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Through-the-tidal-cycle and Night-time Waterbird Counts as part of the London Gateway Assessment

Authors

M.J.S. Armitage, S.J. Holloway, P. Shaw & M.M. Rehfisch

April 2002

Report of work carried out by The British Trust for Ornithology
under contract to Posford Haskoning Ltd

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EXECUTIVE SUMMARY

1. The London Gateway project involves the development of a major port on the site of the former Shell Haven Oil Refinery at Stanford-le-Hope in Essex, which will occupy approximately three kilometres of Thames River frontage, and reclaim 93 hectares from the river bed. As part of the environmental impact assessment, it has been proposed that through-the-tidal-cycle counts during the day and night are used to determine how the distribution of waterbirds varies with the tidal and diurnal states in the immediate vicinity of the affected area. This report provides a preliminary assessment of the birds' distribution and investigates the feasibility of such an approach.

2. Standard waterbird monitoring in coastal areas is based on two types of counts: high-tide and low-tide counts. However, unlike hourly counts of birds across the tidal cycle, these approaches do not provide a complete impression of waterbird usage of intertidal areas.

3. Through-the-tidal-cycle-counts were carried out at night at Mucking Flats (North, Central and South) and Holehaven Creek using a thermal imager and an image intensifier. One through-the-tidal-cycle count was also carried out during the day at North Mucking.

4. There was considerable variability in the number of waterbirds present at North Mucking at different stages of the tidal cycle during the day. This may have been due to different exposure times of the different areas at Mucking Flats or because the data were collected on two different days. The maximum count of Redshank at North Mucking was much higher than the numbers recorded by standard monitoring procedures in the same winter, although maximum counts of other species were similar to those recorded by standard monitoring procedures.

5. Use of an image intensifier proved ineffective for counting birds at night due to the nature of the substrate and the large distances involved. The thermal imager proved to be much more effective, but waterbirds could not be identified to species. The numbers of large- (Shelduck, Mallard, Oystercatcher, Avocet, Curlew and Black-tailed Godwit) and medium-sized (Redshank and Grey Plover) birds recorded at North Mucking at night were similar to those recorded during the day, but occurred at different stages of the tidal cycle. Smaller birds (Ringed Plover and Dunlin) were visible when close to the sea wall, but were difficult to detect beyond 200-300 metres distance.

6. There was evidence that most, if not all, of the medium- and large-sized birds were being detected at night at Central and South Mucking, but, unlike at North Mucking, there was little change in their numbers through the tidal cycle. Fewer small birds were recorded than expected, based on previous counts using standard low-tide monitoring procedures, suggesting that these were not being detected when distant from the observer. There was, however, noticeable movement of birds along the tide line, probably between the different areas of Mucking Flats, but not in any particular direction.

7. Night-time counts of birds from only one side of the creek at Holehaven covered only a small part of the whole creek. The maximum numbers of large and small birds recorded during the night-time TTTCC were much lower than those recorded during standard day-time low tide counts during the same winter, probably because of reduced detectability of birds at night and that only part of the count area was covered, compared to the standard day-time counts. To ensure complete counts, even during the day, it was established that two observers would be required to undertake simultaneous counts of birds from either side of the creek.

8. Although there was no strong evidence that birds used the different areas of Mucking Flats for feeding during the day and during the night, it is possible that they used the parts of each site differently during the day and during the night at different stages of the tidal cycle. There was some evidence that birds moved between the areas at different stages of the tidal cycle. Wherever possible, the relative importance of these sites should, therefore, be determined by through-the-tidal-cycle counts, rather than single monthly counts carried out at any one stage of the tidal cycle.

9. In summary, the viewing distances involved at Mucking Flats and Holehaven Creek reduced the accuracy and value of night-time observations of birds at the sites, but the approach is considered to

provide a reasonably accurate indication of the overall number of birds (particularly larger species) using the intertidal areas at night. Regular through-the-tidal-cycle counts during the day would provide a fuller picture of bird usage of the different sites over the course of a tidal cycle. It is recommended that a set of monthly night-time counts are carried out for a complete winter to confirm that day-time counts provide an accurate representation of the numbers of birds using the area at night. If the relationship between day- and night-time usage recorded is confirmed, further night-time counts will probably be unnecessary.

1. INTRODUCTION

The London Gateway project, promoted by The Peninsular and Oriental Steam Navigation Company (P&O) and Shell UK Limited (Shell), includes the development of a major port on and around the site of the former Shell Haven Oil Refinery at Stanford-le-Hope in Essex. The proposed London Gateway site comprises approximately 600 hectares and occupies some three kilometres of river frontage along the Thames. The port development will occupy 75 hectares of existing land and a f further 93 hectares to be reclaimed from the river bed, using the spoil produced from dredging the approach channel.

As part of a comprehensive environmental impact assessment, it has been proposed that through-the tidal-cycle counts (TTTCC) are used to help determine how the distribution of waterbirds on adjacent intertidal areas varies during the day and night with the tidal state. Mucking Flats are adjacent to the proposed development site, and it is possible that the mudflats there and those at Holehaven Creek will be affected by the development through increased disturbance and through sediment accretion due to dredging of the main approach channel.

The Department of Environment, Transport and the Regions (now DEFRA) recently classified the Thames Estuary and Marshes as a Special Protection Area (SPA) for Birds and also as a Wetland of International Importance under the Ramsar Convention. Covering approximately 5,500 hectares, the site is of special importance within Britain and Europe for the number of waterbird species which use it, both for over-wintering and as a migratory staging post. In winter, the Thames Estuary and Marshes SPA regularly supports over 20,000 waterbirds. Species with nationally important populations wintering within the SPA include Little Grebe, Shelduck, Gadwall, Teal, Shoveler, Avocet, Grey Plover, Knot (also internationally important), Dunlin and Black-tailed Godwit. A site is considered important for a species, at a national or international level, if the five-year mean of the maxima for that species exceeds the 1% national or international threshold value (this is typically 1% of the national and international populations respectively) (see Musgrove *et al.* 2001).

Standard waterbird monitoring in coastal areas is based on two types of counts: high tide counts, when waterbirds are concentrated at roost sites; and low-tide counts, which give an indication as to how waterbirds use intertidal areas for feeding. These counts form the basis of the Wetland Bird Survey (WeBS) monitoring of estuaries within the UK. However, this approach does not provide a complete impression of waterbird usage through the tidal cycle. TTTCCs are complete counts of birds carried out hourly during a full tidal cycle of approximately twelve hours. The information gathered can be summarised to provide an indication of the usage that waterbirds make of an area through the different parts of the tidal cycle. With suitable imaging equipment, this approach can also be carried out at night (see section 2.2 for full details of the count methodology and night-viewing equipment).

This study forms a preliminary assessment of waterbirds use of Mucking Flats and Holehaven Creek during the day and night using TTTCC methodology.

