Report

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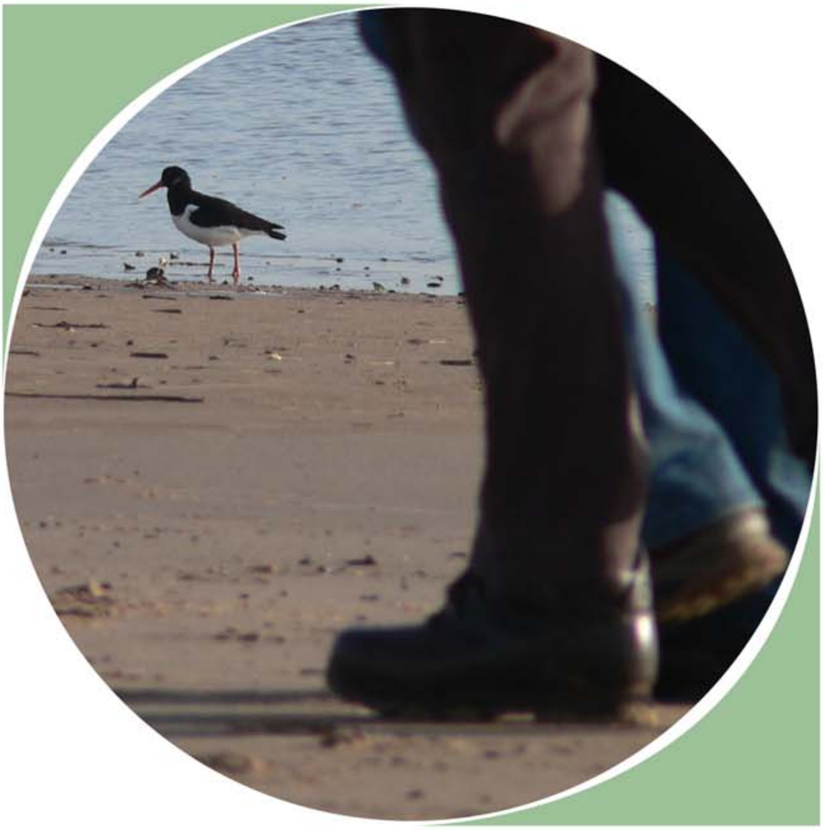
The Solent Disturbance & Mitigation Project Phase II

Results of bird disturbance fieldwork 2009/10



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Date: 14th January 2011

Version: Final

Recommended Citation: Liley, D., Stillman, R. & Fearnley, H. (2010). The Solent Disturbance and Mitigation Project Phase 2: Results of Bird Disturbance Fieldwork 2009/10. Footprint Ecology / Solent Forum.

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Summary

This report looks at the issue of recreational disturbance to wintering waterfowl along the coast between Hurst Spit (Hampshire) and Chichester Harbour (East Sussex), including the north shore of the Isle of Wight. This area is internationally important for wintering waterfowl and also subject to intense pressure from development and new housing. This report forms part of a series of studies as part of the Solent Disturbance and Mitigation Project.

Disturbance can result in birds flying away or stopping feeding, both of which will have energetic consequences for the birds concerned. Disturbance will also potentially result in birds simply avoiding areas of suitable habitat due to the presence of people. Tide, prey abundance and the physical geography of an estuary (for example how far it is to fly to alternative feeding locations) will determine the relative impacts of birds being flushed or avoiding particular areas. The issues are therefore complex and the impacts of disturbance cannot be assessed from simply recording the behaviour of birds and how they respond to people. The long term aim of the Solent Disturbance and Mitigation Project is to assess the impacts of disturbance through a series of models which will take into account prey abundance, tidal coverage, energetic requirements etc. These models will be used to test different scenarios of development and access management along the coast, and determine (at a Solent wide scale) the impact of disturbance.

In order to gather some of the disturbance data needed to set up the models, fieldwork at twenty different locations was conducted during the period December 2009 to February 2010. The fieldwork (a total of 420 hours) involved recording all recreational activity, undertaking counts of birds and detailed behavioural observations (of birds within a small, predefined focal area of intertidal habitat) to document how birds responded to different activities and the distances at which they respond. This information on its own does not describe the impacts of disturbance, it simply provides the basic information necessary to develop the models and consider disturbance at a Solent-wide scale.

A total of 44 different bird species (including waders, ducks, geese, herons, cormorants, divers, grebes and rails) were recorded. Bird densities varied between sites and also within sites (i.e. within bands at different distances from the mean high water mark).

Visitor rates were 12.9 groups, 20.4 people and 6.7 dogs per hour. A wide range of activities were recorded, but four activities – dog walking, walking, cycling and jogging – were noteworthy in accounting for the majority (91%) of observations. Dog walking was the most frequently recorded single activity, involving 41% of observations.

A total of 2,507 potential disturbance events were observed, where the event coincided with birds being present within the count area and the birds were either within 200m of the event and/or were seen to be disturbed. These 2,507 events generated 4,064 species specific observations. Around one in five (17%) resulted in disturbance, i.e. a change in behaviour of birds within the focal area. Disturbance included birds simply becoming alert (4% of observations), walking or swimming away (3%), a short flight of less than 50m (2%) or a major flight (8%).

Most human activity involved people staying on the shore/sea-wall rather than on the intertidal or on the water. The majority (81%) of species-specific observations involved recreational activities that were shore-based, a further 15% involved activities on the intertidal and 4% were water-based.

In general, across all species, and for most individual species, disturbance tended to occur when the activity was relatively close to the birds, and birds tended to respond less the further away the activity was. Activities that took place on the intertidal were more likely to result in disturbance (a change in behaviour by the birds), with 41% of observations (involving activities on the intertidal) resulting in disturbance (compared to 12% of shore-based observations and 25% of water-based observations). A range of different activities took place on the intertidal, but one activity (dog walking) was particularly common, involving over half of all intertidal observations and also responsible for a disproportionate amount of the disturbance recorded: 27% of disturbance events involving major flight were caused by dogs off leads on the intertidal.

There was no significant correlation between people numbers at each site and the number of disturbance events, indicating that high numbers of visitors per se does not necessarily result in high levels of disturbance.

There was variation between species in terms of the response to different activities; oystercatcher and wigeon were the two species where the highest proportion of observations involved the birds being disturbed.

General linear models were used to relate the response of the birds to different explanatory variables in various multivariate analyses to inform the parameters that would underpin the individual based models to be developed in the future. In order to simplify the analyses, activity types were aggregated into simple aggregates: land-based and water-based, and only a selection of bird species were included. The main variable that was consistently related to the response to disturbance was the aggregated activity type. Typically, the responses to dog walking and other land-based activities were of similar magnitude, but less than the responses to water-based activities. Bird body mass was significantly positively related to response distance, providing a means of predicting the response to disturbance of species other than those included in the analyses. Other variables that had a less consistent influence on the response to disturbance included whether or not a disturbing activity occurred on the intertidal, and whether any of the disturbed birds were feeding prior to the disturbance.

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Acknowledgements

This report was commissioned by the Solent Forum with the contract managed and let by Fareham Borough Council We are grateful to Ian Burt, Rhian Edwards and Karen McHugh for the day to day management and for overseeing the contract. Our thanks also to the various members of the Forum for useful discussion and ideas.

The survey work was conducted during very cold weather and involved long hours in cold conditions. The work was conducted by Simon Curson, Neil Gartshore, Nick Hopper, Malcolm Stott and Mike Trubridge. Neil Gartshore also helped organise the fieldwork logistics and implementation of the fieldwork.

Our thanks to Ralph Clarke for helpful discussion.

1. Introduction

1.1 A real and current issue for nature conservation in the UK is how to accommodate increasing pressure for new homes and other development without compromising the integrity of protected sites. This report describes the results of winter fieldwork assessing the impact of recreational disturbance to wintering waterfowl. The work relates to the coast between Hurst Spit (Hampshire) and the mouth of Chichester Harbour (West Sussex), and includes the north shore of the Isle of Wight. This area is internationally important for wintering waterfowl and also subject to intense pressure from development and new housing. The results of the work will be used in predictive models which will be used to test different scenarios of development and access management along the coast. These models will provide a means of understanding the potential impacts of further development and a means of assessing the effectiveness of different mitigation measures.

Disturbance to Birds

1.2 Human disturbance to birds is essentially any activity that results in a change in a bird's behaviour. There is wide range of studies and a large volume of scientific literature that considers disturbance and its consequences.

1.3 Studies have shown disturbance effects for a wide range of activities besides simply people, for example aircraft (see Drewitt 1999), traffic(Reijnen, Foppen, & Veenbaas 1997), dogs (Lord, Waas, & Innes 1997; Banks & Bryant 2007) and machinery (Delaney et al. 1999; Tempel & Gutierrez 2003).

1.4 Disturbance can have a variety of impacts. There are studies showing behavioural effects, such as birds changing their feeding behaviour (Fitzpatrick & Bouchez 1998; Verhulst, Oosterbeek, & Ens 2001; Thomas, Kvitek, & Bretz 2003), taking flight (Burger 1998; Blumstein et al. 2003a; Fernandez-Juricic et al. 2005a; Webb & Blumstein 2005) or being more vigilant (Fernandez-Juricic & Schroeder 2003; Randler 2003, 2005). Other studies have focused on physiological impacts, such as changes in the levels of stress hormones (Remage-Healey & Romero 2000; Tempel & Gutierrez 2003; Walker, Boersma, & Wingfield 2005) or heart rate (Hubert & Huppop 1993; Nimon, Schroter, & Stonehouse 1995; Weimerskirch et al. 2002). In very general terms, both distance from the source of disturbance and the scale of the disturbance (noise level, group size) will both influence the response (Beale and Monaghan, 2004, Delaney et al., 1999).

1.5 Direct mortality resulting from disturbance has been shown in a few circumstances (Liley 1999; Yasue & Dearden 2006) and many (but not all) studies have shown a reduction in breeding success where disturbance is greater (Murison 2002; Bolduc & Guillemette 2003; Ruhlen et al. 2003; Arroyo & Razin 2006). There are also many examples of otherwise suitable habitat being under-used as a result of disturbance (Gill 1996; Liley & Clarke 2003; Kaiser et al. 2006; Liley & Sutherland 2007).

1.6 Despite this large body of work, there is still contention (see Gill 2007) as it is often difficult to understand whether there is a real issue and whether disturbance is a cause of conservation concern. For example, the fact that a bird takes flight when a person approaches is to be expected and a short flight in unlikely to have a major impact on the individual in question, let alone the population as a whole. However, repeated flushing, over extended periods or in particular circumstances may have consequences for the population as a whole (West et al. 2002). Very few studies have actually placed disturbance impacts in a population context, although there are examples where the actual impact of disturbance on population size has been demonstrated (West et al. 2002; Liley & Sutherland 2007; Mallord et al. 2007; Stillman et al. 2007; Kerbiriou et al. 2009).

Solent context

1.7 This report focuses on the Solent shoreline between Hurst Castle and Chichester Harbours, including the north shoreline of the Isle of Wight, a length of shoreline totalling some 250km. This coast includes three Special Protection Areas (SPAs): the Solent & Southampton Water SPA, Chichester and Langstone Harbours SPA and Portsmouth Harbour SPA. These sites are designated for a range of features that include wintering waterfowl. The international designations and their wintering bird interest are summarised by Stillman *et al.* (2009).

1.8 The area also supports a high human population, with urban centres such as Portsmouth, Southampton and Chichester occurring very close to the shoreline. Estimates suggest that some 3 million people may live within 50km of the Solent shoreline (Stillman et al. 2009). Pressure for new housing is also high, and future development may result in a substantial increase in the number of people living in the area, particularly in the vicinity of Southampton, Fareham and Portsmouth.

The Solent Disturbance and Mitigation Project

1.9 While there is a large body of scientific and grey literature addressing the impacts of access in coastal environments, these rarely provide detailed guidance to inform policy or planning. It is often difficult for conservation practitioners or policy makers to fully understand the implications of the research, let alone see a plan or project through appropriate assessment or understand the practical measures necessary to avoid adverse effects on the integrity of a European Protected Site. In order to inform the likely impacts of large scale development and to provide the necessary evidence base to underpin Local Development Frameworks in the general area, the Solent Disturbance and Mitigation Project has been established. This project will establish the potential links between housing, access and visitor numbers, and the impacts of human disturbance on the bird interest of the European Protected Sites. The Project focuses on the wintering bird interest.

1.10 The work by Stillman *et al.* (2009) provides an initial review of the issues and the background to the Project. The issues are complex. Disturbance could have an adverse effect on the wintering bird interest of the relevant SPAs around the Solent in a variety of ways. Direct flushing and interruption of feeding is the most obvious impact, and this will have energetic consequences. Birds will also distribute themselves so as to potentially avoid disturbance, for example areas close to footpaths etc might simply support much lower densities of birds. Disturbance to roost sites may result in birds flying further to alternative roosts and there may be energetic costs as a result of the increased time spent in flight.

1.11 In order to understand these issues it is necessary to look across the whole Solent. It is necessary to consider the distribution and abundance of food available for the birds. It is also necessary to understand the tidal cycle and how much time there is for birds to feed at each location. It is also necessary to understand how interference and competition affect the birds' ability to feed. Such information provides the context necessary to understand the issues, allowing models to be developed that explore the winter survival of birds, taking into account energetic requirements and the impacts of disturbance. Such models make it possible to look at the number of birds an estuary is supposed to support and make predictions of how many birds might survive through a winter given particular disturbance levels. The models take into account the ability of birds to relocate, use alternative sites etc., and recognise that disturbance will have different effects at different locations, due to the habitats present and different levels of invertebrate prey.

1.12 The Solent Disturbance and Mitigation Project has the following components:

- Fieldwork over the winter 2008/2009 to assess disturbance to wintering waterfowl
- Fieldwork over the winter 2009/2010 to determine in detail how birds respond to different activities (this report)
- On-site visitor monitoring over the winter 2009/2010
- A household survey, sent out to a random sample of addresses in the study area in the early autumn 2010
- Development of an Individual-based Model for the birds within Southampton Water and Chichester Harbours, models to be developed over the summer /autumn2010
- Development of models to predict visitor patterns to the coast in relation to housing levels around the Solent, to be developed over the winter 2010/2011
- Use of the visitor and bird models to test how changes in housing may result in changes in access, increased disturbance and subsequent impacts to the birds. Use of these models to test different housing and mitigation scenarios.

1.13 The on-site visitor monitoring in 2009/10 took place at the same sites as the ornithological work set out in this report, and therefore the two pieces of work document both access patterns and the impacts of access on the birds. The two pieces of work together provide detailed site-specific information. On a wider scale the household survey provides a strategic overview of access to the entire Solent, allowing visitor rates to all parts of the coastline to be determined. This will provide important context and allow the on-site data to be scaled up to cover the entire Solent coastline.

1.14 How these different elements will fit together can be understood from Figure 1. The amount and distribution of housing determines where people live and the number of people at different distances from the coast. Some residents will visit the coast and a subset of these will actually visit parts of the SPA and potentially cause disturbance. A proportion of these may actually flush birds.

1.15 With the Solent Disturbance and Mitigation Project, the household survey will determine how housing links to access to the coast, and how this varies over the entire study area – providing an understanding of B in Figure 1. The on-site visitor work considers how people move around sites during their visit, for example identifying which activities take place on the intertidal habitats, the on-site work therefore provides information relating to arrow C in Figure 1. The red boxes show the different impacts of disturbance that need to be assessed within the individual based models. In order to provide the data necessary to set up the models, information is required on lost feeding time, the distance at which birds respond to people and so on. This is the information that is set out within this report.

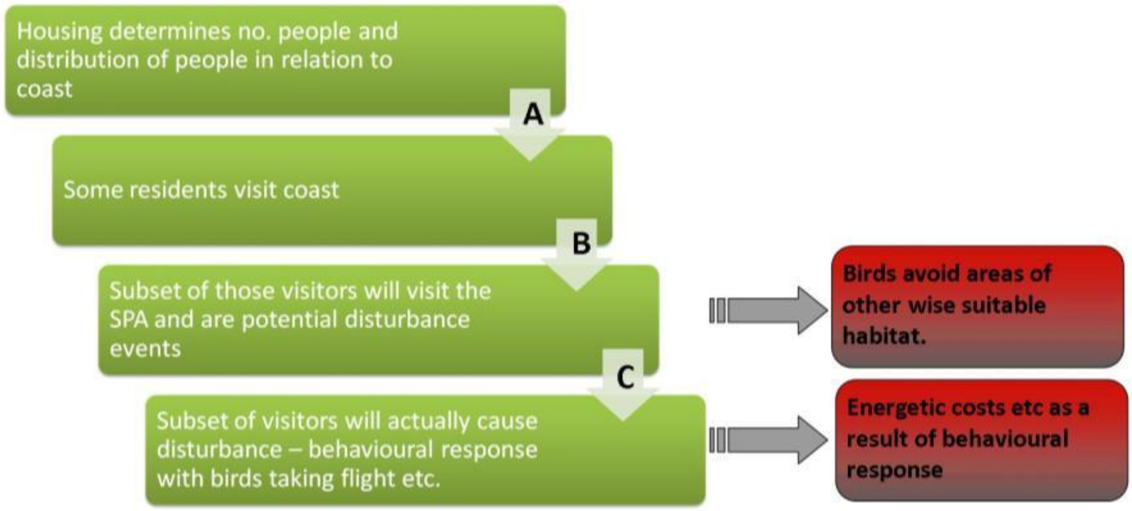


Figure 1: Overview of potential links between housing and impacts of disturbance

Aims and Objectives

1.16 This report therefore needs to be seen as part of a series of different studies that interlink and will provide the parameters necessary to develop models of disturbance and visitor access patterns. Fieldwork was carried out over the mid winter period and for sampled locations determined the numbers of birds present and the extent of disturbance, recording in detail how birds respond to disturbance and carefully assessing this in terms of distance moved, lost feeding time etc.

1.17 The principal questions addressed are:

- How does the distribution of birds vary between sites and in relation to distance from the shore?
- What are the current levels of disturbance within the study area?
- Which types of activities and particular circumstances result in disturbance?

- How do birds respond to disturbance, in terms of distance from disturbance and types of response?
- How can the data be combined to derive parameters for the Individual Based Modelling?

2. Our Approach

Identification of Survey Sites

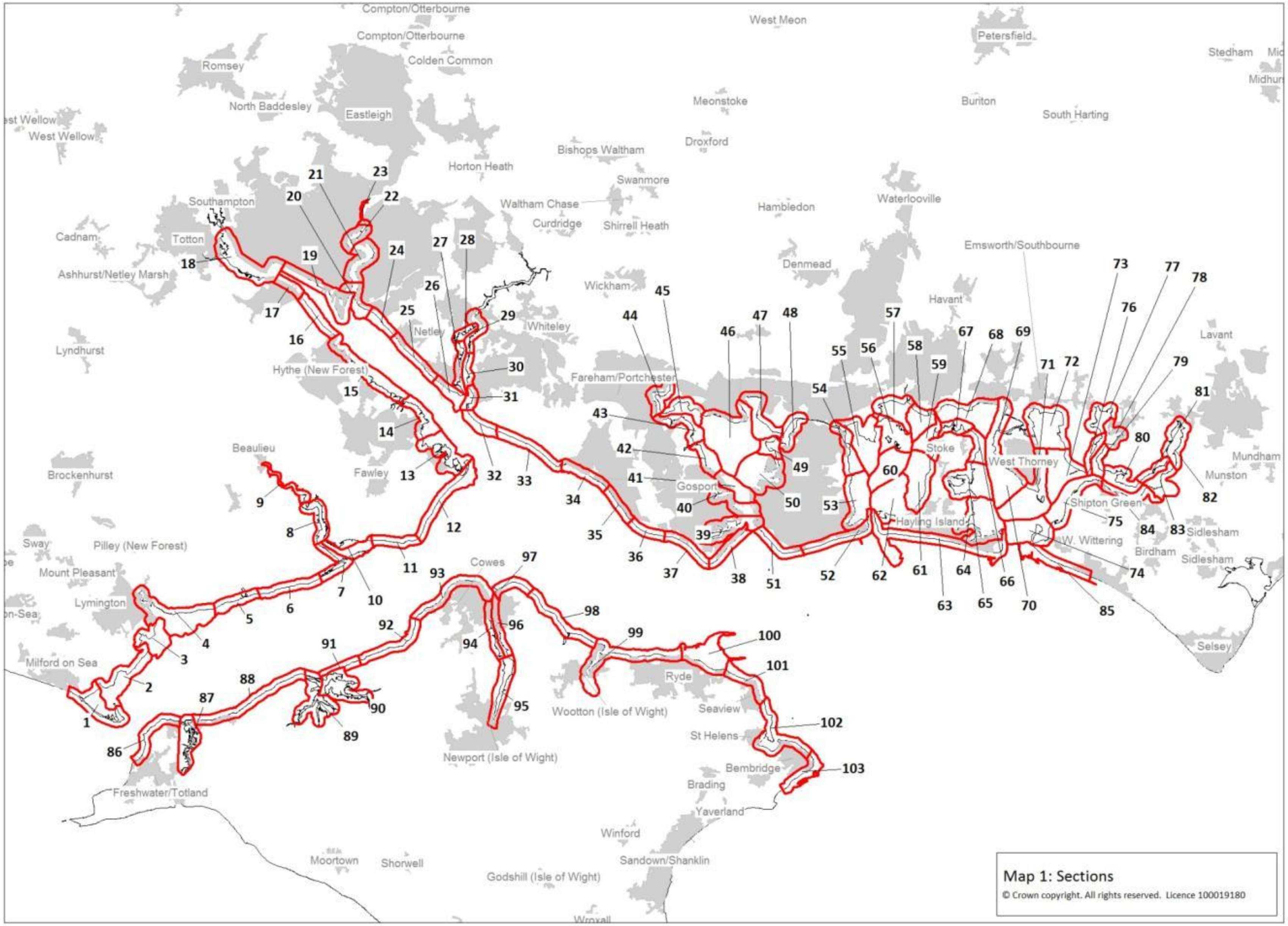
2.1 The study area is defined as the coastline from Hurst Castle to Chichester Harbour and the north shore of the Isle of Wight; it includes Langstone Harbour, Portsmouth Harbour and Chichester Harbours as well as Southampton Water (and the Hamble and the Itchen). The entire shoreline was broken into discrete patches, based loosely on WeBS boundaries. It was possible to combine similar WeBS patches to produce a series of patches which was representative of discrete units in terms of access and/or habitat. Map 1 shows where the boundaries of each patch lie along the shoreline.

