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Monitoring the Use Made of *Chara intermedia* Beds by Waterbirds on Hickling Broad During the 2000/2001 Winter

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EXECUTIVE SUMMARY

1. The intended cutting programme for the *Chara intermedia* beds at Hickling Broad did not take place in summer 2000, due to the poor growth of *Chara*. The aim of this winter's waterbird monitoring was to collect baseline data and identify other factors, such as disturbance, which had an influence on waterbird distribution.

2. Monthly maximum counts of Pochard, Tufted Duck and Coot during winter 2000/2001 showed that numbers of these species were much lower than in the previous winter, particularly during the first three months. This may be due to the lower biomass of *Chara* in the Broad this winter.

3. Pochard distribution did not appear to be significantly affected by *Chara* biomass, but bird densities were significantly reduced by the presence of windsurfers and yachts or sailing boats.

4. Once Whiteslea and Heigham Corner, two sectors where *Chara* had not been sampled, were excluded from the analysis, Tufted Duck distribution did not appear to be affected by the distribution of *Chara*. It is likely that birds were feeding on other plants growing in the Broad, as well as other organisms such as invertebrates. In areas of lower *Chara* biomass, these may have been more accessible. Tufted Duck densities were negatively affected by the presence windsurfers and rowing boats.

5. Coot distribution was significantly affected by *Chara* biomass, with bird density increasing with increased biomass. Coot density was also higher on the proposed Cut sectors than on the proposed Uncut sectors, highlighting the need for two winters of monitoring bird distribution when cutting does take place reversing the sampling protocol between winters. Windsurfers and yachts had a negative impact on Coot density.

6. The species of dabbling duck identified as likely to feed on *Chara intermedia* were largely absent from the Broad in winter 2000/2001, as in the previous winter. Mute Swan were also scarce this winter. This is probably due to a combination of high water levels and reduced growth of *Chara* preventing these birds from reaching the plants.

7. Although the findings of this winter's study are not conclusive, they support evidence, particularly for Coot, for a relationship between waterbird numbers at Hickling Broad and the abundance of *Chara intermedia*. This is reflected in the low numbers present on the Broad this winter and the significant relationship between Coot density and *Chara* biomass.

8. Further monitoring of the abundance and distribution of waterbirds is recommended. A suite of matched pairs of cut and uncut sectors would ideally be monitored over two winters. To make the analysis very robust the cutting treatment would be reversed during the second winter to make it possible to account for natural differences in the physical nature and geographical position of the sectors. Measurements of the depletion rates of *Chara intermedia* on the cut and uncut sectors would make it possible to estimate whether the decline in waterbirds occurred as a result of food depletion or environmental factors that are unrelated to food supply. It is also advised that foraging rates be measured for each sector type.

9. Between 5,000 – 10,000 gulls congregated on the Broad by sunset on each monthly monitoring occasion. More probably arrived after this time. Recommendations are made to monitor the gull roost more intensively during the winter in order to collect information on the potential amount of nutrient enrichment being caused by the gulls. Nutrient loading by gulls can play an important role in the nitrogen and phosphorous cycles, which are significant factors in determining the state of the Broad.

10. Other species of conservation interest observed either on or around the Broad include Bittern, Bewick's Swan, Pink-footed Goose, Red-crested Pochard, Smew, Marsh Harrier, Hen Harrier, Common Crane, Jack Snipe, Mediterranean Gull, Little Gull, Barn Owl, Kingfisher, Water Pipit, Cetti's Warbler and Bearded Tit.

1. INTRODUCTION

Hickling Broad is located within a large area of low-lying land in east Norfolk and forms part of a nationally and internationally important area for nature conservation. It is the largest of The Broads and one of the oldest and most extensive areas of open water in southeast England. It is part-owned and part-leased by the Norfolk Wildlife Trust and is managed as a nature reserve. It lies within a National Nature Reserve (NNR) and forms part of the Upper Thurne Broads and Marshes Site of Special Scientific Interest (SSSI). The latter is a component of The Broadland Special Protection Area (SPA), designated under the European Birds Directive, is a part of the Broads candidate Special Area of Conservation (cSAC), and is proposed for designation under the European Habitats Directive. Hickling Broad also forms part of the Broadland Ramsar site and the Hickling Broad and Horsey Mere Ramsar site.

Until the late 1960s, Hickling Broad was in sound ecological condition, with clear water and a rich aquatic flora of submerged and floating plants. In the late 1960s, large numbers of Black-headed Gulls *Larus ridibundus* began to regularly roost on the broad, and the faeces from the birds, in addition to increased nutrient input from land-drainage water through changing farming practices, caused a significant increase in the phosphorous levels in the water (George 1992, Marren 1994, Bales *et al.* 1993). As a result of the change in water quality, dense plankton blooms became more frequent and the broad became eutrophic. The rate of sediment deposition also increased primarily due to the fall-out of dead and dying algae. Lack of light and physical smothering led to the rapid decline in the macrophyte flora of the Broad. Following a major programme of removing siltation in the early 1990s and a decline in the size of the gull roost, the nutrient levels in the Upper Thurne Broads have gradually fallen. The declining amounts of phosphorous available for plant life resulted in Hickling Broad beginning to revert to a macrophyte-dominated condition. In 1998, the water in Hickling Broad became clear for the first time since 1969. One likely consequence of the improved water quality has been the recent marked increase in the total mass of aquatic vegetation including the nationally rare alga *Chara intermedia* (henceforth referred to as *Chara*), which in turn led to potential conflict between navigation and nature conservation interests. In autumn 1999 however, the water became turbid again and in the subsequent winter, a bloom of toxic *Prymnesium* algae occurred. This may have caused fairly large-scale fish mortality, although good evidence for this is lacking (Michael Green pers. comm.). Although the algae are permanently present in the broad, this was the first bloom since the mid-1980s. Another recent negative impact occurred in January 2000 when an unprecedented tidal surge pushed saltwater into the local ecosystem driving up the salinity level of the water. This may have caused further fish mortality, although there is no evidence that the saline water reached Hickling Broad.

It is well documented that waterbird populations can have an impact on aquatic ecosystems, for example, through deposition of faeces (Hussong *et al.* 1979, Mitchell & Wass 1995) and grazing on submerged macrophytes (Sondergaard *et al.* 1996). Waterbirds may also influence the eutrophication of lakes and have a role in the turnover of nutrients (Gere & Andrikovics 1992). Although feeding extensively on aquatic plants (Jacobs *et al.* 1981, Tubbs & Tubbs 1983, Lodge 1991) waterbirds may also take other food types such as invertebrates. Eight species of waterbird which spend the winter at Hickling Broad were identified by Balmer and Rehfisch (1999) as likely to feed at least partially on *Chara*: Mute Swan *Cygnus olor*, Gadwall *Anas strepera*, Teal *Anas crecca*, Mallard *Anas platyrhynchos*, Shoveler *Anas clypeata*, Pochard *Aythya ferina*, Tufted Duck *Aythya fuligula* and Coot *Fulica atra*. Pochard, Tufted Duck and Coot can dive for their food, the other five species feed from the surface. The principal food types consumed by each species, and their preferred feeding depths are given in Balmer and Rehfisch (1999). Balmer and Rehfisch had estimated that, if all of the energy requirements of the principal species of waterbird on Hickling were met by *Chara*, they would consume the large majority of it over the winter.

The predominant macrophytes on the broad since the mid-1990s have been Fennel Pondweed *Potamogeton pectinatus*, Spiked Water Milfoil *Myriophyllum spicatum* and *Chara*. The pondweed and milfoil have been cut from the central portion of the Broad since the mid-1990s to aid navigation. The unprecedented growth of *Chara* in the central portion in 1998 was an impediment to navigation

and an assessment was undertaken by the Broads Authority to consider the possible effects of cutting *Chara* at Hickling Broad. As a result of the assessment, it was considered possible that cutting the *Chara* might affect waterbird populations on the Broad. Therefore in 1999, an experiment was established involving cutting, to determine the usage of the *Chara* beds by waterbirds on Hickling Broad, with particular attention to differences in the relative use made of the cut versus uncut areas (Armitage *et al.* 2000). Significant positive relationships were detected between *Chara* height and densities of Coot, Mute Swan and Pochard. The effect of cutting the *Chara* beds was not significant in explaining the distribution of Coot or Tufted Duck, but Mute Swan and Pochard appeared to prefer feeding on the cut areas of the Broad. However, no difference could be detected between the height of the *Chara* in the cut and uncut areas. Species of dabbling duck were largely absent from the Broad during winter 1999/2000, most likely due to the high water levels that kept plants out of reach of these surface-feeding species. Even though other waterbirds such as Coot that fed extensively on the *Chara* beds were unusually abundant at Hickling Broad in winter 1999/2000, no firm conclusions could be made as to whether there was differential feeding preferences in the cut and uncut areas. Various forms of recreational disturbance were also identified as significant factors in explaining the distribution of birds, having a negative impact on their numbers.

This report presents the results of a study of waterbird usage of different areas within Hickling Broad undertaken during the autumn and winter of 2000/2001, with the aim of collecting baseline data and identifying significant factors to explain the distribution of the birds. It is important to note that, as a result of the changes in water quality and poor growth of waterweeds, no cutting of the experimental area was carried out during summer 2000.

2. METHODS

2.1 Study Design

In summer 1999, experimental blocks of *Chara* totalling approximately 14 hectares adjacent to the central navigation channel were cut. A reversal of the cut/uncut sectors planned for 2000 was postponed due to the poor state of the *Chara* beds. The location of the proposed cut and uncut areas, in the event of vigorous growth occurring again, are shown in Figure 2.1.

The main part of the Broad was divided into 19 sectors according to the cutting regime proposed and the geographical nature of the sectors (Figure 2.1). Some of these sectors were further divided to ease counting and data were collected individually for these sectors. These data were later consolidated in order to allow detailed analyses of the distribution of waterbirds on the proposed sectors. Six types of sector were determined: proposed "Cut" sectors near the central boat channel in which the *Chara* bed may be cut in the future if necessary; proposed "Uncut" sectors which were in a similar position relative to the central navigation channel as the Cut sectors; "Channel" sectors which covered the central navigation channel; "Fringe" sectors of variable width around the edge of the Broad adjacent to the reedbeds; "Edge" sectors which were between the Fringe sectors and the proposed Cut and Uncut sectors; and "Other" sectors which encompassed Heigham Corner, Whiteslea and Chapman's Bay in order to allow complete hourly counts of the whole Broad. The study design ensured that comparisons between proposed Cut and Uncut sectors were not confounded by possible edge effects. If Edge and Fringe sectors had not been identified, it would have been possible that apparent avoidance of cut sectors was, in fact, driven more by a preference for feeding at the edge of the Broad.

Sectors Channel (A), Cut (C), Uncut (C), Edge East (D), Edge West (D), Fringe South, part of Fringe North and Chapman's Bay were counted from a temporary hide situated in the reedbed on the north side of the Broad. Sectors Channel (B), Cut (A), Uncut (A), Edge North (B), Edge South (B), and the remainder of Fringe North were counted from a temporary hide situated on the south side of the Broad. Sectors Channel (C), Pleasure Island, Opposite Pleasure Island, Whiteslea and part of Heigham Corner Fringe were counted from a boat anchored just to the north of sector Channel (C). Sectors Heigham Corner and the remainder of Heigham Corner Fringe were counted from a boat anchored in Heigham Corner (Figure 2.1).

2.2 Count Methodology

All-day counts were carried out between October 2000 and March 2001 to allow examination of the relative use made of different areas by the waterbirds on the Broad. The all-day counts were made once per month and covered all sectors. Counts were excluded if visibility was severely impaired. Counts of each sector were made once every hour of the day throughout the hours of daylight and feeding and loafing/roosting birds were counted separately. Events causing disturbance to a sector were quantified and recorded. In addition to individual sector disturbance, a more general disturbance factor to the whole Broad was recorded each hour. This was recorded as the number of windsurfers, sailing boats, cruisers (including motor-powered boats) and rowing boats present on the Broad during each one-hour period. Counts were made simultaneously by four observers at the four observation points, two from hides at the edge of the Broad and two from stationary boats on the Broad. Survey dates are shown in Table 2.1. Observations were made using binoculars and 20-60× magnification telescopes and data were recorded in pre-prepared recording tables.

Wetland Bird Survey (WeBS) counts are carried out monthly in the United Kingdom on most large inland water bodies during the winter months. The counts are made once per month, usually on predetermined dates, to allow counts across the country to be synchronised. To provide background for this study, WeBS counts of waterbirds at Hickling Broad for winters 1997/98, 1998/99 and 1999/2000 were examined in conjunction with the maximum counts of waterbirds recorded by the all-day counts this winter to assess the abundance of birds present in this part of the Norfolk Broads through the winter months.

2.3 *Chara* Height, Cover and Biomass

Data relating to the percentage cover and height of *Chara* and depth of water in the Broad were collected for the Broads Authority by Jane Harris between November 2000 and February 2001. Five or ten measurements were made in each sector on six occasions, with the exception of Heigham Corner, Whiteslea, and the Channel sectors, where *Chara intermedia* was assumed to be absent. At locations where height and cover were sampled, the depth of water in the Broad was also recorded. Sampling dates are shown in Table 2.1. Biomass samples were taken in November and February. The biomass sampling dates are shown in Table 2.1 and the biomass sampling locations are shown in Figure 2.2.

Regression analysis was used to determine whether *Chara* "Biomass" (in g) could be accurately predicted by its "Height" (range 0-0.43 m) and "Cover" (percentage of sample plot covered by *Chara*, range 0-100 %). Biomass, Cover and Height of *Chara* were recorded in 88 sample plots (50 cm × 50 cm in size), 44 each in November and February. The analysis excluded samples where *Chara* was not present and the equation was forced to cross the x- and y-axes at 0 as clearly if the *Chara* height and cover were zero then biomass would also be zero.

2.4 Modelling of Bird Densities on All Sectors

Modelling was carried out for the three most widespread species – Coot, Pochard and Tufted Duck - using all counts from October to March. Mute Swan, Gadwall, Shoveler and Mallard data were not analysed because so few birds were present this winter. Generalised Linear Models (GLMs) were used to relate the feeding densities of these species to the sector type, month, hour relative to dawn or dusk, these represented by the estimable factors α, β and γ and estimated *Chara* biomass, a continuous variable multiplied by δ. In addition the numbers of the following potential disturbance factors were considered: windsurfers, yachts, cruisers and rowing boats, both within the sector and on the broad as a whole, both during the count and in the preceding hour. Numbers of these factors recorded in the sector during the count were represented respectively by ε, ζ, η and θ and numbers recorded the previous hour by ι, κ, λ and ν. Likewise, numbers of these factors recorded on the whole broad during the count were represented respectively by ξ, o, π and ρ and numbers recorded the previous hour by σ, τ, υ and ϕ. Disturbance factors were treated as categorical variables. Models only considered the presence or absence of a rowing boat. Models for Tufted Duck and Pochard only considered the presence or absence of yachts, but for Coot four categories were defined for this variable – 0, 1, 2 and 3 or more yachts. The Coot model considered six categories for cruisers – 0, 1, 2, 3, 4 and 5 or more cruisers, that for Tufted Duck, four categories – 0, 1, 2 and 3 or more cruisers and that for Pochard, just the presence or absence of cruisers. Models for Coot and Tufted Duck considered three categories for windsurfers – 0, 1 and 2 or more windsurfers and that for Pochard, just the presence or absence of windsurfers. The disturbance factors were treated as categorical variables because it was assumed that the relationship between quantity and effect of disturbance was not linear, and that there was a threshold at which disturbance caused complete absence of birds. Different categories are used for different species as the threshold identified varied between species.

