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Aerial surveys of waterbirds in the Wash, 2005/06

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Cover note

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From October 2006, English Nature, the Landscape, Access and Recreation division of the Countryside Agency and the environmental land management functions of the Rural Development Service have been brought together to form a new independent body - Natural England. This research report was completed by English Nature, but has been published by Natural England to complete the English Nature Report series.

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1 Introduction

Data on the numbers and distribution of waterbirds and seabirds in UK inshore waters are required for a variety of purposes, including 'condition monitoring' of European sites and also nationally important Sites of Special Scientific Interest.

English Nature (EN) has a responsibility to undertake and co-ordinate condition monitoring of sites such as the Wash, classified as a Special Protection Area because of its importance for wintering waterbirds and part of the EN Natura 2000 Network of important sites for wildlife.

It is acknowledged that there is an information gap on the use of the Wash by wintering seaducks and seabirds that is not covered by existing monitoring schemes and surveys. English Nature therefore commissioned WWT Consulting (formerly the WWT Wetlands Advisory Service) to undertake a baseline survey of the numbers and distribution of seaducks and seabirds wintering in the Wash.

This report presents results from aerial surveys of the Wash between November 2005 and March 2006, and summarises seaduck data collected by other surveys recent surveys of the site.

2 Methods

2.1 Aerial survey – 'distance sampling'

Aerial surveys used for this report were undertaken using a methodology recently developed in Denmark by the National Environment Research Institute (NERI) (Kahlert and others 2000; see also Camphuysen and others 2004). This involved a 'distance sampling' approach (see Buckland and others 2001), whereby the distance to each bird/flock of birds was recorded. Because birds further from the observer will be more difficult to detect, recording of distance allows the number of missed birds to be estimated. This approach allows statistical analyses of the data (eg confidence limits to be calculated for estimates of numbers). Further, using a combination of the time at which birds were encountered and the track flown by the plane (recorded using a Global Positioning System (GPS)), the locations of observed birds can be calculated with considerable accuracy (in most cases, to within a few hundred metres).

A series of transects spaced 2 kilometre apart was designed to cover nearshore waters. Ideal survey design is for transects to be orientated perpendicular to major environmental gradients (primarily sea depth). Transects that run north-south reduce the effect of glare during the survey and aid the detectability and identification of birds and, for ease of navigation and subsequent analysis, followed northings of the GB Ordnance Survey grid. Transects used in the Wash were created by an extension of those already in use for the 'Greater Wash' – an area off the North Norfolk and Lincolnshire coasts being surveyed for the strategic environmental assessment of proposed offshore windfarms (eg WWT Wetlands Advisory Service 2005); survey in the two areas was thus consistent and contiguous, enabling data to be pooled in future.

A Partenavia PN68 aircraft was used, flying at an altitude of 250 ft and at a speed of approximately 200 kilometreh^{-1}. The location of the plane was recorded every five seconds using a GPS.

Aerial surveys were undertaken by two experienced observers, both of whom have undertaken aerial surveys for at least seven years and, in particular, have considerable experience of counting large flocks of birds.

For each bird or flock of birds, the species, number, behaviour, distance band and the time at which it was perpendicular to the flight path of the plane were recorded using a dictaphone. Using a clinometer, birds were attributed to one of four distance bands covering an area from 44 m to 1,000 metres either the side of the plane (Figure i); birds beyond 1,000 metres from the flight path of the plane were not recorded. The survey method assumes that all birds in distance Band A were detected, and effort was concentrated on this band. Inevitably, birds further from the plane in other bands are missed owing to their distance from their plane and the need for the observers to concentrate observation on the area of sea nearest the flight line.

Surveys were generally made during a two-hour period centred on midday GMT to minimise the effects of glare on counts. Surveys were undertaken in good weather conditions, generally with winds of 15 knots or less.

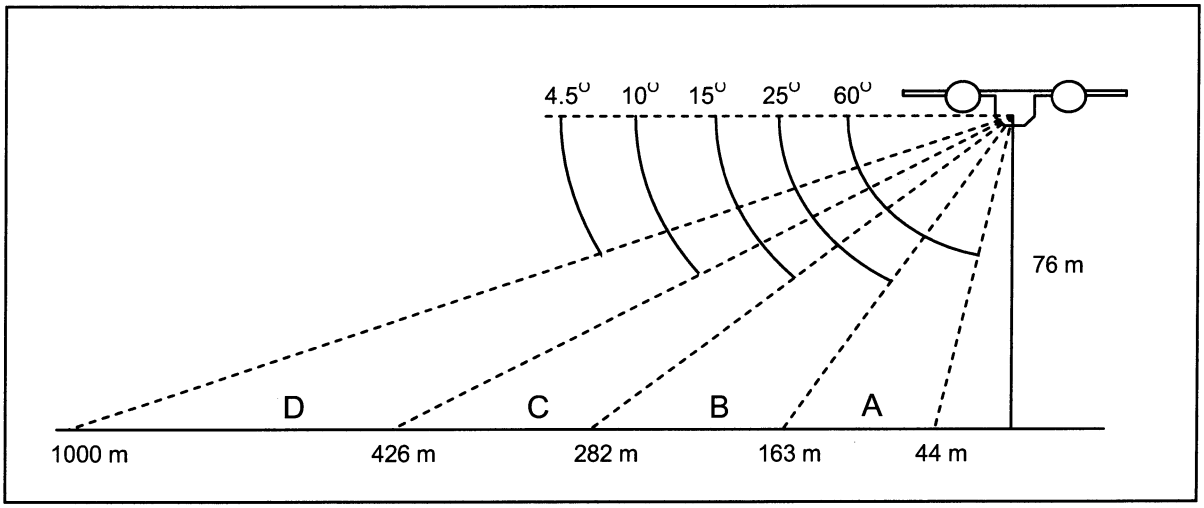

Figure i Distance bands used for aerial survey (not to scale).

Survey was suspended during the turns between the end of one transect and the start of the next. Significant observations, eg cetaceans or large flocks of birds, were sometimes recorded on an *ad hoc* basis. These records were not included in subsequent analyses or map production.

2.2 Aerial survey – 'total count'

Eiders, one of the key target species for this survey, often show clumped distributions, and many may occur relatively close to the water's edge, or even in channels that remain at low tide. Further, distribution is likely to vary to a lesser or greater extent at different times of the tidal cycle. The proclivity of eider to use nearshore areas may mean that any transect-based survey struggles to cover the full extent of distribution (since transects often have to be ended just short of the shoreline due to flying regulations). The clumped distribution of eiders may also limit the accuracy of any estimate of numbers using distance analysis.

Consequently, in addition to the transect survey, additional coverage of the shoreline and channels was undertaken on each flight. This aimed to locate and count any significant flocks of eiders in these areas. This survey was undertaken using the 'total count' method, whereby the plane flew parallel to the shore or along other features – adjusted according to the observed distribution of eider flocks – in an attempt for observers to count all birds present. As with the transect method, numbers, distance band and time of the observation were recorded to enable precise co-ordinates for the location of any birds to be determined.

Although this method precludes robust analysis of the data, this approach has been used successfully by WWT in the Firth of Forth in 1996/97 – where this approach recorded more eiders than land-based survey – and is often used in Scandinavian countries to survey common eiders *Somateria mollisima* and king eiders *Somateria spectabilis*. Eiders are particularly robust to the presence of plane and rarely flush or move position even if overflown at heights of 100 feet (PA Cranswick pers obs).

2.3 Species identification

A cautionary approach was taken with regard to species identification, such that only those individuals that were observed clearly were identified to species level; otherwise, birds were identified as being in a species group, eg diver (*Gavia* spp.). Such groups are regularly used during aerial survey for gulls: 'grey gull' (common gull *Larus canus* or herring gull *Larus argentatus*), 'black-backed gull' (lesser black-backed gull *Larus fuscus* or great black-backed gull *Larus marinus*), large gull (herring gull, lesser black-backed gull or great black-backed gull), small gull (black-headed gull *Larus ribidundus*, common gull, little gull *Larus minutus* or kittiwake *Rissa tridactyla*) or gull (*Larus* spp. or Kittiwake); and for waders: 'large wader' (curlews, godwits), 'medium waders' (eg *Pluvialis* spp. redshank *Tringa totanus*, knot *Calidris canutus*), and 'small waders' (most *Calidrid* spp.), while mixed flocks may often be recorded simply as 'waders' owing to time constraints to record observations when encountering large numbers of birds over extended periods. Many divers and gulls can be identified to species, but auks and smaller waders are difficult to distinguish except using binoculars under good conditions.

Scoters at large distances are not easily identifiable as common scoter *Melanitta nigra*, are indistinguishable from velvet scoter *Melanitta fusca* at that range, particularly within mixed flocks. The vast majority of birds in Bands A and B can, however, be identified to species – and any velvet scoter in flight in Band C would be readily distinguished. As only very small numbers of velvet scoters were recorded during aerial surveys, it has been assumed that the vast majority of scoters present were common scoters.

Previous aerial surveys around English and Welsh coasts have shown the vast majority of diver species (*Gavia* spp.) identified to be red-throated divers *Gavia stellata* (eg WWT Wetlands Advisory Service 2005). Considerable caution is exercised given the possibility of confusion with black-throated diver *Gavia arctica* and the inexperience of the observers with observations of this species from the air. Great northern divers *Gavia immer* are readily separated from both red-throated and black-throated divers and few will have been overlooked within those birds recorded as 'diver spp.'.

2.4 Survey area

The extent of the survey area within the Wash covered the marine and intertidal area up to the Mean High Water Mark (MHWM), or as close as possible as is permissible under Civil Aviation Authority low-level flying exemptions (transects often have to end about one kilometre from MHWM to avoid overflying people or buildings during turns between transects); transects were, however, stopped several kilometres from the shore around Gibraltar Point, to avoid entering the restricted flying zone there for birds. The seaward boundary of the survey area was contiguous with the survey areas being used for offshore windfarm strategic assessment surveys (Figure 1). The intended waypoints and routes used for the transect survey are shown in Figure 2. Reference to locations within the Wash made in this report for convenience follows the names of count areas used by the Wetland Bird Survey (WeBS) (Figure 3).

2.5 Map production

The precise location of each bird or flock of birds was calculated by linking the time (to the nearest second) at which they were recorded to the location of the plane, recorded by the GPS

(generally, every five seconds). Interpolation of the GPS data enabled the position of the plane to be located along the flight path at each second. The locations of birds detected were displaced either side of the flight path at a distance roughly in the middle of the distance band in which they were recorded. The location of most observations is consequently considered to be accurate to within 200-300 metres.

The distribution of the more numerous species (or species groups) is shown using encounter rate, ie the numbers of birds counted per unit length of transect flown. Data are summarised by 2 x 2 kilometre grid squares, corrected for survey effort (distance flown over which observers were actively looking for birds) in each cell. Casual observations of 'out of transect birds' (eg those recorded while the plane was turning between transects) were omitted from this analysis.

The density scales used in the maps were selected to illustrate the distribution patterns of encounter rates. They are broadly consistent between surveys but small variations will occur owing to the different conditions of visibility during and between surveys, and the different abilities of observers. Densities are not, however, comparable between species due to the different detectability of different species. Note that the range of relative density values may vary markedly between species, and reference should be made to the key in each figure to interpret apparently high concentrations of birds appropriately.

2.6 Analytical methods for assessment of numbers

Estimates of waterbird numbers were derived using 'Distance 5.0' software (Thomas and others 2005). This software permits seabird density estimates (and hence population estimates) to be calculated from the aerial survey. For each survey and bird species (or species grouping) the best-fit function describing the pattern of observations was identified, leading to the use of a mixture of line and strip transects. Distance analysis methods work best for target species which are evenly distributed within a survey area, while density estimates for species which aggregate (eg birds in large flocks) tend to be bounded by wide confidence intervals. While steps were taken to minimise this effect and improve precision (including post-stratification by flock size, and exclusion of observations from Band D and in some cases C), these measures can only improve precision to a limited extent. Thus, the confidence intervals for the final population estimates remained wide. The variance estimates reported were obtained analytically, although very similar results were obtained from bootstrap simulations.

2.7 Historical data on seaduck use of the Wash

A review of relevant literature was undertaken to assess numbers of seaducks, seabirds and divers in the Wash. Recent Wetland Bird Survey (WeBS) data (see Collier and others 2005) were also assessed to determine numbers and distribution of seaducks and divers in the survey area.

3 Results

3.1 Aerial survey 2005/06

3.1.1 Coverage

Two extensive military danger areas in the Wash are active during weekdays, at which time they are closed to civilian air traffic. Surveys were thus conducted at weekends. Surveys were made once a month from November 2005 to March 2006, on 27 November, 10 December, 15 January, 11 February and 11 March.

Although the precise routes followed differed slightly between months, largely due to the accuracy with which it is possible to fly the plane, there were no significant differences and all of the intended transects were completed successfully in each month.

The flight path used for the 'total count' survey followed the shoreline, usually within 200-400 metres of the water's edge. Consequently, the precise path for this part of the survey differed between months according to the tidal state at the time of the survey (see Figures 4 & 5).

No significant numbers of the key target species – eiders, common scoter or divers – were recorded during the 'total count' that had not already been located during the 'transect survey'. Consequently, 'total count' data are not considered further and the results, analysis, maps and discussion refer only to the data collected during the 'transect survey'.

3.1.2 Overall numbers and distribution

The total numbers of birds encountered during aerial surveys of the Wash in 2005/06 are given in Table 1 (Note these do not represent absolute numbers of birds in the survey area, which need to be calculated using 'distance', to allow for the numbers of birds that are missed with increasing distance from the transect line). Between 13,500 and 27,000 waterbirds and seabirds were counted in each month between November and March.

Large numbers of observations (one bird, and one flock of birds, are both treated as single observations) were made during surveys in Wash during the course of 2005/06 (Figure 6). Note that the apparent distribution of waterbirds in lines along the transect paths is an artefact of the increasing difficulty of observing birds in the outer distance Bands (C and D); most observations are made in the inner Bands (A and B).

The majority of observations relates to the very large numbers of waterbirds, particularly ducks, waders and gulls, particularly along the southern and western shores. Waders and gulls were found primarily over the intertidal habitat, and many of the duck species on the water, but close to the water's edge. Consequently, the numbers and distribution of observations was closely related to the extent of intertidal habitats exposed at the time of the survey, with obvious variation during the course of the winter (Figures 7-16).

In many cases, waders and gulls were encountered on exposed mudflats and sandflats within relatively short distances (c 1 kilometre) of the water's edge; often, when considerable intertidal areas were exposed, there were few waterbirds directly below the MHWM. Such patterns are notable along the western shore in January, February and March (Figures 11, 14

& 15), although it is obscured to an extent in these figures since each observation (whether or one individual or a flock of 300) is represented by a single dot.

Relatively high numbers of observations were made over areas of water in midwinter months, roughly in the centre of the Wash. It should be noted again, however, that in many cases these observations related to individuals or small groups of birds, and the actual numbers of birds in most cases will have been much lower than those found over intertidal areas.

Notable concentrations in marine areas were found near the coast off Heacham to Hunstanton in the first half of the winter, and, on the west coast, patchily between Butterwick and Friskney during much of the winter, though particularly in the second half. These concentrations related primarily to flocks of eiders and common scoters.

Large numbers of birds were often located just before the end of transects when over land, usually comprising mixed flocks of brent geese *Branta bernicla*, shelducks *Tadorna tadorna* and curlews *Numenius arquata*.

3.1.3 Eider

Surveys consistently recorded around 1000 eiders throughout the winter during aerial survey, with the exception of a peak of over 2300 birds in January (Table 1).

Eiders were mainly found in the west of the Wash throughout the winter, though the precise location changed as the winter progressed, becoming more restricted in February and March (Figures 17-21). In early winter, eiders were spread over a larger area, occupying 13 2x2 kilometre grid cells, falling to 11 in December and January, and by February and March they occupied only six and four cells, respectively (Figures 22-26); in each month, high densities were found in only a small number of cells. Large numbers were found adjacent to the Freiston/Butterwick area in all months (though perhaps slightly north of there in March). There appears to have been a northerly shift during winter, eiders being found in a broad area from Freiston to Terrington at the start of the winter, later moving to between Freiston to Friskney, often then found almost exclusively in two discrete areas.

Most eiders were found in just three or four large flocks during each survey. In nearly all cases, these were relatively close to shore, judged to be within 500-1000 metres of the water's edge, though some flocks were within just 100 metres.

Numbers of eiders calculated to be present in the Wash using 'Distance 5.0' were between two and five times greater than actual counts, suggesting a minimum of approximately 2400 birds in December and a maximum of 8800 in January (Table 2). In all cases, confidence intervals were large, the upper 95% interval being 22,400 in January, and exceeding 15,000 in November and 20,000 in March. Such figures are clearly a considerable overestimate of the true numbers present, and should be treated with caution (see Discussion).

3.1.4 Common Scoter

The numbers of common scoters encountered in the Wash varied through the winter. Counted numbers increased from around 1300 in early winter to around 2300 in mid winter, then declined again to around 1300 in March; virtually no birds were recorded in January, however (Table 1).

As with eiders, scoters were found in large concentrations in discrete areas in the Wash (Figures 27-31). In early winter, common scoters were found mainly off Heacham to Hunstanton, about 3-4 kilometre offshore. In February and March the distribution had shifted to a small area adjacent to Leverton and Wrangle.

Distribution was even more restricted than that of eiders, and nearly all birds were found in a small number (usually just two or three) of large and often very dense flocks, resulting in high densities in just a few 2x2 grid cells (Figures 32-36). In the latter half of the winter, the flocks were found close to the western shore, though usually slightly further offshore from the water's edge (estimated to be 750-1500 m) than eiders.

Estimated numbers of scoters calculated using 'Distance 5.0' were – excluding the low count in January – generally four times higher than actual counts, varying between 2750 and 9650 (Table 2). The confidence intervals are, however, extremely high (eg in March, suggesting an upper 95% interval of 36,500). These estimates and large intervals result from the extremely clumped nature of the encountered distribution, and it is believed that the numbers counted directly from the plane (rather than those calculated using 'Distance 5.0') should be used in any assessments for the Wash (see Discussion).

3.1.5 Divers

The number of divers (red-throated, black-throated, great northern and those not identified to species) counted varied throughout the winter, though with no obvious pattern: a peak of 50 was recorded in November and a low count of eight in December (Table 1, Table 3).
The distribution of divers in the Wash showed no obvious pattern between months. All surveys found some divers just offshore from exposed intertidal sand banks, especially in November and January (Figures 37-41). During the course of the winter, divers were found throughout most of the marine areas of the Wash. Although the lowest count co-incided with the highest tide, there was no obvious link between tidal state and diver numbers: the highest count co-incided with the second highest tide.

Estimated numbers of divers (all species combined) calculated using 'Distance 5.0' were generally four times higher than numbers counted, although that for February was ten times higher than the count. Confidence intervals were much smaller than those for the seaducks, the upper interval generally around twice the estimate. Estimated numbers varied between 38 in December and 233 in November (Table 2).

3.1.6 Shelduck

Numbers of shelducks in the Wash recorded by aerial surveys showed an obvious increase from a low of around 700 in November to a midwinter peak of almost 2000, before declining again to around 1000 in March (Table 1). Estimates of shelduck numbers calculated using 'Distance 5.0' were generally three to four times the counted totals, ranging between 1550 and 7150.

These figures are, however, likely to be underestimates as many shelducks were encountered at the start or end of transects; some will therefore have been missed beyond the end of transects, when the plane was turning. Although some birds were observed over intertidal habitat near the water's edge, many shelducks were consistently found nearer the MHWM, irrespective of the state of tide (Figures 42-46). Shelducks were most often encountered on or near extensive areas of saltmarsh, and largest numbers were therefore observed along the

southern shore and in the south-eastern and south-western corners of the Wash. The extent of this distribution remained reasonably consistent across all months, despite the variation in total numbers.

3.1.7 *Anas* duck species

Large numbers of dabbling ducks (*Anas* spp) were observed during the aerial survey. Many wigeons *Anas penelope*, mallards *Anas platyrhynchos* and teals *Anas crecca* were identified, along with smaller numbers of pintails *Anas acuta*. Many sizeable flocks of ducks were also observed that could not be readily identified to species – or were mixed flocks where time prevented accurate counts and recording of individual species onto the dictaphone. Such flocks were often observed close to the water's edge, and it is believed that these comprised almost entirely the above species – shelducks and seaducks (eiders and scoters) are readily separated by size, and also by flock shape and location, and no appreciable numbers of other duck species were recorded during the five surveys (Table 1). Consequently, those birds recorded as 'duck spp' have been treated and combined with other *Anas* spp to give total numbers for this group (Table 3).

Numbers of *Anas* ducks increased from fewer than 200 in November to a midwinter peak of 1250 in January, falling again to 130 in March. Although distribution varied somewhat between months (Figures 47-51), most were found in the southern half of the Wash. Although many were relatively close to the MHWM, most *Anas* species were encountered in both large and small channels in the mudflats. Large numbers of *Anas* were noted during the 'total count' flights, when they were usually encountered as long linear flocks in the water, normally within 50-100 metres of the water's edge, particularly along the southern shore, although *Anas* were not formally recorded during the 'total count'.

3.1.8 Waders

Large numbers of waders were counted in the Wash, varying between 5700 and 16,800 over the five surveys, though with no discernable seasonal pattern or link to tidal state (Table 1, Table 3). Numbers estimated by 'Distance 5.0' ranged between 21,500 and 65,000 waders.

Oystercatchers *Haematopus ostralegus* were by far the most numerous species recoded, with 1900 to 3100 counted in each month, although this partly reflects the ease of their identification from the plane; large numbers of small *Calidrids* – judged probably to be dunlin *Calidris alpina*– were also recorded, but only rarely could be identified to species with confidence. Increasing numbers of bar-tailed godwits *Limosa lapponica* were recorded towards the end of survey period, although this reflects increasing confidence of the observers to identify this species during aerial surveys.

The distribution of waders in the Wash was, as expected, clearly linked to the extent of intertidal habitat at the time of the survey (Figures 52-56). Most birds, particularly flocks of oystercatchers and *Calidrids*, were located relatively close (within 2000 m) of the water's edge. Many curlews were found near the MHWM on the south shore, often on saltmarsh.

3.1.9 Gulls

Numbers of gulls (black-headed gull, common gull, lesser black-backed gull, herring gull and greater black-backed gull, plus those not identified to species) in the Wash varied greatly between months (Table 1, Table 3). Numbers appear to be linked to the tidal state during

survey – most gulls were encountered loafing on exposed intertidal areas – and very few birds were found, for example, in December, when the survey was conducted near high tide. Highest densities of gulls were distributed on exposed intertidal areas, though low densities were also recorded over much of the marine areas, representing birds flying between feeding or loafing areas (Figures 57-61). In March there was a particularly strong relationship between exposed intertidal areas and gull distribution.

3.2 Data from previous surveys

3.2.1 Data sources

A literature review of historical data on seaducks and divers in the Wash was conducted. A complete list of literature and data sources investigated is given in Table 4. Four main data sources were available:

Wetland Bird Survey (WeBS) WeBS counts are made on a monthly basis at important UK wetlands. Surveys involve counting all waterbird species within a predefined area. The Wash is divided into 22 sectors for WeBS, all of which are counted synchronously by different observers on the same date to provide a complete count of waterbirds. For each species the accuracy of count is recorded, in effect noting if large numbers were thought to have been missed during the count. WeBS data from the winters 1994/95 to 2004/05 inclusive were analysed to assess total numbers, distribution and trends in seaduck numbers.

County Bird Reports Data were obtained from the systematic lists of the Norfolk (1994-2004) and Lincolnshire (1994-1996) County Bird Reports (CBRs). These document significant records provided by local observers. As such, these observers often have good knowledge of the best vantage points and are not constrained by the need to count on particular dates for the sake of survey co-ordination. Such counts are, however, usually from individual counting positions, providing incomplete coverage of the whole Wash. Further, they are not regular counts, and reports simply document *ad hoc* records if significant numbers of a species are seen.

Low tide counts from specific surveys Low tide surveys of the Wash have been undertaken as part of ecological studies during the winters of 1985-87, 1989/90, 1990/91 and 1991/92 (Goss-Custard & Yates 1988, Yates & Goss-Custard 1991, Yates and others 1996), and as part of a monitoring study for an outfall licence in the Great Ouse (Yates pers comm). None of these surveys, however, covered seaducks.

Low tide surveys were carried out in the winter of 2002/03 to assess waterbird numbers and distribution in the Wash Special Protection Area, and did include counts of eider and scoter (Yates *et al* 2004). Surveyors walked along coastal flats within two hours of spring low tide, recording the number and location of any wildfowl or waders seen. Offshore banks were accessed by boats within one-and-a-half hours of low tide. Areas of saltmarsh were not covered. The survey covered the whole intertidal area between the River Steeping and Holme-next-the-Sea. Survey was undertaken by just two or three observers, and took 25 days over seven weeks.

The Central Science Laboratory (CSL) conducted surveys of eiders in the Wash from October 2005 to March 2006 as part of a small-scale trial of the effectiveness of non-lethal scaring devices protecting commercial mussel beds. Eiders were surveyed from the shore of tidal

flats at low water and from rigid inflatable boats at high water. The survey area consisted of three mussel lays and their adjacent waters, located on the Roger, Toft and Gat Sands – offshore from Butterwick to Dawsmere – within the south western part of the Wash.

Aerial and boat-based surveys The Joint Nature Conservation Committee conducted some sample aerial and boat based surveys in the Wash in 1984, 1989 and 1992. These surveys were only trials of limited extent. These surveys used single observers and recorded all seabirds in 180 metre wide strip transects over open water. Seaducks were only observed during sample inshore and offshore aerial surveys in March and November 1989: in March, 300 common scoters, 20 velvet scoters and four eiders were counted in an area surveyed of 6.26 kilometre^2; in November, 40 eiders were counted in an area surveyed of 6.54 kilometre^2 (JNCC pers comm). These were only sample surveys and of limited extent and have not been discussed further in this report.

3.2.2 Eider numbers and distribution

Numbers of Eiders in the Wash recorded by WeBS during 1994/95 to 2004/05 showed marked variation between years (Figure 62). The peak count during the period was 2546 birds, in January 2003, while counts exceeding 1500 were also recorded in 1995/96, 1996/97 and 2001/02. In 1994/95, 1998/99 and 2004/05, however, total counts did not surpass 300 birds.

Count totals were highest in the winter period (September to March) in over half the years, with peak numbers generally occurring in late winter (January/February), although large numbers were also found in April in some years.

Eiders were distributed throughout the Wash, with small numbers regularly recorded in most count sectors. The largest counts have generally been made off Snettisham, and from Bennington to Wrangle (Figure 64). Numbers were, however, sporadic, and matched the overall pattern for the Wash. Large numbers in many sectors were recorded in 1995/96 and 1996/97, and then again during 2000/01 to 2002/03. Following the peak counts off Snettisham in 1996/97, however, the average count did not exceed 11 birds in subsequent years. Few sectors held mean counts of more than 100 in any one year, although peaks of around 500, and exceptionally 1500, were recorded in just under half the sectors.