2.2 Twenty patches were selected for bird and visitor monitoring work over the winter 2009/2010. These patches will form the basic units within the later modelling. Visitor monitoring locations and bird survey points were not in exactly the same locations, but were within the same discrete 'patch'. The visitor work focussed on the main access point to a location to ensure exposure to as many visitors as possible. These access points were typically car-parks or major path junctions. The bird surveys were conducted from locations that provided a good vantage point and sight line of the birds (typically along the sides of a bay, or a headland where it is possible to look into the middle of the bay). The location of the bird monitoring locations are detailed in Map 2.

Overview of Data Collected

2.3 Each location was visited twelve times over the period from 1st December 2009 – 28th February 2010. Visits were spread evenly over the three months, such that four visits were made to each location each month. No attempt was made to limit visits to particular states of tide or tide heights. One visit per month per location was made at a weekend. Each visit lasted around 2 hours and included the following:

- A count of all birds present within the focal area at the start and end of the count
- A map of all people / activities taking place at the start of the visit
- A 'diary' of all recreational events – essentially all people / activities observed over a period of 1 hour 45 minutes, recording the activity, time, duration etc.
- Recreational events that occurred within 200m of birds within the focal area (or in a very few cases where disturbance occurred at greater than 200m) were categorised as 'potential disturbance events'. For this subset of all recreational events , a record of the response of each species present to the activity was recorded. This included distance at which birds responded (or not), the behavioural response observed, distance displaced, etc.
- In addition information was collected at each visit on the weather conditions, state of the tide, temperature, etc.


Compton/Otterbourne
West Meon
Petersfield
Romsey
Colden Common
Stedham
Meonstoke
Buriton
North Baddesley
Eastleigh
South Harting
West Wellow
Droxford
Bishops Waltham
Horton Heath
Swanmore
Waterlooville
Southampton
Waltham Chase
Hambledon
Curdridge
Shirrell Heath
Cadnam
Totton
Emsworth/Southbourne
Denmead
Ashhurst/Netley Marsh
Wickham
Havant
Netley
Whiteley
Lavant
Lyndhurst
Hythe (New Forest)
Fareham/Portchester
Stoke
West Thorney
Beaulieu
Mundham
Brockenhurst
Fawley
Gosport
Munston
Shipton Green
Hayling Island
Sidlesham
W. Wittering
Birdham
Sway
Pilley (New Forest)
Mount Pleasant
Cowes
Lymington
Selsey
Milford on Sea
Ryde
Wootton (Isle of Wight)
Seaview
St Helens
Newport (Isle of Wight)
Bembridge
Freshwater/Totland
Brading
Yaverland
Winford
Moortown
Shorwell
Sandown/Shanklin
Godshill (Isle of Wight)
Wroxall
Map 1: Sections
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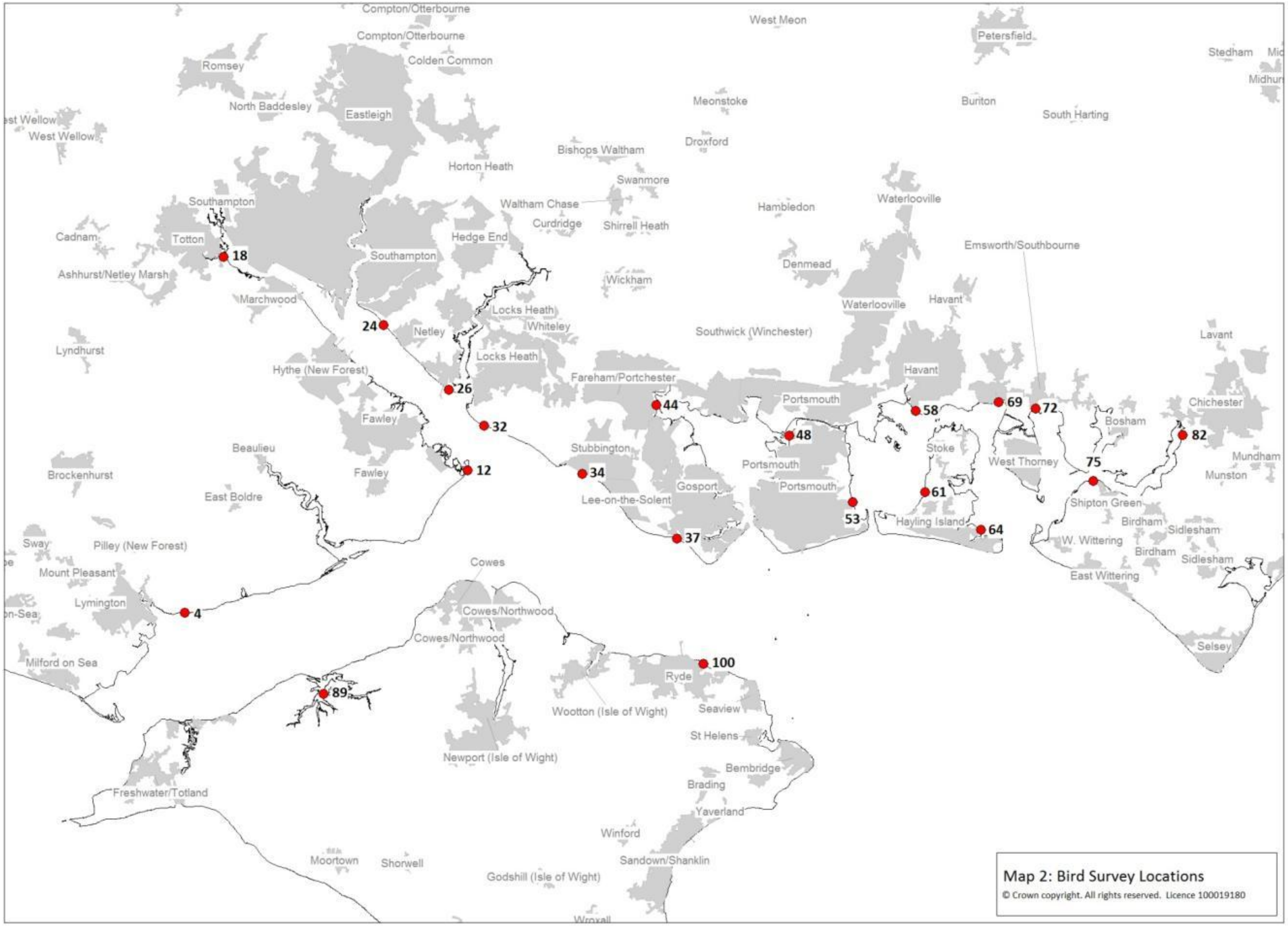


Map 2: Bird Survey Locations

Definition of a Focal Area and Counts of Birds

2.4 At each survey location a focal area for the bird fieldwork was defined. This area stretched up to 500m from the surveyor and included all visible areas of intertidal habitat, below MHWM, within this 500m radius. The 500m radius was selected as, based on trials, this was the maximum distance at which surveyors felt confident counting birds at the same time as recording levels of human activity, and within which it was possible to reliably estimate distances between disturbance events and the birds.

2.5 On straight sections of shore this area was typically defined simply as an arc (radius 500m) drawn from the survey location. Where jetties, creeks, headlands etc meant that there were no clear sight-lines, then the boundaries of the focal area became more complex. The focal area encompassed a different total area at each survey point.

2.6 The focal area was then split into a series of bands, representing distance from MHWM (i.e. these bands were parallel to the shore rather than concentric rings around the surveyor). These bands were defined within the GIS and plotted onto aerial photographs which each surveyor carried in the field with them. These plots provided a simple and effective means for the surveyors to establish the distances and 'layout' of each survey location and focal area.

2.7 At the beginning and end of each visit all birds were counted within the focal area, and the total count was broken down so as to reflect the number of birds within each distance band.

Diary of Recreational Activity

2.8 All events that involved recreational access or other events that might cause disturbance were then recorded over the following 105 minutes, in chronological order. Each event was given a unique letter code (A, B, C etc), enabling diary events to be crossed referenced to other data sets. All activities/people were recorded by the surveyors, regardless of whether they entered the focal area used for the bird counts. For each event the following were recorded:

- Start and end time (i.e. when first in view to when lost from sight)
- Whether the event came within 200m of birds within the focal area
- Habitat (simply coded as shore, intertidal or water)
- Group size (number of people), this was not always possible to record, e.g. with boats
- Number of dogs
- Activity (categorised according to activity types see Table 1)
- Any other information / notes

The diary data therefore provides a description of the total amount of activity and types of activity taking place at each location.

Table 1: Activity Codes used during field recording

Description	Code
Dog walker	DW
Dog off lead	dx
Dog on lead	dl
Bait digger (use for Crab tiling, Cockle raking or bait digging – but use notes to specify)	BD
Cycling	C
Jogger	J
Fishing (from shore)	F
Walking / rambling (without dog)	W
Kids playing (with or without parents)	KP
Picnic	P
Windsurfer on water	WS
KiteSurfer on water	KS
Canoe on water	Ca
Jet Ski on water	JS
Water skiing	WSk
Rib or similar fast small boat	SMb
Small sailing boat (e.g. Laser / dinghy)	SS
Moderate – large sailing boat, not running motor	LS
Large boat on outboard motor	LMb
Person working on boat (boat stationary)	B
Person accessing boat or water (inc e.g. windsurfers walking across mudflat)	BW
Motor vehicle	MV
Rowing boat	RB
Birdwatcher	BR
Horse Riding	HR
Metal Detecting	MD

Response of the Birds

2.9 All recreational events that occurred within 200m of birds within the focal area (or resulted in birds within the focal area being disturbed) were classed as 'potential disturbance events'. For these events – a subset from the diary of all recreational activity - the response of each species (present within 200m) was recorded. Each potential disturbance event could therefore be associated with more than one observation, where multiple species were present within the focal area.

2.10 For each species, and each potential disturbance event within 200m, the following were recorded:

- Species
- Count (number present within 200m)
- Behaviour of the birds (prior to the disturbance event), simply categorised as F (feeding) or R (roosting/preening/loafing)
- Response of the birds (see Table 2) ultimately observed

- Distance at which the response occurred (if "No response" this distance was the minimum distance from the potential disturbance event to the nearest individual; if disturbance occurred then this distance was the maximum distance from one individual to the disturbance event when the disturbance occurred)
- Distance displaced, i.e. the distance that the disturbed bird(s) walked/swam/flew if disturbed
- Total time until original behaviour resumed
- Notes

2.11 In order to ensure accurate and consistent estimation of distances (both the distance from the source of disturbance to the birds and the distance the birds were displaced), only a small group of surveyors were used. All surveyors spent a day jointly undertaking counts at the start of the fieldwork, this training session ensured consistency between observers. In the field surveyors used the aerial photographs with the distance bands plotted to ensure they were familiar with the 'layout' of the focal area and the distance of different features from the shore. Surveyors also used laser range finders to measure distances and at the end of fieldwork distances could be paced exactly as an additional check. The process of counting the birds within distance bands, conducted at the start and end of each visit, ensured each surveyor was familiar with how the birds were distributed, the species present etc. before any attempts were made to record behaviour and disturbance.

2.12 Where the birds flew it was not always possible to estimate distances, for example where the birds flew out of sight. In such cases the distance displaced was simply not recorded and left blank.

Table 2: Response Codes

Response	Code
No response	NR
Alert, heads up, no change in birds' position	A
Alert, birds walked/swam short distance and resumed previous behaviour	W
Birds flew short distance (<50m) and resumed previous behaviour in general area	f
Birds took flight and flew more than 50m	F

2.13 In summary, the data therefore describes all events recorded by the surveyors, a subset of which were potential disturbance events, and a subset of these resulted in a behavioural response from the birds. These three 'tiers' are summarised in Figure 2.

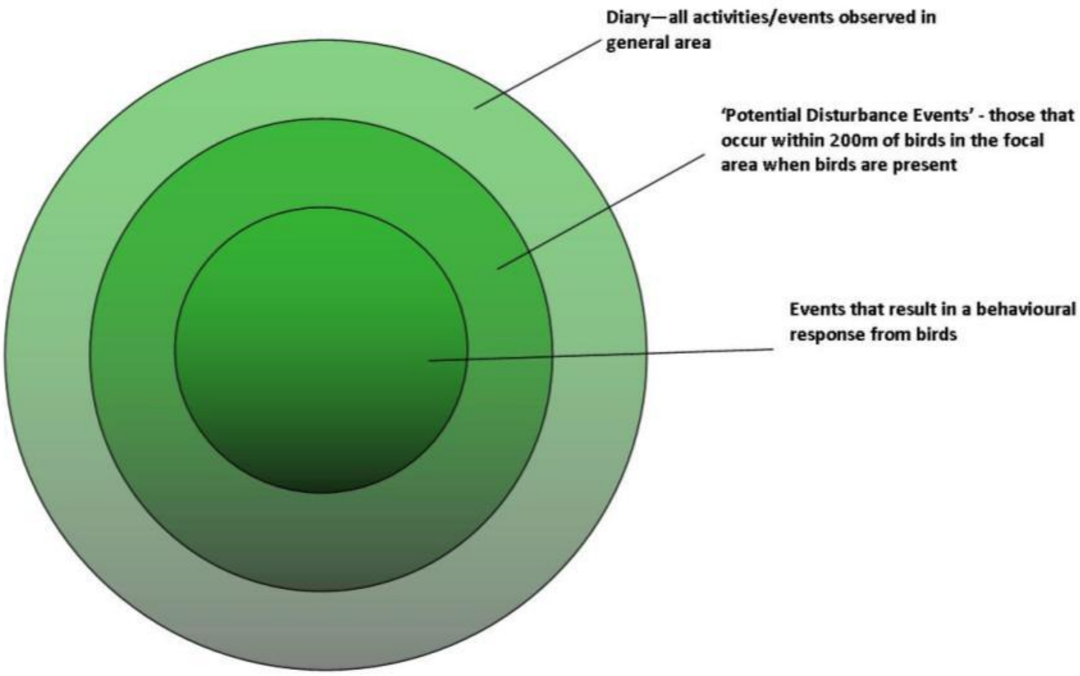


Figure 2: The different counts of people recorded during the bird fieldwork

Additional information

2.14 Additional information recorded for each visit included details of the weather (rain, wind etc), temperature (recorded using a thermometer in the field), tidal coverage (estimated as the percentage cover of water over the focal area at the start and end of each count), the time of the nearest high and low tide.

Data presentation and analysis

2.15 We use box plots frequently throughout the report. These plots describe the data for particular groupings, and typically include the following:

- Horizontal line: indicating the median value for that group
- Box: indicating the 25th and 75th percentiles (i.e. half of all the data falls within between these two lines)
- Vertical lines: "whiskers" indicating the upper and lower limits of the data
- Asterisks: indicating outlier values (i.e. any data points that fall outside the upper and lower limits of the data).

2.16 All statistical analysis was conducted using Minitab (version 14) or SPSS (SPSS Statistics 19). GIS data extraction and presentation was conducted using MapInfo (version 9.5).

3. Results

Distribution of birds in relation to sites and distance from the shore

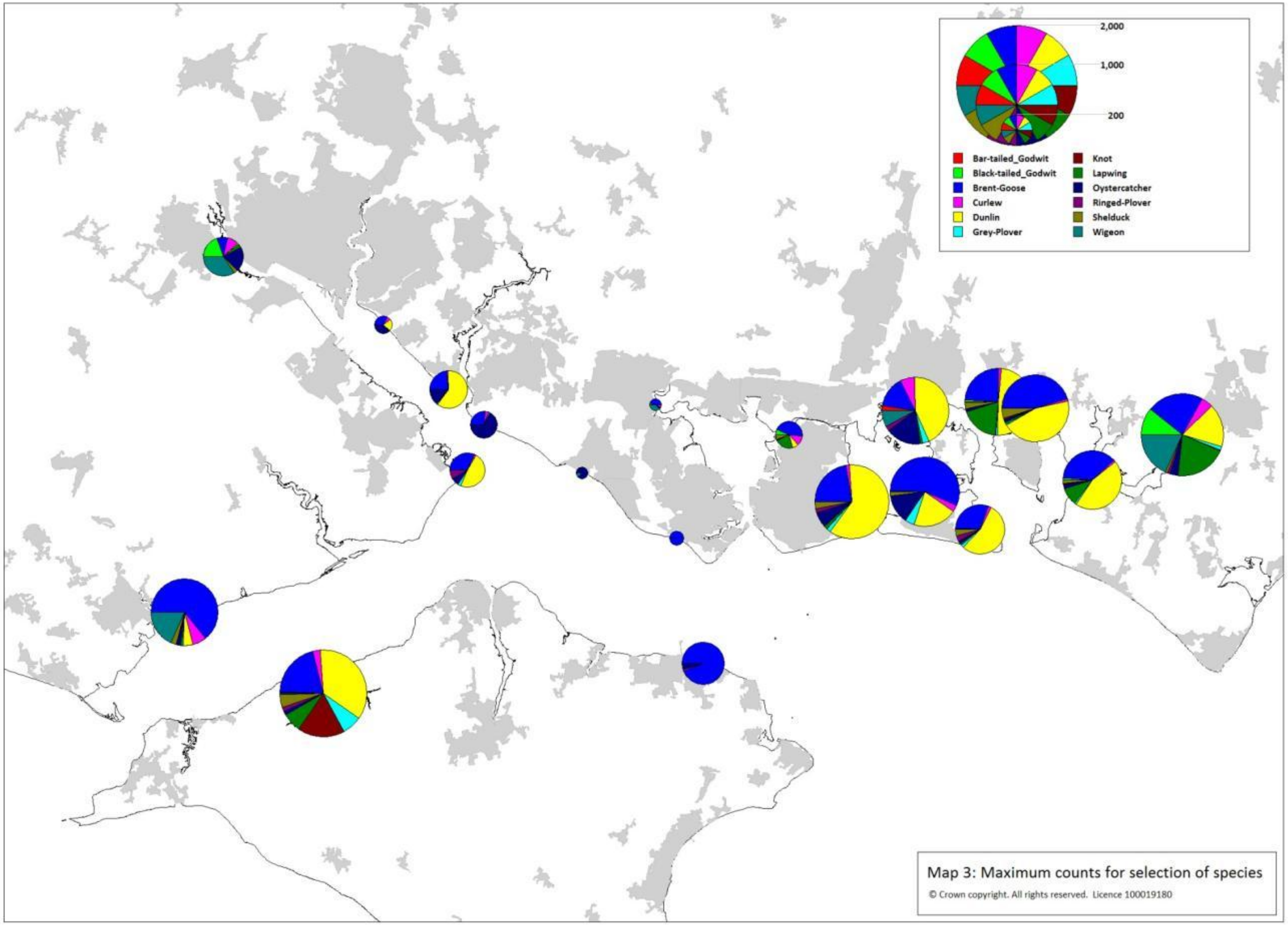
3.1 In total, across all counts, 44 species were recorded. This total included 14 species of wildfowl (i.e. ducks and geese), 20 species of wader and 10 additional species (divers, grebes, egrets, herons and rails). Appendix 1 lists all the species and shows the totals for each site. Only one species (brent goose) was recorded at all sites. Map 3 summarises the maximum counts at each location for a selection of the more abundant species.

3.2 There were significant differences between sites in the density of birds recorded (Kruskal-Wallis H (adjusted for ties) = 223.10, 19 df, $p<0.001$). The highest densities of birds recorded during the winter were at Fishbourne and at Langstone, while the lowest densities were at Hookwith Warsash Nature Reserve and Salterns Park (Figure 3).