Complete models with all factors considered were thus as follows:

$$\ln(\text{count}_{abcdefghijklmnopqrs}) = \mu+\alpha_a+\beta_b+\gamma_c+\delta(\textit{Chara}\ \text{biomass})+\varepsilon_d+\zeta_e+\eta_f+\theta_g+\iota_h+\kappa_i+\lambda_j+\nu_k+\xi_l+o_m+\pi_n+\rho_o+\sigma_p+\tau_q+\upsilon_r+\phi_s$$

Models assumed a Poisson distribution for the number of birds counted and specified a log link function. The models also treated the natural logarithm of sector area (*ha*) as an offset, effectively changing the counts into densities thus making it possible to make comparisons between sectors unbiased by sector size. The problem of over-dispersion caused by a combination of a large number of zero counts with several relatively high counts, typical of flocking species, was addressed by the application of a scale factor estimated from the square root of the Pearson's Chi-squared statistic divided by its degrees of freedom (PSCALE in the GENMOD procedure – SAS Institute 2000). Only

those variables, which were significant in explaining the variation in densities, were retained in the final models.

Differences between the proposed cut and uncut sectors were tested for by considering a 'null' model in which the effects of these two sector types were constrained to be equal. F-tests were used to test for the difference in the use of the proposed cut and uncut sectors by feeding Pochard, Tufted Duck and Coot:

$$F = \frac{D_1 - D_0}{r\phi}$$

where D_1 is the deviance of the GLM, treating cut and uncut sectors differently
D_0 is the deviance of the null model
r is the difference in the number of parameters between the two models, which in this case is 1 as only the proposed Cut and Uncut sector types have been combined
ϕ is an estimate of the dispersion parameter (PSCALE)

This test statistic has a F-distribution with (n-p) degrees of freedom, where n is the number of observations and p is the number of parameters in the model that is used to estimate ϕ (Crawley 1993).

Chara biometrics were not measured in the Whiteslea and Heigham Corner sectors and biomass was assumed to be zero for these sectors in the first models. Birds present in these sectors would probably have been feeding on other macrophyte vegetation and aquatic invertebrates. The modelling process was, therefore, carried out again, excluding Whiteslea and Heigham Corner from the analyses.

For species other than Coot, Pochard and Tufted Duck, the maximum numbers of feeding birds and total birds were calculated for each month. The maximum number of birds was the maximum count summed across all sectors in any one hour recorded during any one of the hourly counts.

2.5 Gull Roost Counts

The number of gulls coming to roost on the Broad were counted after the last waterbird count of the day had been made and before it became too dark to count them accurately. The numbers counted are described.

2.6 Other Birds in the Surrounding Area

During the all-day observations, notes were made on all other bird species seen in the surrounding area and flying over. Accounts of the species of wider conservation interest are given with comments on their status in the United Kingdom and habitat requirements.

3. RESULTS

3.1 Relationship Between *Chara* Height, Cover and Biomass

The mean heights of *Chara* and depths of water above the *Chara* beds each month of the winter are shown in Table 3.1.

Stepwise analysis indicated that Biomass was significantly related to Height×Cover ($r^2 = 0.83$, $F_{1,87} = 410.64$), but not height or cover independently:

Biomass = 21.35 (Height×Cover)

Figure 3.1 shows the relationship between the biomass predicted from this equation and actual biomass.

Height×Cover thus provided a good measure of *Chara* Biomass and an average for each sector each month was used as a surrogate estimate for biomass in all following analyses. It was necessary to estimate biomass from Height and Cover values because biomass sampling is time consuming and damaging to the *Chara* beds. Height and Cover values can be more quickly sampled in numerous locations without damaging the plant or disturbing the sediment.

3.2 Analysis of WeBS Count Data

Figures 3.2 and 3.3 show the number of bird days for each month for Pochard, Tufted Duck and Coot during winters 1997/98 to 2000/2001. For the first three winters, the number of bird days was calculated by multiplying the monthly WeBS count by the number of days in the month. For winter 2000/2001, this has been calculated by multiplying the maximum monthly summed hourly count made during all-day counts by the number of days in the month. For all three species, numbers this winter were much lower than in winter 1999/2000 during the first part of winter and similar or slightly lower in the latter part of the winter. The number of Pochard bird days was similar to those recorded in 1997/98 and 1998/99, while the numbers of Tufted Duck and Coot bird days were lower than in all three previous winters.

3.3 Maximum Monthly Counts

The maximum feeding and total (feeding and loafing/roosting) numbers of Pochard, Tufted Duck and Coot recorded during the all-day observations each month are shown in Table 3.2. Of the other key species likely to feed on *Chara*, Mute Swan, Gadwall, Teal, Mallard and Shoveler were all recorded during the all-day counts. Their maximum feeding and total numbers are shown in Table 3.3. These species did not occur in sufficient abundance to carry out detailed analyses. The maximum feeding and total numbers of all other species recorded on the Broad are shown in Table 3.4.

3.4 Observed Feeding Densities

The mean densities of feeding and total Pochard, Tufted Duck and Coot (± s.e.) on each sector each month are tabulated in Appendices 1 to 6. Figures 3.4 and 3.5 show maps of the monthly summed daily count of Pochard for each sector in winter 2000/2001. One dot on the map represents one bird hour placed randomly within the sector. The distribution of Pochard was scattered, but showed a bias to eastern sectors and sectors south of the channel. Most Pochard were recorded in roosting groups in areas of Chapman's Bay, and near Ling's Mill in the Fringe South sector.

Figures 3.6 and 3.7 show similar maps for Tufted Duck. Feeding Tufted Duck were observed more frequently than Pochard and were recorded in all sectors. They appeared to show a preference for the Heigham Corner, Whiteslea, Fringe and Edge sectors.

Figures 3.8 and 3.9 show maps of the monthly summed daily counts of Coot for each sector in winter 2000/2001. It is evident that Coot utilised all count sectors for feeding, but highest numbers were found on the Edge sectors, particularly Edge North and Edge East.

Very few birds of any species were observed feeding within the navigation channel.

3.5 Modelled Bird Densities Across All Sectors

The parameter estimates for the models including (model 1) and excluding (model 2) Whiteslea and Heigham Corner sectors are shown in Appendices 7 to 8.

Pochard

Modelling indicated that densities of feeding Pochard at Hickling were significantly related to month, sector type and hour of day (Tables 3.5 and 3.6). Pochard densities did not appear to be affected by *Chara* biomass. The highest densities were found on the Edge and Fringe sectors and the lowest densities occurred on the Channel sectors (Figure 3.10). There was no difference between densities on the proposed cut and uncut sectors (model 1: $F_{1,986} = 0.35$, ns; model 2: $F_{1,860} = 0.42$, ns). Pochard densities were negatively affected by three disturbance factors: the number of windsurfers during and in the hour preceding the count and the number of yachts during the count (Tables 3.5 and 3.6 and Figure 3.11).

Tufted Duck

Densities of Tufted Duck were significantly related to month, sector type and, perhaps, estimated *Chara* biomass (Tables 3.5 and 3.6). A higher density of birds was found with decreasing *Chara* biomass in model 1, including Whiteslea and Heigham Corner, but there was no significant relationship found by model 2 excluding these two sectors. Highest Tufted Duck densities were found on Cut, Edge and Other sectors and lowest densities occurred on Channel sectors (Figure 3.10). Model 1 detected no difference between sectors proposed to be cut and those proposed to be left uncut ($F_{1,993} = 2.53$, ns). However, model 2 detected significantly greater densities of birds on sectors proposed to be cut, than on those proposed to be left uncut. Tufted Duck densities were negatively affected by windsurfers and rowing boats, both during the count and in the hour preceding the count (Tables 3.5 and 3.6 and Figure 3.12).

Coot

Densities of Coot were significantly related to month, sector type and estimated *Chara* biomass (Tables 3.5 and 3.6). A higher density of birds was found with increasing *Chara* biomass. Highest Coot densities were found on Edge, Other and proposed Cut sectors, lowest densities occurred in the Channel (Figure 3.10). Densities were significantly greater on sectors proposed to be Cut than on those proposed to be left Uncut (model 1: $F_{1,992} = 8.22$, $P = 0.004$; model 2: $F_{1,886} = 7.33$, $P = 0.007$). Coot densities were negatively affected by the presence of windsurfers and yachts (Tables 3.5 and 3.6 and Figure 3.13).

3.6 Gull Roost Counts

The number of gulls counted at sunset are shown in Figure 3.14. The predominant species were Black-headed Gulls accounting for approximately 75-80% of the numbers, Lesser Black-backed Gulls accounted for a further 10-15%, with Herring and Common Gulls accounting for most of the remainder. Small numbers of Great Black-backed Gulls were also recorded.

3.7 Other Birds in the Surrounding Area

Bittern *(Botaurus stellaris)*

Bitterns were regularly seen around the Broad between November and March, with a minimum of four different individuals present during November. Two Bitterns were found dead or dying in the area during January (George Taylor pers. comm.), and this may explain the apparent decrease in the number of sightings during the subsequent month. At least one pair of Bitterns bred at Hickling during 2000, and it is quite feasible that the majority of the winter sightings related to individuals from the family group. The majority of the observations during the course of the winter were in the southern section of the Broad, particularly between Ling's Mill and Swim Coots, perhaps reflecting favourable feeding conditions along the edge of the reedbeds.

Bitterns require extensive standing water with overgrown, tall, emergent vegetation, particularly reeds (*Phragmites)* giving dense cover close to sheltered open stretches of water, including small pools and channels. Within this habitat, they feed and breed, avoiding those reedbeds that are particularly even-aged including older, and drier stands, and those with a pH below 4.5 (Cramp (ed) 1977 – 93). The main food items of Bitterns comprise fish, amphibians, small birds (including ducklings), mammals such as Water Vole and insects. During the winter observations on the Broad, it would appear that the Bitterns were feeding on fish (and also possibly amphibians and large aquatic invertebrates) in the wet reed margins.

Nationally, Bitterns are now virtually confined as a breeding species to East Anglia and part of Lancashire, and are subject to a government-backed Species Recovery Programme. There are currently estimated to be between 13-18 booming males in England (Ogilvie *et al.* 2000).

Bewick's Swan *(Cygnus columbianus)*

No birds were actually recorded on the Broad, but small flocks were noted flying over, with a maximum count of 29 during the December counts.

Pink-footed Goose *(Anser brachyrhynchus)*

No birds were actually recorded on the Broad, but small flocks were noted flying over, with a maximum count of 30 during the November counts.

Red-crested Pochard *(Netta rufina)*

A pair was noted on the Broad during the December counts in the Edge South Sector. This European species is commonly kept in wildfowl collections, and many of the annual sightings within the UK probably relate to escapees. However, genuine migrants from the wild European population probably do still occur, and it is conceivable that the Hickling individuals were derived from the continent. It is best described as a scarce annual migrant to the UK, with most of the records within the southern half of the country.

Smew *(Mergellus albellus)*

Smew are a scarce winter visitor in varying numbers to the UK, returning to northeastern Europe to breed. The British wintering population is estimated as typically around 250 individuals (Stone *et al.* 1997). Hickling Broad is a fairly regular site for this species, particularly Rush Hill Scrape. During the February counts, up to five Smew were noted feeding in Fringe North, Fringe South and Chapman's Bay, with a pair also present in March in Fringe South. Smew dive to get their food, which during the winter months, is mostly comprised of small fish (Cramp (ed) 1977 – 93). During other times of the year, Smew feed on aquatic invertebrates, occasional molluscs and crustaceans and some plant material.

Marsh Harrier *(Circus aeruginosus)*

Marsh Harriers were observed hunting over the reedbeds around much of the Broad during all of the winter visits, with birds beginning to pair up and to hold territory by March. Up to five different individuals were estimated during the January counts. Despite recent increases in the breeding population within the UK over the past 20 years, the Marsh Harrier is still a rare breeding species, and continues to enjoy special protection under the Wildlife and Countryside Act. There are currently thought to be over 137 breeding pairs within the UK, mostly confined to areas of wetland with reedbeds (Ogilvie *et al.* 2000).

Hen Harrier *(Circus cyaneus)*

Single female birds were noted hunting around Ling's Mill in both December and January. This species is a winter visitor to Hickling, returning to northern Britain and the continent to breed. It is afforded special protection under the Wildlife and Countryside Act. There are estimated to be around 570 pairs of Hen Harrier breeding in Britain (Olgilvie *et al.* 2000).

Common Crane *(Grus grus)*

Three were seen and heard flying over the fields behind Rowland Green's Mill during the December and February counts. Cranes are afforded special protection under the Wildlife and Countryside Act. There is a small resident population in the Norfolk Broads, comprising four breeding pairs (Ogilvie *et al.* 2000).

Jack Snipe *(Lymnocryptes minimus)*

A single individual was flushed from the path at dusk near Ling's Mill. This species is likely to be a regular winter visitor to Hickling in small numbers, but is rarely seen due to its secretive nature. It is a difficult species to monitor on a national scale, and the wintering population is unknown, but estimated as between 10,000 and 100,000 individuals (Stone *et al.* 1997).

Mediterranean Gull *(Larus melanocephalus)*

An adult in full breeding plumage joined the large evening gull roost on the Broad during the March counts. Although this species is fairly widespread during the winter months, it is a rare breeding species within the British Isles, with a current population of between 54 and 65 pairs (Ogilvie *et al.* 2000). Mediterranean Gulls are afforded special protection under the Wildlife and Countryside Act.

Little Gull *(Larus minutus)*

An adult was in the main gull roost on the Broad during the December counts. Little Gulls are a fairly widespread passage visitor to Britain, with the greatest numbers encountered during the spring and autumn. They are mostly a coastal species, but are also regularly recorded inland. On very rare occasions, Little Gulls have attempted to breed in the British Isles.

Barn Owl *(Tyto alba)*

Barn Owls are a widespread breeding species within Britain, although it has declined over much of country during recent years (Gibbons *et al.* 1993). The current British breeding population is estimated as around 4,400 pairs (Stone *et al.* 1997). During the winter counts, hunting individuals were noted around Ling's Mill and around Swim Coots in January, February and March. Barn Owls are afforded special protection under the Wildlife and Countryside Act. Barn Owls are known to nest close to Hickling Broad.