CBRs generally reported smaller numbers of eiders than WeBS (Table 5). From 1997, however, counts of eiders off Hunstanton were generally higher than WeBS data from the corresponding sector. The largest count from CBRs was off Snettisham in 1996, the only count of 1000 or more birds.

Low tide counts in 2002/03 recorded a total of 1736 eiders, mainly located along the west side of the Wash, especially off Friskney Flats to Wrangle Flats (counted between 17 November and 2 December). The majority of these birds (1700) were recorded close to shore, with only 36 on outer sandbanks. This count recorded more eiders than the corresponding WeBS count (1125) (Yates and others 2004).

CSL surveys in 2005/06 regularly recorded counts of 2,500 eiders in the western part of the Wash. Numbers generally increased through the winter, from 541 in October, climbing sharply in late December and peaking at 3224 in February. Numbers stayed around 3000 into March. There was, however, a high degree of variation in numbers between surveys,

although there was no obvious link to tidal state: the number recorded at both high and low tidal states varied greatly. There appeared to be a movement towards the inshore sandbank from January onwards, perhaps as a result of mussels being harvested from the outer bank in January (Hart & Brown 2006).

3.2.3 Common Scoter numbers and distribution

Large peak counts of scoters were recorded by WeBS – 2000 in April 1996 and 2650 in January 2001, the highest WeBS count to date. Counts are, however, very sporadic and peak counts were below 500 in nine of the last 11 years, and no birds were recorded in nearly half the monthly counts over that period (Figure 63). The timing of the peak count varied between years and was not always during winter. In three of the past 11 years, the peak count occurred in July.

The majority of birds were recorded off Heacham to Hunstanton, with smaller numbers off Leverton and off Terrington East (Figure 67). There is no obvious link between numbers in different sectors: large numbers off Hunstanton do not coincide with larger numbers in the other sectors. In only eight of the 19 sectors where scoters have been recorded do average monthly WeBS counts exceeded ten birds in the last 11 years. Common scoter distribution in the Wash is highly localised.

County Bird Reports regularly recorded higher numbers of scoter than WeBS counts, from just one location rather than the whole of the Wash. The majority of the high counts were made at Hunstanton, a well-known site for seaducks. Between 2000 and 4000 were recorded in most years from 1995/96 to 2000/01. Notably, the majority of the large counts were made in early spring (March or April).

Surveys using low tide counts have recorded very low numbers of scoter. Just 23 were found in 2002/03, all recorded on the inner banks along the west of the Wash. This compares to a total of 199 scoters during the corresponding WeBS count; the difference is attributable to these species not using the exposed intertidal areas, as only exposed areas or immediately adjacent waters were surveyed (Yates and others 2004).

4 Conclusions/discussion

4.1 Survey efficacy and data interpretation

When comparing data collected from different survey techniques it is important to understand the efficacy of each technique, their limitations and thus the comparability of different data sources. Surveying birds that occur in offshore habitats presents several problems. Land-based counts give accurate counts of birds seen, but are limited in seaward extent, in most terrains up to about three kilometre offshore, and are thus unlikely to give an accurate assessment of total numbers unless all birds are positioned close to shore. Boat surveys also give good count accuracy, but in very shallow water coverage may be limited by the draught of the boat, particularly since a minimum height above the water is ideally required to conform to international standards for boat-based surveys. Aerial surveys are not limited by water depth but the speed of the aircraft inevitably limits the count accuracy of large flocks.

The accuracy of seaduck counts from land is also affected by suitable viewing conditions, particularly sea state (even small swell can hamper visibility at moderate distances). WeBS counts are made on pre-determined dates, to ensure co-ordination at site and regional levels, and are timed to coincide with favourable tidal rather than weather conditions. Further, the need to record large numbers of waterbirds using high tide roosts often precludes the time needed to make the lengthy scans of the sea needed to record seaduck numbers accurately (Cranswick and others 2005). WeBS counts thus provide co-ordinated survey of the whole Wash, but limited count quality of marine species (seaducks and divers) due to the above constraints. Data collected by aerial survey in 2005/06 show that large numbers of eiders and scoters occur at least three kilometres from the MHWM. Particularly on the southern and western shores, where the low elevation limits suitable vantage points, WeBS data are likely to underestimate numbers of these species.

The *ad hoc* counts reported in County Bird Reports are not limited by tidal state, or the need to count several species at once. Dedicated counts of seaducks from well-known sites, such as the cliffs at Hunstanton, are likely to provide better counts than WeBS data for those locations, but limited or no coverage of other areas – although likely to hold smaller numbers – prevent an assessment of the total numbers in the Wash. Further, as *ad hoc* counts, they are not part of a regular monthly monitoring programme and may be of limited value in describing trends and patterns, not least because smaller counts are less likely to be reported.

Low tide counts on the Wash in 2002/03 concentrated on species utilising exposed sandbanks. Scoter, divers and eiders rarely use such habitat. Practicalities also meant the whole of the Wash area could not be surveyed simultaneously; the whole area was covered in 25 days over a seven-week period. Non-simultaneous coverage increases the risk of double-counting or missing birds. It is therefore impossible to know with confidence if birds counted in each survey area were different, or where the same birds had moved between the different survey dates. Further, low tide counts made on foot would give little elevation and therefore poor offshore coverage.

Surveys conducted by CSL in 2005/06 were designed specifically to look at eider numbers and distribution (Hart & Brown 2006). As both land-based and boat surveys were conducted, centred on known feeding areas, it is likely that the data collected will be an accurate reflection of numbers present. The survey area was, however, limited to the small study area so these results provide only partial coverage of the Wash.

Aerial surveys adopt a sampling approach, using transects spaced (usually) two kilometres apart. This also avoids birds disturbed by the survey aircraft being double-counted in adjacent transects. Because of the distance to the outer limit of the survey area from the observer (1 kilometre), and the speed of the plane, the accuracy of counts of large flocks is reduced compared with other methods, species identification is not always possible, and a proportion of birds is missed. Total numbers present are thus calculated, for example, using 'distance analysis'.

Aerial surveys have traditionally been used for species which occur at relatively low densities, as in marine areas; few surveys have been made of areas with the numbers and diversity of species that occur on the intertidal areas of the Wash. The focus of surveys in 2005/06 was targeted at the marine species, particularly seaducks, divers and seabirds, but the opportunity was also taken to attempt surveys of other waterbird species throughout the survey area, including those using the exposed intertidal habitats.

The formation of large flocks is a characteristic of wintering waterbirds, particularly seaducks. Unfortunately, this feature of their ecology, while apparently lending itself to the collection of population data, reduces the suitability of the data for distance analysis (Buckland and others 2001). Although techniques were used to improve precision, these can only provide a limited improvement and generally the estimates remain bounded by wide confidence intervals. This is most apparent for common scoter estimates, which were generally present in a handful of large flocks. More robust population estimates were obtained for the other species/groups, with waders offering the smallest variances. Despite these short-comings, population estimates derived from distance analysis of aerial survey data are currently the best available method for monitoring large marine regions, in particular for areas such as the Wash which comprise an ever-changing matrix of land and sea.

4.2 Waterbird numbers and distribution

4.2.1 Overall numbers of waterbirds

Counted totals of waterbirds from aerial surveys were characterized by large numbers of wader and gull species, concentrated mostly on exposed intertidal areas which provide feeding and loafing habitat. Moderate numbers of common scoters and eiders were found in high densities in shallow water, usually forming discrete, large flocks with a limited and localised distribution.

Total numbers of waterbirds and seabirds fluctuated considerably between months, mainly due to variation in wader and gull numbers. One of the major factors determining bird distribution was tidal state, affecting feeding and loafing areas for many species, both intertidal and submerged shellfish beds.

4.2.2 Eider

In Britain, eiders breed widely around much of the Scottish coast and south to Northumberland on the east English coast and to Morecambe Bay on the west. Birds are slightly more widespread in winter, though the majority remains close to the breeding areas. The Wash is the most important site for eiders in Britain south of these northern strongholds (Collier and others 2005).

Numbers of eiders counted in the Wash in 2005/06 were fairly consistent between months with the exception of January when numbers doubled. Eiders generally formed large flocks in relatively few areas.

The results of distance analysis suggested much larger totals of eiders in the Wash than the actual counts from the aerial survey. The confidence intervals for these estimates were, however, extremely large, a consequence of the observed birds occurring in a small number of large flocks. Such flocks are relatively easily observed, even at great distances from the plane, and it is felt unlikely that any large flocks were missed during the transect survey. This is corroborated by the 'total count' flight, which found no additional birds. Although the total count survey covered only part of the Wash – a 1-1.5 kilometre strip of water adjacent to the water's edge – all large flocks of eiders encountered were observed in this area, and it is felt that no significant flocks would have occurred in the offshore areas. Consequently, it is recommended that the actual count totals from the aerial survey are used as the best estimate of the total numbers in the Wash. These are likely to be underestimates to a degree, not least because birds cannot be observed in an 80 metre strip directly below the plane – and the accuracy of counts of large flocks is likely to be low owing to the limited time for making a count; counts by CSL confirm that the actual counts obtained during aerial surveys are undercounts to a degree. Aerial survey data are, however, considered to provide a reasonable representation of eider numbers and distribution within the survey area.

Despite the problems of land-based counts of seaducks, WeBS data suggest numbers of eiders in the Wash vary greatly from year to year. Large counts in this period occurred in 1995/96, 1996/97, and in 2000/01, all relatively cold winters (eg see Figure 1 in Cranswick and others 2005). Under such conditions, it is likely that eiders in southeast England are part of an influx from Belgian and Dutch waters, particularly from the Waddensea, and relatively large numbers may continue to occur for a number of following winters as a wintering 'tradition' is established. Peak numbers of eiders recorded by WeBS in the Wash had shown a steady increase from around 250 in the late 1990s to just over 2500 in 2002/03, but numbers fell the following winter, and there was a virtual absence during 2004/05. Numbers of eiders recorded in 2005/06 were at the upper end of the normal range of variation for the last ten winters. The mean peak count for the last five winters easily exceeds the 1% threshold of 750 for Britain (Kershaw & Cranswick 2003), meaning that the Wash qualifies as nationally important for eider.

The distribution of eiders within the Wash in 2005/06 broadly reflected that of the previous five winters, with largest numbers off the southern and central parts of the western shore. Changes in distribution recorded by aerial surveys during the 2005/06 winter appeared to reflect seasonal movements, rather than a tidal relationship. The movement of eider northwards and westwards through the winter, to produce high densities of birds over a small area, may be due to 'feeding out' of other areas in the Wash. By February and March, their location was relatively close to the commercial mussel lays (Figure 68). The mussels had begun to be harvested by 2-15 March (Hart & Brown 2006) and, with the aerial survey conducted on the 11th, it may be that eiders were feeding on dislodged mussels left by the harvesting process.

Eiders were not recorded over all mussel beds in the Wash. A survey of mussel beds in the intertidal area of the Wash by the Eastern Sea Fisheries Joint Committee in 2005 showed several mussel beds off Welland, Holbeach and Dawsmere, areas where few or no eiders were recorded during aerial surveys. This may be due to several factors, including unsuitable prey

size or density for maximum profitability to eider, limited access to the beds for eiders, for example, as a result of tidal state, disturbance from humans, or other bird species (eg kleptoparasitism by gulls).

The CSL survey in 2005/06 found eiders in their study area were feeding at low tide. During high tide, the birds floated on the water and aggregated into large rafts close to but not over the feeding areas, especially in the Freeman Channel, North of Roger Toft sands. No obvious tidal variation could be determine from aerial survey data, although more data points would be required to separate tidal effects from the seasonal variation observed.

It should be noted that all aerial surveys were conducted at weekends. Human pressures on wetlands – particularly increased recreational disturbance on reservoirs and gravel pits – may affect bird distribution at this time. It is unlikely that such activities will influence waterbird distribution on a relatively large site such as the Wash with relatively few access points for the public. It might be speculated, however, that military activity (low flights and bombing runs by jet aircraft within the danger areas) may cause significant disturbance in parts of the Wash. Many birds, however, may become habituated to regular activity, even if extreme (eg waterbirds and seaducks show no obvious reaction to the presence of regular military aircraft traffic in St Andrews Bay, Fife; PA Cranswick pers obs), and it is currently unknown if such factors influence seaduck distribution within the Wash.

4.2.3 Common Scoter

As with eiders, scoters observed during aerial survey in the Wash in 2005/06 tended to form very tight, dense flocks, with the majority of birds recorded in just one area in any one month. Such distribution confounds the production of estimates using distance analysis and confidence intervals are correspondingly large. As with eider, it is felt that the actual counts obtained during aerial survey are reasonably representative of the total in the Wash and these figures should be used in preference to those obtained using distance analysis.

Numbers of common scoters recorded in the Wash by aerial survey varied greatly between months. The general pattern of increase between late autumn and early winter, then decline again in spring, is typical of scoter numbers at many British sites. The large drop in numbers during January is noteworthy. It is felt unlikely that the birds were missed within the Wash itself in that month and it is speculated that the flock – which moved from the favoured site of Hunstanton prior to that month to the western shore thereafter – moved out of the study area altogether in January. Large flocks are regularly found just outside the study area, off Skegness, and off Titchwell on the North Norfolk Coast (WWT Wetlands Advisory Service 2005, Norfolk Bird Reports), and the Wash birds may have temporarily moved to one of these favoured areas. Common scoters show a strong reaction to disturbance, often flying in the presence of boats or planes, and it might be speculated that high levels of boat disturbance (commercial Mussels were harvested from the area off Frampton to Benington in January) may have been responsible for their absence in January.

Scoters observed in the Wash were nearly all found in very tight, sharply defined flocks. This is very similar to flocks observed off the North Norfolk Coast (PA Cranswick, L Smith pers obs), but contrasts sharply with distribution in Carmarthen Bay, off North Wales and over Shell Flat, near Blackpool, where scoter are distributed over a large area, with a 'flocks' of uneven density normally comprising many smaller aggregations of 20-50 birds. The reason

for such differences in flocking behaviour is unknown, but appears to be reasonably consistent at individual sites.

The distribution of scoters in the Wash was very localised, with one or two sites holding the majority of birds. The movement northwards and westwards through the winter was similar to that of eider, possibly due to availability of food resources attractive to both species, possibly mussels, coming to a more profitable size, or a prey shift to satisfy changing nutrient needs. It is notable that the large flocks observed in February, though remaining largely discrete, were in very close proximity in a restricted area.

Historical records of scoters suffer the same problems as those of eiders. Hunstanton is a well-known site for seaducks, aided by its elevated cliff view points, and in recent years appears to have supported the majority of scoters in the Wash. Numbers of scoters in the Wash are, however, very sporadic. Large counts occurred in both 1995/96 and 2000/01, both cold winters, and it is likely that these were linked to an influx of birds from nearby Continental waters. Only small numbers were recorded in the Wash in other winters, but the occasional large counts have usually been sufficient in recent years for the five-year peak mean to surpass 500, the 1% threshold for national importance (eg Cranswick and others 2005).

Interestingly, peak counts often occur out with the midwinter period, and several annual peak counts have occurred in July, perhaps indicative of the use of the Wash as a moult site for common scoters, albeit involving only small numbers. Surveys at other sites have found scoters in late summer to occur further offshore, out of sight of land (eg Cranswick and others 2004), and it is possible that larger numbers than counted may therefore occur in the Wash at this time.

4.2.4 Divers

Small numbers of divers were recorded in all months during aerial surveys in 2005/06. The majority of unidentified individuals are believed to likely to have been red-throated divers, and these counts have been combined with those of red-throated for analysis.

Estimates of total numbers obtained using distance analysis (which, not suffering the same issues of clumped distribution as with seaducks, should be used as the best estimate of numbers) suggest a peak of 223 red-throated divers. Although large numbers have on occasion been recorded by WeBS in the Wash (eg 224 in 1998/99), site totals are generally below 25. This figure easily exceeds the 1% national threshold of 50. With many birds recorded well offshore, it is likely that WeBS consistently under-records true numbers of divers using the Wash.

The distribution of divers showed no obvious patterns between months. Feeding largely on fish, a widespread and mobile distribution of divers may be expected, and perhaps also explains the variation in numbers of divers through the winter. Aerial surveys off the east England coast have recorded a large influx in the Thames area in late winter, and a late winter/early spring peak (perhaps of passage birds) off the North Norfolk Coast (Hall and others 2003, WWT Wetlands Advisory Service 2005); such patterns were not evident in the Wash during 2005/06.

4.2.5 Other waterbirds

Large numbers of other waterbirds (wildfowl, waders and gulls) were recorded by aerial surveys during 2005/06. Numbers were, in most cases, much smaller than the totals obtained by WeBS: the sum of peak species counts in the Wash generally exceeds 300,000 in most winters.

Marked fluctuations in distribution for many species or species groups were clearly linked to the extent of exposed intertidal substrates at the time of the survey. The variations in numbers were, however, less readily explained.

Wader numbers recorded on aerial surveys fluctuated between months, but showed no obvious pattern during the winter. The fact that many birds may use habitats close to the MHWM – where aerial survey ceased while turning between transects – is likely to be responsible for at least some of the difference.

Gulls numbers varied greatly between months, apparently linked to tidal state. Low counts of gulls occurred on surveys at high tide, when gulls have probably moved inland to other feeding or loafing sites while intertidal areas are covered.

The smaller numbers of total waterbirds compared with WeBS are likely to be due to several factors, eg waders were often flushed in front of the aircraft, and the transects did not cover the full extent of habitat used by waterbirds in Wash. The primary reason, however, is likely to be that aerial surveys are flown at around 200 kilometreh^{-1} and it is very difficult to record large numbers of mixed species, occurring at high densities, using this survey technique. Further estimates of true numbers using distance analysis will suffer from the fact that waders flush from the plane, pushing larger numbers into outer bands. Although aerial surveys are not particularly successful in recording numbers of 'terrestrial' waterbirds accurately, they do provide information on the offshore distribution, especially of usage of offshore sandbanks during low tide by waders that is not routinely collected by existing surveys (eg WeBS Low Tide Counts) for such large and inaccessible sites as the Wash.

5 Conclusions and recommendations

- The Wash is a large site, with extensive areas of shallow water, and low elevation of surrounding land, limiting the efficacy of waterbird survey techniques. Aerial survey has provided comprehensive coverage of the whole site at a variety of tidal states.
- Aerial surveys provided representative data on the numbers and precise spatial information on the distribution of seaducks, divers and seabirds using the Wash during winter 2005/06, comparable to, or of higher quality, than other recent surveys.
- The high accuracy of spatial information for seaducks would be useful for assessing potential conflict with other interests, eg by overlaying data with that for mussel leys.
- Future surveys might consider transects at different spatial separation, for example, at 1 kilometre intervals if a greater resolution of spatial location for eiders is required. Eiders show minimal reaction to the plane, so greater density of transects – to obtain more accurate and greater density of information – would not compromise the results through disturbance, a concern for survey accuracy with some other waterbird species.

- Consideration should be given to surveys at other times of year, particularly spring and summer, to provide an assessment of numbers and distribution of seaducks throughout the year. This would be useful both for potential conflict with shellfisheries, but also in view of the possible use of the Wash by moulting common scoter.
- Consideration should be given to conducting future surveys targeted at different tidal states, eg paired high and low tide surveys each month, although the constraints upon aerial surveys, particularly in the Wash, may limit opportunities for such an approach.
- Aerial survey of the Wash using this approach provides a dataset compatible with surveys being undertaken in adjacent offshore areas, enabling a broader scale survey and context setting.
- Although coverage of 'terrestrial' waterbirds, particularly waders, was not a focus of this survey, results demonstrate that useful information of low tide distribution can be obtained for a site that has otherwise proved extremely difficult to survey at this tidal state.

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Figures

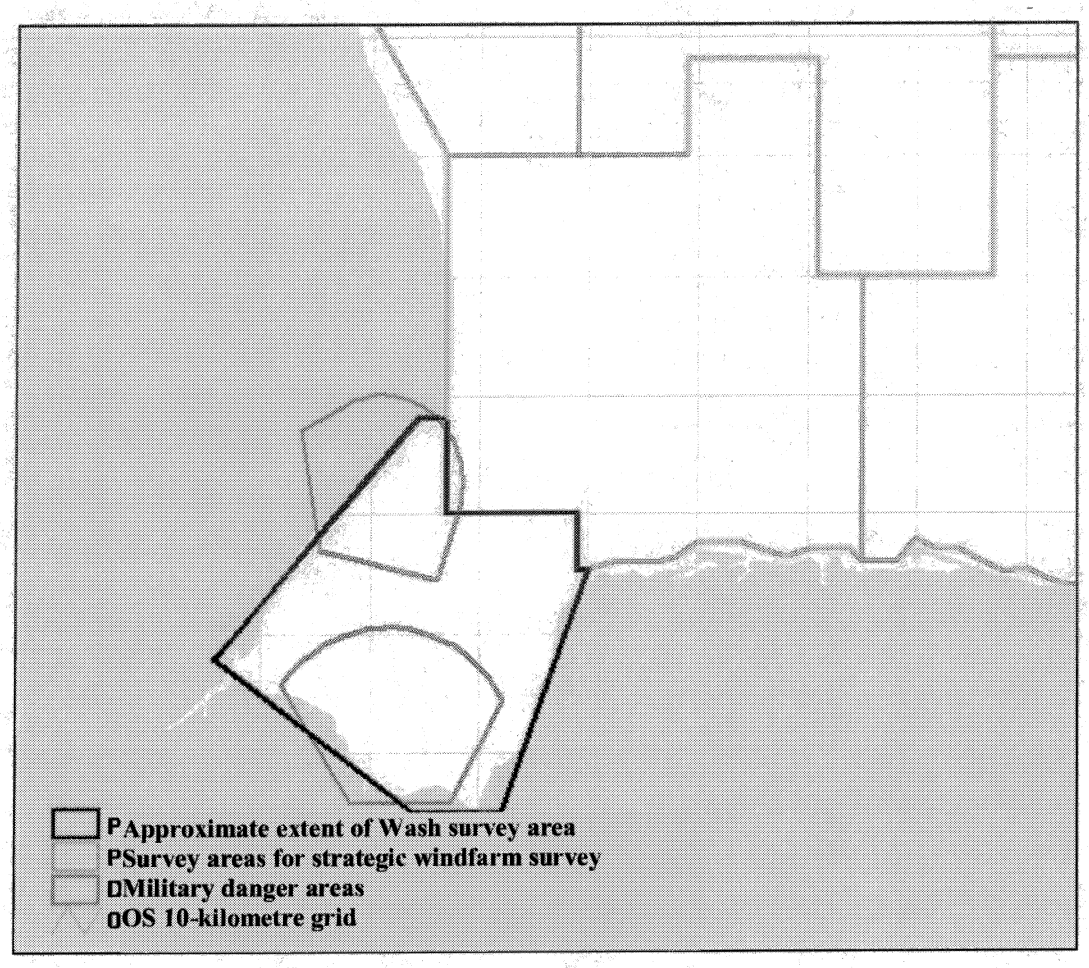

Figure 1 Approximate extent of aerial survey area in the Wash

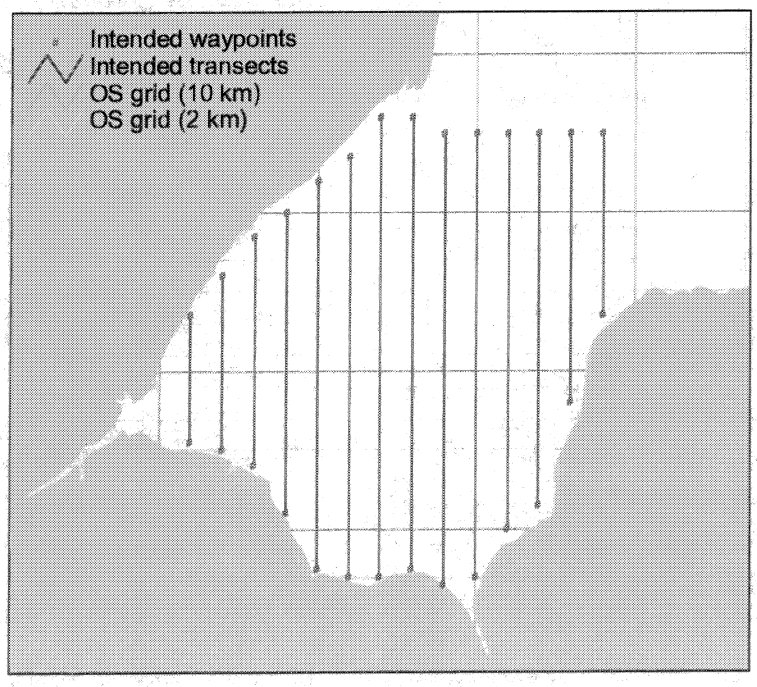

Figure 2 Intended transect routes for aerial surveys of the Wash

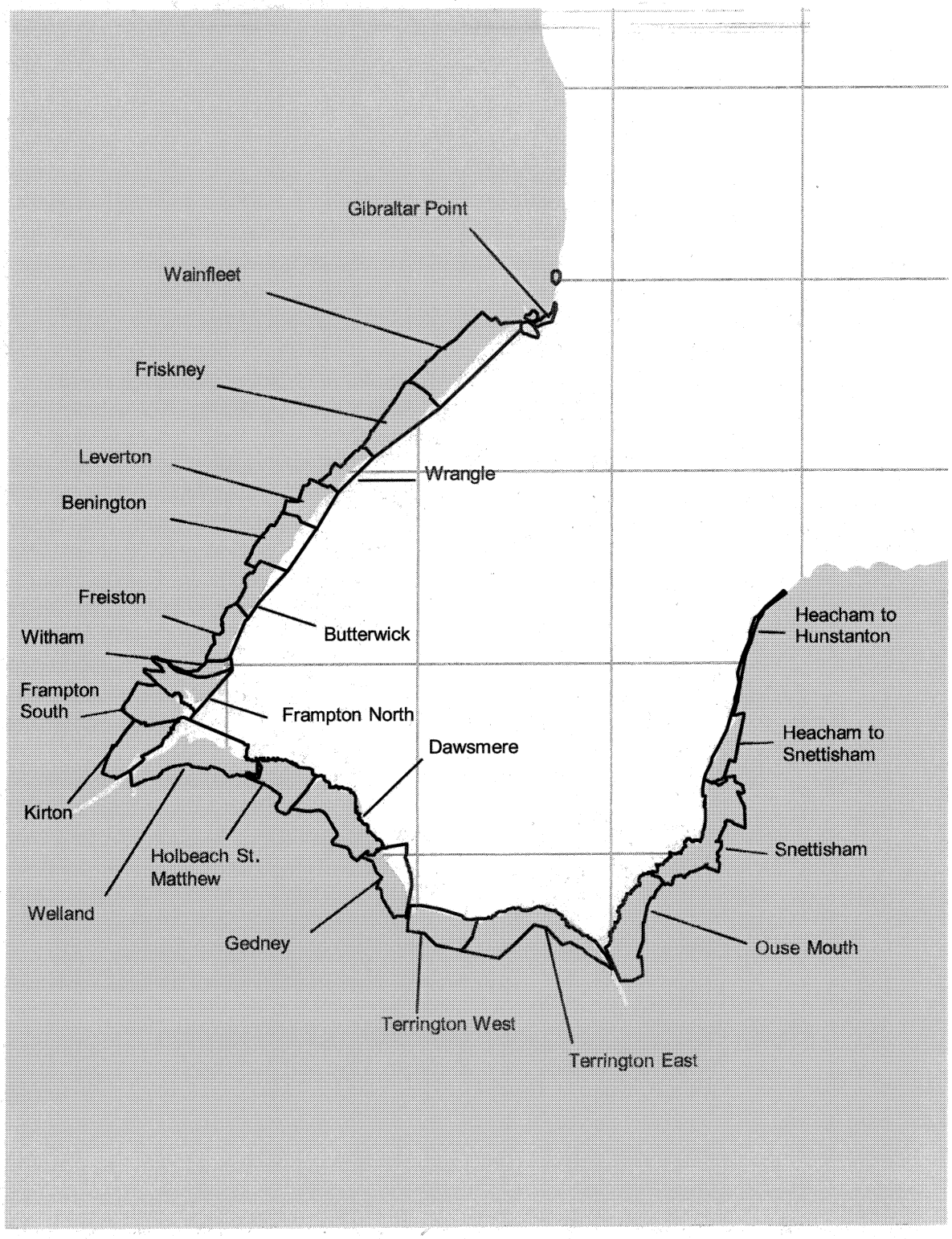

Figure 3 Wetland Bird Survey count sector boundaries in the Wash

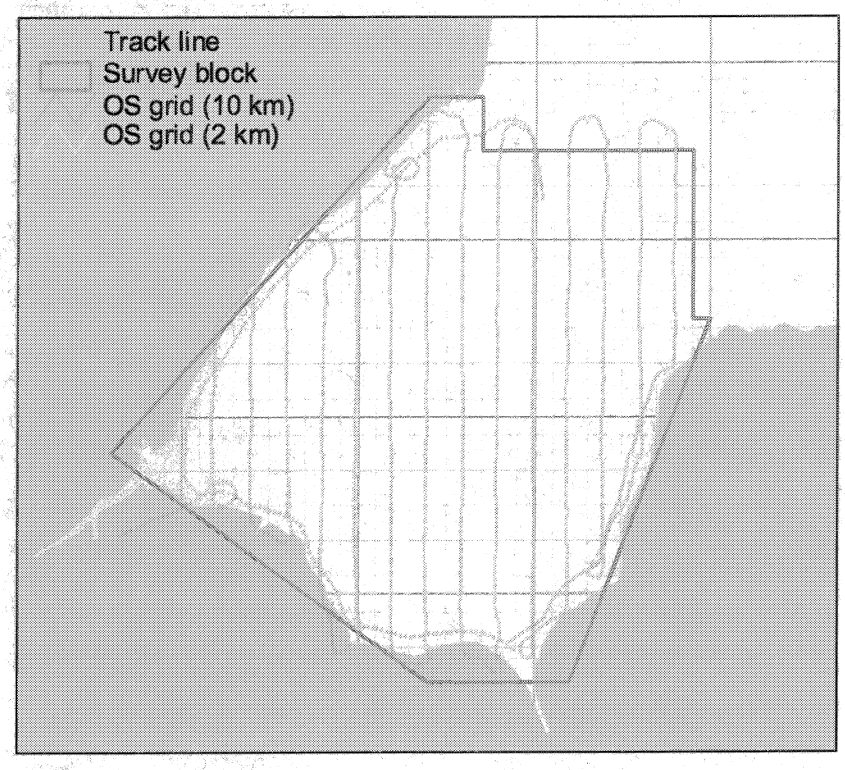

Figure 4 Flight path during aerial survey in December 2005: north-south routes indicate flights along transects; the route taken during the 'total count' follows the shoreline. Note, this survey was undertaken at high tide, and the total count route is close to the MHWM.

