Natural England Commissioned Report NECR017

Comparison of the abundance and distribution of birds along the northern shore of Poole Harbour by day and by night

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Most surveys of overwintering shorebirds eg the Wetland Bird Survey (WeBS) are conducted during the hours of daylight. Our understanding of the relative importance of areas of intertidal habitat, based on daytime observations, may not represent their relative importance at night particularly as human activity in the day may reduce bird numbers in areas that are otherwise highly suitable and are used extensively at night when human activity is reduced.

When assessing the impact of plans or projects on the bird interest features of designated sites there is a risk that the apparent impact on areas of the shore which are little used by birds during the day may underestimate the actual impact if birds use the areas in question more at night.

The northern shore of Poole Harbour has been heavily developed and is under considerable human pressure. An analysis of WeBS data has revealed that bird numbers along many sectors of this shoreline are lower than expected for the available area of intertidal habitat.

This study was commissioned to compare bird abundance and distribution during the night and the day. In particular the aim was to identify any areas of the northern shore of Poole Harbour which are used more at night than in the day.

The results indicate that in general, along the northern shore of Poole Harbour, daylight surveys are a reliable indicator of habitat usage at night.

This may not apply in other sites but, it means that future assessments of the potential impact of plans or projects on the usage of the northern shore of the harbour by birds, which are based on daylight bird survey data, are unlikely to be too far wrong.

However, the results highlight a few species (dunlin, ringed plover, grey plover, snipe and jack snipe) for which daylight surveys do not represent well the night-time patterns of usage. Natural England will take care to ensure that the assessment of any future plans or projects that might impact on these species, considers their nocturnal habitat requirements.

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Further information
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Summary

The northern shore of Poole Harbour has been heavily developed and is urban in character, supporting a high human population. As such the area is under considerable human pressure. An analysis of WeBS counts data between 1991 and 1998 revealed that counts of birds along many sectors of this shoreline are lower than might be expected on the basis of the available feeding area of intertidal habitat. However, such counts are conducted during the day time, when disturbance may cause birds to avoid the shoreline. This work was therefore commissioned by Natural England in order to enhance the understanding of the importance and use of the northern shore of Poole Harbour.

We explore the distribution and abundance of various bird species along the northern shoreline of Poole Harbour during the night time and the day time.

The key findings of this survey were as follows:

- A total of 31 bird species were recorded, 25 of which occurred both during the day and night.
- Overall, there were significantly more waders, waterfowl and gulls present during daylight than at night.
- The only group of birds largely absent at night were gulls, which tended to roost off-shore at night.
- Three areas were more heavily used (total number of birds recorded) at night than during the day: Blue Lagoon, Baiter foreshore and the area of beach / marsh / reeds at the top of Whitley Lake.
- Waders tended to be present at reduced densities at night, with the exception of dunlin, grey plover and ringed plover which were more abundant at night.
- There were three nights when the number of waders (total count data) was higher in the night than during the preceding day.
- Dunlin were notable, with reasonably large flocks present during the night at Parkstone Bay and within Whitley Lake, both areas in which they were not recorded during the day.
- Ringed plovers were recorded during the day, but virtually always in roosting flocks, and in very few locations. At night they were more widely distributed, feeding in small groups / pairs.
- Two species, jack snipe and snipe were recorded only at night.
- Holes Bay and Blue Lagoon held the highest numbers of birds during the day and at night. In general, areas along the northern shore that held more birds during the day than others were also relatively well used at night.
- Recreational use of the shore by people included a range of activities, such as canoeing, kite surfing, para-sailing, windsurfing, dog-walking, fishing and bait digging. The distribution of each of these activities varied and different activities occurred at different times.
- The numbers of people peaked at weekends and was significantly greater during daylight than at night. There was, however, considerable human activity at night.
- There was some evidence that areas that are heavily used by people during the day are also relatively heavily used at night.
- Evidence of a negative association between bird usage and human activity levels on the northern shore of the harbour is mixed.

The key conclusions of this study are as follows:

- Daytime bird surveys of the north shore will underestimate usage of those areas by jack snipe, snipe, dunlin, ringed plover and grey plover.
- Assessment of the relative importance of the various parts of the north shore in terms of bird usage as assessed during daylight is, however, unlikely to significantly misrepresent their relative importance at night.
- However, daytime bird surveys risk underestimating the overall usage of Blue Lagoon, Baiter foreshore and the area of beach at the top of Whitley Lake.
- Surveys aimed at estimating the importance of parts of the northern shore in terms of bird usage should be timed to avoid periods of intensive human activity.

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1 Introduction

1.1 This report explores how the distribution and abundance of various bird species within Poole Harbour changes with the time of the day, and in particular between the night time and the day time. We focus on the northern shore of the Harbour. This shoreline has been heavily developed and is urban in character, supporting a high human population. As such the area is under considerable human pressure. An analysis of WeBS counts data between 1991 and 1998 revealed that counts of birds along many sectors of this shoreline are lower than might be expected on the basis of the available feeding area of intertidal habitat (Caldow et al., 2005). However, such counts are conducted during the day time, when disturbance may cause birds to avoid the shoreline. This work was therefore commissioned by Natural England in order to enhance the understanding of the importance and use of the northern shore of Poole Harbour. Repeat, standardised counts were made at a series of locations along the shoreline. The counts took place on different days of the week and at different times of day (including the middle of the night), throughout the winter period. The aims of this work are to compare the nocturnal and diurnal use of the northern shoreline by key species associated with Poole Harbour Special Protection Area.

1.2 Poole Harbour is designated as a Site of Special Scientific Interest (SSSI) a Ramsar site and an SPA European Marine Site. Under Article 4.1 of the Birds Directive, Poole Harbour is of European importance for breeding common tern *Sterna hirundo*, and Mediterranean gull *Larus melanocephalus,* passage aquatic warbler *Acrocephalus paludicola* and little egret *Egretta garzetta*, and wintering avocet *Recurvirostra avosetta* and little egret (JNCC 2001). Under Article 4.2, the Harbour also supports internationally important wintering populations of the Icelandic population of black-tailed godwit *Limosa limosa* and the North-western European population of wintering shelduck *Tadorna tadorna*. It is also a wetland of international importance by regularly supporting at least 20,000 waterfowl. These include six wader species, four species of duck, dark-bellied Brent goose *Branta bernicla bernicla*, red-breasted merganser *Mergus serrator* and cormorant *Phalacrocorax carbo* as well as lesser numbers of other species.

1.3 The conservation objectives for Poole Harbour include the maintenance in favourable condition of the shallow inshore waters, intertidal sediment communities, saltmarsh and reedbed for the internationally important populations of regularly occurring Annex I and migratory bird species and the internationally important assemblage of waterfowl.

1.4 There is a considerable amount of data on the birds of Poole Harbour. Work funded by BP Ltd. and conducted by the RSPB in the mid 1980s provides useful context (Collins, 1985; 1986). The Harbour is surveyed annually as part of the national Wetland Bird Survey (WeBS). These data have been collated and analysed to provide comparative assessments of the important bird species within Poole Harbour (Pickess & Underhill-day, 2002; Pickess, 2007). Dedicated surveys of roost sites within the Harbour were conducted by Morrison (2004), and detailed mapping and surveying of the invertebrates that are the main prey of the key bird species was conducted by CEH (Thomas et al., 2004), the latter work to provide a baseline against which future verification of favourable condition could be established. A condition assessment of the Harbour was conducted by Footprint Ecology in 2006 (Underhill-Day, 2006).

1.5 The bird data is summarised in the condition assessment (Underhill-Day (2006), which shows that populations of those bird species for which the harbour was designated as an SPA are mostly stable or increasing. Breeding numbers of common terns and Mediterranean gulls have been rising and the wintering populations of black-tailed godwits and avocets have also been increasing. Shelduck numbers have declined but at a lower rate than those nationally.

1.6 The distribution of waders within Poole Harbour is likely to be influenced by a variety of factors (Durell et al., 2006). Factors such as the distance from roost sites (Dias et al., 2006), human disturbance (West et al., 2002; Woodfield & Langston, 2004), prey density (Goss-Custard et al., 1995), prey availability (Pearce-Higgins & Yalden, 2003), interference (Goss-custard & Durell, 1987) and risk of predation (Whitfield, 2003) may all influence the spatial distribution of waders within an estuary. The relative importance of these factors will vary temporally and between sites.

1.7 WeBS data (see Pickess et al., 2002; Pickess, 2007 for summaries) show that the northern shore areas of Poole Harbour are not used as much as the southern shore by waders. Analyses of these data by Caldow et al (2005) showed that bird counts in many of the northern shore count sectors are lower than would be expected on the basis of the area of intertidal habitat exposed at low water of spring tides. The opposite was true of many of the count sectors on the southern shore of the harbour. The northern shore is much more heavily built-up and developed than the more rural and less accessible southern shore. The northern shoreline supports numerous access points, parks, marinas, jetties and shore-side development. Daytime disturbance on the northern shore could therefore be one reason for the apparent under use of the northern shore count sectors. Thus, Natural England are concerned that the value of the northern shore may be underestimated when the potential impacts of new development on the northern shore are assessed on the basis of daytime bird usage patterns.

1.8 Applications and development proposals relate to small proposals (individual properties, such as private jetties and slipways etc.) and also to much larger projects, such as the Full Sail Ahead development project (Hoskin et al., 2007). In order to accurately assess the likely significance of such applications it is essential that the importance of the northern shoreline is understood in context with the rest of the harbour. In particular, if this shoreline is used more heavily during certain stages of the tidal cycle for example, on the falling or rising tides, or in certain weather conditions (for example, cold snaps) or is used more at night than by day, then, these periods of usage must be recognised.

1.9 It is perhaps intuitive that how birds respond to disturbance depends on the circumstances. For example, Brent geese avoid highly disturbed sites when food is abundant (early in the season), but when food is limited they will use disturbed sites (Owens, 1977). By experimentally manipulating the amount of food given to turnstones *Arenaria interpres*, Beale (2004) was able to demonstrate that the same individuals responded differently to disturbance events depending on how much they had had to eat. The north shore could therefore be used by birds only when food is limited (for example during severe weather) and at such times it may be important. It may also be that differences in behaviour may account for the apparent under-use of the north shore. Birds can adjust their behaviour, increasing their intake rate (Stock & Hofeditz, 1997) in response to disturbance or using disturbed areas at quieter times, such as at night (Burger & Gochfeld, 1991). Work on the Severn Estuary (Burton & Armitage, 2005) has shown that redshank *Tringa totanus* used more sites and had larger home ranges at night than during the day. It is therefore possible that the apparent under-usage of many parts of the northern shore of Poole Harbour during daylight does not provide a true indication of the importance of this part of Poole Harbour to the bird populations for which the site as a whole has been designated.

1.10 Nocturnal surveys are rarely undertaken. Birds such as swans, geese, ducks, cranes and waders move around in flocks at night and there is a growing recognition that there is a need to know about such movement and activity of birds at night.

1.11 This work was commissioned by Natural England to inform their condition assessments of Poole Harbour and to inform how they respond to planning applications. The study compliments a series of other detailed ornithological studies of Poole Harbour (Collins, 1985; 1986; Liley, Pickess & Underhill-day, 2006; Morrison, 2004; Pickess et al., 2002; Pickess, 2007; Thomas et al., 2004), and will further our understanding of this internationally important site.

1.12 The following were the key questions we addressed:

1) Does the overall number (and density) of birds on the northern shore vary between night and day?
2) Does the distribution of birds differ between the night and day?

3) Does the overall level of human disturbance on the northern shore differ between night and day?
4) Does the intensity of human disturbance vary between different parts of the northern shore?
5) Can the difference in the distribution of birds between different parts of the northern shore between day and night be related to the difference in the distribution of disturbance between these same areas?
6) Does the distribution of human disturbance in different parts of the northern shore of Poole Harbour differ between the night and the day?

2 Methods

2.1 Two different methods were employed to measure bird usage of the intertidal habitats on the northern shore of the harbour: point counts from fixed locations and total counts of specific areas. The point counts allow density estimates to be calculated at varying distances from the observer and permits analyses which allows the different likelihood of detection between the day and the night to be estimated. Point counts were conducted in a standard fashion at comparable points along the shore. Each point was surveyed repeatedly in a series of paired visits, during the night and the day. The total counts were conducted for defined areas, such as small bays, parks and similar. The total counts included both people and birds, and allowed a greater proportion of the northern shore to be counted than could be done solely using the point count locations. While the point counts all involved comparable open shoreline habitats surveyed in a standard fashion, the count areas included various habitats such as salt marsh, shingle beach, improved grassland and open mudflat. The two approaches were tested during an initial pilot study and are described in detail below.

Point Counts

2.2 Thirteen locations along the northern shoreline were selected (Figure 1). Points were chosen so as to be independent survey points, at least 300m apart and / or separated from each other by breaks or changes in direction along the shoreline. Each point was easily accessible, ensuring that there were no problems with access in the dark and that each point could be reached quickly (this was essential as the tidal cycle limits the amount of survey time available). Each point was visited fifteen times during the day and fifteen times during the night. Day and night visits were paired, allowing direct comparison. Dates for visits usually coincided with spring tides where a comparable tidal cycle (that is, tide heights and duration) could be matched between the day and a subsequent night. As far as possible night and day counts were conducted at identical tide heights, ensuring direct comparison.

2.3 Point count locations were at least 300m apart; were located on the sea wall or top of the shore, and all had mudflats and potential feeding habitat for waders directly in front of the point.

2.4 The point count methodology followed the standard methods (following Buckland et al., 2001). Points were approached quietly and cautiously. The locations of any birds flushed when approaching the point was noted. At the start of each point count the time, weather, tide height, visibility and any potential causes of disturbance (people within 50m of the point, boat traffic, loud noises, dogs etc) were recorded. All birds were recorded, and every encounter assigned to a distance band. The following bands were used:

- 0-10m
- 10-20m
- 20-30m
- 30-40m
- 40-50m
- 50-75m
- 75-100m
- 100-150m
- 150-200m
- 200-250m
- 250-300m
- 300-350m

- 350-400m.

2.5 No records at any points were made beyond 400m. At some points the shape of the shore, presence of jetties etc and aspect of the point meant that only a limited area was available to the birds/visible to the observer. The recording area for each count band was therefore determined using aerial photographs. A hypothetical example is shown in Figure 2. The different distance bands can be seen as circles of increasing radii around the point. The area of mud flats is shown in grey, and the actual area of exposed mudflat within 400m of the point is hatched, this hatching representing the area actually surveyed in each point count.

2.6 Two methods were used to check distances. A laser rangefinder was used to determine the distance to individual birds and to key landmarks, visible from the point. In addition, aerial photographs (UKP aerial coverage provided under copyright by Natural England) were used and, within the GIS, the distance bands plotted as concentric rings, allowing a further means of checking the distance to key landmarks visible from the point.

2.7 Where large numbers of birds were present, such as large flocks, a total count was made of each species, and then the proportion of the total count within each distance band was estimated visually.

2.8 During the daytime counts only binoculars were used.

2.9 The ease with which birds could be seen during the night time visits varied between points and between nights, depending on the intensity of moonlight, background lighting, time of the visit and the amount of cloud cover. Various methods were used to detect birds at night and on most visits all methods were used in order to be confident that all birds had been recorded. As during daylight surveys, conventional binoculars with good light-gathering capabilities were initially used at night (Swarovski EL 8.5x42). The use of these was then complimented by using night vision equipment (Yukon Digital Night Ranger, 5x42), with infra-red illumination. These two methods allowed birds to be seen without disturbing them. Torches were also used. Following trials, battery powered maglites were found to be the most effective as more powerful torches tended to flush birds more readily. The maglites could be held alongside binoculars allowing the two to be used in combination. At one point (point 1), car-headlights were used when leaving the point to check no birds had been missed.

2.10 Identification of birds at night was facilitated by calls, size, shape and behaviour. For some species (such as oystercatcher *Haematopus ostralegus*, shelduck, pintail *Anas acuta* and ringed plover *Charadrius hiaticula*) the black and white patterns were visible through binoculars or the night vision equipment.

2.11 Where birds were heard at night during a point count but could not be seen, the species' presence was recorded, allowing species lists to be drawn up for each point, however no count or distance estimate was made, meaning that such encounters were not included in any estimates of density.

2.12 The use of a point count methodology, offered the following advantages:

- Distance estimates can be incorporated into the methodology, providing the potential to truncate the data at a later point or modify the areas included in the day / night comparison.
- The observer is stationary (facilitating the use of the night vision equipment, ease of hearing bird calls and safer at night- no need to watch steps and try and look for birds).
- Density estimates (with confidence limits) can be calculated.
- It is possible to model detectability using distance software and this will allow us to take into account birds that might be missed at night a long way from the observer.

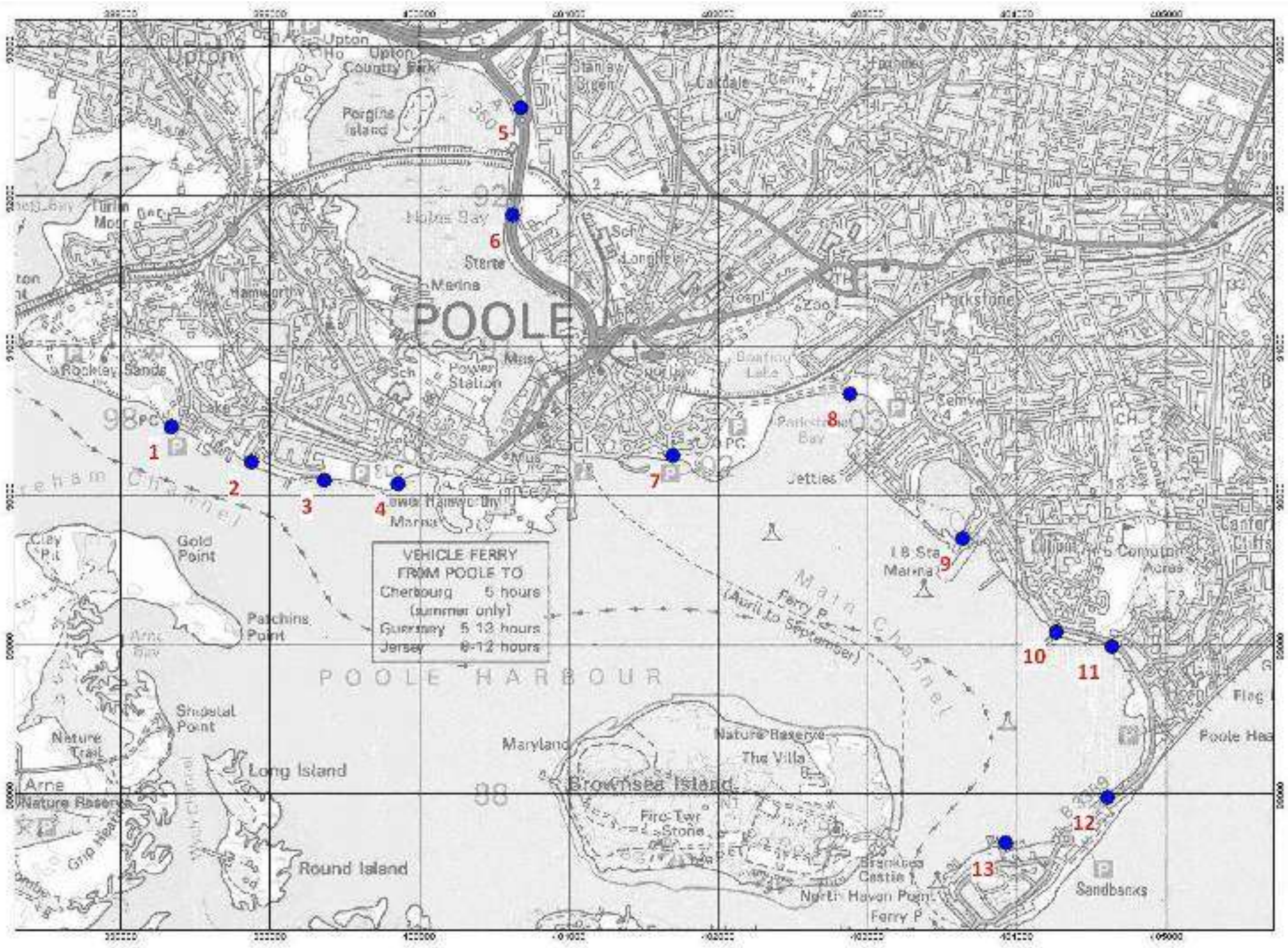

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Figure 1 Point count locations

Total Counts

2.13 The point count methodology was often time consuming, especially when many birds were present and each had to be ascribed to a distance band. Given this constraint, only a limited number of points could be accommodated within a given tidal cycle. There was, therefore, some concern that relying solely on point counts would mean that certain key areas of the northern shoreline would not be surveyed. The point count methodology is also potentially unsuitable where birds are thinly distributed at relatively low densities, as large numbers of locations are required to record the less common species.

2.14 Twelve specific areas were therefore mapped where total counts of birds within the boundaries of those areas could be made, either from a fixed location on the shore or by walking along the seawall (see Figure 3). These areas were typically different from the point count locations (usually on a shoreline with an extended area of mudflat directly in front of the point) and included:

- Discrete, narrow sections of beach, bays or similar.
- Breakwaters or storm beaches where birds were known to gather.
- Areas of grass / park adjacent to the seawall.

2.15 The count areas therefore included a wide range of habitats but all could be searched at night with confidence that birds were not being missed because they were far out on the mudflats.

2.16 The total counts were straight forward to conduct during the day; the area was scanned with binoculars and a total count of people and of each bird species within the area was made. For the night time visits a combination of methods was used. Night vision equipment, torches and binoculars were used to detect birds. Where calls were heard these also provided an indication of species' presence and their locations. By moving along the shoreline (as far as possible taking care not to push birds ahead), it was possible to get closer to any birds present and obtain a count.