2. METHODS

2.1 Study Site

Figure 2.1.1 shows the study area and the location of the proposed London Gateway development. TTTCCs were carried out at two discrete areas: Mucking Flats and Holehaven Creek. The large expanse of Mucking Flats was split into three sites, North, Central and South Mucking, in order to enable full coverage of the area. Birds at both Mucking Flats and Holehaven Creek have been counted (standard monthly counts) by Phil Shaw for WeBS and on behalf of PLA (Figure 2.1.2). The former has been counted during winters 1999-2000, 2000-2001 and 2001-2002. Standard count data at the latter site are only available for winter 2001-2002. TTTCCs at the four sites were carried out from the sea wall along the shoreline.

2.2 Count Methodology

TTTCCs covering one complete cycle were carried out during the night at each of the four sites, and TTTCCs covering one complete cycle were also carried out during daylight hours at North Mucking. One complete TTTCC comprises twelve counts of all waterbirds at a site made at hourly intervals from six hours before low tide (-6) to five fours after low tide (+5) (see Table 2.2.1). All waterbirds present on the exposed mudflats were counted. For the day-time counts at North Mucking, feeding and roosting birds were counted separately. It was not possible to distinguish between feeding and roosting birds at night. Birds roosting in areas of saltmarsh were not counted, as accurate counts are very difficult in this habitat. Wildfowl feeding on invertebrates or plants in the shallow water just offshore were included in the counts, although wildfowl loafing offshore on open water were excluded.

Day-time observations were carried out at North Mucking using 8× magnification binoculars and a 20-60× magnification telescope. Nocturnal observations were made using two pieces of image enhancing equipment: an infra-red image intensifier with a 300 mm telephoto lens (effectively giving 6× magnification) used in conjunction with a Nightforce SL170 spotlight, and a LITE direct view thermal imager, which detects the long-wave (far infra-red) radiant energy emitted by natural vegetation and homeotherms, provided they are not obscured by vegetation. Image magnification of 9× is achieved with the thermal imager.

The counts were carried out between 30th January and 7th February 2002 (Table 2.2.1). Tidal information was taken from the Port of London Authority's web-site.

2.3 Data Analysis

Counts at each site were summarised in tables or presented graphically to allow visual comparisons of the data collected during the day-time and night-time counts. Maximum counts during the course of the tidal cycle were compared with the standard monthly counts carried out in winters 1999-2000, 2000-2001, and 2001-2002.

3. RESULTS

3.1 Use of Image-enhancing Equipment

Following directly comparative trials using the two pieces of image-enhancing equipment at the start of the project, only the thermal imager was used for the remainder of the night-time counts. The problem with the image intensifier was that it was only possible to visually determine birds on the closer intertidal areas. The definition of small objects declined rapidly with distance relative to binoculars, making it impossible to identify distant birds. With increasing distance from the observer, depending on the size and colouration of a species, and the nature of the substrate, it became impossible to determine whether or not that species was even present. The problem was exacerbated when looking towards the lights of the nearby refinery, as birds became silhouetted against the light (similar to observing birds with binoculars when looking towards the sun). A small number of Redshank, known to be present at approximately 100 metres distance on a pebbly intertidal area, were barely visible using the image intensifier and infra-red spotlight, but were easily detectable, as a medium-sized species, through the thermal imager. The thermal imager depicted birds as bright red, indistinct, oval shapes, while the background image was also illuminated to a lesser degree. It was not possible to identify birds to species beyond the immediate inner shore up to a distance of approximately 50 metres, but an estimate of the size of each bird visible was made and categorised as large, medium or small (Table 3.1.1). Small-sized birds on the mud could not be determined beyond approximately 200-300 m, but flocks of small-sized birds were detectable at greater distances when in flight.

3.2 Waterbird Numbers and Distribution

3.2.1 North Mucking

The North Mucking count site for the TTTCCs represents zone 1 of the standard monthly winter low-tide counts carried out by Phil Shaw on behalf of PLA in 1999-2000, 2000-2001 and 2001-2002 (Figure 2.1.2). The day-time TTTCCs at North Mucking were carried out during two six-hour periods over two different days. This was necessary because there were only eight hours of daylight available each day in winter. The mudflats at North Mucking became covered by water as early as three hours after low tide, and started to become exposed again four hours before low tide, potentially allowing seven hours of feeding for the birds (although this is dependent on the weather and tidal range). With the exception of Mallard and Redshank, considerably more birds were observed at the site on the latter day, during the ebb tide, than on the first day, during the flow tide (Figure 3.2.1.1). Table 3.2.1.1 shows the mean and peak numbers of the main waterbird species recorded during standard single monthly winter low-tide counts (made between November and February) carried out by Phil Shaw on behalf of PLA at North Mucking during winter 1999-2000, 2000-2001 and 2001-2002. The same table also shows the mean and peak numbers of birds at different size categories counted during standard single monthly winter low-tide counts, and during both day-time and night-time TTTCCs in 2002.

The peak count of Shelduck during day-time TTTCCs occurred two hours before low tide, with 73 present. This is similar to monthly counts from winters 1999-2000 and 2000-2001, with peaks of 75 and 85 respectively, but is lower than the mean and peak count made in the same winter (112 and 331 respectively).

Nearly 300 Avocet were recorded at North Mucking during the day-time TTTCCs, which is similar to the number of Avocets recorded by standard monthly counts made in the same winter, but far greater than the numbers recorded at the site on monthly low-tide counts in the previous two winters.

Grey Plover were abundant at North Mucking in winter 1999-2000, with a peak of 217 present. Numbers were much lower the following winter, with a maximum of 27 present. During the TTTCCs this winter, a peak of 83 was observed one hour prior to low tide, which is similar to the peak of 85 recorded by standard monthly counts in the same winter.

Dunlin numbers recorded during TTTCCs compared similarly with those recorded during monthly low-tide counts in the previous two winters but were much higher than numbers of Dunlin recorded by the standard monthly counts during the same winter (mean and peak of 1657 and 2489 respectively). As the tide receded, numbers built up to over 6,000 during the hour prior to low tide. Less than 1,000 were recorded,

however, during the first visit, covering the hours of the flow tide. Standard monthly low-tide counts during the last three winters ranged between 7 and 7,750 Dunlin at North Mucking.

Less than ten Curlew were recorded during winters 1999-2000 and 2000-01 at North Mucking during monthly counts, although up to 63 were counted in winter 2001-2002. During TTTCCs, 26 and 19 were observed during the two hours before low tide, and fewer than five were observed for the rest of the tidal cycle.

Monthly counts of Redshank in winters 1999-2000, 2000-2001 and 2001-2002 varied considerably, between nine and 368. During the TTTCCs, nearly twice as many were recorded with a peak of 635 occurring two hours before low tide. Redshank numbers were similar between the two observation periods covering the ebb and flow tides, although very few birds were observed feeding during the first period (flow tide), and there was a notable decrease in numbers observed an hour either side of low tide, when birds were probably feeding and roosting out of sight in creeks. This pattern is typical for TTTCCs of this species.