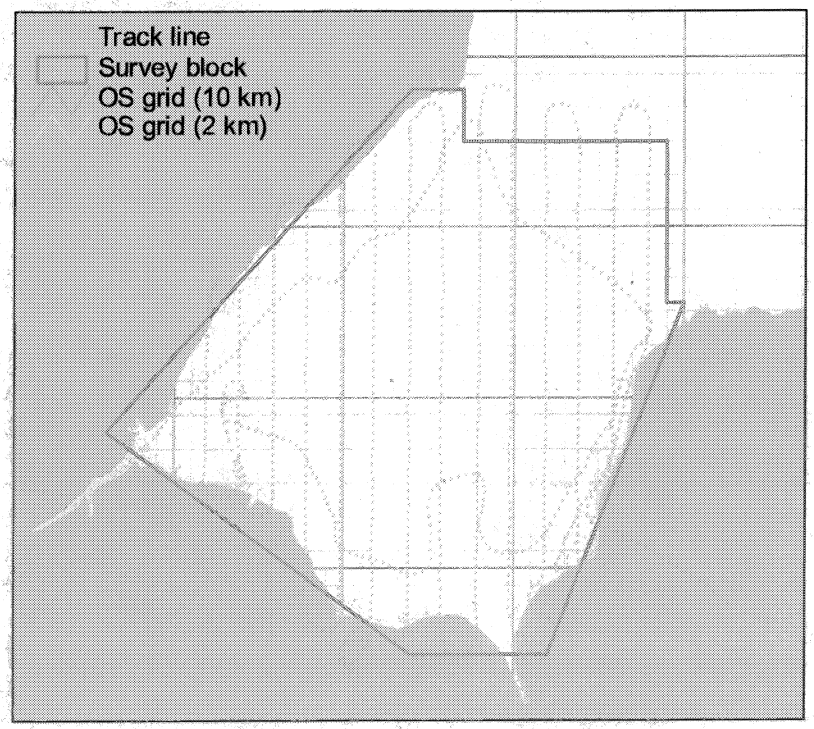

Figure 5 Flight path during aerial survey in January 2006: north-south routes indicate flights along transects; the route taken during the 'total count' follows runs parallel to but several kilometres from the MHWM as this survey was undertaken at low tide.

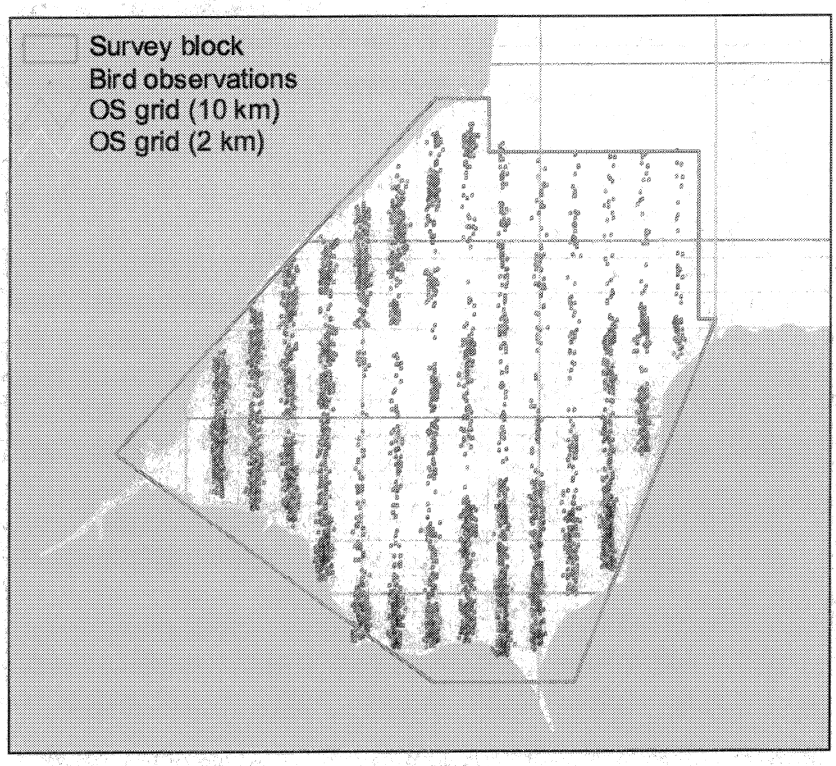

Figure 6 Observations of birds in the Wash during aerial surveys, winter 2005/06. A single record of birds (whether an individual or flock) is treated as one observation. Note, a higher proportion of birds is detected close the plane, hence the apparent distribution is of lines of birds running north-south along the path of the transects

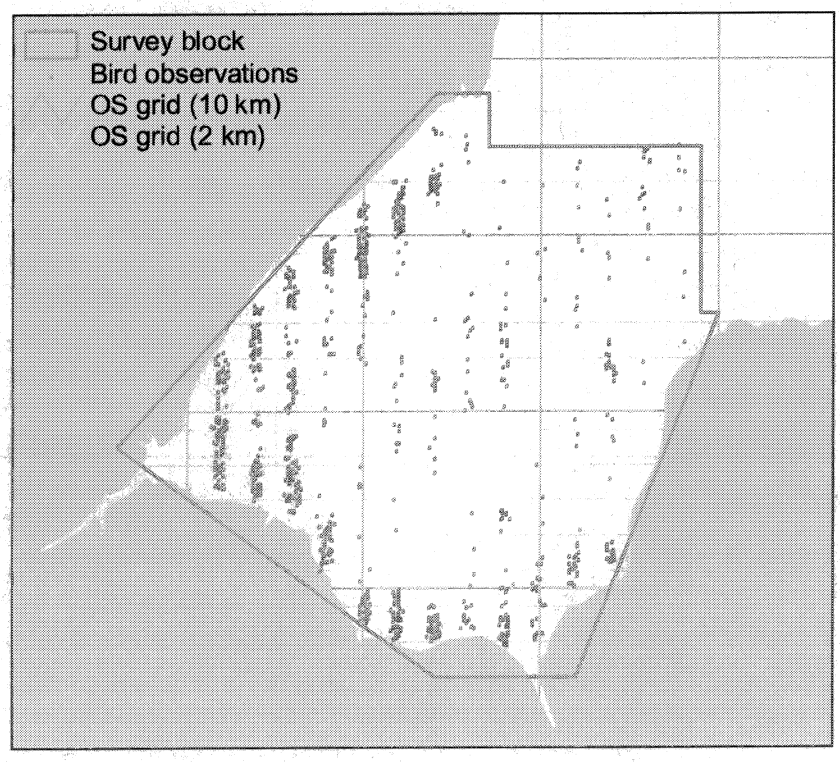

Figure 7 Observations of birds in the Wash during aerial surveys, November 2005 (see also caption for Figure 6).

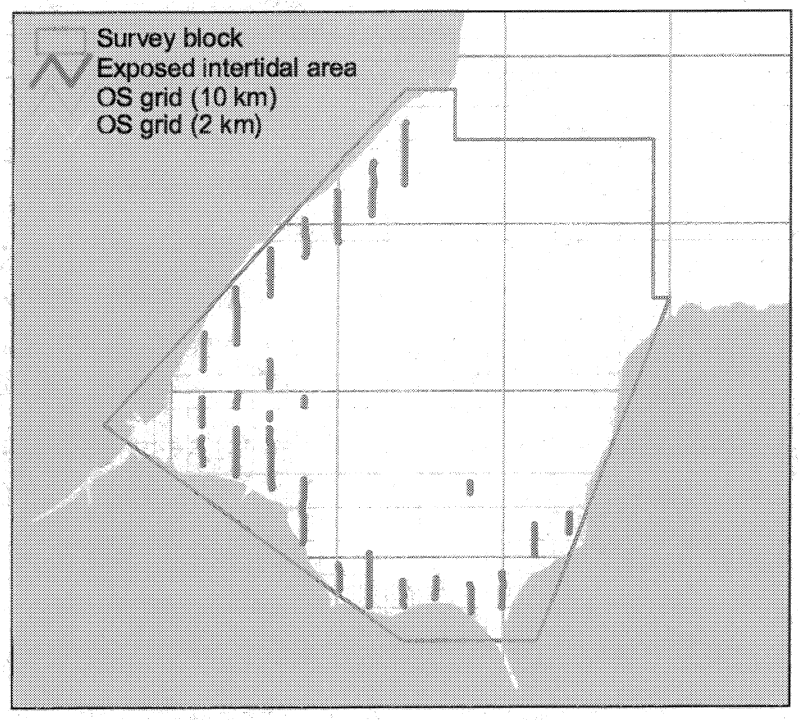

Figure 8 Exposed intertidal area, November 2005. Exposed intertidal area is shown as parts of flight path at which the plane was directly above exposed intertidal area (apparent gaps in intertidal area near the MHWM relate to the cessation of the survey at transect end points).

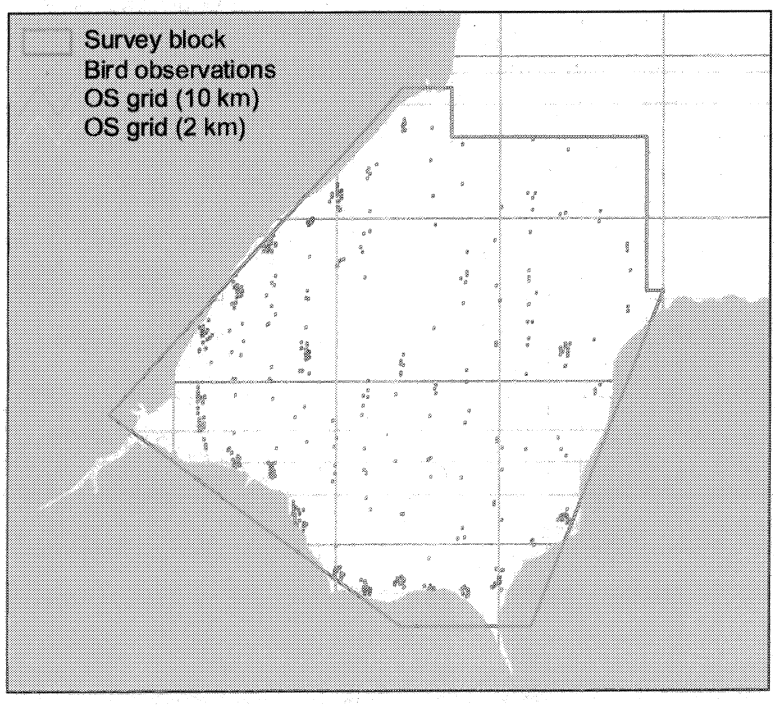

Figure 9 Observations of birds in the Wash during aerial surveys, December 2005 (see also caption for Figure 6).

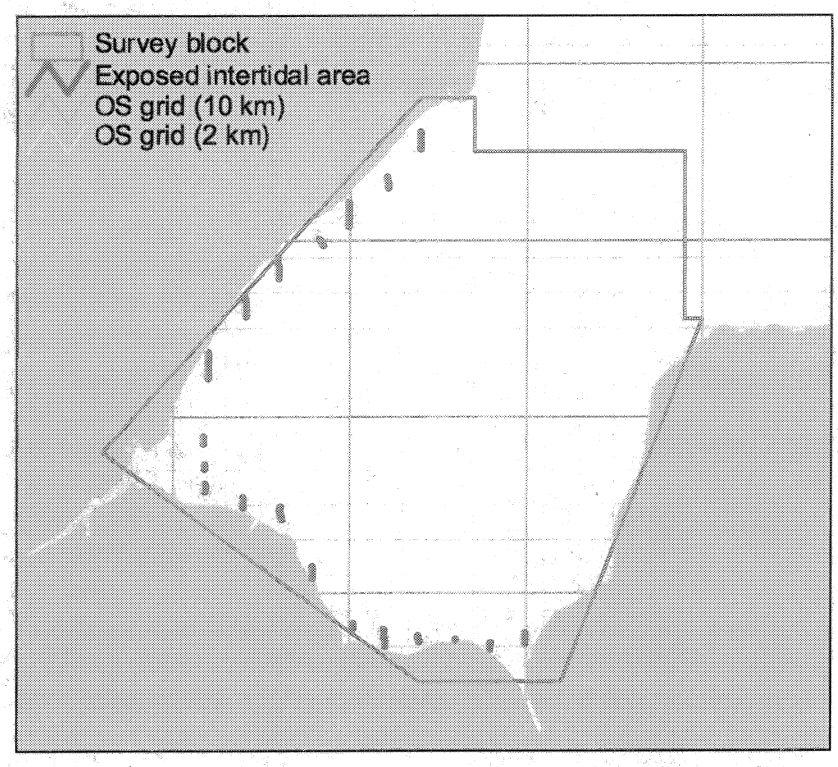

Figure 10 Exposed intertidal area surveyed, December 2005 (see also caption for Figure 8).

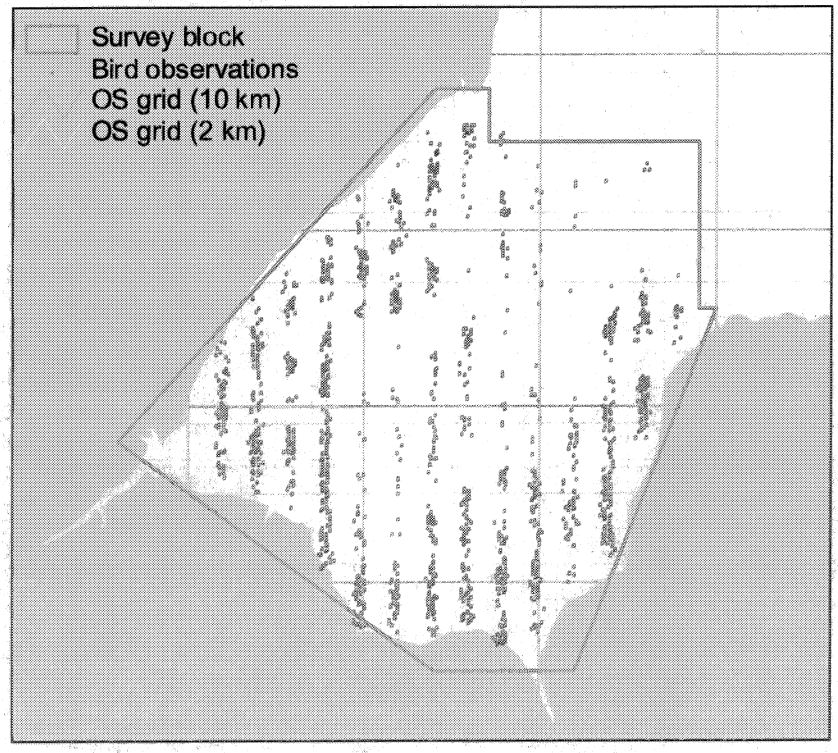

Figure 11 Observations of birds in the Wash during aerial surveys, January 2006 (see also caption for Figure 6)

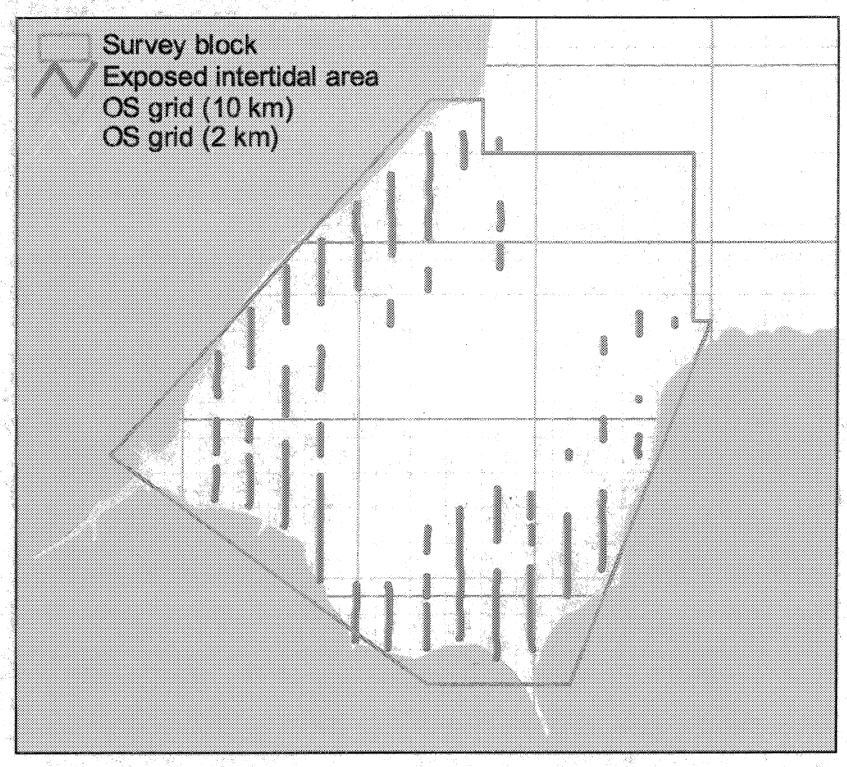

Figure 12 Exposed intertidal area, January 2006 (see also caption for Figure 8).

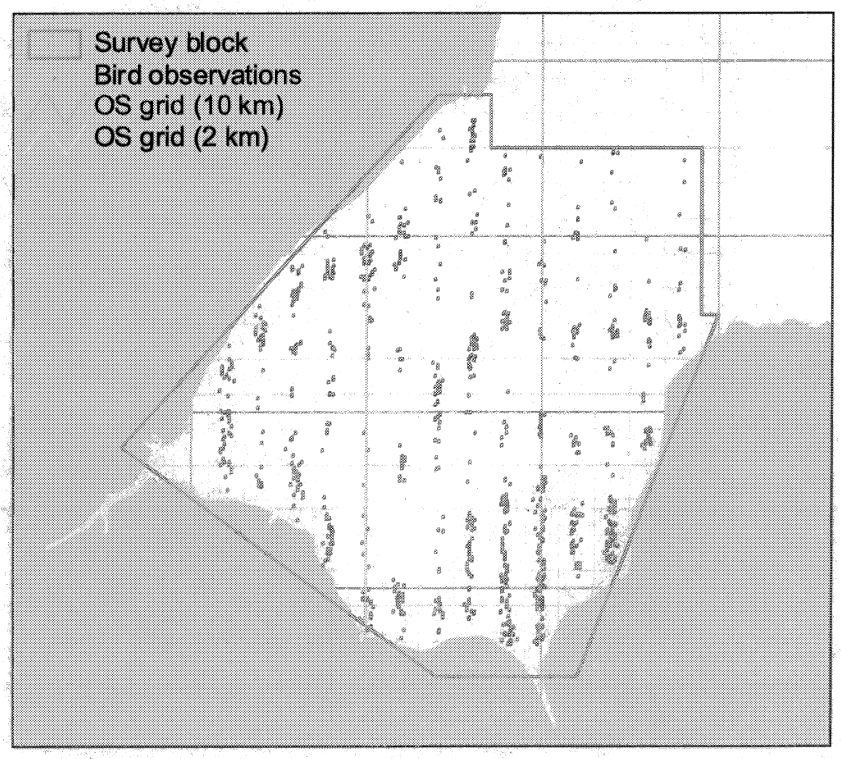

Figure 13 Observations of birds in the Wash during aerial surveys, February 2006 (see also caption for Figure 6).

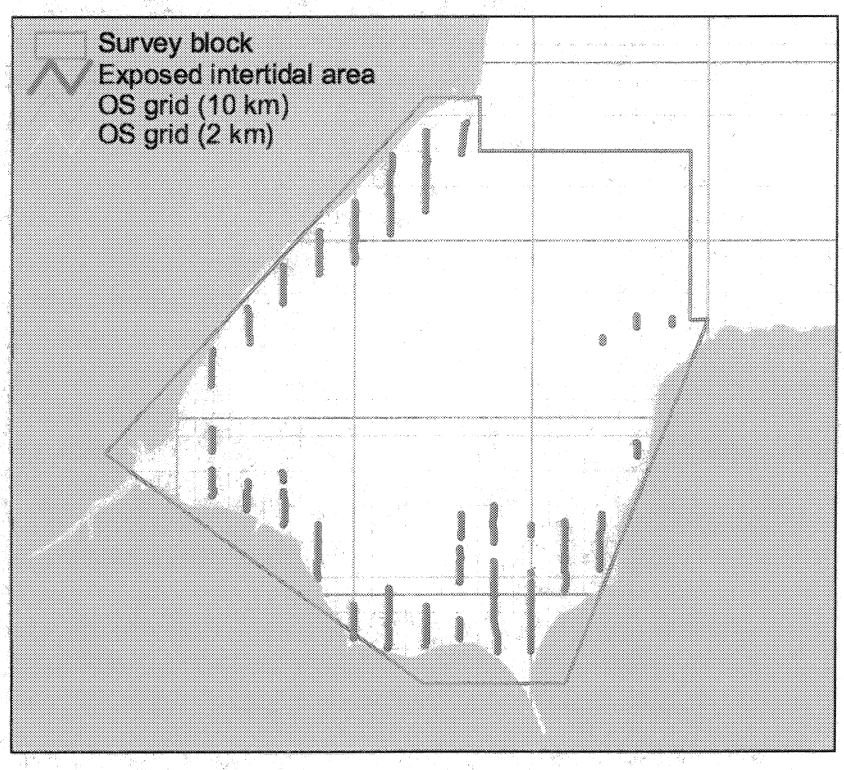

Figure 14 Exposed intertidal area, February 2006 (see also caption for Figure 8).

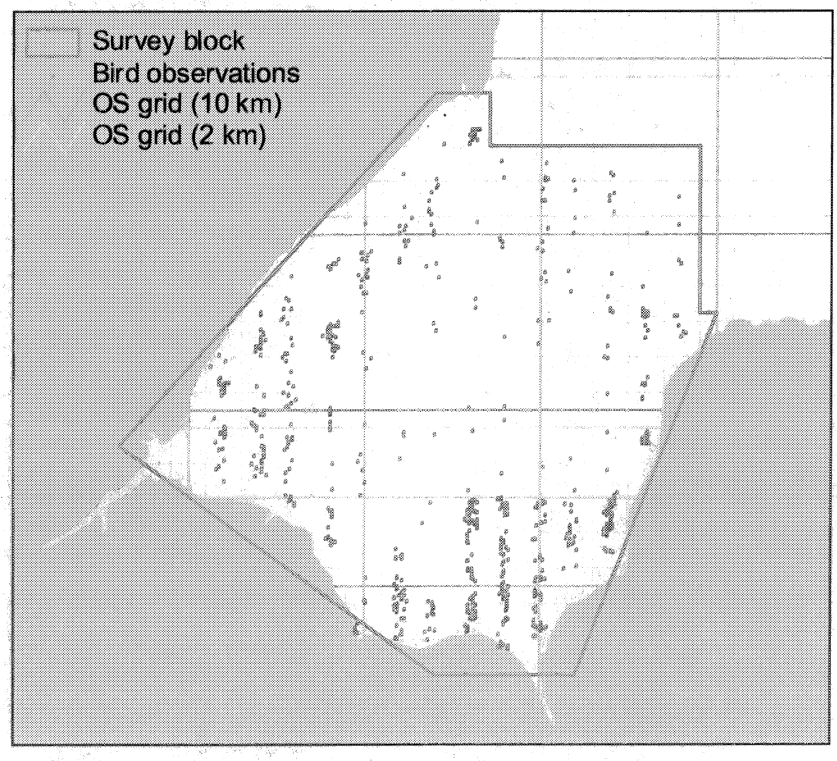

Figure 15 Observations of birds in the Wash during aerial surveys, March 2006 (see also caption for Figure 6).