Kingfisher *(Alcedo atthis)*

The Kingfisher is a widespread breeding species in England and Wales, becoming much more scattered in Scotland. This species is very susceptible to cold severe winter weather, but the current British breeding population is estimated as between 3,300 and 5,500 pairs (Stone *et al.* 1997). At Hickling Broad, single Kingfishers were observed fishing around the margins, particularly in Fringe South and Fringe North, sporadically throughout the winter. Kingfishers are afforded special protection under the Wildlife and Countryside Act.

Water Pipit *(Anthus spinoletta)*

Water Pipits are a scarce but regular winter visitor to Britain, mostly to England. The birds prefer freshwater sites inland such as flooded meadows, Watercress beds and wet reed stubble. Small numbers regularly winter in the Norfolk Broads, including Hickling. The British wintering population is estimated as around 100 individuals in a "typical" year (Stone *et al.* 1997). During the winter counts at Hickling, up to three Water Pipits frequented Swim Coots throughout.

Cetti's Warbler *(Cettia cetti)*

The British breeding population of Cetti's Warbler continues to increase, both numerically and in range, although it is still essentially confined to southern Britain. The current breeding population is just short of 500 pairs (Ogilvie *et al.* 2000). It is relatively widespread in the Norfolk Broads, and during the winter counts, two singing birds were heard during November, December and March in the southwestern corner of Hickling Broad. Cetti's Warblers are afforded special protection under the Wildlife and Countryside Act.

Bearded Tit *(Panurus biarmicus)*

Bearded Tits were recorded during all of the winter counts, but always in very small numbers (less than five individuals). The preferred areas were reeds surrounding Fringe South, Fringe North and Heigham Corner Fringe. There are an estimated 400+ pairs in England (Stone *et al.* 1997) but the species is confined to large tracts of reedbeds (*Phragmites)* with associated dense, tall, non-woody vegetation growing nearby. These habitat requirements alone ensures that its breeding distribution is very scattered within Britain, being solely confined to England. This species is also susceptible to sustained periods of very cold winter weather. The diet comprises of seeds in the winter and invertebrates in the summer months. Bearded Tits are afforded special protection under the Wildlife and Countryside Act.

4. DISCUSSION

This was the second winter of monitoring waterbirds at Hickling Broad to assess the impact of cutting the *Chara intermedia* beds. However, since the late summer of 1999, the water had reverted to a turbid state with increased phytoplankton growth, leading to poor growth of the macrophytes in the Broad. Following recommendations made by the assessment team, the Broads Authority made the decision not to cut the *Chara* beds during summer 2000. Monitoring of the waterbirds on the Broad was, nevertheless, useful in terms of collecting baseline data and determining relationships between the distribution of birds and biomass of *Chara* and disturbance events. It also made it possible to monitor the gull roost through the winter and keep a record of Bitterns and other birds of particular conservation value that help make Hickling Broad such a noteworthy site.

The number of bird days spent by Pochard, Tufted Duck and Coot on Hickling during the 2000/2001 winter was much lower than during the 1999/2000 winter. Pochard counts peaked in December as they had the previous winter, but were six-fold lower in number. These counts were similar to those recorded during the 1997/98 and 1998/99 winters. Tufted Duck numbers steadily increased throughout the winter but the early winter peak and subsequent decline of last winter was not apparent. There were fewer Tufted Duck on Hickling Broad than during any of the previous three winters. Similarly, Coot numbers on Hickling were lower this winter than in any of the previous three winters. This winter, Coot numbers peaked in October, as in 1999/2000 but were some seven times lower. Thereafter Coot numbers declined steadily throughout the winter, with numbers matching those of last winter between December and March. The reduced number of diving waterbirds this year compared to last winter supports the theory that the increased quantity of *Chara intermedia* present during the early part of last winter helped support the very large numbers of waterbirds present during that period in 1999. With a much-reduced biomass of *Chara*, the Broad may have been unable to support such high numbers during this winter. This would appear to support the relationship between the area and thus biomass of the *Chara* beds and the number of Pochard, Tufted Duck and Coot found on Hickling initially reported by Balmer & Rehfisch (1999).

It is likely that the decline in the water quality has caused the reduction in macrophyte biomass in the Broad. The relationship between macrophyte biomass and waterbird abundance is well documented. At Lake Krakesjon in Sweden, when phytoplankton declined and submerged plants expanded spatially, a significant increase in herbivorous birds such as Coot and Mute Swan and also some omnivorous species was recorded (Hargeby *et al.* 1994). Similar relationships were noted at Currituck Sound in North America (Wicker & Endres 1995), Lake Veluwemeer (Van der Winden *et al.* 1997) and Lake Gouwzee (Ruiters *et al.* 1994) in Holland. The cause of the decline in water quality after the brief clarity of water in the Broad in 1997 and 1998 is uncertain. However, it is not thought to be due to the experimental cutting carried out in 1999. It is possible that the waterbirds including the gulls were the cause. Exclosure experiments in lakes on the Continent have provided supporting evidence that waterbirds may suppress macrophyte biomass and have a negative impact on water quality, especially in recovering lakes where macrophytes are beginning to recolonise following reductions in nutrient loading (Sondergaard *et al.* 1996, Van Donk & Otte 1996). Perrow *et al.* (1997) suggested that waterbirds feeding in winter suppressed macrophyte development the following spring at sites in the Norfolk Broads. Hickling Broad is considered to be in a state of recovery and the substantial numbers of waterbirds recorded in winter 1999/2000 may have had a negative impact on the water quality and growth of the waterweeds. Last year's gull roost on the Broad may have been similar in size to this year's, which held up to 10,000 individuals and it could also have reduced water quality. The reduction in water quality can occur partly as a result of the gulls adding nutrients to the system through their excretion products derived from food gathered outside of Hickling Broad. These nutrients favour the growth of phytoplankton, which in turn leads to increased turbidity.

Dabbling ducks were largely absent from Hickling Broad again this winter as they had been last winter. In 1999/2000, it was surmised that high water levels which kept the plants out of reach of the birds were the cause of this (Armitage *et al.* 2000). Those dabbling species, which were on the Broad this winter, were generally recorded at the shallow fringes. At Lake Veluwemeer, high water levels in early winter 1998 caused a shift in the species composition present from predominantly dabbling

species to diving species (Noordhuis *in litt.*). This winter at Hickling Broad, water levels were again very high, and coupled with the fact that the *Chara* beds were much lower, dabbling duck species would have been unable to reach most plants from the surface. Mute Swan, which were present in sufficient numbers to be considered in detail in 1999/2000 (Armitage *et al.* 2000) were so scarce this winter at Hickling Broad that no worthwhile analysis of their distribution was possible. Balmer & Rehfisch (1999) suggested that Mute Swan can up end in water to a depth of one metre. The mean depth of water above the *Chara* beds recorded throughout this winter was between 1.11 m and 1.32 m, therefore most of the *Chara* would have been out of reach of the swans.

The intensive study of the distribution of diving waterbirds at Hickling Broad showed that the highest densities of birds were on the Edge sectors, as recorded in winter 1999/2000 when it had been suggested that this pattern of distribution was mainly due to disturbance which was most frequent in the central navigation channel. This winter, birds again tended to avoid the central channel, probably because of the combination of disturbance and the lack of vegetation. The effect of disturbance is evident in the models for each species. Windsurfers had a significant negative local impact on all three species considered, the effect increasing with the number of windsurfers present. For Pochard, this effect continued into the hour following the presence of the windsurfers. The presence of yachts in a count sector also had a negative impact on the number of Pochard and Coot present in the sector, while rowing boats caused fewer Tufted Duck to be present, both in the hour of counting and in the following hour. No significant effect was determined for cruisers, however, and this may be because cruisers were, in general, restricted to the channel sectors and moved in a predictable manner (see later). The effect of cruisers in the models may, therefore, be masked by the model effect of the type of sector. However, disturbance of different types is known to affect birds in different ways. On the Stour estuary, WeBS counters considered unpowered boats to cause disturbance on 38% of occasions, powered boats on 47% of occasions and windsurfers on 68% of occasions (Musgrove *et al.* 2001). In an overview of disturbance effects in the Dutch Wadden Sea and Delta, Smit & Visser (1993) described studies which had shown that kayaks and sailing boats had more effect than motor boats and that a few zigzag movements of a single windsurfer were enough to cause a complete departure of all ducks present. Similar effects have therefore been recorded at Hickling Broad. It is likely that the rapid movement of windsurfers and the bright sails of both windsurfers and yachts cause more disturbance than the cruisers or motor boats. Similarly, the relatively unpredictable activity of a rower in a rowing boat can cause increased disturbance. In winter 1999/2000, following windsurfer disturbance, birds were noticed moving away from the part of the Broad being monitored. The absence of any significant effect of disturbance on the overall number of birds on the whole Broad this winter suggests that the birds only moved to another part of the Broad rather than leaving the site.

By accounting for the effect of disturbance in the models, the relationship between the distribution of diving birds and the predicted biomass of *Chara intermedia* can be examined. Numbers of feeding Coot increased significantly with increasing *Chara* biomass. In winter 1999/2000 a significant positive relationship was also found between Coot density and *Chara* height (Armitage *et al.* 2000). This supports the notion that numbers of Coot were lower this winter than last winter at least in part because of the reduced biomass of *Chara* in the whole Broad and that Coot in particular are reliant on *Chara* for feeding. Biomass of *Chara* was not a significant explanatory variable in the model for Pochard, unlike in winter 1999/2000 when a significant positive relationship was found between Pochard density and *Chara* height. A significant negative relationship was recorded between *Chara* biomass and Tufted Duck density in the first model. It should be noted here that *Chara intermedia* height and cover sampling was not carried out in the Whiteslea and Heigham Corner sectors and was assumed to be zero in the first models. A second model, excluding these two sectors from the analysis, detected no significant relationship between Tufted Duck density and *Chara* biomass as was the case in winter 1999/2000. Tufted Duck were relatively more numerous in the Whiteslea and Heigham Corner sectors than the other species. The other vegetation that grows in these sectors may provide food for these species and the unmeasured presence of these potential food plants could affect the apparent lack of relationship between Pochard numbers and *Chara* biomass and the direction of the relationship between Tufted Duck and *Chara* biomass. Unlike Coot, Pochard and Tufted Duck are omnivorous, and they may have obtained some of their dietary requirements from other organisms

such as invertebrates that could possibly become more accessible in areas with less dense stands of *Chara*.

Coot and Tufted Duck densities were significantly higher on the proposed cut sectors than on the proposed uncut sectors. This may be due to some underlying physical or geographical nature of the sectors and highlights the requirement of the project design to reverse the cutting procedures between years in order to distinguish between the effects of cutting and not cutting the *Chara* beds.

Although the findings of this winter's study are not conclusive, they support evidence, particularly for Coot, for a relationship between waterbird numbers at Hickling Broad and the abundance of *Chara intermedia*. This is reflected in the low numbers present on the Broad this winter and the significant relationship between Coot density and *Chara* biomass. It has also identified yachts, rowing boats and especially windsurfers as significant factors in determining the distribution of birds on the Broad.

5. RECOMMENDATIONS FOR FURTHER WORK

The second winter of intensive waterbird monitoring has collected baseline data in a slightly unusual year (in terms of the previous two winters), as water quality and *Chara* growth has been poor. It has shown that numbers of waterbirds at Hickling Broad, particularly Coot, may be closely related to the amount of *Chara* available to them.

In order to understand the effect of cutting back the *Chara* beds, when it is carried out in the future, we continue to emphasise the proposals made after last winter's monitoring (Armitage *et al.* 2000):

1. A suite of matched pairs of cut and uncut sectors would ideally be monitored over two winters. To make the analysis very robust the cutting treatment would be reversed during the second winter to make it possible to account for natural differences in the physical nature and geographical position of the sectors.

2. Measuring the depletion rate of *Chara* on the cut and uncut areas of the Broad would make it possible to estimate whether any decline in waterbird numbers was related to the depletion of *Chara*, or environmental factors unrelated to food supply. This would require foraging rates, for at least one of the diving species such as Coot, on the cut and uncut sectors to be measured. These data would make it possible to index the handling time and accessibility of the *Chara* on the different sectors through time. These indices could then be related to any changes in waterbird numbers occurring on Hickling Broad. This would help assess whether *Chara* availability is a causal determinant of waterbird numbers on Hickling.

3. Analysis of the counts using a randomisation approach that makes no assumptions about data distribution. Count data collected from Hickling Broad do not ideally fit any standard distributions and the fit of the Generalised Linear Models was generally poor. Standard errors and tests of hypothesis were adjusted by estimating the scale factor, a measure of variance/mean ratio. Adjustment in this fashion is standard within the application of GLMs. However, with appreciable amounts of over-dispersion of the data, it should not be regarded automatically as producing an acceptable model. It is therefore proposed to consider alternative approaches not restricted by this distributional assumption. Randomisation methods provide a robust alternative and can be applicable in non-standard situations such as this.

4. The Assessment Team have advised that a revised nutrient budget for Hickling Broad should be carried out. This would include nutrient input and cycling by roosting gulls and feeding waterbirds. Phosphorous and nitrogen are particularly important nutrients in determining the state of the Broad's aquatic plant community. Nutrient enrichment can lead to increased phytoplankton growth, until ultimately it dominates and macrophyte vegetation can no longer survive in the turbid water. Outbreaks of blooms of the toxic alga, *Prymnesium*, may also become more frequent. During the first half of the twentieth century, there was an almost exponential increase in the number of black-headed gulls roosting at Hickling Broad and by the 1970s, up to 250,000 may have been present (although this figure appears exceptionally high). It was calculated that between 44%-72% of the total phosphorous loading of the site could have been due to the nutrient input from the gull excreta (Irvine *et al.* 1993). Moss and Leah (1982) emphasised the importance of guanotrophication as a major agent of change in the state of the Broad, as it has been at lakes studied in Michigan, Poland and France (Manny *et al.* 1994, Marion *et al.* 1994, Dobrowolski *et al.* 1996, Gwiazda 1996). A very rapid decline in water quality occurred at Hickling Broad, to the detriment of the macrophyte community, at the same time that the gull roost reached its peak. In subsequent years, numbers of gulls at the roost decreased, to approximately 10,000-15,000 in 1982 (although 40,000 were estimated there during the BTO's 1983 Gull Roost Survey). There was a decrease in the total phosphorous loading of the site, possibly as a consequence of this. Between 6,000-10,000 gulls were recorded each evening in winter 2000/2001, which may signify a recent increase. Due to their possible role in determining the state of the Hickling

Broad, the numbers of gulls coming to roost should be monitored, at least during the autumn and winter months, when local populations are augmented by birds from continental Europe. If the size of the gull roost is found to be increasing in size again, a review of roost management techniques should be carried out. In addition, Horsey Mere, which has also shown the symptoms of eutrophication, and Martham Broad which has maintained clear water and is close to its pre-war state, could be monitored for gulls and other waterbirds to allow comparison with Hickling Broad.

