BSCE 21/WP 11
JERUSALEM 22-27 MARCH 1991

THE INFLUENCE OF TIDE AND WIND ON THE BIRDSTRIKE HAZARD AT COASTAL AERODROMES

J R Allan and T P Milsom

Aviation Bird Unit
Central Science Laboratory
Ministry of Agriculture, Fisheries and Food
Tangley Place
Guildford GU3 3LQ, UK

ABSTRACT

Information about the birdstrike hazard at coastal aerodromes suggests that the nature of the hazard and its severity may be different from that inland.

Advice given to airfields in the U.K. is largely based on research carried out at inland sites.

This paper presents data from a study commissioned by the U.K. Civil Aviation Authority into the nature and severity of birdstrike risk on coastal sites in the U.K.

Data are presented on how two factors, Tide and Wind, influence bird behaviour at coastal airfields.

The paper shows the problems encountered in the statistical analysis of time-series data and offers an alternative approach based on rule breeding computer algorithms.

The results show that tide state, height of the high tide, wind strength and wind direction can all influence the numbers of birds on airfields but that the importance of each factor varies between sites and bird species. Comparatively rare combinations of extremes of several factors are identified as most likely to cause severe birdstrike risk.

The report recommends that awareness of the way that environmental factors influence bird behaviour at coastal sites should be raised so that bird controllers can predict the combinations of factors likely to result in increased birdstrike risk at their own airfields.

ACKNOWLEDGEMENTS

This project was funded by the UK Civil Aviation Authority. We would like to express our sincere thanks to all airfields which cooperated in the survey, to the management and staff of Airfield Wildlife Management for their enthusiastic cooperation throughout the study, to the RAF for permission to undertake counts at their airfields, to the management and staff of British Aerospace Military Aircraft Division at Warton and to the management and air traffic control staff at Blackpool Airport for tolerating JRA's presence on their airfield for over a year.

1. INTRODUCTION

The Aviation Bird Unit at the MAFF Central Science Laboratory has been involved in research into the birdstrike hazard in the UK over the past 25 years. The bulk of this work has however, been conducted on inland airfields (eg., Allan & Watson 1990, Brough 1969, 1987, 1988, Brough & Bridgman 1980, Milsom 1990, Horton 1987, Horton et al 1983) and there are reasonable grounds for supposing that the hazard is different, and potentially more severe, on airfields near the coast (see below).

There is much evidence that the number and species of birds which frequent airfields are influenced by the surrounding environment as well as by the habitat on the aerodrome itself. Airfields in agricultural areas are surrounded by bird species which are adapted to take advantage of open country and are more likely to use flocking as a method of avoiding predators. Such species are likely to use airfield grassland to feed or rest and their flocking habit makes them especially dangerous to aircraft. In contrast, airfields situated in large tracts of woodland are surrounded by bird species which make less use of open grassland to feed and rely on the use of cover to evade predators (ABU unpublished). Such species are likely to make little use of airfields.

In the UK most coastal airfields lie next to agricultural land and so the open country species (gulls, plovers, corvids and pigeons) are augmented by those birds adapted to life on the coast, particularly shore waders and waterfowl (Prater 1981, Bowes et al. 1984, Evans 1984, Owen et al. 1986, Moser 1987. Like the inland agricultural species, coastal birds are adapted to life in open areas and rely principally on flocking behaviour to avoid predators. They can also be extremely numerous during autumn and winter (Lack 1986, Thom 1986, Hutchinson 1989).

Very few comprehensive data sets are available concerning the birds that frequent coastal aerodromes in the UK. The best is from RAF Kinloss in Scotland. This shows that the bird species which use the airfield correspond with those which as a result of ornithological census work are known to be present in the general area. Those species which occur commonlly on aerodromes throughout the UK such as gulls, lapwings and pigeons are joined by others such as Oystercatcher, Curlew, Dunlin, Redshank, Pink-footed and Greylag Geese which are scarce at or absent from airfields inland.

Unlike the situation inland, bird behaviour on or near the shore is strongly influenced by wind and tide. Birds are often thinly dispersed at low tide, accumulating in denser groups closer to the shore as the tide rises and forming large roosts over high tide (Hale 1980). Thus, the risk at a coastal airfield may vary within and between days as the birds' behaviour changes in response to cyclical changes in the time of high tide, tide height and less predictable factors such as wind strength and direction.

There is some evidence to suggest that the risk of birdstrikes involving flocks is greater at coastal sites, but it is not possible to carry out valid comparisons because of variability on reporting standards and bird control efficiency betweeen airfields (Milsom 1990).

In the light of the above, the UK Civil Aviation Authority commissioned a study to examine the relationship between the birdstrike hazard and aerodrome location and to determine how maritime environmental factors influence the nature of the hazard and the level of risk at coastal sites. This paper presents a summary of the findings in respect of two factors, tide and wind, and suggests how this information might be incorporated into advice given to bird controllers and managers on coastal airfields.

2. METHODS

2.1 The Choice of Sites for Detailed Study

The data gathered in a general survey of coastal aerodromes (Fig. 1) were used in the selection of sites for detailed study. Sites were chosen for a combination of scientific and operational reasons. Firstly, it was necessary to monitor a representative range of sites which reflected the variety of situations encountered in the general survey. Factors such as whether an airfield was on an open coast, an estuary or a cliff bound site and its geographical location in the British Isles (significant variations are found between bird populations from the north to the south of the country (Prater, 1981, Lack, 1986) had to be considered. Secondly, reliable data collection by trained observers was essential on those sites where ABU staff were not able to collect data in person.

Two airfields were selected for detailed study by ABU staff. These were British Aerospace Military Aircraft Division's aerodrome at Warton on the Ribble Estuary in Lancashire and the nearby Blackpool Airport on the Fylde coast (Fig. 1). The choice of these airfields allowed a detailed comparison of estuarine and open coast situations to be made between airfields only 10 km apart and where the overall pool of bird species was likely to be similar.