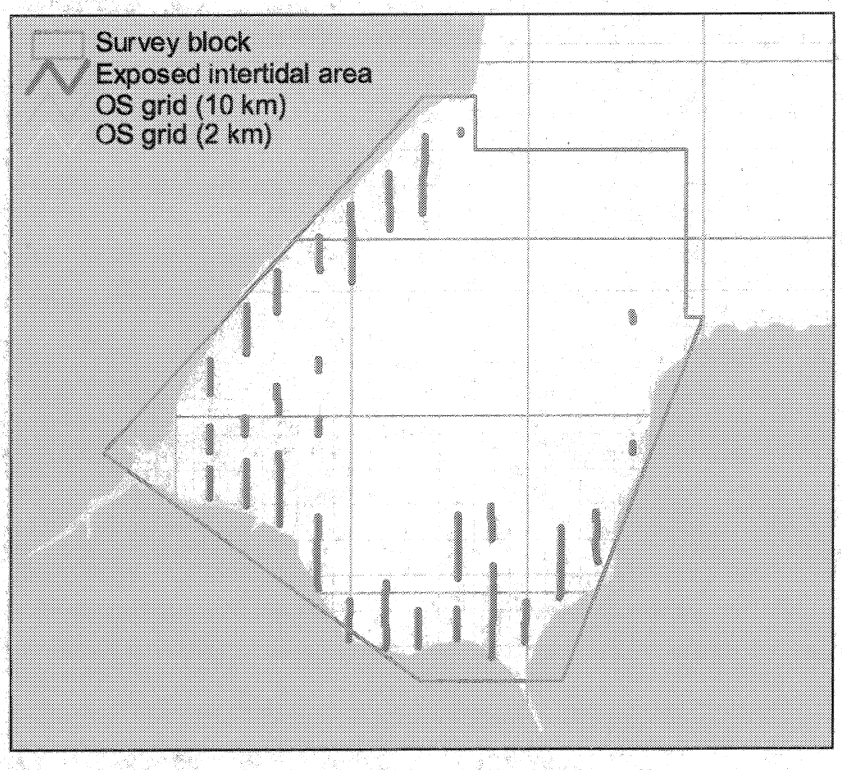

Figure 16 - Exposed intertidal area, March 2006 (see also caption for Figure 8).

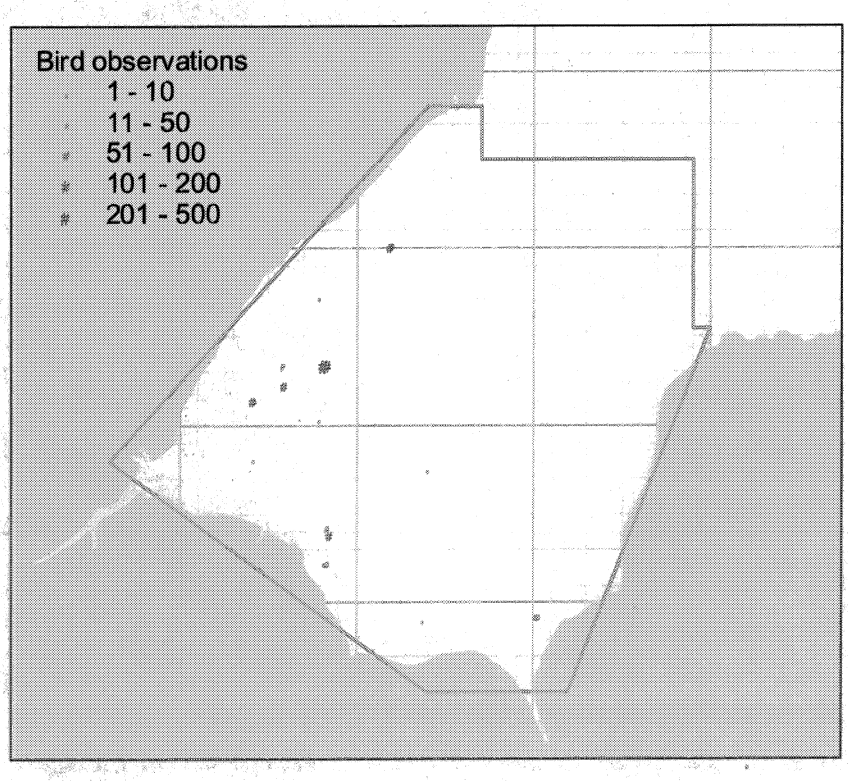

Figure 17 Observations of eiders *Somateria mollissima* in the Wash during aerial surveys, November 2005. The approximate boundary of the survey blocks is shown in green. Grids are the 10-kilometre and 2-kilometre national OS grid.

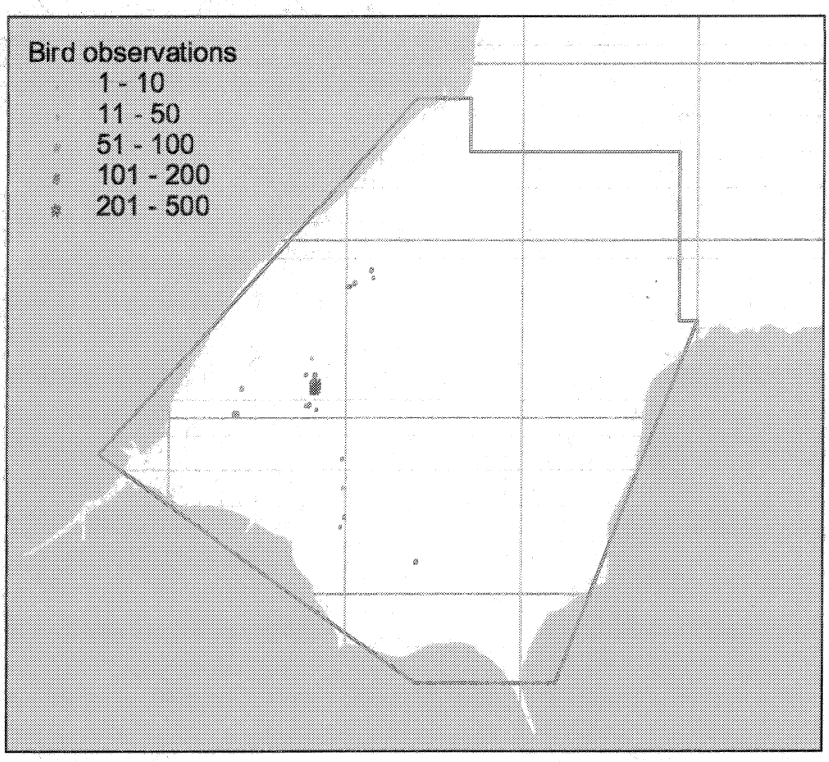

Figure 18 Observations of eiders *Somateria mollissima* in the Wash during aerial surveys, November 2005. The approximate boundary of the survey blocks is shown in green. Grids are the 10-kilometre and 2-kilometre national OS grid.

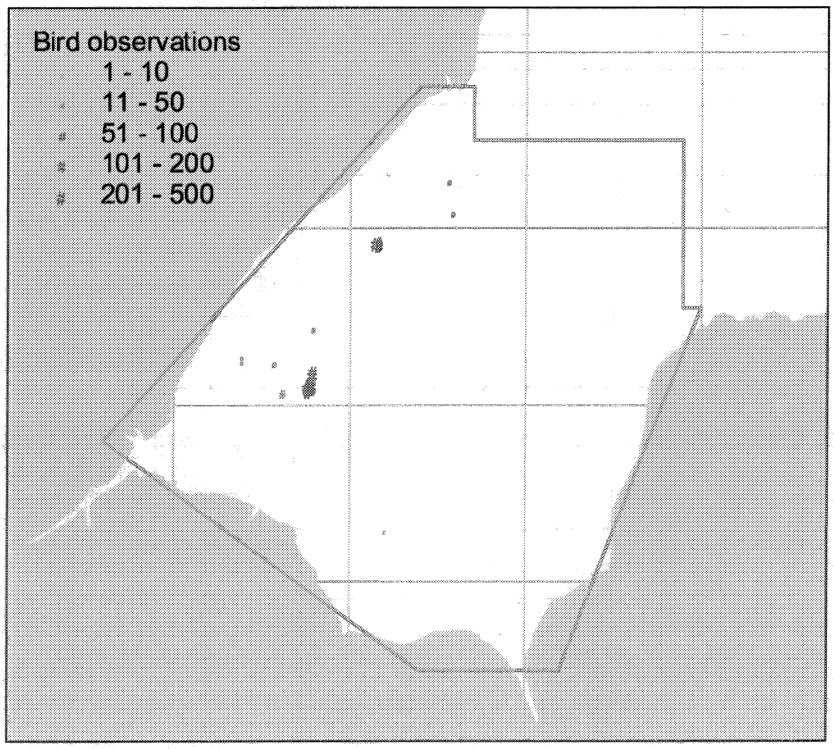

Figure 19 Observations of eiders *Somateria mollissima* in the Wash during aerial surveys, January 2006.

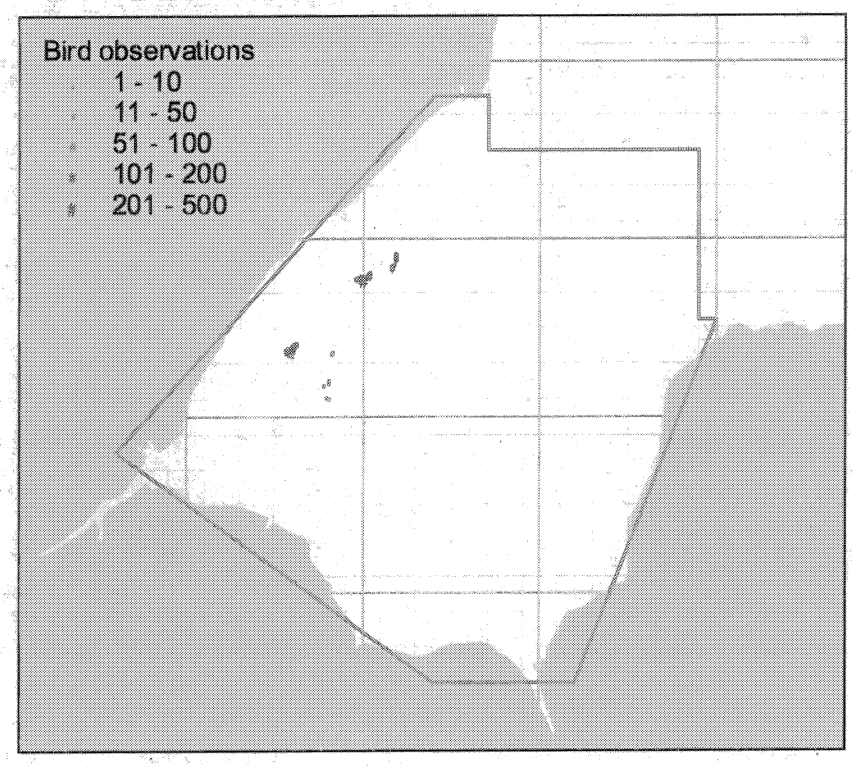

Figure 20 Observations of eiders *Somateria mollissima* in the Wash during aerial surveys, February 2006.

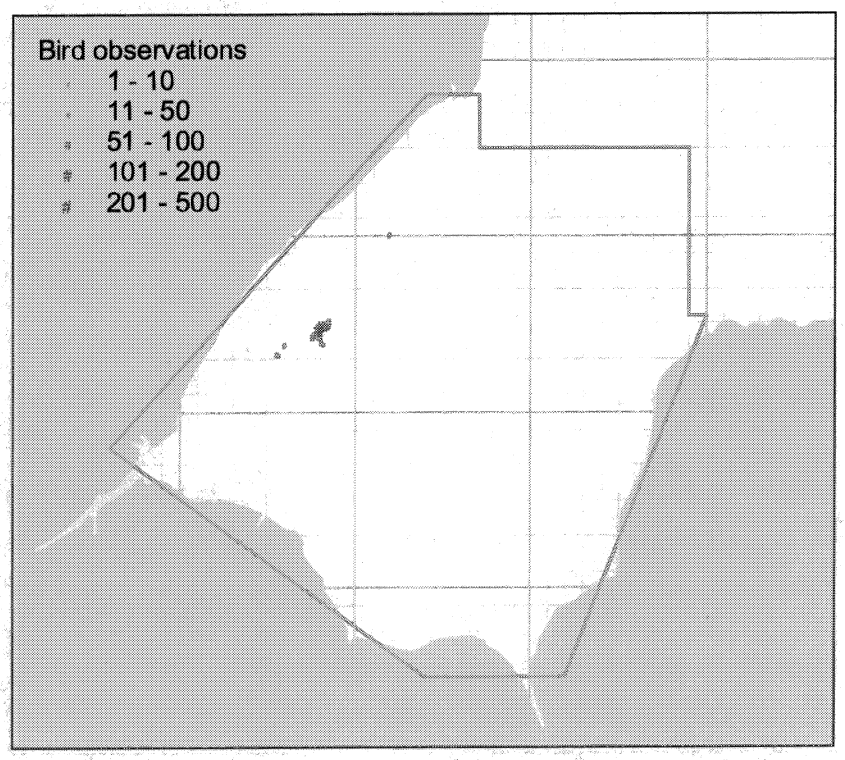

Figure 21 Observations of eiders *Somateria mollissima* in the Wash during aerial surveys, March 2006.

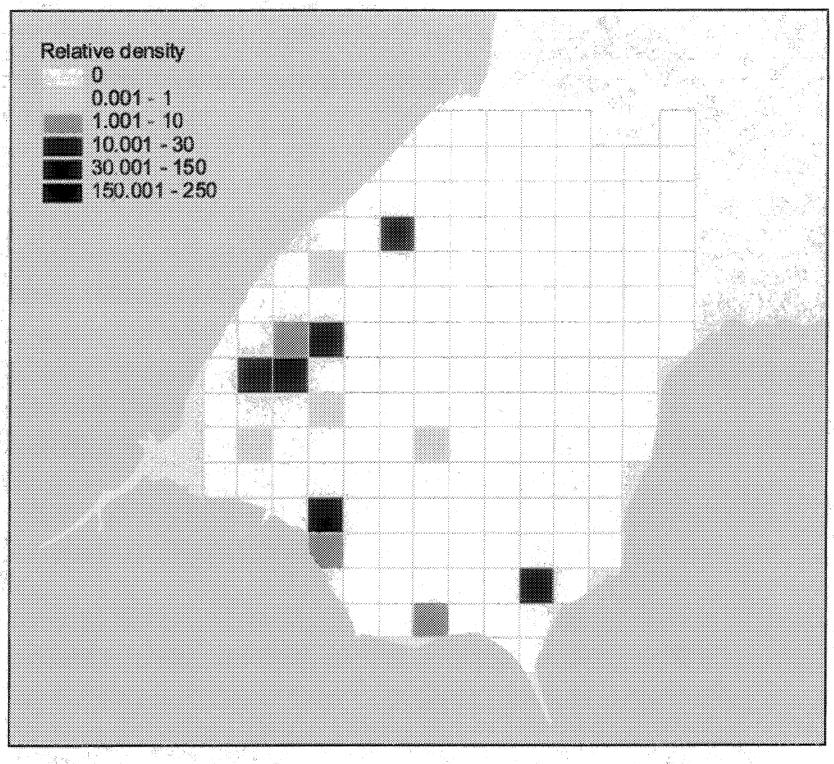

Figure 22 Relative density of eiders *Somateria mollissima* in the Wash during aerial surveys, November 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

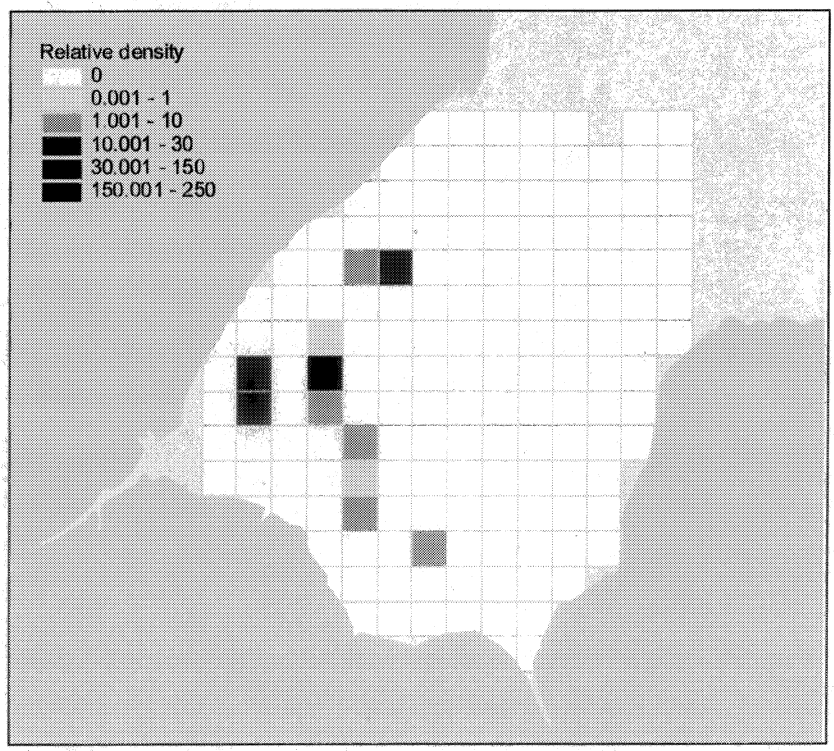

Figure 23 Relative density of eiders *Somateria mollissima* in the Wash during aerial surveys, December 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

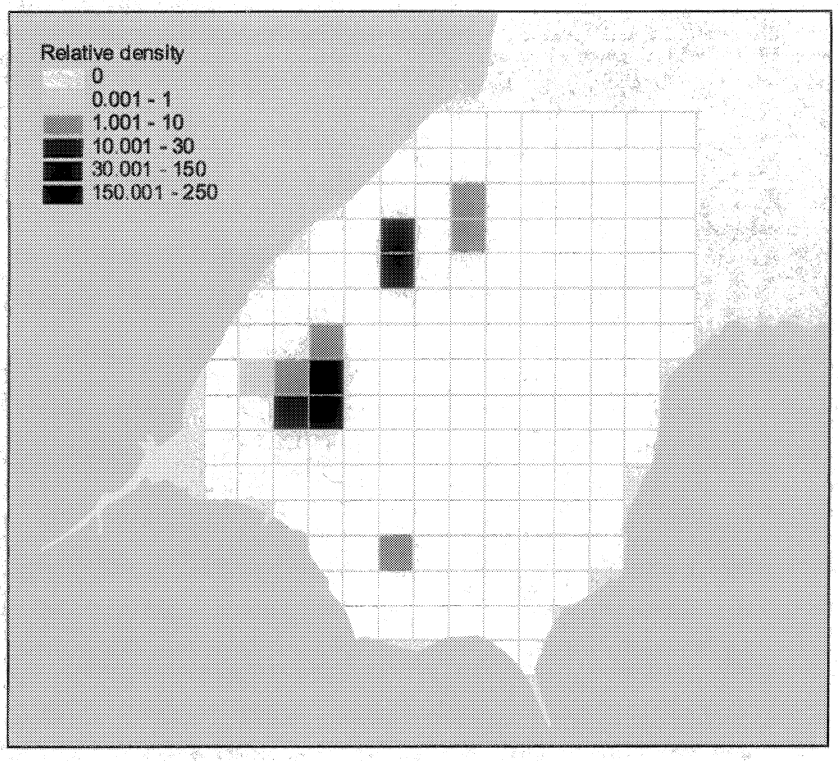

Figure 24 Relative density of eiders *Somateria mollissima* in the Wash during aerial surveys, January 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

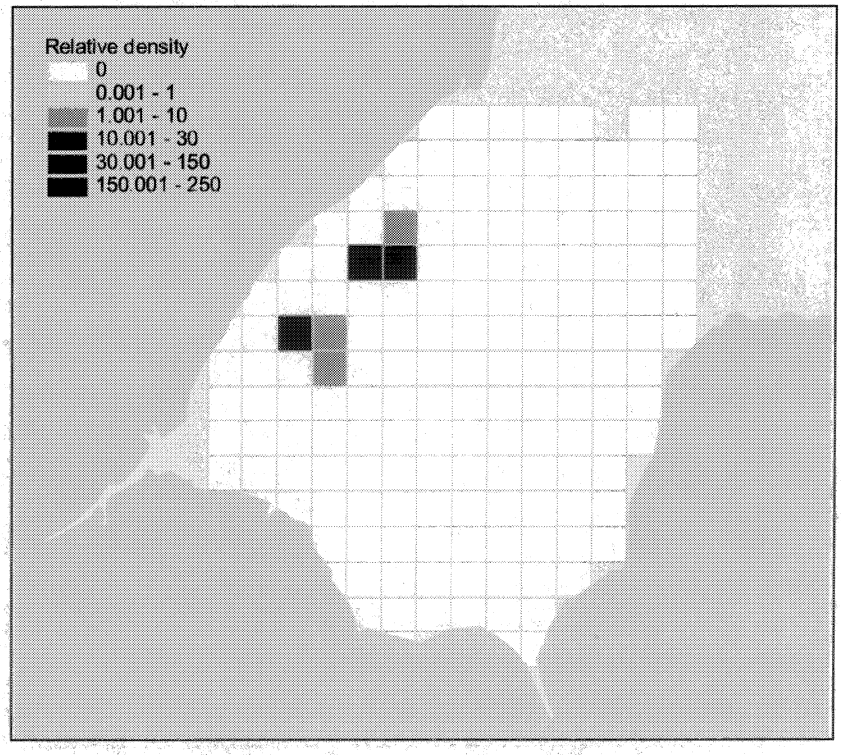

Figure 25 Relative density of eiders *Somateria mollissima* in the Wash during aerial surveys, February 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

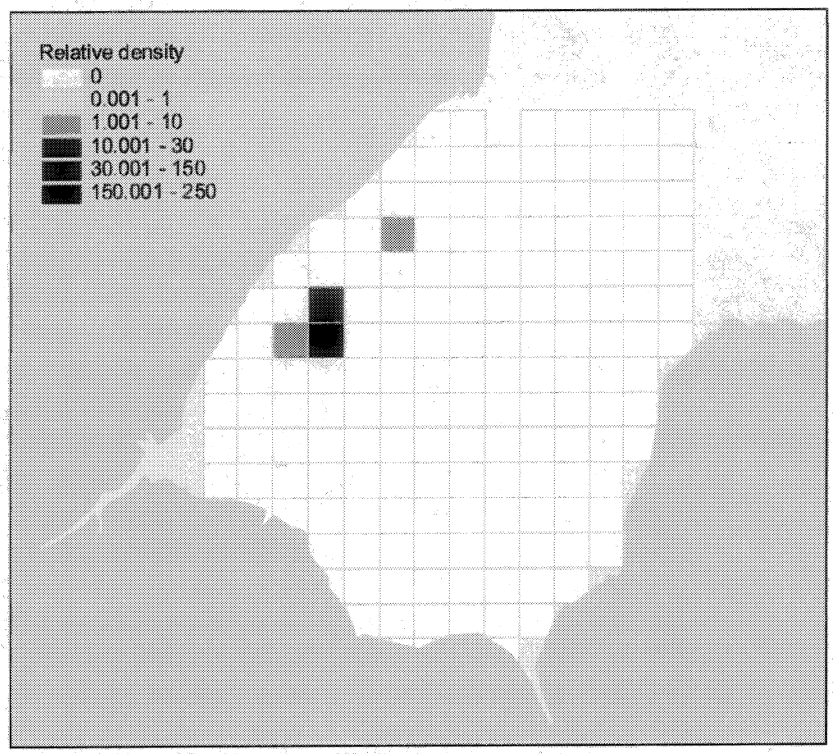

Figure 26 Relative density of eiders *Somateria mollissima* in the Wash during aerial surveys, March 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

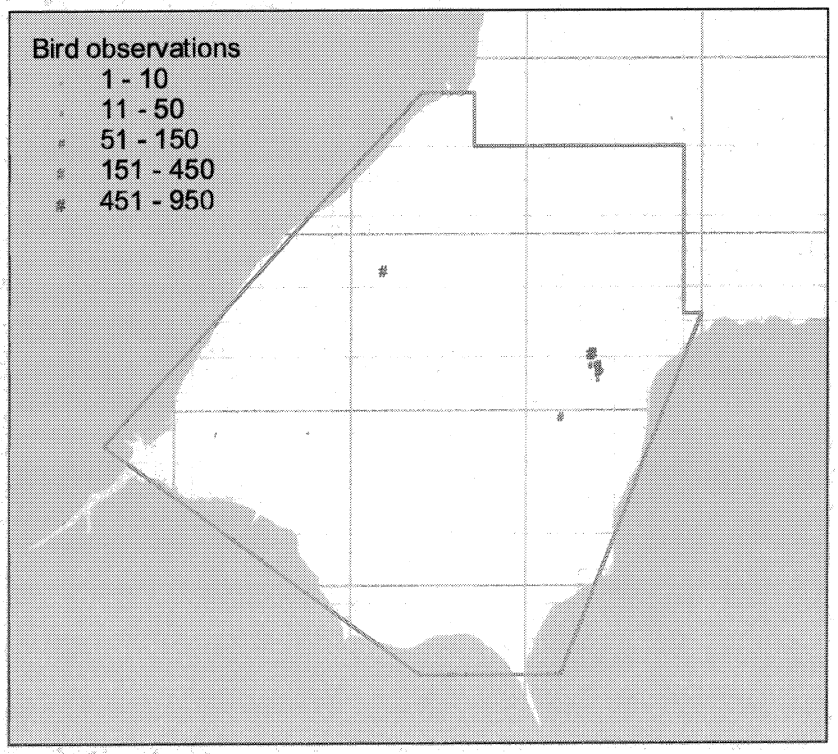

Figure 27 Observations of common scoters *Melanitta nigra* in the Wash during aerial surveys, November 2005. The approximate boundary of the survey blocks is shown in green. Grids are the 10-kilometre and 2-kilometre national OS grid.