Night-time counts of large, medium and small sized birds during each hour of the tidal cycle are shown in Figure 3.2.1.2. These are plotted against the counts of the main species of birds observed at North Mucking during the day-time counts, consolidated into large, medium and small birds for comparison. Large birds, comprising Shelduck, Avocet, Curlew and Mallard for North Mucking, were mainly observed from one hour before low tide until the tide came in. The maximum number counted was similar to the numbers observed during day-time TTTCCs, but occurred at low tide rather than during the ebb tide. Medium birds, comprising mainly of Redshank and Grey Plover, were present in similar numbers to those recorded during the day. However, in contrast to the day-time counts, more were recorded over the low-tide period rather than during the ebb and flow tides. The number of small birds observed at night, which consisted principally of Dunlin, but also Ringed Plover, was considerably lower than the number recorded at the site during the day, especially in the hours prior to low-tide.

3.2.2 Central and South Mucking

The Central Mucking and South Mucking count sites for the night-time TTTCCs represent Zones 2, 3 and 4 of the standard monthly winter low-tide counts carried out by Phil Shaw on behalf of PLA in 1999-2000, 2000-2001 and 2001-2002 (Figure 2.1.2). Table 3.2.2.1 shows the summed mean and peak counts of the main waterbird species during the last three winters. Table 3.2.2.1 also shows the mean and peak summed counts of large, medium and small waterbirds at South and Central Mucking during the standard monthly winter counts and during the night-time TTTCCs. Figure 3.2.2.1 shows how the numbers of large, medium and small birds varied across the tidal cycle at night at both South and Central Mucking.

The maximum number of large birds recorded during the night-time TTTCCs, including Shelduck, Mallard, Oystercatcher, Avocet, Black-tailed Godwit and Curlew, was well below the peak numbers recorded during standard monthly day-time counts in 1999-2000, 2000-2001 and 2001-2002. However, the mean monthly counts for the last three winters varied considerably, and the peak number recorded during the night-time TTTCCs was similar to the mean of the standard monthly winter counts in 2001-2002.

The maximum number of medium sized birds recorded during the night-time TTTCCs, including Redshank and Grey Plover, was similar to the peak count recorded by standard monthly day-time counts in 2001-2002 and well above the mean figure from the standard monthly day-time counts of the last three winters.

As with North Mucking, the maximum number of small birds recorded during the night-time TTTCCs, consisting mostly of Dunlin, but also Ringed Plover, was much lower than the peak and mean numbers recorded during the standard monthly day-time counts during winters 1999-2000, 2000-2001 and 2001-2002.

During the night-time TTTCCs at South Mucking, the highest number of birds was present during the ebb tide, with numbers recorded decreasing towards low tide (Figure 3.2.2.1). Numbers of large and medium birds remained low as the tide came back in, but a peak in the number of small birds occurred again three hours after low-tide. At Central Mucking, the number of large and medium-sized birds remained fairly

constant during much of the cycle that the mud was exposed. A peak in the number of small birds occurred two hours before low tide.

3.2.3 Holehaven Creek

The Holehaven Creek site for the night-time TTTCC represents part of zone 3 of the standard monthly winter low-tide counts carried out by Phil Shaw on behalf of PLA at Holehaven Creek in 2001-2002 (Figure 2.1.2). Table 3.2.3.1 shows the mean and peak counts of the main waterbird species recorded by standard monthly winter low-tide counts in zone 3 in 2001-2002. Table 3.2.3.1 also shows these counts consolidated into size categories for comparison with the peak counts of large, medium and small waterbirds recorded during the TTTCC. The numbers of large, medium and small waterbirds recorded during each hour of the tidal cycle during the night-time TTTCC at Holehaven Creek are shown in Figure 3.2.3.1. The number of large and small birds recorded during the night-time TTTCC was much lower than the mean and peak counts recorded in zone 3 of the standard monthly winter low-tide counts. However, the number of medium-sized birds recorded during the night-time TTTCC was twice the number recorded by standard winter low-tide counts. During the TTTCC at Holehaven Creek the highest number of birds recorded occurred during the third hour before and after low-tide, with many fewer being recorded at low-tide. Numbers of small birds were particularly low for much of the tidal cycle, but a small flock of over 200 was present three hours after low-tide.

4. DISCUSSION

For large-scale and high-profile developments, it is essential that potential impacts on the surrounding environment and species are fully examined. The main objective of this study was to provide a preliminary assessment of day-time and night-time through-the-tidal-cycle counts (TTTCC) at Mucking Flats and part of Holehaven Creek. Some discussion about the number and distribution of birds at the different sites at different stages of the tidal cycle is possible, but firm conclusions cannot be made on the basis of one TTTCC at each site.

The day-time counts at North Mucking show that there is considerable variability in the number of birds present at different stages of the tidal cycle. Considerably more birds of each species were recorded during the ebb tide than during the flow tide. A possible explanation for this is that the mudflats become exposed slightly earlier than at Central and South Mucking and birds moving out of their high-tide roosts initially utilise this site, before moving to the other sites. Without more TTTCC information for this and other sites, this can only be treated as speculation. Alternatively, it may be an artefact of the data, as they were collected on two different days. The birds may use different sites on different days depending on the weather, or because of variation in the availability of food or variation in the level of disturbance.

The mudflats at Mucking are shelf-like, so the tide flows and recedes rapidly before and after high tide. At the lower stages of the tide, a steep shelf is exposed near the water-line, which is not visible from the sea wall. It was noticeable that relatively few birds were recorded around the low-tide period, which may be due to many birds no longer being detectable from the observation points, as they fed or roosted along the shelf near the water-line, or in the deep creek present at the west end of the North Mucking mudflat, rather than being absent from the site.

The numbers of most species recorded during the day-time TTTCC were similar to numbers recorded by standard monthly counts in the last three winters. However, as expected from counting the birds throughout the tidal cycle, the maximum number recorded for some species was much higher. Approximately twice as many Redshank were recorded at the site during TTTCCs than by standard counts in the last three winters.

As single nocturnal and diurnal TTTCCs were carried out at North Mucking, it is possible to make some comparisons between the numbers of birds recorded during the day-time observations and night-time observations. The maximum numbers of both medium and large-sized birds were similar between the day and night counts, but occurred at a different stage of the tidal cycle. Peak numbers during the night occurred at low-tide, when, during the day, fewest birds were recorded. It is possible that birds remained on the large, flat expanses of the mud during low-tide at night, instead of moving to the steep shelf at the edge of the mudflat, possibly because the risk of aerial predation is lower at night. Another possible explanation is that some of the substantial number of gulls present, which generally seemed to congregate in large flocks on the river or at the water-line, moved onto the flat expanses of mud. Although gulls were not counted either during the day or at night, as the number present was so large and variable, some could have been mis-identified as waders during night-time counts. Great Black-backed, Lesser Black-backed and Herring Gulls would be classed as large-sized birds while Common and Black-head Gulls would be classed as medium-sized birds.