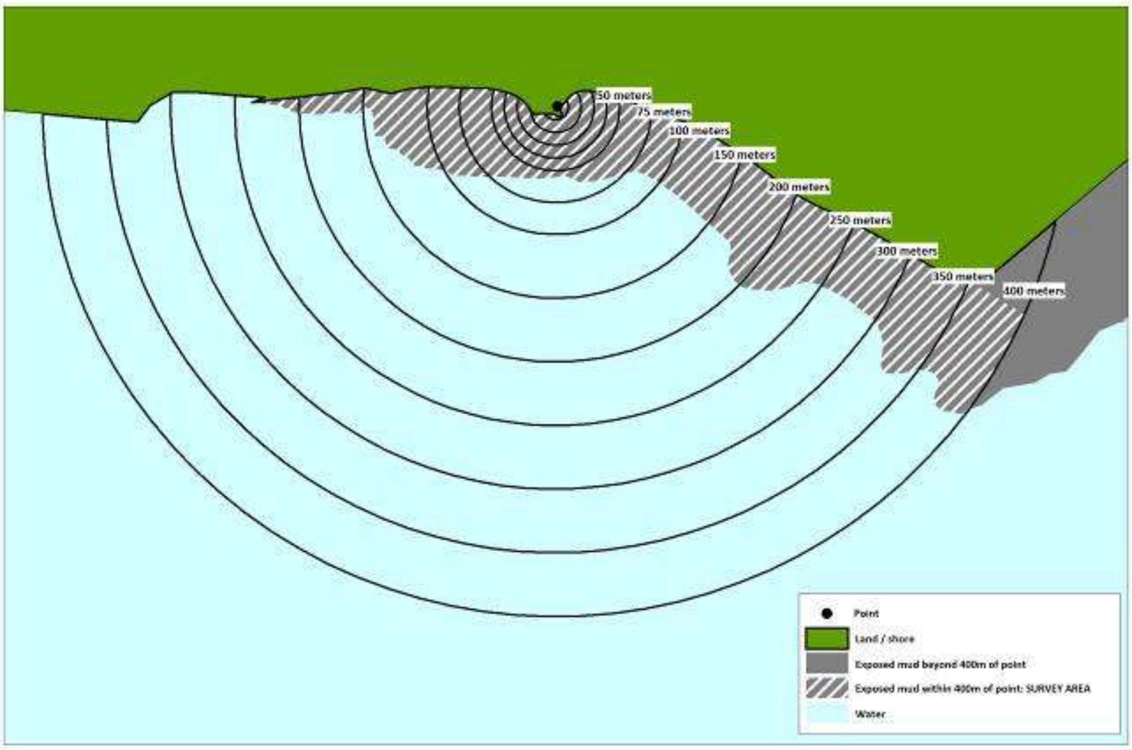


Figure 2 Hypothetical example of a point count

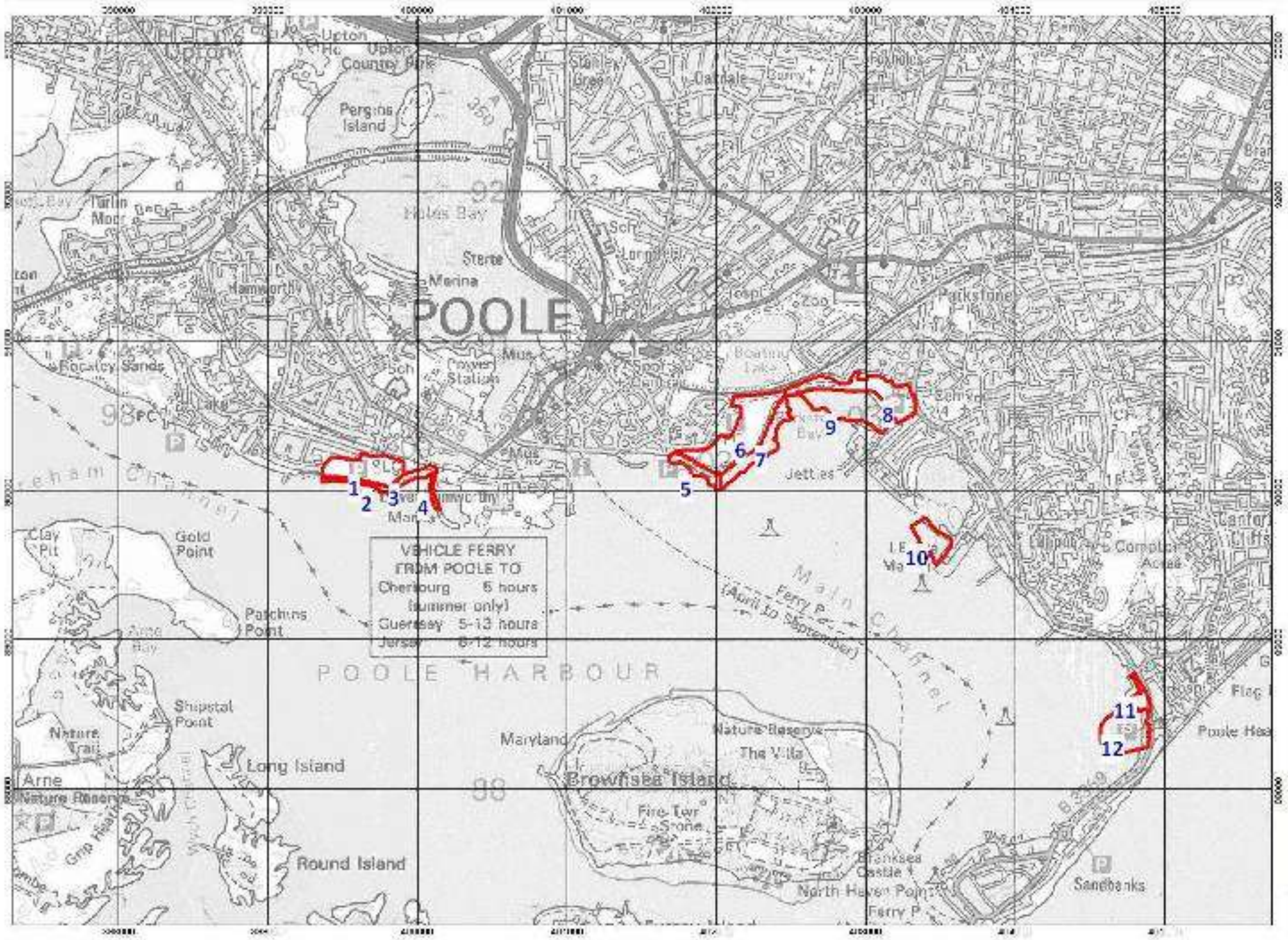


Figure 3 Total count areas

Data recording

2.17 Data were entered in the field using palm-top computers, the use of which removed the need to keep switching a torch on and off to write. For each point count the following summary information was collected:

Table 1 Summary information collected for each point count

Point Number	
Date	
Time	
Day / Night	
Tide state	Scored from 1 (very low) to 4 (tide high, no mud visible)
Visibility	Scored from 1 (very poor) to 4 (excellent).
Weather	Cloud cover, rainfall etc
Total people Sea Wall	Total number of people on sea wall within 50m
Total people Flats	Total number of people below sea wall within 50m
Total dogs	Total number of dogs within 50m
Bait diggers	Total number of bait diggers within 50m
Fishing	Total number of people fishing within 50m
Disturbance	Presence / absence of other potential forms of disturbance, including dogs running loose on mudflats, boats offshore with 100m, people launching boats, birds of prey in the area or loud noise / works taking place

2.18 For the point counts and total counts all species of wader, dabbling duck, swans, herons and gulls were recorded. No counts were made of grebes, diving ducks, mergansers, cormorants or passerines.

2.19 A separate spreadsheet was created for each point count on each visit. Each spreadsheet was in the form of a matrix, with a count for each species within each distance band. For the total counts a single count for each area on each visit was made. Besides the birds, the following were also recorded:

- Walkers
- Dog walkers total
- Dog walkers on mud flats
- Dogs total
- Dogs on mud flats
- Fishermen
- Bait diggers
- People on beach launching boats or similar
- Kite flyers
- Land surfers
- Joggers
- Cyclists
- Children Playing.

Analysis

2.20 The survey area (ha) for each point count location was determined using GIS, with polygons being drawn to indicate the visible area of mud at low tide within 400m of each point - that is, the area from which birds were recorded (see Figure 2). The area of mudflat within each distance band could then be calculated using the GIS. For all point count data, the data were filtered to remove any pairs of counts where the tides were different between the night and day, in particular any tides where there was no mud exposed during either the day or night visit. The number of matched pairs used for each point, and the survey area, are summarised in Appendix 1.

2.21 This filtering exercise was not repeated for the total count areas as they included a wide range of habitats, many of which were not affected by the tide - such as the grass areas at Baiter and Hamworthy. The total area was calculated using GIS. Where the count area included habitats below MHW the area below MHW was calculated using aerial photographs. Bird density (per ha) was then calculated for each count area from this area value.

2.22 All statistical tests were conducted using Minitab (version 14).

2.23 The methods allowed various different approaches to be adopted within the analysis. These were structured as follows:

Species Recorded

2.24 In order to summarise which species were recorded during the night and day, all data were pooled and simple presence / absence (on any visit) for a given location recorded. Points and total count areas were grouped into the main areas of shoreline (Hamworthy, Holes Bay, Parkstone Bay, Blue Lagoon and Whitley Lake). Birds were assigned as present at night if they were heard only as well as if they were seen.

Detectability at night

2.25 Data from point counts (discounting those from visits where the tide was too high or the tide height was markedly different between night and day) were combined and the total number of birds of each species within each distance band extracted. These totals were expressed as density and the frequency distribution (by distance band) plotted for each species, for day and night. These plots then allowed visual comparison of the difference in detectability between night and day. These detection functions would be expected to show no variation in density if birds were equally detectable at all distances and used the entire area available to them. If birds avoid the shoreline (or distances have been overestimated) there will be lower densities near the shore. If birds were being missed further away from the observer, or for some reason were tending to feed closer to the shore, then the densities would be expected to decline with distance.

Comparisons between day and night

2.26 Here we address whether the abundance of birds is significantly different between the day and the night.

2.27 We used paired t tests to compute a confidence interval and perform a test of the mean difference between paired observations (night and day) for each species. This matching allows us to account for variability between pairs (for example in the amount of exposed mud or month), thus increasing the sensitivity of the hypothesis test or confidence interval. For species with many observations this approach is valid as the distributions are normal. For those with small sample sizes there are potentially problems where the assumption of normal data is invalid. Our approach is to perform the same tests for all species, but we use box plots to highlight the distribution in the count data and to show where single large counts may skew the distribution. Paired t tests were conducted on both the point count data and the total count data.

2.28 The point count data allowed the bird observation data to be truncated at particular distances. Experience from the field and the pilot study suggested that birds were often missed beyond 200m, especially at night. This was checked using the detection functions and we then truncated the point count data at 200m, to allow directly comparable data. This truncated data was used in subsequent analysis, for the paired t tests we also ran the tests using all data and data truncated at 75m.

2.29 This truncation does constrain the point count data to quite small areas of mudflat, reducing the bird numbers that can be analysed and therefore results in a loss of information. In order to use all data we also generated density estimates using the Distance software (Thomas et al., 2006). This software is widely used to generate density estimates from point or transect data and can take into account survey effort, search area and detectability. It allows direct comparison between different habitats or circumstances (night and day) where the detection of the target species may differ (Buckland et al., 2001).

2.30 Distances were entered in the software as the mid-point of each distance band and the actual bands used to set the intervals used in the analysis. Density estimates were only calculated for selected species where sample sizes were adequate. Estimates were stratified by night / day, to allow different models to be fitted to the night and day data. Four different models (uniform, hazard rate, half-normal and negative exponential) were tested for each species (Bibby, Jones & Marsden, 1998; Buckland et al., 2001). Where sample sizes allowed, density estimates were generated for each point count location, for both the night and the day. Model fits were evaluated for goodness of fit to detection probability function models. The AIC value was also assessed for model selection. Density estimates generated by Distance were compared using Z tests (after Buckland et al., 2001)

People and Access Levels

2.31 The data from the point counts and total count areas were different. The point count data were specific to limited distances around the point count and were specific to that small area at a given time, allowing direct comparison with the bird data. The total count data gave data for much wider areas, including the open grass of parks at Hamworthy and Baiter. These total count data included car park counts and gave a much broader picture of access along the northern shore.

2.32 The analysis addressed whether the overall level of human activity on the northern shore differed between night and day, whether the level of human activity varied between different parts of the northern shore and whether the distribution of activity differed between day and night.

2.33 We compared the total count data using paired t tests, to determine whether there were significantly more people present during the day than the night. Data were also grouped into different broad areas (Hamworthy, Parkstone Bay, Blue Lagoon and Whitley Lake) and also individual count areas. At these levels, the data were not normally distributed and a non-parametric equivalent to an ANOVA (Kruskal-Wallis) was used to test whether there were significant differences between groups.

2.34 If the same areas were busy both during the day and the night it would be expected that the total number of people recorded during the day at a given location would positively correlate with the number of people recorded during the night. This was tested by summing the data for each point count location and each total count area across all visits for the day and night and testing to see whether a significant correlation was present.

Variation in bird distribution between the night and day

2.35 In this section we address whether the distribution of birds differed between the night and day. We tested the bird data (both the total counts and point count data) to determine whether the number of birds present during the night correlated with the number recorded during the day. A positive correlation would indicate that birds were tending to feed in the same areas by both day and night, whereas a negative correlation would show that, during the night, birds were moving into areas avoided during the day.

2.36 A general linear model was used to test the significance of location, night / day, visit, and the interactions between these terms, on the density of waders present. Separate models were constructed for the point count data (truncated to 200m) and the total count areas. Each model was tested with all terms, and then non-significant terms removed sequentially.

Relationship between bird and human distribution

2.37 In this section we tested whether the difference in the distribution of birds between different parts of the northern shore between day and night was related to the difference in the distribution of disturbance between these same areas. The mean density (per point and per count area) was plotted against the mean number of people counted at each location. These plots were drawn using counts made during the night, during the day and using all data. These plots described the extent to which the areas favoured by birds tended to be the areas with lower disturbance levels.

2.38 Were birds to respond to disturbance by avoiding an area during the day and using the area instead during the night, it would be expected that the difference between the day and the night usage would be greater when daytime disturbance levels were higher. The difference between the density of each wader species during the day and night (calculated from the point count data truncated to 200m) was therefore plotted against the total number of people recorded at the point during the day.

2.39 We tested the effect of disturbance further by including the total number of people in the two general linear models described above. The total number of people (per point count and per total count area) was included as a covariate in the models.

3 Results

Summary of site visits

3.1 Fifteen paired visits (that is, fifteen daytime and fifteen night time visits) were made between 7th November 2007 and 8th February 2008. Details of these visits (tide heights, times etc.) are summarised in Appendix 3. Five of these pairs took place at weekends. Five of the night time visits took place in the early evening (that is, before 9pm), three started between 9pm and midnight and the remaining seven night visits were started after midnight.

Bird species recorded

3.2 A total of 31 species were recorded. Virtually all species were recorded both during the day and during the night. Two species (jack snipe *Lymnocryptes minimus* and snipe *Gallinago gallinago*) were only recorded in the night and not during the day, both of these were rarely recorded. The only species recorded during the day, and not during the night, were gulls: Mediterranean gull, common gull *Larus canus*, lesser black-backed gull *Larus fuscus* and yellow-legged gull *Larus michahellis*.

3.3 The species recorded, by species group and location, are shown in Table 2a-d. The tables combine the point counts and total counts and simply highlight which species were present at night and during the day in each area. For Blue Lagoon it can be seen that more wader species were recorded during the day than during the night. For Parkstone Bay, Whitley Lake, Hamworthy and Holes Bay more wader species were recorded at night. The species that seem most often absent from these areas during the day, but present at night were dunlin *Calidris alpina*, ringed plover and grey plover *Pluvialis squatarola*. Dunlin and ringed plover were particularly marked in their presence at night. Ringed plovers were rarely recorded during any of the day visits, the few day records were mostly of a flock of up to 38 birds roosting in Blue Lagoon. At night the species was widespread, in small numbers. Dunlin were not recorded during the day at all in Parkstone Bay, Holes Bay or Whitley Lake. Flocks were occasionally recorded in these areas at night. Grey plover were never common, but were recorded at night in a few locations where they were not seen during the day, including the shoreline at Hamworthy Park and along the shoreline at Whitecliff / Baiter, within Parkstone Bay.

3.4 All wildfowl species were recorded both during the day and the night. Wigeon *Anas penelope*, pintail and teal *Anas crecca* were largely restricted to Holes Bay, where they were present on virtually all visits, night and day. Locations that held birds during the day also appeared to hold birds during the night.

3.5 Gulls were largely absent at night and widespread during the day. Gulls were regularly heard calling offshore at night, presumably from birds roosting on the water. On a number of occasions gulls were picked out roosting on the water or circling low over the water well off-shore from Ham Park, with 1000s of birds clearly using this area to roost. On the night of the 1st February, at c.02.30, gulls were recorded leaving this roost and 100s were counted flying low over Ham Park (count areas 1 and 2) and heading due north. None landed within the count area. Holes Bay occasionally held roosting gulls, on one night 6500 black-headed gulls *Larus ridibundus* were estimated to be roosting here, and it was in Holes Bay that the only night time records for herring gull *Larus argentatus* and great black-backed gull *Larus marinus* occurred (both roosting). The roosting gulls were often very distant (400m plus) and therefore counts were very approximate. At such distances some of the rarer species would have been missed.

Table 2a Species recorded in different areas, during the night and day - Waders

Species	Hamworthy		Holes Bay		Parkstone Bay		Blue Lagoon		Whitley Lake		All Sites	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Oystercatcher	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	5	5
Curlew	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	4	5
Redshank	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	4	5
Dunlin	×	×	×	✓	×	✓	✓	✓	×	✓	1	4
Grey plover	×	✓	×	×	✓	✓	✓	✓	×	✓	2	4
Black-tailed Godwit	×	×	✓	✓	×	×	×	×	✓	×	2	1
Bar-tailed Godwit	×	×	✓	✓	✓	×	✓	×	✓	✓	4	2
Avocet	×	×	✓	✓	✓	×	✓	×	×	×	3	1
Ringed plover	✓	✓	✓	×	×	✓	✓	✓	×	✓	3	4
Greenshank *Tringa nebularia*	✓	✓	✓	×	×	✓	✓	×	✓	✓	4	3
Spotted redshank[1] *Tringa erythropus*	×	×	✓	✓	×	×	×	×	×	×	1	1
Turnstone	✓	×	×	×	✓	✓	✓	(✓)	✓	×	4	2
Jack Snipe	×	×	×	✓	×	×	×	×	×	×	0	1
Snipe	×	×	×	(✓)	×	(✓)	×	×	×	×	0	2
Knot	×	×	×	×	×	×	×	×	✓	✓	1	1
Total Species	**4**	**6**	**9**	**10**	**7**	**10**	**10**	**7**	**8**	**9**	**13**	**15**

Ticks indicate that the species was present on at least one occasion in the given area. Birds only heard at night are included, in such cases the ticks are in parenthesis.

[1] During the pilot study a spotted redshank was recorded in Parkstone Bay, but not during the main study

Table 2b Species recorded in different areas, during the night and day - Wildfowl

Species	Hamworthy		Holes Bay		Parkstone Bay		Blue Lagoon		Whitley Lake		All Sites	
	Day	Night	Day	Night	Day	Night		Day	Night	Day	Night	Day
Mute swan	✓	✓	✓	✓	×	✓	✓	×	×	×	3	3
Brent goose	✓	✓	×	×	✓	✓	✓	✓	✓	✓	4	4
Wigeon	×	×	✓	✓	✓	×	×	×	×	×	2	1
Shelduck	×	×	✓	✓	✓	×	✓	✓	✓	×	4	2
Mallard *Anas platyrhynchos*	×	×	✓	✓	✓	✓	✓	✓	×	✓	3	4
Teal	×	×	✓	✓	×	×	×	×	×	×	1	1
Pintail	×	×	✓	✓	×	×	×	×	×	×	1	1
Total Species	**2**	**2**	**6**	**6**	**4**	**3**	**4**	**3**	**2**	**2**	**7**	**7**

Table 2c Species recorded in different areas, during the night and day - Gulls

Species	Hamworthy		Holes Bay		Parkstone Bay		Blue Lagoon		Whitley Lake		All Sites	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Black-h Gull	✓	×	✓	✓	✓	✓	✓	×	✓	✓	5	2
Common Gull	✓	×	✓	×	✓	×	✓	×	✓	×	5	0
Herring Gull	✓	×	✓	✓	✓	×	✓	×	✓	×	5	1
Lesser Bb Gull	×	×	✓	×	✓	×	×	×	×	×	2	0
Great Bb Gull	×	×	✓	✓	✓	×	✓	×	✓	×	4	1
Mediterranean Gull	×	×	×	×	✓	×	✓	×	✓	×	3	0
Yellow-legged gull	✓	×	✓	×	×	×	×	×	✓	×	3	0
Total Species	**4**	**0**	**6**	**3**	**6**	**1**	**5**	**0**	**6**	**1**	**7**	**3**

Table 2d Species recorded in different areas, during the night and day - Herons

Species	Hamworthy		Holes Bay		Parkstone Bay		Blue Lagoon		Whitley Lake		All Sites	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Grey Heron *Ardea cinerea*	✗	✓	✓	✓	✗	✓	✗	✗	✗	✓	1	4
Little egret	✓	✗	✓	✓	✓	✗	✓	✗	✓	✗	5	1
Total Species	**1**	**1**	**2**	**2**	**1**	**1**	**1**	**0**	**1**	**1**	**2**	**2**

Detectability at night

3.6 The ability to detect birds at night varied between different points. The amount of ambient light and the amount of lighting on the opposite shore / line of site influenced the effectiveness of the night vision equipment. When the mud was wet and there were lights opposite the mud often reflected light and this sometimes dazzled the observer. Some species were much more obvious than others, and were easy to pick out, even at large distances. Species such as mute swan *Cygnus olor* could be easily counted at considerable distances, and were clearly visible with the night vision equipment at 400m. Species such as avocet and shelduck stood out well. Avocet were also easy to detect as the night records tended to involve tight flocks feeding vigorously in shallow water.

3.7 In general we struggled to differentiate species at distances beyond 200m. This was particularly the case for mixed feeding flocks of waders on open mud. Curlew *Numenius arquata* and dunlin could usually be differentiated by size, but redshank, godwits, oystercatcher and grey plover were difficult to differentiate. When oystercatchers were reasonably close (somewhere between 100 and 200m depending on the light levels) it was possible to see the black and white body pattern.

3.8 At distances up to c.100m the infra-red illumination would pick out eye-shine, and this gave added confidence of picking out birds. Ringed plover feeding on the upper shore or amongst sea weed and rocks were typically picked up in this way.

3.9 Figures 4, 5, 6 and 7 give the densities of individuals at different distance bands, across all point counts, for selected species. Distance bands are pooled to 50m intervals, and the frequency distributions for the species are compared between night and day.

3.10 For some species (such as dunlin, ringed plover, oystercatcher, Brent goose and shelduck) there are declines in density above 200m during the day. It is unlikely that these species would be missed at such distances during daylight, and therefore the distribution is likely to be linked to habitat, tide or disturbance (for example, birds avoiding boats further out).

3.11 The distributions, at night, for redshank, ringed plover, Brent goose and dunlin all show peaks that are closer to the shore than during the day, suggesting these species are either missed at greater distances at night or that they tend to feed closer to the shore at night. For dunlin there is a marked decrease in recorded densities beyond 200m, oystercatcher and avocet both peak at 250, redshank at 150m and ringed plover at 100m. These data would suggest that at distances beyond 200m birds may be being under recorded.

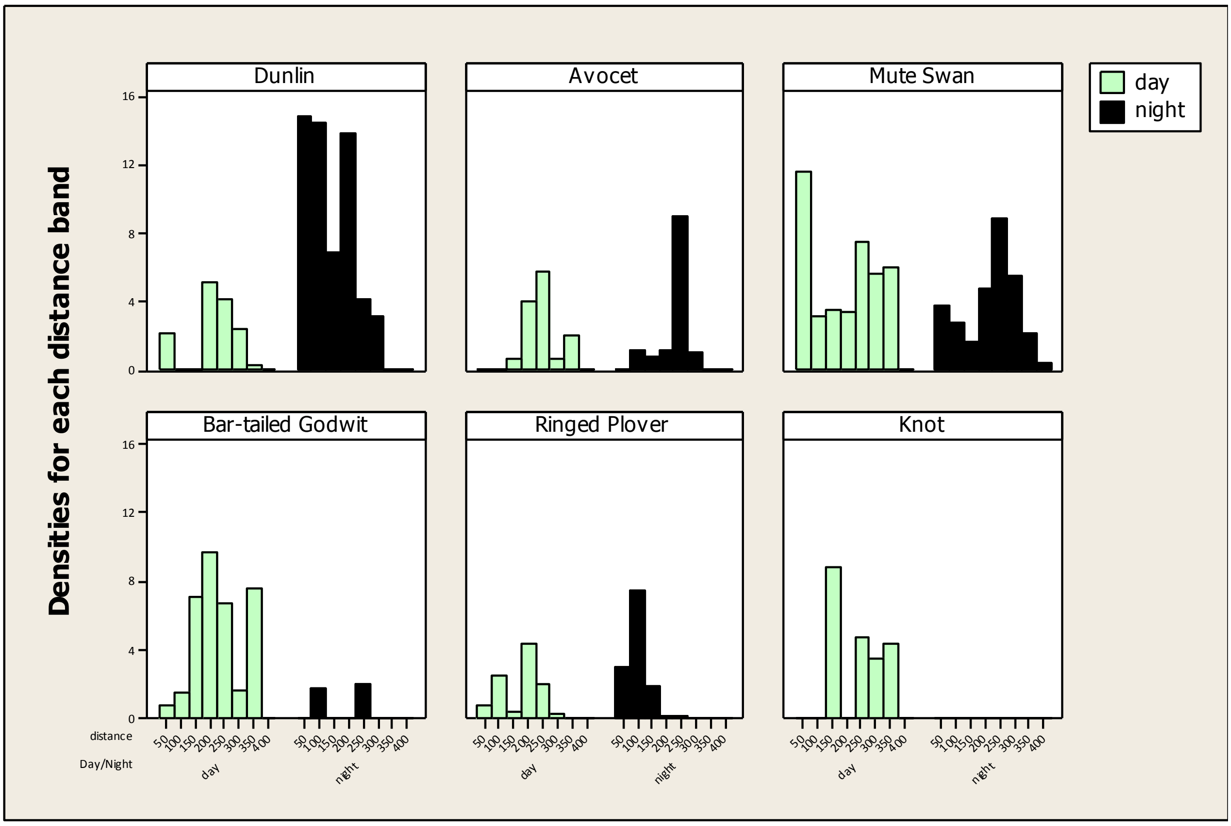
3.12 There is also a general pattern of higher counts during the day, or relatively little difference between the day and the night. Dunlin is the clear exception, with many more counted at night than during the day. There is some variation in the shapes of the distributions for the different species. Oystercatchers show the highest day time densities close to the shore and decline with distance from the shore, whereas curlew tend to show increased densities with distance, indicating that the highest densities of this species were recorded away from the shoreline. Brent goose and shelduck show a peak in the middle distance bands.

Comparisons between day and night

Total counts

3.13 For the total count areas there were generally more birds during the day than during the night. This was significant for waders (paired T test, N = 180, T = 2.90, p = 0.004), for gulls (paired T test, N = 180, T = 7.90, p = <0.001) and wildfowl (paired T test, N = 180, T = 3.40, p = 0.001). In fact there were no gulls recorded at all from any of the count areas during the night.

3.14 There were however differences between species. Simply using the total count area data, ringed plover, grey plover and dunlin were present in significantly higher numbers at night than during the day (Table 3 and Figure 8). Waders that were present in significantly higher numbers during the day were bar-tailed godwit *Limosa lapponica*, knot *Calidris canutus*, oystercatcher and turnstone. Most gull species and little egret were also present on the northern shore during the day in significantly higher numbers than at night.



All bands are 50m width (counts pooled for closer distances).

