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A Study of the risk of collision with power lines by Common Terns and waterbirds at Shotton Steel Works, North Wales

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1. EXECUTIVE SUMMARY

1. At Shotton Steel Works, North Wales, over 540 pairs of Common Terns breed within the industrial complex. A report by Henderson *et al.* (1995) investigated the risk of collision with power lines in relation to the stage of the breeding season and time demands on adults, the age of the birds, the significance of distance between the power lines and the breeding colony and climatic variables. Balmer (1998) re-assessed the risk of collision with power lines of terns crossing the 132 kV line and in addition investigated the use of the two breeding islands in relation to the pattern of crossing the power lines.

   The lagoons are also used by significant numbers of waterfowl (Cormorant, Grey Heron, wildfowl, and Gulls) outside of the breeding season, and reports by Balmer *et al.* (1995), and Balmer & Holloway (1998) investigated the impact of the power lines on the waterbirds flying onto and leaving the lagoons.

   The aim of the two studies within this report was to assess the impact of the new 132 kV line (Line 3), sited between the existing 132 kV line (Line 1) and the lagoons, on the tern colony and other waterbirds using the lagoons.

2. During the 2001 breeding season, systematic observations were made of terns making feeding journeys to and from the estuary during the courtship, incubation and nestling stages the breeding season. Their direction, flight pattern and weather variables were recorded. Surveys were also made of the ground beneath the power lines in order to look for casualties. Unusually hot weather in mid-summer caused high mortality amongst chicks (heat exhaustion), so few juvenile terns were available to study. In total, 7213 observations were made of terns crossing the two power lines.

3. During the autumn observations were made of waterbirds journeying to and from the lagoons during October and November. Their direction of flight, flight pattern and weather variables were recorded. Surveys were also made of the ground beneath the power lines in order to look for casualties. A total of 508 observations of birds crossing line 1, and 248 observations of birds crossing line 3 were made.

4. The majority (97%) of terns crossed the power line above the top earth wire, and only a small proportion were recorded flying either through or beneath the power cables. On outward journeys, 1.8% of terns came within 1 m of the cables of Line 3 and only 0.3% of Line 1.

5. The majority of waterbirds crossed the lines above the earth wire (99.8% over line 1 and 99.7% over line 3). Only a very small proportion of birds were recorded as either flying through or beneath the power cables. Only two instances of birds approaching to within 1 m of the cables were recorded, one along each of the two lines. The majority (86.6%) of all the observations of waterbirds crossing the two lines involved birds merely flying over, and not using the lagoons.

6. Unlike previous years, terns were observed making longer journeys on outgoing flights to avoid Line 3 by flying around the end of the power line.

7. The crossing height of Line 1 (spans 1 & 2) in this study was compared to the previous study in 1998. There was a statistically significant difference in the between year crossing height of Line 1 (spans 1 & 2 combined) by Common Terns on outward journeys; Common Terns flew over at a greater height in 2001 than in 1998. There was no significant difference on Incoming journeys.

8. No terns were seen to hit the power lines during extensive observations. Seven casualties were found beneath the power lines during the ground search; one Common Tern, two Oystercatchers, two Black-headed Gulls and one Magpie were found under Line 3 and one Black-headed Gull was found under Line 1. In general, mortality rate of Common Terns due to collisions with wires was considered to be very low.

9. The number of "near misses" involving waterbirds passing over line 1 was much greater during the 1998 survey, when an estimated 2% of all wildfowl flying into or out of the lagoons approached to within 1 m of the cables. No wildfowl were involved in "near misses" during 2001, even with the new line 3 situated closer to the lagoons. Wildfowl leaving the lagoons flew around several times in order to gain sufficient height before crossing the lines. Birds flying onto the lagoons cleared the lines by several metres before making a steep descent to the water

10. This report showed that there was a change in behaviour of breeding terns in the summer and waterfowl in the autumn, but there was no evidence for increases in mortality or energetic costs that would be enough to exert significant negative effects on the populations using the lagoons.

2. INTRODUCTION

For over 50 years there has been documented evidence of the threat that power lines may pose to birds (Borell 1939, Walkinshaw 1956, Bevanger 1994). Birds have been at risk either from collision with power lines (Scott *et al.* 1972) or, in larger species, from electrocution where their wingspan can connect two parallel wires (Fielder & Wissner 1980, Ferrer *et al*. 1991, Orloff *et al.* 1992). The importance of mortality in birds due to collisions with power lines depends on the demography of the population (Rose & Baillie 1989). In species with high survival rates and relatively high reproductive rates (*e.g.* many geese and swans) the problem is less pronounced than for species with high survival rates but low reproductive rates (*e.g.* many large raptors). A comprehensive review of the affect of power lines on mortality is provided by Henderson *et al.* (1995). This study focused on the risks to two groups of birds; breeding Common Terns and waterbirds using the area in the autumn.

The Common Tern *Sterna hirundo* is a medium sized (200g) migratory species, which arrives in Britain during April to breed. Most of the population breeds in widely dispersed colonies along the coast of Britain and Ireland, usually on bare shingle expanses but also on rocky inlets. The coasts of south-west England and mid south Wales are sparsely populated. Most inland colonies are in central and eastern England, east Scotland and central Ireland (Gibbons *et al.* 1993). Numbers of Common Terns in Britain and Ireland have declined this century, but their ability to occupy man-made sites such as purpose-built rafts and islands has probably prevented a greater decline (Lloyd *et al.* 1991). The majority of Common Terns winter on the western seaboard of Africa, principally west and southern Africa (Wernham *et al*. In press, Snow & Perrins 1998).

Common Terns forage for small, shallow water fish and in the absence of locally abundant sources of food they must travel some distance to forage, particularly where breeding colonies are inland. When provisioning young, the parents carry one, and rarely two, fish back to the colony and must make several journeys during the day in order to provide their nestlings with sufficient food (Cramp 1985).

At Shotton Steel Works, North Wales, Common Terns breed within the Deeside Industrial Park and each journey from the breeding colony to the estuary means that the birds must negotiate two spans of power lines. They are agile species and small, agile and diurnal birds are probably considered less vulnerable to collisions with power lines than large birds or nocturnally migrating species.

Previous studies by Henderson *et al.* (1995) and Balmer (1998) have focussed on the Common Terns using Line 1 and Line 2 within the Deeside Industrial Park (Fig 1). The aim was to determine how the risk of collision with power lines would vary in relation to the activity of the birds during the breeding season and the significance of the distance between the power lines and the breeding colony.

The aim of the present study is to assess the impact of a new 132 kV power line (Line 3). Manweb constructed a new 132kV power line within the Deeside Industrial Park parallel to an existing 132kV power line (Line 1). The new power line is located just to the south of Line 1 and closer tern colony. In this study, fieldwork concentrated on the existing 132kV power line (Line 1) and the new 132 kV power line (Line 3) and but did not include the 400kV line (Line 2) that was studied by Henderson *et al.* (1995).

The Common Tern colony at Shotton Steelworks has increased in size over the period of study (1994-2001). The population has increased from an estimated 200 pairs in 1994 (Henderson *et al*. 1995) to around 470 pairs in 1998 (Balmer 1998) to an all-time high of 545 pairs in 2001 (John Birch *pers. comm.*).

