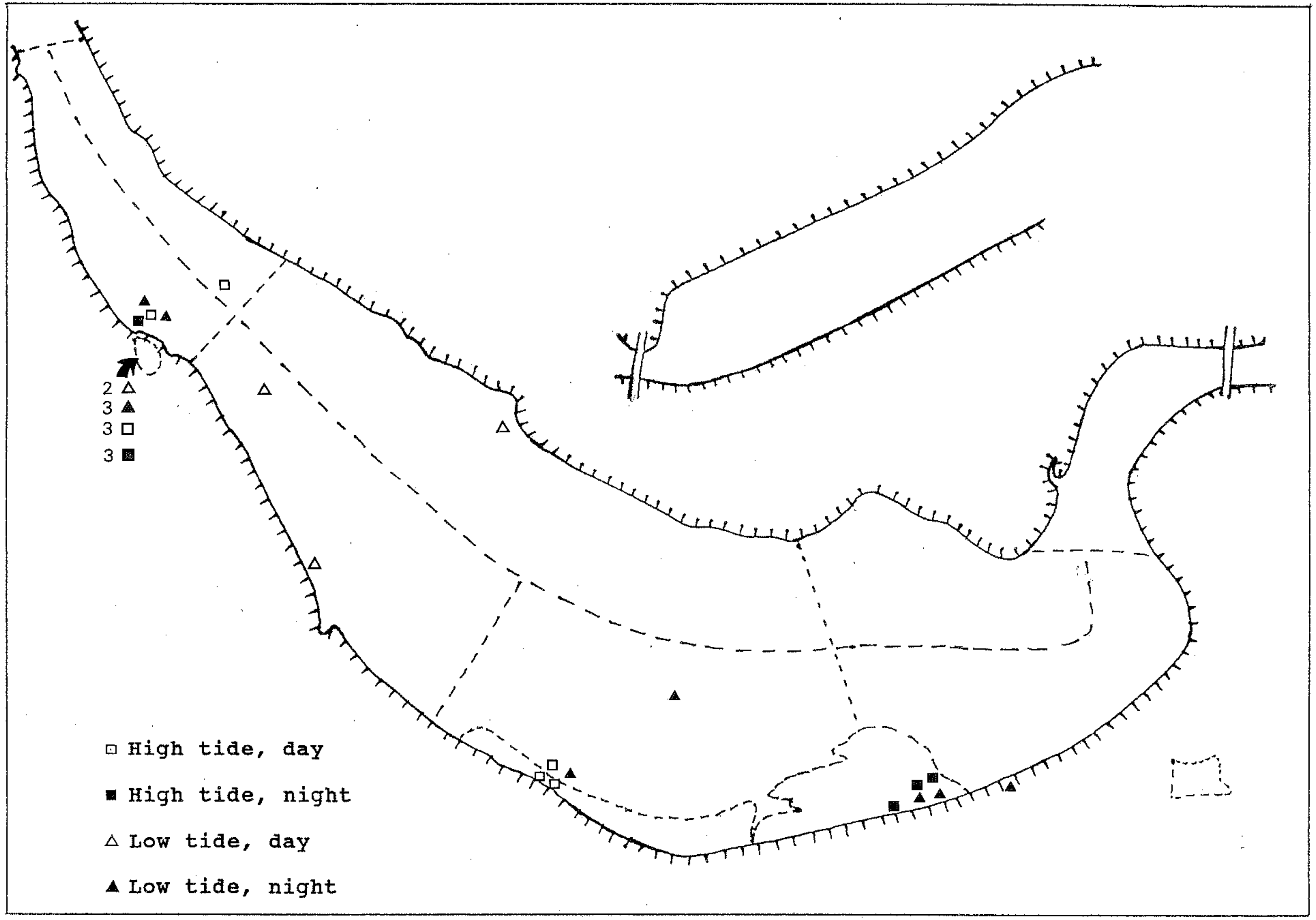


Figure 3.3.7 Movements of a first year female Teal, caught at Bromborough, from 8 January to 4 March 1991.