Daily counts were also made by staff from Airfield Wildlife Management Ltd, a bird control contractor, at a further five airfields: RAF Lossiemouth, RAF Kinloss, RAF Leuchars, RAF Machrihanish and RAF Chivenor. Of these Lossiemouth, Kinloss and Machrihanish are on open coasts, whilst Leuchars and Chivenor are principally estuarine. The location of each airfield is given in Fig. 1. Thus, a sample of seven airfields were studied at locations from Devon to Morayshire, representing habitat types from exposed open coast to muddy estuary.

2.2 Data Collection Techniques

In order to monitor how bird numbers and behaviour fluctuate within the tidal cycle at coastal sites, ABU conducted detailed counts at set time intervals at Blackpool and Warton. Counts were undertaken once per week at each airfield over 12 months and were timed to cover the high tide period (thought from previous experience to be the time at which birds were most likely to frequent the airfields). The counts were conducted at either hourly or two hourly intervals for an equal length of time before and after high tide. A standard transect of the site was covered for each count in order to ensure uniform coverage. Bird species, numbers and behaviour were recorded on each habitat type present at the sites as well as meteorological data and information on tide state, disturbance etc., At Warton, the survey was not conducted on the airfield itself, but on Warton saltmarsh, which lies immediately beneath the western approach.

Few birds frequented the airfield as a result of a good sward of long grass but, in common with a number of airfields close to estuaries, the approaches pass over areas of saltmarsh and grazing marsh which are managed as wildfowl refuges or nature reserves and where birds are numerous. This poses particular problems to bird controllers since scaring is frequently not permitted outside the airfield boundry (a similar situation exists at RAF Chivenor and at John F Kennedy Airport on New York; the latter has a particularly severe bird problem as a result (Seubert 1990)).

It was therefore thought more worthwhile to study the factors influencing the numbers and behaviour of birds in these approach areas at Warton. Counts were conducted on the aerodrome itself at Blackpool.

2.3 <u>The Bird Species Studies</u>

As coastal airfields are frequently close to both agricultural land and urban areas as well as the shore, they are likely to be used by an extremely wide variety of bird species. Some of these species may only frequent coastal sites whilst on migration, and may, therefore only occur on a particular airfield very infrequently. Although these species may pose a birdstrike hazard they are not suitable subjects for an intensive study of this type. This project concentrated on those bird species which occur on coastal airfields throughout most of the year, and particularly those of medium to high weight, which habitually form flocks and are thus regarded as the most dangerous to aircraft (the 'Priority Group' species (Milsom 1990)).

Numbers of the following priority group species were recorded at all of the study airfields:

Small Gulls	(*Larus sp.*)
Common Gulls	(*Larus canus*)
Black Headed Gulls	(*Larus ridibundus*)
Large Gulls	(*Larus sp.*)
Herring Gulls	(*Larus argentatus*)
Great Black Backed Gull	(*Larus marinus*)
Lesser Black Backed Gull	(*Larus fuscus*)
Oystercatcher	(*Haematopus ostralequs*)
Lapwing	(*Vanellus vanellus*)
Golden Plover	(*Pluvialis apicaria*)
Starling	(*Sturnus vulgaris*)
Curlew	(*Numerius arquata*)
Rook	(*Corvus frugilegus*)
Jackdaw	(*Corvus monedula*)
Carrion Crow	(*Corvus corone*)

In addition to the priority group species, number of other species or species groups which were either especially numerous at a particular site or whose behaviour was thought to be particularly influenced by such factors as tide and wind strength were also recorded. These species were not necessarily present at every study site. They were:

Greylag Goose	(*Anser anser*)
Shelduck	(*Tadorna tadorna*)
Mallard	(*Anas platyrhyncos*)
Redshank	(*Tringa totanus*)
Teal	(*Anas crecca*)

Woodpigeon	(*Columba palumbus*)
Feral Pigeon	(*Columba livia*)
Swallows and Swifts	(*Hirundinidae and Apodidae*)
Magpie	(*Pica pica*)
Grey Partridge	(*Perdix perdix*)
Raptor species	(*Accipitriformes and Falconidae*)
Small passerines	(*Passeriformes*)

2.4 Data Analysis and Presentation

In order to build a comprehensive picture of the bird hazard at coastal sites it is necessary to collect extremely large data sets, which cover the wide range of environmental variables, such as tide state, height of the high tide, wind strength and direction, rainfall, atmospheric pressure, cloud cover, season of year and time of day, which might combine to affect the behaviour of birds at particular coastal airfields. The situation is further complicated by the possibility that the environmental factors could affect different bird species in different ways. To address these questions the data set needs to be large to include a sufficient number of all of the relevant combinations of environmental conditions to allow meaningful statistical analysis.

To present all of the data (a total of almost 1,500 possible combinations of environmental factor, bird species and habitat type for each site) is neither feasible nor desirable in a paper of this nature. This paper therefore focuses on the effects of two factors, tide and wind, on numbers of Lapwings and Black-headed Gulls, the two most frequently struck species in the UK. A detailed discussion of the full data set will be published elsewhere.

Statistical analysis of data of the type collected in this study poses particular problems. The relationships between bird numbers and the environment variables measured are usually rather weak and, because none of the environmental variables acts in isolation, a complex and noisy data set results. Problems with nonlinearity and autocorrelated errors mean that multiple regression techniques are not valid for use on most of the data set, even with the appropriate transformations. The use of principal component analysis was considered but rejected because it was felt that linking variation in bird numbers to artificially created components of environmental variables would not be particularly meaningful to bird controllers and aerodrome managers.