The Common Tern is a convenient study species to observe the responses of birds to power lines, due to their being diurnal and because of the high frequency of their foraging journeys. This meant that continuous observations, carried out over long time spans were possible, resulting in large sample sizes and an accurate assessment of collision frequency or collision risk.

The lagoons are used by several species of waterbird throughout the year, but particularly during the autumn months, when the numbers of wildfowl and gulls around the Dee Estuary are swelled by visiting continental birds. Wildfowl in particular frequently fly between the lagoons within the Shotton Steelworks, and large numbers of gulls fly over the lagoons and the electricity lines as they commute to and from the adjacent Dee Estuary. The study aimed to update the previous observations by Henderson *et al.* (1995) and Balmer & Holloway (1998), and assess the effect of the new 132 kV power line (Line 3) on the waterfowl both using the lagoons and flying over the study site.

3. METHODS

3.1 Study Site

The Common Tern colony of around 545 pairs is situated within the industrial area of Shotton Steelworks, on Deeside, North Wales (OS 296 707). The artificially constructed nesting islands are set within water-filled lagoons, which are surrounded by scrub. Beyond the lagoons and scrub is wasteland, which gives way to saltmarsh to the north and west (Fig 1.). Terns flying to and from the estuary need not cross any industrial construction, except for power lines. However, terns also have to negotiate the recently constructed suspended road. Three sets of power lines run more or less south-west from the National Power power station towards the River Dee and in doing so act as potential obstacles which the terns must cross on their journeys to and from the estuary (Fig. 2). The estuary is approximately 5 km to the north-west of the tern colony, or approximately 10 minutes flight time.

Line 1 is approximately 100 m from the nesting islands at its closest point. Line 1 carries 132kV on cables between 6.7m and 26m high (the height of the pylon). Line 1 comprises six groups of four closely held cables plus an earth cable running from the top of the pylon. The groups of cables are 2.8m apart.

Line 2 is a relatively new construction carrying 400kV and is approximately 200m away from the nesting island at its nearest point. It is almost twice as high as line 1 but carries fewer cables (three groups of two, plus an earth wire) with the 5.7m distance between cables groups. The pylons rise to 46m and at their lowest point the power cables are 7.6m above the ground. In the present study, observations of terns crossing line 2 were not recorded.

Line 3 is the new 132kV power line and is approximately 30m away from the nesting island at its nearest point. Line 3 is the same height and specification as Line 1.

During the autumn, the lagoons are used by several species of waterbirds, principally Cormorants, ducks, Coots and gulls.

3.2 Data Collection

3.2.1 Tern Observations

Systematic observations were made of terns making journeys to and from the estuary during the nestling and juvenile phases of the breeding season. There was a period of hot weather in mid-June that caused many chicks to die as a result of heat exhaustion (John Birch *pers comm*.). Observations suggest that once juvenile Common Terns have left the nest they tend to move away from the colony quite quickly, therefore few were available to record.

Three visits were made to the site. The first visit (35 hours observations) was during May and was timed to coincide with the courtship/early incubation period. The second visit was during June (33 hours observations) and the majority terns were provisioning young and some were still incubating. Over 400 chicks had been ringed by the end of June (John Birch *pers comm*.). The third visit was in mid-July (31 hours) by which time adults were still provisioning young and many juveniles had fledged.

For each tern crossing Line 1 and Line 3 the following criteria were recorded:

1. Direction of journey.

2. Number of birds in flock.

3. Whether the bird passed over, under or between the wires.

4. The estimated height in metres of the bird when crossing above the top earth wire.

5. Whether a bird approached the power line either level with, above (the top wire) or below (the lowest line) the cables at a distance of 6 m away from them.

6. Weather estimations: Wind speed (Beaufort estimate) and direction, visibility (metres), percentage cloud cover and rain (1 - barely raining, 2 - light rain, 3 - steady rain, 4 - heavy rain, 5 - storm).

7. Age of bird. Juveniles are easily separated from adults on their flight pattern (juveniles have a much quicker wing beat than adults) and on plumage features (White & Kehoe, 2001).

The number of terns taking an outward route over Line 3 or avoiding Line 3 was also counted in randomly selected 10-minute periods. There were 15 10-minute counting periods in May, six in June and seven in July. These counts were instigated when it became obvious that many terns had changed their behaviour and were taking a new route out to the estuary that avoided crossing Line 3.

3.2.2 Waterbird Observations

The methods follow Balmer & Holloway (1998). Systematic observations were made of the all waterbirds attempting to cross lines 1 & 3, journeying to and from the water-filled lagoons during the early autumn. Any individuals also merely flying over the power lines, and not necessarily on or off the lagoons were also recorded. No terns were present on the lagoons, these birds having left the site by mid September. The first visit (comprising a total of 24 hours of observations) was during early October, the second visit (33 hours of observations) was in late October and the final visit (30 hours of observation) was made during mid-November. On most days, the observations were made from dawn to dusk.

For each bird or flock crossing Line 1 and Line 3, the following criteria were recorded:

1. Direction of journey.

2. Number of individuals.

3. Whether the bird(s) passed over, under or between the wires.

4. The estimated height (in metres) of the bird(s) when crossing above the top earth wire.

5. Whether a bird approached the power line either level with or above the top (earth) wire or below the lowest line of wires at a distance of 6 m away from them.

6. Weather estimations: Wind speed (Beaufort estimate) and direction, visibility (metres), percentage cloud cover and rain (1 – barely raining, 2 – light rain, 3 – steady rain, 4 – heavy rain & 5 – storm)

3.3 Ground Survey of Casualties

The ground beneath Line 1 and Line 3 was walked on two occasions during each of the three visits (six times in total) both during the summer and autumn surveys in order to look for corpses and casualties which might have struck the power cables. As much of the ground as possible was covered to within 30 m either side of the outside wire using a zig-zag path through the grass or undergrowth. Not all of the ground was either accessible or visible, including the majority of span 8 of Line 3.

3.4 Presentation of Results for the Autumn Survey

The water birds recorded have been split into four groups for the purposes of the analyses; these are Cormorant, wildfowl, gulls and waders. The species comprising each group are as follows.

1. CORMORANT: Cormorant (*Phalacrocorax carbo)* and Grey Heron *(Ardea cinerea)*

2. WILDFOWL: Gadwall *(Anas strepera)*, Mallard *(Anas platyrhynchos)*, Shoveler *(Anas clypeata)* and Tufted Duck *(Aythya fuligula)*.

3. GULLS: Black-headed Gull *(Larus ridibundus)*, Common Gull *(Larus canus)*, Lesser Black-backed Gull *(Larus fuscus)*, Herring Gull *(Larus argentatus)* and Great Black-backed Gull *(Larus marinus)*.

4. WADERS: Lapwing *(Vanellus vanellus)*.

4. RESULTS

4.1 Summer Tern Survey

4.1.1 Crossing Pattern

A total of 7213 observations were made of Common Terns crossing Line 1 and Line 3, which is slightly more than in the previous study (Balmer 1998). The approach line of terns at a distance of 6m away from the cables was recorded for Line 1 and Line 3. Terns could either be level with or above the top earth wire or below the lowest wire. For Line 1 and Line 3, the majority of terns (87% and 81% respectively) approached the power line above the top earth wire. Fewer terns (13% and 19% respectively) approached level with the top earth wire. Very few birds (less than 1% for each line) approached below the lowest cable.