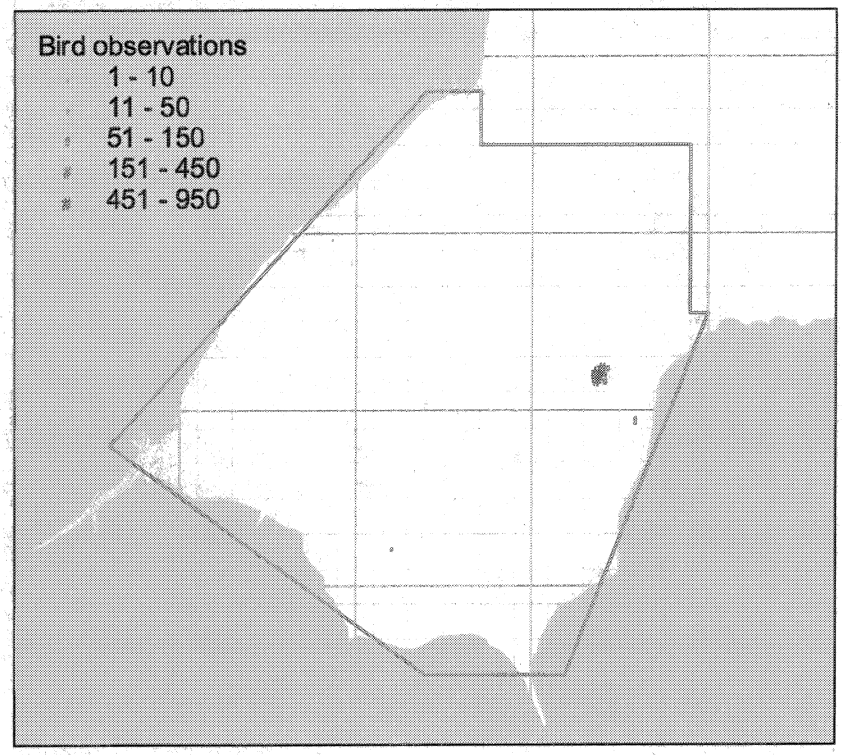

Figure 28 Observations of common scoters *Melanitta nigra* in the Wash during aerial surveys, December 2005.

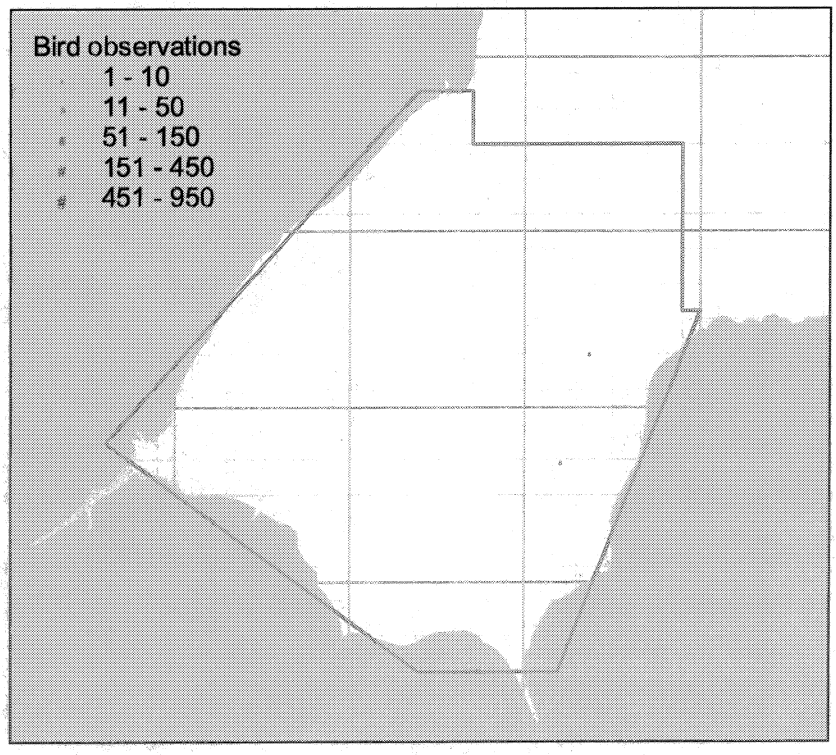

Figure 29 Observations of common scoters *Melanitta nigra* in the Wash during aerial surveys, January 2006.

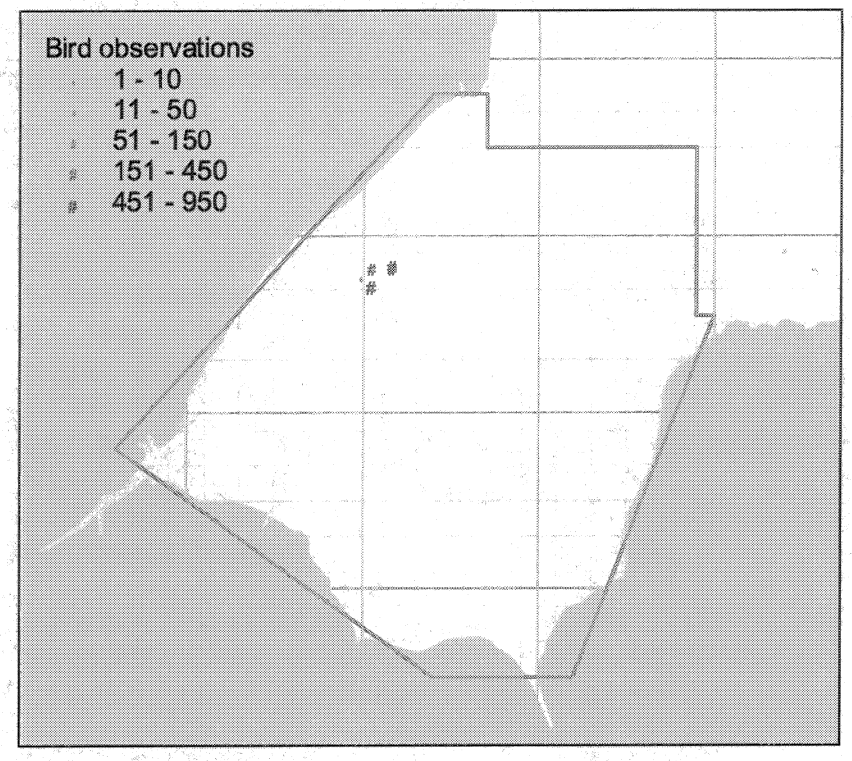

Figure 30 Observations of common scoters *Melanitta nigra* in the Wash during aerial surveys, February 2006.

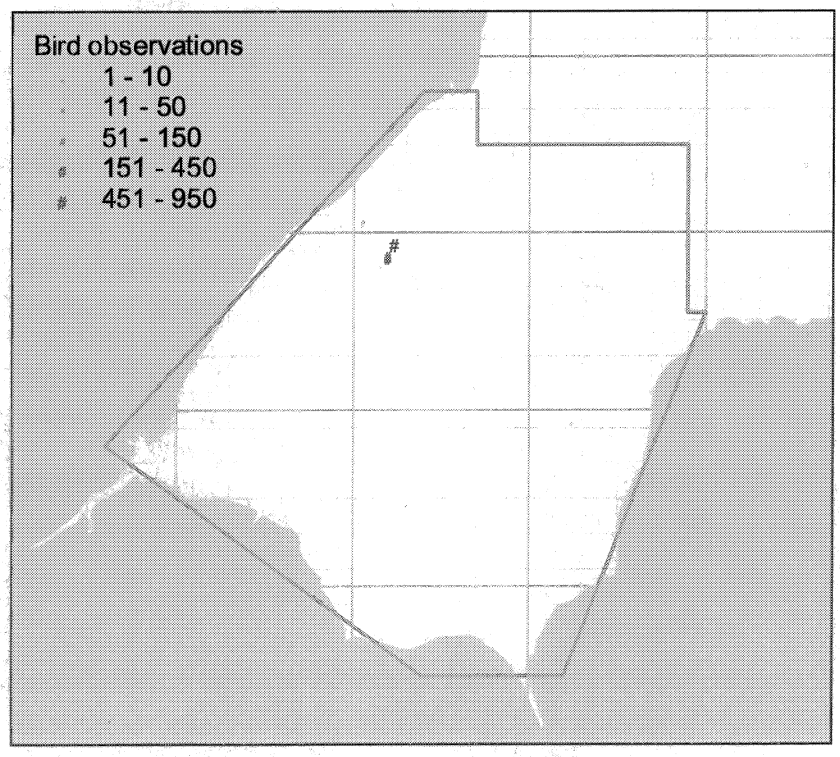

Figure 31 Observations of common scoters *Melanitta nigra* in the Wash during aerial surveys, March 2006.

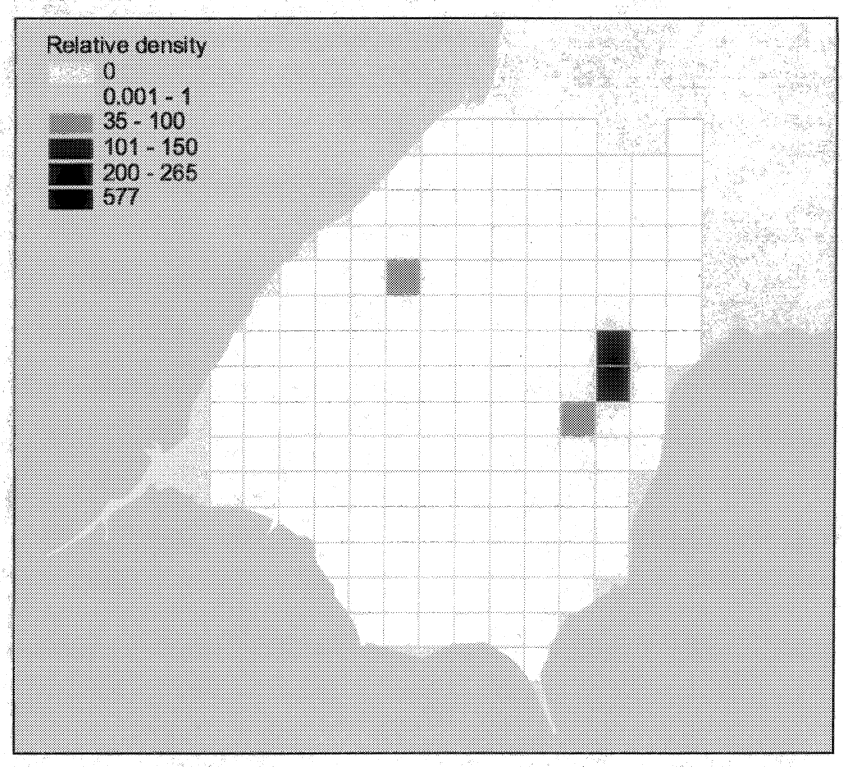

Figure 32 - Relative density of Common Scoters *Melanitta nigra* in the Wash during aerial surveys, November 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

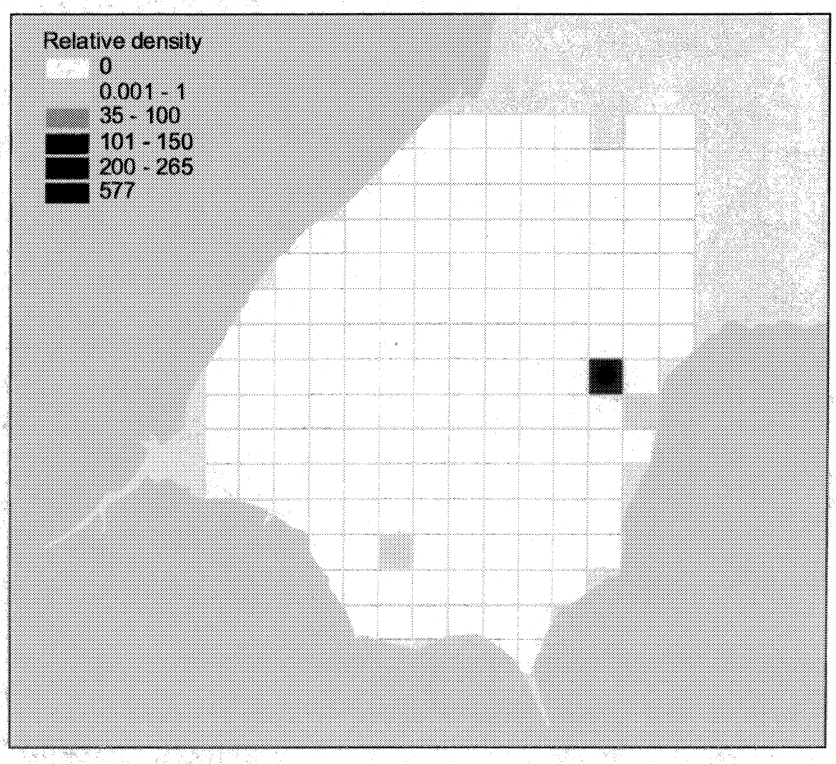

Figure 33 - Relative density of common scoters *Melanitta nigra* in the Wash during aerial surveys, December 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

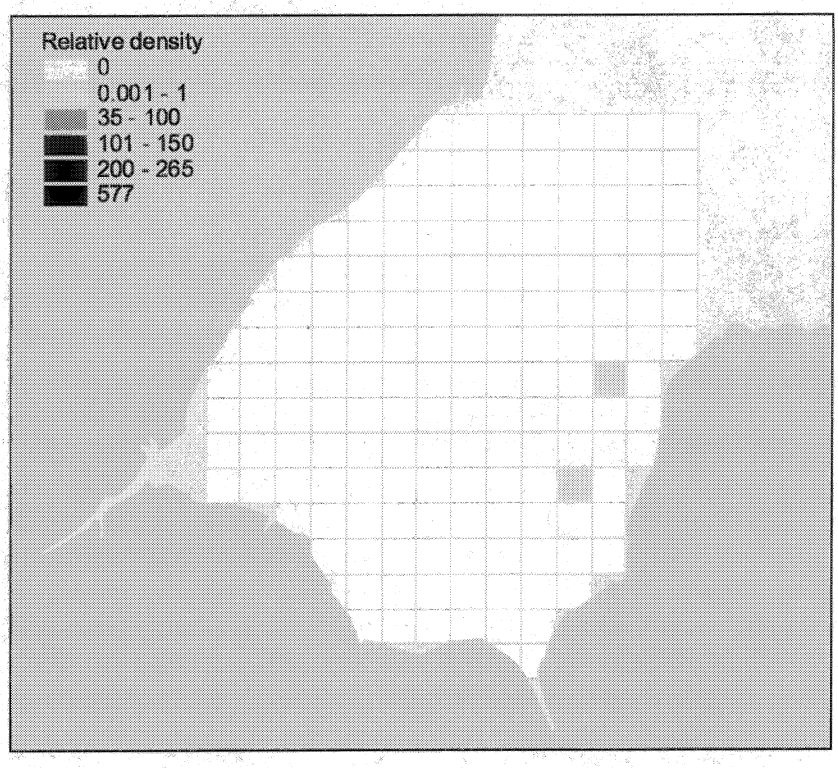

Figure 34 Relative density of common scoters *Melanitta nigra* in the Wash during aerial surveys, January 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

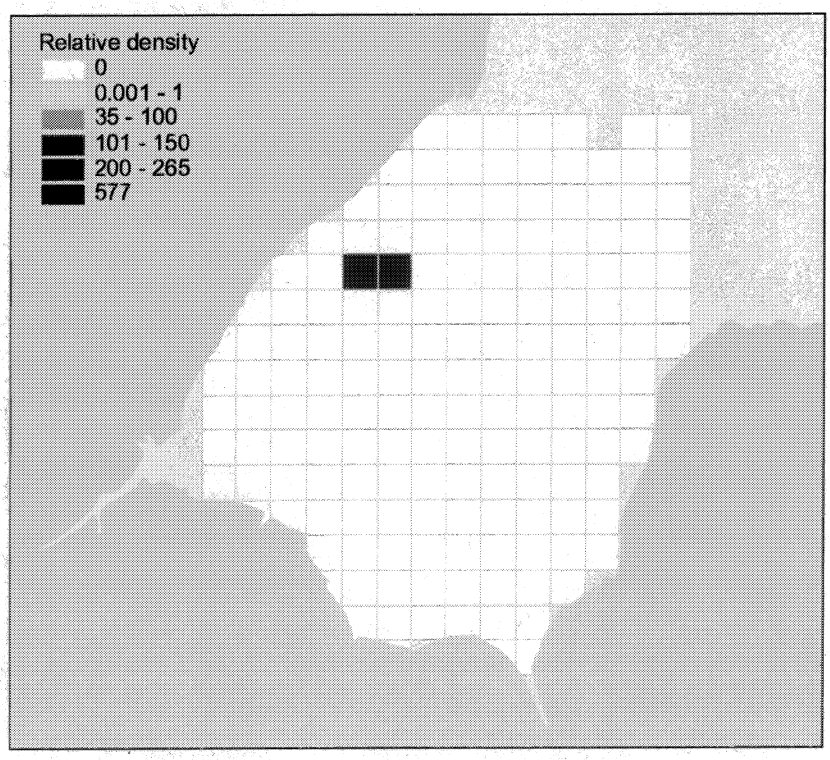

Figure 35 Relative density of common scoters *Melanitta nigra* in the Wash during aerial surveys, February 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

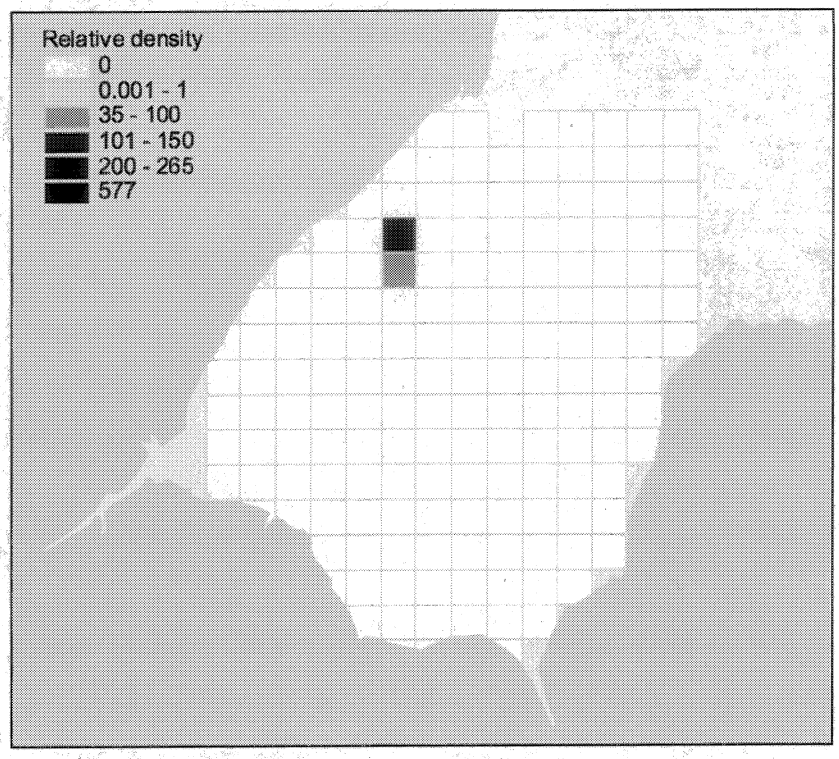

Figure 36 Relative density of common scoters *Melanitta nigra* in the Wash during aerial surveys, March 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

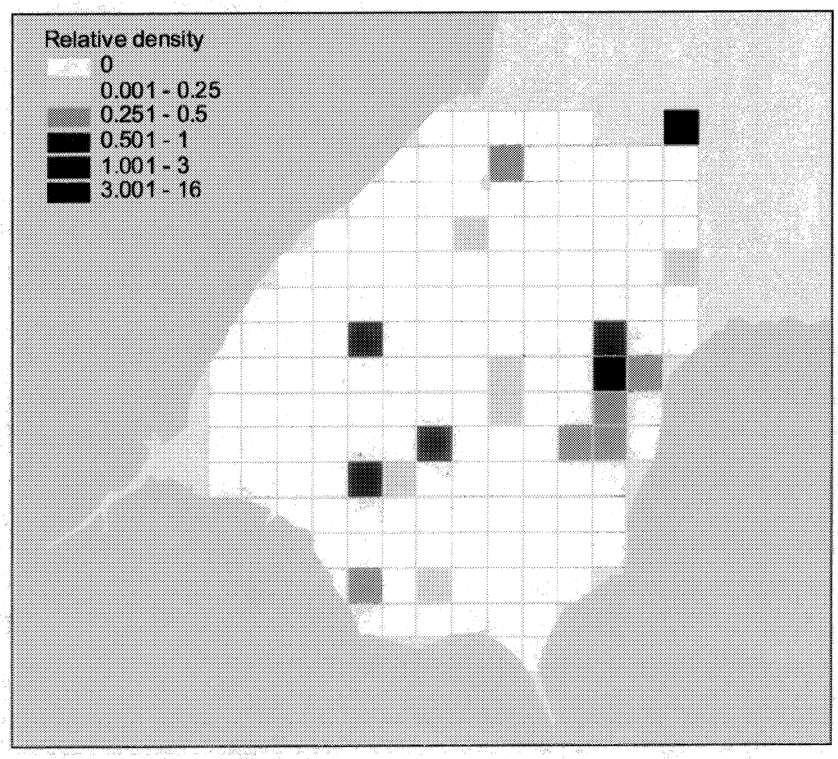

Figure 37 Relative density of divers *Gavia* spp. in the Wash during aerial surveys, November 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

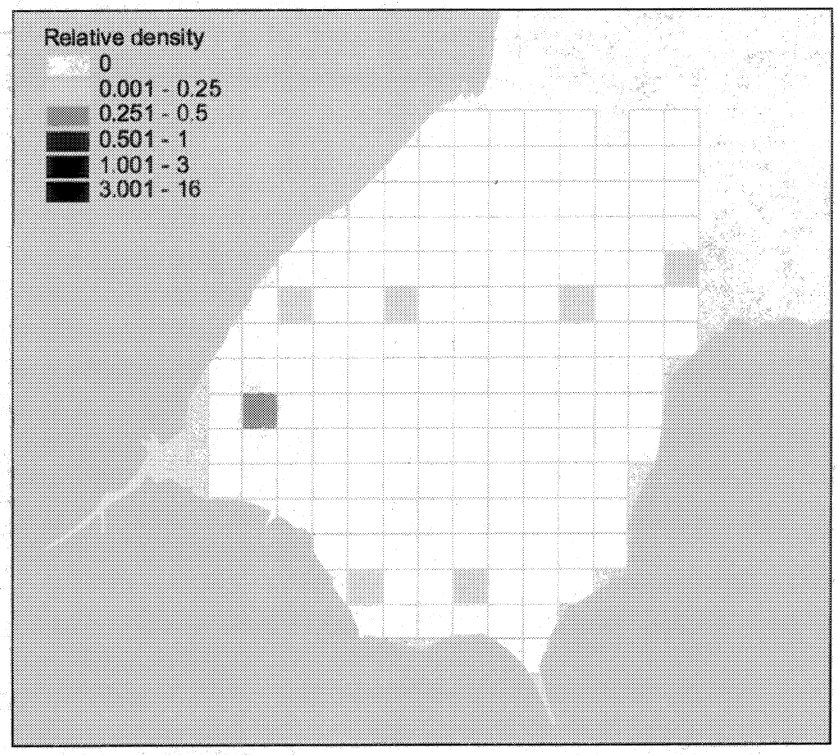

Figure 38 - Relative density of divers *Gavia* spp. in the Wash during aerial surveys, December 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

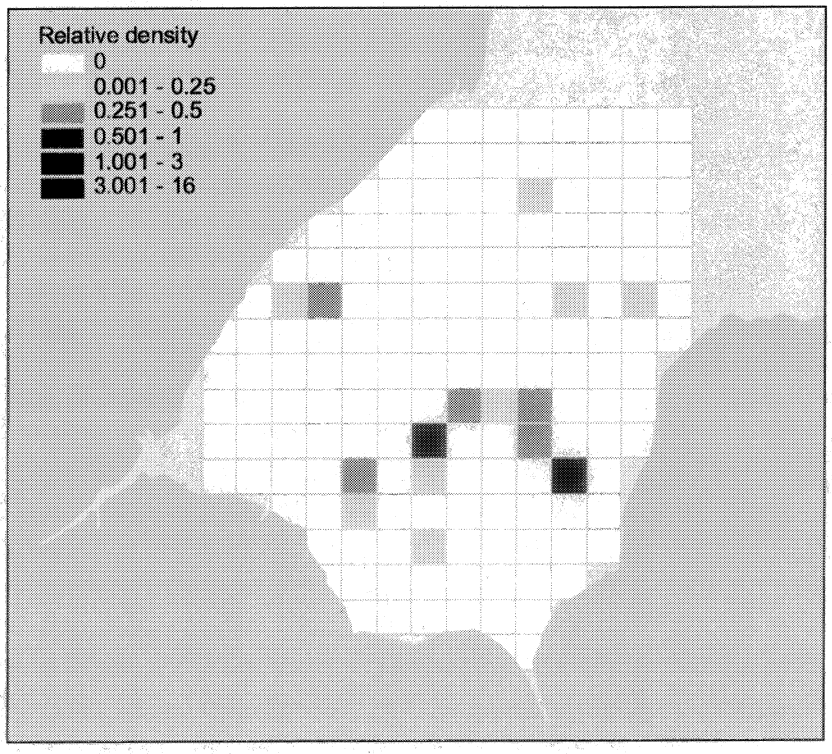

Figure 39 Relative density of divers *Gavia* spp. in the Wash during aerial surveys, January 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

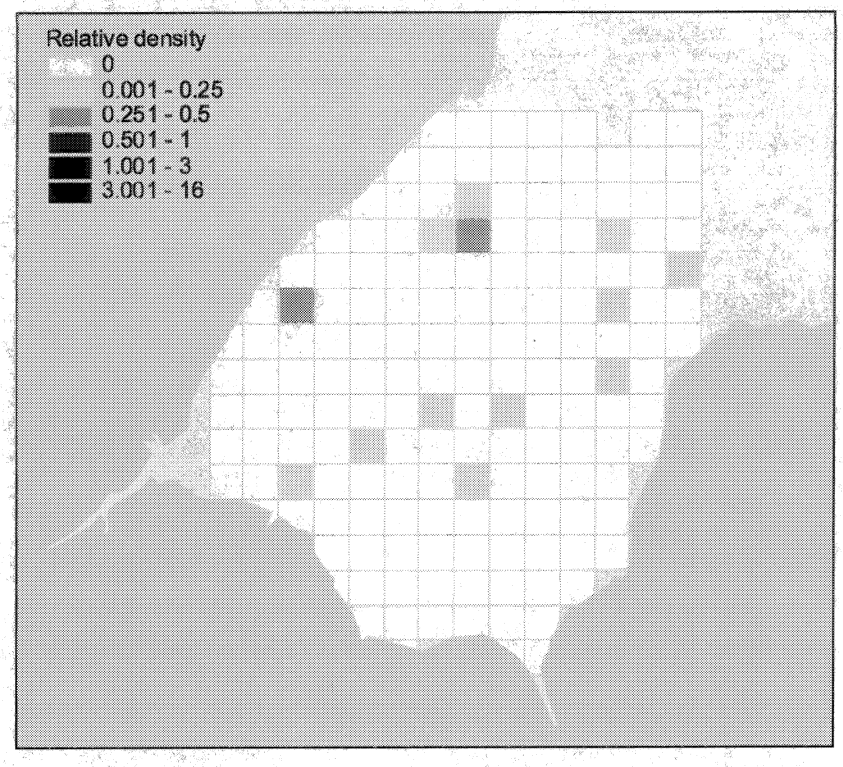

Figure 40 Relative density of divers *Gavia* spp. in the Wash during aerial surveys, February 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