Figure 4 Frequency distributions showing densities for each distance band for selected species - Dunlin, Avocet, Mute Swan, Black-tailed Godwit, Ringed Plover and Knot

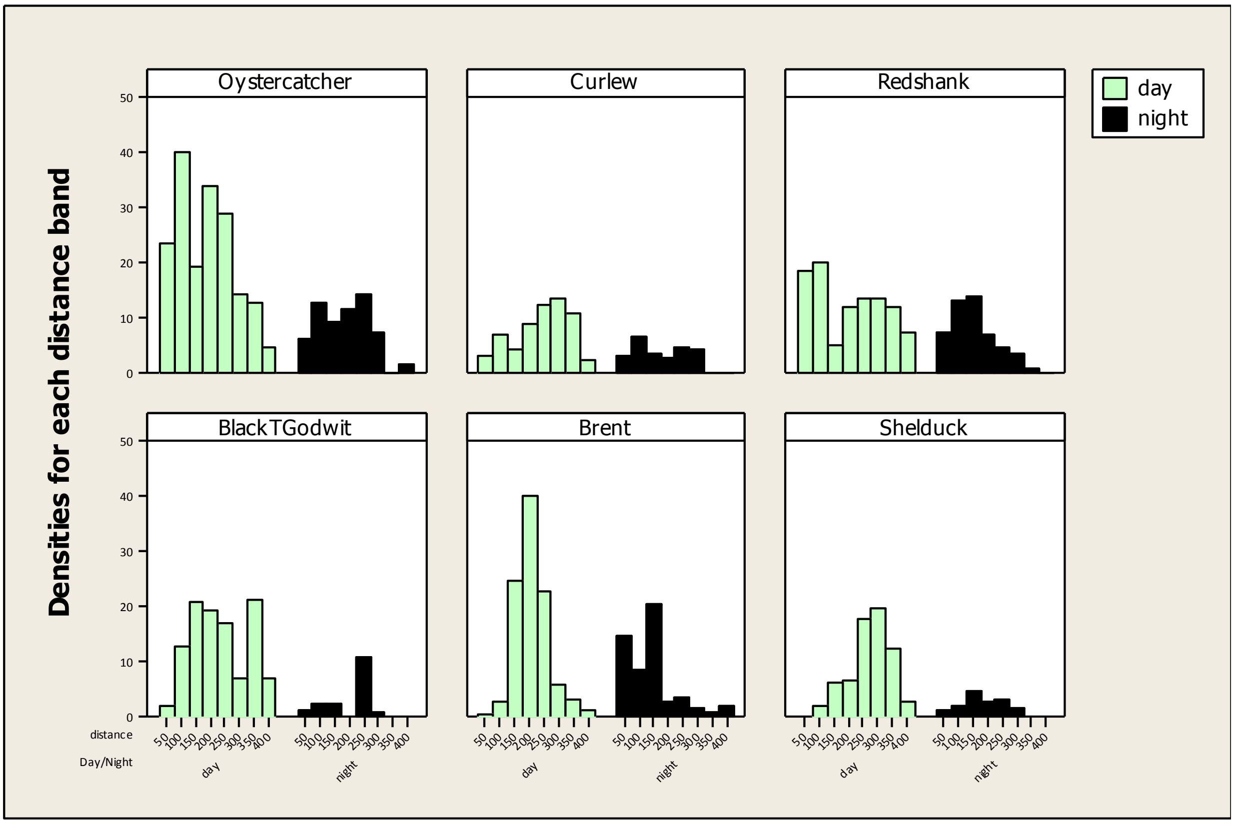


Figure 5 Frequency distributions showing densities for each distance band for selected species - Oyster catcher, Curlew, Redshank, Black-tailed Godwit, Brent goose and Shelduck

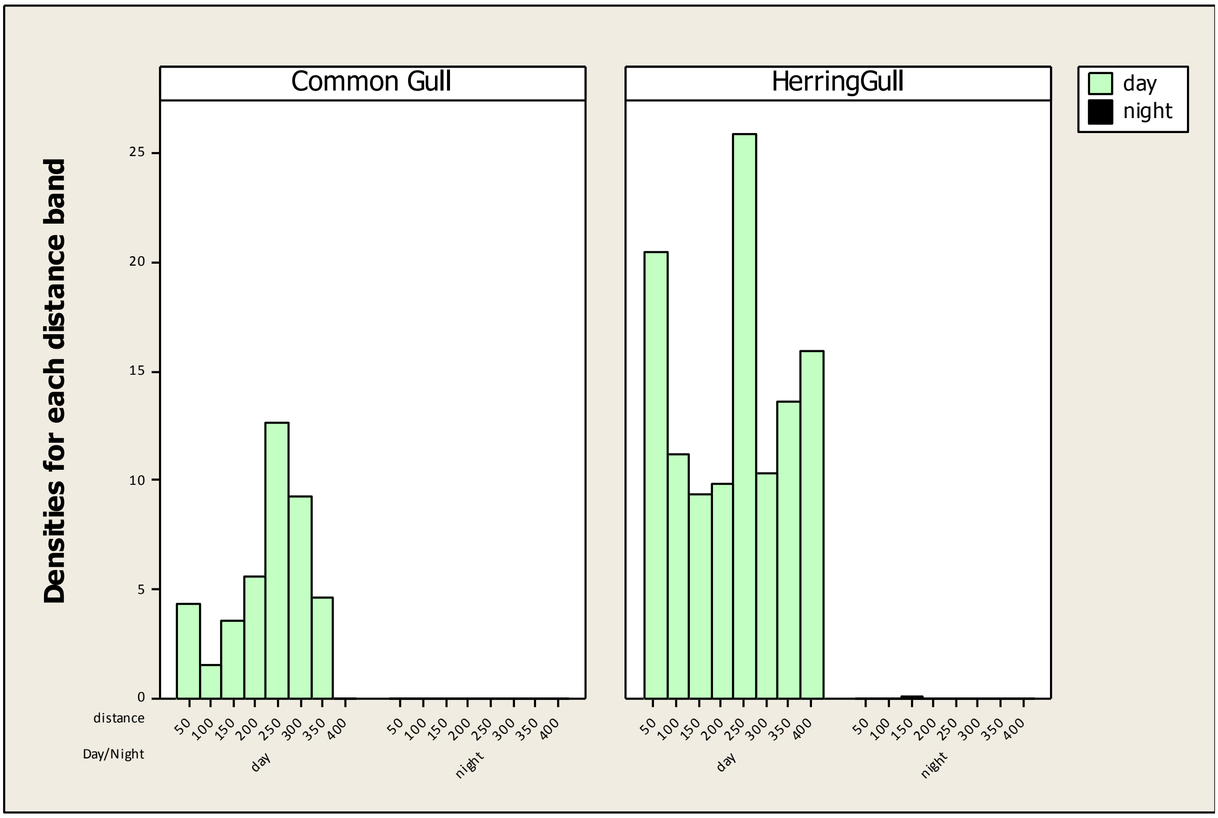


Figure 6 Frequency distributions showing densities for each distance band for selected species - Common Gull and Herring Gull

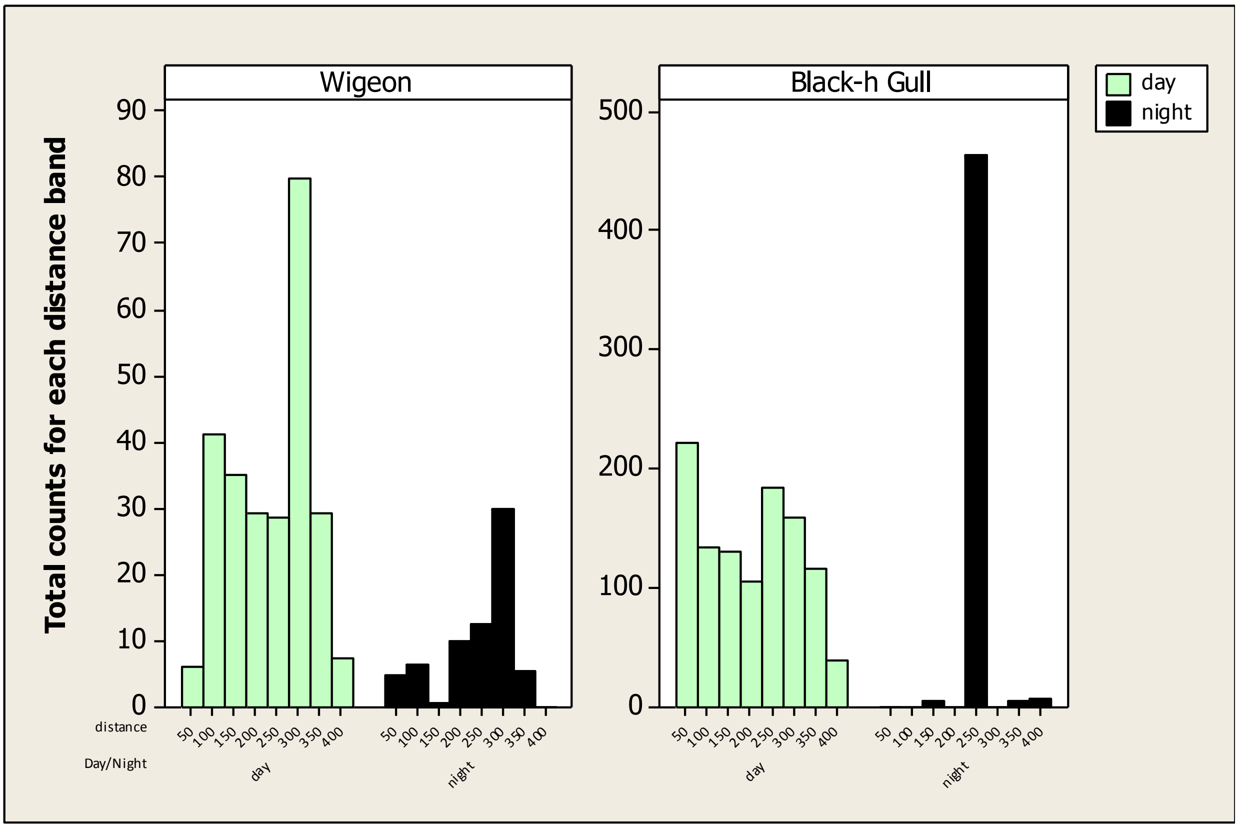
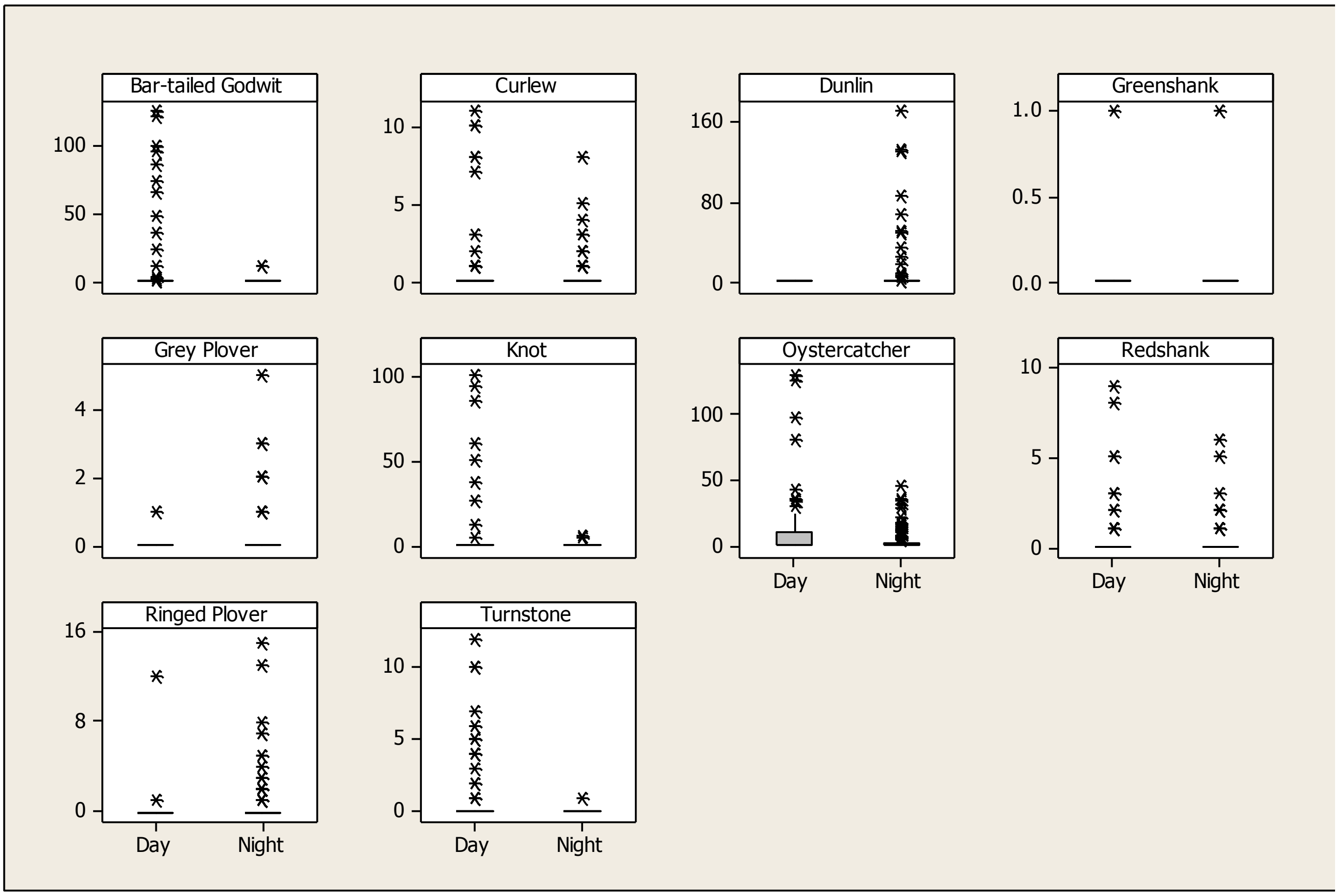


Figure 7 Frequency distributions showing densities for each distance band for selected species - Wigeon and Black-headed Gull

Table 3 Totals for different species from the total count areas, by day and by night

Species	Total Day	Total Night	T	p
Bar-tailed Godwit [1]	788	23	3.03	0.003
Black-headed Gull [1]	4469	0	7.74	0
Brent goose [1]	1243	73	3.44	0.001
Common Gull [2]	91	0	3.07	0.040
Curlew	66	40	1.08	0.281
Dunlin [3]	0	778	-2.77	0.006
Great Black-backed Gull	83	0	1.81	0.072
Greenshank	1	1	0	1
Grey Heron	0	4	-1.64	0.103
Grey Plover [3]	1	23	-2.8	0.006
Herring Gull [1]	528	0	5.79	<0.001
Knot [2]	474	11	2.54	0.012
Lesser Black-backed gull	1	0	1	0.319
Little Egret [1]	9	0	2.76	0.006
Mallard	46	20	0.64	0.522
Mediterranean Gull [1]	13	0	3.05	0.003
Mute swan	0	11	-1.41	0.16
Oystercatcher [1]	1368	447	3.74	<0.001
Redshank	44	31	0.78	0.436
Ringed Plover [3]	13	107	-3.28	0.001
Shelduck	4	0	1	0.319
Snipe	0	1	-1	0.319
Turnstone [1]	88	1	3.64	<0.001
Wigeon	1	0	1	0.319
Yellow-legged Gull	4	0	1.27	0.207

The p values are not adjusted for multiple comparison. Those species marked [1] and [2] are those for which there was a significant difference between the night and the day - [1] ($p < 0.01$) and [2] ($p < 0.05$) indicate species where there were significantly more records during the day, and for those marked [3] there were significantly more recorded during the night ($p < 0.01$ for all). In each case, paired t tests were used to compare day and night bird abundance (n = 180, ie 15 visits * 12 count areas).



Data are from total count areas and include data from all dates (n = 180). Note that the scales are different for each panel. Horizontal bars denote the median number of birds seen, shaded boxes denote the upper and lower quartiles, whiskers describe the 5th and 95th percentiles and asterisks depict individual counts outside these bounds

Figure 8 Comparison of night and day counts for wader species

Point count data

3.15 Direct comparison (paired t tests) between day and night for the point count data reveal different results depending on the distance at which the data are truncated (Table 4). Perhaps not surprisingly, taking all data (that is, to 400m) most species were, as might be expected given the difficulty of recording birds at night at the bigger distances, significantly more abundant during the day. Within 200m there were fewer, but more reliably significant, differences between day and night abundance. Of the 13 significant differences detected in the total count area dataset, seven were repeated in this dataset, and in a further four species the same trend as in the total count dataset (albeit non-significant in the point count data) was also apparent. The tendency for grey plover to be seen more at night in the total count areas was not apparent at the point count locations and nor was the tendency of knot to be seen more during daylight. When the point count data were restricted to only those birds seen within 75m of the observation point by day and night the only major change from the 200m dataset was that the abundance of black-tailed godwits was no longer significantly greater during daylight (though the trend remained the same). The only highly significant differences between day and night abundance within this highly restricted dataset related to herring gulls and black-headed gulls. The data truncated at 200m, are summarised in Figure 9.

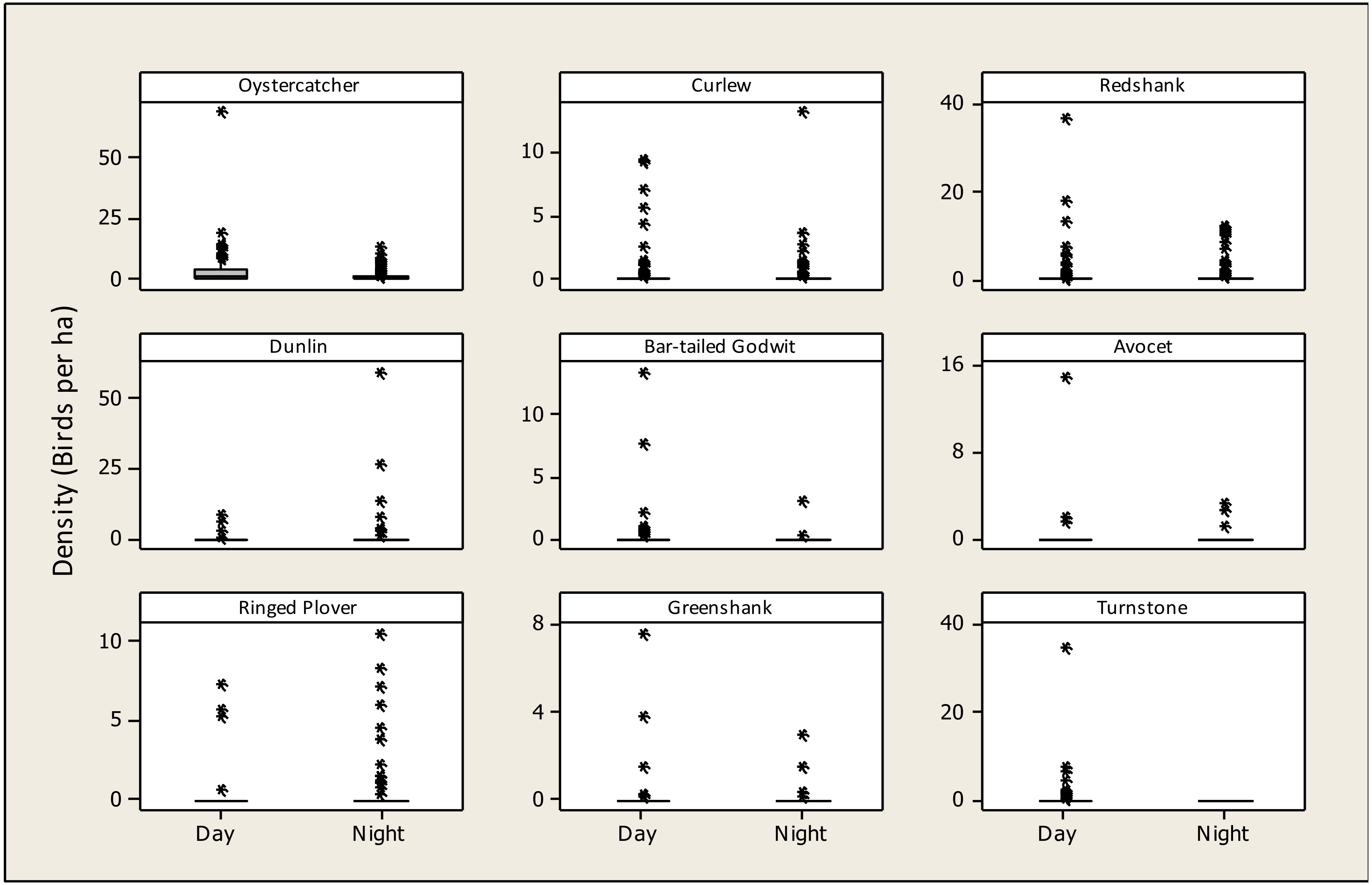
Table 4 Totals for different species from the point counts, by day and by night

Species	All data				Within 200m				Within 75m			
	Total Day	Total Night	T	p	Total Day	Total Night	T	p	Total Day	Total Night	T	p
Avocet	175	173	0.02	0.985	56	32	0.59	0.554	0	10	-1.00	0.319
Bar-tailed Godwit	445	43	2.48	0.014	94	16	1.45	0.149	6	16	-0.65	0.515
Black-headed Gull	11985	6732	0.8	0.422	3954	62	8.13	<0.001	1198	2	5.90	<0.000
Black-tailed Godwit	1349	209	2.3	0.023	588	49	2.23	0.027	51	12	1.86	0.064
Brent goose	1269	494	2.37	0.019	574	384	0.63	0.528	5	132	-0.96	0.338
Common Gull	521	0	4.17	<0.001	90	0	3.87	<0.001	12	0	2.22	0.028
Curlew	797	275	3.54	0.001	198	136	0.90	0.367	28	35	-0.33	0.746
Dunlin	168	535	-1.45	0.147	73	420	-1.56	0.121	8	55	-1.12	0.263
Great Black-backed Gull	52	6	3.32	0.001	22	6	1.59	0.113	9	6	1.00	0.319
Greenshank	10	8	0.45	0.656	7	7	0	1	4	4	0.000	1.000
Grey Heron	11	17	-0.61	0.542	1	10	-1.89	0.060	0	4	-2.02	0.045
Grey plover	33	5	1.73	0.085	18	5	0.88	0.379	3	0	1.00	0.319
Herring Gull	1340	1	5.23	<0.001	310	1	6.05	<0.001	121	0	3.48	0.001
Jack Snipe	0	4	-1.27	0.207	0	4	-1.27	0.207	0	4	-1.27	0.207
Knot	278	0	1.98	0.05	0	0			0	0		
Lesser Black-backed Gull	24	0	3.29	0.001	3	0	1.35	0.181	0	0		
Little egret	121	7	4.44	<0.001	51	7	2.42	0.017	23	0	2.37	0.019
Mallard	230	90	1.77	0.079	109	74	0.71	0.476	40	19	0.95	0.344

Table continued…

Species	All data				Within 200m				Within 75m			
	Total Day	Total Night	T	p	Total Day	Total Night	T	p	Total Day	Total Night	T	p
Mediterranean Gull	11	0	2.32	0.021	8	0	2.02	0.045	1	0	1.00	0.319
Mute swan	425	358	0.68	0.498	132	84	1.01	0.312	61	20	1.00	0.318
Oystercatcher	1948	712	4.92	<0.001	900	330	3.35	0.001	235	51	2.29	0.023
Pintail	49	6	2.54	0.012	12	6	0.97	0.332	3	6	-0.62	0.533
Redshank	1117	505	2.97	0.003	412	364	0.33	0.742	92	52	1.16	0.246
Ringed plover	116	101	0.47	0.637	80	99	-0.69	0.490	25	32	-0.27	0.786
Shelduck	936	173	4.65	<0.001	124	103	0.30	0.763	0	11	-1.65	0.101
Spotted redshank	5	1	0.94	0.347	4	1	0.73	0.469	4	1	0.73	0.469
Teal	1408	192	2.72	0.007	431	177	1.64	0.103	30	10	1.17	0.243
Turnstone	88	0	2.79	0.006	81	0	2.62	0.010	64	0	2.26	0.025
Wigeon	3273	914	2.68	0.008	909	184	1.75	0.082	116	67	0.69	0.493
Yellow-legged gull	6	0	1.42	0.158	1	0			0	0		

The p values are not adjusted for multiple comparison (using the Bonferroni adjustment the 0.05 level of significance, for 3 tests with 14 df, is lowered to 0.016 and for the 0.01 significance level the alpha is lowered to 0.0013). Comparisons between day and night abundance were made by paired t tests in all cases



Density calculated using the survey area (within 200m) at each point. Data are filtered so that any visits where the tide did not match between day and night visits, or there was no mud present, have been excluded. Horizontal bars denote the median number of birds seen, shaded boxes denote the upper and lower quartiles, whiskers describe the 5th and 95th percentiles and asterisks depict individual counts outside these bounds