To overcome these problems the BEAGLE (Biologically Evolving Algorithm Generating Logical Expressions) algorithm was selected (Forsyth, 1987). BEAGLE incorporate developments in the fields of artificial intelligence to produce rule sets which describe a particular facet of a data set and then tests the predictive power of the rules it has generated using discriminant analysis techniques. Put simply, BEAGLE can be asked a question (eg., when are there more than 100 Lapwings on a particular airfield) and it will use the variables given to it to find a set of rules which best describes when the condition is true (eg., when winds are over 25 kts and there is less than 1 hour to high tide and it is raining). It also calculates how accurate the rule set it has produced is by testing its predictions against a subset of the data removed before the original rules were generated and determining how many times its predictions are correct.

This system has the advantage that it makes no assumptions about data structure, normality etc., but most importantly it works in a similar way to the bird controller on the ground insofar as it can formulate a set of rules about when birds are likely to be a severe problem in an airfield. One of the prerequisites of good bird control is that the bird controller should formulate a similar set of rules for their airfield. The rules need not be formal mathematical ones, but to produce them requires the officer concerned to be aware of all of the environmental variables likely to affect bird behaviour and then to determine how those variables interact to influence bird numbers at the particular aerodrome concerned.

3. THE INFLUENCE OF TIDE AND WIND ON BIRD BEHAVIOUR

3.1 The Influence of Tide State

The effect of the tidal cycle on the distribution and behaviour of shore birds is widely understood by ornithologists. However, surprisingly few of those responsible for bird control at the civil airfields visited during the general survey were aware of the importance of this factor.

The tide might cause birds to move onto an airfield for two reasons. Firstly, by covering the available intertidal feeding areas causing birds to move onto the airfield in search of food or a place to roost, and secondly, by inundating shoreline or saltmarsh roosts, thereby forcing birds to move onto the airfield to find an alternative roosting site (Goss-Custard et al. 1977, Furness, 1973). The numbers of birds moving from the shore to an airfield to feed will be influenced by the availability of food in comparison with the surrounding area, and the numbers using it to roost by the degree of perceived risk on the airfield compared to alternative sites nearby.

The following figures show examples of how tide state affects the way in which Black-headed Gulls and Lapwings use Blackpool Airport and the approach areas at B.Ae Warton for both feeding and roosting.

Figs. 2(a) and 2(b) show data for Black-headed Gulls at Warton. There was a clear relationship between the numbers of both feeding and resting birds and the state of the tide. The highest numbers usually occured at high tide, but on most days no birds are present whatever the tide state. This suggests that other factors were combining with tide state to cause birds to move onto the study area. In this case, the height reached by the high tide was the critical factor (see 3.2 below).

Figs. 2(c) and 2(d) show the data for Black-headed Gulls at Blackpool. Here the pattern was slightly different from that at Warton. The highest numbers of birds were present on the rising tide, but numbers decended rapidly as soon as the tide began to fall. The pattern observed suggests that birds were being displaced from intertidal feeding and roosting areas by the rising tide and were then returning to feed on the newly exposed mudflats as soon as the water level falls. Early departure after high water would be favoured in order to maximise the time available to collect whatever food is left by the falling tide. The fact that few birds fed on the airfield throughout the tidal cycle indicated that the airfield grassland was a poorer feeding site for Black-headed Gulls than the intertidal areas nearby.

Figs. 3(a) to 3(d) show corresponding data for Lapwings. At Warton, there was a tendency for more birds to feed at high tide, but the trend was much weaker than that shown for Black-headed Gulls. More resting birds were present at hig tide than at other times. The situation at Blackpool was similar, with a weak relationship between feeding bird numbers and tide state, and a tendency for more resting birds to be present at high tide. The difference between species at the two sites is indicative of the ways in which birds make use of the two areas. Lapwings use both sites as preferred feeding and resting areas, with large numbers present throughout the tidal cycle, whilst Black-headed Gulls use the sites as secondary feeding and resting sites at high tides, and in the case of Warton, high spring tides only (see below).

3.2 The Effect of the Height of the High Tide

The height of the high tide can have a profound effect on bird behaviour, particularly in estuarine areas with large expanses of intertidal mud and saltmarsh. Problems for the airfield bird controller can arise when high spring tides inundate the roosting or feeding areas of intertidal species and displace birds onto secondary habitats such as coastal airfields.

On a spring tide of over 9.8m the saltmarsh area at Warton is flooded at high tide and gulls moved onto the area in order to feed on food items flushed out of the vegetation by the rising water. As gulls are able to alight on water, they were able to remain on the saltmarsh to rest even when it was fully flooded. The high numbers of both feeding and resting birds were, therefore concentrated closely around the time of high tide (Figs. 2(a) and 2(b), but only on tides of over 9.8m in height (Fig. 4(a)). There was no similar effect at nearby Blackpool during the day (although a clear effect was found to occur at night during periods of strong onshore winds, see section 3.3).

Lapwings numbers were significantly influenced by tide height at Warton (Fig. 4(b)) with large numbers present on high tides of 9.5m in height, but few birds present on the highest spring tides when the saltmarsh was flooded and Lapwings were forced off to roost further inland. No effect of the height of the high tide on lapwing numbers was detected at Blackpool.

The BEAGLE rule sets which best predict when the total number of Black-headed gulls will exceed 50 at Warton and when total gull numbers will exceed 200 at Blackpool illustrate this point. The best predictive rule at Warton is that the time until high tide is less than the time since sunrise or that the time of year is between February and September. The second best rule is that the height of the high tide is greater than 8.7m. Thus time of day, time to high tide, season of year and height of high tide are all predictors of high gull numbers. The rule set is not a particularly good predictor in the is case, however being correct on 65% of occasions when none of the rules are true. The rule set predicting when the total number of all gulls will exceed 200 at Blackpool shows the same environmental predictors of gull numbers as at Warton, except that rainfall and wind strength enter the equation as significant predictors. As Blackpool is an exposed coastal site it is not surprising that strong winds and accompanying rainfall will combine with tidal effects to cause birds to move onto the airfield. As at Warton, the rule set is a relatively poor predictor, being correct on 60% of occasions.

