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A model for assessing bird strike risk at proposed new airports

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Abstract

There are many criteria which need to be assessed when carrying out site selection for new airport developments. One of those which should be assessed is prospective bird hazard and bird strike risk – unfortunately, this is rarely considered as a factor. One reason for this may be the lack of available methodology for such work.

This paper presents the methodology used during a recent hazard assessment for a proposed new airport for London. The methodology builds on previously described risk assessment techniques, which were developed for operational airports. It allows an assessment of the likelihood of bird strikes to be used to assign a risk rating for all potentially hazardous species which occur around the proposed site. Additionally, a numerical comparison was conducted to assess the risk against already operating major airports in the UK. This demonstrated that the risk at the proposed new airport would probably be greater than at any other airport already operating in the UK, even with a high quality and intensive bird management programme in place.

Introduction

Birds can pose a safety risk to aircraft, particularly around aerodromes, where birds and aircraft are most likely to come into conflict. Many airports were constructed before birds had been recognised as a threat to aircraft, and as such were often constructed in bird rich environments (e.g. John F. Kennedy, Liverpool, Vancouver International). However, even though there is now a better understanding of the problem, it is uncommon to see the bird strike hazard assessed and used as a factor in site selection for new airports.

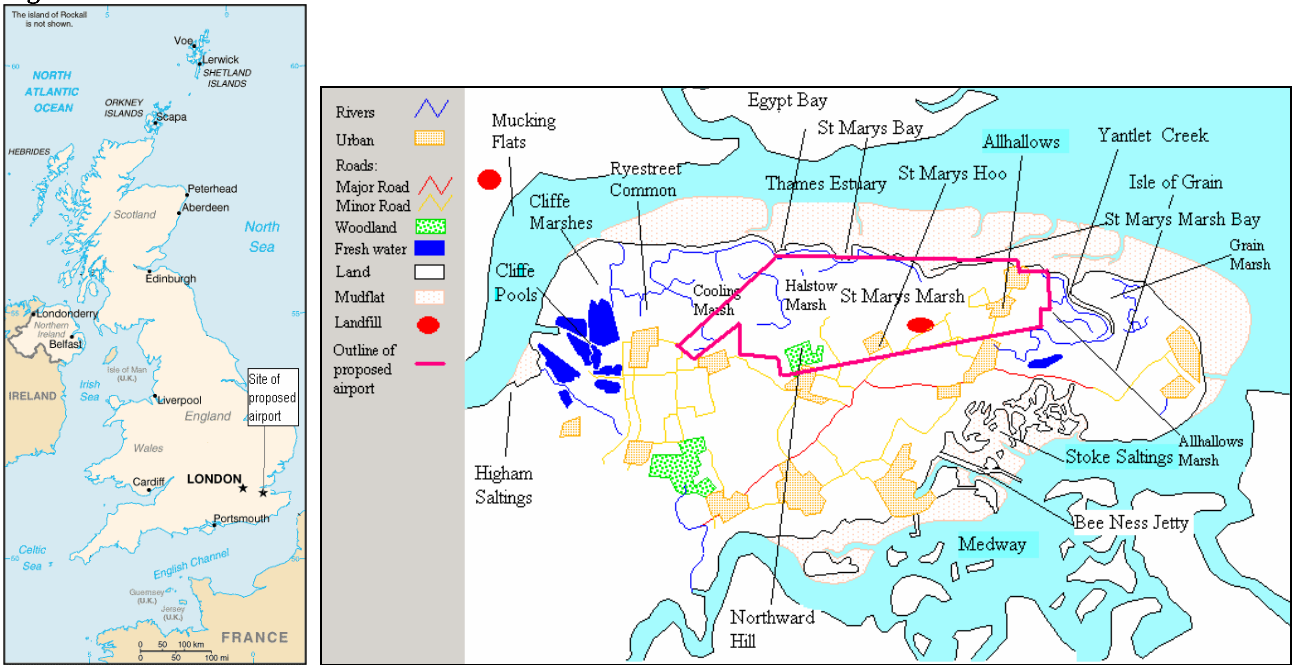
This in part has been due to the lack of suitable methodology for assessing bird strike risk. Until recently, bird strike risk assessments have tended to be qualitative rather than quantitative. Assessments which have been carried out at proposed new airports (e.g. at Mexico City (Cleary *et al* 2002)) have tended to produce qualitative results, and comparisons between sites are themselves rare (no such comparison was carried out at Mexico City). An assessment of sites at Lisbon did use a mathematical model (Pessoa *et al* 2002), but based upon land types, rather than bird populations.