The large counts of small birds at all three Mucking sites at night generally involved flocks of birds, most likely to have been Dunlin, observed when they were fairly close to the sea wall. Very few small birds were recorded at greater distances from the sea wall. It is likely that they were present, but not detectable with the thermal imager. The peaks and troughs in numbers at each site may therefore represent times when flocks were close to and distant to the observer, rather than their presence and absence at a site. As the numbers recorded during the night were considerably lower than those recorded during the day, at all three Mucking sites, it strongly suggests that small birds of Dunlin and Ringed Plover size are not detectable beyond a certain distance with the thermal imager. However, there is obvious movement of birds, especially Dunlin, between the sites. It was generally thought that birds moved from North to Central to South Mucking as the tide covered the mudflats, and flocks of birds rested near the sea wall at South Mucking before moving elsewhere to roost.

The consistency of counts of large- and medium-sized birds at Central and South Mucking and their similarity to the standard day-time counts of the same winter suggest that most, or all, of each species in these groups were being detected. It also suggests that there was little movement of birds of this size between the sites.

The night-time TTTCCs at Holehaven Creek covered only part of one of the sectors counted for the Holehaven Creek standard day-time counts. The maximum numbers of large and small birds recorded during the night-time TTTCC were much lower than those recorded during standard monitoring day-time low tide counts during the same winter, probably because of reduced detectability of birds at night and that only part of the count area was covered compared to the standard day-time counts. To gain complete coverage of this most seaward sector, two observers would be required to count from either side of the mouth of the creek.

4.1 Conclusions

The thermal imager provided a much better indication of the number of birds present at each site than the image intensifier, although species could not be determined, unless they were close to the observer (within approximately 50m). With the pitted, rippled, stony substrate typical of intertidal areas and interference from surrounding light sources, such as the nearby refinery, the image intensifier was ineffective in determining numbers of birds, as they were hard to define beyond about 100m from the observer. With more advanced technology available and lenses with higher magnification than the one used during this study, it may still be possible to use an image intensifier to count waterbirds at Mucking Flats and Holehaven Creek. This might allow birds to be determined to species. The thermal imager was also affected by surrounding heat sources, such as the refinery, but seemed to provide a good indication of the number of large and medium-sized birds at each site. This included birds of size and weight greater than a Redshank. The presence of gulls on the intertidal areas may have caused an overestimation of the number of waterbirds of medium and large size. Smaller birds, such as Dunlin and Ringed Plover could not be resolved at long distances (>200-300m), but were visible closer to the observer.

TTTCCs provided evidence that there is movement of birds between the sites at Mucking Flats across the tidal cycle. Ideally, the relative importance of the different intertidal areas should, therefore, be determined by this counting approach, rather than single monthly counts carried out consistently at the same stage of the tidal cycle. Although there was no strong evidence that birds used different areas for feeding during the day and during the night, it is possible that they used the parts of each count site differently during the day and during the night at different stages of the tidal cycle.

In summary, the viewing distances involved reduce the accuracy and value of night-time observations of birds at the sites, but the approach provides some indication as to the overall number of birds (particularly larger species) using the intertidal areas at night. Day-time TTTCCs would provide a fuller picture of bird usage of the different sites over the course of a tidal cycle, if carried out regularly during the winter and passage periods. This report has shown that during a single set of night-time counts carried out in January/February 2002, there appeared to be a good relationship between the numbers of large- and medium-sized waterbirds using North Mucking during the day and at night, and that waterbirds were using the remainder of Mucking Flats at night. The relationship between day-time and night-time counts is very important. If shown to hold true for the whole of Mucking during a complete winter it would demonstrate that day-time counts are sufficient to assess the overall usage made by waterbirds of the Mucking intertidal area both day and night. Thus for Mucking, but not necessarily for other areas, it would be unnecessary to carry out further night-time counts. It is therefore recommended that a set of monthly night-time counts are carried out for a complete winter (September to March) to confirm this important result.

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DATE & Low-tide height (m)	TIME																							
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Wed																				20.26				
30 Jan														-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4
0.4/0.7																	<----------NORTH MUCKING-------							
Thurs									09.07												21.09			
31 Jan	+5	HI	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-6	-5	-4	-3	-2	-1	0	+1	+2	+3
0.2/0.6	->								<---NORTH MUCKING-->												<-SOUTH MUCK-			
Fri										09.52												21.49		
1 Feb	+4	+5		-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-6	-5	-4	-3	-2	-1	0	+1	+2
0.2/0.6	ING-->			<-NORTH																				
				MUCKING->																				
Mon												11.49												23.48
4 Feb	+2	+3	+4	+5	HI	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-6	-5	-4	-3	-2	-1	0
0.6/1.0																		←-SOUTH MUCKING-→						
Tue													12.36											
5 Feb	+1	+2	+3	+4	+5	HI	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-6	-5	-4	-3	-2	-1
0.9																			<----------CENTRAL					
Wed	00.39													13.36										
6 Feb	0	+1	+2	+3	+4	+5	HI	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-6	-5	-4	-3	-2
1.3/1.2	MUCKING---------->																			<----------HOLE-				
Thurs		01.45													14.50									
7 Feb	-1	0	+1	+2	+3	+4	+5	HI	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5				
1.5/1.4	-HAVEN---------->								<--NORTH MUCKING-->															

Table 2.2.1 Coverage of TTTCCs at the four sites at Mucking Flats and Holehaven Creek during January and February 2002. shaded areas represent hours of night. Dotted lines represent hours of counts.

Size category	Species	Approximate length (cm)	Approximate weight (g)
Large	Shelduck	58-67	1080
	Mallard	50-65	1080
	Oystercatcher	40-45	500
	Avocet	42-45	330
	Black-tailed Godwit	40-44	300
	Curlew	50-60	770
Medium	Grey Plover	27-30	200
	Redshank	27-29	130
Small	Ringed Plover	18-20	60
	Dunlin	16-20	50

Table 3.1.1 Approximate size and weight measurements of the waterbird species considered. Data taken from Brough (1983) and Cramp & Simmons (1977, 1980).