On average, terns flew closer to the top earth wire of Line 1 and Line 3 on outgoing flights than incoming flights. Juveniles flew closer to the top earth wire than adults (Table 1). Comparing spans 1 & 2 of Line 1, terns flew significantly closer to the top earth wire of span 2 on outgoing flights and span 1 on incoming flights (Table 2). Terns were only recorded using span 8 of Line 3. During the observations no terns were recorded crossing span 7, probably because this would have involved a detour to the estuary.

For both Line 1 and Line 3, 180 adult Common Terns were observed flying through the spans. On outgoing flights over Line 1 and Line 3, 133 terns flew through the spans of each line; this represents 5% and 6% respectively of the total outward crossings. Only 1% of the inward journeys concerned terns flying through the spans of Line 1 and Line 3 (Table 3). There was no significant difference in the number of terns flying through spans 1 and 2 on outward journeys but significantly more terns flew through span 1 than span 2 on inward journeys.

On outward journeys, more terns flew under Line 3 than Line 1 but on incoming journeys the number was similar (Table 4). Sample sizes were too small to detect any difference in the pattern of use of spans 1 and 2 of Line 1.

For adults and juveniles combined, 54 outward crossings were estimated at less than 1m above the earth wire, this represents 1% of the total outward crossings. On outward journeys, 1.8% of terns came within 1 m of the cables of Line 3 and only 0.3% of Line 1 (Table 5). There were 29 inward crossings of less than 1m above the earth wire; this represents 0.3% of the inward crossings. Looking specifically at the phases of the breeding season (courtship, incubation and hatching), there were more ‘near misses’ (a crossing estimated to be less than 1 m above the earth wire) during the hatching stage than during courtship or incubation (Table 5). Of the 83 ‘near-misses’, 63% were over Line 3 and 37% were over Line 1.

4.1.2 Route to Estuary

During 28 10-minute counting periods, more terns (64%, n= 715) were observed flying out to the estuary by taking a route that avoided crossing Line 3 than taking a more direct route crossing Line 3 (36%, n= 405).

4.1.3 Crossing Height and Climatic Factors

There was a highly statistically significant negative correlation between cloud cover and the height at which terns crossed Line 1 (ρ= -0.167, p= <0.0001, n= 7025) and Line 3 (ρ= -0.120, p= <0.0001, n= 7047). There was a weak statistically significant negative correlation between wind speed and the height at which terns crossed Line 1 (ρ= -0.030, p= 0.0123, n=7024) and between rain and the height at which terns crossed Line 1 (ρ=-0.026, p=0.0287, n=7025) (Table 7).

4.1.4 Ground Survey of Casualties

The ground beneath Line 1 and Line 3 was searched twice during each visit. In total seven casualties were found of four species. One freshly dead Common Tern was found under span 7 of Line 3, representing a tiny fraction of the colony population (0.09%). Two Oystercatchers, two Black-headed Gulls and a Magpie were also found under span 7 of Line 3. One Black-headed Gull was found under Line 1. All three Black-headed Gulls were found after a period of strong winds. In addition, a recently fledged Common Tern was found under power lines to the south-east of the colony during a period of strong winds. In the previous survey by Balmer (1998) no corpses were found during comparable searches.

4.1.5 Comparison of Crossing Heights (by Span) of Line 1 Between 1998 and 2001

During this study and the previous study in 1998 we monitored the crossing height of Line 1 and therefore we have been able to make a comparison between these years to detect any changes in crossing height. There was a statistically significant difference in the between year crossing height of Line 1 (spans 1 & 2 combined) by Common Terns on outward journeys (Kruskal-Wallis Test: χ^2 = 299.35, DF= 1, p= <0.0001); Common Terns flew over at a greater height in 2001 than in 1998. There was no significant difference on Incoming journeys (Kruskal-Wallis Test: χ^2 = 0.19, DF= 1, p= <0.6666). We also made separate comparisons for span 1 and span 2 of Line 1 between 1998 and 2001 for outgoing and incoming journeys. There were statistically significant differences in the crossing height of Common Terns over span 2 for both outgoing and incoming journeys (χ^2= 17.5, DF= 1, p= <0.0001 and χ^2= 40.90, DF= 1, p= <0.0001 respectively). Similarly, there were statistically significant differences in the crossing height of outgoing and incoming Common Terns over span 1 (χ^2 = 312.3, DF= 1, p=<0.0001 and χ^2 = 5.22, DF= 1, p= 0.0223 respectively). In all but the latter case, terns flew over the spans at a greater height in 2001 than in 1998.

4.2 Autumn Waterbird Survey

4.2.1 Crossing Pattern

On average, more gulls (108 birds per day) crossed lines 1 & 3 than any other group. Waders and wildfowl crossed the lines at a similar rate (28 and 26 birds per day respectively). Cormorants were only occasionally observed crossing the lines (2 birds per day). The majority of the gull records comprised flocks of up to 100 birds, flying over span 2 (Line 1) as they headed to and from the Dee Estuary. Very few actually flew onto or off the lagoons. Similarly, the wader totals refer to flocks of Lapwing (comprising up to 80 individuals during early October) moving to and from the estuary, with the majority passing over span 2. The largest flocks of wildfowl recorded were of 37 Shoveler and 24 Mallard flying off the lagoons and over the lagoons respectively.

Compared to the results of the autumn 1998 survey of line 1, where the average numbers per day of Waders and Wildfowl crossing line 1 were 41 and 30 respectively, the 2001 survey revealed declines in the daily numbers of both species groups. Cormorant numbers per day were, however, similar during both surveys. Conversely, the average number of Gulls flying over line 1 was markedly greater during autumn 2001 (108 per day compared to 29 per day during the 1998 study).

During 2001 the second half of October was the peak month of occurrence of Wildfowl and Gulls, which was also the case in 1998. More Waders were recorded in November during the current study, by virtue of several flocks passing over the area. During 1998, October was the peak month for waders, with none recorded during November at all. November was also the peak month for Cormorants during both of the surveys.

4.2.2 Route to Estuary and Use of Wire Spans

Table 8 shows the direction (expressed as a percentage) that the birds were following when crossing the wires. Cormorants crossed Line 1 in a mainly north-westerly direction (47.8%), with 39.1% also flying in a south-east direction. These two directions were also the two most important during the 1998 survey. The few Grey Herons noted flew either south or north-west. Wildfowl crossed the lines in many directions, but mainly in a northerly or south-easterly direction in similar numbers (27.3% and 24.1% respectively). The previous survey also found that more of the wildfowl crossed the wires in a northerly direction (33.3%), but 31.5% flew due south, compared to only 15.5% during the present survey. An appreciable number of wildfowl (18.8%) during 2001 were also recorded flying in a north-westerly direction, slightly more than during the 1998 survey. Gulls also crossed the lines in most directions, but with the majority heading north-west (57.2%), compared to the previous survey, which found that the gulls crossed the line mostly either in a south-easterly (25.8%), southerly (24.2%), or northerly (22.5%) direction. Waders mainly flew north-west (25.6%) or north (20.4%), compared to 80% of all the waders recorded during the 1998 survey, which were flying in a north-westerly direction.