This paper presents the methodology used to carry out a quantative risk assessment of a proposed new airport in the south of England (Bell *et al.* 2003).

The site

The UK government is currently reviewing future air transport growth and assessing what the implications are for future airport development. A consultation document has been produced, outlining options for increasing airport capacity throughout the UK. In the south-east of England, the options are to increase the number of runways at one or some of the already operational airports (e.g. London Heathrow, London Stansted, London Gatwick) and/or to build a new international airport at Cliffe Marshes, on the Hoo Peninsula, Kent (Figure 1). However, surrounding the proposed new airport is an area of land designated as important to birds, much of it under European Law. The area is of international importance due to its holding large numbers of overwintering number of waterbirds (ducks, swans, geese, herons, waders and gulls) (Musgrove *et al.* 2001). Additionally, it holds the UK's largest heronry of Grey Herons (Marchant *et al.* in prep.), as well as a colony of Little Egrets (a species that started breeding in the UK in 1996 (Lock & Cook 1998)), many breeding pairs of species such as Lapwing, various wildfowl, and smaller numbers of gulls.

Figure 1 Location of Cliffe Marshes in the UK.



Methodology – data collection

Bird populations and bird behaviour were assessed on and around the proposed site using a combination of desk study and fieldwork. A review of the bird populations was carried out by the British Trust for Ornithology (BTO), using data from national bird surveying schemes (e.g. Gibbons *et al.* 1994, Lack 1986, Rehfisch *et al.* 2003), along with other recent historical information (e.g. county bird reports, counts from nature reserves within the area). Additionally, five months of fieldwork was undertaken by the CSL Birdstrike Avoidance Team during the winter months (when most birds were present) to identify regular movements around the area, and the general behaviour of birds present on the peninsula.

Methodology and results – risk assessment

These data on bird populations and movements were then used to carry out a risk assessment based upon that described in Allan (2001). This is a risk assessment methodology developed for operational airports, using the number of bird strikes reported. However, in this case, it provided a framework for the risk assessment of an airport that is not yet in operation. The risk depends upon the likelihood of an event occurring (the likely strike rate) and the severity of the outcome (the damage rate).

The damage rate was calculated by taking the percentage of damaging strikes involving a particular species in the UK reported to the Civil Aviation Authority, between 1976-1996. A damaging strike is one defined as a strike where damage to an aeroplane was reported. Many of the species considered in the assessment had fewer than five strikes reported within the period – for these species, a damage probability was derived using the relationship described in Bell (2002).

Likely strike rates were arrived at by assessing for each species a number of factors including:

- the population size in the vicinity of the airport,
- the location of its feeding, roosting and breeding sites,
- the likelihood of it trying to use any part of the airfield,
- the likelihood of movements across the airport,
- the likelihood of movements through the approaches to the airport,
- its behaviour and movements, and
- the likely effects of any mitigation techniques on the above.

It was considered extremely important to take account of the behaviour of birds around the area as this can be critical in increasing or decreasing the hazard posed by them.

The likely strike rate was then classified into one of five categories ranging from "Very Low" to "Very High". For example, a species would be considered to have a Very High likely strike rate if it occurred on or around the site in large numbers, it preferentially used the airfield and it was extremely difficult to mitigate for.

Combining the damage rate and the likely strike rate allowed a risk assessment to be carried out. This assumed that an intensive bird management programme similar to that found at other large airports in the UK would be in place at the proposed Cliffe airport,. Table 1 shows the results of the risk assessment. A full example species account is shown in Appendix 1. Eleven species were identified as posing a high risk at the airport, even with mitigation for the bird hazard in effect. On operational airports in the UK, the number of high risk species identified by similar risk assessments (but using numbers of actual bird strikes reported) is likely to be between one and four.

Table 1: Risk assessment of potentially hazardous species found on or around the Hoo Peninsula. Dark shading indicates high risk, no shading indicates low risk and intermediate shading indicates medium risk. Scientific names for species listed can be found in Appendix 3.