		By species							By size category							
		Standard monthly counts						TTTCC	Standard monthly counts						TTTCC	
		1999-2000		2000-2001		2001-2002			1999-2000		2000-2001		2001-2002			
Size category	Species	mean	peak	mean	peak	mean	peak	day-peak	mean	peak	mean	peak	mean	peak	day-peak	night-peak
Large	Shelduck	40	75	46	85	112	331	73	115	194	222	350	497	960	389	341
	Mallard	18	73	172	256	35	120	107								
	Oystercatcher	1	2	0	0	1	2	1								
	Avocet	33	85	0	0	160	375	294								
	Black-tailed Godwit	19	53	0	0	151	470	0								
	Curlew	4	8	4	9	40	63	26								
Medium	Grey Plover	140	217	8	27	28	85	83	256	315	172	368	381	454	693	720
	Redshank	116	265	164	368	353	395	635								
Small	Ringed Plover	30	74	4	14	0	1	9	5070	7791	3180	7664	1657	2489	6258	1907
	Dunlin	5040	7750	3177	7650	1657	2489	6258								

Table 3.2.1.1 Standard winter day-time mean and peak monthly low-tide counts of the main waterbird species and different sized waterbird groups at North Mucking (equivalent to Zone 1 in Figure 2.1.2) in 1999-2000, 2000-01 and 2001-02, and the peak day-time and night-time TTTCCs of the main waterbird species and different sized waterbird groups at North Mucking in January/February 2002. Numbers are rounded to the nearest integer.

		By species						By size category						
		Standard monthly counts												TTTCC
Size category	Species	1999-2000		2000-2001		2001-2002		1999-2000		2000-2001		2001-2002		2002
		Mean	Peak	Mean	Peak	Mean	Peak	Mean	Peak	Mean	Peak	Mean	Peak	Peak
Large	Shelduck	240	582	77	107	209	371	1088	2249	396	1160	689	1539	746
	Mallard	42	94	45	177	77	260							
	Oystercatcher	1	5	4	9	2	7							
	Avocet	478	951	269	861	322	708							
	Black-tailed Godwit	297	560	0	0	68	159							
	Curlew	30	57	2	6	12	34							
Medium	Grey Plover	45	143	114	187	176	508	729	1480	360	701	429	972	1009
	Redshank	684	1337	246	514	253	464							
Small	Ringed Plover	3	7	31	76	53	178	4823	7469	7714	8403	8731	11803	2048
	Dunlin	4820	7462	7683	8327	8678	11625							

Table 3.2.2.1 Standard winter day-time mean and peak summed monthly low-tide counts of the main waterbird species and different sized waterbird groups at South and Central Mucking (equivalent to zones 2, 3 and 4 in Figure 2.1.2) in 1999-2000, 2000-01 and 2001-02, and the peak night-time TTTCCs of the different sized waterbird groups at South and Central Mucking in January/February 2002. Numbers are rounded to the nearest integer.

		By species		By size category		
Size category	Species	2001-2002 standard counts				TTTCC 2002
		mean	peak	mean	peak	night-peak
Large	Shelduck	80	170	876	1007	99
	Mallard	47	121			
	Oystercatcher	4	7			
	Avocet	0	0			
	Black-tailed Godwit	316	620			
	Curlew	430	790			
Medium	Grey Plover	10	22	74	133	266
	Redshank	64	133			
Small	Ringed Plover	0	0	4216	6500	212
	Dunlin	4216	6500			

Table 3.2.3.1 Standard winter day-time mean and peak monthly low-tide counts of the main waterbird species and different sized waterbird groups at Holehaven (equivalent to Zone 3 in Figure 2.1.2) in 2001-02, and the peak night-time TTTCCs of the different sized waterbird groups at Holehaven in January/February 2002. Numbers are rounded to the nearest integer.

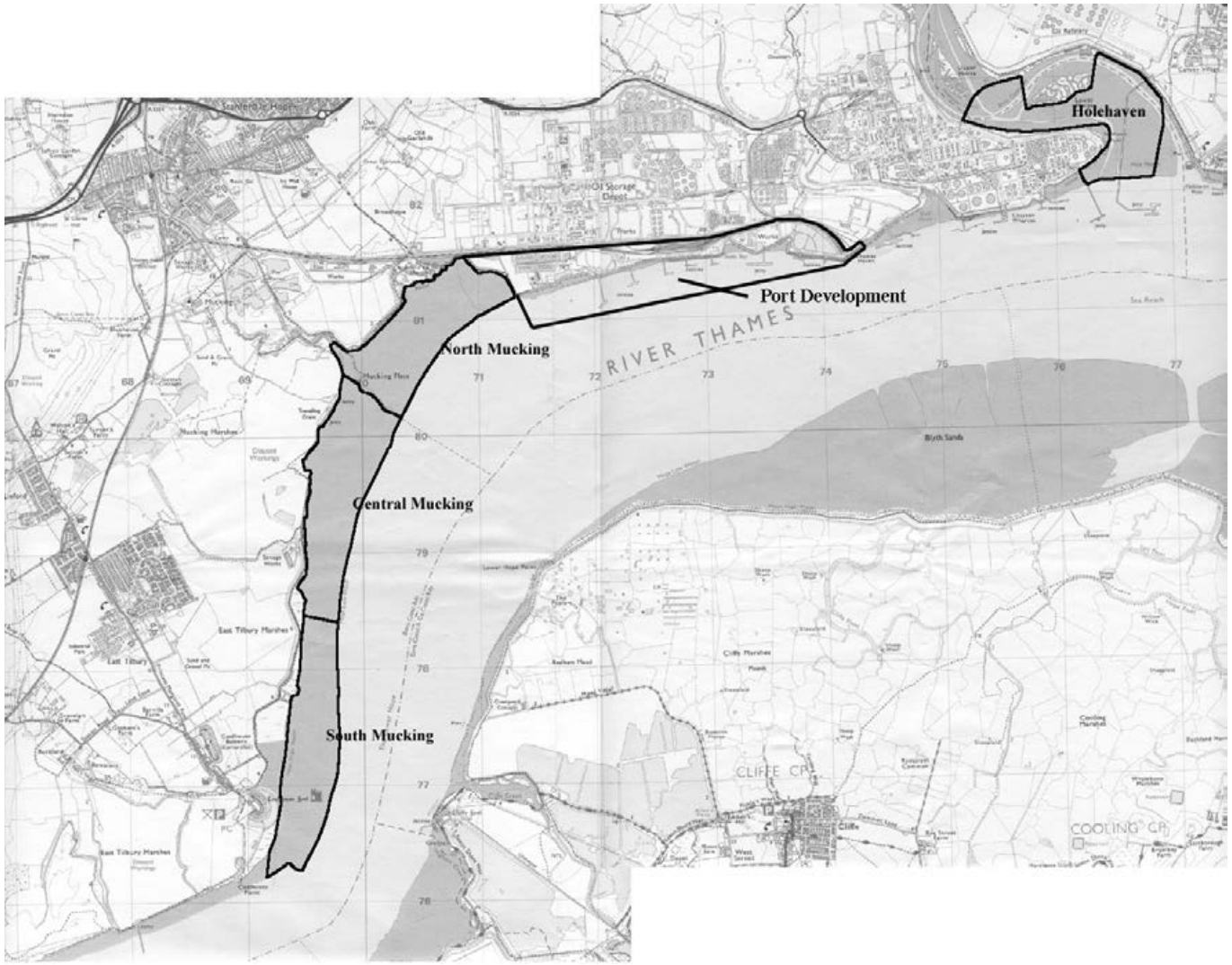
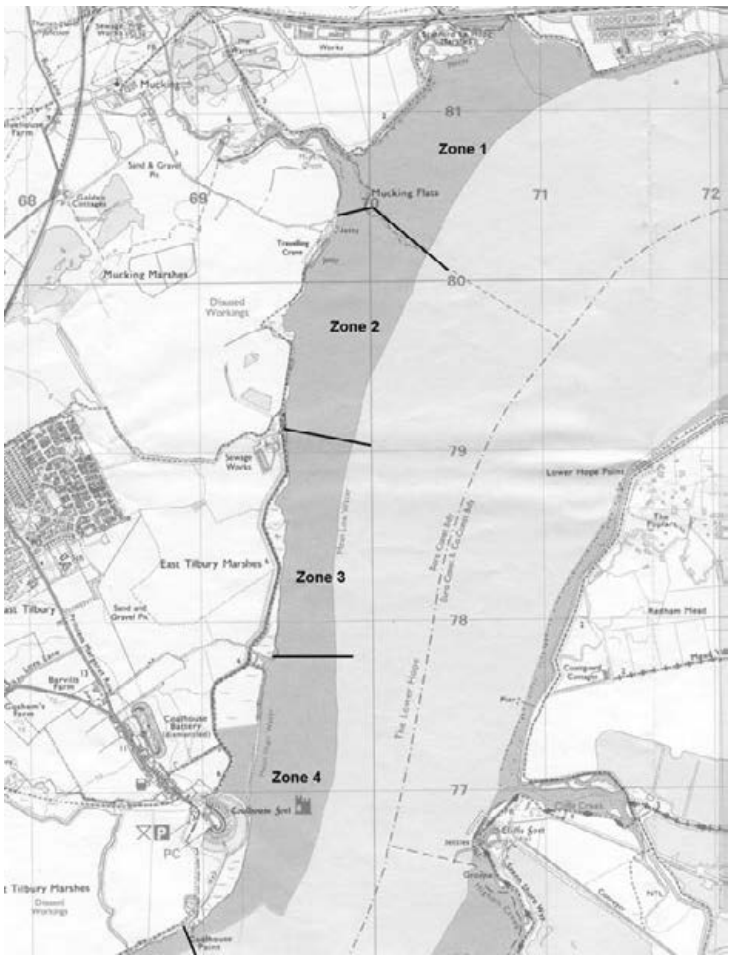