The birds crossing the power lines are either flying onto the lagoons from the estuary or other nearby lagoons, flying out of the lagoons to surrounding habitats, or flying over the power lines *en route* to other feeding or roosting sites. Cormorants and Waders (both 100%) were only recorded flying over the power lines, whilst Gulls (98.5%) were mostly seen flying over, with very few using the lagoons. These figures are very similar to those of the 1998 survey, although some use of the lagoons by waders (20% of all observations) was noted then. The current survey recorded reasonable amounts of Wildfowl activity around the lagoons, with 40% of all observations involving birds flying into the lagoons, and 37% birds leaving the lagoons. The respective percentages during the previous survey were 49.1% and 37%.

Waterbirds crossing line 1 were recorded crossing either span 0, 1 or 2 (Table 9). Most of the Cormorants (69.6%) crossed span 2, with smaller numbers (21.7%) crossing span 1. The equivalent values from the 1998 survey were 44.4% and 37.9% respectively. As found during the previous survey, the majority of Wildfowl crossed span 0 (54.4% *vs* 65.7% in 1998). In 2001 the majority of Waders crossed span 2 (76.6%), whereas in 1998, 80% of all the waders recorded crossed span 1. All of the Wader observations during autumn 2001 relate to Lapwings, with the majority involving flocks moving to and from the estuary, whereas during autumn 1998 several wader species were recorded, with some using the lagoons. Gulls also show a mark difference of route between the 2001 and 1998 surveys, with virtually all birds (87.4%) crossing span 2 during 2001 compared to 41.7% and 34.6% crossing spans 0 and 1 respectively during 1998. The majority of all Gulls recorded in this study were flocks moving to and from the estuary, with the largest concentrations around dawn and dusk. For all birds, 72.2% of observed crossings over line 1 were over span 2, compared with 14.2 % over span 0 and 13.3% over span 1 (Table 10). These figures differ markedly from the 1998 survey, when most observed crossings were over span 0 (46.3%), with figures for span 1 of 34.5% and span 2 of 19.2% respectively.

Of the waterbirds crossing line 3, each bird crossed either span 7 or 8. Most Cormorants crossed span 8 (71.4%)(Table 11). The majority of wildfowl (58.1%) crossed span 7 of line 3, with smaller numbers crossing span 8 (41.9%). As both Waders and Gulls either made no use of the lagoons, or rarely used them, the number of individuals observed crossing line 3 was comparatively low. Most Waders (73.4%) crossed span 8, whilst the majority of gulls (54.1%) crossed span 7. Of all the birds crossing Line 3, 51.1% of observed crossings were over span 7, and 48.9% over span 8 (Table 12).

4.2.3 Crossing Height

Line 1:

As recorded during the previous study, there was a significant variation in the height at which the four groups crossed line 1 (Kruskal-Wallis Test: X^2 = 9.92, df = 3, p = 0.0193). As noted in 1998, waders tended to cross the line higher than the all the other species groups (average height of 17.8 m) (Table 13).

There was no significance difference in the height that Cormorant, Wildfowl and Waders passed over spans 0, 1 and 2 of line 1. Gulls, however, flew over span 2 at a significantly greater height than the other two spans (Kruskal-Wallis Test: x^2 = 9.39, df = 2, p = 0.0091). This might be explained in that most of the gull observations during the study involved birds flying over span 2 as they headed to and from the estuary either to feed or roost. As they were in transit, they invariably passed over the lines at a greater height than would have been the case had they been using the lagoons.

The height at which the birds approached the power lines varied, and was classified by their height when 6 m from the cables into three categories: above (the earth wire), level (between the earth wire and lowest) and below (the lowest wire). All four species groups tended to approach line 1 above the earth wire, rather than level or below the cables. If all the four groups are combined, it is apparent that over 99.8% of birds crossed line 1 above the earth wire. This is a greater percentage than recorded both during the 1998 survey (93.7%) and the earlier 1995 survey (93.5%).

Birds approaching line 1 at a level below the lowest cable included Mallard and Black-headed Gull (0.17% of all birds). No Cormorants or Waders were recorded flying below the cables. The 1998 survey only recorded very small numbers of birds passing beneath the cables, with Cormorant the most frequent (2%), and gulls and waders less frequently (less than 1%).

Those birds that were level with the power cables at a 6 m distance either flew between the cables or took late avoidance action to prevent a collision. The only bird observed flying through the cables of line 1 during the 2001 survey was a single Grey Heron (0.0004%). Only a few Gulls (less than 1%) and no other group were observed flying through the cables during the 1998 survey.

Birds that passed over the earth wire within a distance of 1 m or less are termed as "near misses". There was only one instance of a "near miss" along line 1, involving a Lesser Black-backed Gull over span 1.

Line 3:

There was no significant variation in the height at which the four species groups crossed line 3 (Table 13) (Kruskal-Wallis Test: X^2 = 1.65, df = 3, p =0.6489), perhaps as a result of the relatively small sample size.

There was no significance difference in the height that any of the species groups crossed over spans 7 and 8 of line 3 (Kruskal-Wallis Test: x^2 = 4.04, df = 1, p = 0.0442).

All four species groups tended to approach line 3 above the earth wire, rather than level or below the cables. If all the four groups are combined, it is apparent that over 99.7% of birds crossed line 3 above the earth wire.

The only species observed flying under the cables of line 3 was Mallard (0.3% of birds). There was only a single instance of a "near miss" involving a Lesser Black-backed Gull passing over span 8.

4.2.4 Crossing Height and Climatic Factors

There was a statistically significant negative correlation between wind speed and the height at which gulls crossed over line 1 (rho = -0.197, n = 250, p = 0.0017) (Table 14). This result is similar to that obtained during the 1998 survey. However, as with the 1998 survey, there was no significant correlation between wind speed and the height at which Cormorant, wildfowl and waders crossed line 1. Gulls were also found to fly across line 1 at a greater height as the amount of cloud increased (rho =0.173, n = 250, p = 0.0059). This correlation was not recorded during the previous survey, although there was a statistically weak significant positive correlation found between visibility and the height at which Wildfowl crossed line 1. No such correlation was recorded during the current survey. A weakly significant negative correlation was found between the height at which Waders (but none of the other species groups) crossed line 1 and rain (rho = -0.515, n = 20, p = 0.0199). Conversely, during the 1998 survey, no significant correlates were found for any of the four species groups linking rain and the height at which they crossed line 1. However, the sample sizes for Waders for both the current and previous survey were very small.

Cormorants showed a statistically positive correlation between wind speed and the height that they flew over line 3 (rho = 0.932, n = 8, p = 0.0007) (Table 14). There was no significant correlation between wind speed and crossing height for Wildfowl, Gulls or Waders, nor between rainfall and crossing height for any of the four species groups. Gulls, however, showed similar statistically significant negative and positive correlations respectively between both wind speed and cloud cover and the height at which they crossed line 3 (rho = -0.215, n = 132, p = 0.013 and rho = 0.208, n = 132, p = 0.016 respectively). These results are very similar to those for Gulls flying over line 1. No significant correlation between wind and rain and the height at which the other three species groups crossed line 3 was found.