		Probability of strikes				
		Very Low	Low	Moderate	High	Very High
Probability of damage	Very Low	Red-legged Partridge	Ringed Plover		Dunlin	
	Low		Golden Plover Stock Dove Woodpigeon Jackdaw Carrion Crow Bar-tailed Godwit Kestrel	Teal Grey Plover Knot Black-tailed Godwit Rook	Black-headed Gull Starling	
	Moderate	Little Egret Shoveler Feral Pigeon Marsh Harrier Hen Harrier Grey Partridge	Mallard	Common Gull	Lapwing	
	High	Lesser Black-backed Gull Gadwall Pintail Coot Short-eared Owl Pheasant	Brent Goose Thrush species	Herring Gull Shelduck Wigeon	Oystercatcher Curlew	
	Very High	Grey Heron Bewick's Swan White-fronted Goose Canada Goose Red-throated Diver	Great Black-backed Gull Cormorant Mute Swan Greylag Goose Redshank			

Methodology and results – Total risk

Although the risk assessment provided an indication of the severe hazard that birds would pose to an operational airport in this location, it was decided to attempt to also quantify total risk to allow comparison with other airports in the UK.

The worst possible result from a bird strike is a hull loss (i.e. an incident where an aircraft crashes, or is otherwise damaged to the extent that it cannot be repaired). Since 1976, when the current format of the bird strike reporting form was introduced (Milsom & Horton 1995), there has been one catastrophic civil hull loss caused by birds in the UK.

By using data available from the Civil Aviation Authority it is possible to calculate empirically the ratio of hull losses to damaging bird strikes in the UK. This gives a ratio of 1 catastrophic hull loss per 883 damaging strikes, the *RCHL*, where the ratio is the number of catastrophic hull losses / damaging strikes. If this is then applied to the expected number of damaging strikes per year at an airport, the period of time over which a single hull loss would be expected due to birds at a particular airport can be calculated. The number of expected damaging strikes can be calculated using the probability that a strike with each species will cause damage, and the number of actual strikes reported with each species – or, in the case of the proposed airport, using the predicted strike rate to assign a range within which the number of bird strikes will be expected to fall (Equation 1).

Equation 1 PDS_i per year $=$ $LSR_i \times DP_i$

where PDS_i is the predicted number of damaging strikes, LSR_i is the likely strike rate (numbers of strikes per year), and DP_i is the damage probability, for a species i. The range of possible PDS_i values is calculated using the lower and higher values of the range of annual likely bird strike rates for the species. For a calculated example see Appendix 2.

The expected number of damaging strikes per year is then summed for all species (Equation 2).

Equation 2 $$TPDS = \sum_{i=1}^{n} PDS_i$$

where *TPDS* is the total predicted damaging strikes per year for a site based on all species. The range of possible *TPDS* values is calculated by summing the lowest and highest PDS_i values for all species.

The value of the ratio of hull losses:damaging strikes is then multiplied by the expected number of damaging strikes in a year, to give the figure for number of years in which a hull loss would be expected (Equation 3).

Equation 3 $$TR = TPDS \times RCHL$$

where TR is the total risk, which is the estimated number of catastrophic hull losses occurring in any particular year. The range of possible *TR* values is calculated from the lowest and highest *TPDS* values.

Table 2 shows the results from the calculation for the proposed new airport.

Table 2: The predicted number of years in which a hull loss at the proposed new airport could be expected to occur – maximum and minimum values are presented because the numbers of bird strikes were derived from the strike probability estimate, which provided a numerical range.

	Maximum no. of bird strikes	Minimum no. of bird strikes
Expected no. of damaging bird strikes per year (*TPDS*)	8.65	2.97
Probability of hull loss in a given year (*TR*)	1/102 = 0.0098	1/297 = 0.0034
Number of years in which a hull loss could be expected to occur	102	297

This methodology makes it possible to compare the predicted bird strike risk at the proposed Cliffe airport with those at other airports in the UK. At operational airports the estimate of number of years in which a hull loss would be expected can be calculated more precisely by using the number of strikes reported between 1997-2001 (CAA unpublished data). A similar calculation to the above was carried out for ten of the largest civil airports in the UK. These ten airports produced a range of estimated times over which a hull loss would be expected to occur of between 304 and 1210 years ($\bar{x} = 653.5$) - all outside the range estimated for the proposed airport at Cliffe. Thus the proposed airport, even after extensive habitat management and active bird control, would be more hazardous than virtually all airports currently operating in the UK. This is to be expected as airports within areas of high bird density are likely to have a greater number of damaging bird strikes than airports within areas of lower bird densities.