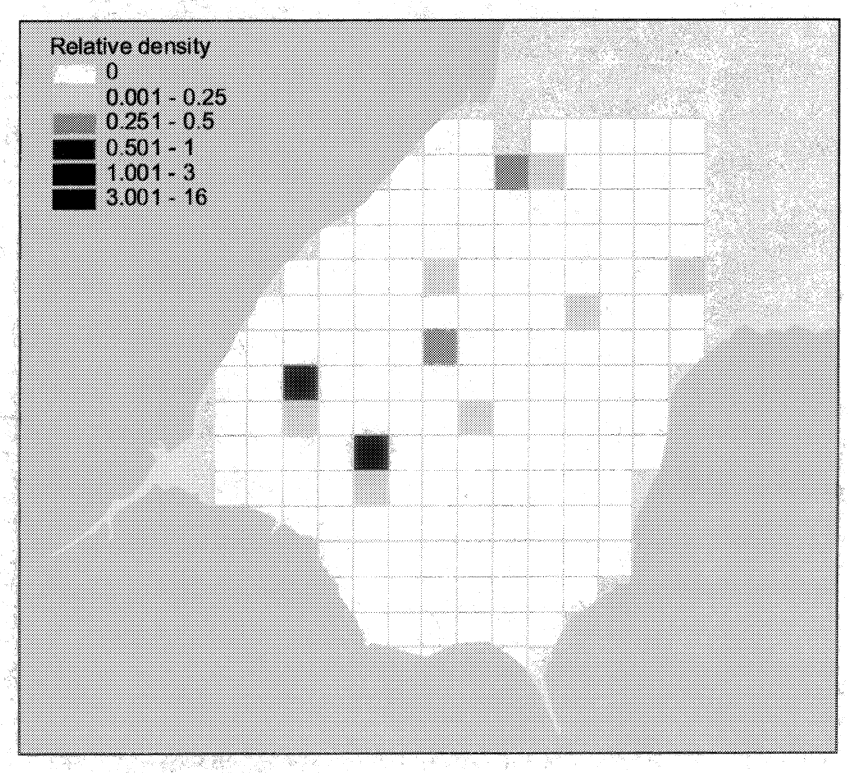

Figure 41 Relative density of divers *Gavia* spp. in the Wash during aerial surveys, March 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

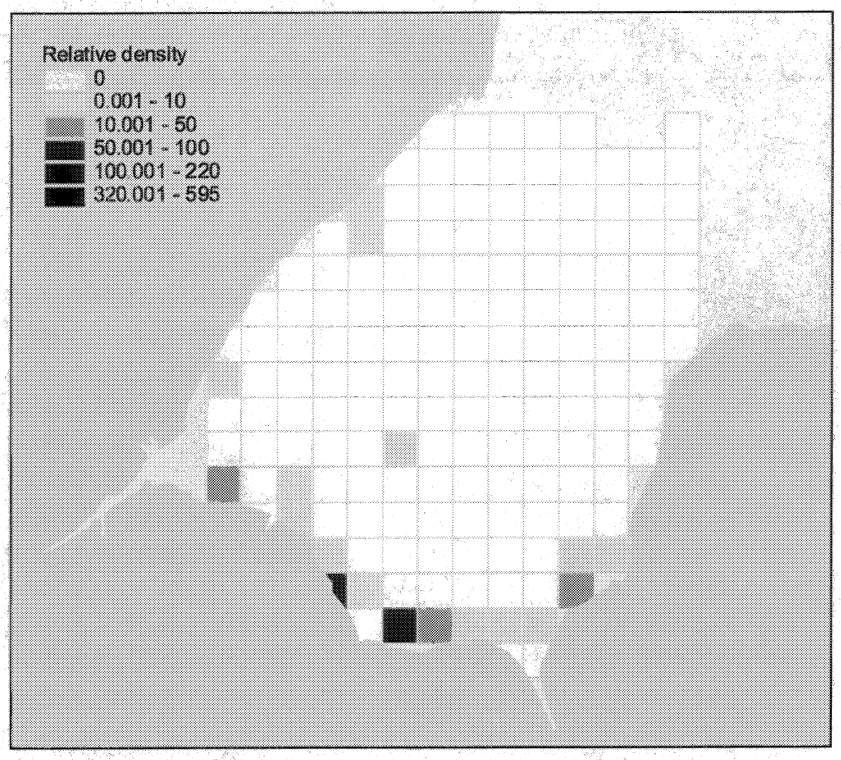

Figure 42 - Relative density of shelduck *Tadorna tadorna* in the Wash during aerial surveys, November 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

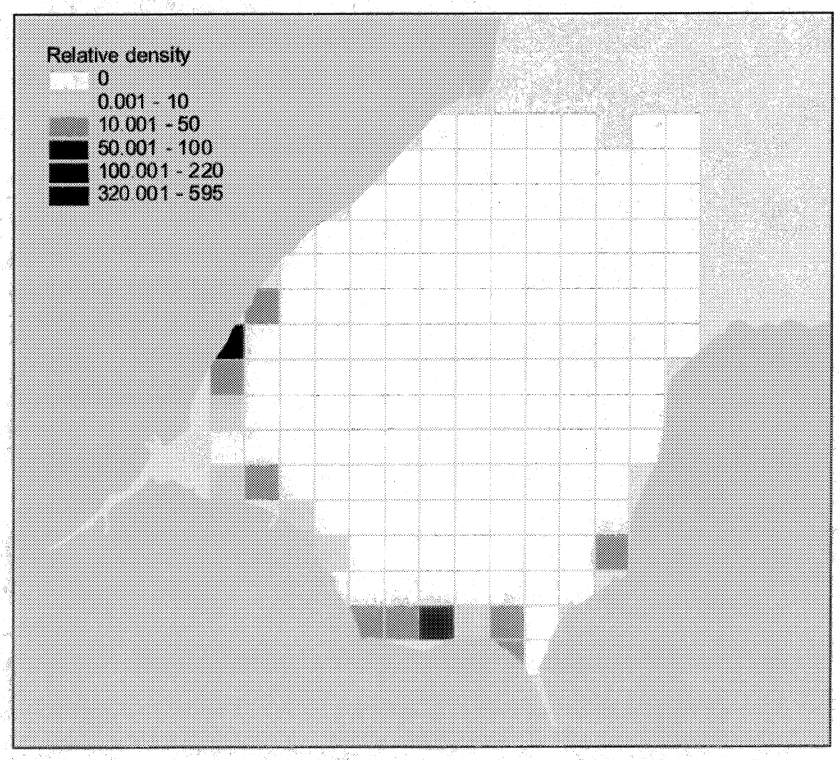

Figure 43 Relative density of shelduck *Tadorna tadorna* in the Wash during aerial surveys, December 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

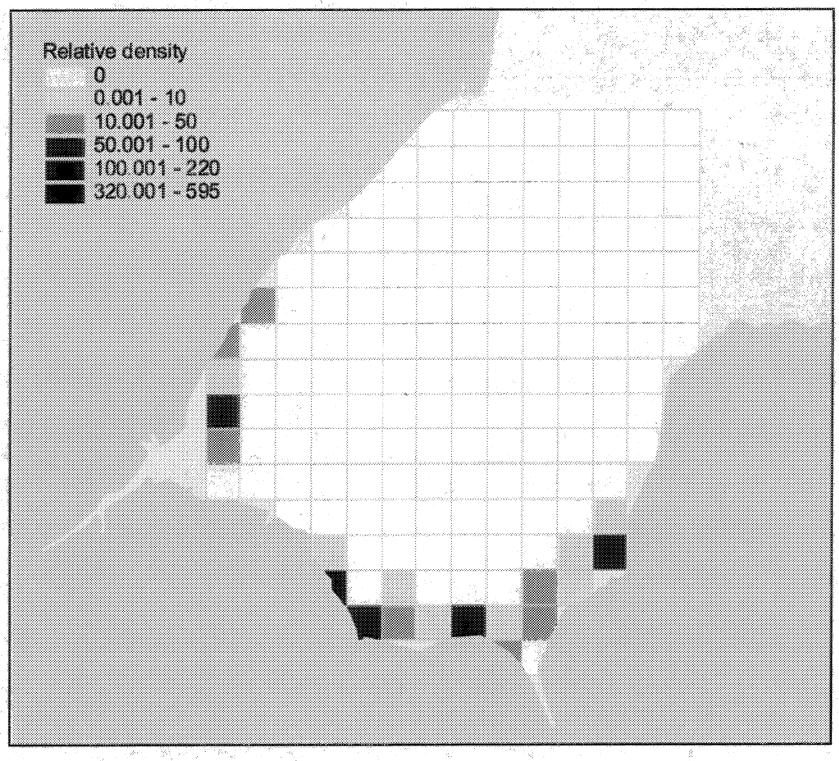

Figure 44 - Relative density of shelduck *Tadorna tadorna* in the Wash during aerial surveys, January 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

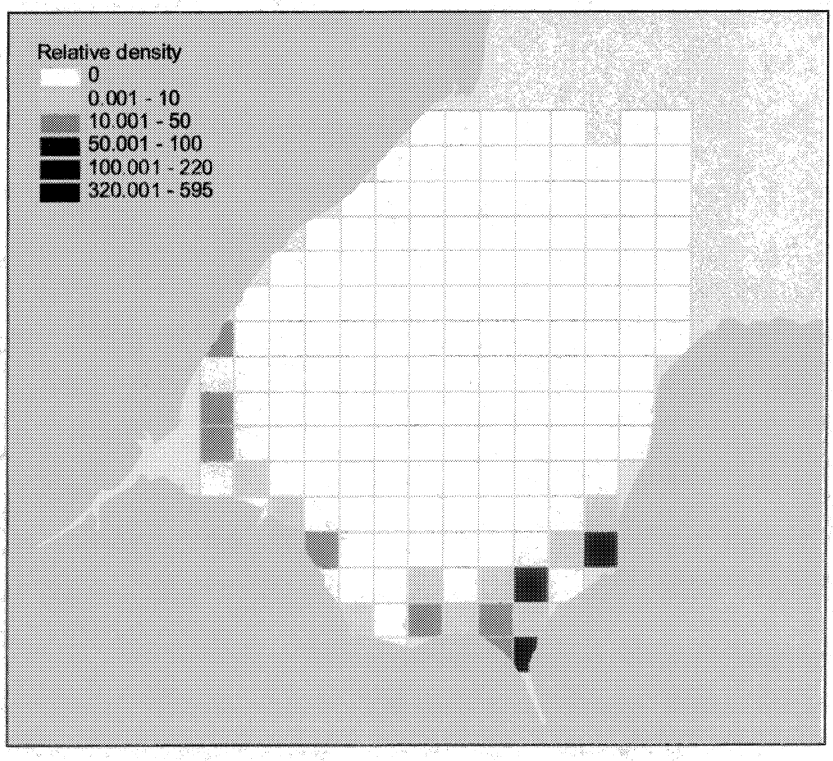

Figure 45 Relative density of shelduck *Tadorna tadorna* in the Wash during aerial surveys, February 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

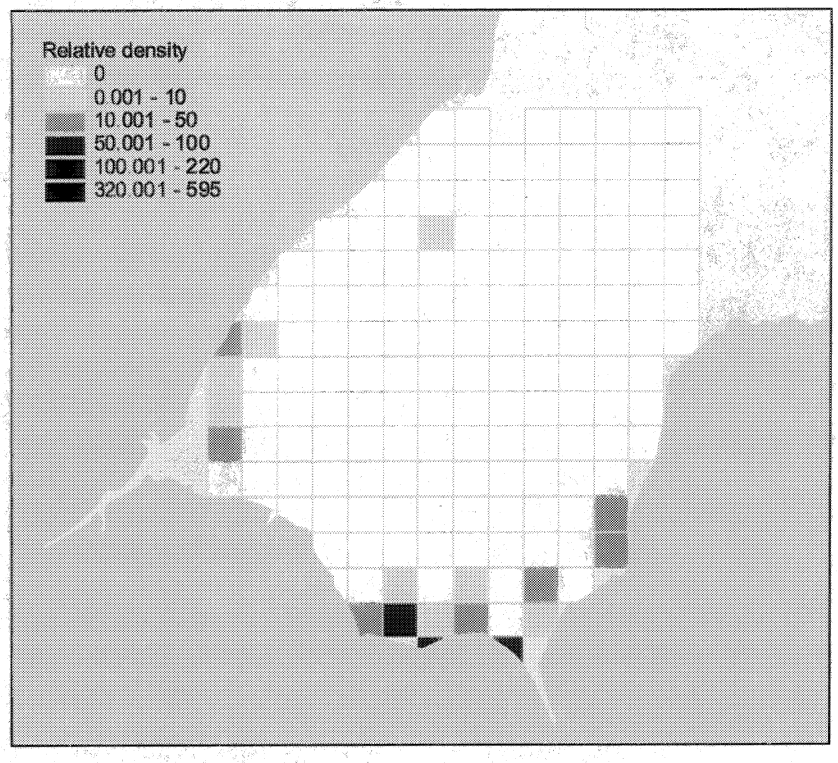

Figure 46 Relative density of shelduck *Tadorna tadorna* in the Wash during aerial surveys, March 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

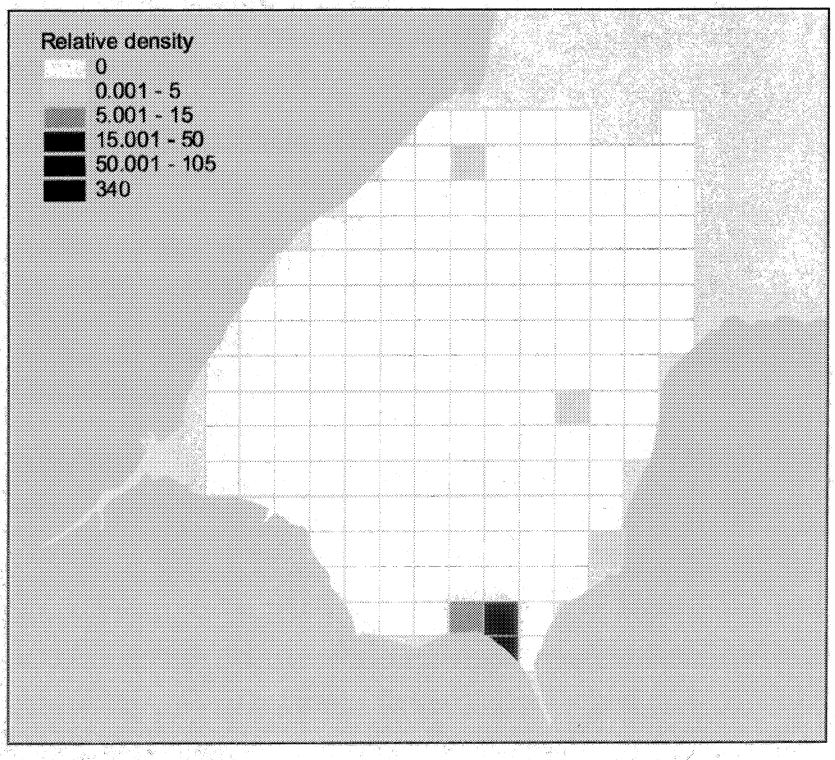

Figure 47 Relative density of ducks *Anas* spp. in the Wash during aerial surveys, November 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort

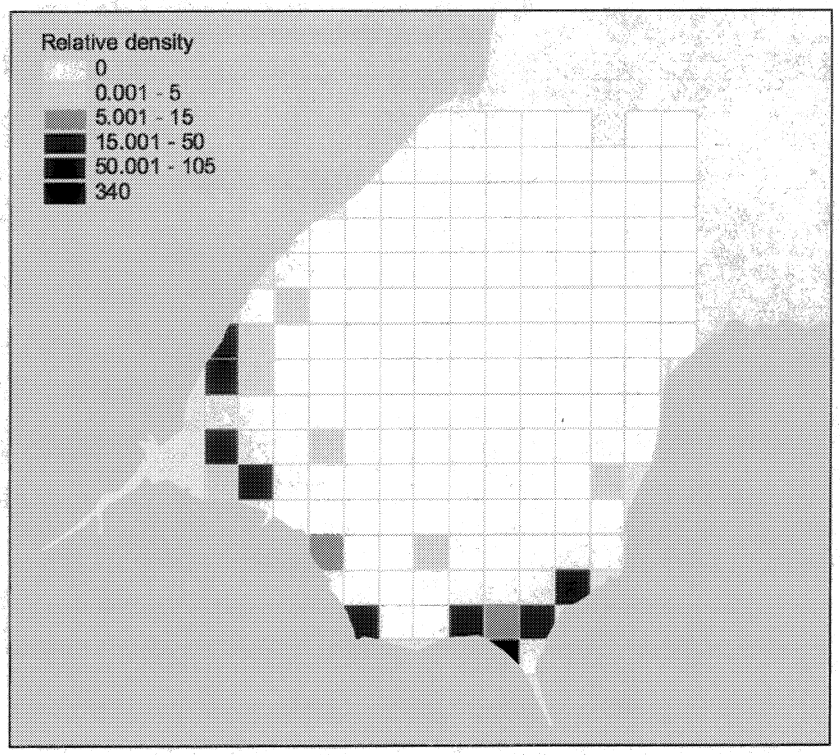

Figure 48 Relative density of ducks *Anas* spp. in the Wash during aerial surveys, December 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

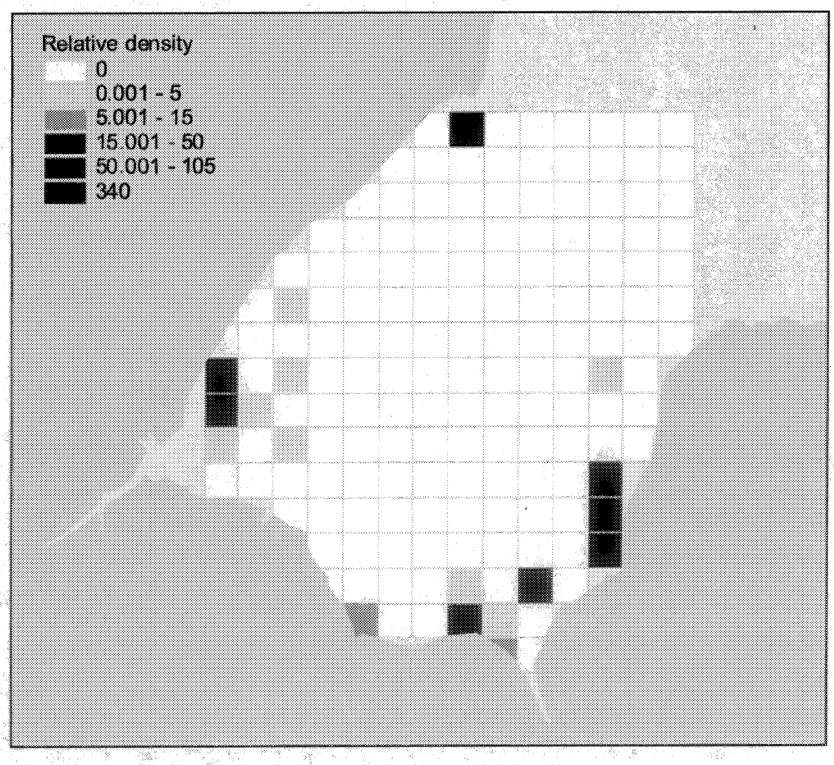

Figure 49 Relative density of ducks *Anas* spp. in the Wash during aerial surveys, January 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

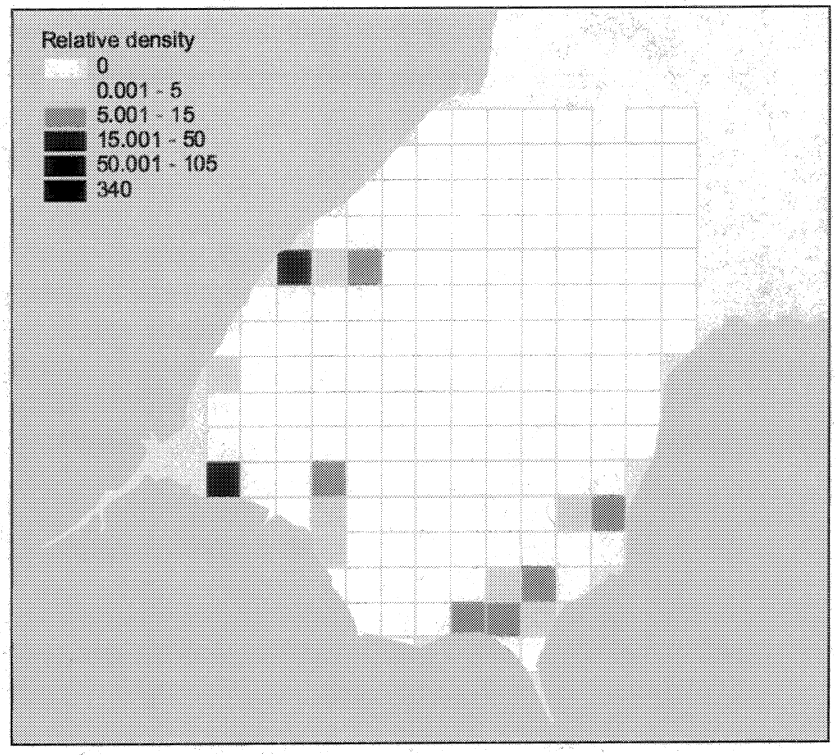

Figure 50 Relative density of ducks *Anas* spp. in the Wash during aerial surveys, February 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

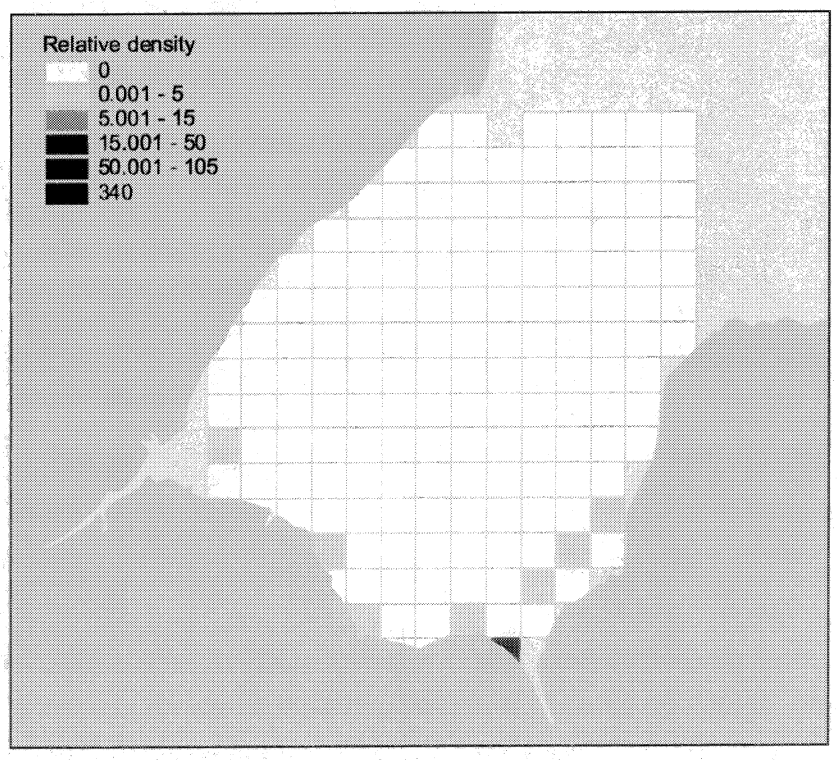

Figure 51 Relative density of ducks *Anas* spp. in the Wash during aerial surveys, March 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

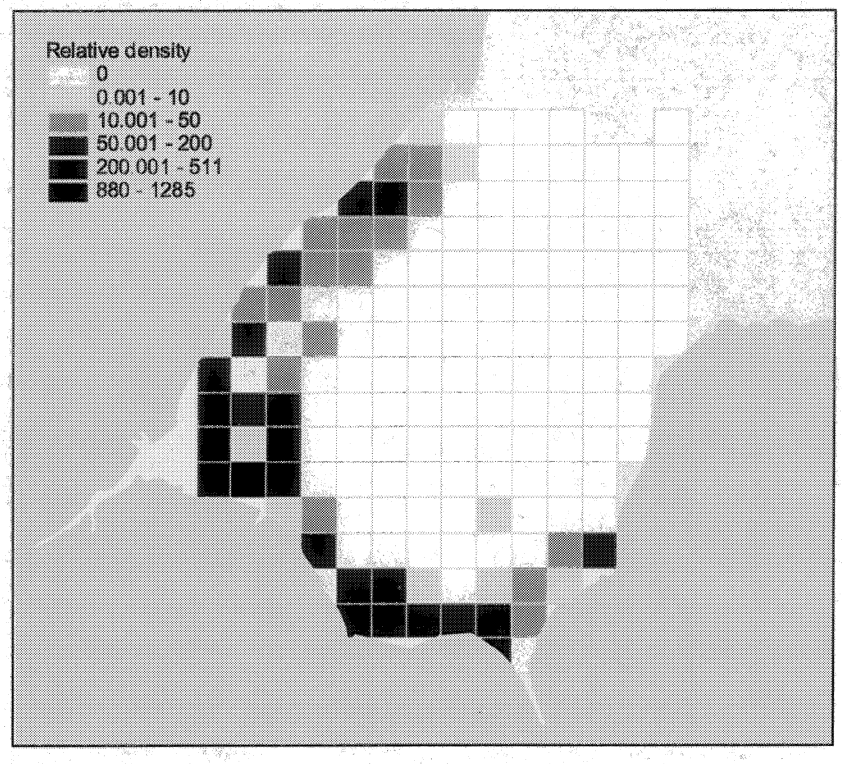

Figure 52 Relative density of waders in the Wash during aerial surveys, November 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

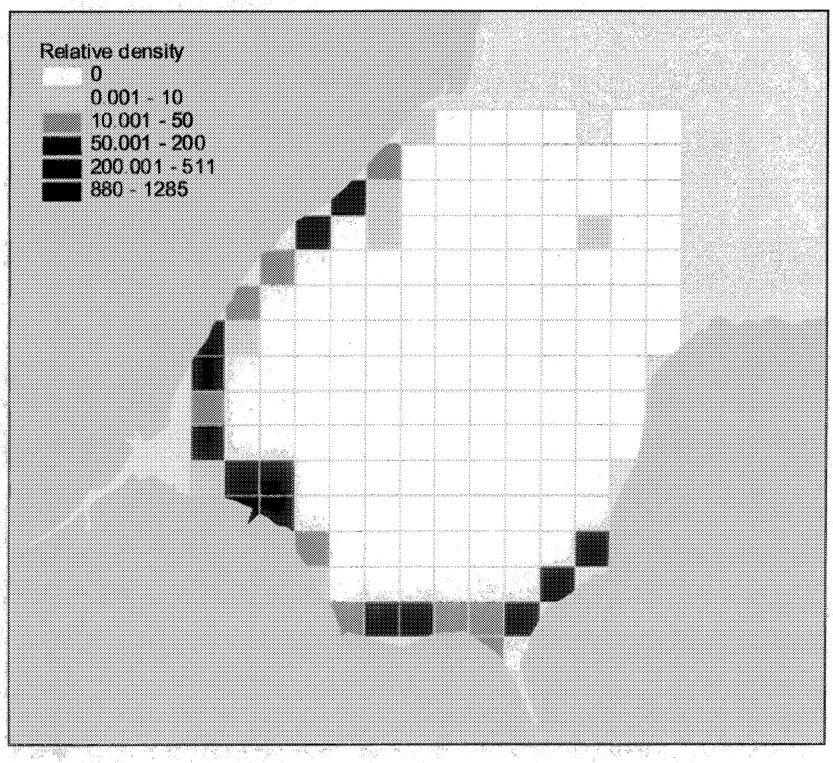

Figure 53 Relative density of waders in the Wash during aerial surveys, December 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