4.2.5 Comparison of Crossing Heights (by Span) of Line 1 Between 1998 and 2001

There was no significant difference in the between year crossing height of span 0 by either Cormorants or Waders. Gulls and Wildfowl both flew over at a greater height during 1998, than in 2001 (Kruskal-Wallis Test: X^2 = 22.5, df = 1, p = <.0001 and x^2 = 21.8, df = 1, p = <.0001 respectively). Cormorants, Wildfowl and Gulls also flew over span 1 at a greater height in 1998 than 2001 (Kruskal-Wallis Test: X^2 = 5.0, df = 1, p = 0.0247, X^2 = 39.1, df = 1, p = <.0001 and X^2 = 23.1, df = 1, p = <.0001 respectively). There was no significance between year difference in the height that Waders crossed span 1. The crossing heights of Cormorants and Gulls over span 2 were also significantly higher in 1998 than 2001, (Kruskal-Wallis Test: X^2 = 11.9, df = 1, p = 0.0006 and X^2 = 13.8 df = 1, p = 0.0002 respectively). However, Wildfowl and Waders showed no significant differences in their crossing height of span 2 between the two years. Overall, comparing the two studies, Gulls were consistently recorded flying over all the spans at a greater height in 1998 than in 2001.

4.2.6 Ground Survey of Casualties

No corpses of waterbirds were found during the systematic surveys of the ground beneath the power lines. This was also the case during the autumn 1998 survey.

5. DISCUSSION

5.1 Summer Tern Survey

In all, over 7200 observations were made of Common Terns crossing Line 1 and Line 2 during the study period May 2001 to July 2001. Birds were recorded throughout the day, but most activity was recorded during the early morning and late afternoon.

The timing of the study was aimed to cover the courtship, incubation and hatching stages of the breeding cycle. Merseyside Ringing Group ringed over 400 chicks by the end of June, and more were ready to ring in early July. Due to hot weather in mid-June a number of chicks died as a result of heat exhaustion. Fledged terns moved away from the colony quickly and less than 1% of all observations made were of juvenile terns, so in 2001 we were unable to statistically test for differences between the behaviour of adult and juvenile terns.

In this study, Common Terns preferred to cross the top earth wire (97% of observations) on both outward and inward flights, thus only 3% flew through or under the wires. This is a greater percentage than in the 1998 study, which showed 85% of observations above the top earth wire. In the previous study, more terns crossed through or under the wires than over the top earth wire.

Terns flew much closer to the earth wire of Line 3 than Line 1 on outward journeys because terns leaving the colony have to climb more quickly to gain enough height to cross the earth wire safely. Line 3 is the first power line that terns have to negotiate and is in close proximity to the tern colony, and once terns are over Line 3 then it is easier for them to cross Line 1. On inward journeys, the terns are already flying quite high because they have already crossed the 400kV power line (Line 2) before reaching Line 1 and Line 3. Terns tend to cross over Line 1 then drop quite quickly in height over Line 3 to make their descent to the colony. Despite the small sample size, it is fairly clear that juveniles crossed over the earth wire much closer than adults on outward and inward journeys.

On outward journeys, terns that crossed over span 8 of Line 3 then crossed span 1 of Line 1 in greater numbers than over span 2. For the majority of terns the most direct route to the Dee estuary would involve crossing span 1. On outward flights, terns tended to cross closer to the earth wire of span 2 than span 1, and on inward flights the reverse was true.

Birds that approached the top earth wire level or below the cable were forced to take late avoidance action and generally flew close to the earth wire. Some terns double-backed on themselves to have a second attempt at crossing the earth wire whilst other terns flew through the cables. Those terns that crossed at a distance of 1m or less are termed 'near misses'. A total of 54 outward crossings were estimated at less than 1m over the earth wire, compared with 174 recorded in 1998 (Balmer 1998). The proportion of 'near-misses' has fallen during the three studies. Henderson *et al*. (1995) found less than 7% of adult crossings to be less than 1m above the earth wire. Balmer (1998) found 4% of the outward crossings, for adults and juveniles combined, to be less than 1m above the earth wire. The present study has found only 1% of outward crossings, for adults and juveniles combined, to be less than 1m above the top earth wire. Although these proportions are not directly comparable, it may suggest that the Common Terns 'learn' about the power lines over time and are able to avoid them. Of the 83 'near-misses' recorded, 63% involved birds crossing Line 3 and 37% crossing Line 1. The majority of 'near-misses' concerned birds crossing over Line 3 on outgoing journeys, this is because Line 3 is the closest power line to the colony. Conversely, there were more 'near-misses' over Line 1 in inward flights than over Line 3; Line 1 is the first power line terns reach after crossing the much taller 400kV Line 2. In general, the proportion of birds involved in 'near misses' was very low.

The incidence of 'near-misses' was greatest during the hatching phase (63%), compared with the incubation phase (30%) and the courtship phase (7%). This result matches by the result found by Henderson *et al.* (1995). Early in the season terns tend to fly high and so avoid the power lines. Also during incubation, terns make regular flights to and from the estuary but are not under any urgency to reduce journey time. During the hatching phase when adults are provisioning chicks, the adults need to reduce the journey time by taking short-cuts and more risks when crossing the wires, hence an increase in the number of 'near-misses' during this phase.

Line 1 was monitored during the present study and also during the previous study (Balmer 1998), so we are able to compare the crossing height over Line 1 (spans 1 & 2) during outgoing and incoming journeys in 1998 and 2001. There was a statistically significant difference in the between year crossing height of Line 1 (spans 1 & 2 combined) by Common Terns on outward journeys, with the birds flying over at a greater height in 2001 than in 1998. However, there was no significant difference in the crossing height over Line 1 (spans 1 & 2 combined) on incoming journeys. During this study, Common Terns on outgoing journeys now have to cross Line 3 before reaching Line 1. This means that the terns have to gain height steeply to clear Line 3, and are more likely to fly over Line 1 at a greater height than they did in 1998 when Line 3 was not there. On incoming journeys there has been no change in the layout of the power lines that might affect the approach of Line 1, Common Terns in both studies need to negotiate Line 2 (400 kV) before crossing Line 1.

During the first visit in May it became obvious that a number of terns making outgoing journeys to the estuary were taking a route that took them beyond the end of span 8 of Line 3 and then across span 2 of Line 1, rather than taking the more direct route over span 8 of Line 3. During outgoing journeys only, the number of terns taking a route over Line 3 or around Line 3 was counted in 28 10-minute periods. More terns (64%) were observed flying out to the estuary by flying beyond the end of Line 3 rather than crossing it. This involved a more indirect flight to the estuary but eliminated the necessity to cross Line 3 and therefore reduced the risk of collision. This aspect of behaviour has not been recorded quantitatively in previous years but personal observations suggest that few terns followed this route to the estuary. It is likely that due to the close proximity of Line 3 to the colony, terns would rather take a longer route than attempt to climb steeply to safely cross the power line.

The negative correlation coefficient between cloud and the height at which terns crossed Line 1 and Line 3 means that as cloud cover increases, terns fly closer to the top earth wire. The weak negative correlation between wind speed and the height at which terns crossed the top earth wire of Line 1 suggests that as wind speed increases terns are more likely to fly closer to the earth wire of Line 1. The same applies for the weak negative correlation with rain and height over Line 1, as rain increases terns fly closer. Dull, overcast weather and especially thick fog and wind are known to influence the flying height of birds, usually forcing them to fly at a lower altitude (Avery et al. 1977, Elkins 1988). However, terns are agile species and are more likely than most species to be capable of taking late avoidance action if necessary.