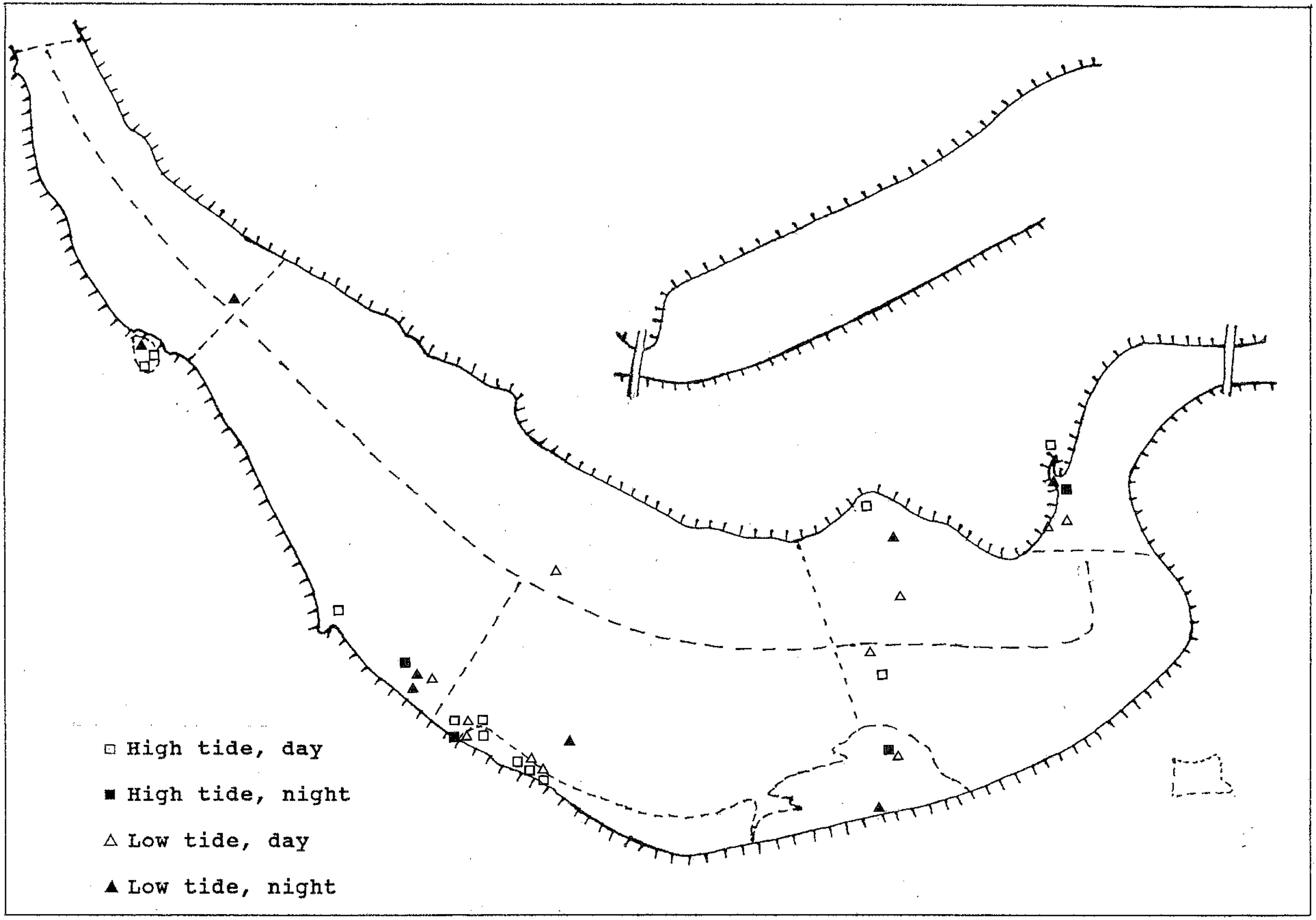


Figure 3.3.8 Movements of an adult male Teal, caught at Bromborough, from 8 January to 4 March 1991.