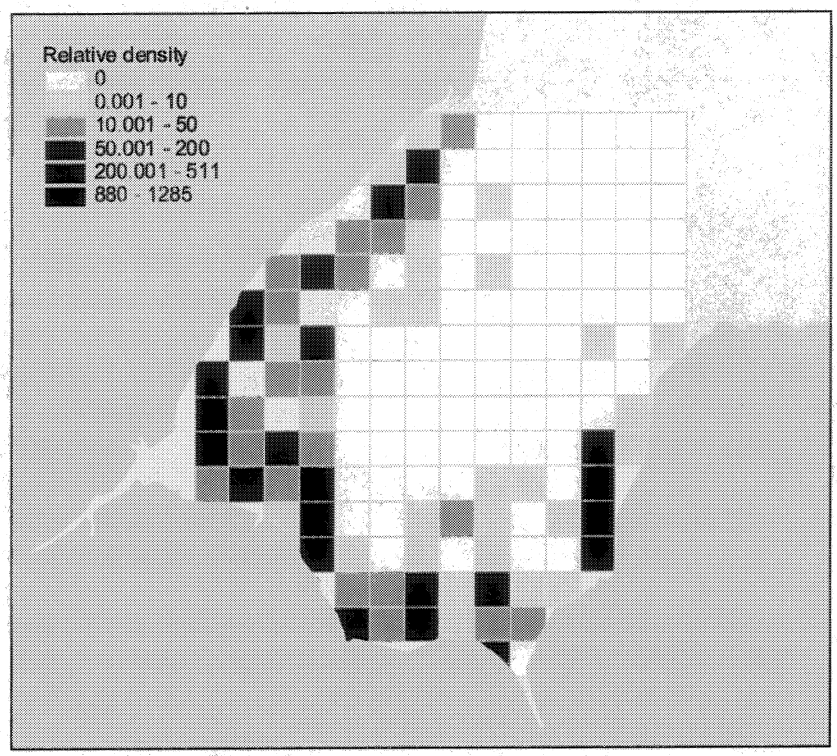

Figure 54 Relative density of waders in the Wash during aerial surveys, January 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

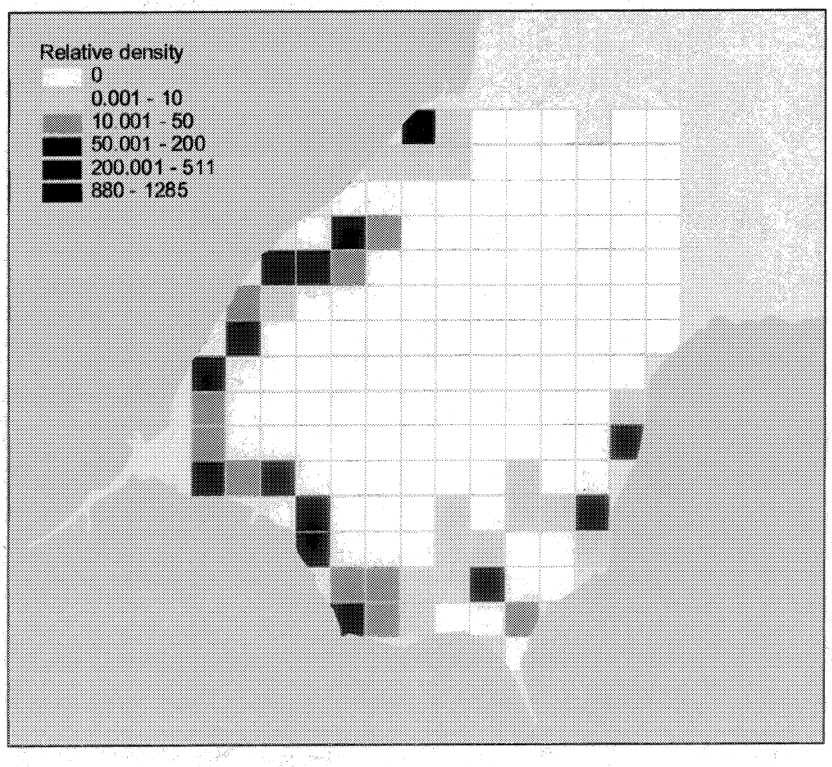

Figure 55 Relative density of waders in the Wash during aerial surveys, February 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

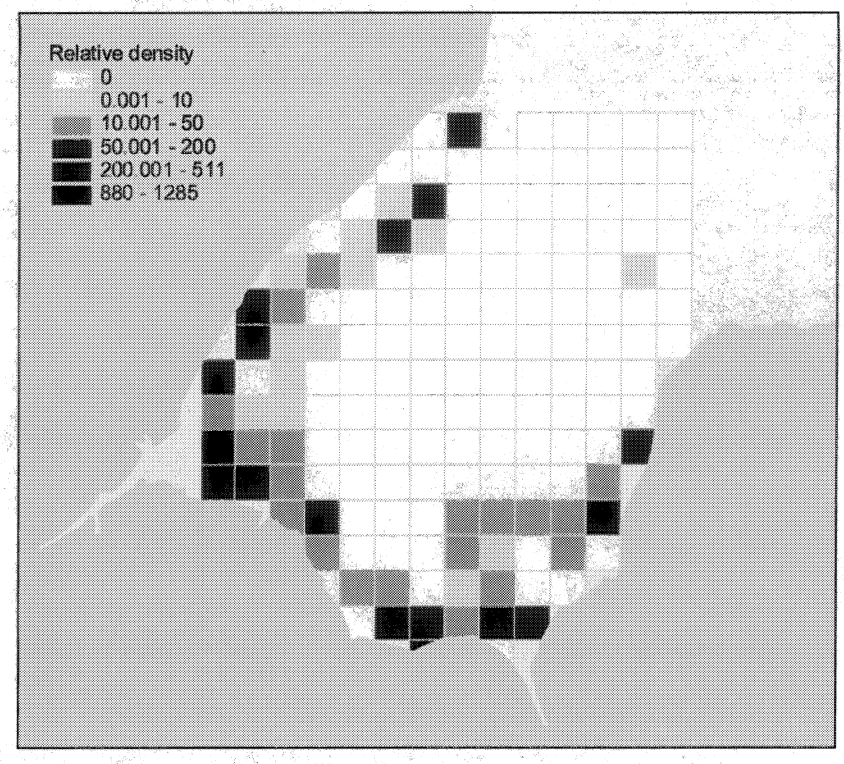

Figure 56 Relative density of waders in the Wash during aerial surveys, March 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

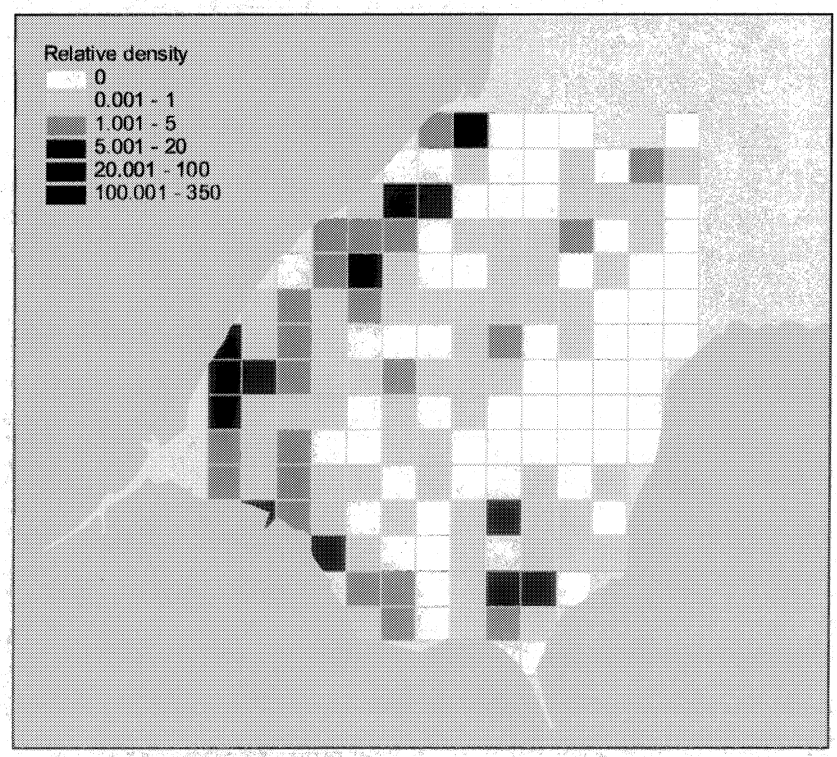

Figure 57 Relative density of gulls *Larus* spp. in the Wash during aerial surveys, November 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

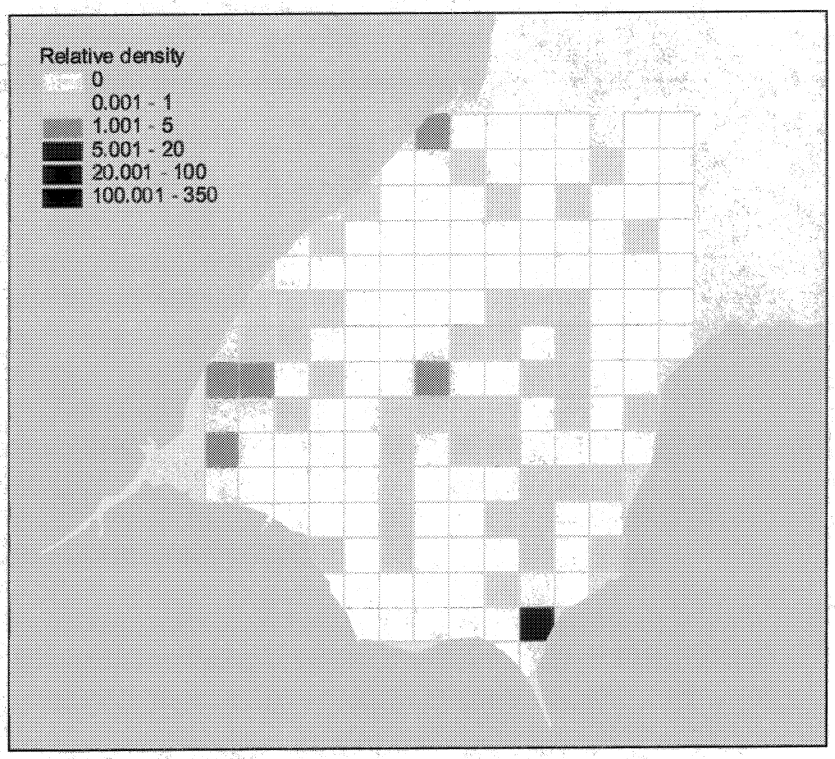

Figure 58 Relative density of gulls *Larus* spp. in the Wash during aerial surveys, December 2005. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

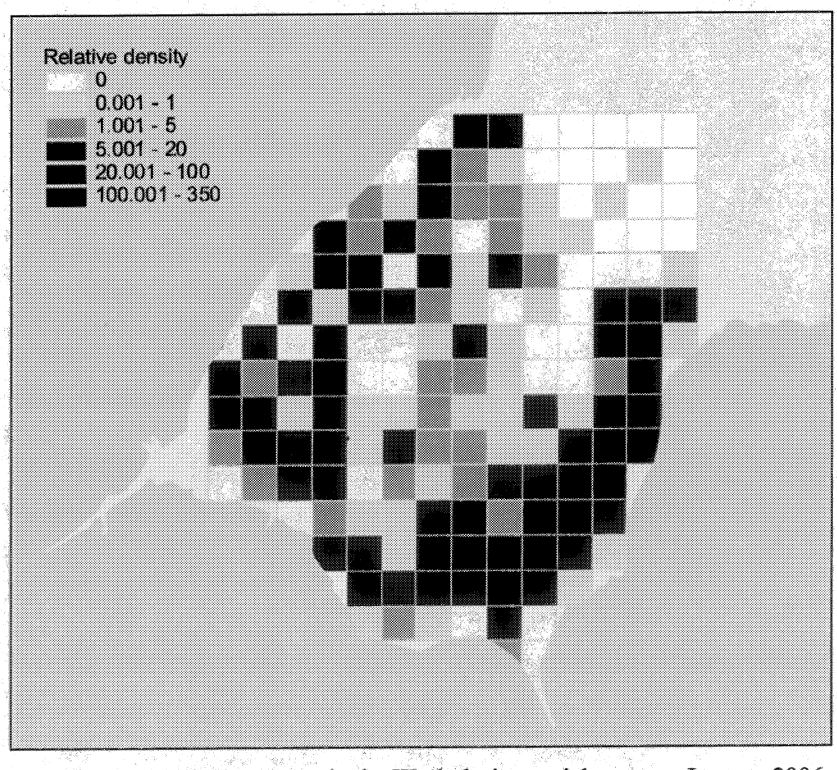

Figure 59 Relative density of gulls *Larus* spp. in the Wash during aerial surveys, January 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

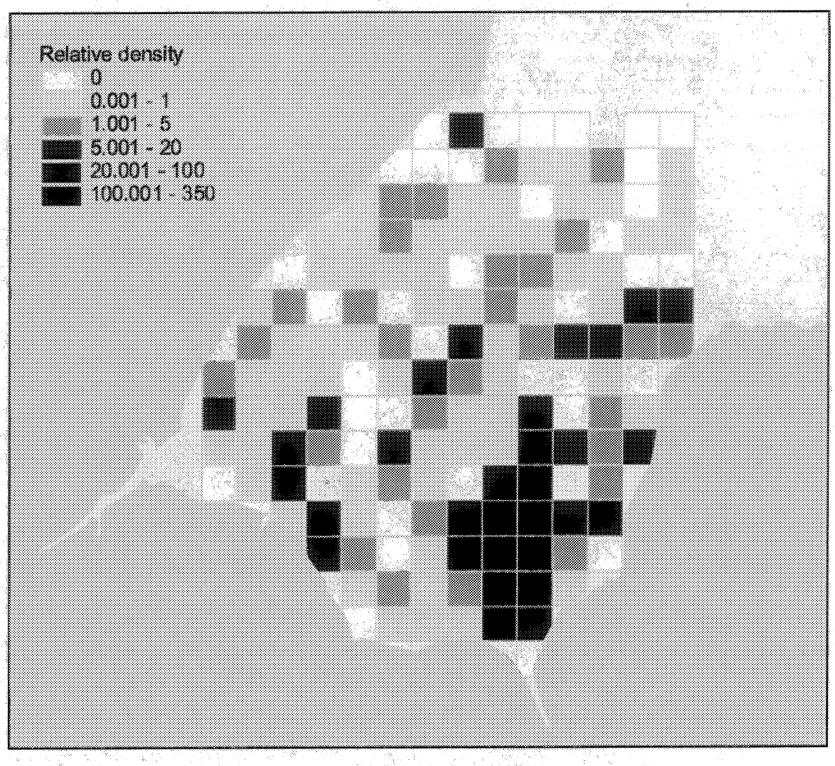

Figure 60 Relative density of gulls *Larus* spp. in the Wash during aerial surveys, February 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort

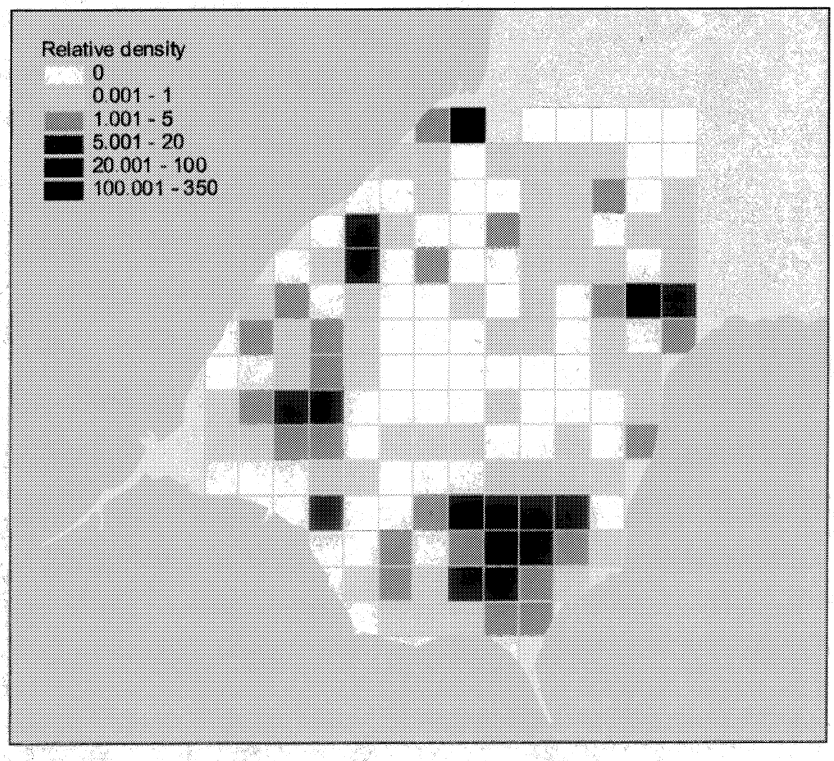

Figure 61 Relative density of gulls *Larus* spp. in the Wash during aerial surveys, March 2006. Numbers of all birds are summed by 2x2 kilometre grid squares, corrected for survey effort.

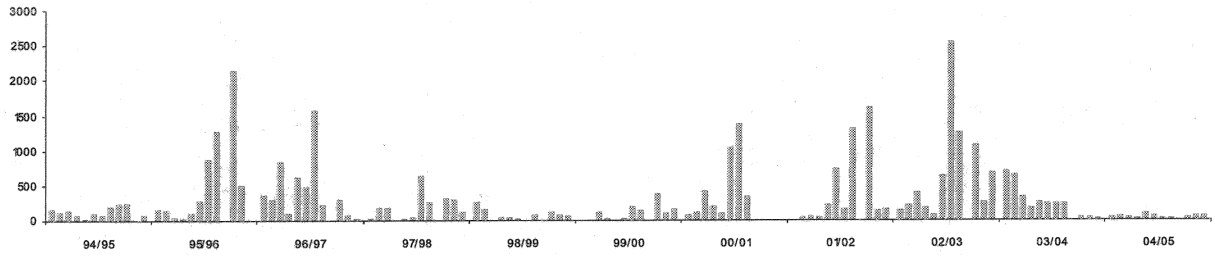

Figure 62 Total counts of eiders *Somateria mollissima* recorded by WeBS in the Wash, 1994/95 to 2004/05.

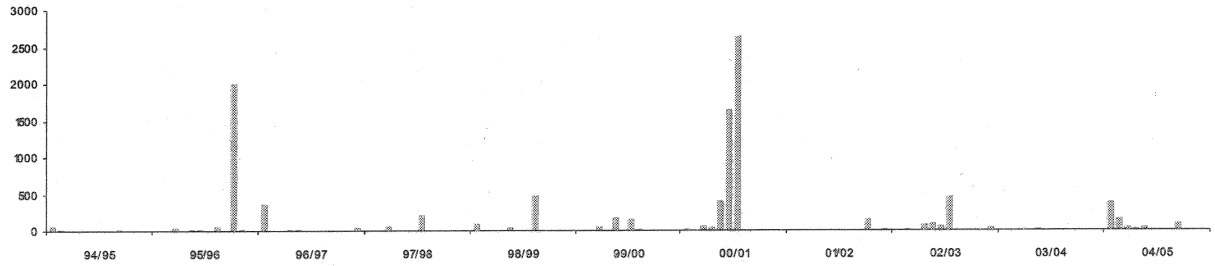

Figure 63 Total counts of common scoters *Melanitta nigra* recorded by WeBS in the Wash, 1994/95 to 2004/05.

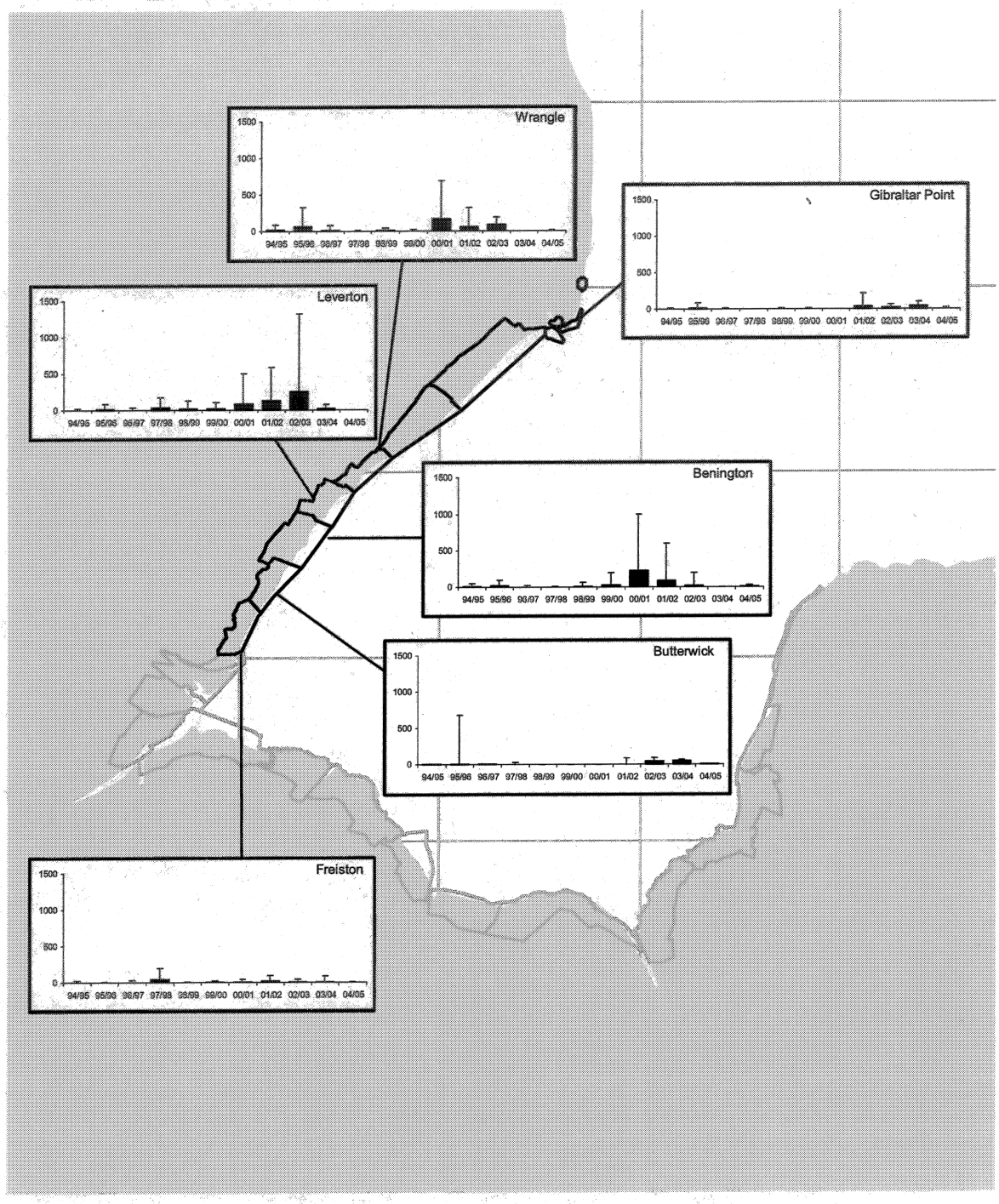

Figure 64 Average monthly WeBS counts of eiders *Somateria mollissima* in the Wash, Gibraltar Point to Freiston, 1994/95 to 2004/05. Peak counts are shown by standard error bars. Data are only given for those sectors where the monthly average exceeded ten birds in at least one year. Monthly averages are zero in years with no data (undercounts and incomplete counts are only included where they increased the monthly average; see Collier and others 2005).

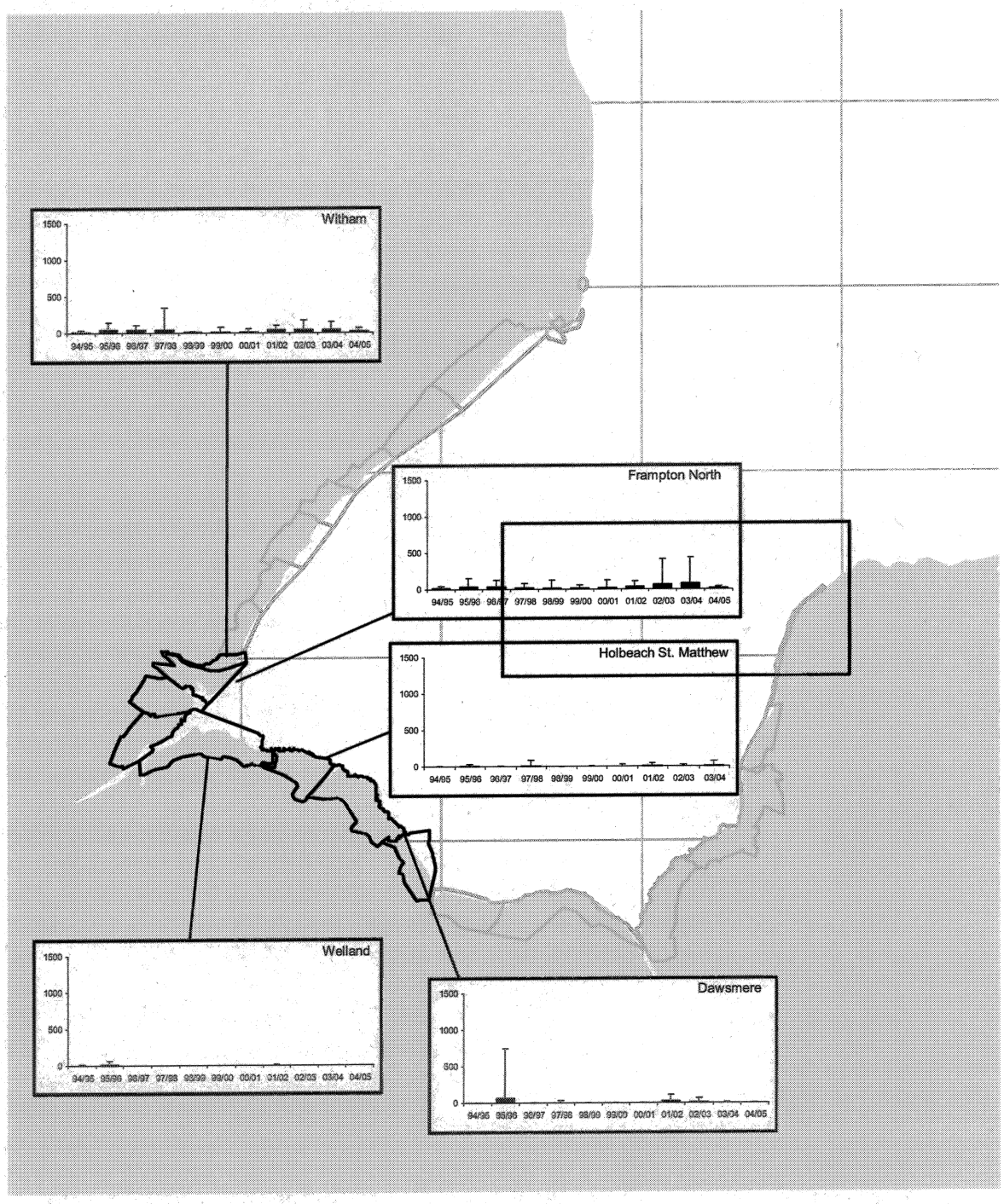

Figure 65 Average monthly WeBS counts of eiders *Somateria mollissima* in the Wash, Witham to Gedney, 1994/95 to 2004/05. Peak counts are shown by standard error bars. Data are only given for those sectors where the monthly average exceeded ten birds in at least one year. Monthly averages are zero in years with no data (undercounts and incomplete counts are only included where they increased the monthly average; see Collier and others 2005).