3.3 There were also significant differences in the density of birds between distance bands (Kruskal-Wallis H (adjusted for ties) = 69.34, 7 df, $p<0.001$), indicating that across all sites the distribution of birds, in relation to MHWM was not even.

3.4 In Figure 4 we show the total area (in hectares) within each band, summed across all locations, and also show the number of birds recorded in each band (totalled across all visits and all locations), the density of birds (all species, across all locations) and the variation in density for a selection of individual species.

3.5 For the distance bands closer to the shore there is relatively little variation in area, yet the number of birds shows a steady increase away from MHWM, at least in the distance bands up to 150m. Across all sites the density of birds was highest in the distance band 75-100m from MHWM. Plots for individual species show this distance band held the highest densities (across all sites and all visits) for brent goose, dunlin, oystercatcher and shelduck. Grey plover densities were progressively higher down the shore, peaking in the 200-250m band and for black-tailed godwit the highest densities were closest to the shore, in the 0-25m band. These plots show the variation between species, reflecting the feeding ecology (areas further down the shore are likely to be underwater for a greater proportion of the time, potentially wetter and may have higher densities of invertebrates), how birds use the sites and potentially the impacts of disturbance (as access being perhaps more likely to be concentrated at the upper sections of the beach).



Map 3: Maximum counts for selection of species

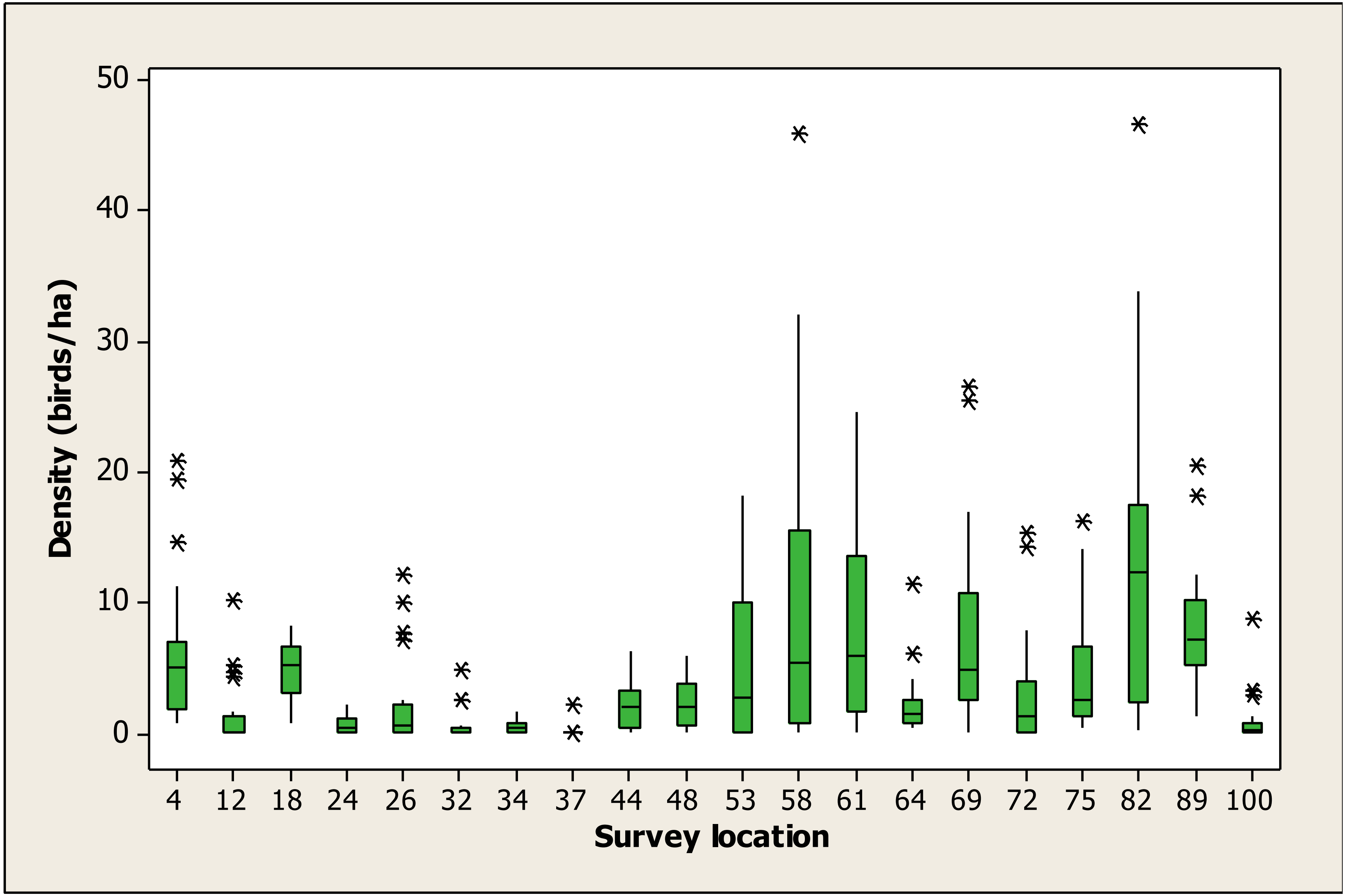


Figure 3: Densities of birds at different sites. Data for all species combined, across all distance bands within the focal area.

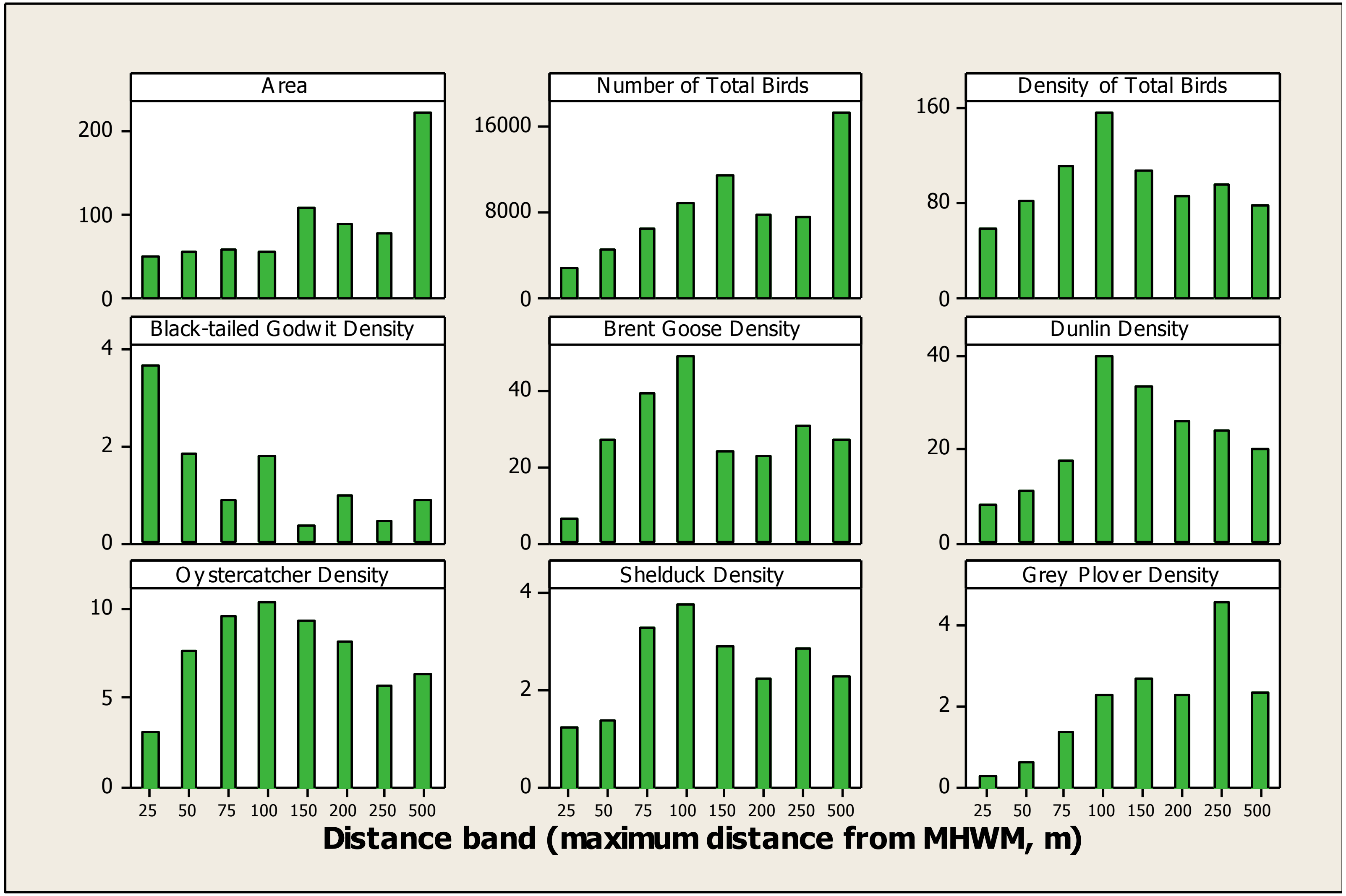


Figure 4: Distance from MHWM and numbers and densities of birds within the focal areas. The x xis shows the distance bands (note different widths). The top left plot shows the area (in ha) across all sites. The top middle plot shows the number of birds, summed across all sites, within each band, all other plots show density (birds per ha). The top right plot shows total bird density, while the remaining plots show densities for a selection of species, summed across sites.

Levels of human activity

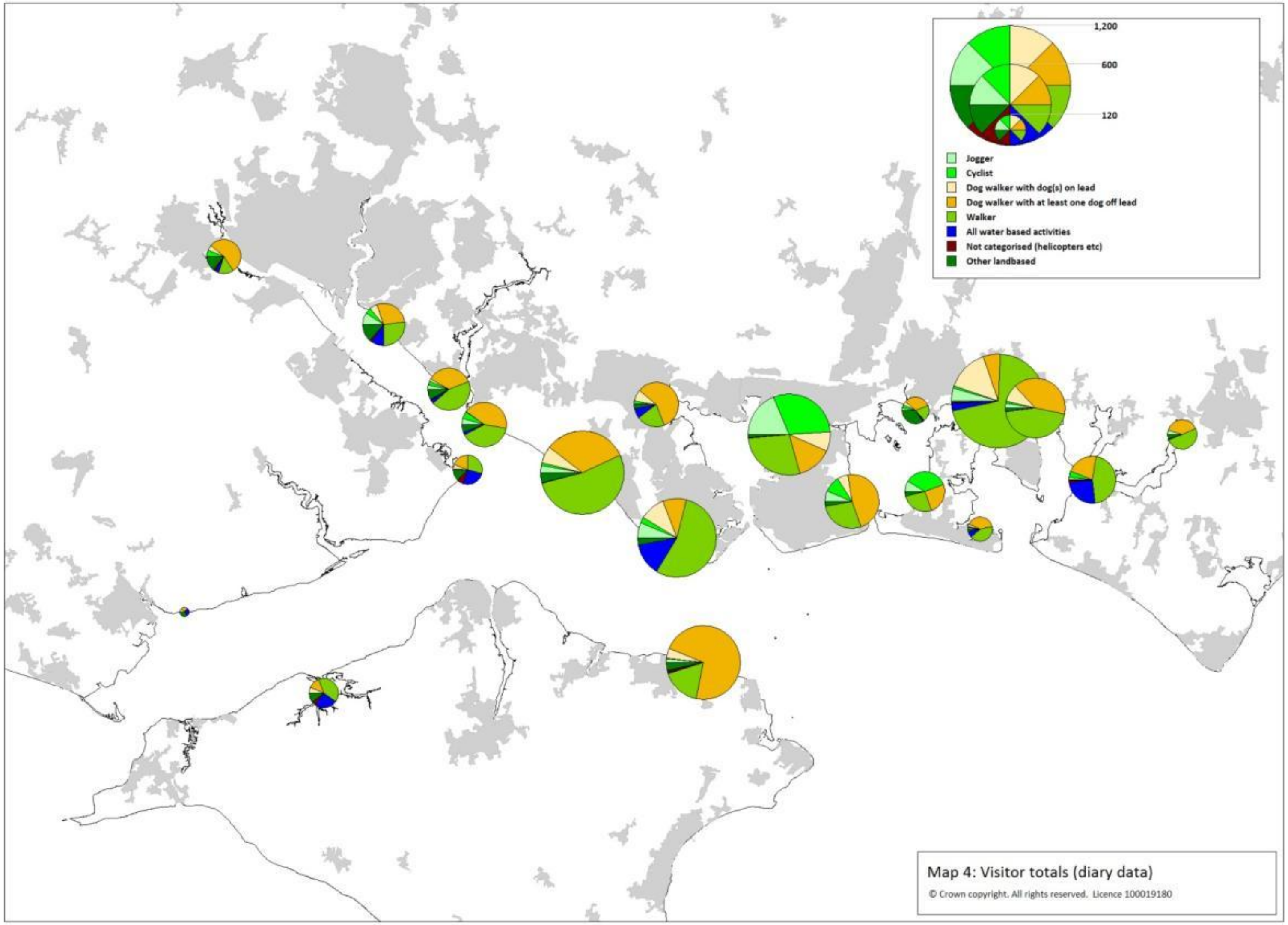
3.6 The 'diary' forms completed by the surveyors documented a total of 5,405 different entries (i.e. different observations of recreational activity), involving 8,555 people and 2,835 dogs. These totals represent minimum numbers of people as the surveyors were positioned at locations where they had a good view of the birds present, rather than the best locations to count people (and therefore some people may not have been seen). Also at the Promenade, at Emsworth (the busiest site) the surveyors found it impossible to keep an accurate count of people and watch the birds, therefore all surveyors reported that at this site not all people were necessarily counted. A further difficulty in obtaining accurate counts of people was the difficulty in ascertaining the number of people on boats.

3.7 The surveys involved 1 hour and 45 minutes of data recording at each visit, and twelve visits were made to each site (and there were 20 sites). A total of 420 hours of fieldwork was therefore undertaken. Taking the data from all sites combined, the hourly visitor rate was therefore 12.9 groups, 20.4 people and 6.7 dogs.

3.8 A wide range of activities were recorded, but four activities – dog walking, walking, cycling and jogging – were noteworthy in accounting for the majority (91%) of observations (Figure 5). Dog-walking was the main activity type recorded (41% of observations). In Figure 5 dog walkers are split to show the number with dogs off leads; 81% of the dog walkers observed had at least one dog off the lead. After dog walking the next most frequently observed activity was walking, with about a third (36%) of all events observed involving one or more people walking without a dog. Numbers of visitor events recorded in the diary data are summarised in Map 4.

3.9 The promenade at Emsworth was the busiest site, and Lymington was the site where the fewest people were recorded (Figure 6). There was wide variation in the activities observed at each site, for example there were no walkers without dogs recorded at Lymington. At two sites (the Promenade, Emsworth and Alverbank East) the majority of dog walkers were those with dogs on leads. At other sites, dog walkers with dogs off leads outnumbered those with their dogs on leads. Ryde was particularly notable in the number of dog walkers with dogs off leads. Hilsea was noteworthy in that the cycling was the most frequently observed activity.

3.10 Of the 5405 diary entries, 535 (10%) involved people on the intertidal. Lymington (36% of diary events on the intertidal) and Saltern's Park (24%) were the two sites where the most activity took place on the intertidal. Sites with very little activity on the intertidal (around 1%) were Milton, Hayling Billy Trail, Emsworth and West Itchenor.



Map 4: Visitor totals (diary data)

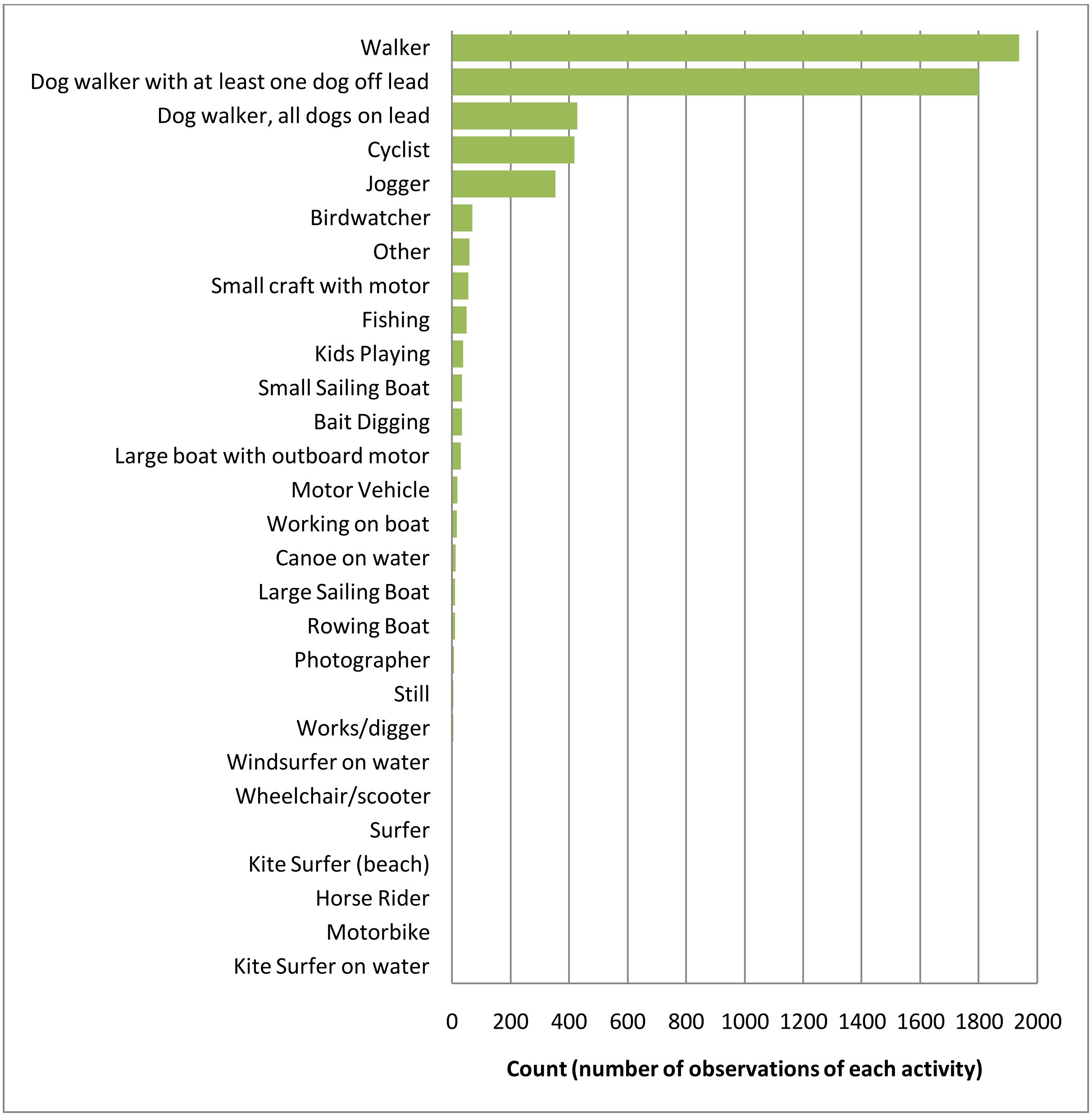


Figure 5: Different activities recorded. Data are from the diary forms and therefore show all people observations, regardless of whether close to birds or whether any disturbance observed. "Other" includes a range of different events that could not be easily classified.