Discussion

Potential bird strike hazard can clearly be an important factor in deciding whether a site is appropriate for a new airport. However, there are few methods for determining the relative importance of the hazard. The method presented here has the advantage of identifying which species are posing the greatest risk and by calculating the number of years over which a hull loss is expected to occur it also allows comparisons to be made with operational airports.

There is a degree of subjectivity in assessing the likely strike rate of species which occur around a proposed location. Ideally, this should be carried out by someone with some knowledge of bird management on airfields, as experience with the way that species respond to control measures is preferable. Additionally, knowledge of bird populations, and particularly their behaviour around the site is required, as behaviour can strongly modify bird strike risk. It would be nearly impossible and irresponsible to attempt to assess bird strike risk without knowing about both population size and behaviour.

Our method calculates the probability of damage using reported bird strikes. This assumes that all bird strikes are reported, and that damage is reported correctly. Whereas it is considered unlikely that all bird strikes are reported, it is thought that most damaging strikes are reported. Thus, the damage probabilities used by this method are likely to be over-estimates. It could be considered preferable to use a wider data set to increase the accuracy of the derived relationship. However, simple comparisons with other bird strike data sets have identified differing damage rates for the same species, and since this is likely to be indicative of differing reporting rates, only the UK data have been used. More work is likely to be required to improve the accuracy of damage rates for different species.

The ratio of hull losses to damaging strikes will vary between countries. It will also change considerably if there are more catastrophic hull losses in the future. However, this is less important if the estimate of the number of years over which a hull loss will occur is thought of as a relative, rather than an absolute statistic. Thus, the ratio of hull losses to damaging strikes statistic allows relative comparisons to be made between proposed and operating airports. However, it does depend on the operating airports reporting bird strikes correctly, and as far as is possible identifying the species struck accurately (although the percentage damage caused by unidentified birds can be used as part of an assessment). However, it is likely that the airports that do not report all bird strikes will preferentially report those that involve large and/or flocking birds (Horton & Milsom 1995), which will make up the majority of the total risk for any airport. Underreporting of small birds is not going to affect the calculation of overall risk greatly as the number of damaging incidents with small bird species tends to be low. Our method will greatly underestimate risk on airports that underreport all bird strikes and so should not be used in such situations, as it could generate a false sense of safety.

Our new method, and attendant work, has identified that there are major safety concerns relating to the proposed new Cliffe airport on the Hoo Peninsula identified that there was a major safety concern for an airport in this area, which could not be managed to an acceptably low level of risk. It has also identified that the risk at Cliffe would be much greater than that at most airports already operating in the UK, and was higher than those for which a similar calculation was carried out. Following a public consultation on the options presented, the decision as to whether Cliffe will proceed will be announced with the publication of a White Paper expected in the autumn (fall) that will outline the future development of air transport in the UK.

Acknowledgements

The work was carried out by the BTO and CSL Birdstrike Avoidance Team under contract to Department for Transport. Our thanks are extended to those who made data available for the historical analysis, including the Royal Society for the Protection of Birds, Kent Ornithological Society and Ecoscope. A number of people struggled with inclement weather during the fieldwork phase – our thanks to Justin Hart, Phil Mountain and Hugh Fidgen for this. Stephen Freeman provided statistical advice for the paper. The Ministry of Defence kindly allowed access onto their land on the Peninsula.

References

Allan J.R. (2001) The Use of Risk Assessment in Airport Bird Control. *Proceedings of Birdstrike Committee USA/Canada pp. 232-241.*

Bell, J.C. (1999). The effects of changes in Northern Lapwing populations on the birdstrike hazard in the UK. *Proceedings of Birdstrike Committee USA/Canada 99* pp. 125-132.

Bell, J.C. 2002. Using bird strike reports - at both an international and a local level. *Proceedings of the 2nd ESAF Bird Hazard Workshop ICAO*.

Bell, J.C., Burton, N.H.K., Walls, R., Musgrove, A.J., Allan, J.R., Rehfisch, M.M. & Watola, G. 2003. *Study on the potential safety risks from birds at and around a potential new airport at Cliffe Marshes and measures for mitigating those risks*. Report by the Birdstrike Avoidance Team, Central Science Laboratory and British Trust for Ornithology to the Department for Transport. Department for Transport, London.

Brough, T. 1983. *Average weights of birds*. Aviation Bird Unit, Worplesden Laboratory, UK.