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Bird count date	Hours after dawn	Nearest *Chara* monitoring date	Biomass sampling
26 October 2000	1 – 10	8 November 2000	No
21 November 2000	1 – 9	14/15 November 2000	Yes
19 December 2000	1 – 8	19 December 2000	No
25 January 2001	1 – 9	24 January 2001	No
14 February 2001	1 – 10	20 February 2001	No
7 March 2001	2 – 11	22/27 February 2001	Yes

Table 2.1 Dates of waterbird monitoring with hours counted and dates of *Chara* height, cover and biomass sampling.

Date	Mean *Chara* height ± s.e. (m)	Mean depth of water ± s.e. above *Chara* (m)
8 November 2000	0.16 ± 0.01	1.28 ± 0.01
14/15 November	0.13 ± 0.01	Not recorded
19 December	0.16 ± 0.02	1.32 ± 0.02
24 January 2001	0.06 ± 0.01	1.11 ± 0.01
20 February	0.06 ± 0.01	1.20 ± 0.01
22/27 February	0.05 ± 0.01	Not recorded

Table 3.1 Mean height of *Chara* beds (±s.e.) and mean depth of water (±s.e.) above the *Chara* beds on each sampling occasion during winter 2000/2001. Depth of water data were not recorded when biomass was being sampled.

Month	Pochard		TuftedDuck		Coot	
	Feeding	Total	Feeding	Total	Feeding	Total
October	13	56	36	47	656	722
November	35	95	27	49	596	635
December	16	176	40	56	410	469
January	18	120	64	74	380	410
February	24	91	61	94	216	223
March	16	59	75	90	184	208

Table 3.2 Maximum number of feeding and total Pochard, Tufted Duck and Coot counted at Hickling Broad during all-day counts each month of winter 2000/2001.

Month	Mute Swan		Gadwall		Teal		Mallard		Shoveler	
	Feeding	Total	Feeding	Total	Feeding	Total	Feeding	Total	Feeding	Total
October	2	3	2	2	0	0	15	52	0	4
November	0	0	2	2	0	41	23	38	0	0
December	0	0	3	14	3	3	16	33	6	12
January	8	8	32	43	0	21	39	44	0	0
February	1	1	10	16	0	22	4	11	0	2
March	0	0	0	2	0	0	7	15	0	0

Table 3.3 Maximum number of feeding and total Mute Swan, Gadwall, Teal, Mallard and Shoveler counted at Hickling Broad during all-day counts each month of winter 2000/2001.

Species	October		November		December		January		February		March	
	feeding	total	feeding	total	feeding	total	feeding	total	feeding	total	feeding	total
Little Grebe *Tachybaptus ruficollis*	8	8	4	4	3	3	5	5	5	5	3	4
Great-crested Grebe *Podiceps cristatus*	11	13	11	13	13	17	11	11	14	17	10	16
Cormorant *Phalacrocorax carbo*	3	9	2	7	3	5	3	7	6	7	3	8
Greylag Goose *Anser anser*	0	3	0	2	0	5	0	1	0	8	0	2
Canada Goose *Branta canadensis*	0	0	0	0	0	0	0	43	0	22	6	29
Egyptian Goose *Alopochen aegyptiacus*	0	2	0	2	0	0	0	2	0	5	0	0
Shelduck *Tadorna tadorna*	0	0	0	0	0	6	0	0	0	1	0	4
Wigeon *Anas penelope*	0	4	0	3	0	10	0	0	0	0	0	0
Red-crested Pochard *Netta rufina*	0	0	2	4	0	0	0	0	0	0	0	0
Goldeneye *Bucephela clangula*	2	2	7	9	10	10	18	19	27	35	33	37
Smew *Mergellus albellus*	0	0	0	0	0	0	0	1	3	3	2	2
Ruddy Duck *Oxyura jamaicensis*	4	4	0	0	0	0	0	0	2	2	0	0
Moorhen *Gallinula chloropus*	0	0	2	2	0	0	0	0	0	0	0	1

Table 3.4 Maximum feeding and total numbers of all other species recorded at Hickling Broad during all-day counts each month of winter 2000/2001.

	Month	Hour of Day	Sector Type	Biomass	WS	LAG (WS)	Y	RB	LAG (RB)
PO	$F_{5,986} = 7.5$ $P < 0.0001$	$F_{9,986} = 4.2$ $P < 0.0001$	$F_{5,986} = 9.1$ $P < 0.0001$	ns	$F_{1,986} = 14.7$ $P < 0.0001$	$F_{1,986} = 4.5$ $P = 0.0350$	$F_{1,986} = 5.1$ $P = 0.0238$	ns	ns
TU	$F_{5,993} = 7.6$ $P < 0.0001$	ns	$F_{5,993} = 10.4$ $P < 0.0001$	$F_{1,993} = 4.0$ $P = 0.0447$	$F_{1,993} = 6.2$ $P = 0.0020$	ns	ns	$F_{1,993} = 9.1$ $P = 0.0026$	$F_{1,993} = 5.3$ $P = 0.0219$
CO	$F_{5,992} = 27.2$ $P < 0.0001$	ns	$F_{5,992} = 73.1$ $P < 0.0001$	$F_{1,992} = 47.9$ $P < 0.0001$	$F_{2,992} = 4.7$ $P = 0.0095$	ns	$F_{2,992} = 6.4$ $P = 0.0003$	ns	ns

Table 3.5 Analysis of deviance statistics and associated *p* values for month, hour after dawn, sector type, biomass and disturbance factors in models (which include Whiteslea and Heigham Corner sectors) describing the densities of Pochard (PO), Tufted Duck (TU) and Coot (CO) at Hickling Broad between October 2000 and March 2001. WS is a categorical variable describing the number of windsurfers recorded in the sector during the count and LAG (WS) a similar variable describing numbers the preceding hour. Likewise, Y and RB are categorical variables describing the numbers of yachts and rowing boats, respectively, recorded in the sector during the count and LAG (RB) a similar variable describing numbers of rowing boats the preceding hour. Cruisers, the numbers of yachts in the preceding hour and disturbance on the broad as a whole were not significant in the model.

	Month	Hour of Day	Sector Type	Biomass	WS	LAG (WS)	Y	RB	LAG (RB)
PO	$F_{5,880} = 5.6$ $P < 0.0001$	$F_{9,880} = 3.4$ $P = 0.0004$	$F_{5,880} = 10.5$ $P < 0.0001$	ns	$F_{1,880} = 14.1$ $P = 0.0002$	$F_{1,880} = 3.6$ $P = 0.0576$	$F_{1,880} = 6.7$ $P = 0.0100$	ns	ns
TU	$F_{5,886} = 15.0$ $P < 0.0001$	ns	$F_{5,886} = 4.6$ $P = 0.0004$	ns	$F_{1,886} = 3.1$ $P = 0.0475$	$F_{2,886} = 5.3$ $P = 0.0051$	ns	$F_{1,886} = 7.5$ $P = 0.0062$	$F_{1,886} = 4.5$ $P = 0.0347$
CO	$F_{5,886} = 33.9$ $P < 0.0001$	ns	$F_{5,993} = 82.9$ $P < 0.0001$	$F_{1,886} = 25.4$ $P < 0.0001$	$F_{2,886} = 6.1$ $P = 0.0022$	ns	$F_{3,993} = 10.6$ $P < 0.0001$	ns	ns

Table 3.6 Analysis of deviance statistics and associated *p* values for month, hour after dawn, sector type, biomass and disturbance factors in models (which exclude Whiteslea and Heigham Corner sectors) describing the densities of Pochard (PO), Tufted Duck (TU) and Coot (CO) at Hickling Broad between October 2000 and March 2001. WS is a categorical variable describing the number of windsurfers recorded in the sector during the count and LAG (WS) a similar variable describing numbers the preceding hour. Likewise, Y and RB are categorical variables describing the numbers of yachts and rowing boats, respectively, recorded in the sector during the count and LAG (RB) a similar variable describing numbers of rowing boats the preceding hour. Cruisers, the numbers of yachts in the preceding hour and disturbance on the broad as a whole were not significant in the model.

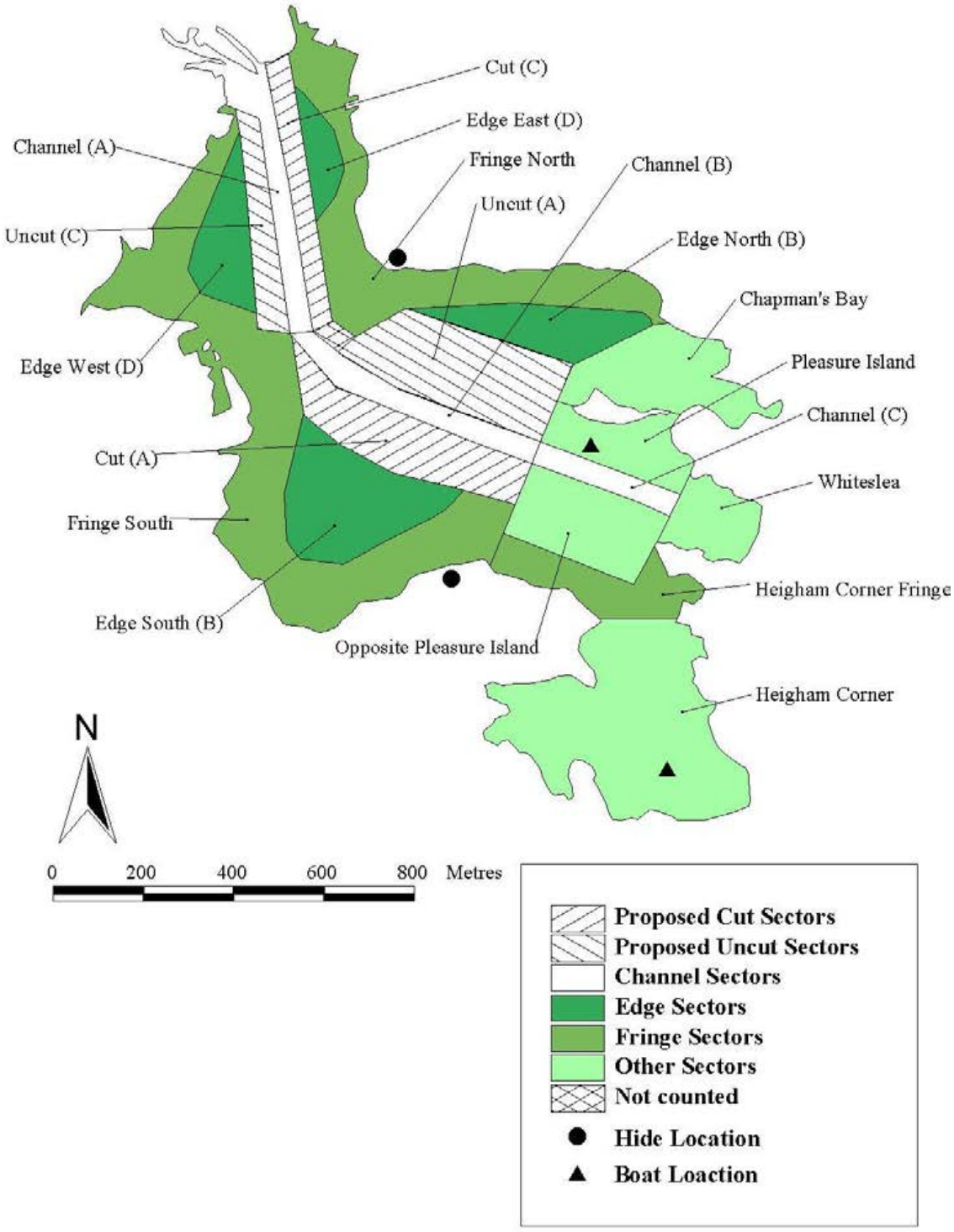


Figure 2.1 Hickling Broad study site showing observation points from hides and boats and named count sectors. All sectors consist of open water *i.e.* they do not include reedbeds.

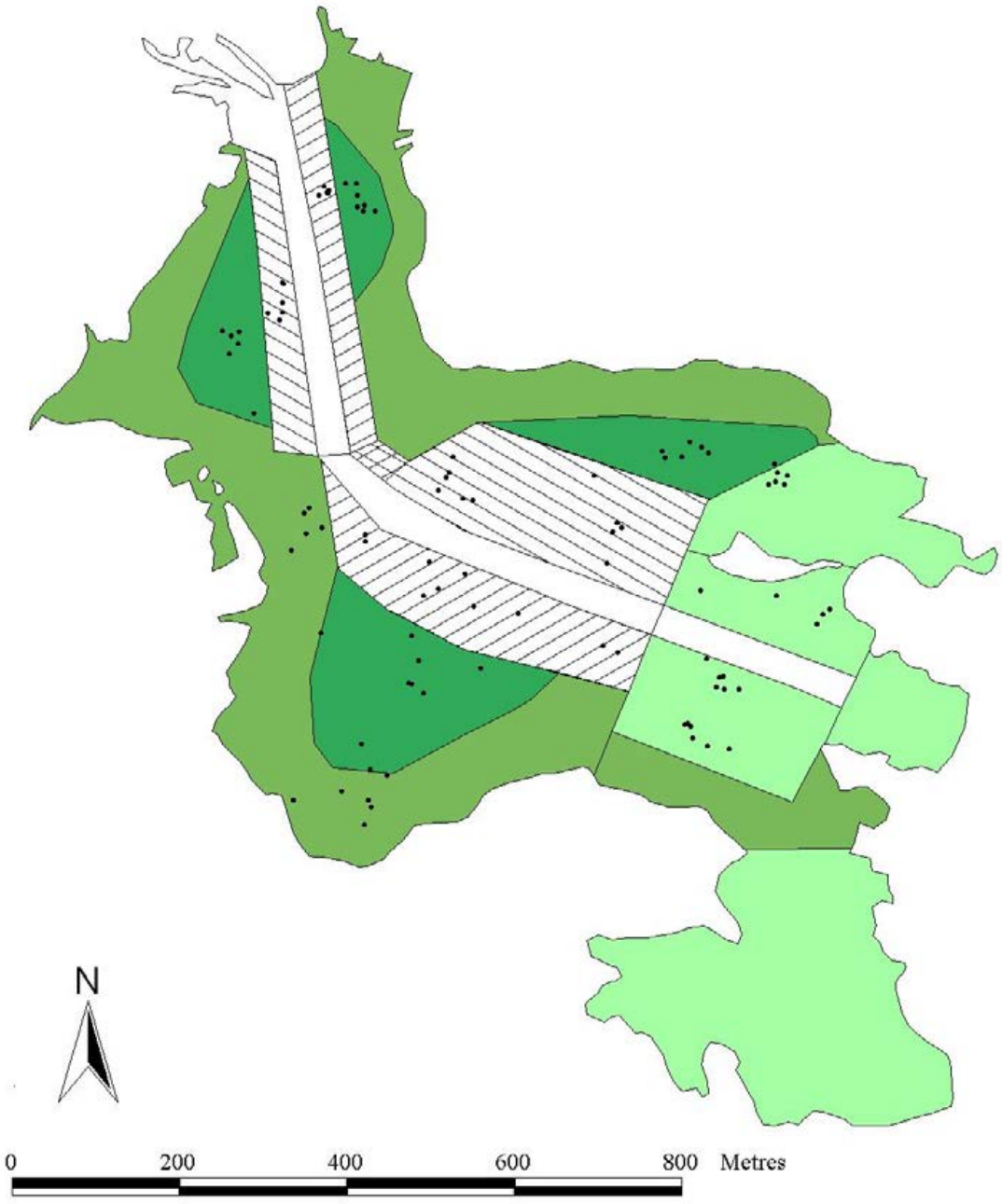


Figure 2.2 Map of Hickling Broad showing the locations of the *Chara intermedia* biomass sampling locations.