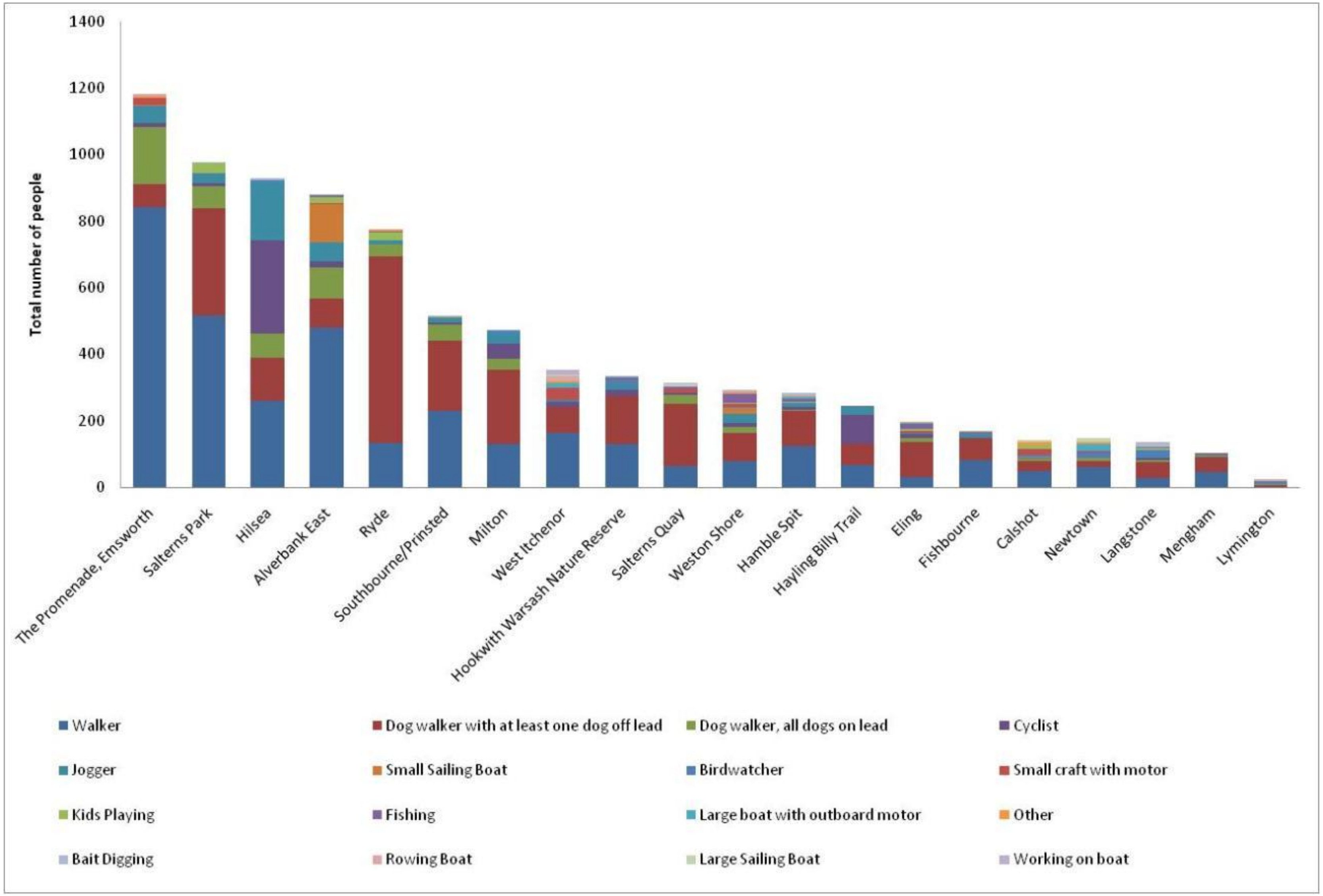


Figure 6: Total number of people observed undertaking different activities at different sites. Not all activities are shown, only those where at least 20 people were observed in total across all sites are included. "Other" includes a range of different events that could not be easily classified. Data in figure is also given in Appendix 2.

Levels of disturbance

3.11 The surveyors focused their observations of birds to a small area of intertidal habitat where disturbance events could be recorded in detail. Across all the survey work, a total of 2,507 different visitor events were recorded where people were within 200m of birds present within the focal areas. Of these 2,507 potential disturbance events, 495 different events (20%) were attributed as causing disturbance (i.e. a change in behaviour of the birds present), as summarised in Figure 7. Note that this 20% figure does not indicate that 20% of all recreational events across the Solent area might cause disturbance as the 20% figure solely relates to the (relatively small) focal areas observed by the surveyors. In other words, 20% of events – that occurred when birds were present within a pre-defined area and were within 200m of those birds – resulted in a visible behavioural response from the birds.

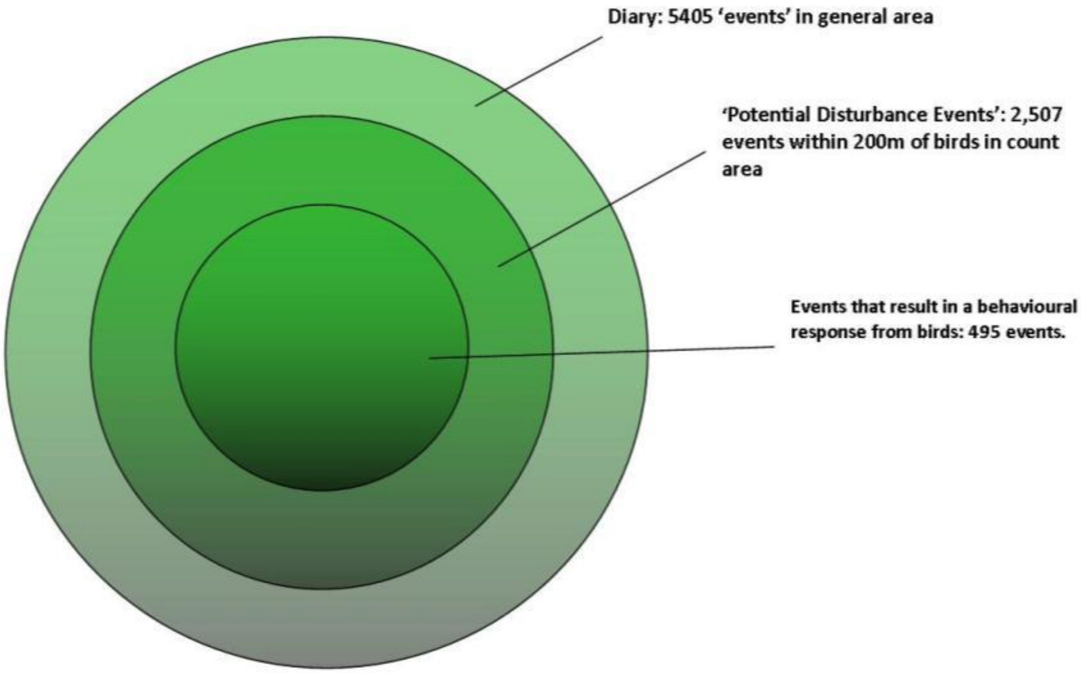


Figure 7: Summary of number of events observed and that actually resulted in a behavioural response. Note circle sizes are not to scale.

3.12 Many of the potential disturbance events were within 200m of more than one species, and therefore from these 2,507 events, 4,064 different observations were made where the people recorded were within 200m of a particular species. From this total of 4,064 observations, 82% were categorised as "No response", i.e. no change in behaviour was observed. There were eleven observations that were uncategorised, these involved instances where the surveyor was watching other birds or where it was impossible to be sure whether a dive, walk or flight was directly linked to a particular activity. The remaining observations (17%) involved a change of behaviour and were therefore categorised as disturbance. In 4% of all observations the birds became alert, in 3% of observations a short walk was recorded, 2% resulted in a short flight and in 8% of observations the birds undertook a major flight (i.e. more than 50m) as a result of the disturbance event.

Types of activities and disturbance

3.13 Across all counts there were 4064 observations of potential disturbance events involving an individual (or individuals) of a particular species. In Figure 8 response to each activity is shown, combining data for all species. It can be seen that activities such as cycling, jogging, dog walking (with the dogs on a lead) and bird watching were the activities where the highest proportion of events resulted in no response from the birds (i.e. the longest green bars in the graph). Surfing, rowing and horse riding by contrast were all activities where a high proportion of events resulted in disturbance, i.e. these activities were more likely to result in disturbance to the birds.

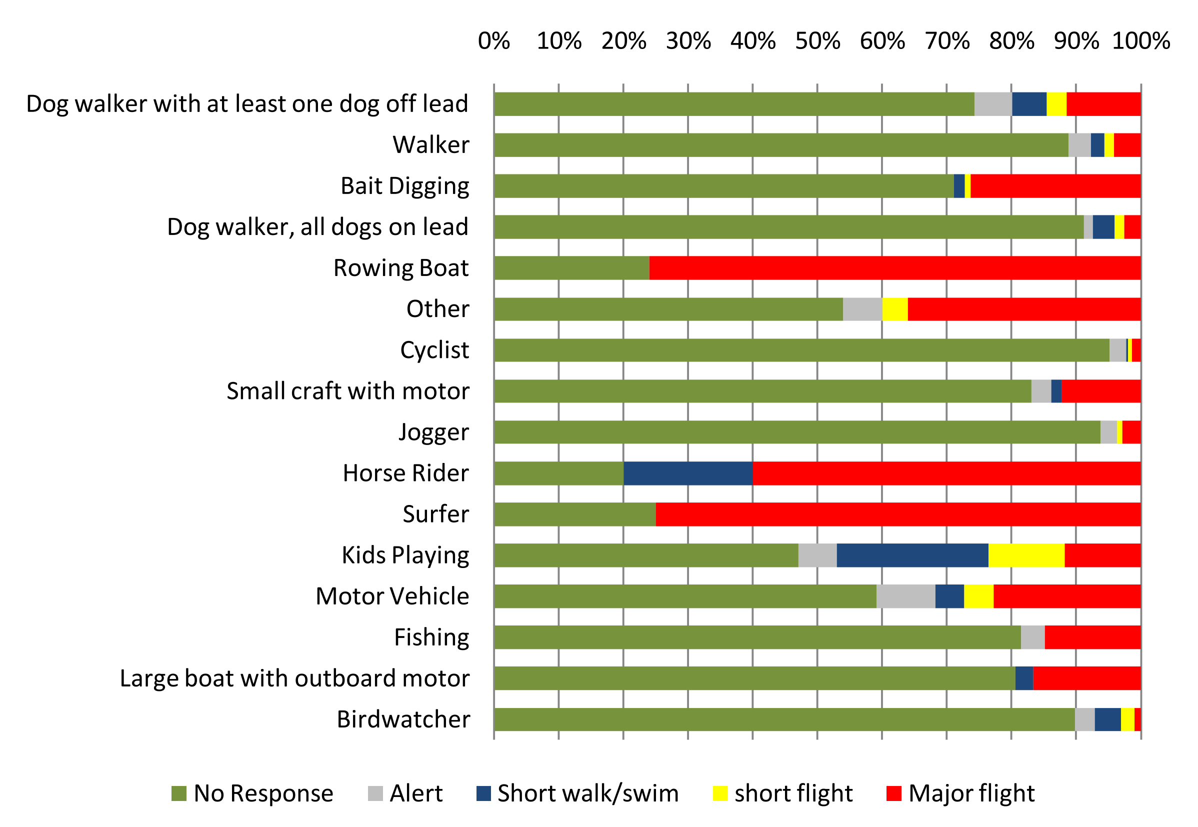


Figure 8: Responses of birds (grouped across all sites and all species) according to activity.

3.14 In Table 3 the response to each activity are summarised. It can be seen that the majority of observations involved activities on the shore (81% of observations), while 15% of observations involved activities on the intertidal and just 4% on the water. Just looking at the shore-based activities, 2,855 of the 3,279 observations involved no response from the birds – i.e. 12% of observations relating to shore-based activities resulted in disturbance (a change in the bird's behaviour). By contrast, for water-based activities 25% of the observations resulted in disturbance and on the intertidal 41% of observations resulted in disturbance.

3.15 Activities taking place on the intertidal therefore appear to be more likely to result in disturbance. In fact, over half the incidences where major flight was observed involved activities on the intertidal. Of the 341 instances where major flight was observed, 156 (i.e. 45% of major flights) were caused by activities taking place on the intertidal. Overall some

2% of observations involved dog walkers with their dogs off leads, on the intertidal, however this group was also responsible for 93 of the instances of major flights – some 27% of occurrences of major flight. If the major flights caused by dogs off leads on the shore are also included (68 shore based, 93 on the intertidal, total 161), then 47% of the major flight events were caused by dogs off leads.

Table 3: Number (%) of potential disturbance events and response of birds, by activity and zone.

Zone	Activity	No Response	Alert	Short walk/swim	short flight	Major flight	uncategorised	Total
shore	Birdwatcher	76 (2)	3 (0)	4 (0)	2 (0)	1 (0)		86 (2)
	Cyclist	333 (8)	9 (0)	1 (0)	2 (0)	4 (0)	1 (0)	350 (9)
	Dog walker, 1+ dog off lead	871 (21)	65 (2)	49 (1)	28 (1)	68 (2)	4 (0)	1085 (27)
	Dog walker, all dogs on lead	238 (6)	4 (0)	8 (0)	4 (0)	5 (0)	2 (0)	261 (6)
	Fishing	11 (0)				2 (0)		13 (0)
	Jogger	252 (6)	7 (0)		1 (0)	6 (0)		266 (7)
	Kids Playing	6 (0)	1 (0)	2 (0)	2 (0)			11 (0)
	Motor Vehicle	11 (0)	2 (0)		1 (0)	4 (0)		18 (0)
	Other	22 (1)	3 (0)		2 (0)	14 (0)		41 (1)
	Photographer	6 (0)		1 (0)		1 (0)		8 (0)
	Still	4 (0)			1 (0)			5 (0)
	Surfer	2 (0)				6 (0)		8 (0)
	Walker	1021 (25)	36 (1)	19 (0)	14 (0)	34 (1)	1 (0)	1125 (28)
	Wheelchair/scooter	2 (0)						2 (0)
	Total Shore	2855 (70)	130 (3)	84 (2)	57 (1)	145 (4)	8 (0)	3279 (81)
intertidal	Bait Digging	81 (2)		2 (0)	1 (0)	30 (1)		114 (3)
	Birdwatcher	12 (0)						12 (0)
	Cyclist	3 (0)				1 (0)		4 (0)
	Dog walker, 1+ dog off lead	173 (4)	17 (0)	26 (1)	15 (0)	93 (2)	2 (0)	326 (8)
	Dog walker, all dogs on lead	9 (0)		1 (0)		2 (0)		12 (0)
	Fishing	11 (0)	1 (0)			2 (0)		14 (0)
	Horse Rider	1 (0)		1 (0)		3 (0)		5 (0)
	Jogger	5 (0)			1 (0)	2 (0)		8 (0)
	Kids Playing	2 (0)		2 (0)		2 (0)		6 (0)
	Large Sailing Boat					1 (0)		1 (0)
	Motor Vehicle	2 (0)		1 (0)		1 (0)		4 (0)
	Other					1 (0)		1 (0)
	Small craft with motor	2 (0)						2 (0)
	Walker	57 (1)	6 (0)	7 (0)	3 (0)	17 (0)		90 (2)
	Working on boat	2 (0)				1 (0)		3 (0)
	Total Intertidal	360 (9)	24 (1)	40 (1)	20 (0)	156 (4)	2 (0)	602 (15)
Water based	Working on boat	10 (0)						10 (0)
	Rowing Boat	6 (0)				19 (0)		25 (1)
	Small craft with motor	52 (1)	2 (0)	1 (0)		8 (0)	1 (0)	64 (2)
	Small Sailing Boat	6 (0)		1 (0)	1 (0)			8 (0)
	Large boat with outboard motor	29 (1)		1 (0)		6 (0)		36 (1)
	Large Sailing Boat	13 (0)				2 (0)		15 (0)
	Canoe on water	14 (0)		1 (0)		1 (0)		16 (0)
	Total water-based	130 (3)	2 (0)	4 (0)	1 (0)	36 (1)	1 (0)	174 (4)
	Other	5 (0)				4 (0)		9 (0)
	Overall Total	3350 (82)	156 (4)	128 (3)	78 (2)	341 (8)	11 (0)	4064 (100)

Comparison between sites

3.16 The response of birds at each of the survey locations is summarised in Map 5.

3.17 We used the data from the end of each count to determine the total density of birds within the focal area. Bird density was then plotted against the number recreational activity events (taken from the diary data) recorded during each count (Figure 9). The plots show a weak negative correlation for all disturbance variables used, typically showing a range of bird densities at low disturbance levels but when disturbance levels are high there are no counts with high bird densities. This would potentially suggest that, when disturbance levels are low, a range of factors may influence bird density, but where disturbance levels are high birds tend to leave or avoid the area entirely.

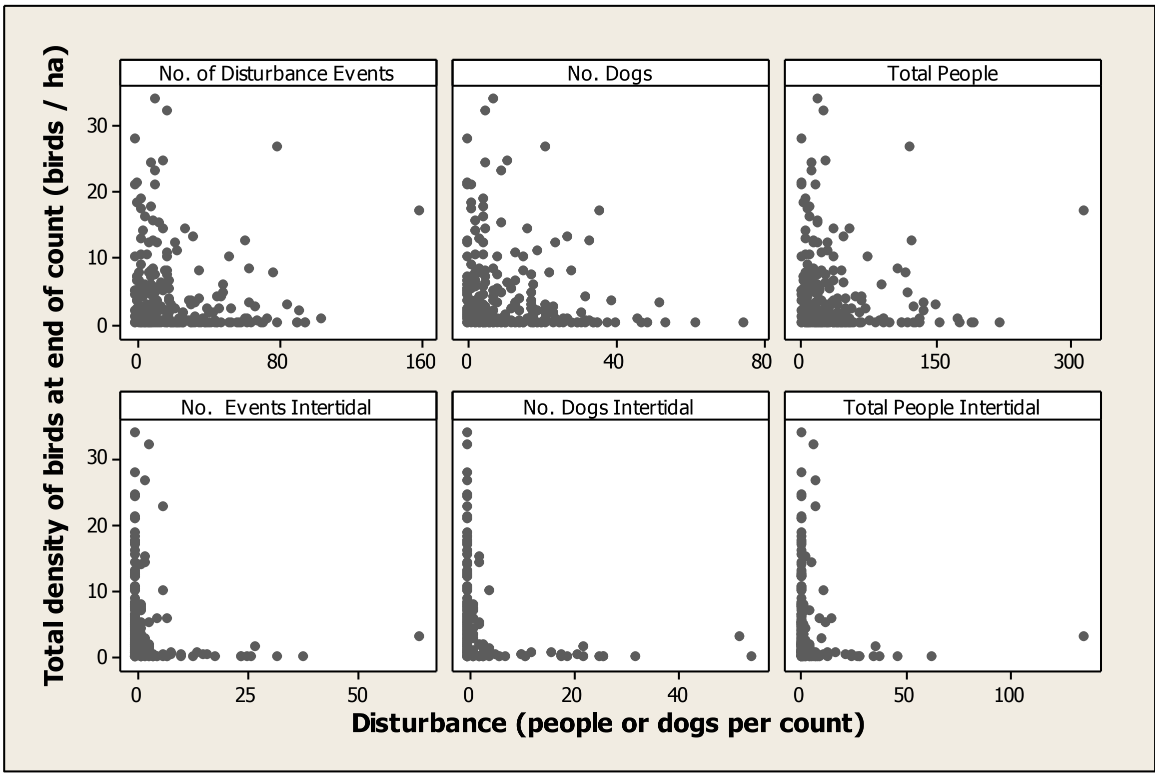
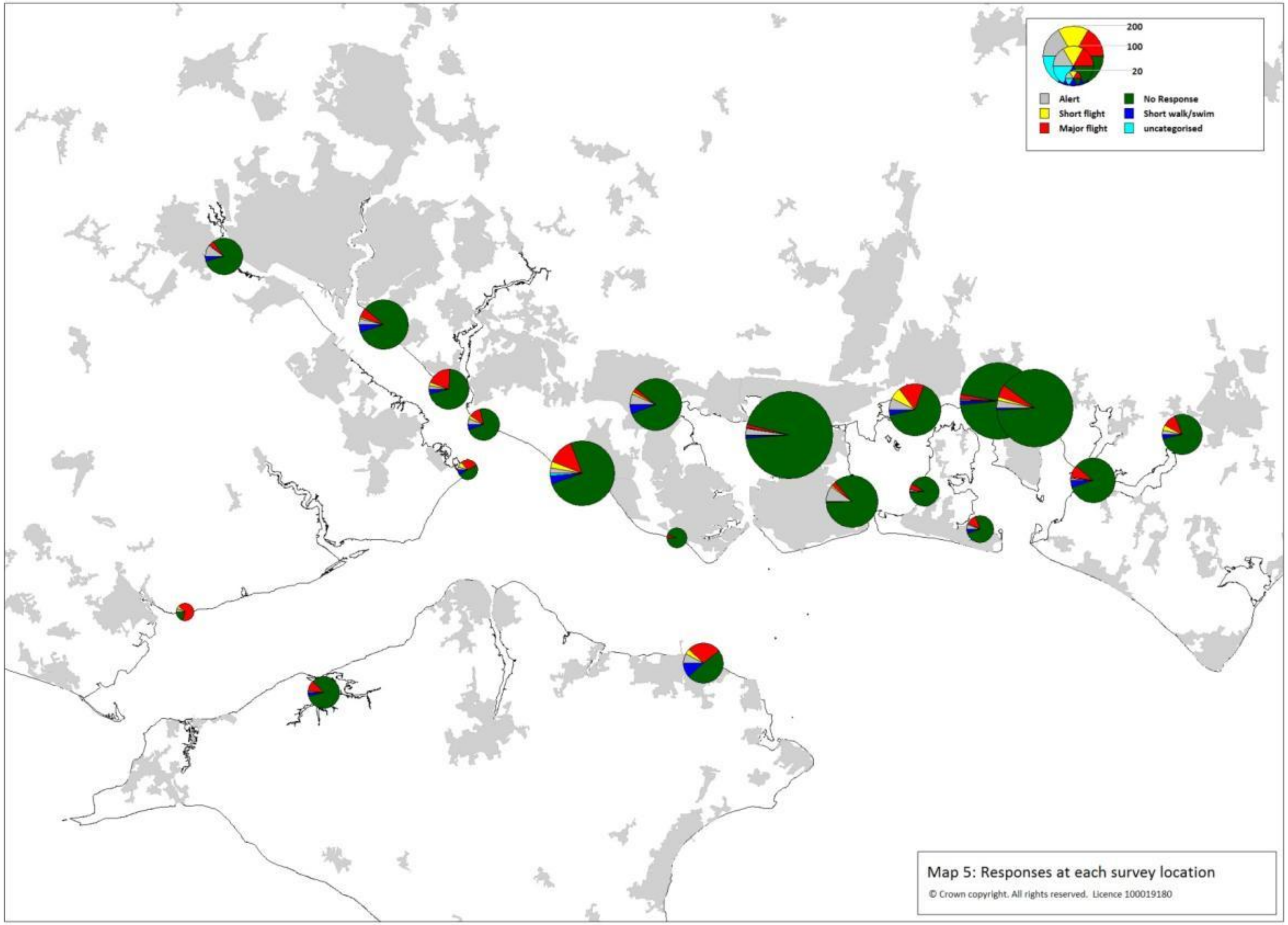


Figure 9: Bird density (at the end of each count) in relation to the number of recreational events (from the diary data) recorded during each count. The top three plots use data relating to all diary entries and in the lower three plots the data are filtered so that only events on the intertidal are used. To minimise the effect of tide, only bird counts conducted around low tide, i.e. where at least 20% of the focal area contained exposed mud for the duration of the count, are included. All plots show a significant (p<0.01) negative correlation: rank spearman correlation coefficients (for each row, right – left): -0.27; -0.29; -0.27; -0.20; -0.25; -0.21.