Figure 2.1.1 Map of the study area showing the count sections at Mucking Flats and Holehaven Creek. Counts were made from the sea wall running along the west side of Mucking Flats and from the sea wall along the west side of Holehaven Creek from within the BP refinery. OS license no. AL50618A.

Mucking Flats



Holehaven

Figure 2.1.2 The corresponding count zones used by Phil Shaw for WeBS counts and low-tide counts on behalf of PLA at Mucking Flats and Holehaven Creek. OS license no. AL50618A.

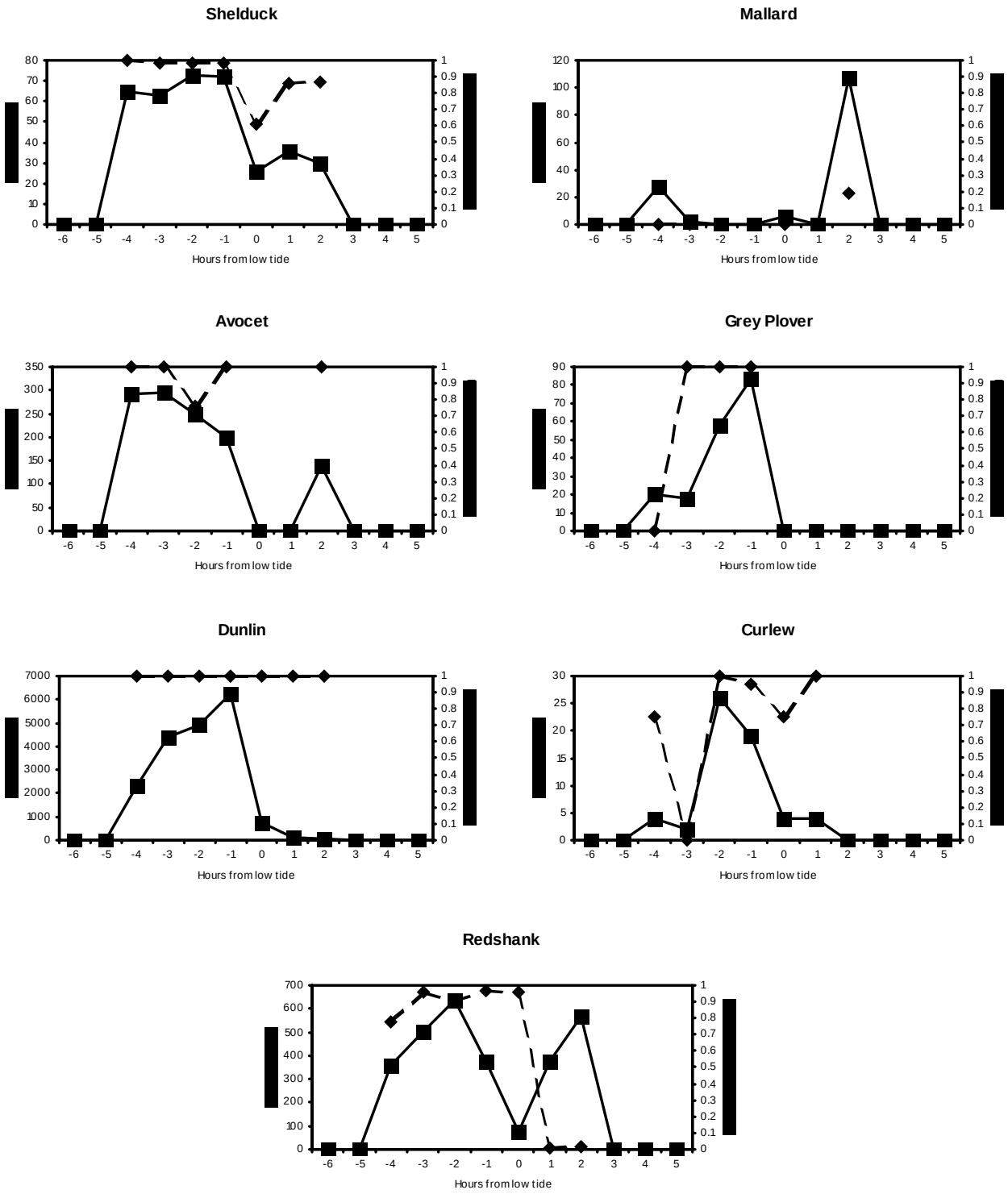


Figure 3.2.1.1 The number and proportion feeding of Shelduck, Mallard, Avocet, Grey Plover, Dunlin, Curlew and Redshank recorded for each hour of the tidal-cycle during the day-time counts at North Mucking. Note that different scales are used on each graph. Number present: solid line/square points. Proportion feeding: dashed line/diamond points. Low-tide is represented by 0.