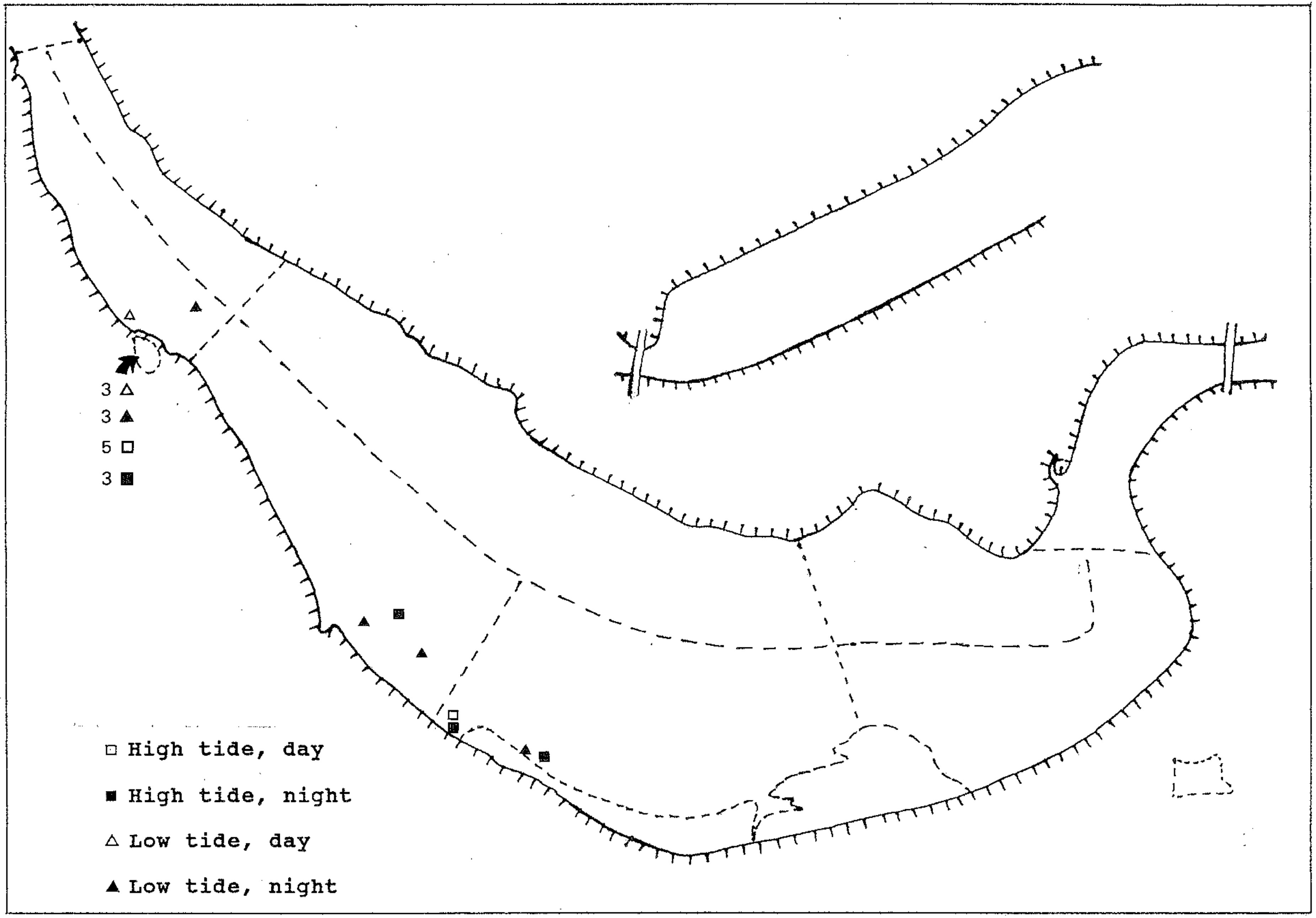


Figure 3.3.9    Movements of an adult male Teal, caught at Bromborough, from 5 February to 4 March 1991.