Map 5: Responses at each survey location

3.18 There was no significant correlation between the total number of people recorded within 200m of the birds and the number of disturbance events at each site (Pearson correlation coefficient=0.314, p>0.05). Similarly there was no significant correlation between the total number of people present (i.e. recorded in the diary) at each site (Pearson correlation coefficient=0.171, p>0.05), nor the count of the number of groups recorded at each site and the number of disturbance events (Pearson correlation coefficient=0.196, p>0.05). This would indicate that sites with high levels of access per se (i.e. high visitor numbers) do not necessarily see the most disturbance events, perhaps indicating that other factors, such as the types of activity taking place, how people behave and how access is managed at each location, determine the extent of disturbance.

3.19 The site where the most disturbance events (i.e. events causing birds to change their behaviour) was Saltern's Park. Langstone and Ryde also had similar, but slightly lower levels of disturbance (Figure 10).

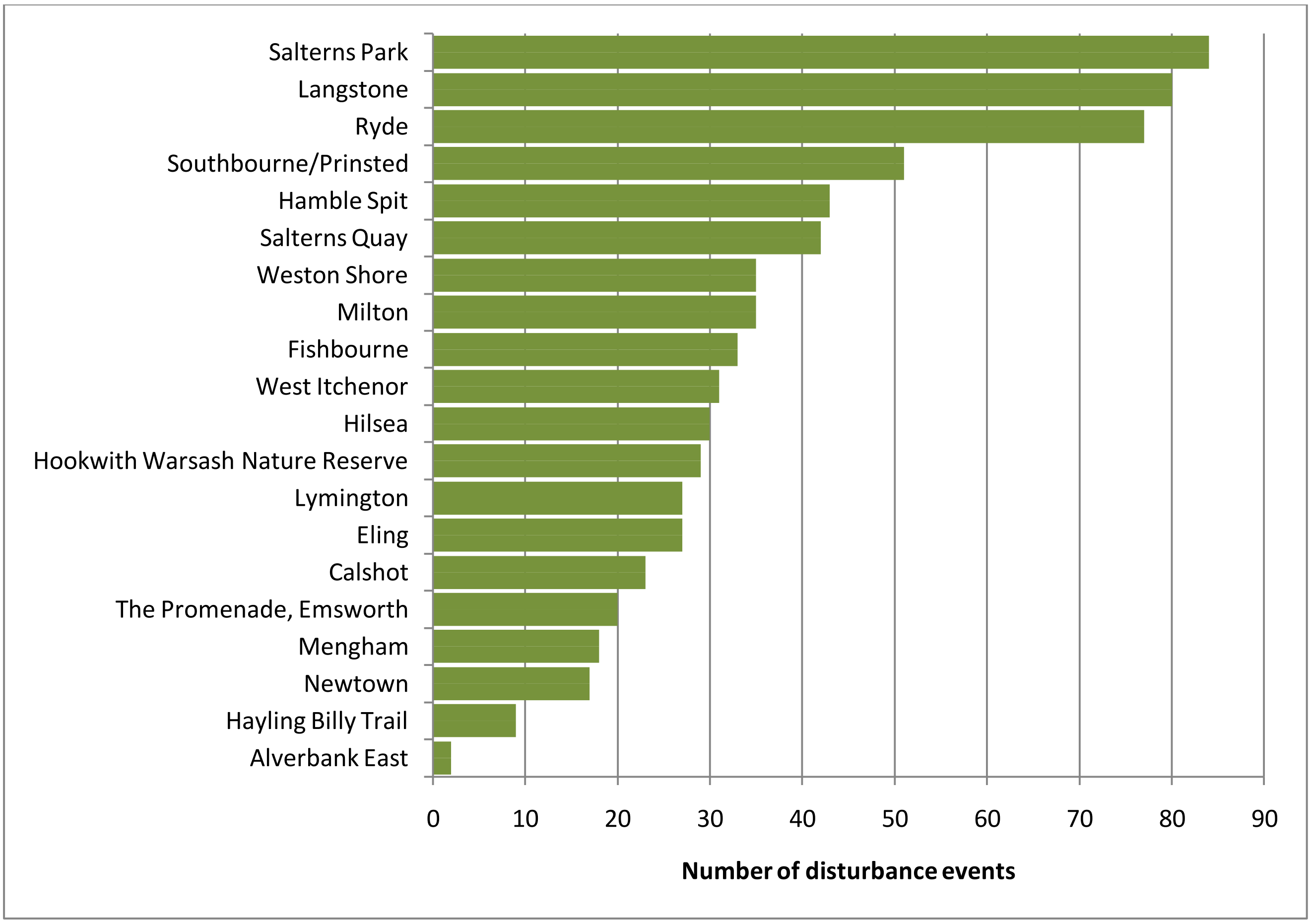


Figure 10: Number of disturbance events at each location – i.e. events where the birds became alert, walked/swam or flew.

3.20 There was some variation between sites as to how birds responded to potential disturbance events (Figure 11), with a significant difference between sites in the proportion of events to which there was 'no response' ($\chi 2 = 473.85$, 19df, $p<0.01$).

3.21 There was no significant correlation with the number of events resulting in birds of a given species taking a major flight and the number of disturbance events (Pearson correlation coefficient=0.107, $p>0.05$), indicating that there was no pattern whereby birds took major flight more (or less) at busier sites.

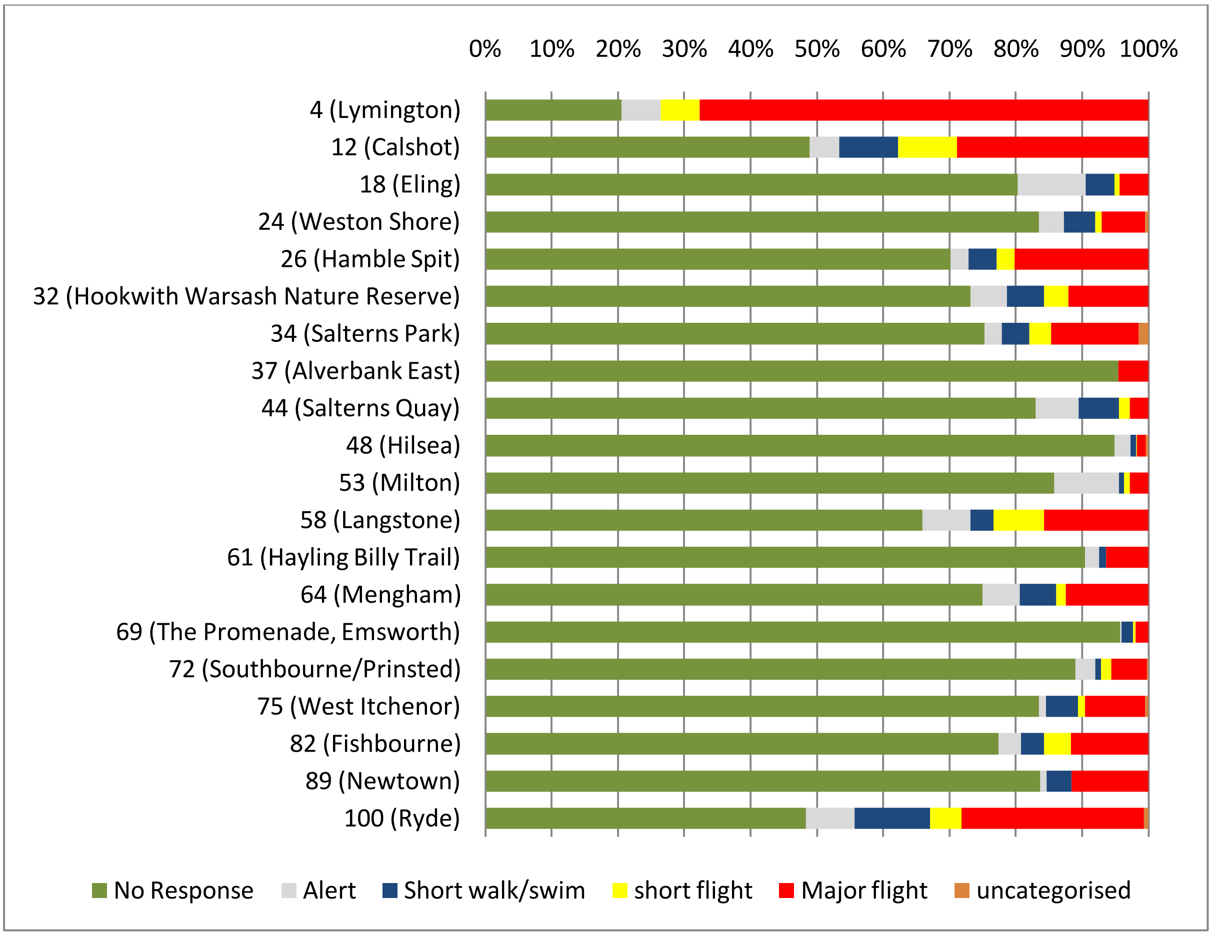


Figure 11: Percentage of potential disturbance events at each site resulting in disturbance.

Table 4: Number of observations (events within 200m of birds at each site) and the responses by site. Sites ranked according to the number of observations.

Section No.	Site	Total number of observations	Response of birds						% Disturbed
			No Response	Uncategorised	Alert	Short walk/swim	Short flight	Major flight	
4	Lymington	34	7		2		2	23	79
37	Alverbank East	44	42					2	5
12	Calshot	45	22		2	4	4	13	51
64	Mengham	72	54		4	4	1	9	25
61	Hayling Billy Trail	94	85		2	1		6	10
89	Newtown	104	87		1	4		12	16
32	Hookwith Warsash Nature Reserve	108	79		6	6	4	13	27
18	Eling	137	110		14	6	1	6	20
26	Hamble Spit	144	101		4	6	4	29	30
82	Fishbourne	146	113		5	5	6	17	23
100	Ryde	149	72	1	11	17	7	41	52
75	West Itchenor	188	157	1	2	9	2	17	16
24	Weston Shore	212	177	1	8	10	2	14	17
58	Langstone	235	155		17	8	18	37	34
53	Milton	246	211		24	2	2	7	14
44	Salterns Quay	247	205		16	15	4	7	17
34	Salterns Park	340	256	5	9	14	11	45	25
72	Southbourne/Prinsted	462	411	1	14	4	7	25	11
69	The Promenade, Emsworth	469	449		1	8	2	9	4
48	Hilsea	588	558	2	14	5	1	8	5
	Total	**4064**	**3351**	**11**	**156**	**128**	**78**	**340**	**18**

Variation in response between species

3.25 Response data for a selection of species are shown in Figure 12. There were significant differences between species in the proportion of events for which there was no response (for all species in Figure 12; $\chi2 = 180.15$; df = 15; $p<0.001$). Mute swan was the species for which the percentage of events resulting in no disturbance was the highest at 98% of events. Oystercatcher and wigeon were the two species with the highest percentage of events resulting in disturbance (i.e. alert, short flight, short walk/swim or major flight), with 26% of events for each species resulting in disturbance. Oystercatcher was the species with for which the highest percentage of events resulted in major flights: 16% of potential disturbance events resulted in a major flight for this species.

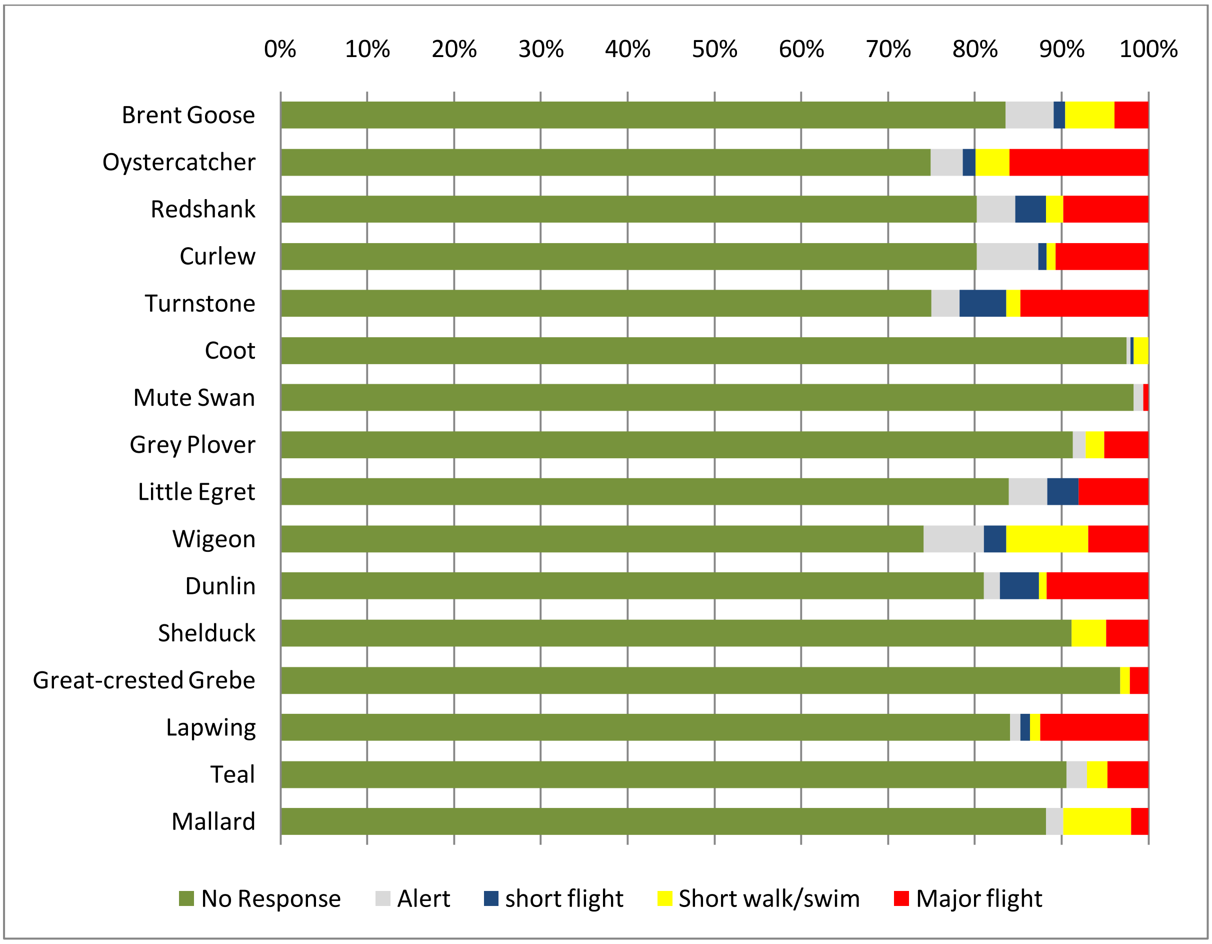


Figure 12: Response to disturbance events by species. All species for which there were data from at least 50 events are included. Species are listed in order of sample size (n= 816 for brent goose and n = 51 for mallard).

Distance from the source of disturbance

3.26 Response distances by species are summarised in Appendix 3. Looking across all species (Figure 13), birds tended to not respond when disturbance events where further away and while there was considerable overlap between the distances at which birds showed a response, there were significant differences between the distances at which birds showed the different types of response (Kruskall-Wallis H = 366.5 (adjusted for ties), 5df, $p<0.001$). As Figure 13 does however show, there were instances where no response occurred and the potential disturbance event was within a few metres of the birds and there were instances where major flight occurred and the birds were over 200m from the source of disturbance, suggesting that there is no clear set-back distance (at least for all species on all sites) that would result in no disturbance.

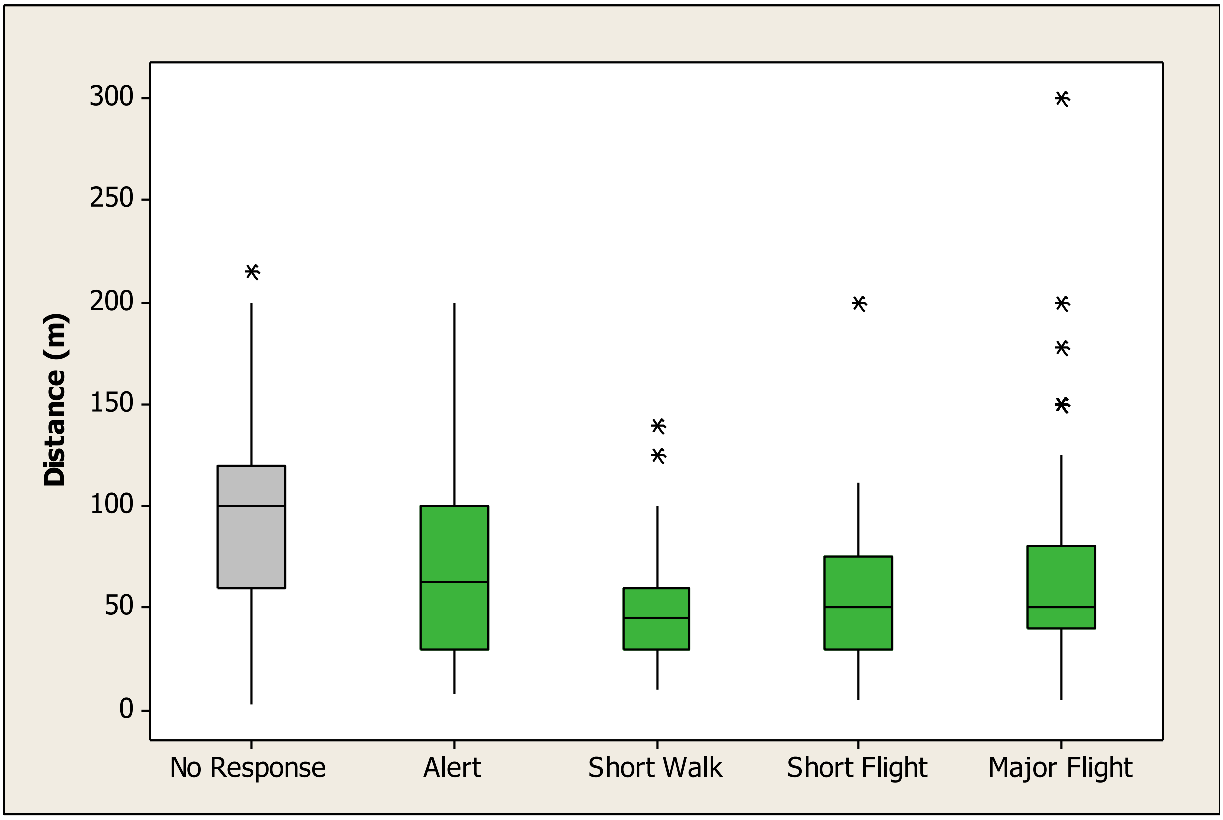


Figure 13: Distance data, for all species and events combined.

3.27 Looking across individual species (Table 5), in all cases the median distance at which no response was recorded was greater than the distance at which birds responded and disturbance occurred. The difference was significant for 12 of the 16 species for which there were at least 50 observations, with the exceptions being coot, mute swan, grey plover and great-crested grebe.