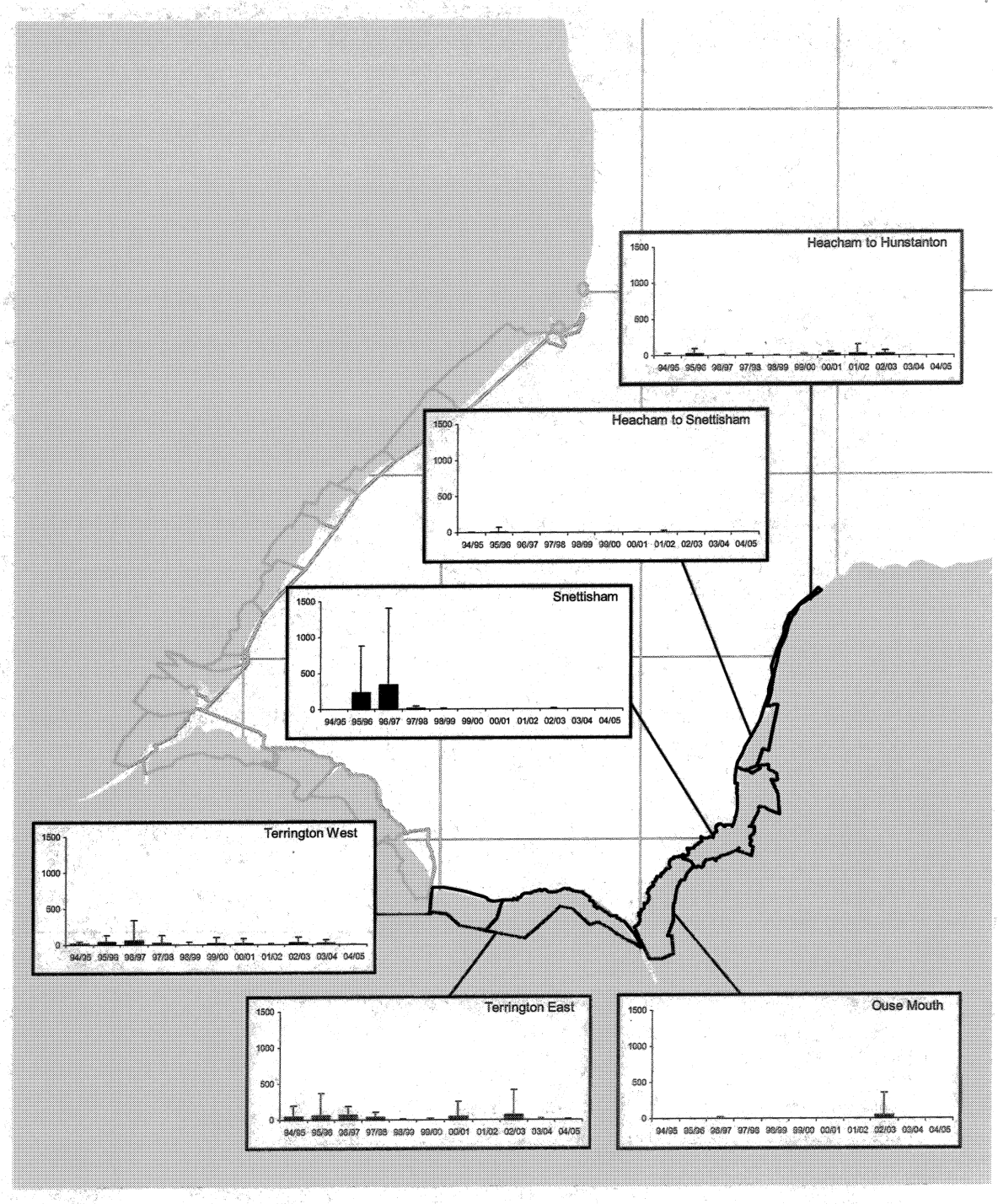

Figure 66 Average monthly WeBS counts of eiders *Somateria mollissima* in the Wash, Terrington West to Hunstanton, 1994/95 to 2004/05. Peak counts are shown by standard error bars. Data are only given for those sectors where the monthly average exceeded ten birds in at least one year. Monthly averages are zero in years with no data (undercounts and incomplete counts are only included where they increased the monthly average; see Collier and others 2005).

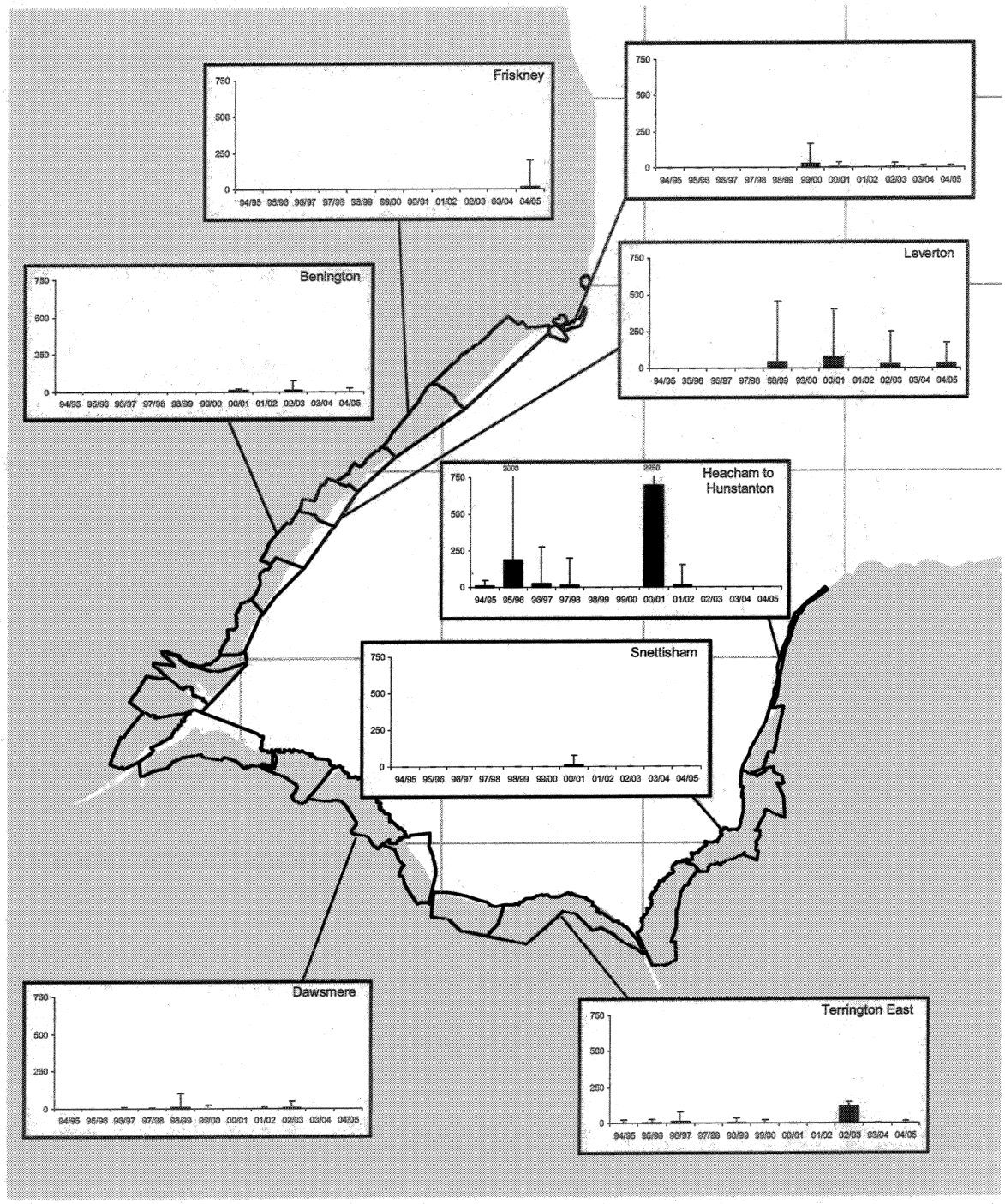

Figure 67 Average monthly WeBS counts of common scoters *Melanitta nigra* in the Wash, 1994/95 to 2004/05. Peak counts are shown by standard error bars. Data are only given for those sectors where the monthly average exceeded ten birds in at least one year. Monthly averages are zero in years with no data (undercounts and incomplete counts are only included where they increased the monthly average; see Collier and others 2005). Note, peak counts for Heacham to Hunstanton in 1995/96 and 2000/01 go beyond the scale shown; actual counts are given above the standard error bars.

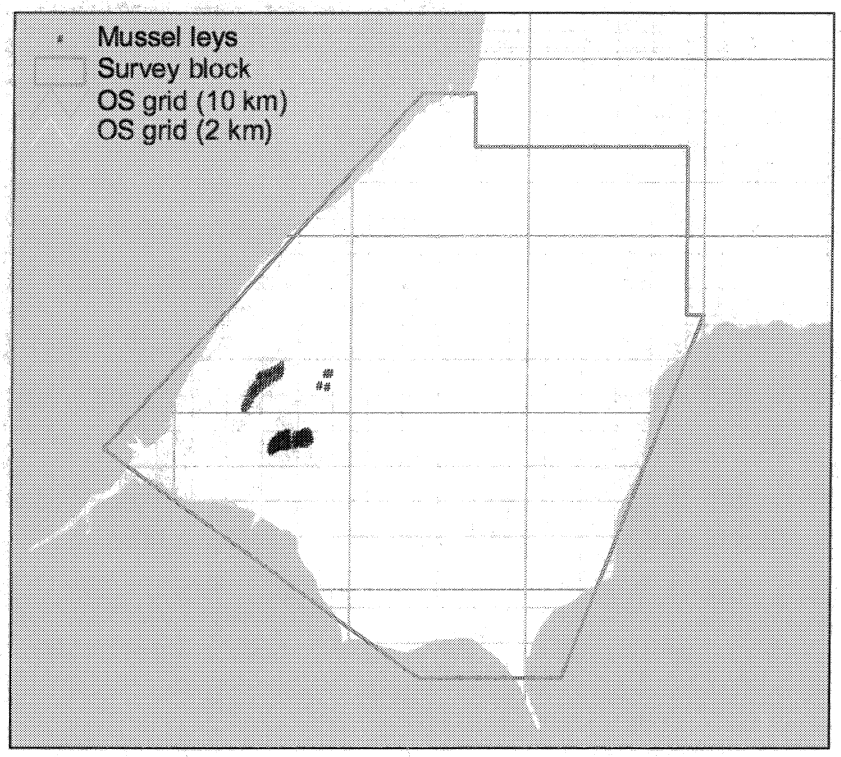

Figure 68 Mussel lays in the southwest Wash, 2005/06.

Tables

Table 1 - Numbers of birds counted during aerial survey of the Wash, November 2005 to March 2006 (Note, figures shown are not absolute numbers of birds in the survey area, which need to be calculated using 'distance' to allow for the numbers of birds missed with increasing distance from the plane).

Species	Nov	Dec	Jan	Feb	Mar
Brent Goose	255	645	290	36	595
goose sp.		22	179		
Shelduck	688	1190	1990	1204	1013
Wigeon	48	440	644	12	10
Teal	57	45		3	
Mallard	74	82	83	147	13
Pintail	14		2	42	
dabbling ducks		9			
Pochard	1				
Eider	1105	1120	2358	929	1124
Common Scoter	1311	2317	5	2051	1290
Velvet Scoter		2			
Goldeneye		2		1	
duck sp.	3	527	530	275	106
Red-breasted Merganser	5	7	13	23	33
diver sp.	22	4	25	12	21
Red-throated Diver	28	3	2	3	2
Great Northern Diver		1	1		
Great Crested Grebe	1				2
grebe sp.		1	1	7	1
Fulmar			1	5	3
Gannet	1				
Cormorant	49	22	24	18	13
Shag			2	1	
Cormorant/Shag	1	2		1	1
Oystercatcher	2444	2381	2919	1919	3089
Grey Plover		1		1	
Lapwing		1	286	230	
Knot		45	760	150	15
Dunlin			130		6
Bar-tailed Godwit			14	154	336
Curlew	1	87	53	59	16
wader sp.	3601	1138	4724	1080	4355
small wader sp.	9756	2271	2509	1829	5664
medium wader sp.	669	599	700	266	50
large wader sp.	373	401	27		2
Arctic Skua	1				
Great Skua	1				
Black-headed Gull	79	25	739	348	51
Common Gull	13	1	172	416	43
Lesser black-backed Gull	1	3	6	2	4
Herring Gull	152	37	371	140	394
Great Black-backed Gull	24	10	18	22	3
Kittiwake	33	18	3	1	
grey gull spp	107	1	1098	1064	311
black-backed gull spp	43	11	56	10	5
large gull sp.		1	4	7	9
small gull sp.	10		151	89	5
gull sp.	484	26	6003	1878	2093

Species	Nov	Dec	Jan	Feb	Mar
auk sp.	40	42	24	14	5
Fieldfare		1			
Carrion Crow				6	1
Total	21495	13541	26917	14455	20684

Table 2 - Estimated density and population size of selected waterbirds calculated using 'Distance 5.0' for aerial surveys in the Wash.

Eider	Density estimate (n/kilometre^2)	Estimated population size (95% confidence intervals)		Analysis details	
				Bands used	Transect type
Nov 05	1.26	4214	(1159, 15322)	A-C	Line
Dec 05	0.68	2412	(808, 7205)	A-C	Line
Jan 06	2.95	8765	(3436, 22362)	A-C	Line
Feb 06	0.83	2962	(1259, 6967)	A-C	Line
Mar 06	1.57	5569	(1476, 21011)	A-C	Line

Common Scoter	Density estimate (n/kilometre^2)	Estimated population size (95% confidence intervals)		Analysis details	
				Bands used	Transect type
Nov 05	2.39	5319	(1756, 16109)	A-B	Strip
Dec 05	3.26	9651	(3108, 29969)	A-B	Strip
Jan 06	0.04	21	(6, 76)	A-B	Strip
Feb 06	2.32	2751	(467, 16198)	A-C	Strip
Mar 06	9.16	5420	(806, 36459)	A-B	Strip

Shelduck	Density estimate (n/kilometre^2)	Estimated population size (95% confidence intervals)		Analysis details	
				Bands used	Transect type
Nov 05	0.47	1560	(727, 3351)	A-C	Line
Dec 05	1.18	4174	(1990, 8754)	A-C	Line
Jan 06	2.01	7145	(3953, 12914)	A-C	Line
Feb 06	0.94	3339	(1918, 5812)	A-C	Line
Mar 06	1.01	3586	(1972, 6519)	A-C	Line

Divers	Density estimate (n/kilometre^2)	Estimated population size (95% confidence intervals)		Analysis details	
				Bands used	Transect type
Nov 05	0.21	233	(100, 548)	A-C	Line
Dec 05	0.06	38	(15, 99)	A-C	Line
Jan 06	0.10	123	(55, 272)	A-C	Line
Feb 06	0.26	154	(71, 336)	A-C	Line
Mar 06	0.08	93	(42, 205)	A-C	Line

Waders	Density estimate (n/kilometre^2)	Estimated population size (95% confidence intervals)		Analysis details	
				Bands used	Transect type
Nov 05	16.29	54466	(36566, 81129)	A-C	Line
Dec 05	7.62	27061	(14058, 52088)	A-C	Line
Jan 06	11.25	40074	(26265, 61144)	A-C	Line
Feb 06	6.08	21645	(13986, 33499)	A-C	Line
Mar 06	18.26	64866	(40930, 102798)	A-C	Line

Table 3 Number of selected species groups counted during aerial survey of the Wash, 2005/06. (Note, figures shown are not absolute numbers of birds in the survey area, which need to be calculated using 'distance' to allow for the numbers of birds missed with increasing distance from the plane). See text for details of species groups.

Species group	Nov	Dec	Jan	Feb	Mar
Anas spp	196	1103	1259	479	129
Seaducks	2424	3975	2906	3279	2553
Cormorants	50	24	26	20	14
Divers	50	8	28	15	23
Waders	16,844	6924	12,122	5688	13,533
Gulls	946	133	8621	3977	2918

Table 4 - Recent surveys of seaducks and other waterbirds in the Wash.

Year	Season	Survey	Reference
1960- 2004	Summer and Winter	Wetland Bird Survey	BTO pers comm.
1976	Summer and winter	Low tide survey (waders)	Goss-Custard, J.D., Jones, R.E., & Newberry, P.E. 1977. The ecology of the Wash. 1. Distribution and diet of wading birds (Charadrii). *Journal of Applied Ecology,* 14, 681-700.
1979-1991	Summer and winter	Boat and aerial surveys	Stone, C.J., Webb, A., Barton, C., Ratcliffe, N., Reed, T.C., Tasker, M.L., Camphuysen, C.J., & Pienkowski, M.W. 1995. *An atlas of seabird distribution in north-west European waters.* Peterborough: Joint Nature Conservation Committee.
1981-1984	Winter	Winter Atlas	Lack, P.C. 1986. *The atlas of wintering birds in Britain and Ireland.* Calton: Poyser.
1984	Winter	Boat and aerial surveys	JNCC pers comm.
1984/85	Winter	Winter Shorebird Count	Moser, M.E., & Summers, R.W. 1987. Wader Populations on the non-estuarine shores of Britain and Northern Ireland: results of the 1984-85 Winter Shorebird Count. *Bird Study* 34, 71-78.
1985-1987	Winter	Low Tide Survey	Goss-Custard, J.D., & Yates, M.G. 1988. *Wash birds and invertebrates.* London: ITE Report to the Dept of Environment.
1988-1991	Summer	Breeding bird survey	Gibbons, D.W., Reid, J.B., & Chapman, R.A. 1993. *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991.* London: T&AD Poyser.
1989	Summer and winter	Aerial survey	Barton, T.R., Barton, C., Carter, I.C., & Webb, A. 1993. Seabird distribution in inshore waters between Flamborough Head and Dungeness from aerial surveys in 1989. *Joint Nature Conservation Committee Report*, No 182.

Year	Season	Survey	Reference
1989-1992	Winter	Low tide survey	Yates, M.G., Goss-Custard, J.D., & Rispin, W.E. 1996. Towards predicting the effect of loss of intertidal feeding areas on overwintering shorebirds (Charadrii) and shelduck (*Tadorna tadorna*): refinements and tests of a model developed for the Wash, east England. *Journal of Applied Ecology*, 33, 944-954.
1991	Winter	Low tide survey	Yates, M.G., & Goss-Custard, J.D. 1991. A comparison between high water and low water counts of shorebirds on the Wash, east England. *Bird Study*, 38, 179-187.
1992	Winter	Boat survey	JNCC pers comm.
1995-2005	Summer and winter	*Ad hoc* observations	Lincolnshire Bird Reports (1994-1996); Norfolk Bird Reports (1994-2004)
1997-2005	Winter	Low tide survey	Binnie, Black & Veatch. 1997. *Denver Licence Monitoring Study. Denver Licence Variation 1st Monitoring Group Meeting, Agenda and Reports*. Redhill: Binnie, Black and Veatch.
2003-2006	Winter	Gull roost survey	Banks, A.N., Burton, N.H.K., *et al.* (in prep) *Results of the UK and Isle of Man Winter Gull Roost Survey 2003-2006.* BTO Research Report. BTO, Thetford.
2002-2003	Winter	Low tide survey	Yates, M.G., Garbutt, A., Rispin, E., & Brown, N. 2004. Low tide survey of The Wash Special Protection Area: Final report of the winter 2002-2003 shorebird survey. *English Nature Research Reports, No.* 589.
2005/06	Winter	Boat survey	Hart, J., & Brown, S. 2006. *Deterring Eider predation of commercial mussel lays in the Wash Estuary: the effectiveness of non-lethal scaring devices.* Draft Report. Central Science Laboratory, Sand Hutton, York.

Table 5 - Significant counts of seaducks reported in Norfolk (1994-2004) and Lincolnshire (1994-1996) County Bird Reports.

Year	Eider	Scoter	Diver spp.
1994			
Hunstanton	130 (Jan)	--	--
Gibraltar Point		85 (May)	46 (Jan)
Benington	101 (July)	--	--
1995			
Terrington	197 (March)	--	--
Gibraltar Point	--	110 (Jan)	147 (Jan)
Frampton Marsh	75 (April)	--	--
1996			
Snettisham	1000 (Dec)		--
Hunstanton	--	2000 (Mar/April)	--
Gibraltar Point		--	202(Feb)
Dawsmere	750 (April)	--	--
Witham Mouth		100 (July)	--
1997			
Hunstanton	800 (Feb)	300 (Jan/Feb)	3 (Feb)
1998			
Hunstanton	120 (Jan)	2500 (April)	2(Sept-Dec)
1999			
Hunstanton	170 (Dec)	2000 (Mar/April)	2 (Oct)
2000			
Hunstanton	170 (Feb)	4000 (Mar/April)	3 (Nov)
2001			
Hunstanton	150 (Dec)	2250 (Jan)	12 (Dec)
2002			
Hunstanton	181 (Jan)	--	1 (Sept/Nov Dec & April)
2003			
Hunstanton	60 (Jan/Feb)	--	-
2004	--	--	--

ENGLISH NATURE

Research Information Note

English Nature Research Reports, No. 708

Aerial surveys of waterbirds in The Wash, 2005/06

Report Authors: L Smith, C Hall, J Worden, AL Harrison, L Allen, G Bradbury, PA Cranswick, R Woodward, P Shepherd, D Paynter & M McGill. Date: August 2006
Keywords: seaduck, waterbirds, Wash, scoter, eider, aerial survey

Introduction

Data on the numbers and distribution of waterbirds and seabirds in UK inshore waters are required for a variety of purposes, including 'condition monitoring' of European sites and also nationally important Sites of Special Scientific Interest.

English Nature (EN) has a responsibility to undertake and co-ordinate condition monitoring of sites such as the Wash, classified as a Special Protection Area because of its importance for wintering waterbirds and part of the EN Natura 2000 Network of important sites for wildlife.

It is acknowledged that there is an information gap on the use of The Wash by wintering seaducks and seabirds that is not covered by existing monitoring schemes and surveys. English Nature therefore commissioned WWT Consulting (formerly the WWT Wetlands Advisory Service) to undertake a baseline survey of the numbers and distribution of seaducks and seabirds wintering in The Wash.

What was done

The report presents results from aerial surveys of the Wash between November 2005 and March 2006, and summarises seaduck data collected by other recent surveys of the site.

Aerial surveys used for this report were undertaken using a methodology recently developed in Denmark by the National Environment Research Institute (NERI). A series of transects spaced 2 kilometre apart was designed to cover nearshore waters. A Partenavia PN68 aircraft was used, flying at an altitude of 250 ft and at a speed of approximately 200 kilometreh^{-1}.

For each bird or flock of birds, the species, number, behaviour, distance band and the time at which it was perpendicular to the flight path of the plane were recorded. Surveys were generally made during a two-hour period centred on midday GMT to minimise the effects of glare on counts. Surveys were undertaken in good weather conditions, generally with winds of 15 knots or less.

A review of relevant literature was undertaken to assess numbers of seaducks, seabirds and divers in The Wash. Recent Wetland Bird Survey (WeBS) data were also assessed to determine numbers and distribution of seaducks and divers in the survey area.

Results and conclusions

Counted totals of waterbirds from aerial surveys were characterized by large numbers of wader and gull species, concentrated mostly on exposed intertidal areas which provide feeding and loafing

Continued .....

habitat. Moderate numbers of common scoters and eiders were found in high densities in shallow water, usually forming discrete, large flocks with a limited and localised distribution.

Total numbers of waterbirds and seabirds fluctuated considerably between months, mainly due to variation in wader and gull numbers. One of the major factors determining bird distribution was tidal state, affecting feeding and loafing areas for many species, both intertidal and submerged shellfish beds.

Between 13,500 and 27,000 waterbirds and seabirds were counted in each month between November and March.

Aerial surveys consistently recorded around 1000 eiders throughout the winter during aerial survey, with the exception of a peak of over 2300 birds in January.

The numbers of common scoters encountered in The Wash varied through the winter. Counted numbers increased from around 1300 in early winter to around 2300 in mid winter, then declined again to around 1300 in March.

The Wash is a large site, with extensive areas of shallow water, and low elevation of surrounding land, limiting the efficacy of waterbird survey techniques. Aerial survey has provided comprehensive coverage of the whole site at a variety of tidal states.

Aerial surveys provided representative data on the numbers and precise spatial information on the distribution of seaducks, divers and seabirds using The Wash during winter 2005/06, comparable to, or of higher quality, than other recent surveys.

English Nature's viewpoint

This is an important piece of work which increases our understanding of the use of The Wash by seabirds, information on which is not effectively gathered by existing monitoring schemes and survey techniques.

Selected references

CAMPHUYSEN, C.J., FOX, A.D., LEOPOLD, M.F., & PETERSEN, I.K. 2004. *Towards standardised seabird at sea census techniques in connection with environmental impact assessments for offshore wind farms in the UK: a comparison of ship and aerial sampling methods for marine birds, and their applicability to offshore wind farm assessments.* NIOZ report to COWRIE.

WWT WETLANDS ADVISORY SERVICE. 2005. *Aerial Surveys of Waterbirds in Strategic Windfarm Areas: 2004/05 Final Report.* WWT Wetlands Advisory Service Report to Department of Trade and Industry.

YATES, M.G., GARBUTT, A., RISPIN, E., & BROWN, N. 2004. Low tide survey of The Wash Special Protection Area: Final report of the winter 2002-2003 shorebird survey. *English Nature Research Reports*, No. 589.

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