Brough, T. & Bridgeman C.J. (1980) An evaluation of long grass as a bird deterrent on British airfields. *Journal of Applied Ecology*, 17 (2), 243-253.

Cleary, E.C, Dolbeer, R.A, & Ramirez Bastida, P. (2002) Evaluation and mitigation of bird hazards in Ex-Vaso de Texcoco: proposed site for a new international airport for Mexico City. BSCUSA, Sacremento 2002.

Gibbons, D.W., Reid, J.B., & Chapman R.A. 1994. *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991*. T. & A.D. Poyser, London.

Lack, P. 1986. *The Atlas of Wintering Birds in Great Britain and Ireland.* T. & A.D. Poyser, London.

Lock, L. & Cook, K. 1998. The Little Egret in Britain: a successful colonist. *British Birds*, **91**, 273-280.

Marchant, J.H., Freeman, S.N., Crick, H.Q.P. & Beaven, L.P. (in prep.) The BTO Heronries Census of England and Wales 1928-98: new indices and a comparison of analytical methods.

Milsom, T.P. & Horton, N. (1995). Birdstrike An assessment of the hazard on UK civil aerodromes 1976-1990. Birdstrike Avoidance Team, MAFF.

Musgrove, A.J, Pollitt, M., Hall, C., Holloway, S., Hearn, R., Marshall, P., Robinson, J., Cranswick, P.A., 2001. *The Wetland Bird Survey 1999-2000: Wildfowl and Wader Counts*. BTO/WWT/RSPB/JNCC, Slimbridge.

Pessoa, S, Sequeira, C. & Blokpoel, H. (2000). Bird strike hazards as a factor in the site selection process and planning for the future new Lisbon airport. Proceedings of the 25th Meeting of the International Bird Strike Committee, Amsterdam April 2000.

Rehfisch, M.M., Austin, G.E., Armitage, M.J.S., Atkinson, P.W., Holloway, S.J., Musgrove, A.J. & Pollitt, M.S. 2003. Numbers of wintering waterbirds in Great Britain and the Isle of Man (1994/1995-1998/1999): II. Coastal waders (Charadrii). *Biological Conservation*, **112**, 329-341.&&Rochard & Horton 1980&&

Stone, B.H., Sears, J., Cranswick, P.A., Gregory, R.D., Gibbons, D.W., Rehfisch, M.M., Aebischer, N.J. & Reid, J.B. 1997. Population estimates of birds in Britain and in the United Kingdom. *British Birds*, **90**, 1-22.

Appendix 1: Example species account (see Figure 1 for site names)

Lapwing *Vanellus vanellus* **RISK: High**

GB Breeding population: 190 000-240 000 pairs (Stone *et al*. 1997)
GB Non-breeding population: 1 500 000-2 000 000 individuals (Stone *et al*. 1997)
Mass: 215 g (Brough 1983)
Damage probability: 0.0846- Moderate
Likely Bird Strike Rate (with off-airfield mitigation): Very High
Likely Bird Strike Rate (after off-airfield mitigation): High

Historic Data

Breeding Season

Local Population Size

Lapwing breed on terrestrial grasslands throughout the Hoo Peninsula. RSPB surveys in 2002 recorded six pairs at Shorne Marshes, nine pairs at Higham Marsh, 32 pairs at Cliffe Marshes (including Rye Street Common), 13 at Cliffe Pools, 40 at Cooling Marshes, five at Halstow Marshes, 31 at Northward Hill and 33 at St. Mary's Marsh.

Distribution

In addition to the above sites, the previous 1982 Breeding Waders of Wet Meadows Survey indicated that Lapwing also breed in small numbers at Yantlet, Allhallows Marsh and Kingsnorth.

Non-breeding Season

Local Population Size

Lapwings occur in the study area in large flocks in the autumn and winter. Wetland Bird Survey (WeBS) Core Counts recorded an average of 2256 Lapwing over five autumn periods on those areas of the Thames for which data were collected and 1788 Lapwing on the Medway Estuary. Similarly, WeBS counts also recorded 3633 Lapwing over five winters on those areas of the Thames for which data were collected and an average of 5198 on the Medway Estuary. Further flocks may occur on terrestrial habitats of the Hoo Peninsula not covered by the WeBS counts. Kent Bird Reports for 1995 to 1999 record mean annual peaks of 5470 and 6452 Lapwings along the Thames and Medway respectively.