The weather on 11 July was generally very windy (up to Force 6 – Strong Breeze) interspersed with heavy showers throughout the day. It was noticeable that fewer birds were crossing to the estuary than usual. During the early morning period, usually the busiest time of day for journeys, virtually no birds were attempting to fly to the estuary. Those that did attempt to cross were clearly battling against the wind. Later in the day, still very few birds were crossing to the estuary. It is likely that when it is very windy, the terns stay at the colony and go without food, rather than risk crossing the power lines to reach the estuary, where they are more likely to find it difficult to fish in rough seas. Elkins (1988) reported that in strong surface winds most birds go to ground to avoid the risk of collision with obstacles. This fits well with the behaviour noted on 11 July.

The survey of the ground beneath Line 1 and Line 3 revealed seven corpses of four species (Common Tern, Black-headed Gull, Oystercatcher and Magpie). The ground survey gave an accurate representation of the casualty rate in the areas that could be surveyed. Much of the ground under span 1 of Line 1 and span 8 of Line 3 could not be surveyed because of the dense vegetation (reedbed and scrub). All but one corpse (Black-headed Gull) was found beneath the new power line (Line 3). In the two previous studies, two Common Terns were found in 1994 (Henderson *et al*. 1995) and none were found in 1998 (Balmer 1998). Seven corpses represent a notable increase. It is likely that these fatalities occurred on outward journeys when birds are under more pressure to rise quickly from the lagoons to clear Line 3.

No birds were seen to strike wires. In conclusion, the mortality rate of birds due to collisions with wires, although an increase on previous studies, still remains low.

Other studies on power lines and bird interactions have suggested that removing earth wires can reduce collision frequency (Beaulaurier 1981). Earth wires in particular have been found to cause bird collisions because they are thinner and less visible. Improved wire marking would improve the visibility of the wires to the birds and is likely to reduce collisions.

5.2 Autumn Waterbird Survey

Thirteen species of waterbird were recorded crossing the line 1, (the same number recorded during the study of 1998), and a total of 11 species was recorded crossing line 3 during the study period of early October to November 2001.

A total of 508 flocks crossed line 1 during the field observations, comprising a total of 2,349 individual waterbirds. This is considerably higher than the respective totals of 380 crossings and 924 individuals recorded during the 1998 survey. Much of the difference can be explained by the large flocks of Gulls moving to and from the estuary each day, and passing over span 2 of line 1. A total of 248 crossings of line 3 were recorded during field observations, resulting in 655 individual waterbirds crossing the spans. This is considerably lower than the totals for line1, as the large flocks of Gulls moving to and from the estuary each day missed the spans of line 3 altogether.

As noted during the 1998 survey, Gulls and Waders were the two most frequently recorded species groups. November was the peak month for Waders (October during the previous survey), whilst October (particularly late October) was the peak month for both Gulls and Wildfowl (as in 1998). The peak month for Cormorants was November, as recorded during the previous survey.

Not all of the waterbirds crossing the power lines were making use of the lagoons, 86.6% of all records involved birds merely flying over the lines en-route to feeding or roosting areas within the surrounding habitats. During the 1998 survey, a slightly higher number of birds were recorded using the lagoons (73% merely flying over). In 2001, Cormorants (100%) and Waders (100%) were only recorded as flying over, and never made use of the lagoons at all. Very few of the Gulls used the lagoons (98.5% merely flying over), which is similar to the previous survey, when 97.9% of all Gulls were flying over the site. Conversely, most of the Wildfowl recorded used the lagoons (only 22.5% flying over). Most of the Waders and Gulls flying over the site were high enough to avoid the possibility of collision with the wires.

As noted during the 1998 survey, the main direction of travel for each of the four groups was related to their feeding and roosting areas. Cormorants and Herons tended to cross the lines in a mainly south or south-easterly and north-westerly direction, the birds commuting from the estuary and the adjacent saltmarsh to inland areas and back again, similar to the previous survey. Wildfowl crossed the lines in a northerly/north-westerly and south/south-easterly direction, and were probably commuting to and from pools and reservoirs to the north and north-east of the National Power Plant. This is very similar to 1998, although the birds tended to follow more of a north/south route then. Gulls also followed a north-westerly/northerly and south-easterly/southerly route, again virtually identical to 1998. During autumn 2001, the majority of the Gulls flying over were passing over span 2 of line 1 as they headed to the estuary towards dusk, presumably to roost, and out again during the early morning, presumably to inland feeding sites. Waders flew in a mainly north-westerly or northerly direction, either towards the estuary or adjacent saltmarsh. Smaller numbers also crossed in a south-easterly or southerly direction, heading for inland fields. During the 1998 survey, most of the Waders were recorded crossing in a north-westerly direction.

The frequency with which the birds crossed spans 0 to 2 of line 1 and spans 7 and 8 of line 3 reflects the direction of travel of the different groups. Span 2 of line 1 was crossed with the greatest frequency, 72.4% of all crossings (mostly comprising large flocks of Gulls moving to and from the estuary). Span 1 accounted for 14.3% of all crossings of line 1, and span 0 13.3%. This compares to 46.3% crossing span 0, 34.5% crossing span 1, and 19.2% crossing span 2 during the 1998 survey. The numbers of birds crossing spans 7 and 8 of line 3 was roughly equal, with 51.4% over the former, and 48.6% over the latter.

Waders crossed line 1 at a greater height than the other species groups, as was the case during the 1998 survey. Gulls also flew relatively high over line 1. The vast majority of birds (99.8% over line 1 and 99.7% over line 3) approached the lines above the earth wire. These are greater percentages than recorded during the 1998 survey. Very few birds were observed as passing below the level of the lowest cable of line 1 (Mallard and Black-headed Gull being the only species involved), and only the occasional Mallard flew below the level of the lowest cable of line 3. The only species observed flying through the cables of line 1 were Grey Heron and a few Gulls, whilst no species were observed doing so along line 3. Only a couple of instances of "near misses" along the two lines were noted, both involving Lesser black-backed Gulls.

There appears to have been fewer incidences of "near misses" particularly involving Wildfowl crossing line 1 than during the previous survey, when incidents occurred as the birds were leaving the lagoons to commute to nearby pools and reservoirs in 1998. The birds were observed to rise steeply in order to clear line 1, and apparently not see the wires, particularly the earth wire, until the last second. With the construction of line 3, closer to the lagoons than line1, Wildfowl leaving the lagoons now have to gain even more height in a shorter space of time in order to clear the lines. During 1998, it was estimated that 2% of all the wildfowl observations of birds flying into or out of the lagoons involved "near misses" with the top earth wire of line 1. It is conceivable that with the construction of the newer 132kv line 3 closer to the lagoons since 1998, Waterfowl have learnt to attain height very quickly by flying around the lagoons several times after take-off before then crossing the lines. During 2001 it was noticeable that virtually all of the Wildfowl leaving the lagoons flew around the pools several times in order to gain sufficient height to clear line 3, (at an average height of over 10 m). This allowed them to avoid "near misses" for both lines 1 and 3 altogether, a much-improved situation from the previous survey. Wildfowl coming into the lagoons cleared the two lines at a reasonable height (over nine metres), and then made a steep descent towards the surface of the lagoons, but often circled them at least once before actually landing.