The impact of tide height appears therefore to be heavily dependent on the kind of habitat surrounding the particular airfield concerned, the bird species present and the alternative feeding and roosting sites available locally in high spring tides.

3.3 The Influence of Wind Strength and Direction

As noted above, the strength of the wind might be expected to have a significant influence on the way that coastal birds behave. It is difficult, however to separate the effect of wind strength from that of wind direction at coastal sites. A strong onshore wind will increase wind chill for birds feeding or roosting along an exposed shoreline, and may cause feeding or roosting sites to become inhospitable due to increased wave action. An offshore wind of similar strenth may, however have far less impact on birds occupying what is a comparatively sheltered shore. Such a sheltered area may, indeed be attractive to birds displaced from other more exposed sites.

Considering the significance which many bird controllers attach to wind strength as a predictor of bird numbers, there proved to be surprisingly few instances where either wind speed or direction was correlated with bird numbers. Wind speed itself rarely influenced bird numbers directly, but did influlence the numbers of Black-headed Gulls resting and feeding at Blackpool (Figs. 5(a) and 5(b)). At Warton, wind direction influenced the numbers of Lapwings, Golden Plover and Starling feeding on the saltmarsh (Figs. 6(a) to 6(c)). More birds were present when the wind was from North East to South West ie., onshore than at other times.

The BEAGLE rule sets that predict when Lapwing numbers at Warton exceed either 500 or 1000 both contain rules which include wind speed of greater than 15 kts and wind direction between North-East and South-East as predictors of high numbers of birds. The rule sets do not identify wind speed or direction as predictors of Black-headed Gull numbers at Warton, but do show wind speeds of over 25 kts to be a predictor of high Gull numbers at Blackpool.

3.4 Complex Interactions of Factors

So far in this analysis each environmental factor has been treated separately. It is obvious, however that none of them operates in isolation. The way in which the various factors interact, and the relative importance of each one will inevitably vary from one airfield to another. This can be illustrated by comparing the BEAGLE rule sets which predict when Lapwing numbers will exceed 500 at Blackpool and Warton respectively.

The Rule Set for Blackpool is:

Rule 1 Wind direction is between South-East and North (ie., onshore), wind speed is over 12 kts and it is not January or February.

Rule 2 The height of the high tide is less than 8.8m.

This rule set correctly identifies 87% of cases of Lapwing numbers exceeding 500 when both rules are true.

The Rule Set for Warton is:

Rule 1 Wind speed is over 15 kts and the time of year is between September and March.

Rule 2 Total day length is less than 10 hours.

Rule 3 Height of the high tide is more that 7.4m.

Rule 4 The wind is between East and South-East.

The rule set is 100% correct in predicting Lapwing numbers of greater than 500 when all four rules are true.

Part of the reason that statistical models based on data collected over a long time period are relatively poor predictors of bird numbers is that simultaneous occurance of extremes of several factors is comparatively rate and the effect may be swamped by the rest of the data set. The rare situations when extremes of environmental variables coincide are, however, the times at which exceptionally high bird numbers are likely to occur and effective bird control is most important. The BEAGLE algorithm is, therefore, particularly suitable for generating rules to predict when bird numbers are likely to be high and the risk of birdstrike at its greatest if appropriate action is not taken by the bird controller.

One example of this effect occurred at Blackpool during October 1990 when the highest spring tides of the year coincided with a period of south westerly (ie. onshore) gales and heavy rainfall. Data collected during the general survey showed the wind direction, wind speed and rainfall significantly affected the numbers of gulls on the tarmac areas at Blackpool during the day. Observations were undertaken to determine how such conditions affected behaviour at night.

Counts of the birds present on the airfield were undertaken hourly each night using an image intensifier for the five day period lup to the highest spring tide. During this time wind speed was about 30 kts, for the first four days and around 20 kts on the fifth day. Bird numbers increased each night as the height of the high tide increased until the final night when the wind speed fell and bird numbers were lower despite a higher tide. The timing of the peak in numbers was about 40 minutes later each night coinciding with the time of the high tide.

Up to 6,000 gulls were present at the high tide count on the fourth night which would have posed a severe hazard had the airfield been operational. The combined effects of extremes of wind speed, tide height and tide state were not detected by the general day time survey.

Although the data are too few for statistical analysis and the generation of a predictive model, bird control officers who were aware of the factors influencing bird numbers at coastal sites and who recorded bird numbers and the combinations of environmental factors which produce them, would be able to anticipate future occurrences of similar situations.

4. CONCLUSION AND RECOMMENDATIONS

As well as being familiar with bird dispersal techniques, a good bird control officer needs to build a practical working model of how environmental factors interact at their own airfield to cause bird influxes. This allows them to predict the conditions when high bird numbers are likely to occur and to take appropriate action in good time to prevent the situation developing into a serious hazard. In order to construct such a model, bird controllers need to observe, identify and record bird numbers and behaviour on and around their airfields. These observations need to be made in relation to the full range of environmental conditions encountered at the site. Particular attention should be paid to situations when extremes of environmental conditions interact because it is under these combinations of conditions that the highest bird numbers are likely to occur.

The general survey showed that the need for accurate recording of bird numbers and behaviour was not generally appreciated. An awareness of these factors that are likely to influence bird numbers on airfields was also frequently lacking. These shortcomings need to be addressed.