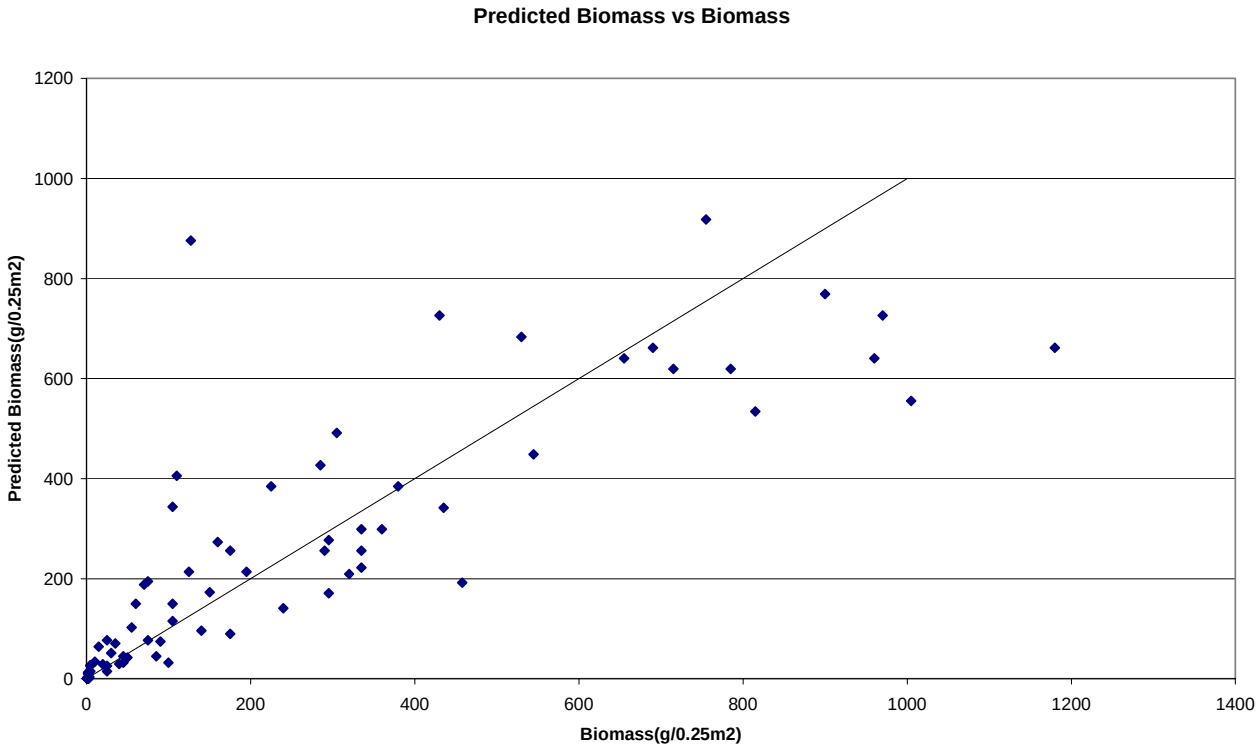
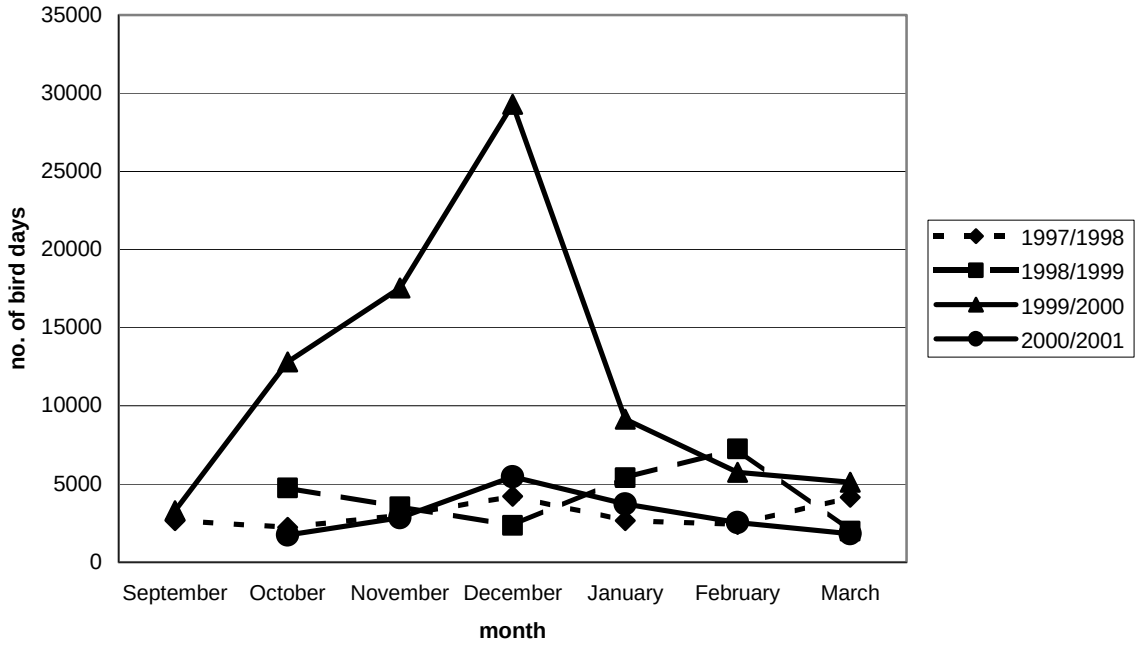


Figure 3.1 Plot of predicted model biomass values against actual biomass values (Biomass = 21.35×Height×Cover, r^2 = 0.83, $F_{1,87}$ = 410.64). The line shows the 1:1 slope. If the model had predicted the *Chara* biomass perfectly (r^2 =1) all points would be on the line.

Pochard



Tufted Duck

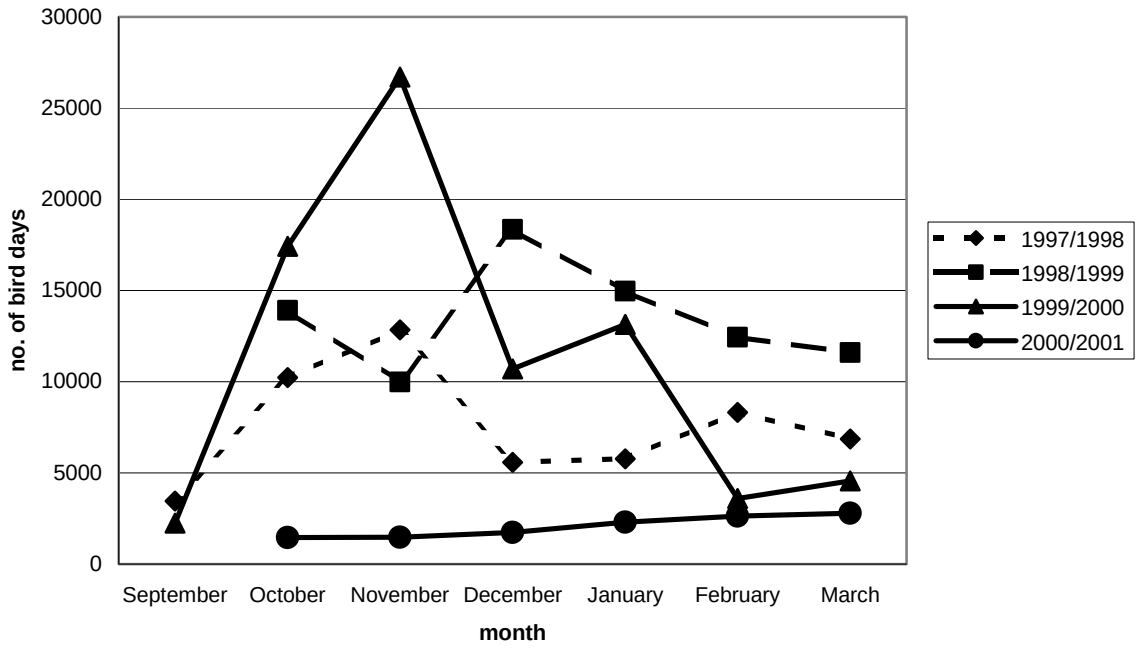


Figure 3.2 The number of bird days of Pochard and Tufted Duck at Hickling Broad during winters 1997/98, 1998/99, 1999/2000 and 2000/2001. Bird days have been calculated using the maximum count made during all day observations each month in winter 2000/2001 and using the WeBS count made each month in the other three winters.

Coot

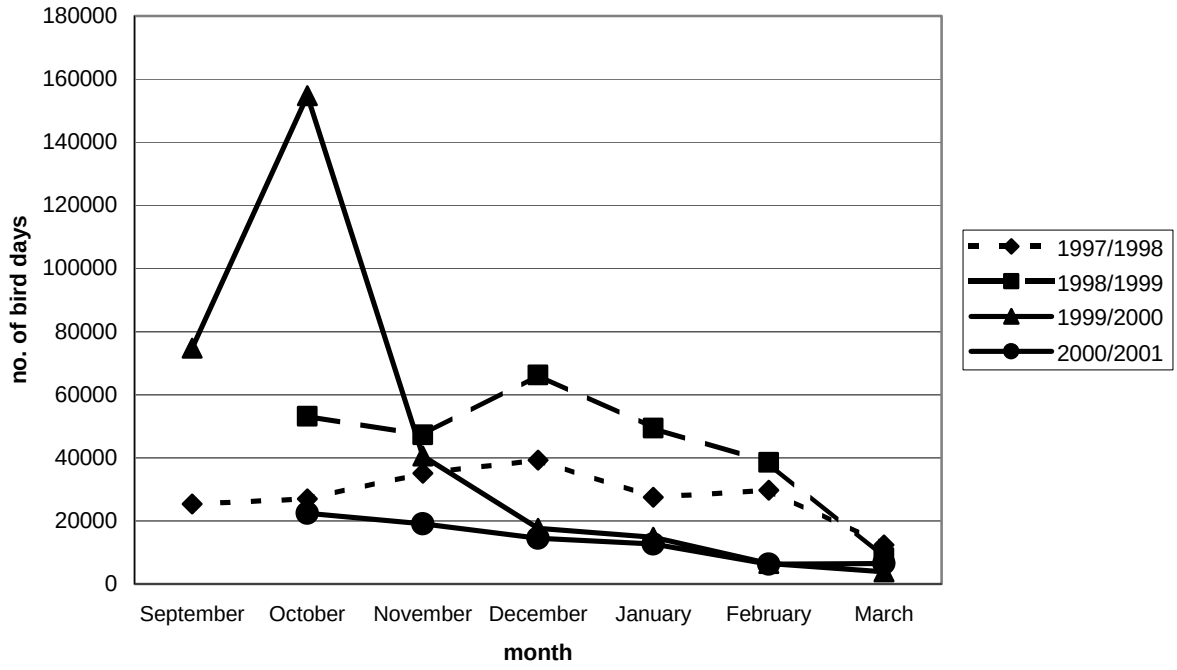


Figure 3.3 The number of bird days of Coot at Hickling Broad during winters 1997/98, 1998/99, 1999/2000 and 2000/2001. Bird days have been calculated using the maximum count made during all day observations each month in winter 2000/2001 and using the WeBS count made each month in the other three winters.

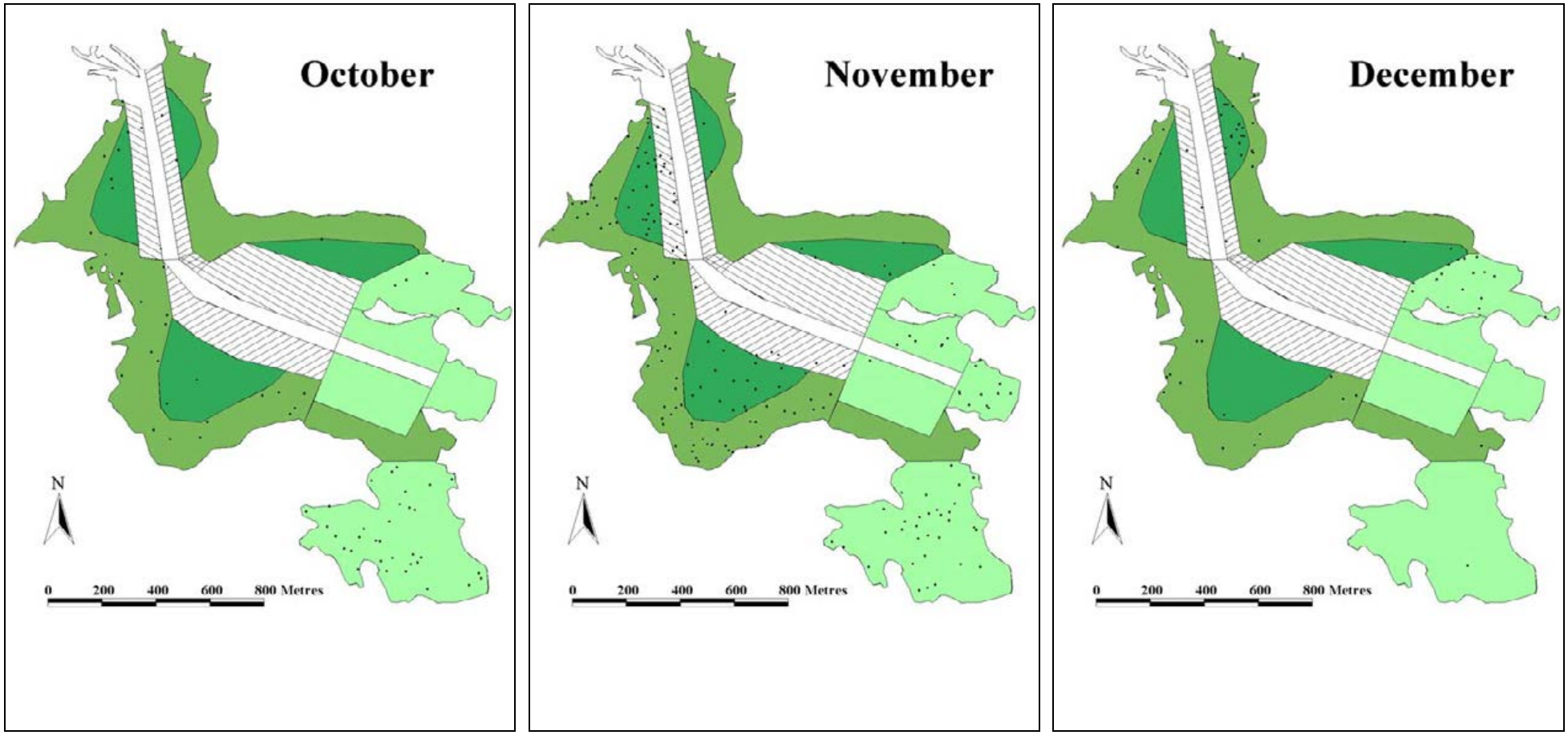


Figure 3.4 Summed daily counts of Pochard for each sector for the months October, November and December 2000. One dot represents the equivalent of one bird hour placed randomly within each sector.