Table 5: Comparison, by species, of distances at which no reponse or disturbance events (i.e. alert, short walk/swim, short flight or major flight) occurred. Significance column indicates Mann-Whitney test results (p<0.01; *p<0.05). Table includes all species with at least 50 observations.**

Species	No Response			Disturbance occurred			Significance
	Median	Range	Count	Median	Range	Count	
Brent Goose	97	17-215	681	51.5	5-178	132	**
Oystercatcher	100	38-200	455	46	10-200	151	**
Redshank	90	20-200	402	44.5	75-150	98	**
Curlew	100	40-200	240	75	25-200	58	**
Turnstone	80	16-200	183	50	5-100	61	**
Coot	20	5-170	232	12	10-20	6	
Mute Swan	45	3-180	175	12	8-50	3	
Grey Plover	80.5	22.5-200	126	75	30-125	12	
Little Egret	150	40-200	115	75	30-200	22	**
Wigeon	125	45-200	86	75.50	20-125	30	**
Dunlin	115	29-200	90	75	25-300	21	**
Shelduck	100	80-200	93	77.5	50-140	8	**
Great-crested Grebe	120	30-200	89	100	50-100	3	
Lapwing	100	30-180	74	75	18-125	13	**
Teal	137	20-175	77	60	35-200	8	*
Mallard	45	20-150	45	25	10-50	6	*

3.29 The data for a selection of species are summarised in Figure 14. It can be seen that in most cases the distances at which no response occurred tended to be greater but for the alert, short walk, short flight and major flight categories the distances all tend to be similar.

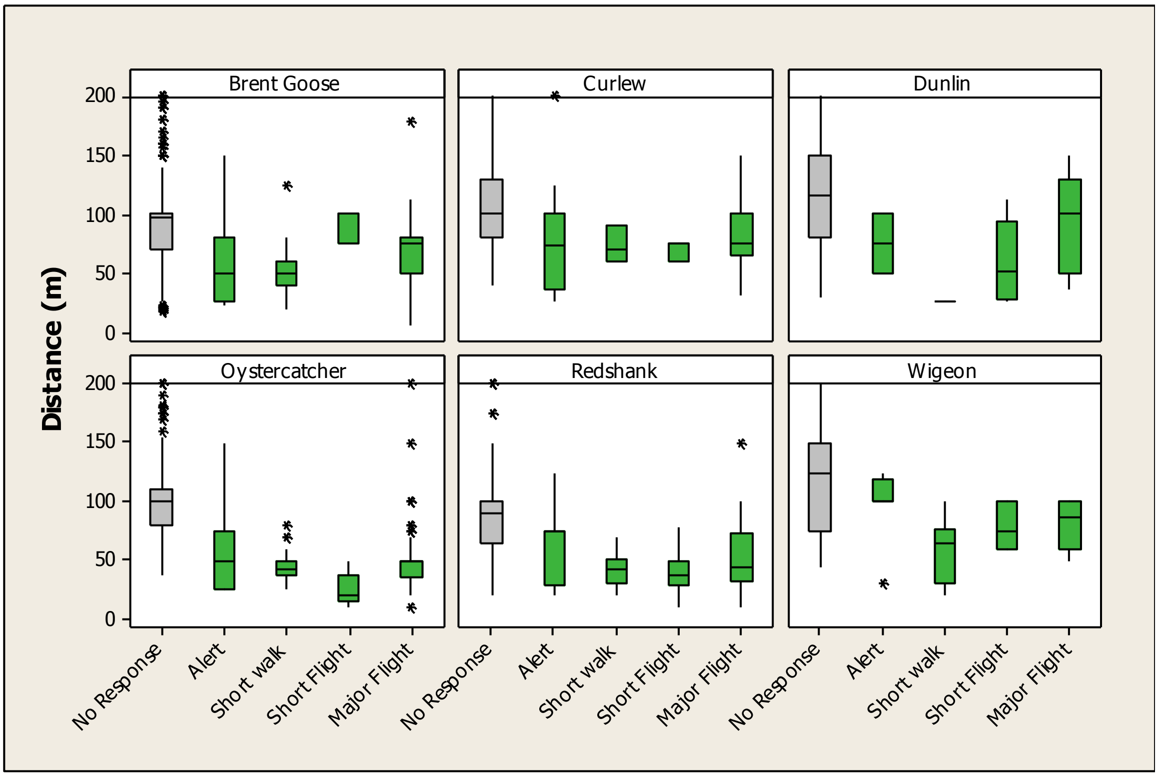


Figure 14: Distances and categories of response for a selection of species (chosen to include species with adequate sample sizes but also so as to include a range of species with different foraging behaviours and life-history traits).

3.30 As might be expected, where the disturbance event occurred close to the birds, a higher proportion of events resulted in disturbance. The proportion of events resulting in the displacement of the birds (i.e. short walk/swim, short flight or major flight) declined with distance for most species such that beyond a 100m few, if any, events resulted in birds being displaced. Taking the average across all species in the region of 1 in 20 events at 100m resulted in a major flight.

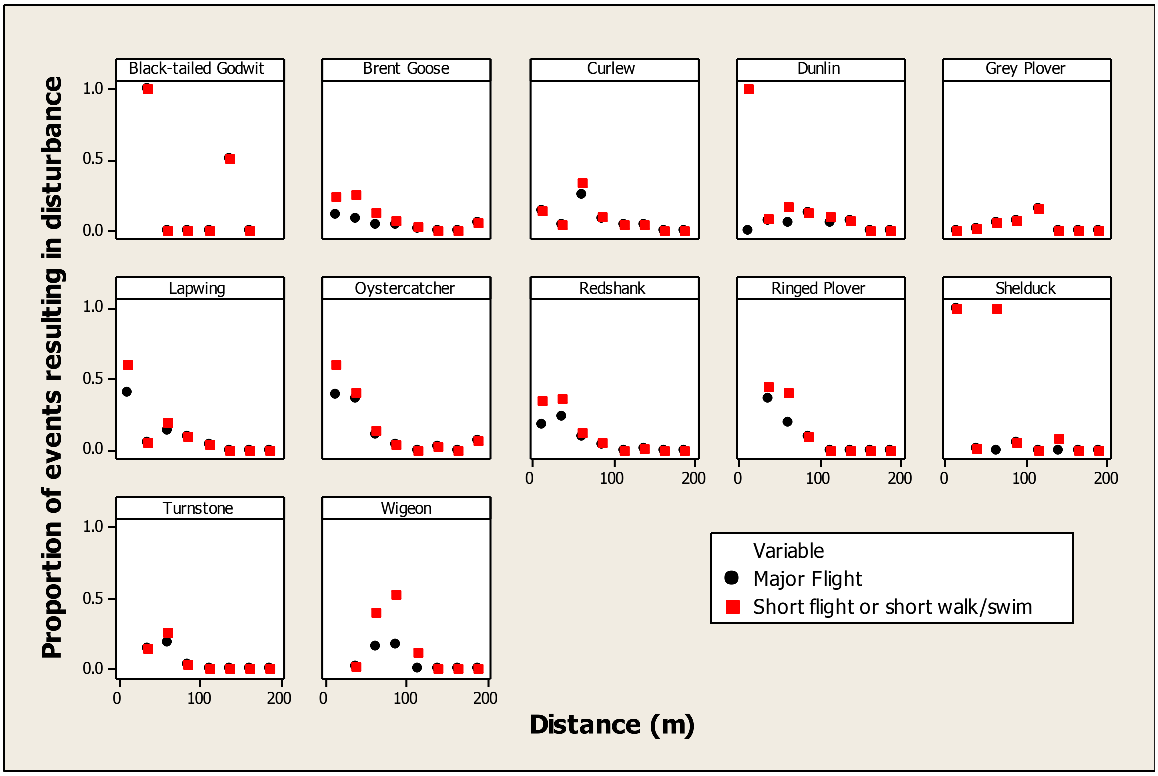
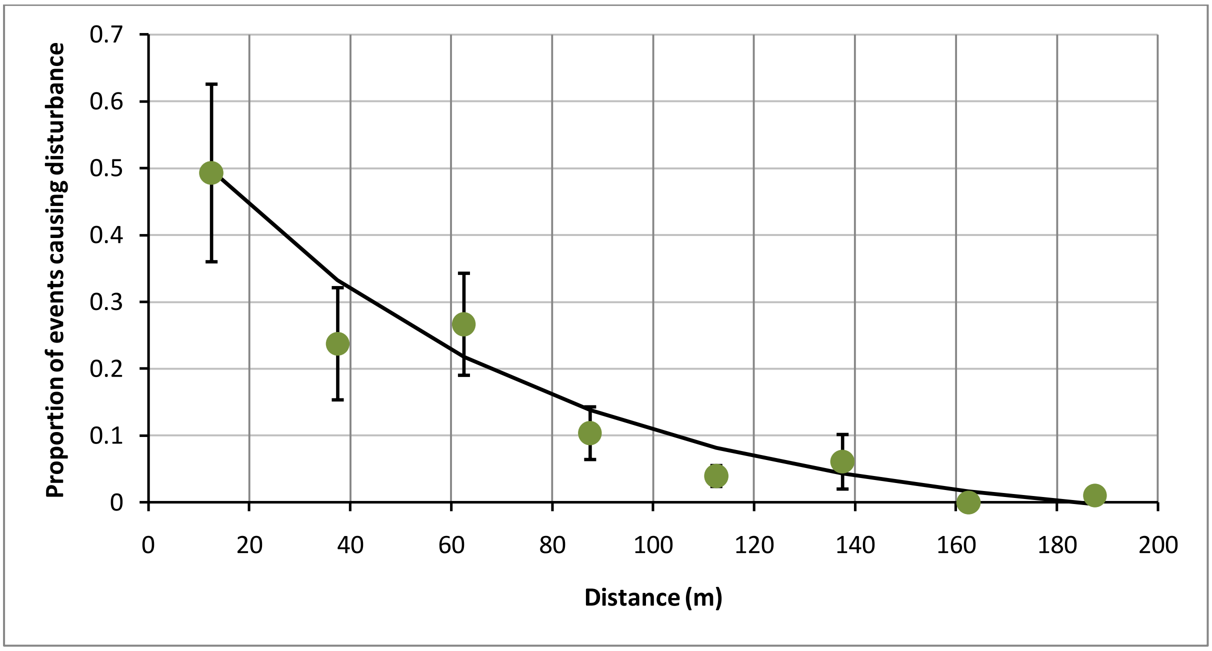


Figure 15: Proportion of events resulting in disturbance in relation to distance, for a selection of species

a)



b)

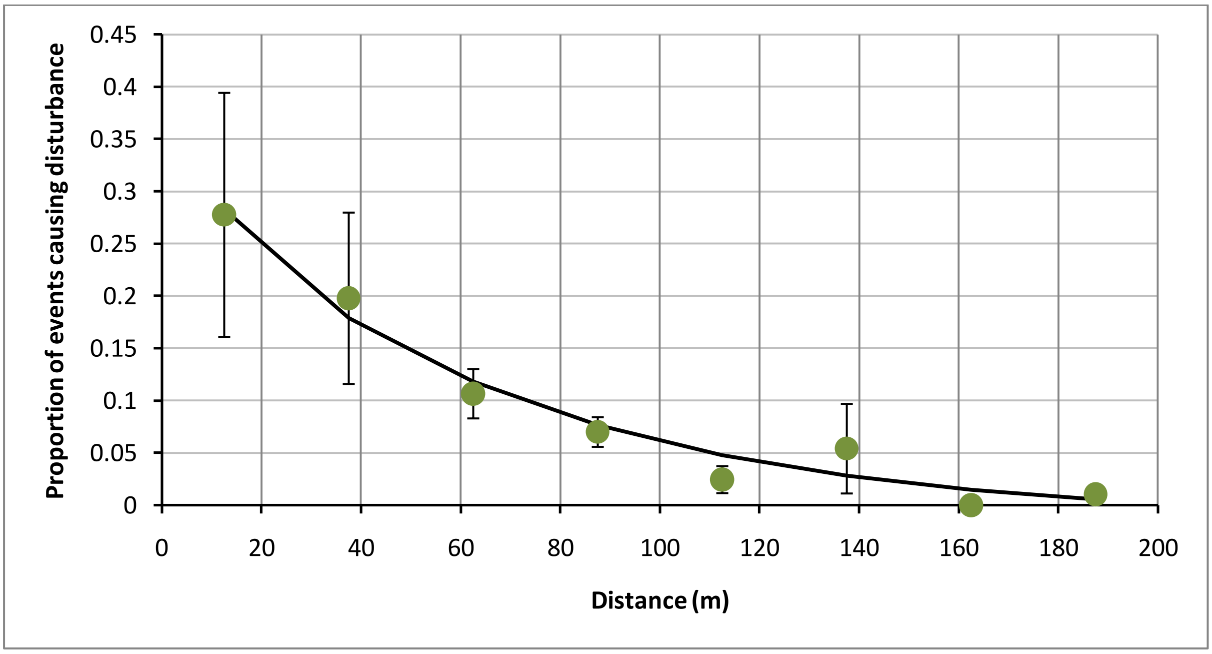
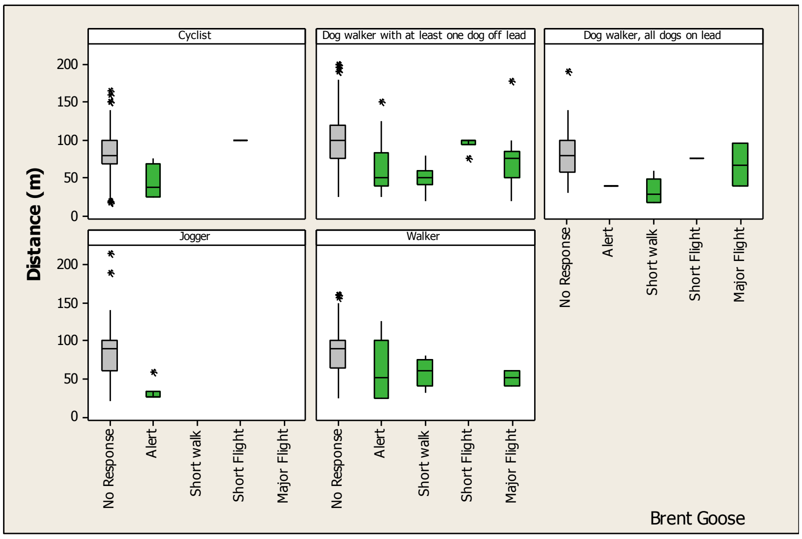
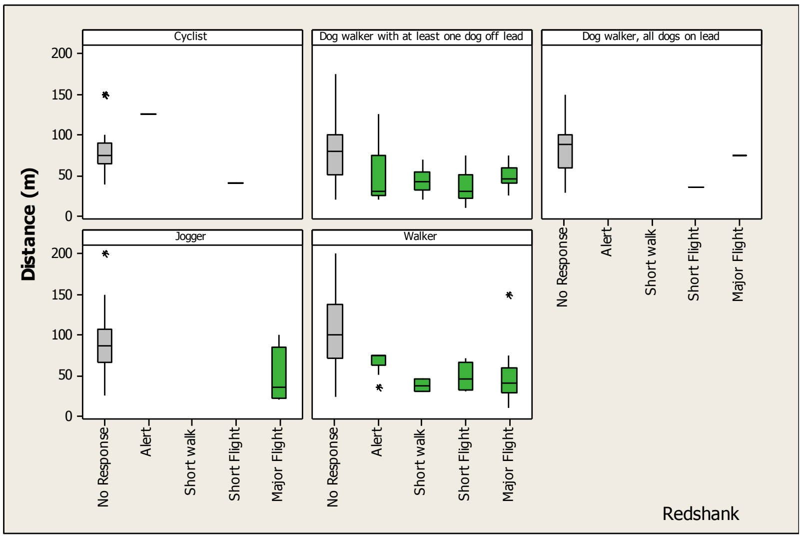


Figure 16: Proportion of events resulting in disturbance in relation to distance. Data points are averages (using the data from twelve species, as in Figure 15), error bars show one standard error. Averages are calculated from data binned in 25m intervals. Trendlines fitted manually, so as to maximise R^2. Top graph (a) is based on disturbance events that resulted in a flight, walk or swim, whereas the lower graph (b) shows major flight only. Note the Y axis scales are different between the two graphs.

a) $y = 0.65^{-0.0145x} - 0.0145$, $r^2=0.93$; b) $y = 0.34^{-0.015x}+0.001$, $r^2=0.96$

3.31 Sample sizes were in many cases too small to allow comparison, for individual species, of the distances at which birds responded in relation to particular activities. Data were extracted for the three species for which there were the largest number of observations (brent goose, oystercatcher and redshank). The data for five different activities are shown for these species in Figure 17. In most cases there is a repeated pattern of birds responding when people activities are close and no response occurring when the activities are distant. There are no apparent differences between the different responses (alert, short walk/swim etc.) in the distance at which the response occurs. This would suggest that other factors may be influencing how the birds respond to disturbance.





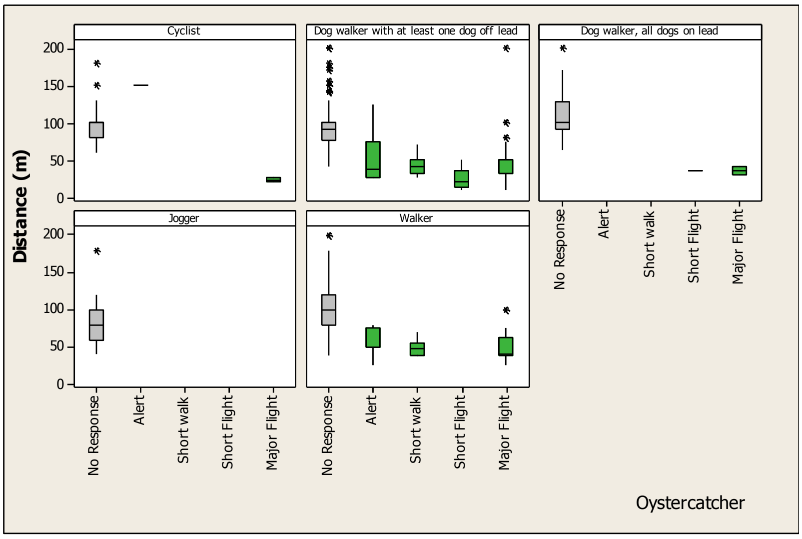


Figure 17: Response distances to different activities for three selected species

Multivariate analyses: Disturbance parameters required for subsequent modelling

3.32 The bird disturbance study was designed to determine patterns of disturbance throughout the Solent, and in addition to provide parameters for modelling that will be conducted in a subsequent phase of the Solent Disturbance Project. Specifically, an individual-based model will be used to predict the effect of disturbance on the survival rates of wading birds in Chichester Harbour and Southampton Water. The predictions for these sites will then be scaled up to predict the effect of disturbance on birds throughout the Solent.

3.33 Individual-based models track the behaviour, location and ultimate fate of each individual within a bird population, and predict the over winter survival rate of a species from the proportion of individuals of the species that survived to the end of winter. Individual birds within these models use behavioural decision rules to determine where and what to feed on (e.g. which part of an estuary to feed in and whether to consume bivalves or worms). These decision rules are designed to mimic the rules that real birds use (e.g. feed on prey that allows the daily energy requirement to be consumed as quickly as possible, but avoid potentially threatening activities). The model birds are therefore expected to respond to changes in their environment (e.g. changes in the amount of disturbance from human activities) in the same way as real birds do.

3.34 The individual-based model divides time into a sequence of one hour time steps, and space into a number of patches (e.g. sections of coast). The model patches will be the same as those used for the purpose of the bird disturbance and visitor components of the project. During each time step the distribution of birds (i.e. number in each patch), their behaviour and their rate of consuming food will be determined by their decision rules as described above. The model birds (as real birds) will respond in a number of ways to compensate for increased levels of human activity and associated disturbance. (1) Birds can avoid areas with higher amounts of disturbance and feed in less disturbed areas. (2) Birds can feed for longer, or at times when disturbance is less frequent. (3) If disturbance means that birds cannot meet their daily energy requirements, they can draw on their energy reserves to compensate. Disturbance will lead to mortality if it persists for a sufficient time, and over a sufficient area, such that the birds' energy reserves fall to zero.

3.35 In order to determine how to parameterise the model it is important to know how the response of birds to human activity is incorporated. Disturbance has three effects on the model birds: (1) it reduces the area of a patch that the birds can feed in; (2) it reduces the proportion of a time step that the birds can feed for; and (3) it increases the energy requirements of birds feeding in a disturbed patch (if it causes birds to take flight). The bird disturbance data needs to be analysed in such a way that these parameters can be derived. Each of (1) to (3) is likely to vary between types of disturbance (e.g. walker / dog walker) and locations (habitats) throughout the Solent (e.g. mudflat / sandflat), through the season and between different bird species.

Simplifying the disturbance dataset

3.36 The individual-based model can incorporate a wide range of disturbance effects but it is important to keep the model as simple as possible in order to understand and interpret its outputs. The appropriate amount of detail will be determined by considering the degree to which the response to disturbance varies between species, sites, disturbance type etc. and the amount of data available to quantify this variation. The following sections describe how the dataset derived from the bird disturbance study has been simplified prior to subsequent analysis.