To that end we made the following recommendations:

1. All bird controllers at coastal airfields should be furnished with a set of local tide tables and encouraged to note any relationships between tidal and weather conditions and bird numbers on the airfield.

2. To facilitate 1) above, all airfields should be required to keep detailed logs of bird numbers. Regular counts through the day, along with notes on weather conditions, tide state etc., will frequently bring to light patterns in bird behaviour not previously recognised by bird control staff. Such logs also prevent the loss of local knowledge which has been built up by one bird controller from being lost if he or she leaves the post.

5. REFERENCES

ALLAN J.R & WATSON L.A (1990) The impact of a lumbridice treatment on the fauna of airfield grassland. 20th. Bird Strike Committee Europe. Helskini working paper 531-541.

BOWES A., LACK P.C., & FLETCHER M.R., (1984) Wintering gulls in Britain, January 1983 Bird Study 31 161-170.

BROUGH T. (1969) The dispersal of Starlings from wodland roosts and the use of bio-acoustics Journal of Applied Ecology. 6: 403-410.

BROUGH T. (1987) Starling roosts and aerodromes. ABU report, Central Science Laboratory, MAFF, Worplesdon.

BROUGH T. (1988) The work of the Aviation Bird Unit. Symposium on Bird Hazards in Aviation, 14th. October 1987 London Royal Aeronautical Society.

BROUGH T. & BRIDGMAN C.J. (1980) An evaluation of long grass as a bird deterrent on British airfields. Journal of Applied Ecology 17: 243-253.

EVANS P.R. (1984) The British Isles. In: Evans P.R., GOSS-CUSTARD J.D. & HALE W.G. eds Coastal waders and wildfowl in winter pp261-275. British Ornithologists Union/Cambridge University Press. Cambridge.

FORSYTH R. (1987) PC/BEAGLE User Guide. Pathway Research Ltd, Nottingham.

FURNESS R.W. (1973) Roost selection by waders. Scottish Birds 7: 281-287.

GOSS-CUSTARD J.D., JONES R.E. & NEWBERRY P.E. (1977) The Ecology of the Wash 1. Distribution and Diet of Wading Birds (Charadrii) Journal of Applied Ecology 14: 681-700.

HALE W.G. (1980) Waders. Collins, London.

HORTON N. (1987) Bio-acoustic Bird Scarers (BABS). Civil Aviation Authority, London.

HORTON N., BROUGH T. & ROCHARD J.B.A. (1983) The Importance of Refuse Tips to Gulls Wintering in an Inland area of South-East England. Journal of Applied Ecology 20:751-765.

HUTCHINSON C. (1989) Birds in Ireland. T & A.D. Poyser, Calton.

LACK P. (1986) The Atlas of Wintering Birds in Britain and Ireland. T & A.D. Poyser, Calton.

MEAD H. & CARTER A.W. (1973) The Management of Long Grass as a Bird Repellent on airfields. Journal of British Grassland Society 28:219-221.

MILSOM T.P. (1990) Lapwings (*Vanellus vanellus*) on aerodromes and the Birdstrike Hazard. Ibis 132:218-231.

MILSOM T.P. (1990) The use of Birdstrike Statistics to Monitor the Hazard and Evaluate Risk on U.K. Civil Aerodromes. 20th. Bird Strike Committee Europe Helsinki. Working Paper 30:303-320.

MILSOM T.P. & ROCHARD J.B.A. (1987) Lapwings and Birdstrikes C.A.A. Paper No. 87015 Civil Aviation Authority London.

MILSOM T.P., ROCHARD J.B.A. & POOLE S.J. (1990) Activity Patterns of Lapwings (*Vanellus vanellus*) in Relation to the Lunar Cycle. Ornis Scandinavica 21:147-156.

MOSER M.E. (1987) A revision of population estimates for waders (Charadrii) wintering on the coastline of Britain. Biological Conservation 39:153-164.

OWEN M., ATKINSON-WILLES G.L. & SALMON D.G. (1986) Wildfowl in Great Britain 2nd edition, Cambridge University Press, Cambridge.

PRATER A.J. (1981) Estuary Birds of Britain and Ireland T. & A.D. Poyser, Calton.

SEUBERT J. (1990) Reducing Gull hazards to avaiation by controlling nesting populations. 20th Meeting Birdstrike Committee Europe. Working paper 54: 613-642.

THOM V.M. (1986) Birds in Scotland T. & A.D. Poyser, Calton.

Figure 1. Map showing the location of the airfields visited during the initial survey of coastal sites (open squares) plus the location of the main study airfields (filled squares).