Figure 9a Density by species, calculated only from point count data, taking all records within 200m of the point

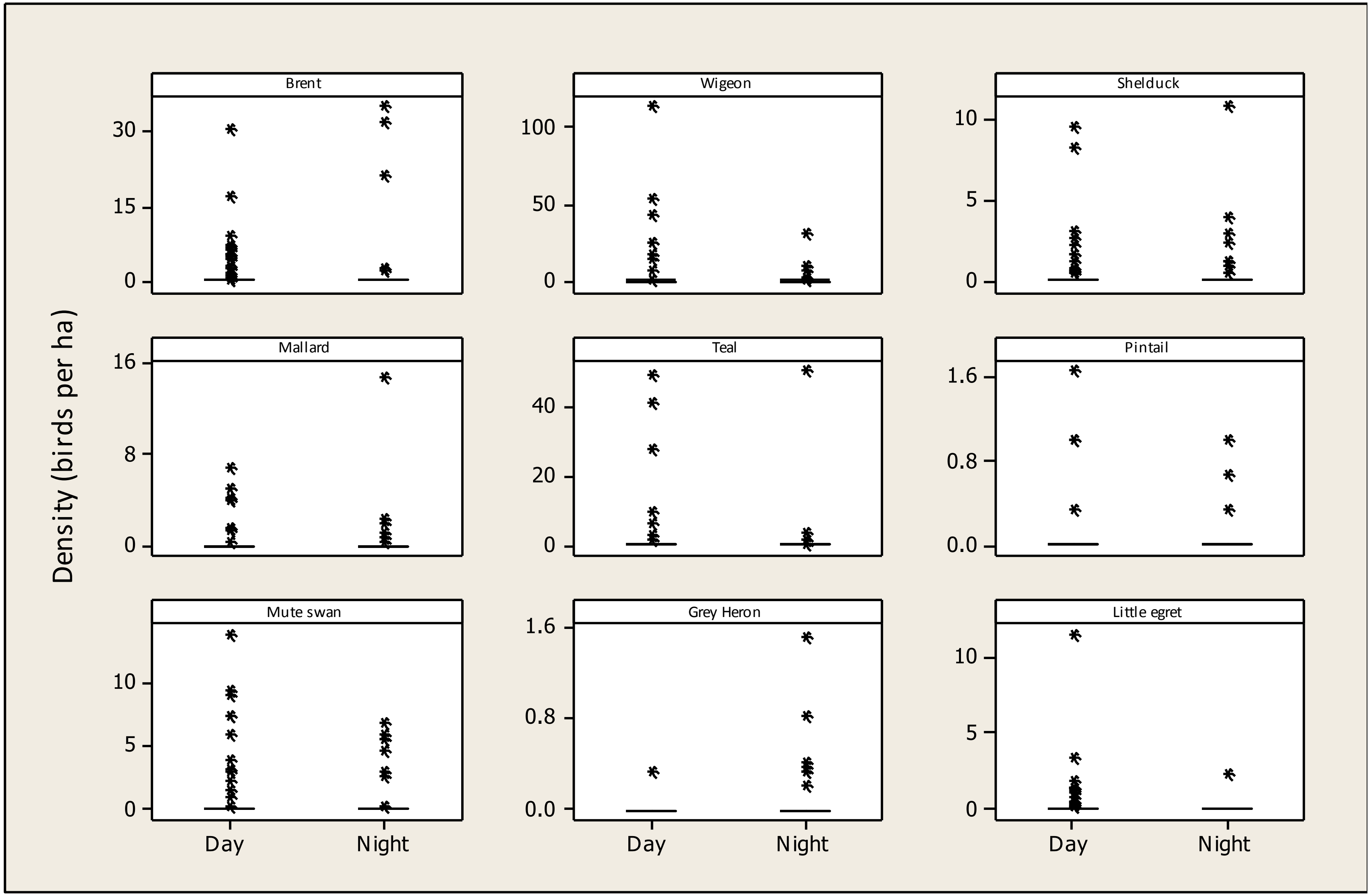
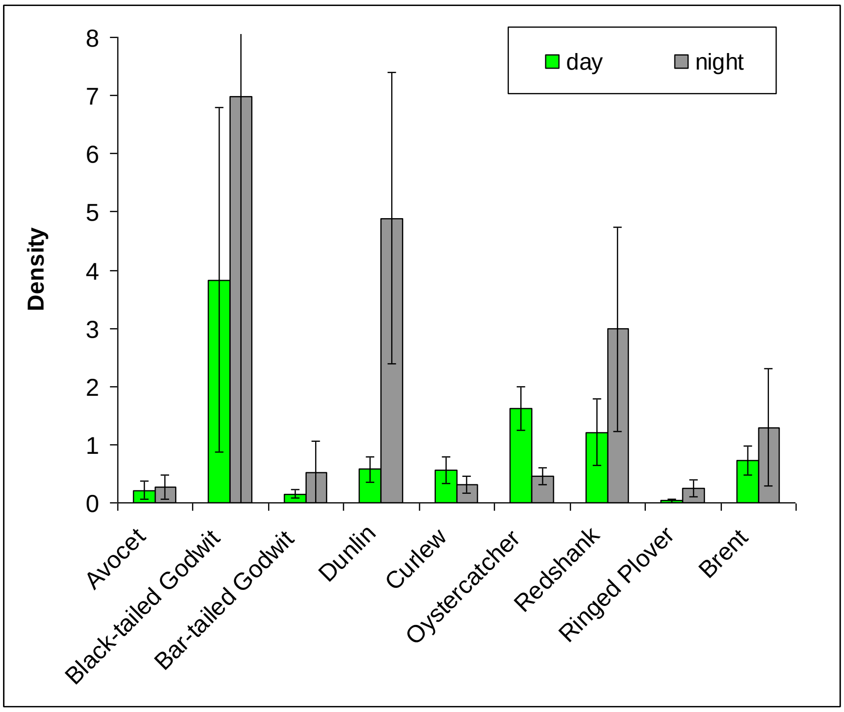


Figure 9b Density by species, calculated only from point count data, taking all records within 200m of the point

3.16 In order to make use of all of the point count data, rather than truncating observations at fixed distances (and hence losing useful information), the Distance software was used to generate density estimates. Data were stratified by night / day and by point. These estimates were generated for species for which reasonably large sample sizes were achieved, and with the focus on the waders, as it was largely this group that the previous analyses have highlighted were widely present during the night. The use of Distance provides estimates of density that utilise all the available data and take into account species specific detectability.

3.17 Density estimates for selected species are summarised in Figure 10 and Table 5. Density estimates were higher at night for black-tailed godwit, bar-tailed godwit, dunlin, redshank, ringed plover and Brent goose, but of these the difference was only significant for dunlin. For both black-tailed godwit and dunlin the standard errors were large, particularly for black-tailed godwit. These large errors reflect the large flocks recorded erratically relatively close to the shore. For black-tailed godwit there were relatively few records at night, but these did include flocks of birds and on at least one occasion involved birds feeding very close to the shore at Holes Bay. For oystercatchers the densities at night were significantly lower than during the day (Table 5).

3.18 The choice of model and the effective detection radius (EDR) value generated by the Distance software are revealing (Table 5). For four species the negative exponential model gave the lowest AIC value and was selected. This curve shape has a pronounced spike at the start (close to the y axis), representing data where the number of birds recorded shows a pronounced drop off with increasing distance. This is perhaps to be expected for data collected in the dark! The hazard rate model is more effective for data that shows a flat shoulder and a long tail, and this model was used for four species for the day-time data. The EDR value is the effective detection radius, essentially the distance from the observer beyond which as many bird contacts are missed as are actually recorded. For all species except oystercatcher this distance was much lower at night than during the day, and was lowest for dunlin, ringed plover and redshank, the smallest species and the ones that would be expected to be hardest to record at night. For these species the EDR would suggest that birds were being missed beyond 100m at night. Avocets were one of the easiest species to pick out at night, due to the pale colouring, the fact that they were usually in flocks and also have a distinctive feeding style. It is not surprising therefore that the EDR value for avocet was the highest, at just under 250m.



Note that the error bar for black-tailed godwit exceeds the y axis scale

Figure 10 Density estimates (+ 1 SE) for selected species as generated using Distance

Table 5 Density estimates (and standard errors) for selected species calculated using the Distance software

Species	Day				Night			
	Model	Density	SE	EDR	Model	Density	SE	EDR
Avocet	Hazard	0.217	0.161	333	Hazard	0.267	0.211	249
Black-tailed Godwit	Negative Exponential	3.831	2.958	147	Hazard rate	6.985	8.48	64
Bar-tailed Godwit	Hazard	0.150	0.69177E-01	319	Negative exponential	0.526	0.542	106
Dunlin*	Hazard	0.575	0.219	265	Negative exponential	4.892	2.504	96
Curlew	Uniform Key	0.561	0.226	209	Uniform Key	0.307	0.150	144
Oystercatcher**	Half-normal	1.615	0.375	141	Hazard	0.455	0.151	192
Redshank	Half-normal	1.215	0.576	162	Negative exponential	2.986	1.7533	78
Ringed Plover	Hazard	0.324E-01	0.299E-01	263	Half-normal	0.252	0.147	89
Brent goose	Uniform	0.734	0.252	238	Negative exponential	1.294	1.01	162

The EDR is the effective detection radius, essentially the distance (m) at which the model estimates that as many birds are being missed as are being recorded. Species in bold are those where the difference between the two means is significant (Z test, *$p < 0.05$, **$p<0.01$)

People and access levels

3.19 A wide range of different types of human activities were recorded. Use of the shoreline areas included dog walking, cycling, jogging, walking, picnicking, fishing, bait digging, kite flying, land surfing (including windsurfers on wheels and skate-board type surfing) and launching of boats / craft.

3.20 Figures 11, 12, 13, 14 and 15 summarise the locations of all bait digger sightings, people fishing and other access types across the survey area. Bait digging (Figure 11) was concentrated in the soft sediment areas, particularly in Holes Bay and, on low spring tides, Whitley Lake. Fishermen (Figure 12) were recorded at a range of locations, but one particularly favoured location was the shore of Holes Bay at Sterte, where cars pulled up on the side of the dual carriageway. Dog-walkers were recorded at all locations, but were relatively infrequent at Holes Bay whereas both Baiter and Whitecliff Park were particularly popular dog-walking locations.

3.21 A summary of people / access data for the total count areas is given in Appendix 6 (by date and location). The most common activities are summarised in Table 6.

Table 6 Totals of main activities recorded in the count areas, across all 15 visits

Activity	Day	Night
Bait digging	9	1
Boat / sail / jet ski	44	0
Cycling	36	13
Dog walking	481	50
Fishing	8	0
On mud / beach	89	1
Sitting on sea wall	48	2
Walking	464	26
TOTAL (inc. other categories)	**1453**	**97**
Cars in car parks (Ham Park and Baiter)	607	24
Dogs	305	43
Dogs off lead on mud	106	5

The TOTAL row gives the total number of people recorded (that is, all activities and not just the ones listed)