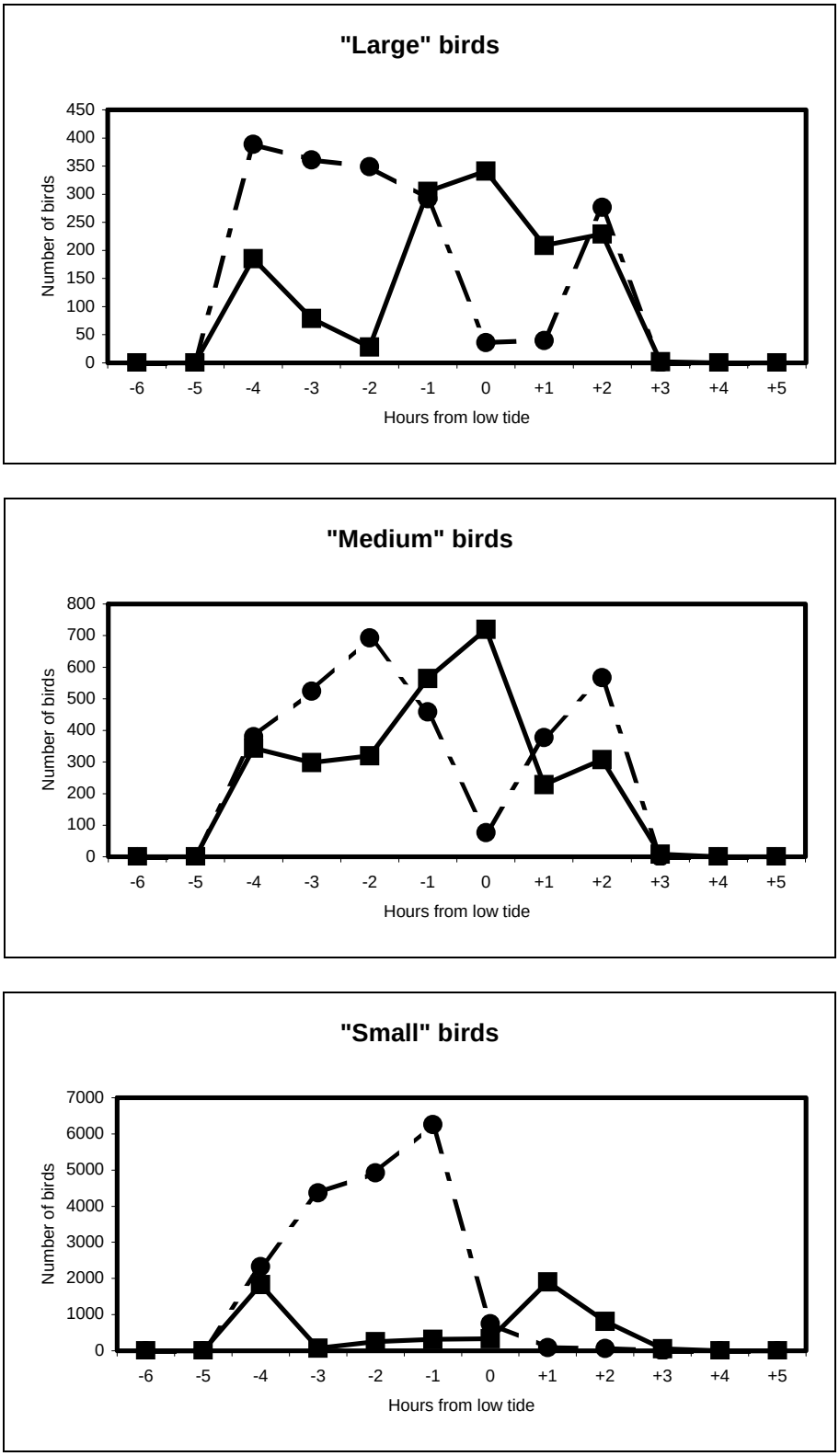
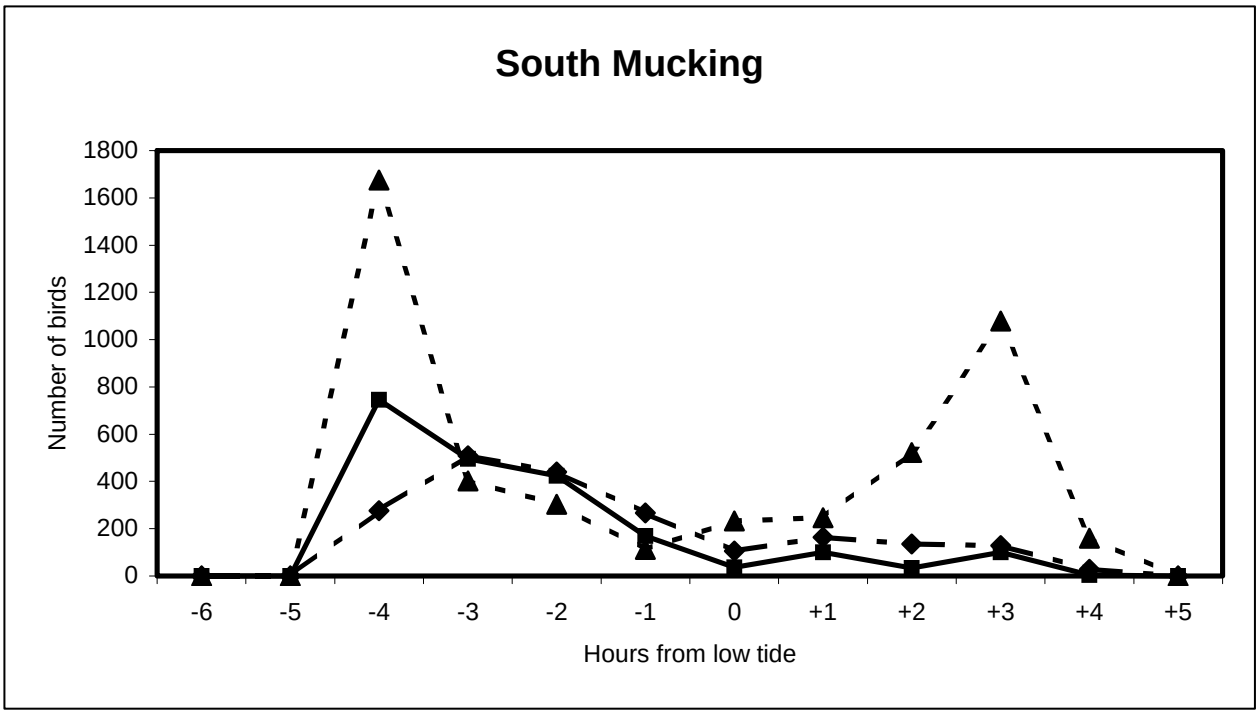


Figure 3.2.1.2 Comparison between day-time and night-time TTTCCs of large (Shelduck, Mallard, Oystercatcher, Avocet, Black-tailed Godwit & Curlew), medium (Grey Plover & Redshank) and small (Ringed Plover & Dunlin) waterbirds at each hour of the tidal cycle at North Mucking. Night-time: solid line/square markers. Day-time: dotted line/round markers. Low-tide is represented by 0.