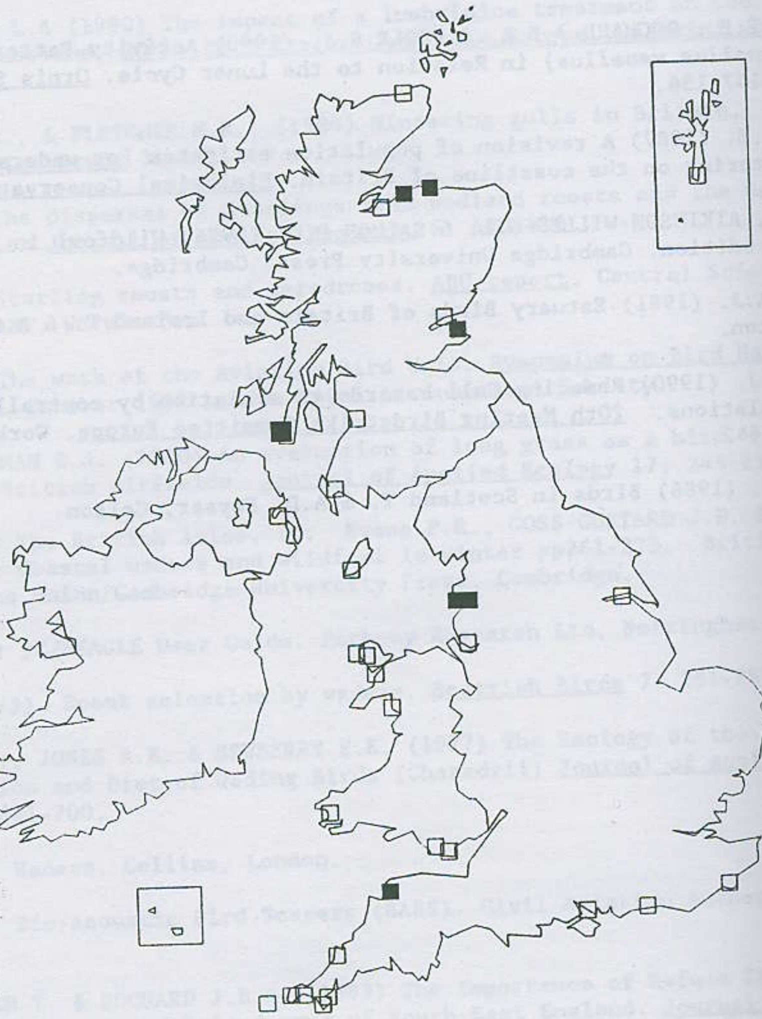
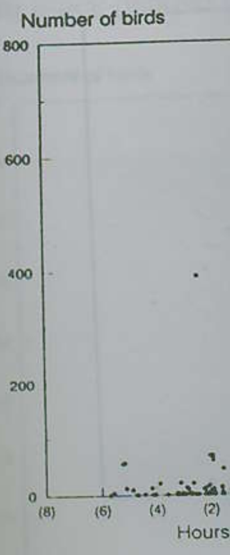


Figure 2. Scatte
gulls present on
and (b) and on th
relation to the t
for an hourly cou
tide at approxima

(a) numbers rest
on Warton saltm



(c) numbers re
on Blackpool g

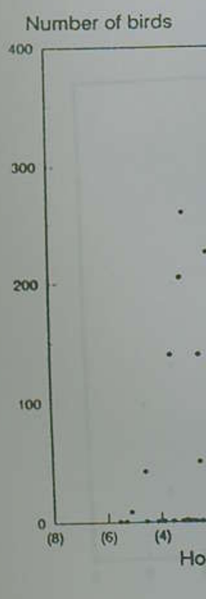


Figure 2. Scatterplots showing the numbers of feeding and resting Black-headed gulls present on the saltmarsh beneath the western approach to BAe Warton (a) and (b) and on the airfield grassland at Blackpool Airport (c) and (d) in relation to the time to high tide. Each data point shows the total recorded for an hourly count. A series of such counts were made before and after high tide at approximately weekly intervals for a year.

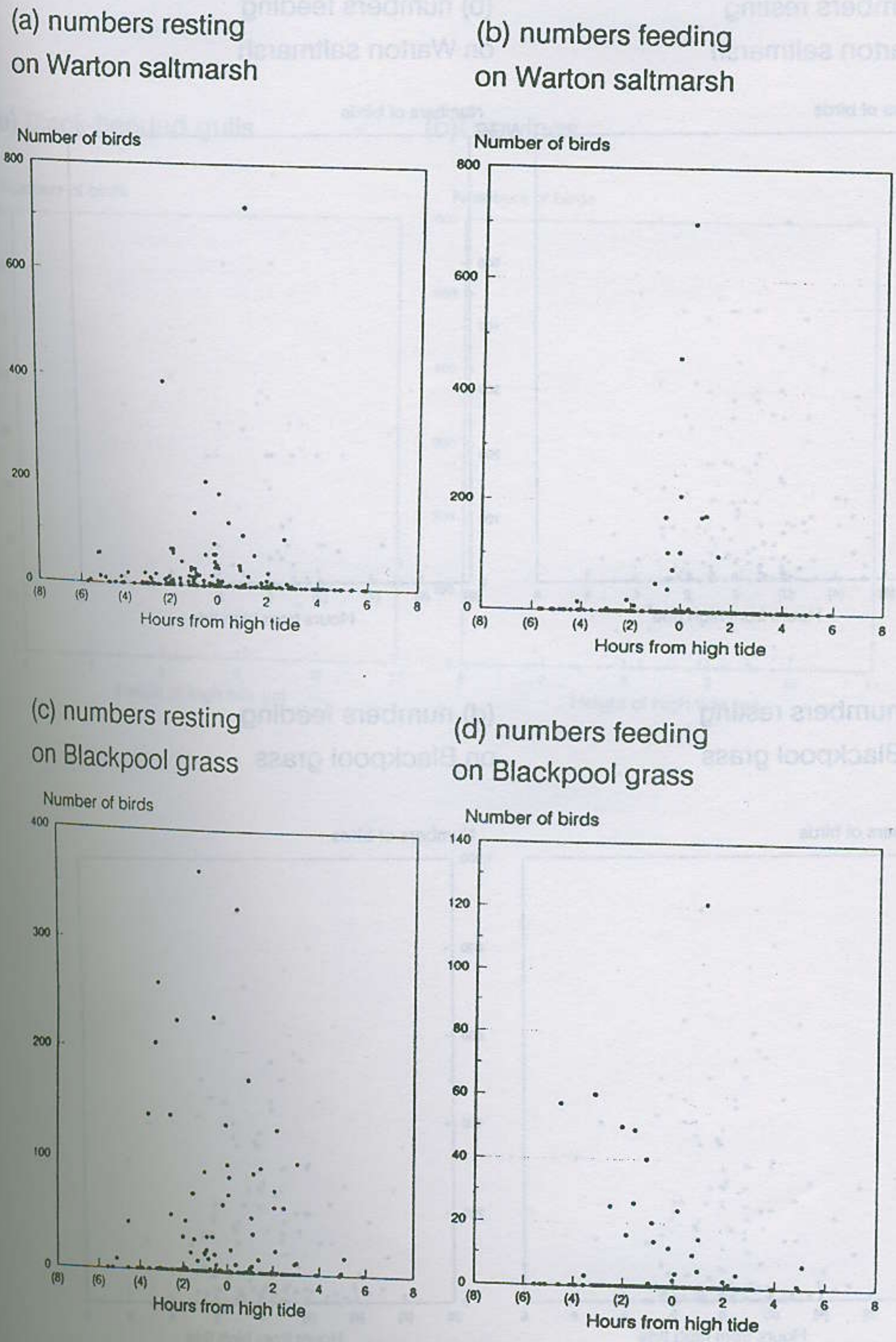
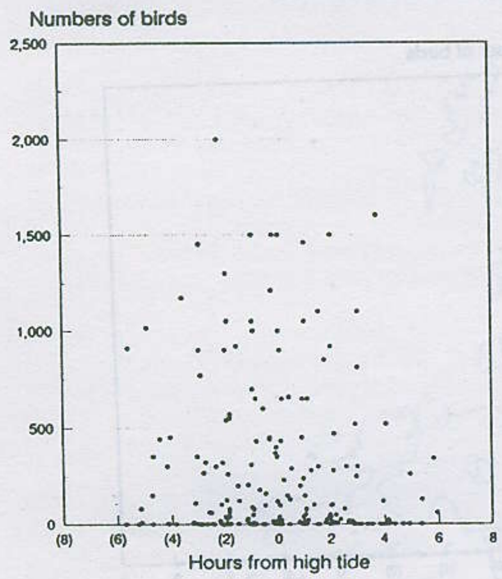
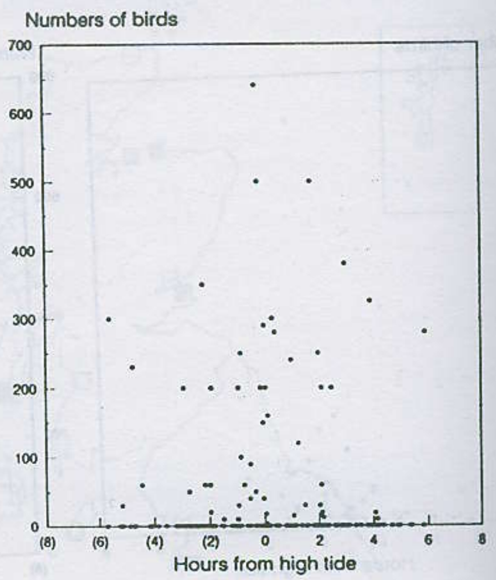