Distribution

Lapwing forage and roost on both terrestrial grassland habitats and intertidal areas in winter. WeBS Low Tide Counts provide the best indication of their distribution over the intertidal areas of the study area (Figures Appendix 1a & 1b). On the Thames Estuary, birds were highly concentrated on mudflats by Mucking Flats, between Higham Saltings and St. Mary's Marsh and between Canvey Island and Hadleigh Marsh. On the Medway Estuary, Lapwing were concentrated on mudflats at Kingsnorth, along the southern shore of the estuary between Riverside Country Park and Motney and at Chetney Marshes.

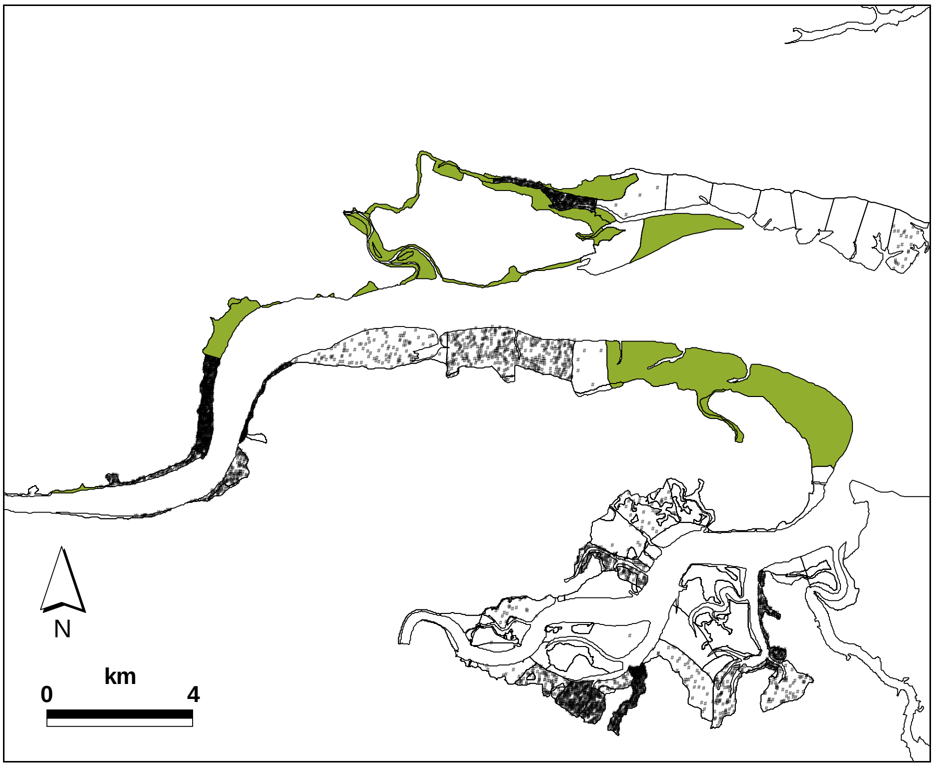


Fig. Appendix 1a. The mean numbers and distribution of Lapwing in the study area in the winter, as shown by data from WeBS Low Tide Counts (1998/99 for the Thames and 1996/97 for the Medway). Shading indicates sections not covered.