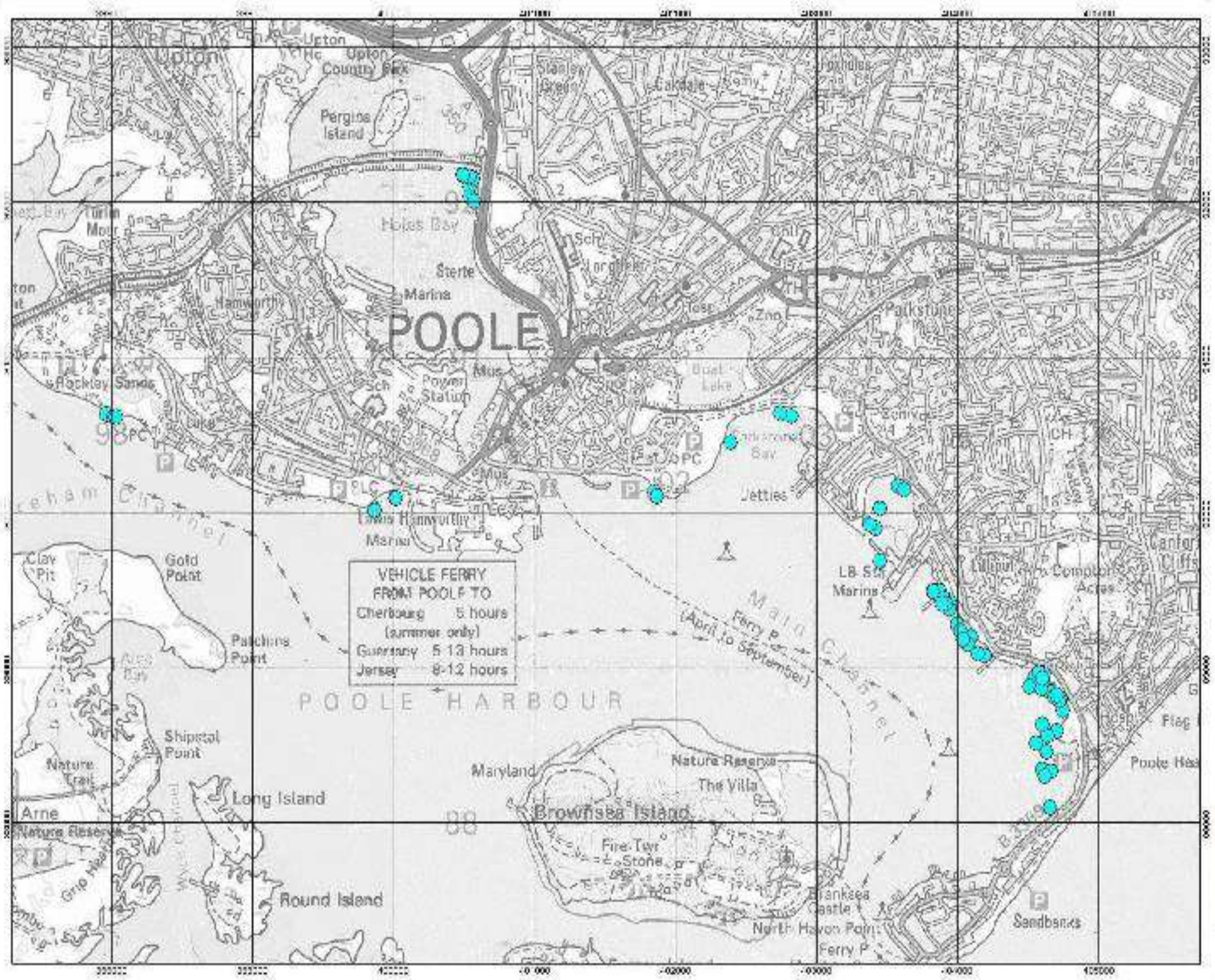


Figure 11 Location of all bait diggers observed throughout the survey

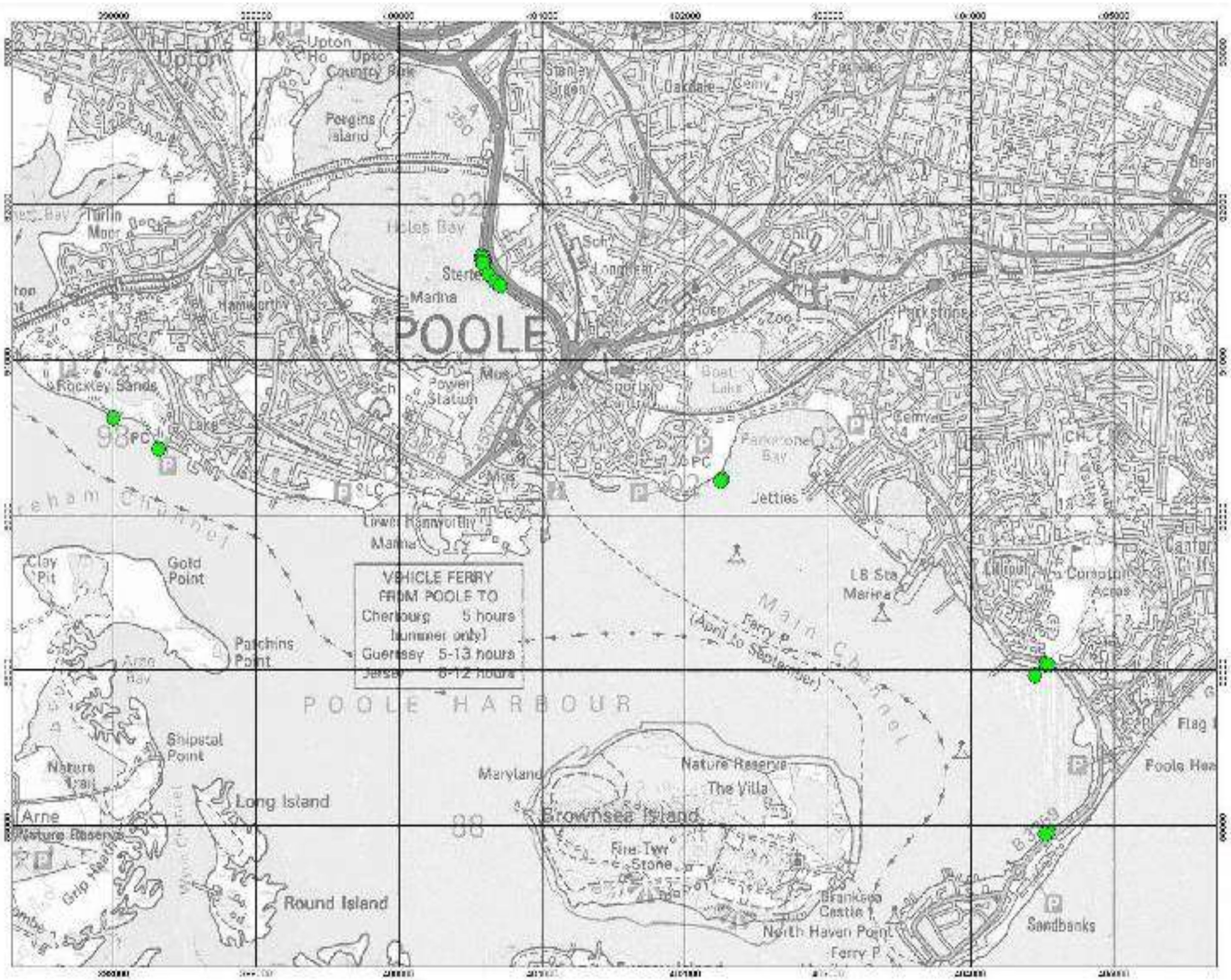


Figure 12 Location of all people fishing observed throughout the survey

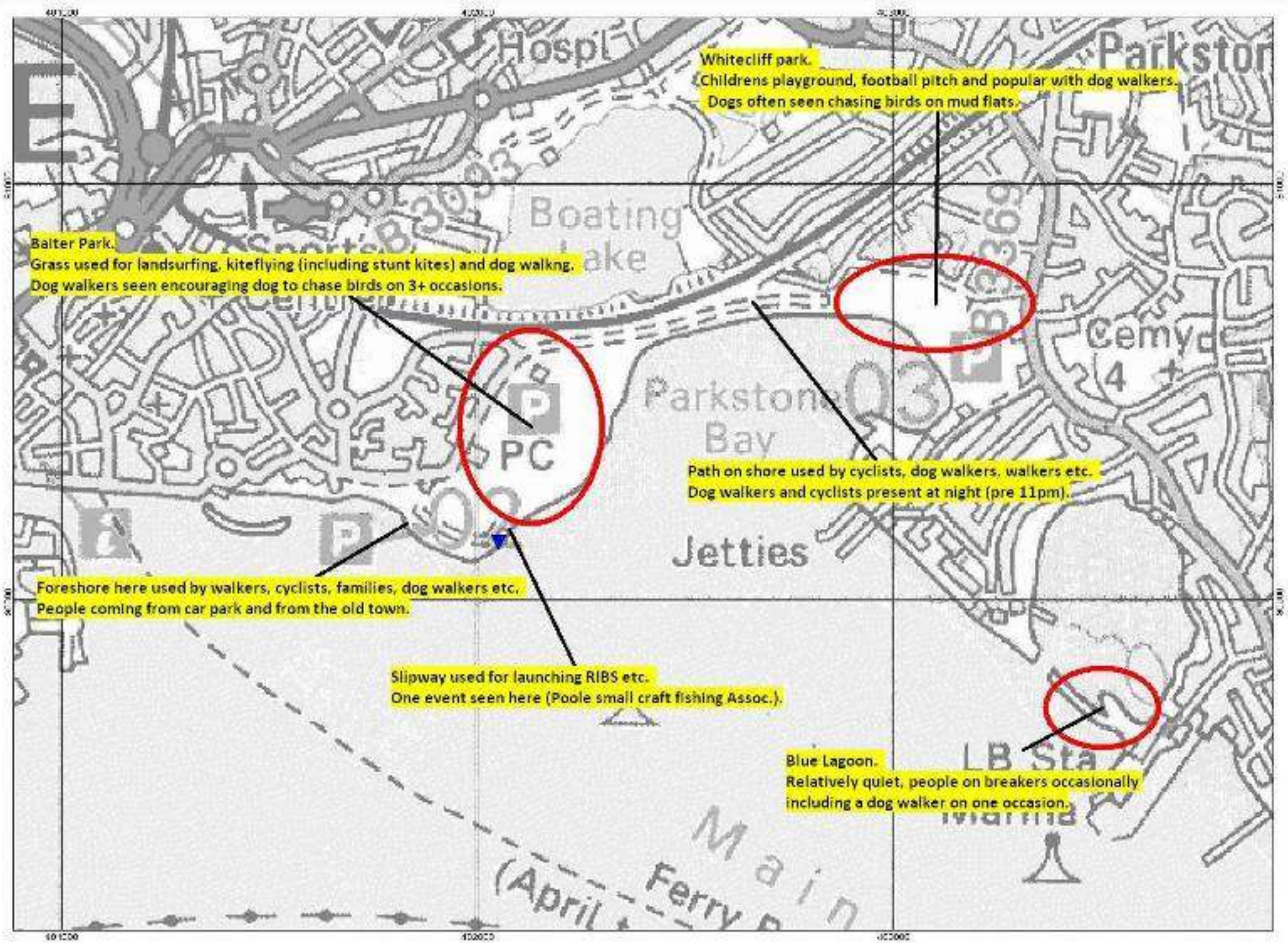


Figure 13 Other disturbance: Parkstone Bay and Blue Lagoon

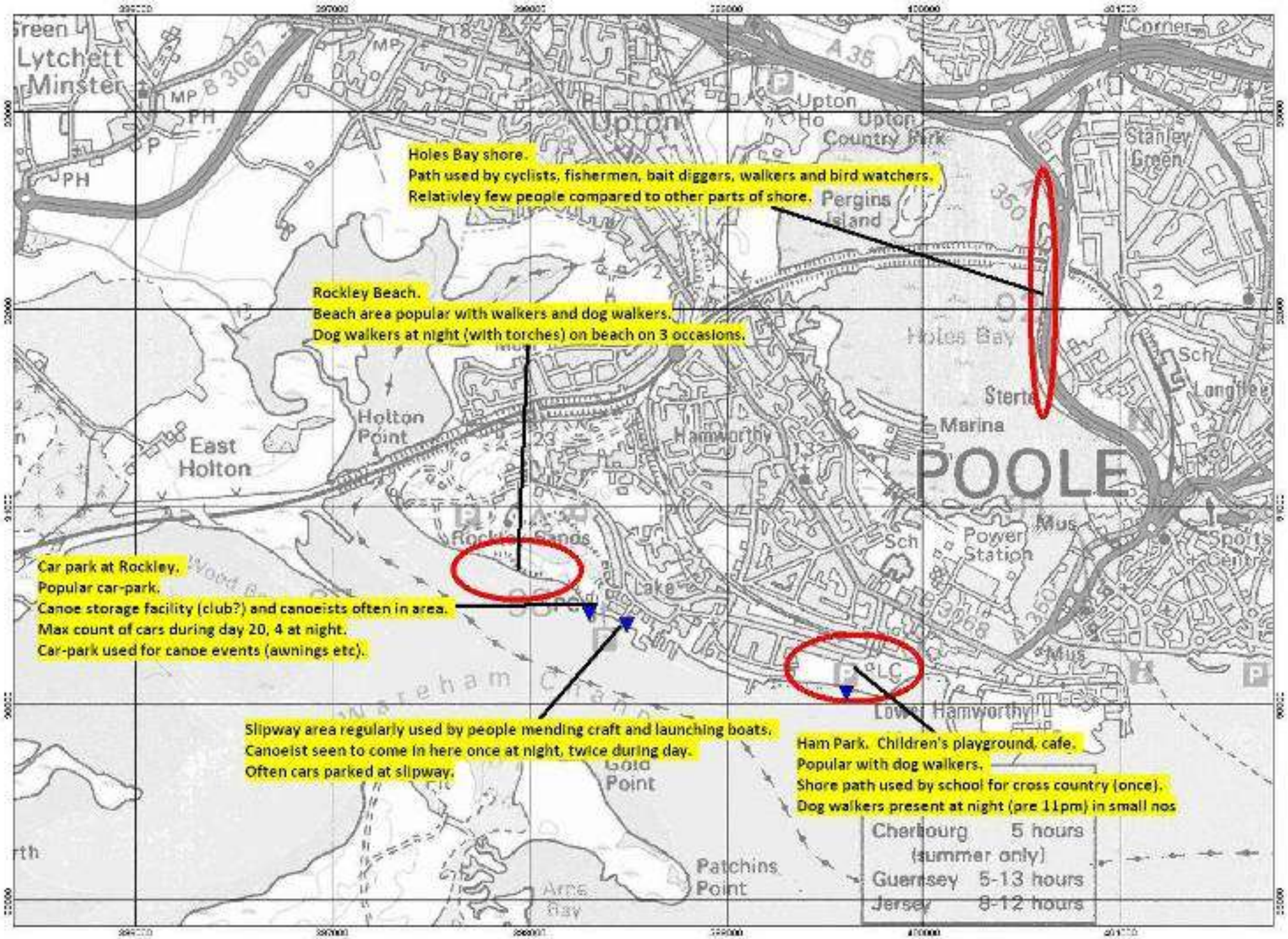


Figure 14 Other disturbance: Holes Bay and Hamworthy

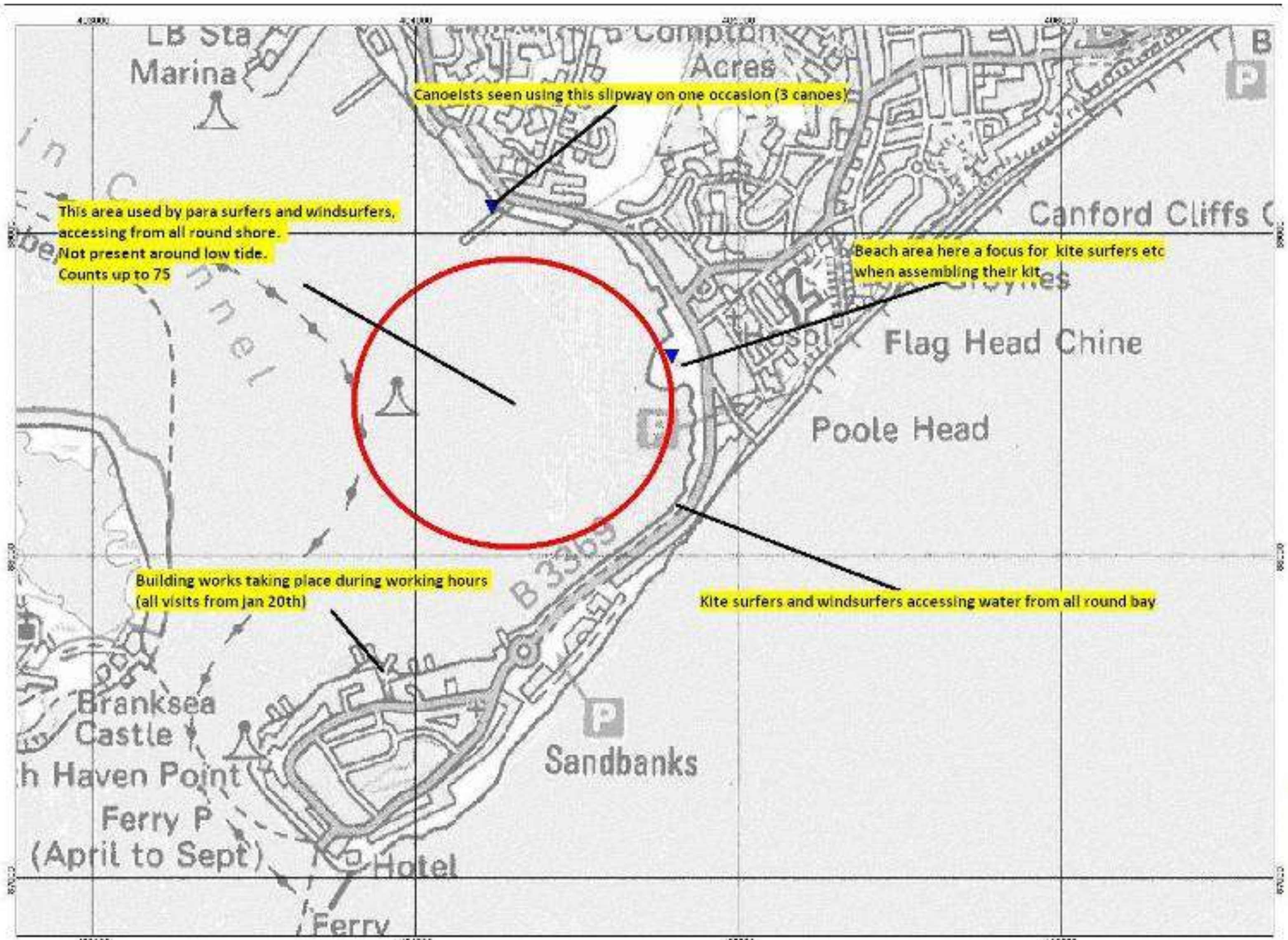
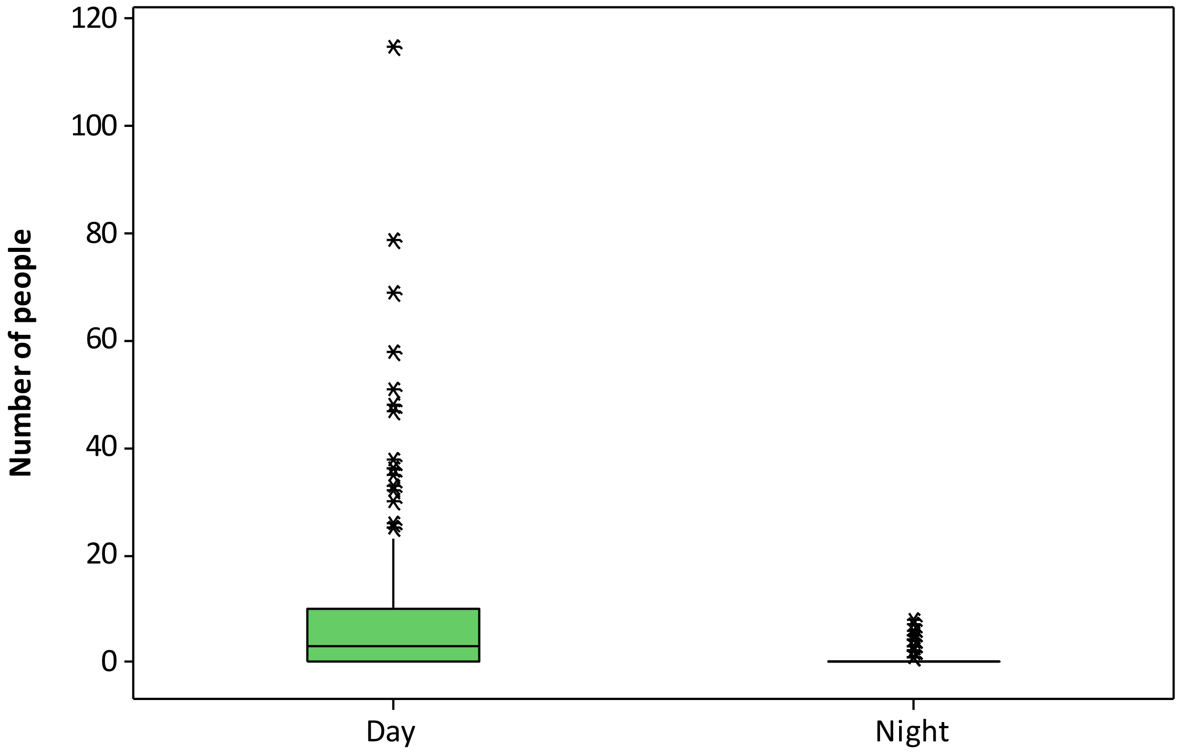


Figure 15 Other disturbance: Sandbanks and Whitley Lake

3.22 The overall level of human activity on the northern shore of Poole Harbour differed significantly between daytime and night time, with higher visitor numbers during the day compared to the night (Figure 16).



Horizontal bars denote the median number of people seen, shaded boxes denote the upper and lower quartiles, whiskers describe the 5th and 95th percentiles and asterisks depict individual counts outside these bounds. The differences are highly significant: paired T, T = 6.76, n = 180 (15 visits, 12 count areas) p < 0.001, Mann Whitney W = 40409, p < 0.001

Figure 16 Boxplot showing total people from count areas, split between night and day (n = 15 for each group)

3.23 Within this overall dataset, there were differences in human activity between days of the week and also between different times of the day. Five of the fifteen visits took place at the weekend. There were significantly more people present during the daytime at weekends than during weekdays (across all count areas, median number of people per day on weekdays=45.50; on weekend days =150; Kruskal-Wallis, H=5.42, p=0.020). This difference was not apparent at night (across all count areas, median number of people per day on Sun-Thurs night=0; Fri & Sat nights median =4; Kruskal-Wallis, H=0.68, p=0.409).

3.24 Nights were not consistently quiet. People were encountered during darkness at most points, with dog walkers, fishermen, cyclists, walkers and canoeists all recorded during darkness. People recorded during the night often carried torches or similar, canoeists were observed with lights on their canoes and even many of the dogs seen at night had fluorescent collars. It was the early night time visits (that is, pre 9pm) that were the busiest (for night time visits only, median number of people recorded on visits before 9=0.24; for visits after 9 median = 0; Kruskal-Wallis H=5.40, p=0.020). Five of the night time visits took place before 9pm.

3.25 For day time visits the afternoon was the busiest period. The two park areas (Hamworthy and Parkstone Bay) were notable in having large numbers of visitors in the afternoons (Figure 17). A high proportion of these people are dog walkers.

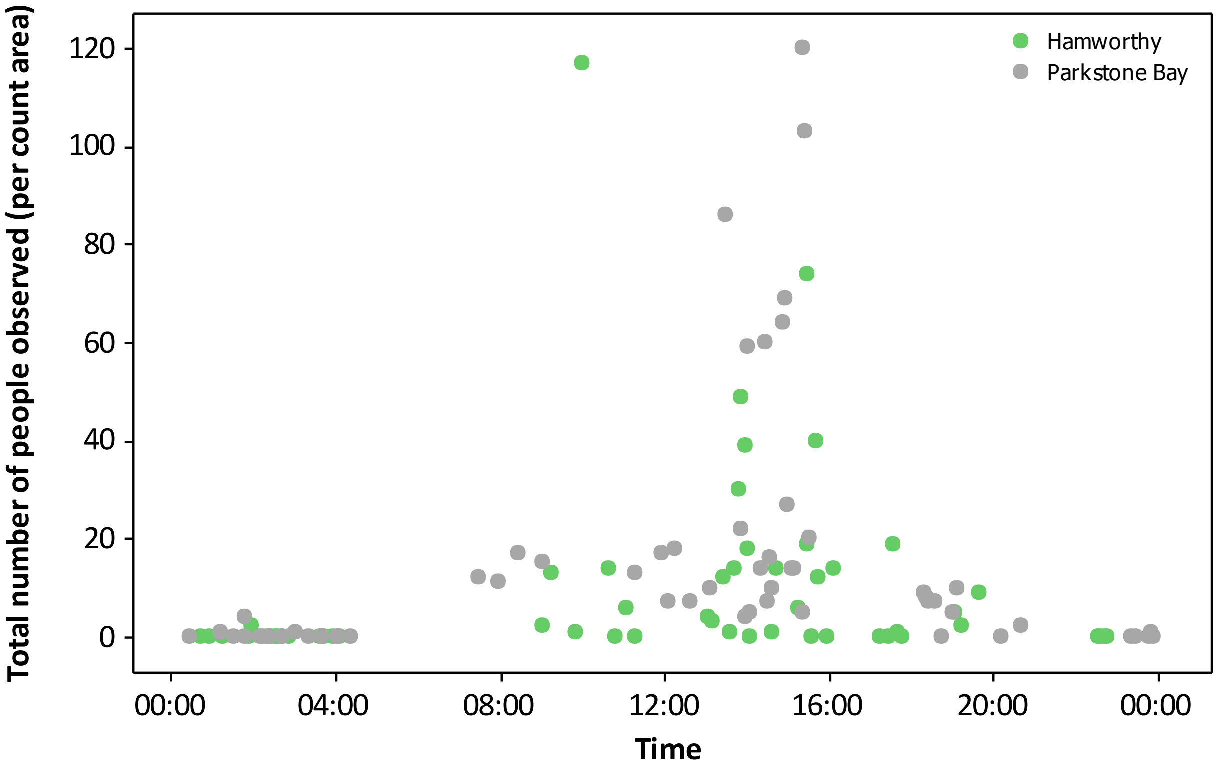
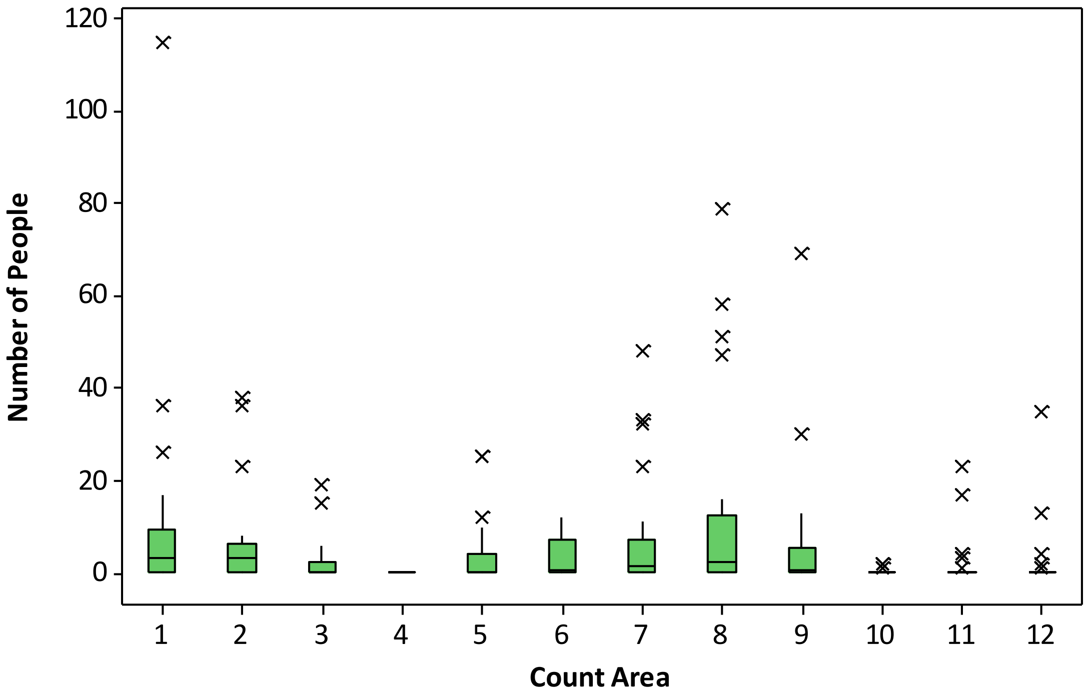


Figure 17 Number of people for each count area in Parkstone Bay and Hamworthy in relation to time of day

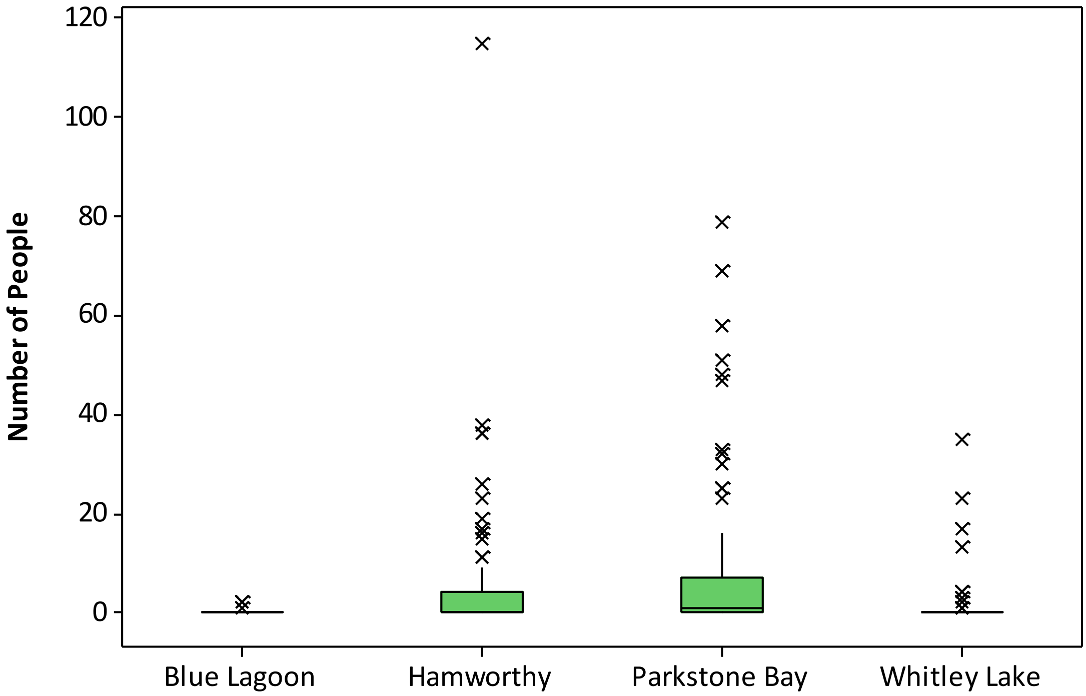
3.26 Thus, it is possible to approximately order the temporal variation in the levels of human activity on the north shore of Poole Harbour in the following order (highest first): weekend afternoons, weekend (other daylight times), weekday afternoons, weekday (other daylight times), weekend evenings, weekday evenings, weekend night, weekday night.

3.27 The number of people observed was significantly different between the different total count areas, with counts being highest in the open grass parts of Ham Park and Whitecliff Parks (Figure 18). The differences were still significant when the count areas were grouped (Figures 19).



Horizontal bars denote the median number of people seen, shaded boxes denote the upper and lower quartiles, whiskers describe the 5th and 95th percentiles and asterisks depict individual counts outside these bounds. Kruskal-Wallis H adjusted for ties = 67.44, $p < 0.001$

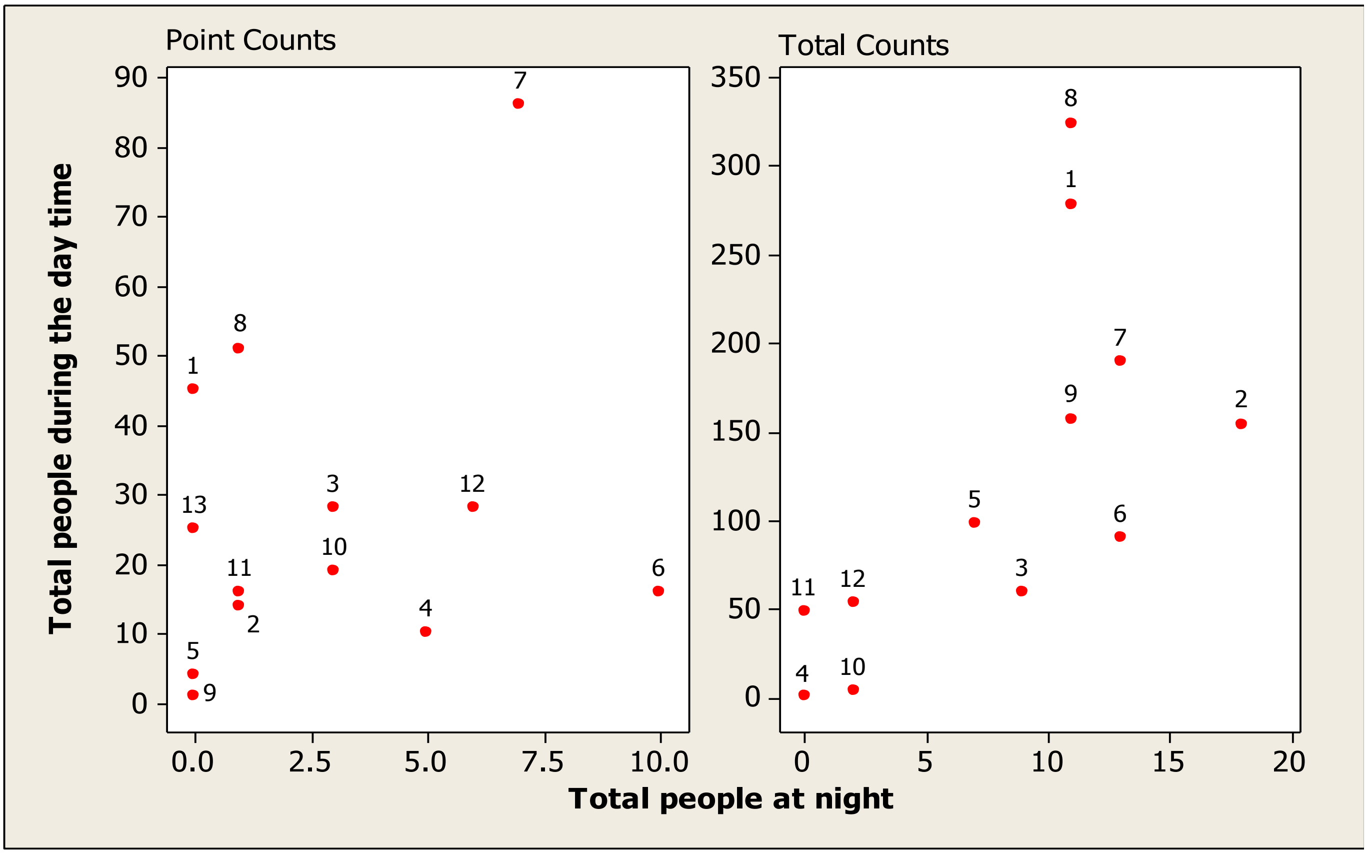
Figure 18 Boxplots showing total number of people per count area, across all visits, night and day



Horizontal bars denote the median number of people seen, shaded boxes denote the upper and lower quartiles, whiskers describe the 5th and 95th percentiles and asterisks depict individual counts outside these bounds. Kruskal-Wallis H adjusted for ties = 33.60. p = <0.001

Figure 19 Boxplots showing total number of people for each broad area

3.28 There was a significant positive correlation between the number of people counted during the day and the number present at night for the total count areas (Figure 20). By contrast there was no correlation with the point counts (Figure 20). This lack of correlation is likely to reflect the very limited and specific areas used for the point counts (people counts within 50m of the point) and the nature of some of the locations, for example Sterte (point 6) was used regularly by fishermen at night.