3.37 *Aggregating behavioural responses*. The following behavioural response categories were recorded during the field study: "Alert", "Short walk / swim", "Short flight" and "Major flight". In subsequent analyses these responses are grouped into those in which the birds did not take flight ("Alert", "Short walk / swim" – termed "Minor response") and those in which birds did take flight ("Short flight" and "Major flight" – termed "Flight response"). The reason for doing this is that when responding to disturbance by taking flight, birds will suffer an increased energy cost due to the flight. The actual energy cost can be calculated from the distance flown by the birds, which was recorded during the field study, and their body mass.

3.38 *Reducing the number of bird species*. The individual-based model will predict the effect of disturbance on overwintering populations of wading birds and so the subsequent analysis is restricted to these species. The number of observations varied between different wading birds and so subsequent analysis is further restricted to bird species that had at least 20 observations of their response to disturbance. Table 6 shows the number of disturbance observations for the wading bird species used in subsequent analyses. The table also shows the body mass of each species. Any relationship between the response to disturbance and body mass will be used to predict the response to disturbance of wading bird species for which insufficient data were obtained during the field study.

Table 6: Summary of disturbance datasets for wading bird species included in subsequent analysis. The body mass for each species was derived from www.bto.org/birdfacts and is an average of male and female mass where these differed. The numbers in the remaining columns are the number of potential disturbance events for each species which resulted either in no response, a minor response or a flight response.

Species	Body mass (g)	No response	Minor response	Flight response
Dunlin	48	90	3	18
Redshank	120	402	32	67
Turnstone	120	183	12	49
Oystercatcher	540	455	46	106
Curlew	885	240	24	35

3.39 *Understanding between-site variation in the response to disturbance*. The sites included in the disturbance study comprise only a proportion of the total length of the Solent's shore, but predictions of the response to disturbance will ultimately be required for the entire coast. It is likely that the response to disturbance will vary between the study sites but it is more important to find a characteristic of sites that is related to this variation. This can be used to predict the response to disturbance on sections of the coast that were not included in the disturbance study. The response to disturbance is often related to the frequency of potential disturbance events at a site. For example, if birds become habituated to disturbance events (e.g. by learning that these are not a threat) they tend to respond less to disturbance events in sites in which disturbance in more frequent. Table 7 shows the number and rate of potential disturbance events recorded at each study site. The rate of potential disturbance events will be used to interpret between-site variation in the response to disturbance. In subsequent modelling the potential disturbance rate in different sections of coast throughout the Solent will be predicted from characteristics of the coast including distance to an access point / car park, and distance from population centres.

Table 7: Summary of potential disturbance events recorded at each study site. The potential disturbance rate is the number of potential disturbance events divided by the observation period at each site (12 visits each 1hr 45 minutes in duration = 21 hrs).

Site name	Site number	Number of potential disturbance events	Potential disturbance rate (events hr^{-1})
Lymington	4	34	1.6
Calshot	12	45	2.1
Eling	18	137	6.5
Weston Shore	24	212	10.1
Hamble Spit	26	144	6.9
Hookwith Warsash Nature Reserve	32	108	5.1
Salterns Park	34	340	16.2
Alverbank East	37	44	2.1
Salterns Quay	44	247	11.7
Hilsea	48	588	28
Milton	53	246	11.7
Langstone	58	235	11.2
Hayling Billy Trail	61	94	4.5
Mengham	64	72	3.4
The Promenade, Emsworth	69	469	22.3
Southbourne/Prinsted	72	462	22
West Itchenor	75	188	9.0
Fishbourne	82	146	7.0
Newtown	89	104	5.0
Ryde	100	149	7.1

3.40 *Effect of stage of the season on the response to disturbance*. It is likely that the response to disturbance will vary with stage of the season as the birds' energy requirements and the quality of their food resources change. These changes will influence the costs and benefits of avoiding a potential disturbance source, and hence the distance and time for which birds respond. However, given that the disturbance study was conducted in late winter (when the response to disturbance in a wading bird species has been shown to vary less than between autumn and winter (Stillman & Goss-Custard 2002), and the relatively low number of disturbance responses observed in some species, it was decided to exclude seasonal effects from any subsequent analyses.

3.41 *Aggregating activity types*. A wide range of activity types were identified during the disturbance survey. Although the disturbance responses of birds may vary between these activity types, several other factors may also influence the response (e.g. species of bird, background level of disturbance on a site). Separating the effect of each individual activity type was not feasible due to the rarity of some activities, and the fact that their effects were confounded with the effects of other factors. Two options were available. (1) To only include the most frequently observed activity types in subsequent analyses. (2) To aggregate activity types into broader categories (e.g. land-based or water-based activities). It was decided to adopt the second option as this meant that observations from rarer activity types could still be used in the analysis, making the most of this information. Table 8 shows the composition of the aggregated activity types (Dog-walking, Other land-based activities and Water-based activities), and Table 9 shows the frequency of disturbances caused by the aggregated activity types in different sites.

Table 8: Composition of the aggregated activity types. The values are the number of disturbances caused by each activity and aggregated activity. The "Other" aggregated activity is not used in further analyses.

Aggregated activity	Number of disturbances observed for aggregated activity	Activity included in aggregated activity	Number of disturbances observed for activity
Dog walking	385	Dog walker with at least one dog off lead	361
		Dog walker, all dogs on lead	24
Other land-based activities	243	Walker	136
		Bait Digging	33
		Cyclist	17
		Jogger	17
		Birdwatcher	10
		Kids Playing	9
		Motor Vehicle	9
		Fishing	5
		Horse Rider	4
		Photographer	2
		Still	1
Water-based activities	51	Rowing Boat	19
		Small craft with motor	11
		Large boat with outboard motor	7
		Surfer	6
		Large Sailing Boat	3
		Canoe on water	2
		Small Sailing Boat	2
		Working on boat	1
Other	23	Other	23

Estimating disturbance parameters

3.42 Several factors were potentially associated with the responses of birds to human activities (and hence the model disturbance parameters), and so the first phase of analysis was to identify which factors were significantly associated with these responses. Separate analyses were conducted for three disturbance responses: *Response distance* – the distance over which birds respond to disturbance; *Response time* – the time taken to resume feeding after disturbance; and *Displacement distance* – the distance bird move following disturbance. The following explanatory variables were initial incorporated into the analysis: *Aggregated activity* – Dog walker, Other land-based activity or Water-based activity; *Aggregated response* - Minor response or Flight response; *Site disturbance rate*; *Intertidal activity* – 0 if land-based activity; 1 if intertidal activity; and *Some birds feeding* – 1 if some birds feeding prior to disturbance, else 0. A general linear model (without transformation of any variables) was used to relate each response type to all explanatory variables combined. Aggregated activity and Aggregated response were included as fixed factors, and the remaining variables as co-variates. No interaction terms were included. Only observations in which birds responded to disturbance were included in the analysis. Separate analyses were conducted for each species.

3.43 Table 9 shows summary results of the analyses. The type of response to disturbance (Minor or Flight) was not related to the response distance or time. Response type was not incorporated in the analysis of displacement distance, as displacement distances were not generally recorded for the Minor response category. Similarly, whether an activity was on the intertidal was only significantly related to one behavioural response in one species. The site disturbance rate was negatively related to the response to disturbance in three cases. Such a relationship would be expected if birds became habituated to disturbance in sites in which disturbance occurs more frequently. The presence of feeding birds was significantly related to the response to disturbance in four cases (three negative and one positive). The aggregated activity types was related to the response to disturbance in three cases, in each case the response to a water-based activity being greater than that to dog walking or other land-based activities.

3.44 The analyses were further simplified by just including the explanatory variables that were most consistently related to the response to disturbance – i.e. Aggregated activity and site disturbance rate. The "Some feeding birds" variable was not included because its direction of association with the response to disturbance was not consistent. Table 10 shows the results of the simplified analysis. Site disturbance rate was significantly negatively related to the response distance of curlew. The response to disturbance was lower to dog walking and / or other land-based activities, in comparison to water-based activities in five cases: indicated by values significantly less than zero. This indicates that birds respond less to land-based activities than to water-based activities.

3.45 Disturbance parameters for the individual-based model could be calculated from Table 10, but only for the species listed. In order to estimate disturbance parameters for other species, a combined analysis was performed in which species were represented by their body mass. The response to disturbance was explained in terms of the disturbance rate on a site, the body mass of the species being disturbed and the activity type causing the disturbance. Table 11 shows the results of the analysis. Site disturbance rate was not related to any of the responses to disturbance. Bird body mass was positively related to response distance, but unrelated to response time and displacement distance. Aggregated activity was related to response distance and response time, with a lower response observed for dog-walking and other land-based activities than for water-based activities (values significantly smaller than values for water-based activities). The relationships in Table 8 can be used to predict the response to disturbance of a range of wading bird species (from their body mass) to a range of disturbance types, in areas throughout the Solent (from disturbance rates).

3.46 Figure 18 and Figure 19 graphically show the relationships described in Table 9. The response to disturbance is consistently higher from water-based than from land-based activities (Figure 18). Response distance increases with increased body size (Figure 19) in all species except dunlin, which has a relatively large response distance for its body mass. Response distance was still significantly related to body mass as relatively few observations were recorded from Dunlin. The remaining disturbance responses were not related to the body mass of waders.

Disturbance parameter summary

3.47 The main variable that was consistently related to the response to disturbance was the aggregated activity type. Typically, the responses to dog walking and other land-based activities were of similar magnitude, but less than the responses to water-based activities. Significant relationships between the disturbance rate on a site and the response to disturbance tended to be negative. This is consistent with the observation in other locations that birds become habituated to disturbance in areas where disturbance is more frequent. Bird body mass was significantly positively related to response distance, providing a means of predicting the response to disturbance of species other than those included in the analyses above. Other variables that had a less consistent influence on the response to disturbance included whether or not a disturbing activity occurred on the intertidal, and whether any of the disturbed birds were feeding prior to the disturbance.

Table 9: Summary of factors explaining variation in (a) response distance, (b) response time and (c) displacement distance. For each species, the tables summarise the direction and significance for each explanatory variable. Aggregated activity: W = water-based activity; D = dog walking; L = other land-based activity (= indicates no significant difference, < or > indicate direction of significant association). Aggregated response: M = minor response; F = flight response (= indicates no significant difference, < or > indicate direction of significant association). Site disturbance rate, Intertidal activity and Some birds feeding: - = significant ($p < 0.05$) negative association; + = significant ($p < 0.05$) positive association; 0 = non-significant association. Grey shaded cells indicate significant associations.

(a) Response distance

Variable	Dunlin	Redshank	Turnstone	Oystercatcher	Curlew
Aggregated activity	W=D=L	W>D=L	W=D=L	W>D=L	W=D=L
Aggregated response	M=F	M=F	M=F	M=F	M=F
Site disturbance rate	-	0	0	0	-
Intertidal activity	0	0	0	0	0
Some feeding birds	0	0	+	0	0

(b) Response time

Variable	Dunlin	Redshank	Turnstone	Oystercatcher	Curlew
Aggregated activity	W=D=L	W>D=L	W=D=L	W=D=L	W=D=L
Aggregated response	M=F	M=F	M=F	M=F	M=F
Site disturbance rate	0	0	0	0	0
Intertidal activity	0	0	0	0	0
Some feeding birds	0	-	0	0	-

(c) Displacement distance

Variable	Dunlin	Redshank	Turnstone	Oystercatcher	Curlew
Aggregated activity	W=D=L	W=D=L	W=D=L	W=D=L	W=D=L
Site disturbance rate	-	0	0	0	0
Intertidal activity	+	0	0	0	0
Some feeding birds	0	-	0	0	0

Table 10: Simplified analysis of factors explaining variation in (a) response distance, (b) response time and (c) displacement distance. The values show the parameters for each variable defined as follows: Site based disturbance – change in response variable per unit change in site disturbance rate; Water-based activity – value of response variable with a site disturbance rate of zero (equivalent to the intercept in the model); Dog walking and Other land-based activity – value of response variable relative to that with water-based activity. Grey shaded cells indicate values significantly different from zero.

(a) Response distance

Variable	Dunlin	Redshank	Turnstone	Oystercatcher	Curlew
Water-based activity	124.3*	92.9*	29.5	84.6*	122.0*
Dog walking	-35.8	-49.7*	0.4	-41.3*	-36.6*
Other land-based activity	-45.1	-38.6*	9.8	-29.3	-26.8
Site disturbance rate	-1.8	0.2	1.0	0.2	-1.9*

(b) Response time

Variable	Dunlin	Redshank	Turnstone	Oystercatcher	Curlew
Water-based activity	335.5*	239.1*	69.8	89.3*	120.9
Dog walking	-215.3	-164.0*	37.6	-11.8	-5.9
Other land-based activity	-225.6*	-162.4*	28.5	-24.9	-15.4
Site disturbance rate	-1.9	0.5	-1.0	0.3	-0.6

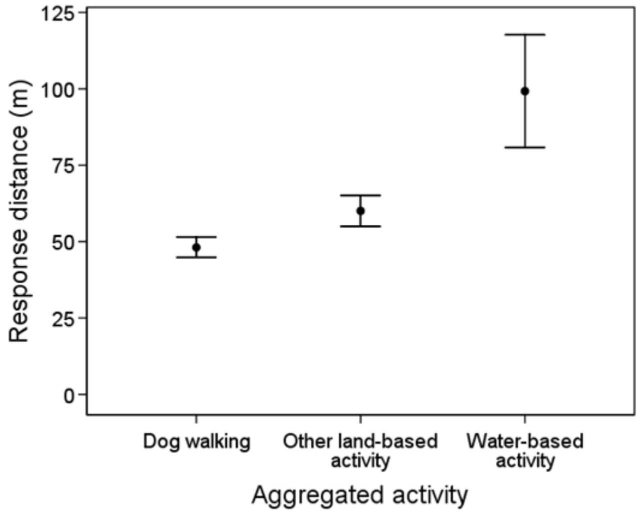
(c) Displacement distance

Variable	Dunlin	Redshank	Turnstone	Oystercatcher	Curlew
Water-based activity	230.2*	287.0*	155.1	122.2	220.2*
Dog walking	-54.2	-159.4	68.9	-19.1	-35.8
Other land-based activity	-64.7	-114.8	25.6	-12.2	-58.7
Site disturbance rate	-5.7	-1.9	-7.3	2.0	3.4

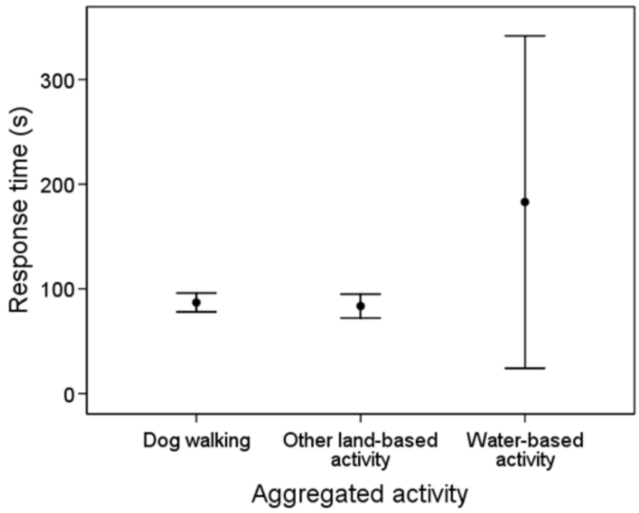
Table 11: Combined analysis of factors explaining variation in response distance, response time and displacement distance. The values show the parameters for each variable defined as follows: Site based disturbance and bird body mass – change in response variable per unit change in variable; Water-based activity – value of response variable with a site disturbance rate and bird body mass of zero (equivalent to the intercept in the model); Dog walking and Other land-based activity – value of response variable relative to that with water-based activity. Grey shaded cells indicate values significantly different from zero.

Variable	Response distance	Response time	Displacement distance
Water-based activity	91.2*	183.2*	195.8*
Dog walking	-52.1*	-95.3*	-76.8
Other land-based activity	-39.9*	-98.6*	-56.3
Site disturbance rate	0.07	-0.13	-1.01
Bird body mass	0.02*	0.00	0.05

Response distance



Response time



Displacement distance

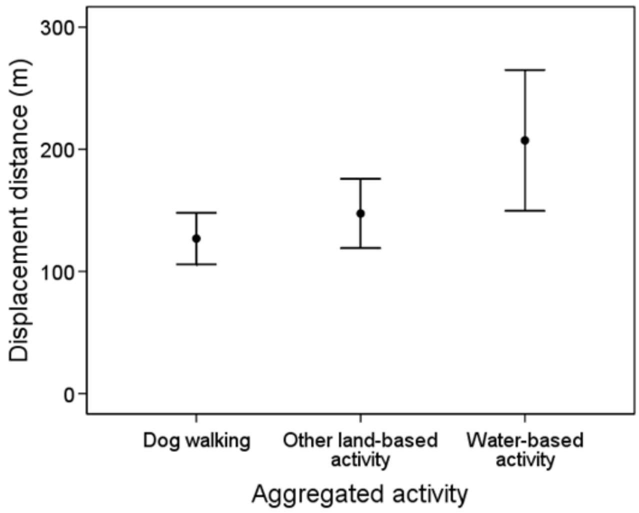
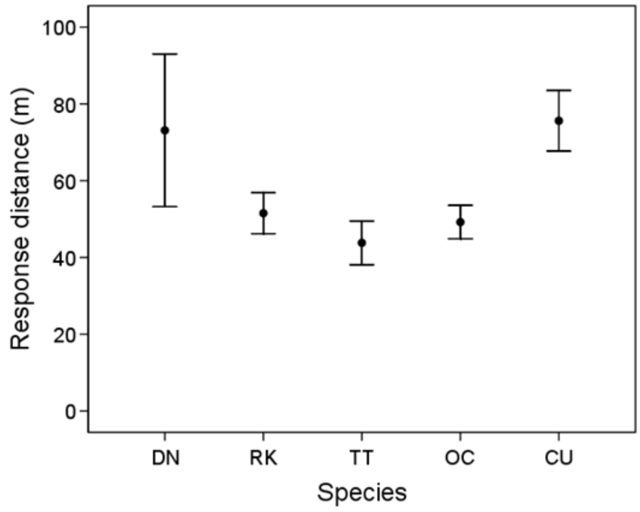
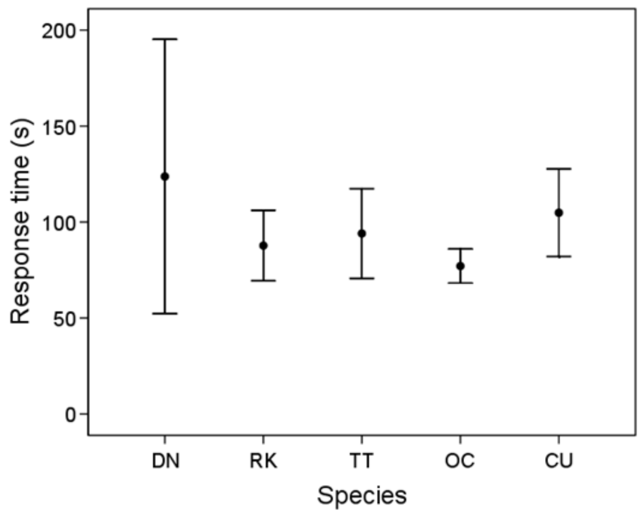


Figure 18: Effect of aggregated activity on the response to disturbance. The symbols are means and associated standard errors across sites and bird species.

Response distance



Response time



Displacement distance

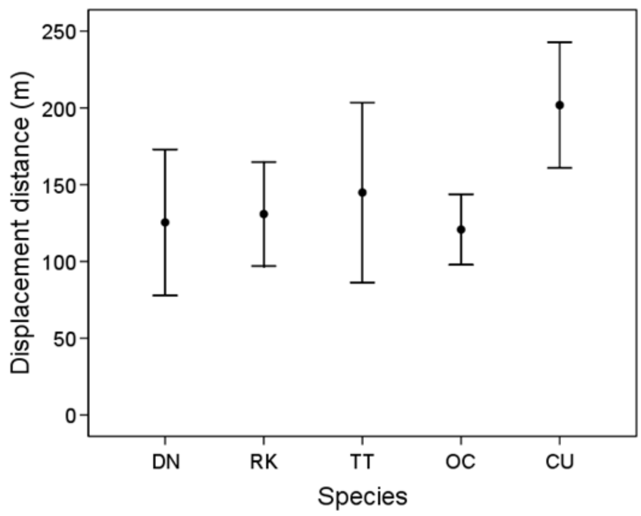


Figure 19: Effect of bird species on the response to disturbance. The symbols are means and associated standard errors across activities and sites. Species are ordered by increasing size and named using British Trust for Ornithology codes (DN = Dunlin; RK = Redshank; TT = Turnstone; OC = Oystercatcher; CU = Curlew).