Figure 3. Scatterplots showing the numbers of feeding and resting Lapwings present on the saltmarsh beneath the western approach to BAe Warton (a) and (b) and on the airfield grassland at Blackpool Airport (c) and (d) in relation to the time to high tide. Each data point shows the total recorded for an hourly count. A series of such counts were made before and after high tide at approximately weekly intervals for a year.

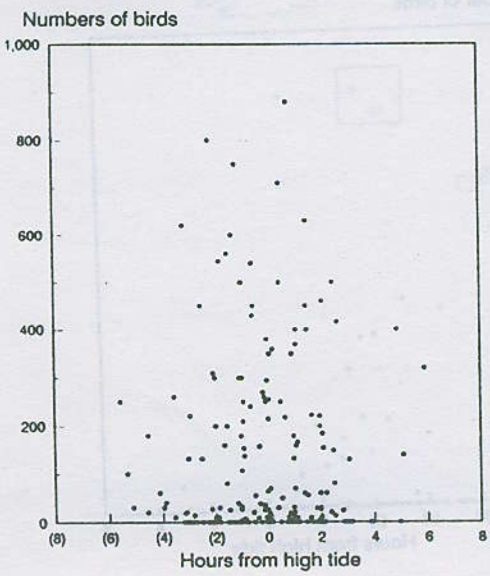
(a) numbers resting on Warton saltmarsh



(b) numbers feeding on Warton saltmarsh



(c) numbers resting on Blackpool grass



(d) numbers feeding on Blackpool grass

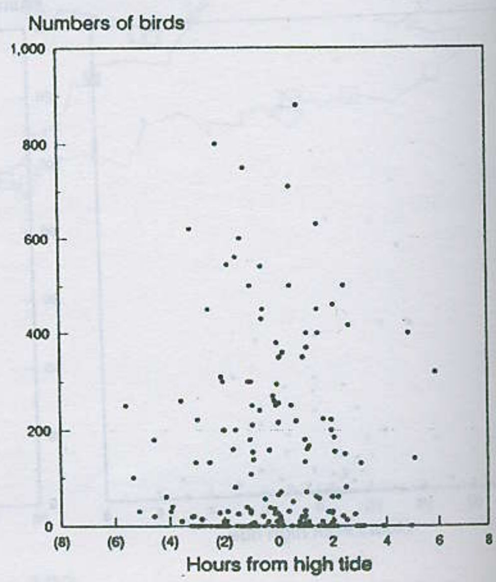


Figure 4. Scatte
and Lapwings (b)
Warton in relatio
mean daily number
counts were made
for a year.