The left hand graph shows the data for point counts, with the people data being the total count of people recorded within 50m of each point summed across all visits. The right hand graph shows the data for the count areas, with the data for each being the total from all visits combined. For the point count data there is no significant correlation (Pearson correlation coefficient = 0.253, p = 0.405); for the count areas the correlation is significant (Pearson correlation coefficient = 0.651, p=0.022)

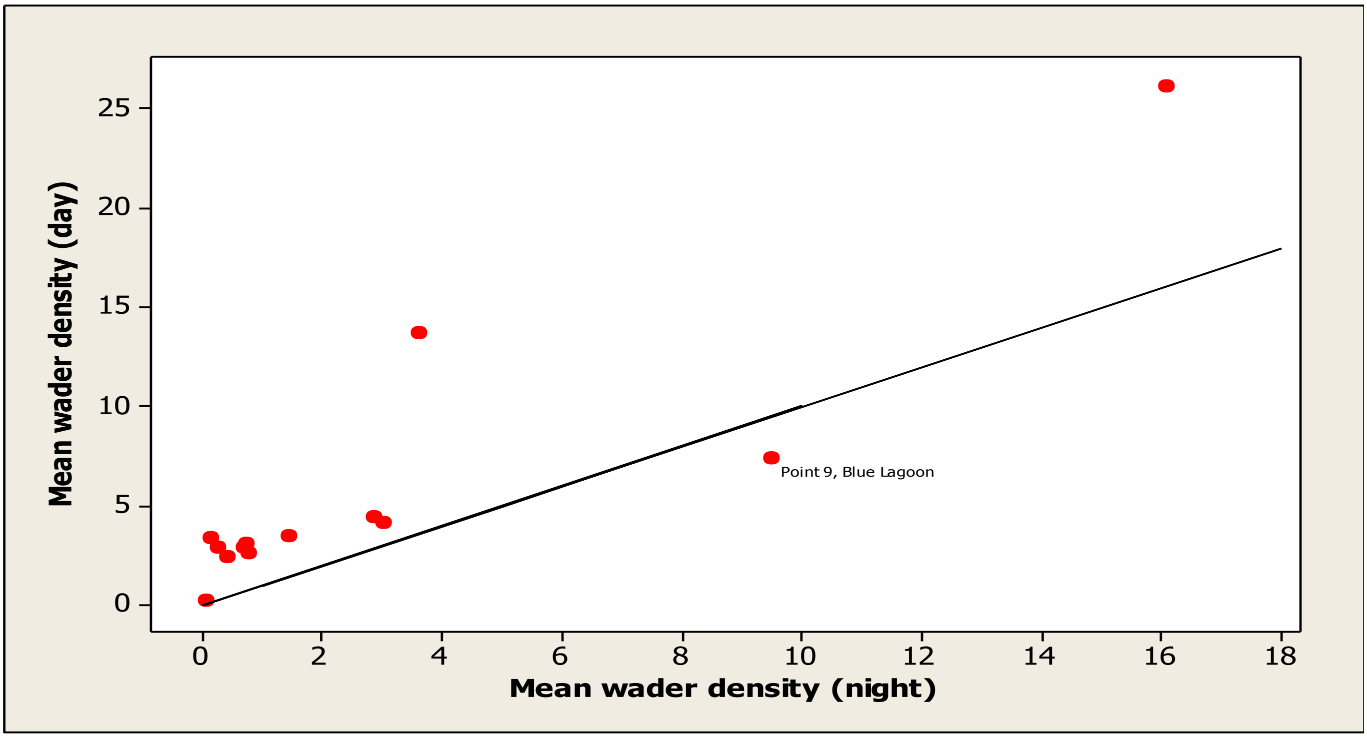
Figure 20 Day and night time counts of people for different locations

Variations in bird distributions in relation to night / day

3.29 We focus on the wader species as these are the species which are clearly present at night in reasonable numbers.

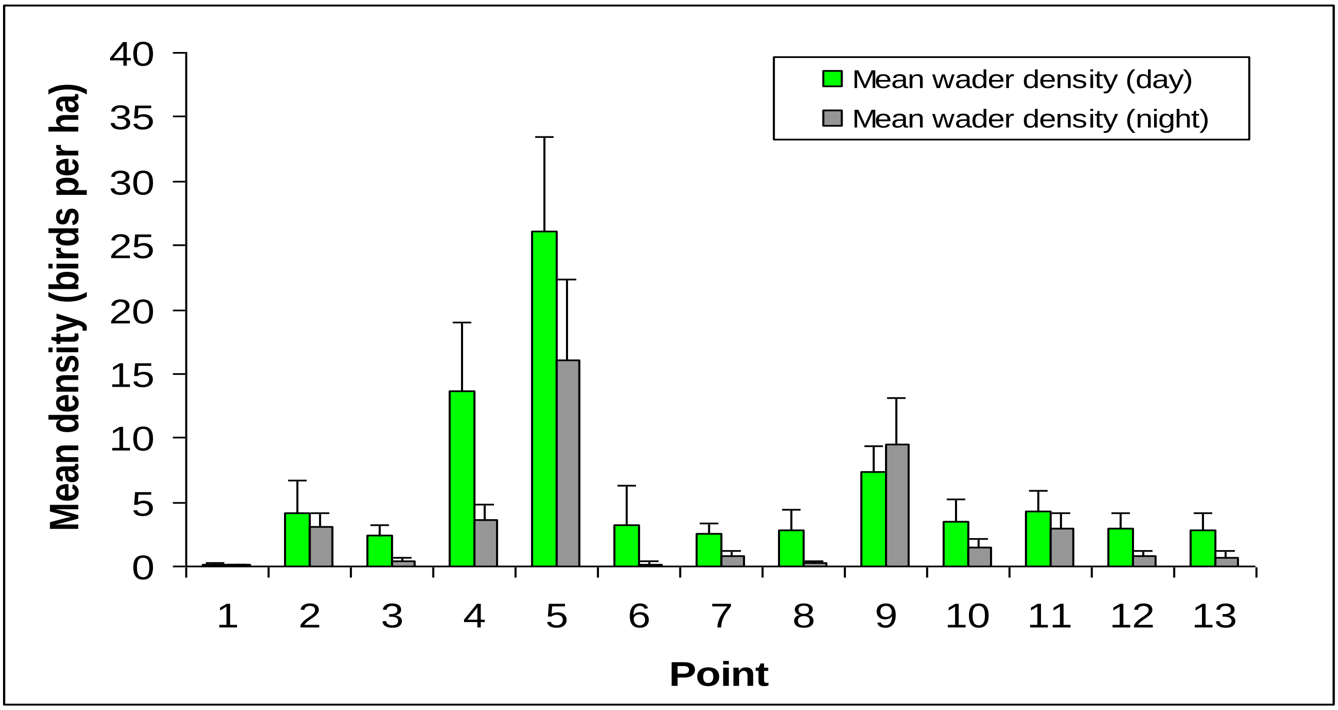
Point count data

3.30 The mean density of waders during the day was significantly correlated with the density of waders recorded at night (Figure 21), indicating that the areas that hold higher densities during the day also hold higher densities during the night, and conversely areas where there are few waders in daytime are also little used at night (relative to other parts of the shore). Across the point count locations only Blue Lagoon had higher numbers of birds at night than during the day. Mean densities for each point are given in Figure 22. Point 1 at Rockley had particularly low densities both day and night and it was the northern part of Holes Bay and Blue Lagoon that in general had the highest densities of birds both day and night (Figure 22).



Densities calculated after truncating the point count data at 200m and discounting those visits when the tide was high. Diagonal line shows the 1:1 ratio, points above this line had higher mean densities during the day than the night. Points below this line (labelled) are those where the mean density of waders was greater at night than during the day. The correlation is significant: Pearson correlation coefficient = 0.891, p<0.001)

Figure 21 Mean wader density per point during the day and night



Mean density is taken from the point count data, discounting data beyond 200m and where the tide was high, and is calculated by summing the waders recorded at each visit and using this total to calculate the density. The mean is then the average across all visits. Points 1 - 4 are at Hamworthy; points 5 and 6 are within Holes Bay; points 7 and 8 at Baiter / Parkstone Bay; Point 9 is within Blue Lagoon and points 10 - 13 are along the Whitley Lake shore round to Sandbanks

Figure 22 Mean density of waders for each point count location

3.31 A general linear model was used to test the significance of location (point count location), night / day, and visit, and the interactions between these terms on the density of waders present. Wader density was calculated using the point count data after truncating to 200m and discounting data from high tide visits. Neither visit nor the interaction between visit and night / day were significant ($p > 0.05$), indicating that there were no significant differences in the density of waders between visits during either the day or the night. Both day / night and point were significant (night / day adjusted sum of squares = 575.43, 1df, $F = 7.20$, $p=0.008$; Point adjusted sum of squares = 9241.25, 12df, $F = 9.63$, $p<0.001$), but when the interaction term between the two was included it was not significant ($p=0.529$), indicating that the density of waders does vary significantly both between points and between night and day (with higher densities during the day). The differences between the night and the day are however consistent across points, indicating that the distribution of birds between point count areas did not differ greatly between day and night. The simple model, involving just point and night / day explained 25% of the variation in wader densities.

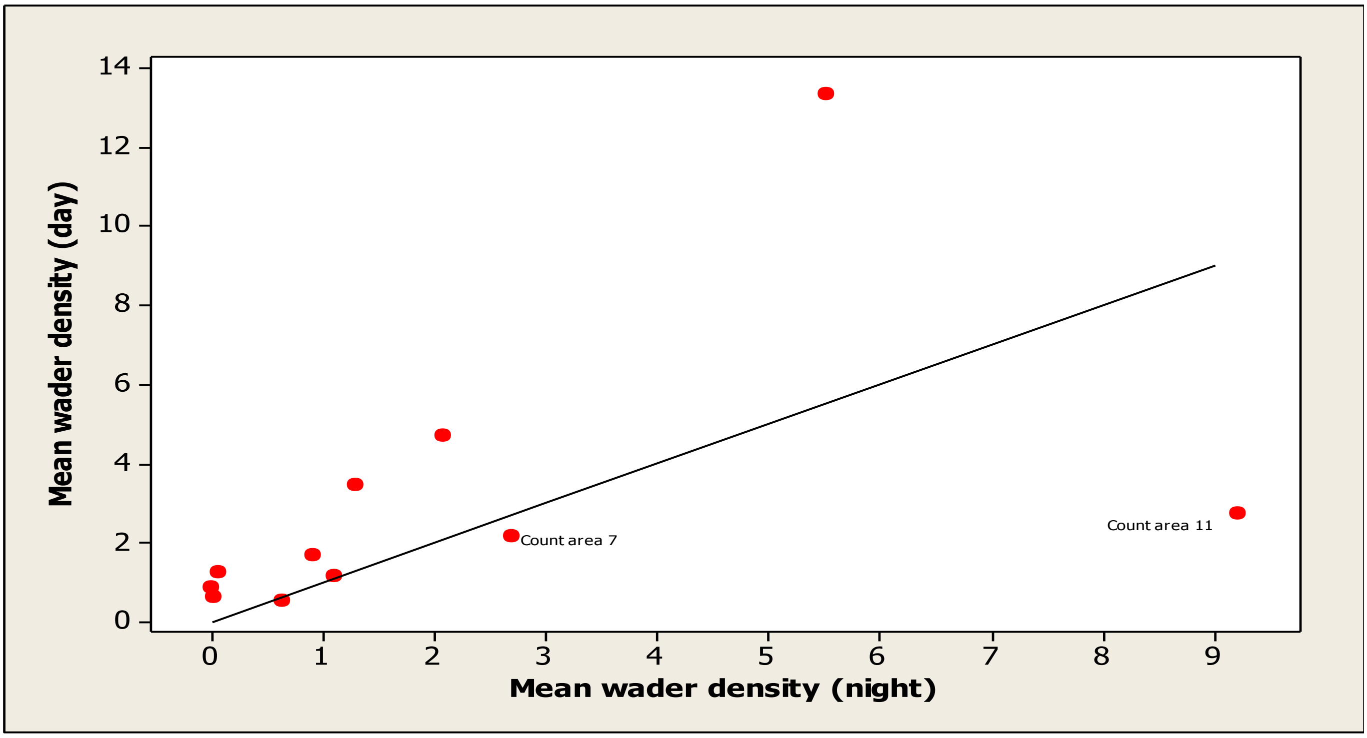
3.32 This approach of looking at total wader densities does mask variation between species. Density estimates also varied markedly between different areas for different species by day and night, further reflecting the complex variation in distribution and abundance across the study area within the winter. Avocets were largely only recorded at the top of Holes Bay, but here they were recorded in reasonably high densities by both day and night. Oystercatchers were relatively ubiquitous, but more abundant at points 4 and 11 during daylight than at night. Bar-tailed godwits were largely limited to Whitley Lake at night but more widespread during the day. Curlew were more abundant In Holes Bay at night than in the day. In contrast, several species for example, dunlin, redshank and ringed plover were more widely distributed at night than during the day.

Total count data

3.33 The mean density of waders during the day was not significantly correlated with the density of waders recorded at night (Figure 23). Densities were typically lower within the count areas than at the point count locations (Figure 24). Very few waders were recorded at all within the grassy areas of the parks at night (count areas 1, 6 and 8). The grass at Baiter did occasionally hold waders when the grass was very wet, snipe (one night only), grey plover (one night only) and ringed plover (two nights) were recorded here. During the day these grassy areas were occasionally used by feeding oystercatchers, but no other waders species were recorded on the grass during the day. No waders at all were counted on the breakers at Hamworthy marina (count area 4).

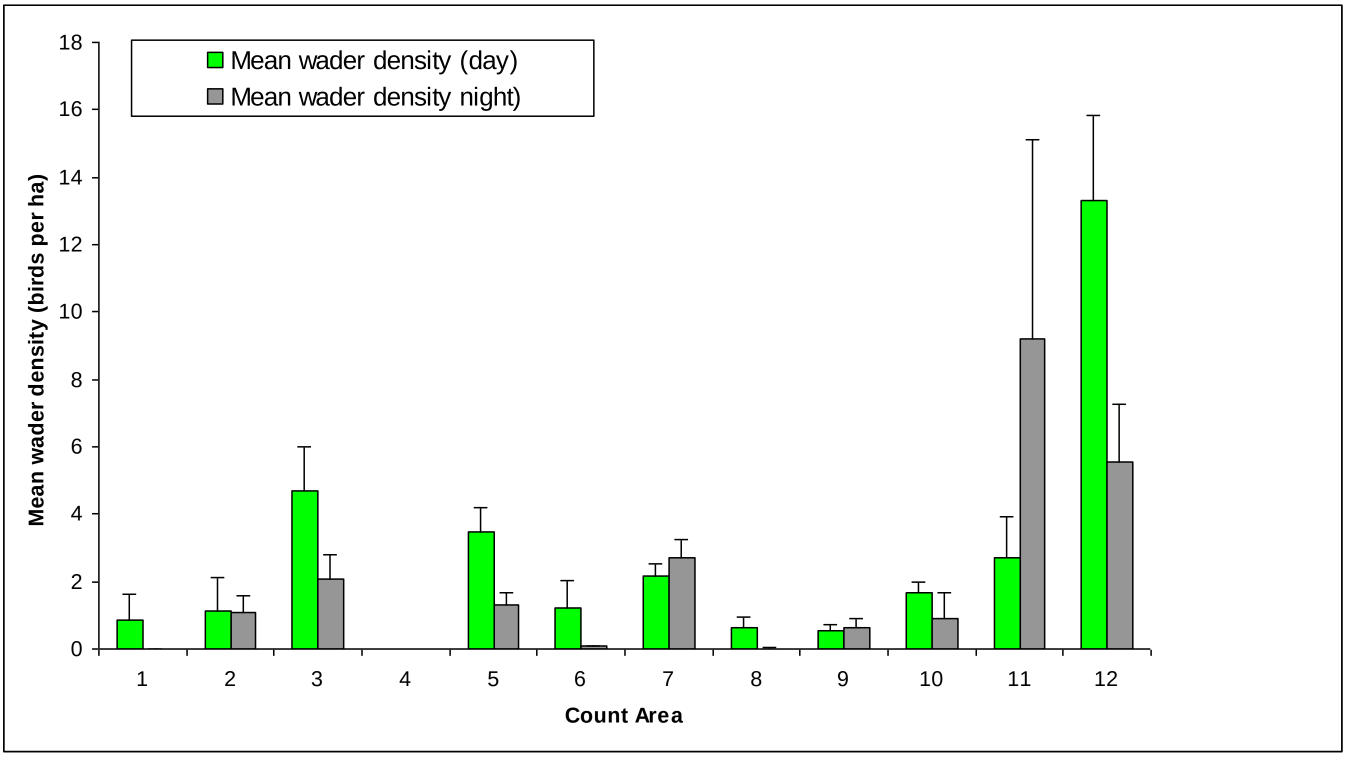
3.34 A general linear model was used to explore the significance of location on the density of waders within the count area by day or night. The density of waders (birds per ha) per visit was the response variable. Across all total count areas there was no significant difference between night and day ($F = 1.49$, 1 df, $p = 0.224$), however there were significant differences between count areas ($F = 7.20$, 11 df, $p < 0.001$), and the interaction tern between count area location and day/night was significant ($F = 2.33$, 11 df, $p = 0.009$). This indicates that the distribution of birds between total count areas differed between day and night (in contrast to the results found for the point count locations). In total the model explained 19% of the variation in the data.

3.35 There were two count areas with higher densities of waders at night than during the day, these were count area 7 (Baiter foreshore) and count area 11, the area of sandy beach/saltmarsh at the centre of Whitley Lake (Figure 23 and Figure 24). Both these count areas held a variety of species at night, the area near the sewage outflow within Parkstone Bay was a particular feature of that part of the shore and ringed plover, grey plover and curlew were all recorded feeding here. At Whitley Lake the raised beach area and outflow was often used by ringed plovers and dunlin, with flocks sometimes present. During the day the area was often very busy: windsurfers and kite surfers often access the open water here and regularly were using the raised beach area to sort out their equipment.



Diagonal line shows the 1:1 ratio, points above this line had higher mean densities during the day than the night. Points below this line (labelled) are those where the mean density of waders was greater at night than during the day. The correlation is not significant: Pearson correlation coefficient = 0.502, p=0.115)

Figure 23 Mean wader density per count area during the day and night



Mean density is calculated by summing the waders recorded at each visit and using this total to calculate the density. The mean is then the average across all visits (n=15). Areas 1-4 are at Hamworthy; areas 5 -9 are within Parkstone Bay; area 10 is at Blue Lagoon and areas 11 - 12 are along the Whitley Lake shore.

Figure 24 Mean density of waders for each count area

3.36 There were three nights (visits 1, 6 and 14) on which the number of waders (total count data) was higher in the night than the day. There was no obvious difference between these nights and other nights (for example they cover a range of tide heights, days of the week etc).

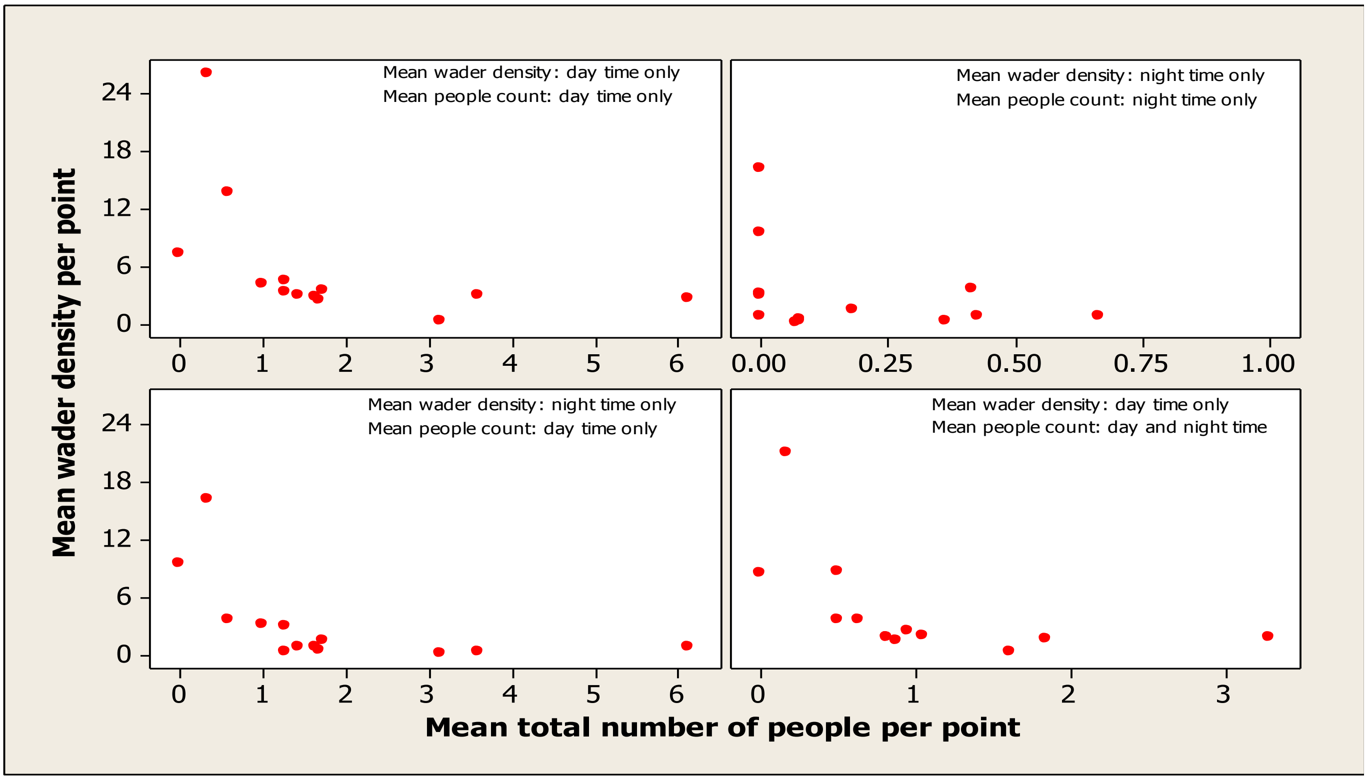
3.37 There were marked differences in the number of birds recorded during the night in relation to the number during the day on different nights. On visits such as visit 6 (3rd January) there were reasonable numbers of birds counted both during the day and the night. There were dates when there were high counts during the day and not during the night (for example, 21st January), and equally some nights such as the 6th February when few birds were counted during the day and many more during the night.

Relationship between bird and human distribution

3.38 As in the previous section we focus on waders.

Point count data

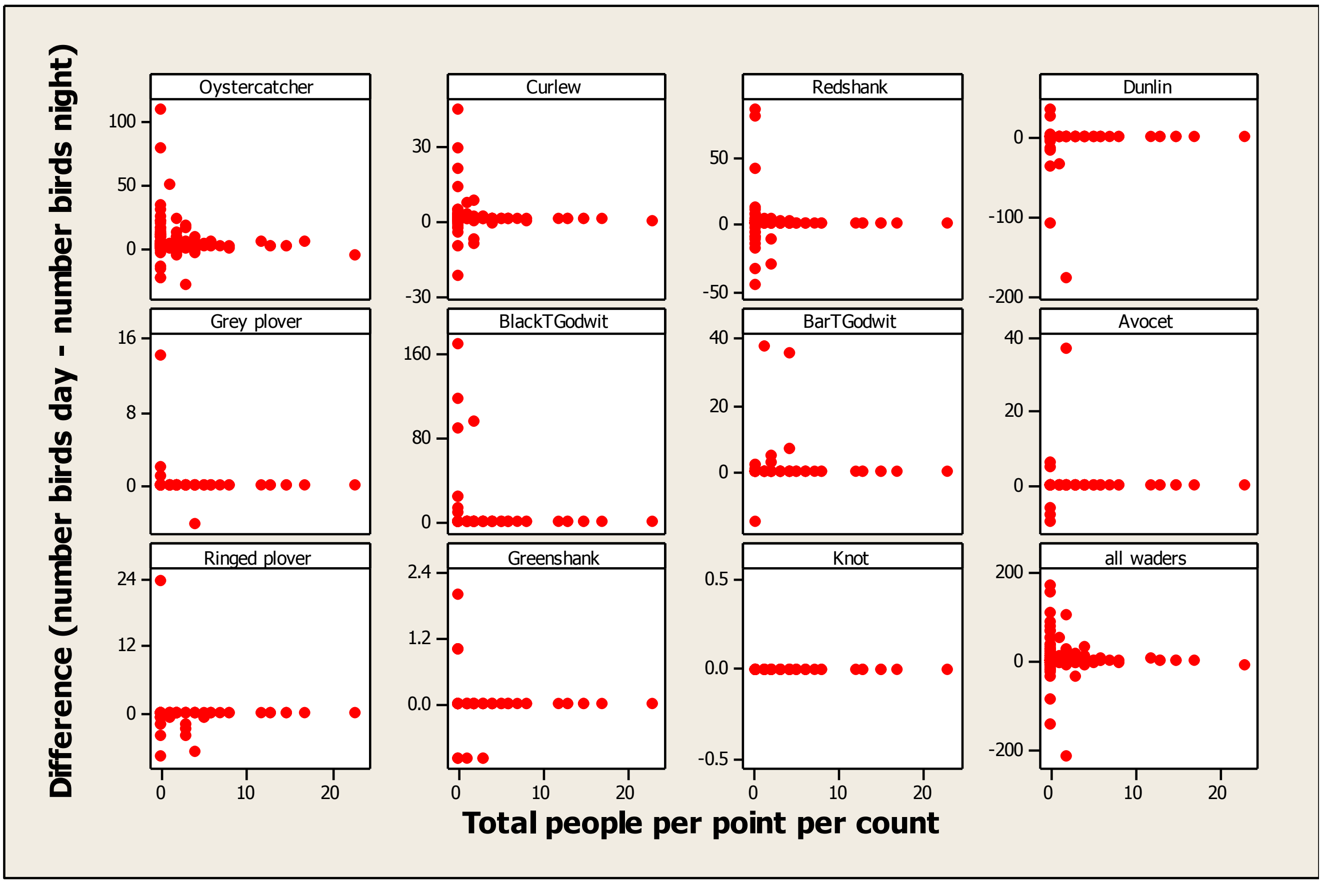
3.39 The mean density of waders, per point, was higher for those points where disturbance levels were low, and was lower where disturbance levels were higher (Figure 25). This pattern was clearest using the day time bird and people counts, and there was little evidence of a clear pattern when only the night time data (that is, the mean number of birds and people during the night for each point) were used, as shown in the top right panel of Figure 25. There is therefore an indication that the distribution of birds, during the day-time at least, is determined by disturbance levels.



Mean density (birds / ha) is taken from the point count data, discounting data beyond 200m and where the tide was high. Mean total number of people per point is the sum of all people counted at the point, per visit (that is, including people on the mudflats), averaged across all visits. All correlations are significant (rank spearman correlation, p = 0.01) apart from the top right panel (not significant) and the bottom left panel (p = 0.05).

Figure 25 Mean density of waders (all wader species combined) and mean people counts for each point

3.40 If disturbance levels during the day were to cause birds to feed less or leave a particular area during the day, it might be expected that birds would compensate by feeding more at night and hence that there would be a more pronounced difference between daytime and night-time bird numbers than would be the case in the absence of such disturbance. For each individual point count visit we tested the relationship between the difference in day and night use by the birds in relation to the number of people recorded during the point count in the day. The difference was calculated by subtracting the count during the night from the count during the day, and therefore a positive value indicates that bird numbers were higher during the day and a negative value that bird numbers were higher during the night. It might be expected that negative values would therefore occur on those occasions when disturbance levels (people count) were high. This was not the case for any of the wader species or for all waders together (Figure 26). This is of course a tough test in that the point counts take minutes to conduct, and therefore we are testing to determine whether the numbers of birds during a very limited window at night is related to the number of people in a similarly short window during the day.