4. Discussion

Overview

4.1 The results provide an overview of the scale and underlying patterns of disturbance across a wide geographic area. The patterns are complex, given the context of a range of species, a wide range of sites (with different habitats) and with survey work undertaken across a range of dates, different weather conditions and tide heights. The results will be used to inform the development of model(s) to explore the impacts of disturbance at a Solent-wide scale. We highlight the following key results:

- Visitor rates were relatively high at around 13 groups (20 people) per hour
- A wide range of activities and recreational use was recorded.
- Around one in five events resulted in disturbance (i.e. a change in behaviour of the birds present).
- Dog walking was the most frequently recorded activity (41% of observations) and accounted for some 47% of instances of major flight. Some 2% of observations involved dog walkers with their dogs off leads and on the intertidal and accounted for a disproportionate amount of disturbance events (for example some 27% of all disturbance events involving major flight).
- There was no evidence that more disturbance events occurred at the busiest sites – sites that were busy typically had lots of activities taking place on the seawall and did not involve activities that necessarily brought people close to the birds.
- Disturbance (i.e. a change in behaviour) tended to occur when the activity occurred close to the birds and birds tended to show no response when the potential disturbance was further away.
- Bird densities are lower where visitor numbers are high, indicating that disturbance does influence the distribution of birds.
- Multivariate analyses indicate that there was a stronger response to water based activities, in that birds responded to water based activities at greater distances and tended to be displaced further.

Use of the results

4.2 The fieldwork has been designed to gather data necessary to model the impact of disturbance at a Solent-wide scale. The data on the distances at which birds respond, length of time lost feeding etc. will form a basis for the later stages of the Solent Disturbance and Mitigation Project.

4.3 The data are not necessarily relevant at a local level, for example in assessing the impacts of a single development, and we urge caution in interpreting the results in this way. The data collection has used twenty different survey locations and at each a relatively small area of mudflat was the focus. It is therefore not possible to use the data collected to determine the amount of disturbance along a stretch of coast, for example an entire creek or length of shoreline. The usefulness and potential of the survey is the overall picture (across a wide range of sites, habitats and levels of use), of how birds respond to the presence of people, providing the basic information necessary to develop models which will all the impacts of disturbance to be determined at a Solent-wide scale.

Understanding the results in context

4.4 Disturbance to birds can be interpreted as in the context of how birds perceive the threat or perceived predation risk (Frid & Dill 2002; Beale & Monaghan 2004b). Such an approach essentially views the behavioural response to disturbance as the result of a trade-off between the perceived threat from the disturbance and the cost of responding. People are essentially predation-free predators. If the cost of fleeing is high (for example birds loose a territory when they vacate it), then birds will be reluctant to flee, and therefore might be expected to respond to disturbance only when it is nearby and perceived to be particularly dangerous. Equally if food supplies are limited or cold weather places additional energetic demands then it might be expected that birds 'appear' particularly tame. When it is not costly to flee (for example food supplies are plentiful, there is little competition and alternative foraging locations exist), it would be expected that birds would respond to disturbance even when the risk is perceived to be relatively low. In such circumstances birds might fly even when the source of disturbance is some considerable distance away.

4.5 We would expect many of the wintering birds to have good site knowledge. Birds will know where disturbance levels are such that they are not worth using, and birds will distribute themselves so as to maximise their food intake and minimise the risk.

4.6 This background is useful in understanding the implications of the results presented here. The densities of birds showed significant negative correlations with the amount of visitor activity, indicating that birds are already avoiding locations with higher levels of disturbance. The behavioural impacts of disturbance – birds taking flight etc. – are therefore occurring despite this redistribution.

4.7 There was no evidence that the most disturbance occurs on the sites with the highest numbers of visitors. While this may seem counter intuitive, it does match the results of some other studies (e.g. Ravenscroft *et al.* 2008). There are a number of potential factors which may account for these findings:

- The sites with high visitor numbers attract particular kinds of visitor, for example the promenade at Emsworth was the busiest site and the visitor numbers here were mostly walkers, whereas quieter sites had higher numbers of dog walkers with dogs off leads (see Map 4).

- People may behave differently at busy sites (for example dog walkers may keep their dogs on leads more).

- Busy sites may, due to the volume of people, have visitor infrastructure such as banks, formal paths etc. that result in people being separated or partially screened from the birds.
- Bird densities are lower at the busier sites, i.e. birds keep away.
- Birds may become habituated at busy sites

4.8 Habituation has been reported in some studies (e.g. Nisbet 2000; Walker, Dee Boersma, & Wingfield 2006; Baudains & Lloyd 2007) but is poorly understood (Sutherland 2007). While it is potentially appealing to believe that the potential impacts of increased visitor levels will be offset through the birds becoming habituated, there is no evidence from this work that this is necessarily the case and the issues are not straightforward. Disturbance levels will relate to the activities undertaken, where people go and the physical geography of the area that dictates how birds might use it.

Weather conditions and tide

4.9 The fieldwork encompassed a range of different sites where prey densities, bird densities and habitat type all varied. Over the course of the fieldwork weather conditions also varied markedly, with a period of intense and prolonged cold weather in January and February providing a marked contrast to milder weather in December.

4.10 The weather conditions during the prolonged period of intense cold weather in January/February included lying snow, ice and sub zero temperatures. This has important bearings for the work. Cold weather can result in particular stress for many species and mortality rates can be high (Clark et al. 1993; Le V. dit Durell et al. 2001). Such weather would be expected to result in birds behaving differently, as the cost of responding to disturbance is higher (as the birds have a need to eat more to keep warm and the conditions can make foraging difficult due to ice etc.). Such weather conditions can also result in considerable bird movements, and it might be expected that numbers of birds on the south coast would increase.

4.11 The distances and responses of the birds should therefore be interpreted in light of these circumstances, potentially suggesting that the distances and levels of disturbance could have been higher in a different winter.

4.12 The tide is an important factor determining availability of feeding sites for the birds and when they can feed. Survey visits were made at a range of tide heights and encompassed some spring and neap tides. It was however impossible to ensure all possible circumstances were incorporated within the survey work. The modelling will use the results to scale up to a Solent-wide scale and will include tidal coverage. The models will include (for each patch) information the amount of intertidal habitat exposed at a given point in the tidal cycle, and therefore will incorporate the full effects of variation in the tide.

Distance

4.13 We recorded the distances at which the potential disturbance events resulted in the birds becoming disturbed, or, if no change in behaviour was observed we recorded the closest distance between the birds and the source of potential disturbance. Such distances are difficult to record accurately, depending on the viewing angle, distance etc. We used a range of methods (laser range finders, direct pacing, scaled aerial photographs) to minimise observer error.

4.14 In most studies of disturbance the 'flight initiation distance' is determined through experiments, with observers directly approaching birds (Blumstein et al. 2003b; Blumstein 2003; Fernandez-Juricic et al. 2005b). This experimental approach provides robust measurements of distance and is used to compare species and determine set-back distances (Whitfield, Ruddock, & Bullman 2008). However a potential flaw with directly approaching birds is that recreational activities rarely involve people directly approaching birds. While photographers and birdwatchers may directly walk towards birds on the intertidal, in most cases visitor flows will be tangential to the birds, as people follow a seawall or coastal path. It is possible that people following such a tangential route will be less likely to cause disturbance, as birds may well perceive people as less of a threat (but this is not always the case; see Fernandez-Juricic *et al.* 2005b for discussion).

4.15 The advantage of the approach used here is that it ensures the responses of the birds can be directly related to the activities and actual behaviours taking place at the sites. It means that the modelling will be based on actual circumstances and data collected in the field.

4.16 Many authors define a definitive distance beyond which disturbance is assumed to have no effect and this is then used to determine set-back distances or similar visitor management measures (Rodgers & Smith 1995, 1997; Stalmaster & Kaiser 1997; Fernandez-Juricic, Jimenez, & Lucas 2001; Fernandez-Juricic, Vaca, & Schroeder 2004; Fernandez-Juricic *et al.* 2005). It is difficult and probably inappropriate to set such generic distances as responses to disturbance vary between species (Blumstein *et al.* 2005) and between individuals of the same species (Beale & Monaghan 2004a). Particular circumstances, such as habitat, flock size, cold weather or variations in food availability will also influence birds' abilities to respond to disturbance and hence the scale of the impact (Stillman *et al.* 2001; Rees, Bruce, & White 2005; Goss-Custard *et al.* 2006).

4.17 In this study the proportion of events resulting in disturbance declined gradually with distance (Figure 15 and Figure 16) such that it is not straightforward to define a consistent set-back distance at which disturbance would always be avoided. From Figure 15, Figure 16, and Figure 19 it is possible to identify that most disturbance events occur when people are within 100m of birds, yet even at distances well beyond 200m there were still some events that resulted in disturbance.

4.18 The distance data will be used within the bird models to calculate an effective area 'disturbed' by each activity type. This area will be similar to habitat loss, and the area of habitat and therefore amount of food potentially available at each location can be adjusted accordingly within the model.

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Appendices

Appendix 1

Table 12: Total numbers of birds recorded at each location. Data are summed from all counts at each site, i.e. 2 counts per visit (c.2 hours apart) made on 12 visits. We have treated dark-bellied brent goose (simply referred to as "brent goose") separately from light-bellied brent goose.

	Lymington	Calshot	Eling	Weston Shore	Hamble Spit	Hookwith Warsash Nature Reserve	Salterns Park	Alverbank East	Salterns Quay	Hilsea	Milton	Langstone	Hayling Billy Trail	Mengham	The Promenade, Emsworth	Southbourne/Prinsted	West Itchenor	Fishbourne	Newtown	Ryde	Total
Section no.	*4*	*12*	*18*	*24*	*26*	*32*	*34*	*37*	*44*	*48*	*53*	*58*	*61*	*64*	*69*	*72*	*75*	*82*	*89*	*100*	
Avocet																			1		1
Barnacle Goose			9																		9
Bar-tailed Godwit												61							2		63
Black-necked Grebe			1																		1
Black-tailed Godwit			306						4	39	2		4	2	8		17	395	9		786
Black-throated Diver				2																	2
Brent Goose	3373	151	117	157	241	101	3	79	166	753	1262	1478	3261	655	705	1380	1656	1350	1394	1298	19580
Canada Goose	6		138									1			28				17		190
Coot															1559						1559
Cormorant			9															18	1		28
Curlew	437	6	265	14	17	20			21	83	158	515	120	94	49	35	87	321	229	22	2493
Dunlin	65	406	7	20	813					28	3133	1756	313	445	1095	1196	1068	1244	4913		16502
Gadwall												51	2		143		1	6			203
Golden Plover																			1		1
Goldeneye									2			30			8			63	12		115
Great-crested Grebe	1	2	71	183	13	20	1	8	3	4		3			2		7	5		5	328
Great-northern Diver			5																		5

	Lymington	Calshot	Eling	Weston Shore	Hamble Spit	Hookwith Warsash Nature Reserve	Salterns Park	Alverbank East	Salterns Quay	Hilsea	Milton	Langstone	Hayling Billy Trail	Mengham	The Promenade, Emsworth	Southbourne/Prinsted	West Itchenor	Fishbourne	Newtown	Ryde	Total
Section no.	*4*	*12*	*18*	*24*	*26*	*32*	*34*	*37*	*44*	*48*	*53*	*58*	*61*	*64*	*69*	*72*	*75*	*82*	*89*	*100*	
Green Sandpiper												11						5			16
Greenshank												1			25			1			27
Grey Heron			1						1	5											7
Grey Plover	42	13	2	5	13	4	1				82	122	138	56	58	35	52	108	913		1644
Knot											4		4		2			4	789		803
Lapwing	9		38							236	24	25		9	432	32	171	756	261		1993
Light-bellied Brent Goose															1						1
Little Egret	18	1	1	3	1		2		4	9	3	22	8	1	4	4		4	18		103
Little Grebe	41		37						41	95		20		4	53			3	73		367
Little Stint																		5			5
Mallard				1					107	2		6			39		13		5		173
Moorhen	1								5						21						27
Mute Swan	14		25	2					23	2	6	3			151		6	53	32		317
Oystercatcher	128	113	742	288	328	311	262		20	5	458	1049	799	104	73	61	152	171	147	157	5368
Pintail																		352			352
Red-breasted Merganser										33	13	35	4	9	1		78	8	30		211
Redshank	157	1	177	12	6	6	11		49	350	122	495	102	223	113	169	81	536	69		2679
Ringed plover	3	74			1						58	94		84		21	4	21	92		452
Sanderling																				5	5
Shelduck	189		87							130	234	10	36	203	62	74	100	74	604		1803
Shoveler			4							46		79									129
Snipe	1		1												1		2				5

	Lymington	Calshot	Eling	Weston Shore	Hamble Spit	Hookwith Warsash Nature Reserve	Salterns Park	Alverbank East	Salterns Quay	Hilsea	Milton	Langstone	Hayling Billy Trail	Mengham	The Promenade, Emsworth	Southbourne/Prinsted	West Itchenor	Fishbourne	Newtown	Ryde	Total
Section no.	*4*	*12*	*18*	*24*	*26*	*32*	*34*	*37*	*44*	*48*	*53*	*58*	*61*	*64*	*69*	*72*	*75*	*82*	*89*	*100*	
Spotted Redshank															2			1			3
Teal	342		13						72	190				2	79		37	151	168		1054
Turnstone	9	89		53	147	23	174		2	51	32	171	4	76	19	57	23	28	4		962
Whimbrel	3																				3
Wigeon	819		1852				18		38			281			6		1	2702	24		5741
Total	**5658**	**856**	**3908**	**740**	**1580**	**485**	**472**	**87**	**558**	**2061**	**5591**	**6319**	**4795**	**1967**	**4739**	**3064**	**3556**	**8385**	**9808**	**1487**	**66518**

Appendix 2

Table 13: Total number of people observed undertaking different activities at different sites. "Other" includes a range of different events that could not be easily classified.

Section Number	4	12	18	24	26	32	34	37	44	48	53	58	61	64	69	72	75	82	89	100	
Location	Lymington	Calshot	Eling	Weston Shore	Hamble Spit	Warsash Nature	Salterns Park	Alverbank East	Salterns Quay	Hilsea	Milton	Langstone	Hayling Billy Trail	Mengham	The Promenade, Emsworth	Southbourne /Prinsted	West Itchenor	Fishbourne	Newtown	Ryde	total
Walker	0	47	29	78	125	131	517	480	65	260	131	27	66	45	840	230	163	83	60	133	3510
Dog walker with 1+ dog off lead	6	31	108	85	103	143	321	87	185	129	223	48	63	45	70	209	77	66	20	562	2581
Dog walker, all dogs on lead	3	8	10	18	5	1	67	93	27	72	32	6	0	4	174	49	1	0	9	35	614
Cyclist	0	0	12	13	9	18	10	20	7	281	46	6	89	1	11	6	16	0	0	1	546
Jogger	0	1	0	27	9	14	27	56	1	175	30	4	22	2	51	13	5	7	0	12	456
Small Sailing Boat	0	4	0	18	0	0	0	116	0	0	0	0	0	0	2	0	0	0	0	0	140
Birdwatcher	8	7	5	3	1	17	2	0	0	5	8	20	2	4	0	3	2	9	14	0	110
Small craft with motor	0	16	5	8	2	2	0	1	10	1	0	0	0	3	23	0	35	0	4	0	110
Kids Playing	0	12	6	4	3	0	29	19	2	0	0	8	0	0	0	2	0	0	0	23	108
Fishing	0	0	16	26	9	2	0	6	5	1	2	1	3	0	0	0	0	0	2	2	75
Large boat with outboard motor	0	0	2	2	6	5	0	0	1	0	0	0	0	0	0	0	16	0	20	0	52
Other	0	11	3	4	3	0	1	0	0	0	0	1	0	0	6	0	5	1	6	8	49
Bait Digging	0	0	0	6	10	1	3	1	1	2	3	12	0	0	0	0	0	0	0	0	39
Rowing Boat	7	0	0	0	0	0	0	0	2	0	0	2	0	0	2	0	16	0	0	0	29
Large Sailing Boat	0	5	0	0	0	0	0	0	6	0	0	0	0	0	0	0	1	0	12	0	24
Working on boat	0	0	0	0	0	0	0	0	2	1	0	0	0	0	3	1	17	0	0	0	24
Motor Vehicle	1	0	0	0	0	0	0	1	0	3	0	7	3	0	2	0	1	0	1	0	19
Canoe on water	0	6	0	2	0	0	1	2	2	0	0	0	0	2	0	0	3	0	0	0	18
Photographer	0	0	1	0	0	0	2	0	0	0	1	0	0	0	1	5	0	0	0	0	10
Surfer	0	4	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	8

Section Number	4	12	18	24	26	32	34	37	44	48	53	58	61	64	69	72	75	82	89	100	
Location	Lymington	Calshot	Eling	Weston Shore	Hamble Spit	Warsash Nature	Salterns Park	Alverbank East	Salterns Quay	Hilsea	Milton	Langstone	Hayling Billy Trail	Mengham	The Promenade, Emsworth	Southbourne /Prinsted	West Itchenor	Fishbourne	Newtown	Ryde	total
Still	0	2	0	2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	6
Horse Rider	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	5
Kite Surfer (beach)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
Kite Surfer on water	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Works/digger	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	4
Wheelchair/scooter	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	3
Windsurfer on water	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Motorbike	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Works/Diggers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Total	25	161	199	296	285	334	983	882	319	931	476	143	250	110	1188	518	358	166	148	783	8555

Appendix 3

Table 14: Summary data for response distances (in m) for all species, ranked according to overall sample size. Range gives the minimum and maximum distance for each response type and species. Count gives the sample size.

Species	No Response		Alert		Short walk/swim		Short flight		Major Flight		uncategorised	Total
	Range	Count	Range	Count	Range	Count	Range	Count	Range	Count	Count	
Brent Goose	17-215	681	23-150	45	18-125	46	75-100	11	5-178	32	1	816
Oystercatcher	38-200	455	25-150	22	25-80	24	10-50	9	10-200	97	4	611
Redshank	20-200	402	20-125	22	20-70	10	10-79	18	10-150	49	1	502
Curlew	40-200	240	25-200	21	60-90	3	60-75	3	30-150	32	1	300
Turnstone	16-200	183	20-75	8	21-50	4	5-100	13	14-80	36	1	245
Coot	5-170	232	14-14	1	10-20	4	10-10	1		0	0	238
Mute Swan	3-180	175	8-12	2		0		0	50-50	1	0	178
Grey Plover	22.5-200	126	75-125	2	30-35	3		0	40-120	7	0	138
Little Egret	40-200	115	30-125	6		0	40-200	5	30-150	11	0	137
Wigeon	45-200	86	30-125	8	20-100	11	59-100	3	50-100	8	0	116
Dunlin	29-200	90	50-100	2	25-25	1	25-112	5	35-300	13	0	111
Shelduck	80-200	93		0	65-140	4		0	50-100	5	0	102
Great-crested Grebe	30-200	89		0	50-50	1		0	100-100	2	1	93
Lapwing	30-180	74	125-125	1	23-23	1	70-70	1	18-125	11	0	88
Teal	20-175	77	100-200	2	35-40	2		0	50-75	4	0	85
Mallard	20-150	45	50-50	1	10-30	4		0	50-50	1	0	51
Ringed Plover	32-200	33	50-125	3		0	50-75	2	30-100	6	0	44
Black-tailed Godwit	36-175	31	125-125	1	40-40	1		0	30-150	2	1	36
Little Grebe	30-190	30	75-100	2	75-100	2		0		0	1	35
Red-breasted Merganser	80-180	21		0	20-20	1	50-50	1	30-150	11	0	34
Goldeneye	100-200	17	75-100	3	75-80	2	75-75	1	150-150	1	0	24
Canada Goose	50-200	12	125-125	2	25-70	2		0		0	0	16
Shoveler	100-150	8	30-150	2		0	50-100	2	15-15	1	0	13
Knot	34-150	9		0		0	51-51	1		0	0	10
Gadwall	69-140	7		0		0		0	50-60	2	0	9
Little Stint	100-150	6		0		0		0	100-100	1	0	7
Greenshank	64-66	3		0		0		0	40-40	2	0	5
Pintail	150-200	4		0		0		0	100-100	1	0	5
Sanderling		0		0		0	30-30	1	75-100	3	0	4
Great-northern Diver	20-20	1		0	50-50	1		0		0	0	2
Moorhen	40-40	1		0	20-20	1		0		0	0	2

Species	No Response		Alert		Short walk/swim		Short flight		Major Flight		uncategorised	Total
	Range	Count	Range	Count	Range	Count	Range	Count	Range	Count	Count	
Snipe	175-175	2		0		0		0		0	0	2
Black Brant	55-55	1		0		0		0		0	0	1
Black-necked Grebe		0		0		0	75-75	1		0	0	1
Eider	150-150	1		0		0		0		0	0	1
Light-bellied Brent Goose	50-50	1		0		0		0		0	0	1
Total		3351		156		128		78		340	11	4064