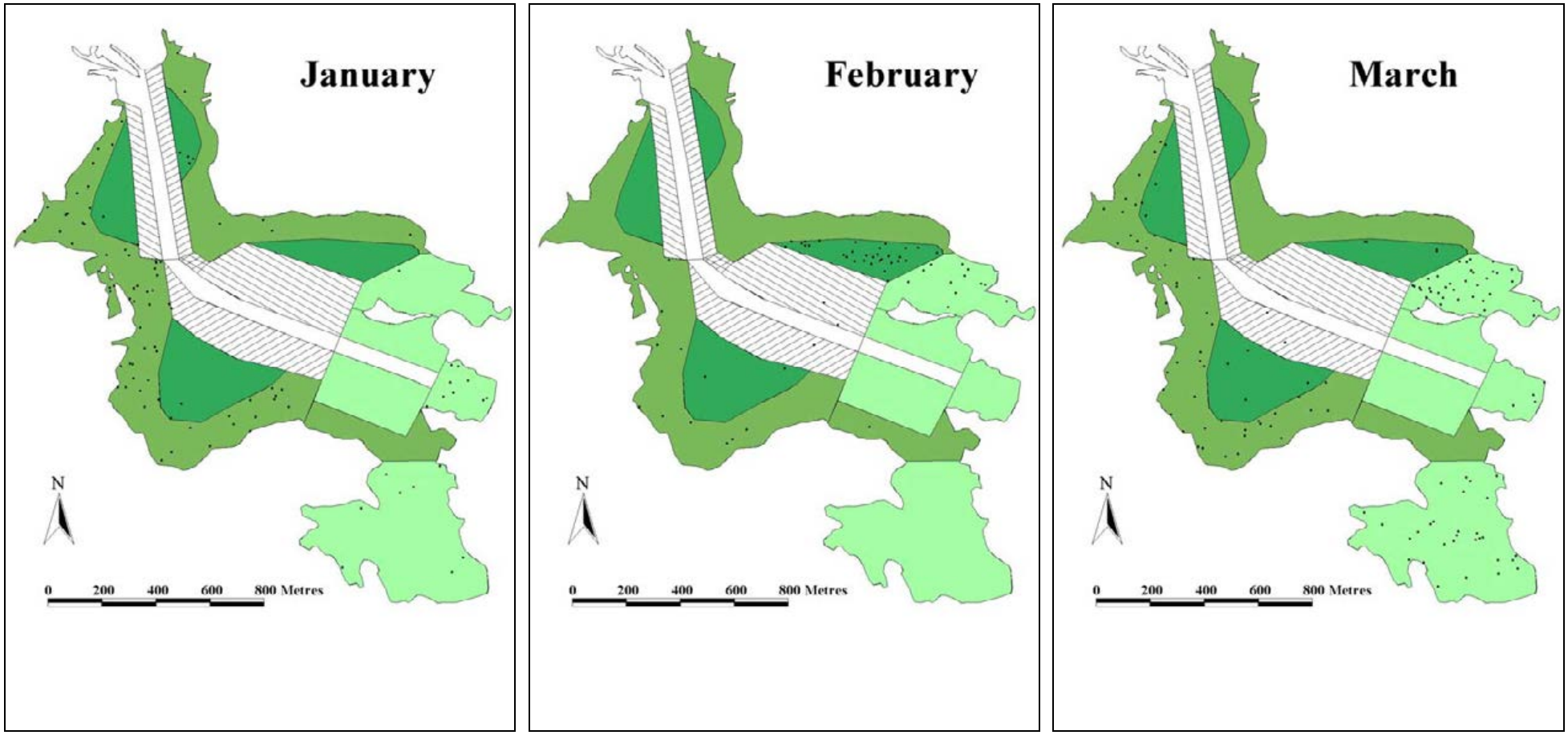


Figure 3.5 Summed daily counts of Pochard for each sector for the months January, February and March 2001. One dot represents the equivalent of one bird hour placed randomly within each sector.

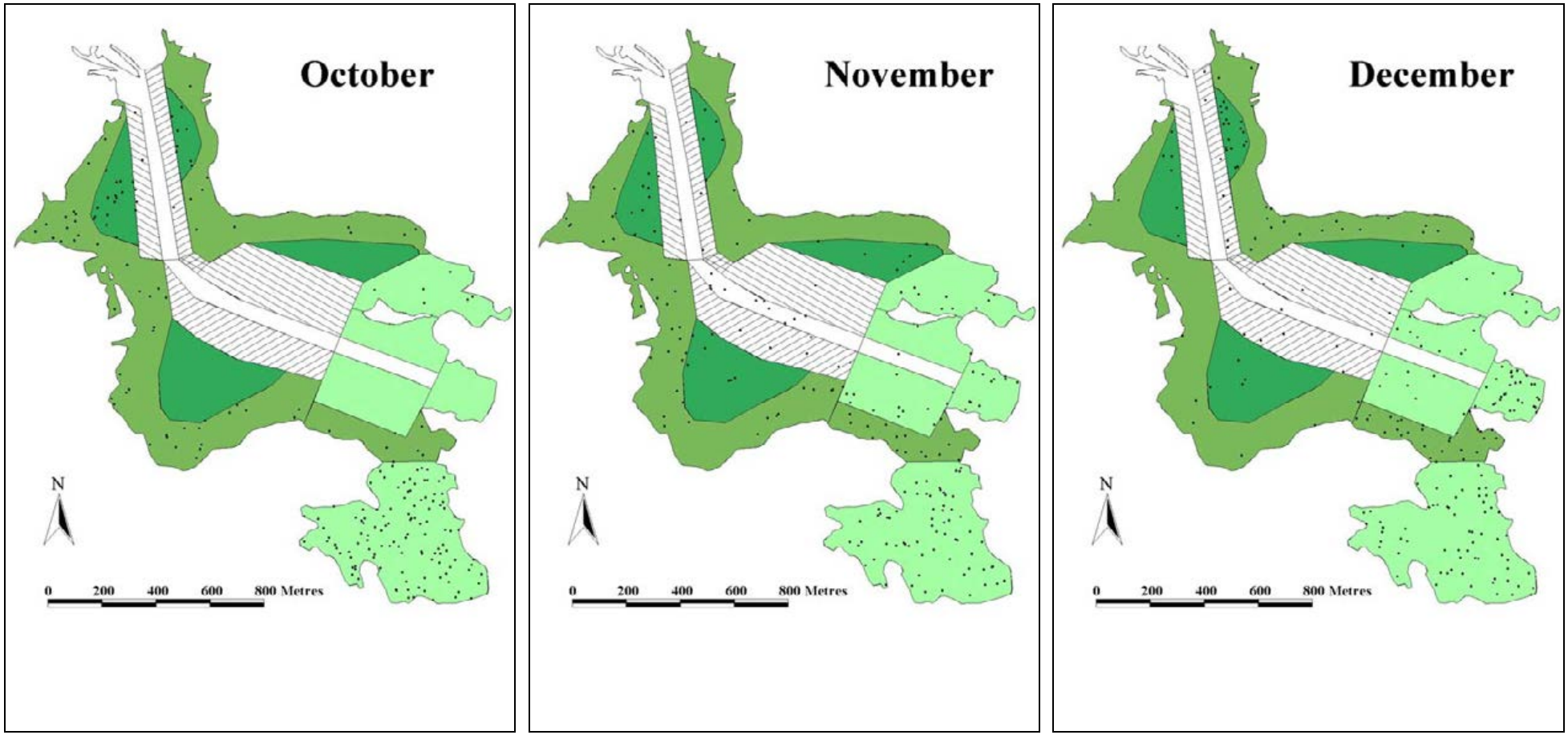


Figure 3.6 Summed daily counts of Tufted Duck for each sector for the months October, November and December 2000. One dot represents the equivalent of one bird hour placed randomly within each sector.

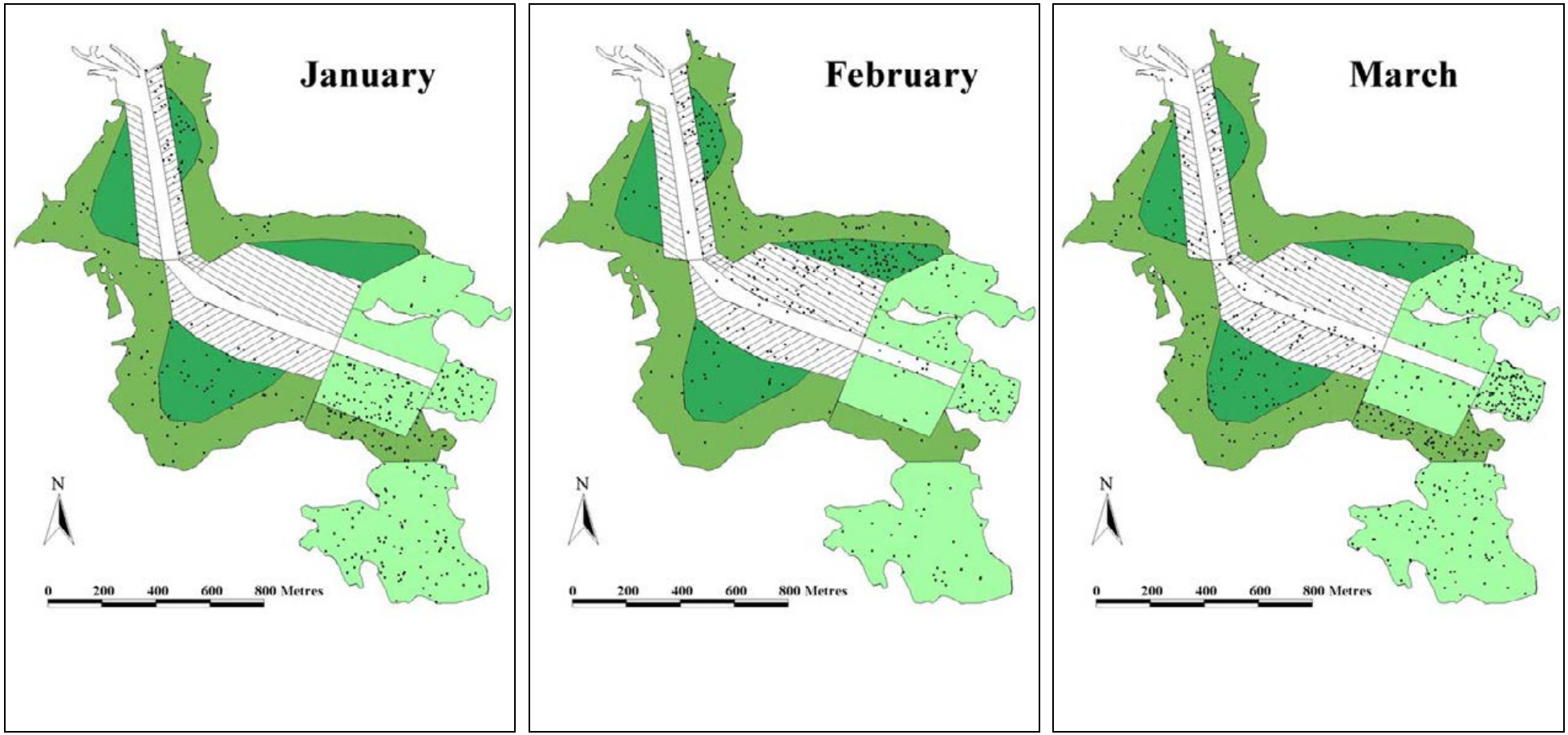


Figure 3.7 Summed daily counts of Tufted Duck for each sector for the months January, February and March 2001. One dot represents the equivalent of one bird hour placed randomly within each sector.

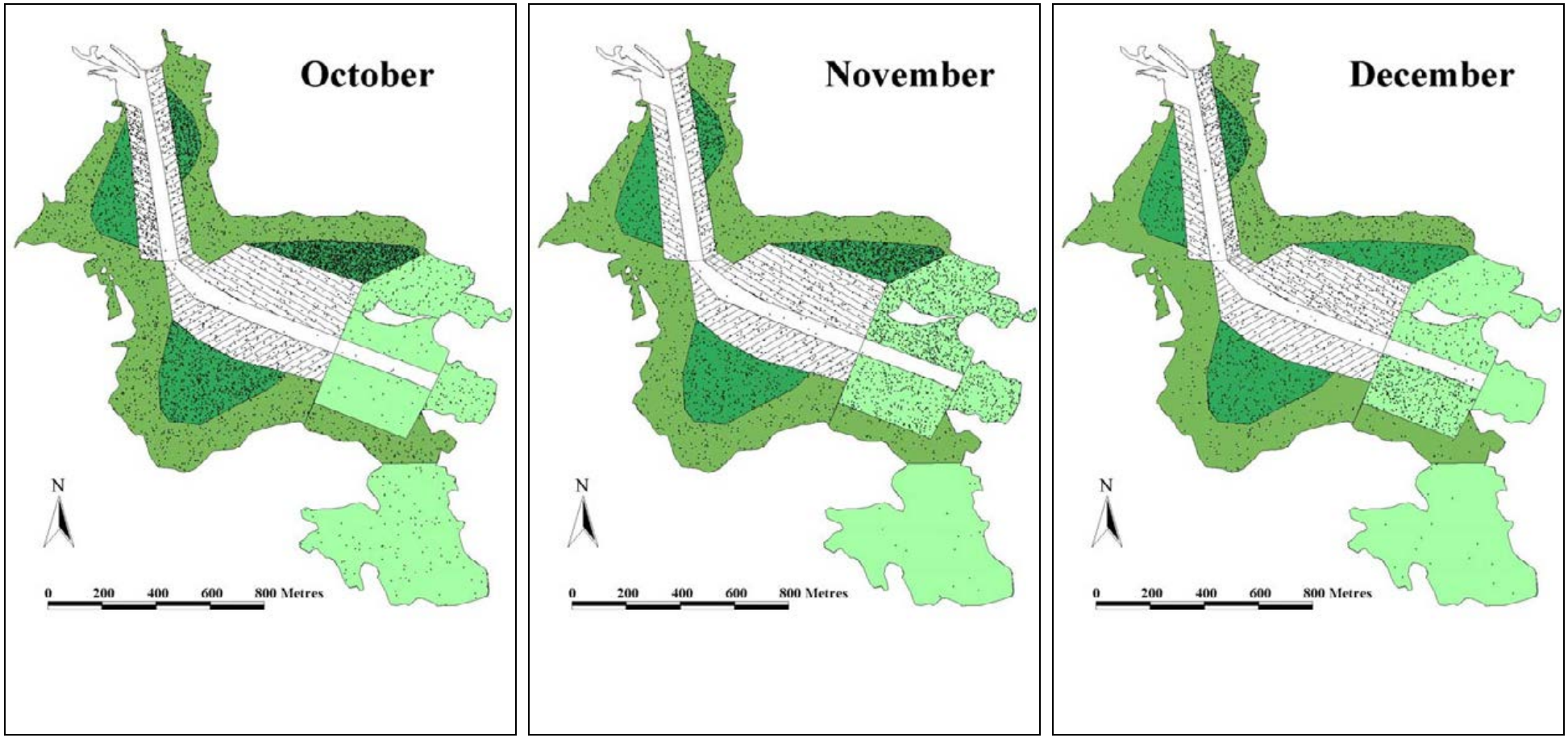


Figure 3.8 Summed daily counts of Coot for each sector for the months October, November and December 2000. One dot represents the equivalent of one bird hour placed randomly within each sector.