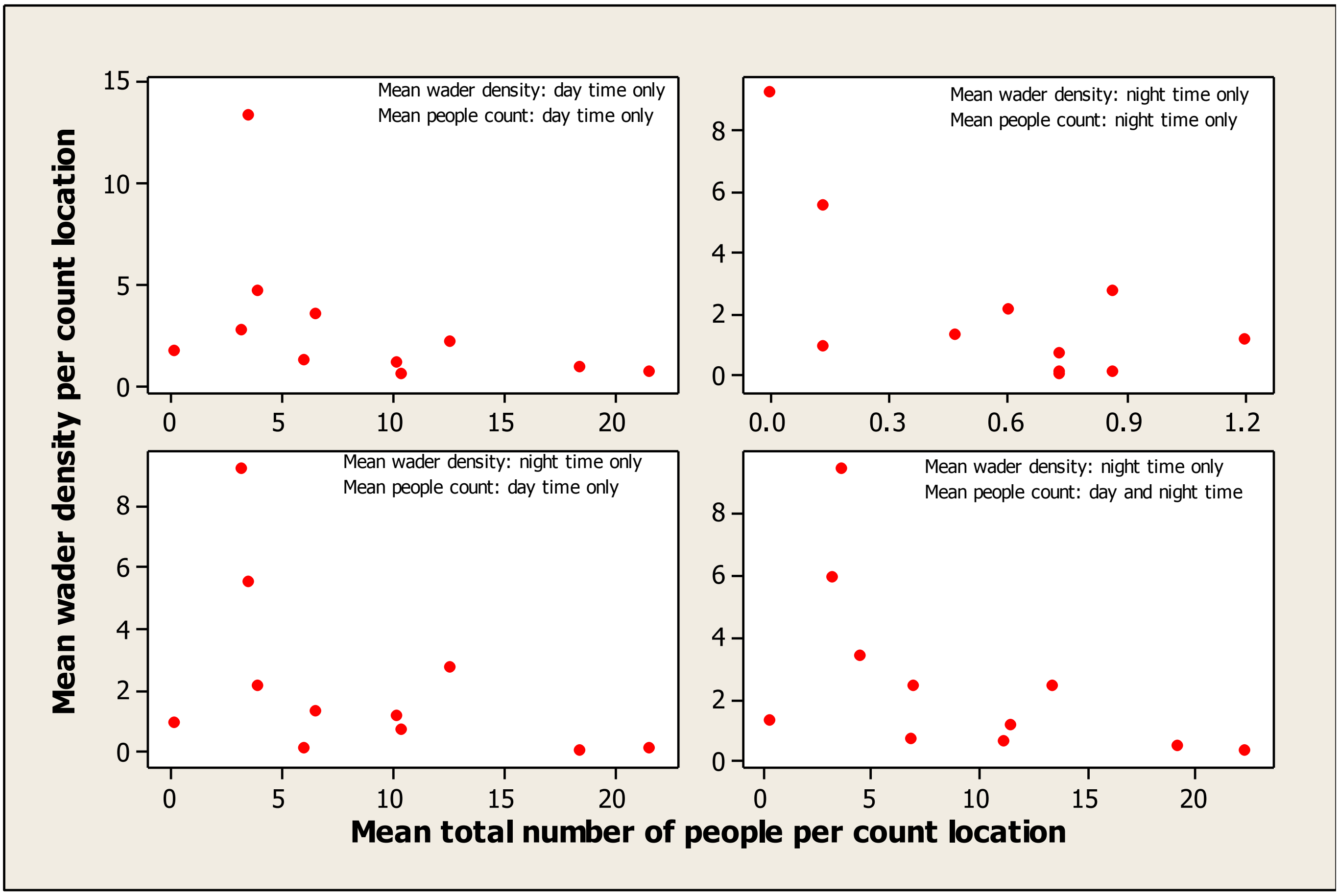
The bird data are from point counts, discounting visits made when the tide was high and truncating at 200m. The difference is the number during the day on a particular visit minus the number during the subsequent night at the same point. The people data are the total number of people recorded from the day time point count on the given visit.

Figure 26 Difference in night / day use by waders in relation to levels of disturbance

3.41 Disturbance levels were added into the general linear model described in Section 3.31. The response variable was the density of waders recorded at each point at each visit (discounting visits made at high tide), with the density calculated using records only within 200m of the point. Location (point count location) and night / day were included as factors within the model and the total number of people recorded at each visit was included as a covariate. The disturbance variable was not significant ($F = 2.43$, $p = 0.120$), indicating that level of disturbance, counted at the same time as the birds, is not an important factor in explaining that count.

Total count data

3.42 In a similar pattern to the point count data (Figure 25), the highest mean densities of waders tended to occur at the point count locations with the lowest mean people counts (Figure 27). There was considerable scatter however, reflecting the range of different locations (count areas included areas of open grass, breakers, sandy shores and mudflats), and with just 11 count areas, there was no significant negative correlations between wader densities and people counts (Figure 27).



None of the correlations are significant (Rank Spearman Correlation, p>0.05 in all cases)

Figure 27 Mean density of waders (all wader species combined) and mean people counts for each total count area

3.43 Disturbance levels were included in the general linear model described in Section 3.34. The density of waders recorded at each visit within each total count area was the response variable and night / day, count area and the interaction between count area and night/day were set as factors within the model. The people count was added as a covariate and was not significant (F=-0.26, p = 0.793), indicating that the density observed at a particular time is not related to the count of people made at that same time.

Predators

3.44 There were no instances of birds of prey observed during the day at any of the point counts / count areas. At night, foxes *Vulpes vulpes* were regularly encountered, often well out on the mud flats and in most parts of the northern shore, with the exception of Holes Bay (Table 7). All fox sightings on the shoreline (that is, the sea wall, mudflats or beach) are shown on Figure 28. Birds were occasionally seen flying or reacting to the foxes, but no predation events were observed.

3.45 A cat was seen on the mud flats once, at Baiter.

Table 7 Total number of foxes seen in different areas. Data totals from all visits, and only for sightings on seawall, shore or beach

Area	Number of foxes observed at night
Hamworthy	5
Holes Bay	0
Parkstone Bay	7
Blue Lagoon	3
Whitley Lake	14

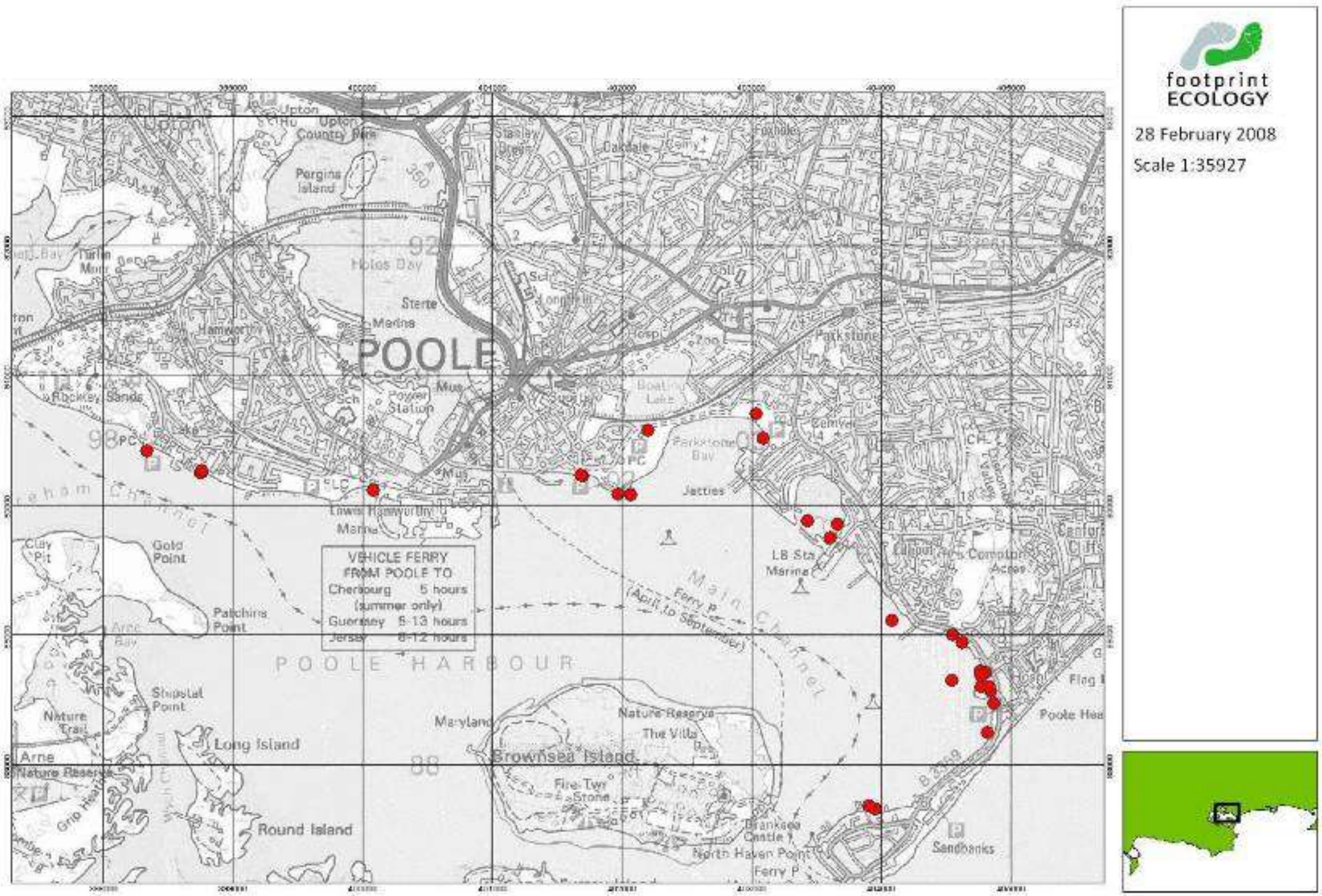


Figure 28 Locations of all foxes observed throughout the study period

4 Discussion

Overview of results

4.1 Six key questions were posed in the introduction, these have been addressed within the analysis and the results are summarised here:

Does the overall number (and density) of birds on the northern shore vary between night and day?

Yes. (See Figure 8, Figure 9a, Figure 9b, Figure 10, Table 3 & Table 5.)

A total of 31 bird species were recorded, 25 of which were present both during the day and the night. Overall there were significantly more waterfowl, waders and gulls present during daylight than at night. Gulls were largely absent at night. Waders were the main group recorded at night. There were three wader species which were significantly more abundant at night than during the day, these were dunlin, ringed plover and grey plover. Two further species, jack snipe and snipe, were only rarely recorded, but all records were at night.

Does the distribution of birds differ between the night and day?

Yes, to some extent. There were differences for some species and some locations. (See Figure 21, Figure 22, Figure 23 and Figure 24.)

Holes Bay and Blue Lagoon held the highest numbers of birds during the day and at night. In general the areas that held the highest densities during the day also held the highest densities at night (Figure 21 and Figure 23). Dunlin were notable, with reasonably large flocks present during the night at Parkstone Bay and within Whitley Lake, both areas in which they were not recorded during the day. Ringed plovers were recorded during the day, but virtually always in roosting flocks, and in very few locations. At night they were more widely distributed, feeding in small groups / pairs. Grey plover, ringed plover and snipe were all recorded on the open grass at Baiter during the night, oystercatcher was the only wader recorded here during the day.

Does the overall level of human disturbance on the northern shore differ between night and day?

Yes. (See Table 6 and Figure 16.)

Recreational use of the shore by people included a range of activities, such as canoeing, kite surfing, para-sailing, windsurfing, dog-walking, fishing and bait digging. The distribution of each of these activities varied and different activities occurred at different times. There were significantly more people during the day than at night (for example, Figure 16). People were still recorded at night, especially prior to 9pm. Canoeists, dog walkers, cyclists, bait diggers and fishermen were all recorded at night. All had artificial light with them.

Does the intensity of human disturbance differ between different parts of the northern shore?

Yes. (See Figure 18 and Figure 19.)

There were clear differences between different parts of the shore. The highest counts of people were from the shoreline parks at Hamworthy and Baiter / Whitecliff.

Can the difference in the distribution of birds between different parts of the northern shore between day and night be related to the difference in the distribution of disturbance between these same areas?

Partly. (See Figure 25 and Figure 27.)

In general the areas (such as Holes Bay and Blue Lagoon) that held the highest densities of birds during the day and the night were the least disturbed. Taking individual simultaneous counts of people and birds there was no significant effect of people on the density of birds.

Does the distribution of human disturbance in different parts of the northern shore of Poole Harbour differ between the night and the day?

Yes. (See Figure 20.)

The total count data, which gives the most complete counts of people shows that the areas that were busiest at night were also busiest during the day, but with less people present during the night than the day.

Ecological context

4.2 Most waders feed at night and there are many studies documenting nocturnal foraging in different species (for example, Burger et al., 1991; Burton et al., 2005; McNeil, Drapeau & Goss-Custard, 1992; Sitters, 2000; Stains & Burger, 1994; Whittingham, Percival & Brown, 2000). Detailed studies using radio-tracking have shown that oystercatchers, feeding in estuarine environments will feed on the same mussel *Mytilus edulis* beds during the day and during the night and that time budgets at night and during the day can be similar (Sitters, 2000). It is therefore perhaps not surprising that we have recorded so many species feeding at night along the northern shore.

4.3 The particularly interesting element of this work is the pressures that exist along the northern shore. Densities of waders in most of the WeBS count sectors on the northern shore of the harbour during the day are lower than would be expected given the area of intertidal mud that lies within them (Caldow et al 2005). The opposite is the case for most of the count sectors on the southern shore of the harbour. It would be interesting to determine whether the additional use of the northern shore at night compensates for the reduced use in day time - that is, is the level of use over the day and night combined similar to the levels of use in other areas of the harbour. To ascertain this further studies would be necessary to determine the use of the southern shore at night.

4.4 The areas of the northern shore that hold the most birds, both during the day and at night, are Holes Bay and Blue Lagoon. These are sheltered bays with large areas of soft sediment. These areas also happen to be the areas with the least disturbance. There is no path or public access to Blue Lagoon, but the bay is surrounded by housing and flats, most of which have access to the shoreline. People, including bait diggers were occasionally present within the lagoon. At Holes Bay the dual-carriageway and lack of close housing is probably the reason that few people were counted. There is a shoreline path, but levels of use here were much lower than at Parkstone Bay or Hamworthy. The only opportunities for people to park and access the shore here, without crossing the dual carriageway, are at Upton Country Park or near the mouth of the bay.

4.5 A range of factors besides simply disturbance are likely to determine choice of foraging location. Habitat quality and prey availability are clearly likely to be important (Caldow et al., 2005), yet were beyond the scope of this study. The fact that the lowest levels of disturbance coincide with large, extensive mudflats, holding soft mud (good foraging habitat) potentially confounds the apparent relationship shown in Figure 25 and Figure 27. Other factors such as distance to vegetation cover are also important to foraging waders (Yasue, 2006). It is therefore perhaps not surprising that the general linear models in Sections 3.31 and 3.34 explained a relatively small proportion of the variance in the data.

4.6 At each point / count area the relative proportion of different types of human activity were markedly different. For example, dog walkers favoured the grassy areas at Whitecliff and Ham Park, canoeists were most frequently recorded at Rockley and within Whitley Lake there were a wide range of water-sports. This study was not designed to determine the relative disturbance impacts of different activities. However, it does highlight the range of different activities that do take place and the varied pressures along the northern shoreline.

4.7 The range of species recorded at night is impressive, and many species were recorded in areas during the night where they were not present during the day. This was particularly apparent with dunlin, which were recorded at higher densities and in different locations at night. This has been shown at other locations, for example in the Wadden Sea, migrating dunlin tended to utilize different habitats during daytime and night-time, with relatively more birds aggregating on soft sediment containing high densities of *Corophium volutator* at night (Mouritsen, 1994). The same authors also found that anti-predator strategies were different at night, with the dunlin being quieter and flying less during darkness (Mouritsen, 1992).

4.8 It is well known that fox densities are higher in urban areas, and particularly where house densities are relatively low (Harris & Rayner, 1986). Foxes were frequently recorded at night, often well out on the mudflats, and the shoreline and mudflats were clearly used for feeding. On a number of occasions foxes were seen underneath or around jetties. Such structures may provide foraging opportunities, for example, crabs etc. or trapped debris, but it is also interesting to speculate the extent to which such structures may provide opportunities for foxes to hunt birds. It is only where there is the potential for foxes to hide or approach feeding birds unobserved that they are likely to pose a predation risk.

Accuracy of results and suitability of approach

4.9 The aim of this work was to determine the extent to which the northern shore is used by birds at night in comparison with daytime usage and the extent to which use varies between locations and species and is influenced by levels of human activity. Given the range of habitats and locations we felt it important to use different methods and therefore chose two different approaches. The advantage of the point counts is that they allow the observer to be stationary, to gain familiarity with specific locations and the use of distance sampling allows detectability to be incorporated in the analysis. The method is most suitable for areas of open habitat. The total count approach is only suitable for areas where it is possible to be confident that all birds within an area have been accurately counted, and is not appropriate for large expanses of open mud where declining detectability with increasing distance will be an issue at night. The total counts did provide a better overview of disturbance data and human use, allowing us to count people over a wide area.

4.10 One of the key difficulties was the tide and ensuring that day / night visits were paired. Tide heights on subsequent tides often varied. Poole Harbour is very shallow, and the tides are complex. Atmospheric pressure and wind speed often influenced the actual height of the tide on a given date, and small differences in tide height can lead to large differences in the amount of mud visible at particular locations, especially in Holes Bay, Blue Lagoon and Whitley Lake, where the gradient of the shore is very shallow. This problem resulted in some paired visits to certain locations being discarded from the dataset due to dissimilarity in tidal conditions.

4.11 Identification of birds at night was not always easy. The smaller waders, godwits and gulls were particularly difficult. Fortunately few gulls were present at night, but in the absence of any vocalisations we did not record Mediterranean gull and yellow-legged gull in darkness. At some locations where there were large expanses of open mud at low tide, such as Whitley Lake, Holes Bay and Blue Lagoon, night time recording was difficult. The night vision equipment would pick out birds far from the shore, but it would be impossible to identify them to species. Calls were often heard for species we had not recorded during the point counts. Our estimates of density and the total counts should therefore all be viewed in this context, they are likely to be under estimates of the number of birds present and it is likely that birds were missed at night. The detectability functions (Figures 4 - 7) reveal interesting patterns. Redshank show perhaps the classic pattern that might be expected were birds being missed at night. For the day time data there is relatively little variation in density across the distance bands, but at night there is a marked decline at 200m, with the highest densities at night recorded from 150m, indicating that birds are being missed beyond 200m. Redshank tend to feed on their own and were difficult to record at night at the larger distances. For other species the pattern is not so clear, but there were markedly few dunlin recorded beyond 300m, few ringed plovers beyond 200m and low densities of Brent goose beyond 200m.

4.12 The EDR values from the density estimates, generated using the Distance software, were below 100m for four species (black-tailed godwit, redshank, ringed plover and dunlin) at night. The EDR indicates the distance at which the software estimated that as many birds were missed as were actually recorded. It is perhaps not surprising that this EDR value is relatively low for ringed plover, dunlin and redshank. Birds the size of black-tailed godwits would be difficult to miss at night, but there is the possibility of the birds being misidentified.

4.13 The confidence of recording at night could perhaps have been improved by using more powerful torches (for example, after Dodd & Colwell, 1998), however these would also have increased the disturbance caused by the observers. We trialled more powerful torches in the pilot study and birds took flight instantly the beam was visible, giving the observers little time to record the species present. This could have served to push birds into other survey areas, potentially confusing the data. A different survey design would have been necessary to accommodate the use of such torches.

4.14 The northern shore comprises a complex range of habitats, with a range of different substrate types (rocky shores, sand and soft mud), a wide range of different types of disturbance that vary temporally and spatially, and a complex tidal cycle that means different areas are exposed for different lengths of time on different days. The interactions between habitat, tide and disturbance are complex and difficult to tease apart.

5 Implications

5.1 In this section we consider the implications of our results in terms of access management issues, development issues and further research.

Assessing the implications of shoreline developments/activities

5.2 Considerable development is planned or is in progress in central Poole. These developments, which include high density housing and some c.6000 new homes in the central part of Poole, have the potential to result in an increase in recreational use of the shoreline and open water.

5.3 The levels of current recreational activity around the Harbour are of current concern (see Underhill-Day, 2006 where access / visitor data is also summarised). Additional visitor pressure as a result of development is likely to occur all along the northern foreshore, but areas such as Holes Bay, Rockley and Ham Park are of particular concern (Hoskin et al., 2007).

5.4 Works have already started in some locations (Plate 1). It is difficult to determine the exact levels of change in recreational use as so little is known about the proportions of residents that visit the shoreline and how far people travel for particular activities.

5.5 The results presented in this report reveal high levels of visitor use along the entire northern shore, involving a suite of activities and all largely un-regulated. We present some tentative evidence for disturbance impacts, in that the highest bird densities are where disturbance is low (Figure 25 and Figure 27). Given the level of protection afforded to Poole Harbour, new developments must therefore demonstrate that there will be no adverse effects on the interest features or integrity of the European designated site. There is a clear need to further understand the links between housing and recreational use of the shoreline, and detailed field studies to determine how the different types of recreational activity affect the bird interest features of the harbour.

5.6 There are a number of clear implications of the work here for assessing the impact of proposed developments on the bird usage of the northern shore of the harbour:

- Daytime bird survey data are unlikely to result in important bird foraging sites on the northern shore being missed completely.
- However, daytime bird surveys risk underestimating the usage of Blue Lagoon, Baiter foreshore and Whitley Lake.
- Daytime surveys risk underestimating the usage of certain parts of the northern shore by certain species that is, dunlin, ringed plover, grey plover, snipe and jack snipe.
- Surveys need to be conducted at a range of times of day and night and also to take into account visitor numbers.
- To gain the best indicator of bird usage in the absence of human disturbance, daytime bird surveys should avoid weekends and weekday afternoons.

Plate 1 Oystercatchers at Baiter, with Poole Quarter developments taking place in the background

Access Management

5.7 There are a number of measures which may serve to reduce visitor impacts along the northern shore. We recognise that some zoning and control of different activities does take place, however we highlight the following additional measures which may have the potential to reduce visitor pressure:

- Boat launching, especially for canoes and other small craft, limited to particular locations.
- Liaison with kite surfer / para surfer / windsurfer shops and clubs and positive moves made to limit where users access the water and where they sail / surf (Plate 2).
- Access restricted on the breakwaters at Blue Lagoon (access levels here are currently low, but the area is an important roost site and would be easy to deter people from).

- Access to beach and water around the centre of Whitley Lake restricted, especially around the raised beach / outflow area.
- Some screening potentially adopted in Parkstone Bay, for example around the sewage outflow.
- People and dogs restricted from the beach at Parkstone Bay (that is, no access below concrete path along shoreline. In particular dogs prevented from running on mudflats.
- Holes Bay shoreline path screened and better landscaping to reduce potential disturbance.
- Different activities such as bait digging and fishing monitored and controlled if necessary.

This area of beach was a focus for these users and the area held few birds during the day

Plate 2 Kite surfers / para sailing in Whitley Lake

Further Research

5.8 Further research could be undertaken to further investigate some of the issues raised in this work. We highlight the following:

Nocturnal use of the southern shore

5.9 Some survey design that allows direct comparison of the nocturnal use of the northern shore and the southern shore would provide a greater sample of points and a larger range of disturbance levels (the southern shore is much less disturbed than the northern shore). The work would be useful in confirming the relative importance of the northern shore within the SPA.

Impact of jetties and other built structures

5.10 It would be interesting to explore in depth the extent to which birds avoid built structures such as jetties etc. The high densities of foxes add a further dimension, and it would be interesting to compare avoidance of built structures and of the shoreline itself both during the day and during the night. Various approaches are possible for such a study, for example looking at the density of footprints, density of droppings or the use of CCTV cameras (potentially with IR illumination) or similar to remotely record use in particular areas.

Foxes

5.11 The extent to which foxes are attracted to areas of shoreline adjacent to housing is of interest and could have implications in the design and location of new development. Urban areas tend to support high fox densities (Harris et al., 1986). The links between development around the edge of European sites, increased fox densities and increased predation on protected species are yet to be made, and this is a gap in our current knowledge (Hoskin et al., 2007) relevant to the Appropriate Assessment of new development in such habitats.