As calculated during the 1998 survey, there was a negative correlation coefficient between the wind speed and the height at which Gulls crossed the lines, with the birds closer to the top wire during windy conditions. There was a positive correlation coefficient between cloud cover and the height at which Gulls crossed line 1 (the greater the amount of cloud, the higher the birds flew). This was not recorded during the 1998 survey. There was a weak negative correlation coefficient between the amount of rainfall and the height that waders crossed line 1. This suggests that during heavy rain, (perhaps with impaired visibility) there is an increased chance of Waders colliding with the top wire.
Conversely, Cormorants showed a positive correlation between wind speed and the height at which they cleared line 3. Gulls revealed a negative correlation coefficient between both wind speed and rainfall as they crossed line 3, suggesting an increased risk of collision during certain weather conditions.

The survey of the ground beneath both lines 1 and 3 did not reveal any corpses. However, there were certain areas along both of the lines that could not be surveyed (*e.g.* impenetrable scrub and reedbeds). However, as these only represent a relatively small proportion of the total area surveyed, it is unlikely that many, if any, corpses were missed. No corpses were detected under line 1 during the 1988 survey, and the overall conclusion remains that the mortality rate of waterbirds due to collision at this time of year remains very low.

During the study carried out during autumn 2001, relatively few birds made use of the lagoons. As noted during the 1998 survey, Wildfowl were found to be the only species group to regularly use the lagoons, with 77.5% of all the species groups using the lagoons and crossing the lines involving Wildfowl. The commonest species accounting for most of the sightings was Mallard, but the largest flocks recorded passing over the lines comprised Shoveler. This is a slightly lower percentage than recorded during the 1998 survey, when 86% of all Wildfowl observations involved birds flying into or out of the lagoons. Virtually all the Wildfowl passed over the top earth and the only observation of birds flying under the power lines involved a group of 7 Mallard leaving the lagoons which passed below span 7 of line 3 and span 1 of line 1.

The movements of birds onto and from the lagoons did not appear to be seriously hampered by the two power lines. Individuals from species groups such as Cormorants, Gulls and Waders are mostly recorded merely passing over the lagoons, mostly at sufficient height to avoid any contact with the power lines. From the recent observations, it would appear that both power line 1 and the newer line 3 are only exerting a negligible effect on waterbirds during the autumn.

6. OVERALL CONCLUSIONS

The building of the new power line (Line 3) changed the behaviour of both terns and waterbirds using the area. In particular, many terns took a longer route around the power lines out to their feeding grounds on the estuary. In circumstances when feeding conditions are poor, this could increase the risk of starvation of chicks, although there was no evidence that this was the case at this site. There was an increase in the number of corpses found under the new line. However, this was unlikely to have had an impact on the bird populations in the area.

The measures taken to mitigate the power line construction by constructing a new nesting site within the lagoon will potentially allow for increased numbers of terns to breed on the site. In 2001 the new island had a smaller colony than the original island, however it is likely that the numbers will increase on this island if the breeding population in the general area increases. It therefore appears that the mitigation that was undertaken has meant there has been a net conservation benefit.

In the autumn there was evidence that waterbirds had to circle in order to gain enough height to cross the lines, but this was unlikely to have had any major effect on the use of the lagoons, as such flights are were taken infrequently.

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	Line 1 (Spans 1 & 2 combined)				Line 3 (Span 8)			
	Adults		Juveniles		Adults		Juveniles	
	n	Height	n	Height	n	Height	n	Height
Outgoing Terns	2593	5.10	9	3.00	2618	3.95	9	1.88
Incoming Terns	4431	8.02	2	1.00	4439	6.90	2	2.00

Table 1. Summary of the number (n) of adult and juvenile Common Terns crossing above the top earth wire of Line 1 and Line 3 on outward and inward journeys. The mean height is given in metres.

	Line 1				
	Span 1		Span 2		Median 1-Way Analysis (Chi-Square Approximation)
	n	Height	n	Height	
Outgoing Terns	1795	5.81	806	3.99	$\chi^2 = 375.3$ DF=1 p=0.01
Incoming Terns	3731	7.77	701	9.33	$\chi^2 = 2070.2$ DF=1 p=0.01

Table 2. Summary of the number of adult Common Terns crossing above the top earth wire of spans 1 and 2 of Line 1 on outward and inward journeys. Number (n), mean height in metres and Chi-Square Approximation are given.

	Line 1			Line 3
	Span1	Span 2	Median 1-Way Analysis (Chi-Square Approximation)	Span 8
	n	n		n
Outgoing Terns	69	64	$\chi^2 = 0.12$ DF=1 p=ns	133
Incoming Terns	46	1	$\chi^2 = 41.2$ DF=1 p=0.01	47

Table 3. Summary of the number of adult Common Terns flying through the spans of Line 1 and Line 3 on outward and inward journeys. Number (n) and Chi-Square Approximation are given. ns= non significant.

	Line 1		Line 3
	Span 1	Span 2	Span 8
	n	n	n
Outgoing Terns	3	5	15
Incoming Terns	2	1	3

Table 4. Summary of the number of adult Common Terns flying under the spans of Line 1 and Line 3 on outward and inward journeys. Sample sizes are too small to perform any statistical analysis.

	Phase	Line 1		Line 3	
		n	% of outgoing/incoming flights	n	% of outgoing/incoming flights
Outgoing Terns	Courtship	0		4	
	Incubation	2	0.3%	12	1.8%
	Hatching	6		30	
Incoming Terns	Courtship	0		2	
	Incubation	8	0.5%	3	0.1%
	Hatching	15		1	

Table 5. Summary of adult and juvenile Common Terns crossing less than 1m above the earth wire by breeding phase.

	Month	**n**	**Over Line 3 %**	**Avoid Line 3 %**
Outgoing Terns	May	402	44	56
	June	355	35	65
	July	363	29	71
Overall		1120	36%	64%

Table 6. The percentage (%) of Common Terns that crossed Line 3 and avoided Line 3 on outward journeys.

	Spearman Correlation Coefficient	Wind Speed	Cloud	Rain
Line 1	ρ p n	-0.030 0.0123 7024	-0.167 <0.0001 7025	-0.026 0.0287 7025
Line 3	ρ p n	-0.002 0.8457 7046	-0.120 <0.0001 7047	-0.004 0.7093 7047

Table 7. Spearman correlation coefficients summarizing the relationship between the height at which adult Common Terns crossed Line 1 and Line 3, estimated wind speed (Beaufort scale), cloud and rain.

Direction	Cormorant		Wildfowl		Gull		Heron		Wader		Grand Total
	Number	%	Number	%	Number	%	Number	%	Number	%	
E	2	8.7	25	6.7	8	0.5		0		0.0	35
ESE		0.0	3	0.8		0.0		0		0.0	3
N		0.0	102	27.3	190	12.8		0	95	20.4	387
N		0.0		0.0	1	0.1		0		0.0	1
NE		0.0	6	1.6	5	0.3		0		0.0	11
NW	11	47.8	70	18.8	852	57.2	2	50	119	25.6	1054
S	1	4.3	58	15.5	174	11.7	2	50	80	17.2	315
SE	9	39.1	90	24.1	168	11.3		0	89	19.1	356
SW		0.0	8	2.1	29	1.9		0	2	0.4	39
W		0.0	11	2.9	63	4.2		0	80	17.2	154
Grand Total	23	100	373	100	1490	100	4	100	465	100.0	2355

Table 8. Summary of the crossing patterns of Waterbirds over Line 1 and Line 3.