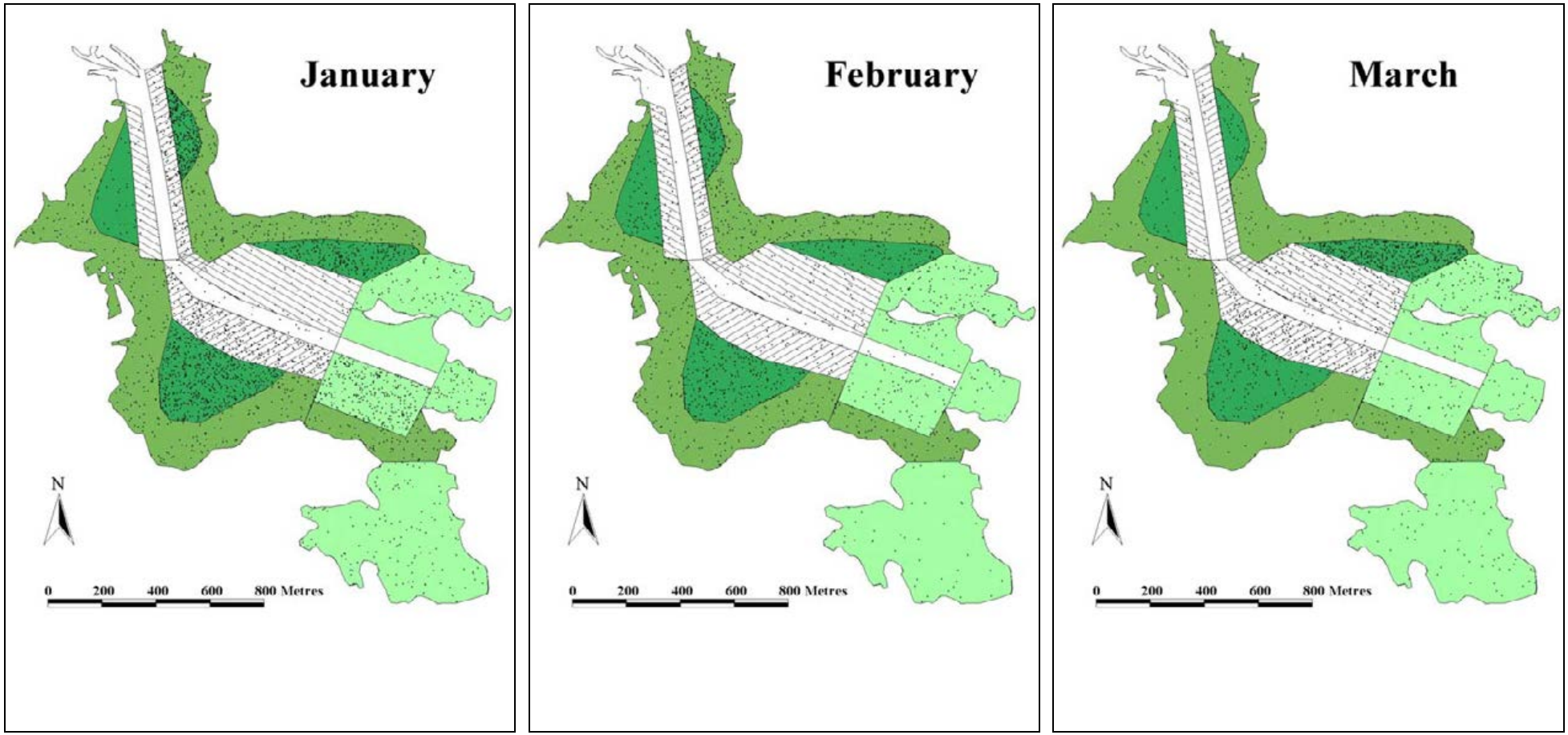


Figure 3.9 Summed daily counts of Coot for each sector for the months January, February and March 2001. One dot represents the equivalent of one bird hour placed randomly within each sector.

Type	Sector	Area	October	November	December	January	February	March
pCut	CutA	7.01	0±0	0.11±0.09	0±0	0±0	0.02±0.02	0.03±0.03
pCut	CutC	3.24	0.06±0.04	0±0	0.04±0.04	0±0	0±0	0±0
pUncut	UncutA	8.87	0±0	0±0	0±0	0±0	0.03±0.03	0±0
pUncut	UncutC	3.05	0.07±0.04	0.61±0.20	0.09±0.06	0±0	0±0	0±0
Edge	EdgeEast	1.84	0±0	0.14±0.09	1.01±0.34	0.24±0.24	0±0	0±0
Edge	EdgeNorth	4.36	0.02±0.02	0.11±0.06	0.06±0.06	0±0	0.71±0.50	0.07±0.05
Edge	EdgeSouth	7.80	0.03±0.03	0.21±0.09	0.02±0.02	0.03±0.03	0.03±0.02	0.04±0.03
Edge	EdgeWest	3.79	0.11±0.06	0.46±0.12	0.04±0.04	0.03±0.03	0±0	0.08±0.06
Fringe	FringeNorth	12.79	0±0	0±0	0.07±0.04	0.05±0.02	0±0	0±0
Fringe	FringeSouth	23.26	0.10±0.03	0.33±0.07	0.11±0.05	0.32±0.08	0.04±0.01	0.17±0.02
Fringe	HCrnFringe	4.62	0±0	0±0	0.03±0.03	0±0	0.02±0.02	0±0
Other	ChapBay	6.66	0.08±0.05	0.06±0.06	0.30±0	0.02±0.02	0.18±0.09	0.47±0.08
Other	HCorner	18.05	0.19±0.07	0.19±0.09	0.01±0.01	0.05±0.03	0±0	0.14±0.04
Other	OppPlIsl	6.14	0±0	0.02±0.02	0±0	0±0	0±0	0±0
Other	PlIsland	3.99	0±0	0.16±0.11	0±0	0±0	0±0	0±0
Other	Whiteslea	3.25	0±0	0.38±0.22	0±0	0.31±0.31	0±0	0.09±0.07
Channel	ChannelA	4.41	0±0	0.03±0.03	0±0	0±0	0±0	0±0
Channel	ChannelB	3.50	0±0	0±0	0±0	0±0	0±0	0±0
Channel	ChannelC	1.88	0±0	0±0	0±0	0±0	0±0	0±0

Appendix 1 Mean densities (±s.e.) of feeding Pochard (birds/ha) during the day on each sector during each month of winter 2000/2001. Means have been calculated from the hourly counts made each month.

Type	Sector	Area	October	November	December	January	February	March
pCut	CutA	7.01	0±0	0.36±0.22	0±0	0±0	0.02±0.02	0.03±0.03
pCut	CutC	3.24	0.06±0.04	0±0	0.18±0.09	0±0	0±0	0±0
pUncut	UncutA	8.87	0±0	0±0	0±0	0±0	0.03±0.03	0±0
pUncut	UncutC	3.05	0.07±0.04	0.82±0.32	0.89±0.74	0±0	0±0	0±0
Edge	EdgeEast	1.84	0±0	0.20±0.10	2.80±0.94	0.30±0.24	0±0	0±0
Edge	EdgeNorth	4.36	0.02±0.02	0.26±0.14	15.02±4.77	0±0	5.50±1.92	0.07±0.05
Edge	EdgeSouth	7.80	0.03±0.03	0.45±0.17	0.29±0.27	0.03±0.03	0.31±0.16	0.04±0.03
Edge	EdgeWest	3.79	0.11±0.06	1.58±0.61	0.75±0.60	0.03±0.03	0±0	0.08±0.06
Fringe	FringeNorth	12.79	0±0	0.20±0.13	0.73±0.22	0.07±0.02	1.95±0.90	0±0
Fringe	FringeSouth	23.26	0.36±0.06	1.21±0.18	1.03±0.47	4.06±0.17	0.16±0.04	0.82±0.05
Fringe	HCrnFringe	4.62	0±0	3.81±0.48	0.81±0.51	0.29±0.19	0.24±0.14	0±0
Other	ChapBay	6.66	0.11±0.06	0.19±0.19	0.45±0.15	0.03±0.02	0.28±0.11	2.85±0.42
Other	HCorner	18.05	1.85±0.14	0.55±0.06	0.01±0.01	0.27±0.07	0.06±0.03	0.19±0.03
Other	OppPlIsl	6.14	0±0	0.02±0.02	0.59±0.39	0±0	0±0	0±0
Other	PlIsland	3.99	0±0	0.16±0.11	0±0	0±0	0±0	0±0
Other	Whiteslea	3.25	0±0	0.38±0.22	0±0	0.79±0.36	0±0	0.09±0.07
Channel	ChannelA	4.41	0±0	0.03±0.03	0±0	0.03±0.03	0±0	0±0
Channel	ChannelB	3.50	0±0	0±0	0±0	0±0	0±0	0±0
Channel	ChannelC	1.88	0±0	0±0	0±0	0±0	0±0	0±0

Appendix 2 Mean densities (±s.e.) of total Pochard (birds/ha) during the day on each sector during each month of winter 2000/2001. Means have been calculated from the hourly counts made each month.

Type	Sector	Area	October	November	December	January	February	March
pCut	CutA	7.01	0±0	0.11±0.04	0.11±0.04	0.14±0.04	0.21±0.09	0.39±0.09
pCut	CutC	3.24	0.03±0.03	0.12±0.06	0.26±0.14	0.86±0.25	0.72±0.24	0.68±0.23
pUncut	UncutA	8.87	0±0	0.01±0.01	0.06±0.06	0.01±0.01	0.70±0.21	0.12±0.04
pUncut	UncutC	3.05	0.13±0.10	0.12±0.06	0±0	0±0	0.11±0.11	0.49±0.16
Edge	EdgeEast	1.84	0.43±0.32	0.27±0.18	1.24±0.45	1.09±0.38	1.27±0.35	0.33±0.23
Edge	EdgeNorth	4.36	0±0	0.14±0.06	0.03±0.03	0±0	1.83±0.65	0.25±0.11
Edge	EdgeSouth	7.80	0±0	0.10±0.08	0.06±0.05	0.36±0.07	0.21±0.09	0.40±0.17
Edge	EdgeWest	3.79	0.42±0.17	0.30±0.11	0.19±0.11	0.12±0.05	0.12±0.12	0.21±0.09
Fringe	FringeNorth	12.79	0.09±0.04	0.03±0.02	0.21±0.07	0.14±0.05	0.36±0.15	0.05±0.03
Fringe	FringeSouth	23.26	0.19±0.04	0.17±0.02	0.05±0.03	0.26±0.05	0.11±0.02	0.26±0.03
Fringe	HCrnFringe	4.62	0.12±0.06	0.35±0.19	0.73±0.47	1.15±0.36	0.07±0.05	1.30±0.43
Other	ChapBay	6.66	0.09±0.05	0.15±0.06	0.15±0.15	0.12±0.05	0.30±0.08	0.77±0.12
Other	HCorner	18.05	0.65±0.19	0.41±0.11	0.46±0.08	0.55±0.11	0.18±0.08	0.38±0.06
Other	OppPlIsl	6.14	0±0	0.22±0.07	0.14±0.05	1.23±0.28	0.11±0.05	0.29±0.11
Other	PlIsland	3.99	0±0	0.06±0.04	0.28±0.19	0.03±0.03	0.47±0.30	0.23±0.08
Other	Whiteslea	3.25	0±0	0.38±0.26	1.12±0.42	1.23±0.41	1.06±0.47	2.68±0.59
Channel	ChannelA	4.41	0±0	0±0	0±0	0±0	0.05±0.03	0.07±0.05
Channel	ChannelB	3.50	0±0	0.29±0.12	0.07±0.07	0.03±0.03	0.10±0.05	0.49±0.15
Channel	ChannelC	1.88	0±0	0.07±0.07	0±0	0±0	0.35±0.20	0±0

Appendix 3 Mean densities (±s.e.) of feeding Tufted Duck (birds/ha) during the day on each sector during each month of winter 2000/2001. Means have been calculated from the hourly counts made each month.