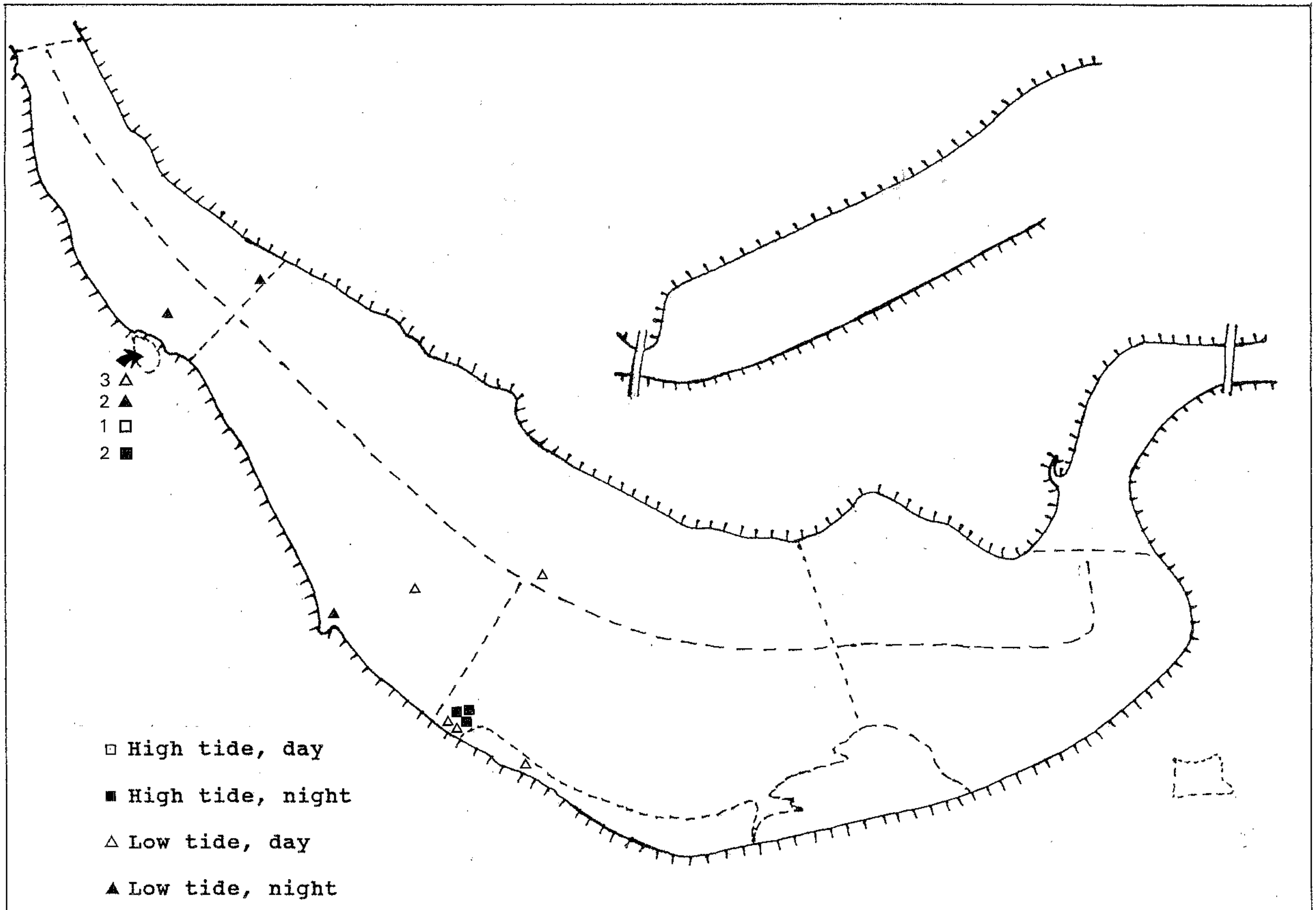


Figure 3.3.10 Movements of an adult male Teal, caught at Bromborough, from 3 February to 4 March 1991.