(a) Black-headed

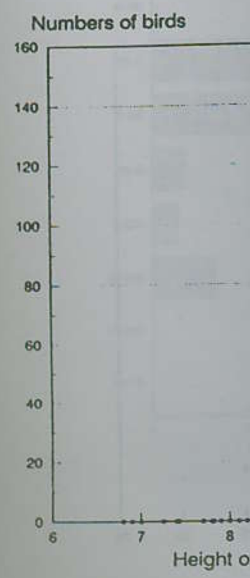


Figure 4. Scatterplots showing the numbers of feeding Black-headed gulls (a) and Lapwings (b) present on the saltmarsh beneath the western approach to BAe Warton in relation to the height of the high tide. Each data point shows the mean daily number present calculated from hourly counts. A series of such counts were made before and after high tide at approximately weekly intervals for a year.

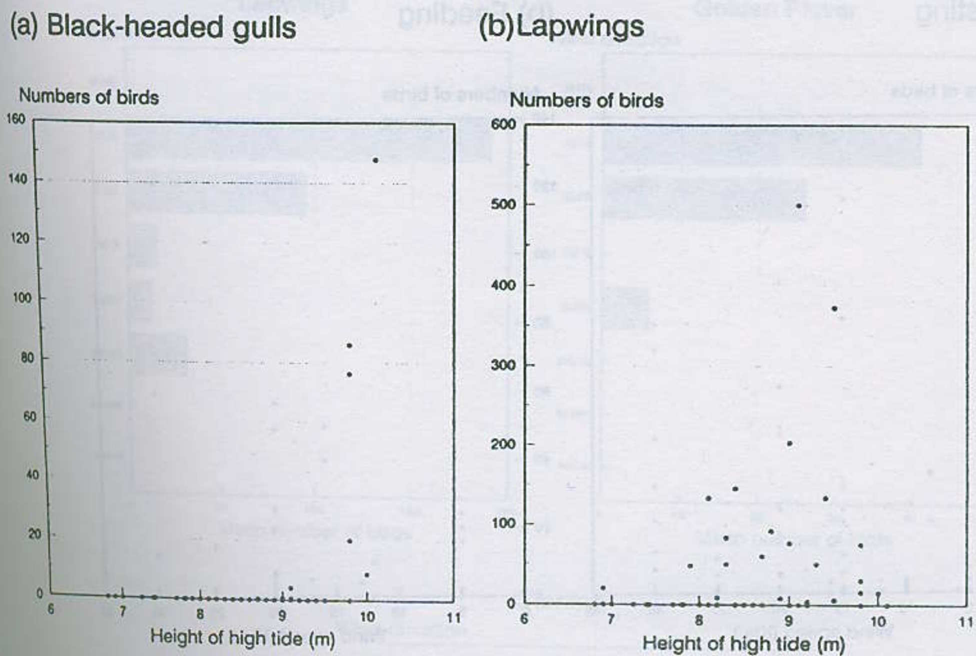


Figure 5. Scatterplots of the numbers of Black-headed gulls resting (a) and feeding (b) on the grassland at Blackpool Airport in relation to estimated wind speed. Data points show the numbers recorded on hourly counts conducted before and after high tide at weekly intervals for a year.

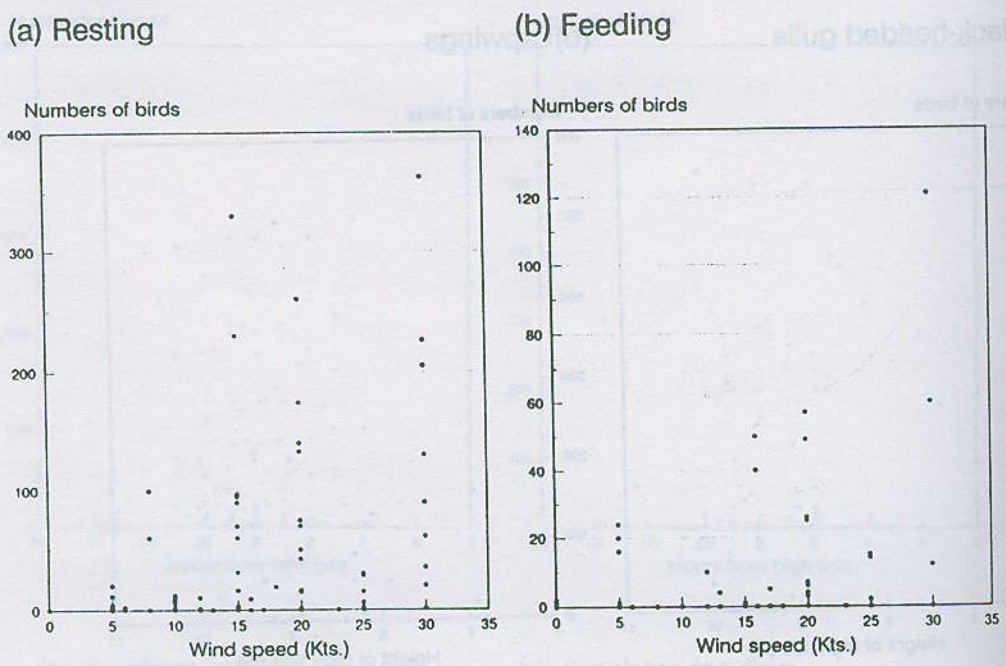


Figure 6. Histog
Starlings recorde
in relation to th
sectors and the m
the high tide per

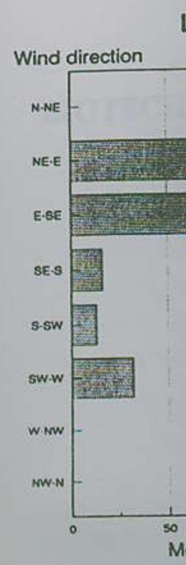


Figure 6. Histograms showing the mean numbers of Lapwings, Golden Plover and Starlings recorded on the saltmarsh beneath the western approach to BAe Warton in relation to the wind direction. Wind direction is categorised into eight sectors and the mean number of birds recorded from hourly counts taken around the high tide period on one day per week for one year is plotted.