Bird movements between north shore, southern shore and roost sites

5.12 We have little understanding of the extent to which birds mix within Poole Harbour, and in particular the extent to which birds in the northern part of the shoreline also use the southern shoreline. Dye marking, tracking or colour ringing studies could provide useful indications of how birds do distribute themselves within the Harbour as a whole, and hence the relative importance of different areas to the populations as a whole.

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Appendix 1 Point Count Locations / Description of Point Counts

Table A Point Count Locations / Description of Point Counts

	General Area	Survey area (ha)	Number of visits included with mud and similar tide at both night and day	Point location	Description
1	Hamworthy	4.52	14	Large public car-park at Rockley, on eastern side of Ham Common	Relatively sandy shore, one large jetty at car-park. Large public car-park. Shore backed by cliffs, scrub and some housing.
2	Hamworthy	0.66	14	Public slipway to east of marina.	Gravelly shore with much bladderwrack. Small outflow and marina entrance.
3	Hamworthy	0.89	13	Far western corner of Rockley Park	Public park with tarmac path along seawall, beach huts, childrens' playground and open grass. Point in corner, with sandy beach, groynes, some gravel and a large jetty.
4	Hamworthy	1.38	12	Eastern end of Rockley Park, middle of shoreline, next to three beach huts	Small bay with groynes, mud and marina opposite. Tarmac path along seawall backed by public park.
5	Holes Bay	17.90	12	Top part of bay, count from shoreline adjacent to roundabout and MacDonald's car-park.	Shoreline with grass strip, scrub and tarmac path. Dual carriageway and roundabout adjacent. Point overlooking extensive mudflats / estuary.
6	Holes Bay	15.30	11	Shoreline at Sterte, at small point	Shoreline with grass strip, scrub and tarmac path, adjacent to dual carriage-way. Point looking westwards, point adjacent to patch of scrub.

Table continued…

	General Area	Survey area (ha)	Number of visits included with mud and similar tide at both night and day	Point location	Description
7	Parkstone Bay	3.48	14	Western end of Baiter, between Poole Old Quay and mouth of bay. Point count above outflow.	Tarmac path and short grass / park, essentially start of Baiter. Large public car-park to east and housing and marina to west. Beach gravely.
8	Parkstone Bay	9.73	13	Adjacent to plinth below Whitecliff viewpoint. Within Whitecliff park.	Busy park with football pitch, playground and dog walking circuit. Muddy bay, with tarmac shoreline path. Marina on far side of bay.
9	Blue Lagoon	12.36	13	On side of lagoon, accessed from Saltern's Marina	Bay approximately circular, surrounded by housing and with relatively little public access. Bay very flat, predominantly mud, with saltmarsh and shingle bank to west.
10	Whitley Lake	3.69	11	Yacht Club car-park.	Small gravely beach and mud flats adjacent to and running north-west from large wooden jetty.
11	Whitley Lake	14.36	11	Shore Road	Promenade and concrete sea-wall at northern end of bay. Relatively sandy substrate.
12	Whitley Lake	9.40	9	Shore Road nr Sandbanks. Adjacent to small pine tree.	Southern end of bay, looking north. Concrete seawall, promenade and open bay.
13	Whitley Lake	0.26	11	Sandbanks, Davis's Boatyard.	Public footpath leading down to shoreline. Relatively sandy beach with some mud, flanked by boatyard and housing. Numerous jetties.

Survey area is the area of exposed mud at low tide (within 400m of point) and number of visits is the count where both the day and night visit were conducted at similar tide heights and exposed mud was present (maximum 15)

Appendix 2 Total Count Areas; Description of Location

Table B Total Count Areas; Description of Location

Area	General Area	Description	Approximate Area (ha)
1	Hamworthy	Ham Park. Grassy area, including children's playground, car-park, café and paddling pool. Seawall (in front of beach huts a separate count area)	8.2
2	Hamworthy	Sea wall, with tarmac path, beach huts and sandy beach.	1.4
3	Hamworthy	Sea wall along edge of park. Tarmac bath, beach huts and mud flats.	1.7
4	Hamworthy	Breakers around marina, opposite Ham Park.	0.62
5	Parkstone Bay	Baiter. Sea wall and mud flats. Sea wall section in front of car-park and along towards Poole old town.	2.52
6	Parkstone	Baiter, open grass / park, with small pond and some scrub.	14.6
7	Parkstone	Baiter. Sea wall along from car-park running north-south. Includes slip way and ends at sewage outflow. Tarmac footpath along top of wall for the length of the count area	5.8
8	Parkstone	Whitecliff. Open grass area, including football pitches, children's playground etc	9.5
9	Parkstone	Parkstone Bay. Inside of Bay from sewage outflow round to Marina.	10.1
10	Blue Lagoon	Small corner of mudflats outside the lagoon at the base of the breakers.	4.2
11	Whitley Lake	Centre of bay. Area of beach and saltmarsh, outflow and reeds.	1.7
12	Whitley Lake	Area of mud adjacent to the above.	8.3

Appendix 3 Visit Summary

Table C Visit summary

Visit	Date[1]	Day	Day start time	Night start time	Low tide times[2]	Low tide heights	Notes
1	07/11/2007	Weds	13.25	01:25	14:59; 03:08	1.0m; 0.8m	Started both night and day counts at Rockley. Day visit and night visit both on falling tide .
2	15/11/2007	Thurs	06:37	17:02	07:27; 19:46	0.9m; 0.7m	Day count started at Sandbanks, night count started at Rockley. Both visits on rising tides.
3	08/12/2007	Sat	13:10	01:40	15:50; 03:58	0.8m; 0.8m	Started both night and day counts at Rockley. Both counts done on falling tide.
4	16/12/2007	Sun	07.33	18:43	08:42; 21:00	1.0m; 0.8m	Started day visit at Sandbanks, night visit at Rockley. Visits both started just before low tide and done largely on rising. Night visit tide lower than day.
5	20/12/2007	Thurs	10:54	22:22	13:02; 01:20	1.1m; 1.0m	Started both night and day counts at Rockley, both counts done on falling tide.
6	03/01/2008	Thurs	10:19	22:02	09:29; 21:32	1.6m; 1.3m.	Started both night and day counts at Sandbanks. Both counts on falling tide.
7	04/01/2008	Fri	10:22	22:21	10:02; 22:04	1.6m; 1.3m	Started both night and day counts at Rockley. Both counts on falling tide.

Table continued…

[1] Date and day refers to date of day visit. Night time visits were always on subsequent night, so if started after midnight will be on the subsequent day

[2] Tide heights and times are for Pottery Pier (Brownsea), provided by the UK Hydrographic Office, taken from their EasyTide website, URL: **http://easytide.ukho.gov.uk/Easytide/EasyTide/Support/About.aspx**. Only relevant tides to the visit are given

Visit	Date[1]	Day	Day start time	Night start time	Low tide times[2]	Low tide heights	Notes
8	20/01/2008	Sun	12:20	00:53	14:34; 02:55	0.9m; 1.0m	Started both night and day counts at Sandbanks. Both counts done on falling tides.
9	21/01/2008	Mon	13:20	17:23	15:24;	0.7m; 1.7m	Started day visit at Sandbanks and started night visit at Rockley, Day visit on falling tide and night visit on rising tide.
10	01/02/2008	Fri	13:39	19:51	13:45; 21:19	1.2m; 1.3m	Started both night and day visits at Sandbanks. Relatively little variation in tide, with low tide heights relatively high.
11	02/02/2008	Sat	13:37	00:25	14:16; 02:27	1.1m; 1.2m	Started day visit at Rockley and night visit at Sandbanks. Both counts on falling tide and over low tide.
12	03/02/2008	Sun	12:38	00:27	14:40; 02:54	1.0m; 1.0m	Started both night and day visits at Sandbanks. Both counts on falling tide.
13	05/02/2008	Tues	13:10	01:22	15:30; 03:53	0.7m; 0.8m	Started both night and day visits at Sandbanks. Both counts on falling tide.
14	06/02/2008	Weds	13:36	02:05	16:04; 04:28	0.5m; 0.6m	Started both night and day counts at Rockley. Both counts on falling tide.
15	08/02/2008	Thurs	13:45	17:30	17:22;	0.3m	Started at Rockley on falling tide and retraced steps on the rising tide. Exceptionally low tide.

Appendix 4 Point Count data

The following tables give the totals recorded for each species summed across all point counts on each visit, by day and by night.

Table Da Point Count Data - Waders

Visit	Knot		Oystercatcher		Curlew		Redshank		Dunlin		Grey Plover		Blk-tailed Godwit		Bar-tailed Godwit	
	day	night	day	night	day	night	day	night	day	night	day	night	day	night	day	night
1	0	0	72	11	110	71	140	137	27	0	3	1	200	160	2	1
2	0	0	119	0	147	0	110	0	90	0	2	0	102	0	22	0
3	0	0	141	63	4	32	9	62	2	0	0	0	0	0	0	0
4	0	0	89	67	25	19	60	36	0	12	2	0	230	46	2	0
5	0	0	142	87	53	42	136	42	0	0	0	0	175	1	56	0
6	0	0	153	31	50	8	77	11	11	119	14	0	349	2	55	0
7	0	0	187	35	13	13	26	13	0	120	1	0	57	0	2	0
8	0	0	147	67	85	13	41	37	0	180	0	0	0	0	0	0
9	0	0	125	0	56	0	45	0	0	0	0	0	0	0	15	0
10	94	0	151	0	49	0	78	0	3	0	5	0	95	0	120	0
11	65	0	174	35	37	15	85	36	0	15	3	0	75	0	70	0
12	0	0	89	24	38	5	55	28	0	6	0	0	45	0	1	0
13	0	0	178	41	52	15	124	49	0	58	0	0	21	0	0	15
14	65	0	80	130	44	37	111	54	0	25	0	4	0	0	59	15
15	53	0	101	121	34	5	20	0	35	0	3	0	0	0	41	12
Total	**278**	**0**	**1948**	**712**	**797**	**275**	**1117**	**505**	**168**	**535**	**33**	**5**	**1349**	**209**	**445**	**43**

Table Db Point Count Data - Waders continued

Visit	Avocet		Ringed Plover		Greenshank		Spotted Redshank		Turnstone		Jack Snipe	
	day	night	day	night	day	night	day	night	day	night	day	night
1	0	10	4	1	0	1	0	0	0	0	0	0
2	37	0	0	0	0	0	0	0	5	0	0	0
3	0	22	7	5	0	0	0	0	0	0	0	0
4	103	29	3	0	2	1	0	0	28	0	0	3
5	1	18	28	0	2	2	0	0	6	0	0	1
6	15	35	31	36	1	1	4	0	13	0	0	0
7	0	0	36	33	2	0	0	0	1	0	0	0
8	0	53	0	4	0	1	0	0	0	0	0	0
9	0	0	1	0	2	0	1	0	0	0	0	0
10	0	0	0	0	0	0	0	0	3	0	0	0
11	8	0	0	1	0	0	0	0	0	0	0	0
12	0	0	0	6	0	1	0	1	20	0	0	0
13	6	0	0	1	0	1	0	0	9	0	0	0
14	5	6	6	11	0	0	0	0	2	0	0	0
15	0	0	0	3	1	0	0	0	1	0	0	0
Total	**175**	**173**	**116**	**101**	**10**	**8**	**5**	**1**	**88**	**0**	**0**	**4**

Table E Point Count Data - Wildfowl

Visit	Mute Swan		Brent goose		Wigeon		Shelduck		Mallard		Teal		Pintail	
	day	night	day	night	day	night	day	night	day	night	day	night	day	night
1	15	57	85	0	31	19	32	17	0	17	0	5	0	1
2	43	0	99	0	510	0	55	0	21	0	49	0	8	0
3	11	24	0	9	41	108	23	16	7	9	0	0	0	0
4	2	3	38	0	515	450	65	0	87	45	294	153	11	0
5	39	72	181	49	210	100	35	0	22	7	200	2	5	0
6	39	57	176	14	593	2	76	0	23	7	290	0	3	0
7	29	16	144	0	159	0	8	2	9	0	2	0	0	0
8	34	0	63	11	200	93	107	53	0	0	60	12	7	3
9	37	0	101	0	130	0	103	0	15	0	17	0	0	0
10	31	27	76	0	160	0	47	0	5	0	85	0	5	0
11	21	22	98	145	160	4	91	5	0	0	155	0	0	0
12	45	31	35	87	210	30	60	19	5	2	6	0	0	0
13	37	0	14	132	99	8	115	4	15	0	148	0	5	2
14	25	29	75	0	165	100	84	45	17	3	100	20	5	0
15	17	20	84	47	90	0	35	12	4	0	2	0	0	0
Total	**425**	**358**	**1269**	**494**	**3273**	**914**	**936**	**173**	**230**	**90**	**1408**	**192**	**49**	**6**

Table F Point Count Data - Gulls

Visit	Black-headed Gull		Common Gull		Herring Gull		Lesser black-backed Gull		Greater Black-backed Gull		Mediterranean Gull		Yellow-legged Gull	
	day	night	day	night	day	night	day	night	day	night	day	night	day	night
1	523	60	20	0	58	1	1	0	0	0	0	0	0	0
2	634	0	3	0	43	0	5	0	7	0	0	0	0	0
3	180	0	1	0	11	0	2	0	4	0	0	0	0	0
4	551	0	4	0	37	0	0	0	1	0	0	0	0	0
5	554	0	13	0	48	0	5	0	2	0	2	0	0	0
6	753	0	22	0	62	0	1	0	11	0	2	0	0	0
7	897	2	17	0	88	0	1	0	5	6	0	0	5	0
8	773	0	26	0	80	0	3	0	2	0	0	0	1	0
9	791	0	63	0	190	0	3	0	5	0	0	0	0	0
10	876	0	46	0	89	0	0	0	3	0	0	0	0	0
11	993	0	58	0	48	0	0	0	0	0	3	0	0	0
12	840	0	90	0	56	0	1	0	11	0	3	0	0	0
13	856	6500	102	0	115	0	2	0	0	0	1	0	0	0
14	1510	0	50	0	194	0	0	0	1	0	0	0	0	0
15	1254	170	6	0	221	0	0	0	0	0	0	0	0	0
Total	**11985**	**6732**	**521**	**0**	**1340**	**1**	**24**	**0**	**52**	**6**	**11**	**0**	**6**	**0**

Table G Point Count Data - Herons

Visit	Grey Heron		Little Egret	
	day	night	day	night
1	0	3	13	0
2	2	0	13	0
3	0	0	4	0
4	0	2	3	0
5	0	2	23	7
6	0	1	6	0
7	1	0	7	0
8	7	4	11	0
9	1	0	6	0
10	0	0	2	0
11	0	0	8	0
12	0	1	1	0
13	0	0	3	0
14	0	0	7	0
15	0	4	14	0
Total	**11**	**17**	**121**	**7**

Appendix 5 Total Count Data

The following tables give the totals recorded for each species summed across all count areas on each visit, by day and by night.

Table Ha Total Count Data - Waders

Visit	Bar-tailed Godwit		Curlew		Dunlin		Greenshank		Grey Plover		Knot	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
1	0	0	1	2	0	48	0	0	0	2	0	0
2	3	0	1	0	0	0	0	0	0	0	0	0
3	127	0	7	5	0	170	0	0	0	1	0	0
4	0	0	10	1	0	0	0	0	0	0	0	0
5	48	0	0	3	0	0	1	0	0	2	0	0
6	73	0	11	0	0	181	0	0	0	1	13	0
7	122	0	12	0	0	0	0	0	0	2	32	0
8	85	0	3	4	0	4	0	1	0	1	38	0
9	95	0	1	0	0	0	0	0	0	0	51	0
10	24	0	0	0	0	131	0	0	0	0	94	0
11	65	12	0	8	0	85	0	0	1	0	60	6
12	36	0	8	3	0	127	0	0	0	4	85	5
13	110	11	8	6	0	18	0	0	0	2	101	0
14	0	0	3	8	0	14	0	0	0	8	0	0
15	0	0	1	0	0	0	0	0	0	0	0	0
Total	**788**	**23**	**66**	**40**	**0**	**778**	**1**	**1**	**1**	**23**	**474**	**11**

Table Hb Total Count Data - Waders continued

Visit	Oystercatcher		Redshank		Ringed Plover		Snipe		Turnstone	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
1	15	23	3	1	0	20	0	0	4	1
2	19	0	9	0	13	0	0	0	1	0
3	325	17	2	10	0	7	0	0	4	0
4	46	21	6	7	0	3	0	0	0	0
5	66	58	9	3	0	9	0	0	2	0
6	83	36	3	3	0	5	0	0	24	0
7	144	0	4	0	0	15	0	0	14	0
8	56	80	0	0	0	3	0	0	2	0
9	108	0	0	0	0	1	0	0	10	0
10	53	0	5	0	0	20	0	0	7	0
11	74	20	2	0	0	5	0	0	0	0
12	90	16	1	1	0	6	0	1	0	0
13	203	47	0	0	0	3	0	0	20	0
14	59	129	0	6	0	10	0	0	0	0
15	27	0	0	0	0	0	0	0	0	0
Total	**1368**	**447**	**44**	**31**	**13**	**107**	**0**	**1**	**88**	**1**

Table I Total Count Data - Wildfowl

Visit	Brent goose		Mallard		Mute swan		Shelduck		Wigeon	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
1	21	0	0	3	0	0	0	0	0	0
2	44	0	0	0	0	0	0	0	0	0
3	163	0	40	2	0	0	0	0	0	0
4	144	0	0	0	0	0	0	0	0	0
5	83	65	0	2	0	0	0	0	0	0
6	60	8	0	6	0	6	0	0	0	0
7	104	0	0	0	0	0	0	0	1	0
8	74	0	0	0	0	0	0	0	0	0
9	108	0	0	0	0	0	0	0	0	0
10	24	0	0	0	0	0	0	0	0	0
11	33	0	0	0	0	0	0	0	0	0
12	149	0	0	0	0	0	0	0	0	0
13	210	0	2	4	0	0	0	0	0	0
14	10	0	4	1	5	5	4	0	0	0
15	16	0	0	2	0	0	0	0	0	0
Total	**1243**	**73**	**46**	**20**	**0**	**11**	**4**	**0**	**1**	**0**

Table J Total Count Data - Herons

Visit	Grey Heron		Little Egret	
	day	night	day	night
1	0	0	2	0
2	0	0	1	0
3	0	0	1	0
4	0	2	0	0
5	0	1	1	0
6	0	1	0	0
7	0	0	1	0
8	0	0	1	0
9	0	0	0	0
10	0	0	1	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	1	0
Total	**0**	**4**	**9**	**0**

Appendix 6 People data (Count Areas)

The following two tables give the people data from the count areas, summed by activity, day and night. The two tables give totals for each visit and for each count area.

Table K People data - totals for each visit

Visit	Day / Night	Time (mid-point)	Number of People									Cars in car parks	Dogs	Dogs off lead on mud
			Bait digging	Boat / sail / jet ski	Cycling	Dog walking	Fishing	On mud / beach	Sitting on sea wall	Walking	TOTAL (inc. other categories)			
1	Day	15:05	0	0	0	39	0	1	12	0	**52**	46	0	0
	Night	03:22	0	0	0	0	0	0	0	0	**0**	0	0	0
2	Day	07:59	0	0	6	23	1	0	0	8	**38**	22	30	1
	Night	18:25	0	0	0	0	0	0	0	0	**0**	0	0	0
3	Day	14:20	1	8	0	7	0	14	5	17	**55**	8	5	1
	Night	03:03	0	0	0	0	0	0	2	1	**3**	0	0	0
4	Day	09:03	0	8	1	137	2	1	0	0	**150**	25	39	24
	Night	20:12	0	0	0	7	0	0	0	2	**9**	5	6	0
5	Day	12:14	0	0	1	5	0	0	1	23	**31**	37	0	5
	Night	23:51	0	0	1	0	0	0	0	0	**1**	2	0	0
6	Day	11:19	4	0	0	4	0	2	0	24	**39**	51	15	15
	Night	23:20	0	0	0	0	0	0	0	2	**2**	0	0	0

Table continued...

Visit	Day / Night	Time (mid-point)	Number of People									Cars in car parks	Dogs	Dogs off lead on mud
			Bait digging	Boat / sail / jet ski	Cycling	Dog walking	Fishing	On mud / beach	Sitting on sea wall	Walking	TOTAL (inc. other categories)			
7	Day	12:05	0	0	3	15	2	3	0	8	**35**	46	12	18
	Night	23:28	0	0	0	0	0	0	0	0	**0**	2	0	0
8	Day	14:26	2	17	7	70	2	29	0	89	**235**	37	30	2
	Night	02:23	0	0	0	0	0	0	0	0	**0**	0	0	0
9	Day	14:37	0	0	0	12	0	1	4	17	**74**	47	11	1
	Night	18:20	0	0	4	16	0	0	0	5	**25**	5	12	2
10	Day	15:10	0	3	2	28	1	8	0	13	**57**	29	23	0
	Night	18:22	0	0	3	17	0	0	0	3	**24**	5	18	3
11	Day	14:56	0	6	8	37	0	22	13	85	**251**	55	33	4
	Night	01:48	0	0	1	0	0	0	0	4	**5**	0	0	0
12	Day	13:52	0	2	3	30	0	0	0	19	**123**	67	26	2
	Night	02:11	0	0	0	0	0	0	0	0	**0**	0	0	0
13	Day	14:31	0	0	2	17	0	0	0	4	**23**	49	7	21
	Night	02:42	0	0	0	0	0	0	0	0	**0**	0	0	0
14	Day	14:59	2	0	1	25	0	7	8	63	**118**	55	42	6
	Night	03:42	0	0	0	0	0	0	0	0	**0**	0	0	0
15	Day	14:53	0	0	2	32	0	1	5	94	**172**	33	32	6
	Night	19:06	1	0	4	10	0	1	0	9	**28**	5	7	0

Table L People data - totals for each count area

Count Area	Day / Night	Number of People									Cars in car parks	Dogs	Dogs off lead on mud
		Bait digging	Boat / sail / jet ski	Cycling	Dog walking	Fishing	On mud / beach	Sitting on sea wall	Walking	TOTAL (inc. other categories)			
1	Day	0	2	3	181	0	3	4	48	**278**	245	75	30
	Night	0	0	0	11	0	0	0	0	**11**	9	10	0
2	Day	1	2	2	44	6	11	9	61	**154**	14	39	22
	Night	0	0	0	14	0	0	2	2	**18**	0	12	5
3	Day	0	0	3	15	0	11	7	6	**59**	0	10	5
	Night	0	0	0	6	0	0	0	0	**9**	0	7	0
4	Day	0	0	0	0	0	0	4	8	**12**	0	12	2
	Night	0	0	0	0	0	0	0	0	**0**	0	0	0
5	Day	0	0	2	11	0	4	8	57	**86**	33	8	1
	Night	0	0	3	1	0	0	0	2	**7**	2	1	0
6	Day	0	8	9	25	0	0	0	29	**90**	222	22	2
	Night	0	0	1	4	0	0	0	8	**13**	13	2	0
7	Day	0	0	10	43	2	16	5	112	**189**	4	30	15
	Night	0	0	4	3	0	0	0	6	**13**	0	3	0
8	Day	4	0	6	122	0	3	0	79	**324**	0	75	12
	Night	0	0	2	7	0	0	0	2	**11**	0	7	0

Table continued...

Count Area	Day / Night	Number of People									Cars in car parks	Dogs	Dogs off lead on mud
		Bait digging	Boat / sail / jet ski	Cycling	Dog walking	Fishing	On mud / beach	Sitting on sea wall	Walking	TOTAL (inc. other categories)			
9	Day	1	0	1	40	0	1	5	48	**157**	89	32	16
	Night	0	0	3	4	0	0	0	4	**11**	0	1	0
10	Day	2	0	0	0	0	0	0	1	**3**	0	0	0
	Night	1	0	0	0	0	1	0	0	**2**	0	0	0
11	Day	1	14	0	0	0	19	6	3	**48**	0	0	1
	Night	0	0	0	0	0	0	0	0	**0**	0	0	0
12	Day	0	18	0	0	0	21	0	12	**53**	0	2	0
	Night	0	0	0	0	0	0	0	2	**2**	0	0	0

Appendix 7 People data (Point Counts)

Table M Totals for each point count location

Point	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Total people counted on seawall within 50m	27	7	24	14	4	26	88	47	1	15	13	31	25	**322**
Total people on mudflats within 50m	18	8	7	1	0	0	5	5	0	7	4	3	0	**58**
Total people, shore and mudflats	45	15	31	15	4	26	93	52	1	22	17	34	25	**380**
Total dogs within 50m	15	14	9	13	1	0	14	15	0	0	0	2	0	**83**
Total bait diggers within 50m	0	0	0	1	0	0	2	3	0	4	9	1	0	**20**
Total people fishing within 50m	4	0	2	0	0	14	0	0	0	3	0	0	0	**23**
Number of counts with boat traffic offshore (within 100m)	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Number of counts with loud noise or works taking place on shore	0	0		0	0	1	0	0	0	0	0	0	3	**4**
Number of visits where dogs running on mudflats	3	1	2	1	0	0	3	4	0	0	0	0	0	**14**
Number of visits where people launching boats	2	2	0	0	0	0	0	0	0	2	3	5	1	**15**