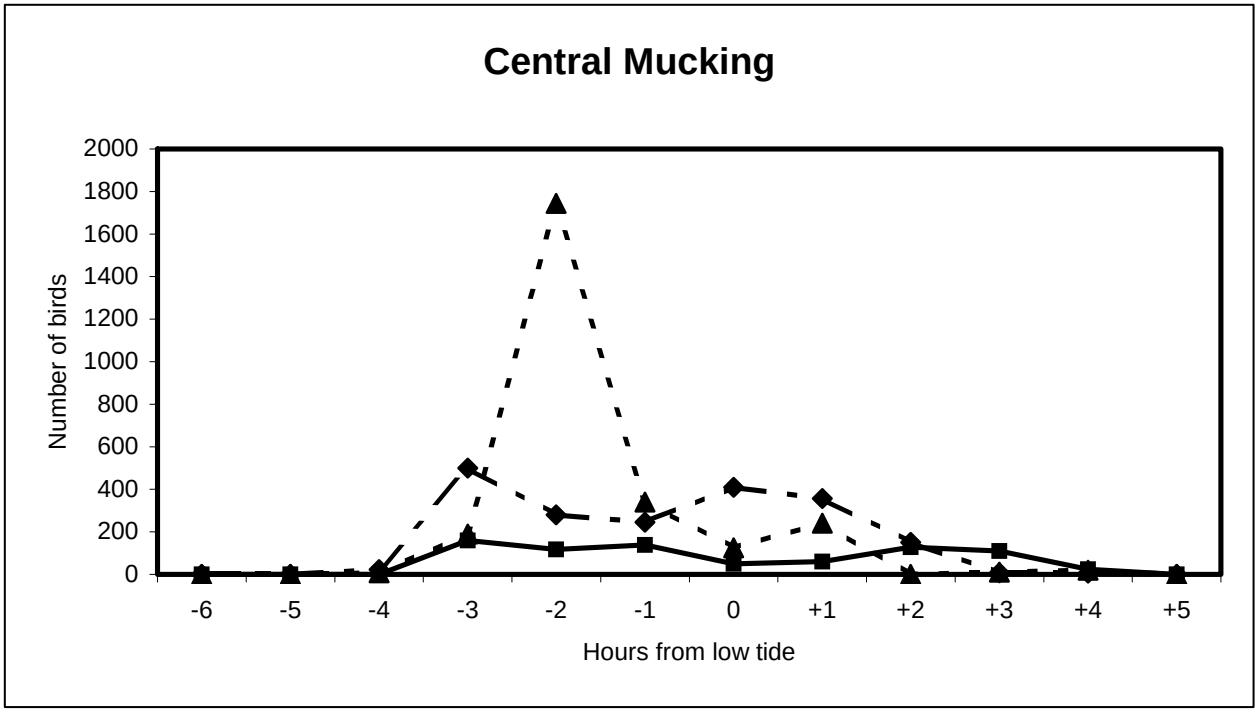


Figure 3.2.2.1 The number of large, medium and small waterbirds observed at South and Central Mucking during each hour of the night-time TTTCCs. Large: solid line/square points. Medium: dot-dash line/diamond points. Small: dotted line/triangular points. Low-tide is represented by 0.

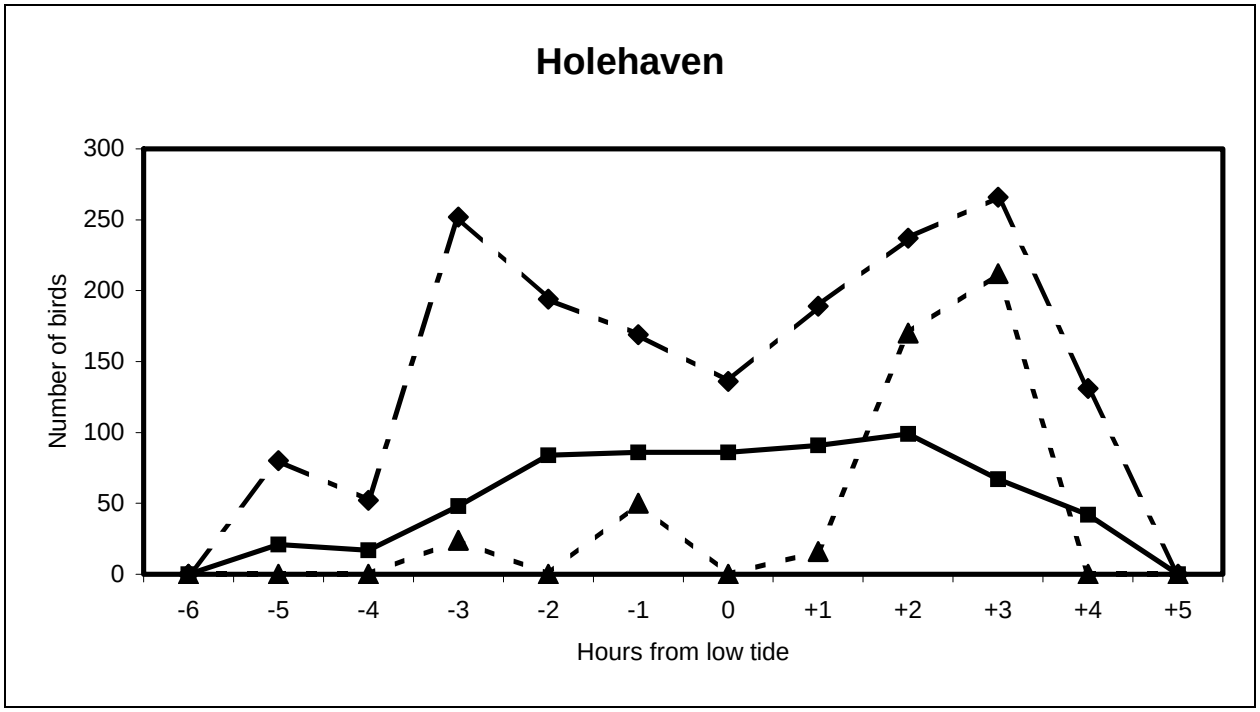


Figure 3.2.3.1 The number of large, medium and small waterbirds observed at Holehaven Creek during each hour of the night-time TTTCCs. Large: solid line/square points. Medium: dot-dash line/diamond points. Small: dotted line/triangular points. Low-tide is represented by 0.