Span	Cormorant	Heron	Wildfowl	Wader	Gull
0	8.7	0	54.4	6.2	6.7
1	21.7	25	38.6	17.2	5.6
2	69.6	25	5.9	76.6	87.4

Table 9. The percentage (%) of each waterbird species group flying over the different spans of Line 1.

Span	Waterbird Total	Percentage
0	334	14.3
1	313	13.4
2	1697	72.3

Table 10. The total numbers of waterbird species groups combined flying over the different spans of different spans of Line 1.

Span	Cormorant	Heron	Wildfowl	Wader	Gull
7	28.6	0	58.1	26.6	54.1
8	71.4	100	41.9	73.4	45.9

Table 11. The percentage (%) of each waterbird species group flying over the different spans of Line 3.

Span	Waterbird Total	Percentage
7	335	51.1
8	320	48.9

Table 12. The total numbers of waterbird species groups combined flying over the different spans of Line 3.

	Line 1 (spans 0-2 combined)		Line 3 (spans 7 & 8 combined)	
	n	**Height (m)**	**n**	**Height (m)**
Outgoing Cormorants			2.0	2.0
Flying over Cormorants	17	10.8	6	11.3
Incoming wildfowl	56	9.9	56	9.7
Outgoing wildfowl	30	9.9	27	10.6
Flying over wildfowl	20	12.4	18	10.0
Incoming gulls	7	5.1	7	5.1
Outgoing gulls	10	5.0	10	5.0
Flying over gulls	233	13.7	115	11.9
Flying over waders	20	17.8	3	13.0

Table 13. Summary of the number (n) of waterfowl crossing above the top earth wire of Line 1 and Line 3 on outward and incoming journeys, and flying over. The mean height is given in metres.

Line 1				
	Spearman Correlation Coefficient	**Wind speed**	**Cloud**	**Rain**
Cormorant	rho	-0.394	-0.056	-0.171
	p	0.1179	0.8322	0.5104
	n	17	17	17
Wildfowl	rho	0.048	-0.051	-0.176
	p	0.6229	0.5987	0.0706
	n	106	106	106
Gulls	rho	-0.198	0.174	-0.019
	p	0.0017	0.0059	0.7650
	n	250	250	250
Waders	rho	-0.368	0.327	-0.516
	p	0.1100	0.1590	0.0199
	n	20	20	20
Line 3				
Cormorant	rho	0.932	-0.117	-0.082
	p	0.0007	0.7820	0.8451
	n	8	8	8
Wildfowl	rho	0.093	-0.045	-0.096
	p	0.3527	0.6525	0.3377
	n	101	101	101
Gulls	rho	-0.215	0.208	-0.072
	p	0.0133	0.0167	0.4080
	n	132	132	132
Waders	rho	-0.866	-0.866	-
	p	0.3333	0.3333	-
	n	3	3	-

Table 14. Spearman correlation coefficients summarising the relationship between the height at which Cormorants, Wildfowl, Gulls and Waders crossed Line 1 and Line 3, and the estimated wind speed (Beaufort Scale), cloud and rain.

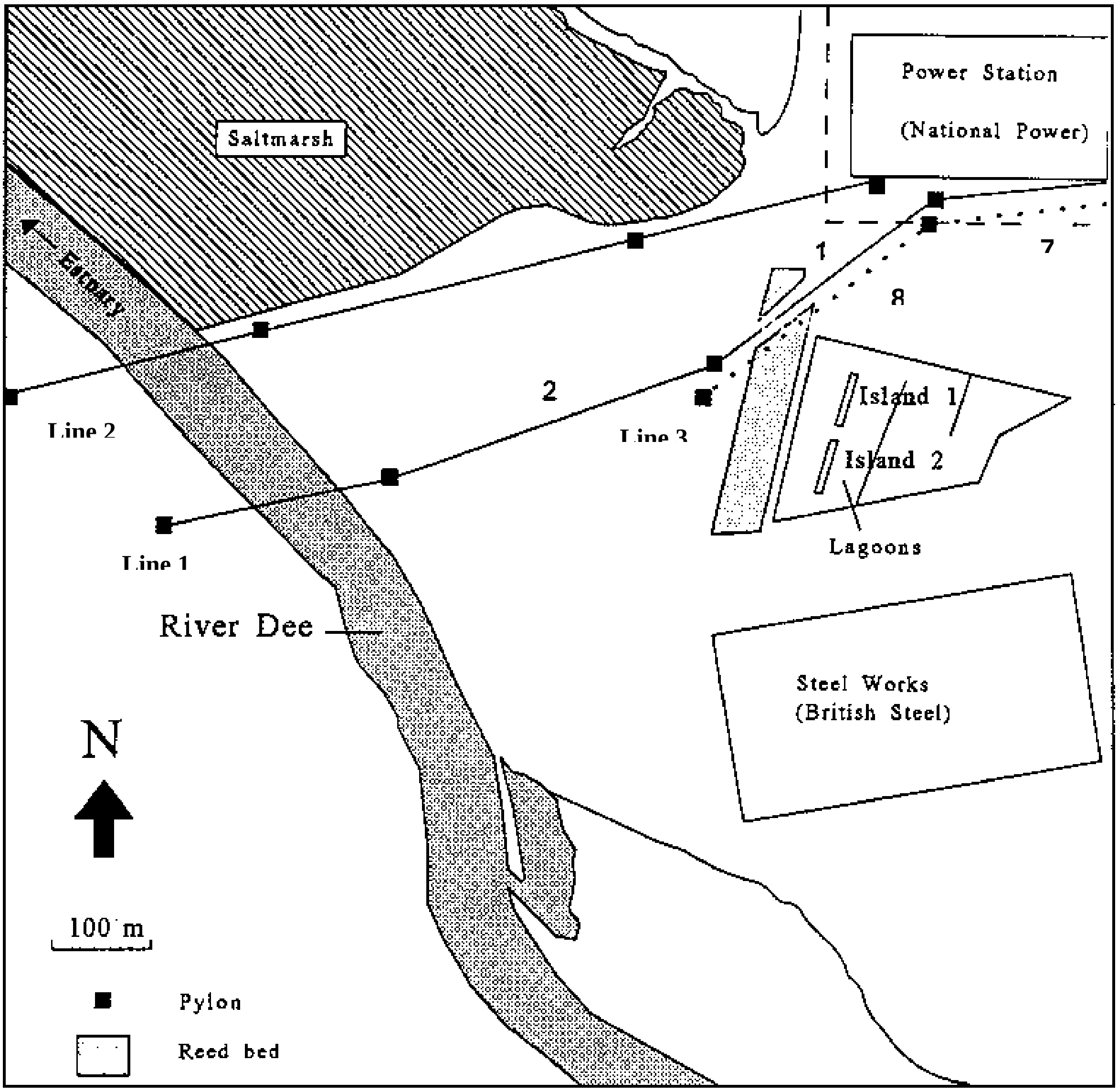

Figure 1. The study area and the position of the lagoons in relation to the power lines, industrial complex and the estuary.

Note

Line 1: 132kV power line. Height 26m
Line 2: 400kV power line. Height 46m
Line 3: 132kV power line. Height 26m