Type	Sector	Area	October	November	December	January	February	March
pCut	CutA	7.01	0±0	0.14±0.05	0.12±0.04	0.24±0.05	0.21±0.09	0.39±0.09
pCut	CutC	3.24	0.03±0.03	0.12±0.06	0.26±0.14	0.89±0.23	0.82±0.28	0.71±0.23
pUncut	UncutA	8.87	0±0	0.01±0.01	0.10±0.10	0.01±0.01	1.23±0.33	0.12±0.04
pUncut	UncutC	3.05	0.13±0.10	0.16±0.06	0±0	0±0	0.11±0.11	0.49±0.16
Edge	EdgeEast	1.84	0.43±0.32	0.27±0.18	1.86±0.65	1.09±0.38	1.87±0.44	0.43±0.24
Edge	EdgeNorth	4.36	0.11±0.08	0.23±0.08	0.03±0.03	0±0	5.10±1.05	0.25±0.11
Edge	EdgeSouth	7.80	0±0	0.13±0.09	0.06±0.05	0.43±0.10	0.24±0.09	0.40±0.17
Edge	EdgeWest	3.79	0.61±0.15	0.53±0.14	0.19±0.11	0.12±0.05	0.12±0.12	0.32±0.12
Fringe	FringeNorth	12.79	0.13±0.05	0.03±0.02	0.48±0.10	0.17±0.07	0.83±0.34	0.05±0.04
Fringe	FringeSouth	23.26	0.44±0.06	0.49±0.08	0.09±0.04	0.43±0.06	0.23±0.05	0.88±0.14
Fringe	HCrnFringe	4.62	0.12±0.06	0.35±0.19	0.95±0.44	2.16±0.62	0.07±0.05	1.30±0.43
Other	ChapBay	6.66	0.09±0.05	0.26±0.12	0.15±0.15	0.13±0.06	0.58±0.12	1.88±0.27
Other	HCorner	18.05	1.10±0.14	0.69±0.11	0.49±0.06	0.66±0.10	0.29±0.11	0.68±0.04
Other	OppPlIsl	6.14	0±0	0.24±0.08	0.14±0.05	1.23±0.28	0.14±0.05	0.31±0.12
Other	PlIsland	3.99	0±0	0.06±0.04	0.41±0.20	0.03±0.03	0.47±0.30	0.23±0.08
Other	Whiteslea	3.25	0±0	0.81±0.45	1.50±0.44	1.57±0.38	1.26±0.63	3.17±0.55
Channel	ChannelA	4.41	0±0	0±0	0±0	0±0	0.05±0.03	0.07±0.05
Channel	ChannelB	3.50	0±0	0.29±0.12	0.07±0.07	0.10±0.07	0.29±0.22	0.49±0.15
Channel	ChannelC	1.88	0±0	0.07±0.07	0±0	0±0	0.35±0.20	0±0

Appendix 4 Mean densities (±s.e.) of total Tufted Duck (birds/ha) during the day on each sector during each month of winter 2000/2001. Means have been calculated from the hourly counts made each month.

Type	Sector	Area	October	November	December	January	February	March
pCut	CutA	7.01	2.82±1.12	2.37±1.23	1.80±0.56	5.15±0.65	1.09±0.24	3.22±0.62
pCut	CutC	3.24	4.14±2.14	4.40±1.45	8.33±2.31	4.08±1.29	2.50±0.34	0.46±0.17
pUncut	UncutA	8.87	1.69±1.06	2.72±0.77	4.85±1.62	0.55±0.16	0.78±0.22	1.79±0.46
pUncut	UncutC	3.05	11.64±1.88	3.28±0.63	4.22±0.79	0.66±0.29	1.64±0.26	0.69±0.23
Edge	EdgeEast	1.84	20.33±4.25	15.29±2.51	21.2±4.01	13.95±2.49	6.82±0.54	1.47±0.30
Edge	EdgeNorth	4.36	32.55±4.51	23.71±1.75	5.56±1.72	6.57±0.94	2.29±0.45	7.84±1.73
Edge	EdgeSouth	7.80	9.31±2.65	4.92±0.76	4.50±0.86	7.49±1.07	3.40±0.42	1.65±0.38
Edge	EdgeWest	3.79	5.83±1.07	3.69±0.48	4.18±0.93	0.70±0.14	1.73±0.21	0.58±0.13
Fringe	FringeNorth	12.79	3.13±0.42	2.37±0.27	3.98±0.77	1.96±0.20	2.12±0.12	0.69±0.10
Fringe	FringeSouth	23.26	3.02±0.54	2.15±0.36	1.19±0.47	1.46±0.29	1.31±0.11	0.42±0.04
Fringe	HCrnFringe	4.62	2.74±0.61	1.54±0.50	0.73±0.26	1.97±0.30	1.20±0.20	1.21±0.15
Other	ChapBay	6.66	2.46±0.68	9.16±0.70	1.28±0.38	1.30±0.38	1.62±0.14	1.52±0.13
Other	HCorner	18.05	0.62±0.05	0.10±0.02	0.12±0.04	0.76±0.07	0.22±0.04	0.31±0.03
Other	OppPlIsl	6.14	0.29±0.23	5.76±0.70	8.82±1.63	5.12±0.92	1.14±0.55	0.75±0.18
Other	PlIsland	3.99	0.50±0.20	11.84±1.13	3.16±1.28	0±0	0.92±0.18	0.48±0.10
Other	Whiteslea	3.25	2.36±0.53	7.00±1.38	0.19±0.08	2.15±0.27	0.68±0.32	0.68±0.17
Channel	ChannelA	4.41	0.02±0.02	0.06±0.04	0.13±0.05	0±0	0.05±0.03	0.05±0.03
Channel	ChannelB	3.50	0.31±0.17	0.36±0.36	0.32±0.19	0.70±0.27	0.29±0.12	0.43±0.23
Channel	ChannelC	1.88	0.24±0.18	0.07±0.07	0.33±0.22	0±0	0.30±0.18	0±0

Appendix 5 Mean densities (±s.e.) of feeding Coot (birds/ha) during the day on each sector during each month of winter 2000/2001. Means have been calculated from the hourly counts made each month.

Type	Sector	Area	October	November	December	January	February	March
pCut	CutA	7.01	4.39±1.33	2.51±1.33	1.93±0.64	6.26±0.76	1.30±0.29	3.69±0.52
pCut	CutC	3.24	4.23±2.19	4.59±1.61	8.51±2.33	4.08±1.29	2.54±0.34	0.49±0.17
pUncut	UncutA	8.87	1.95±1.18	2.86±0.86	5.90±2.04	0.66±0.18	0.90±0.27	1.86±0.48
pUncut	UncutC	3.05	12.10±2.01	3.48±0.63	4.22±0.79	0.77±0.30	1.68±0.24	0.69±0.23
Edge	EdgeEast	1.84	21.09±4.11	15.63±2.64	21.74±4.04	14.01±2.45	6.94±0.56	1.52±0.28
Edge	EdgeNorth	4.36	38.88±5.14	25.49±1.41	7.02±2.07	7.98±0.91	2.52±0.45	9.17±1.85
Edge	EdgeSouth	7.80	12.64±2.68	5.13±0.75	4.84±0.84	8.68±1.02	3.75±0.31	1.83±0.46
Edge	EdgeWest	3.79	6.20±1.10	3.89±0.45	4.18±0.93	0.73±0.13	1.85±0.27	0.58±0.13
Fringe	FringeNorth	12.79	3.56±0.43	2.40±0.28	4.41±0.82	2.24±0.20	2.23±0.15	0.81±0.10
Fringe	FringeSouth	23.26	3.42±0.57	2.40±0.39	1.25±0.51	1.68±0.36	1.51±0.12	0.58±0.05
Fringe	HCrnFringe	4.62	2.74±0.61	1.68±0.53	0.73±0.26	1.97±0.30	1.30±0.17	1.23±0.16
Other	ChapBay	6.66	2.46±0.68	9.85±0.93	1.28±0.38	1.45±0.44	1.77±0.18	2±0.19
Other	HCorner	18.05	0.62±0.05	0.11±0.02	0.12±0.04	0.80±0.06	0.22±0.04	0.31±0.03
Other	OppPlIsl	6.14	0.29±0.23	5.76±0.70	8.82±1.63	5.12±0.92	1.18±0.54	0.75±0.18
Other	PlIsland	3.99	0.50±0.20	12.37±1.11	3.29±1.24	0±0	0.92±0.18	0.48±0.10
Other	Whiteslea	3.25	2.36±0.53	7.12±1.37	0.31±0.12	2.19±0.25	0.72±0.33	0.68±0.17
Channel	ChannelA	4.41	0.07±0.05	0.20±0.13	0.36±0.14	0.13±0.07	0.13±0.10	0.05±0.03
Channel	ChannelB	3.50	0.31±0.17	0.50±0.39	0.39±0.25	0.86±0.27	0.48±0.16	0.46±0.26
Channel	ChannelC	1.88	0.24±0.18	0.07±0.07	0.47±0.23	0±0	0.41±0.17	0±0

Appendix 6 Mean densities (±s.e.) of total Coot (birds/ha) during the day on each sector during each month of winter 2000/2001. Means have been calculated from the hourly counts made each month.

		Pochard		Tufted Duck		Coot	
	Parameter	Estimate ± S.E.	DF	Estimate ± S.E.	DF	Estimate ± S.E.	DF
Intercept		-7.651 ± 1.850	1	-6.050 ± 1.203	1	-0.733 ± 0.608	1
Month	October	0.317 ± 0.308	1	-0.254 ± 0.221	1	0.478 ± 0.106	1
	November	1.175 ± 0.267	1	-0.237 ± 0.226	1	0.358 ± 0.109	1
	December	0.0 ± 0.0	0	0.0 ± 0.0	0	0.0 ± 0.0	0
	January	0.481 ± 0.284	1	0.361 ± 0.193	1	-0.001 ± 0.122	1
	February	-0.133 ± 0.326	1	0.512 ± 0.196	1	-0.589 ± 0.141	1
	March	0.547 ± 0.283	1	0.593 ± 0.187	1	-0.709 ± 0.147	1
Sector type	Cut	-1.368 ± 0.491	1	0.203 ± 0.218	1	0.541 ± 0.128	1
	Other	-0.235 ± 0.165	1	0.581 ± 0.130	1	-0.043 ± 0.104	1
	Uncut	-1.018 ± 0.378	1	-0.266 ± 0.253	1	0.091 ± 0.136	1
	Channel	-3.848 ± 1.657	1	-1.046 ± 0.359	1	-2.035 ± 0.443	1
	Edge	0.069 ± 0.196	1	0.346 ± 0.169	1	1.297 ± 0.090	1
	Fringe	0.0 ± 0.0	0	0.0 ± 0.0	0	0.0 ± 0.0	0
Hour after dawn	1	-1.465 ± 0.438	1				
	2	-0.395 ± 0.284	1				
	3	-0.997 ± 0.339	1				
	4	-1.067 ± 0.355	1				
	5	-0.496 ± 0.304	1				
	6	-0.367 ± 0.296	1				
	7	0.150 ± 0.267	1				
	8	-0.255 ± 0.299	1				
	9	-0.320 ± 0.383	1				
	10 (+11)	0.0 ± 0.0	0				
Disturbance to sector during count	0 Windsurfers	3.307 ± 1.663	1	1.440 ± 0.719	1	0.657 ± 0.409	1
	1 (or more) Windsurfers	0.0 ± 0.0	0	0.605 ± 0.799	1	0.233 ± 0.436	1
	2 (or more) Windsurfers			0.0 ± 0.0	0	0.0 ± 0.0	0
	0 Yachts	1.036 ± 0.537	1			0.586 ± 0.434	1
	1 (or more) Yachts	0.0 ± 0.0	0			-0.094 ± 0.467	1
	2 (or more) Yachts					0.469 ± 0.901	1
	3 (or more) Yachts					0.0 ± 0.0	0
	0 Rowing boats			1.816 ± 0.813	1		
	1 (or more) Rowing boats			0.0 ± 0.0	0		
Disturbance to sector during preceding hour	0 Windsurfers	1.135 ± 0.642	1				
	1 (or more) Windsurfers	0.0 ± 0.0	0				
	0 Rowing boats			1.219 ± 0.642	1		
	1 (or more) Rowing boats			0.0 ± 0.0	0		
	Predicted Biomass			-0.020 ± 0.010		0.027 ± 0.004	1

Appendix 7 Parameter estimates (± S.E.) for the models (which include Whiteslea and Heigham Corner sectors) relating bird counts to month, sector type, hour after dawn and disturbance factors.

		Pochard		Tufted Duck		Coot	
Parameter		Estimate ± S.E.	DF	Estimate ± S.E.	DF	Estimate ± S.E.	DF
Intercept		-7.728 ± 1.806	1	-7.047 ± 1.372	1	-1.533 ± 0.681	1
Month	October	-0.237 ± 0.337	1	-0.328 ± 0.288	1	0.443 ± 0.098	1
	November	0.897 ± 0.261	1	-0.135 ± 0.272	1	0.289 ± 0.101	1
	December	0.0 ± 0.0	0	0.0 ± 0.0	0	0.0 ± 0.0	0
	January	0.296 ± 0.279	1	0.668 ± 0.228	1	-0.141 ± 0.115	1
	February	-0.181 ± 0.310	1	0.961 ± 0.225	1	-0.689 ± 0.131	1
	March	0.313 ± 0.284	1	1.018 ± 0.223	1	-0.822 ± 0.138	1
Sector type	Cut	-1.386 ± 0.461	1	0.233 ± 0.202	1	0.562 ± 0.118	1
	Other	-0.384 ± 0.223	1	0.160 ± 0.166	1	0.511 ± 0.104	1
	Uncut	-1.028 ± 0.355	1	-0.307 ± 0.232	1	0.172 ± 0.125	1
	Channel	-3.855 ± 1.554	1	-0.935 ± 0.332	1	-2.050 ± 0.406	1
	Edge	0.060 ± 0.184	1	0.309 ± 0.156	1	1.343 ± 0.082	1
	Fringe	0.0 ± 0.0	0	0.0 ± 0.0	0	0.0 ± 0.0	0
Hour after dawn	1	-1.210 ± 0.450	1				
	2	-0.333 ± 0.318	1				
	3	-0.756 ± 0.358	1				
	4	-0.851 ± 0.376	1				
	5	-0.317 ± 0.331	1				
	6	-0.212 ± 0.324	1				
	7	0.334 ± 0.295	1				
	8	0.008 ± 0.325	1				
	9	-0.039 ± 0.406	1				
	10 (+11)	0.0 ± 0.0	0				
Disturbance to sector during count	0 Windsurfers	3.182 ± 1.563	1	1.045 ± 0.685	1	0.691 ± 0.376	1
	1 (or more) Windsurfers	0.0 ± 0.0	0	0.383 ± 0.765	1	0.244 ± 0.401	1
	2 (or more) Windsurfers			0.0 ± 0.0	0	0.0 ± 0.0	0
	0 Yachts	1.443 ± 0.708	1			1.468 ± 0.558	1
	1 (or more) Yachts	0.0 ± 0.0	0			0.747 ± 0.582	1
	2 (or more) Yachts					1.060 ± 0.913	1
	3 (or more) Yachts					0.0 ± 0.0	0
	0 Rowing boats			1.663 ± 0.801	1		
	1 (or more) Rowing boats			0.0 ± 0.0	0		
Disturbance to sector during preceding hour	0 Windsurfers	0.997 ± 0.608	1	1.301 ± 0.823	1		
	1 (or more) Windsurfers	0.0 ± 0.0	0	0.285 ± 0.912	1		
	2 (or more) Windsurfers			0.0 ± 0.0	0		
	0 Rowing boats			1.137 ± 0.644	1		
	1 (or more) Rowing boats			0.0 ± 0.0	0		
	Predicted Biomass					0.018 ± 0.004	1

Appendix 8 Parameter estimates (± S.E.) for the models (which exclude Whiteslea and Heigham Corner sectors) relating bird counts to month, sector type, hour after dawn and disturbance factors.