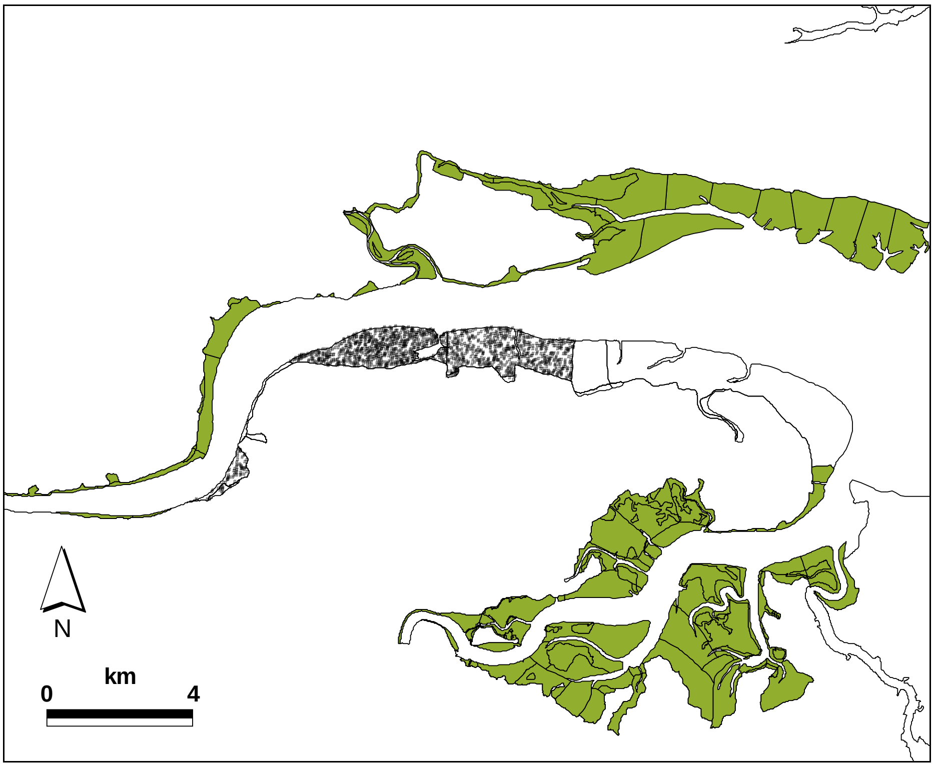


Fig. Appendix 1b. The mean numbers and distribution of Lapwing on the south Thames Estuary in November 2002, as shown by data from WeBS Low Tide Counts. Shading indicates sections not covered.

The distribution of Lapwings at high tide and on grassland is recorded by WeBS Core Counts (Figure Appendix 1c). In part, this distribution reflects that the species' occurrence on intertidal mudflats at low tide. Large concentrations of Lapwings are found along the Thames at high tide close to intertidal foraging areas at Mucking, Cliffe Pools and Cliffe, Cooling and St. Mary's Marshes. On the Medway, high tide concentrations are found at Kingsnorth, Burntwick/Greenborough, Chetney Marshes and Motney. WeBS Core Counts also recorded Lapwings on other grazing marshes on the Hoo Peninsula, at Allhallows, Yantlet and Grain Marsh.

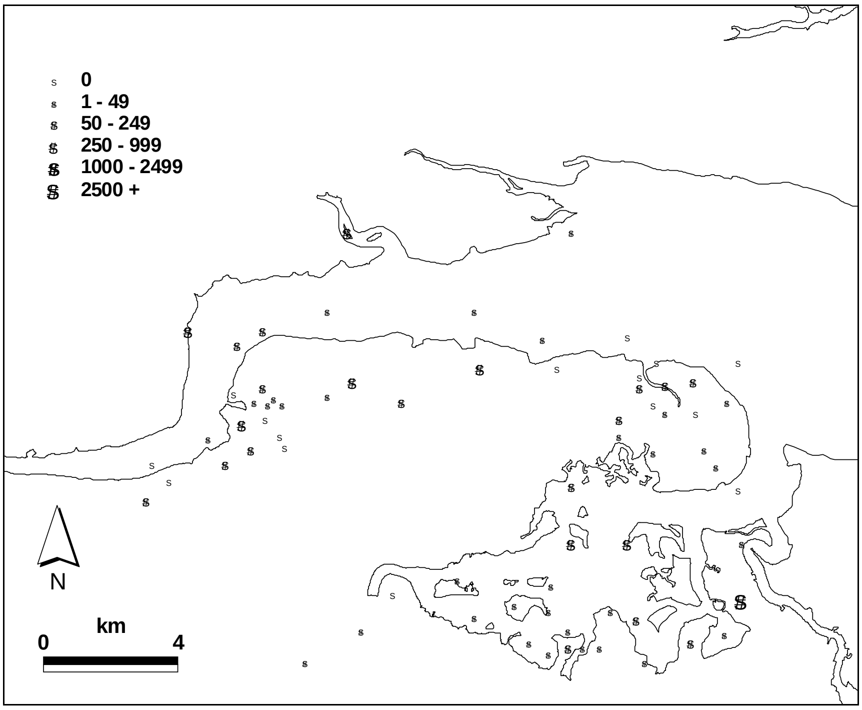


Fig. Appendix 1c. The mean numbers and distribution of Lapwing in the study area in winter, as shown by data from WeBS Core Counts (1996/97 to 2000/01).

Fieldwork Data from Autumn 2002 and Winter 2002/03

A total of 63 524 Lapwing was recorded during the fieldwork. Lapwings were the second most numerous wader recorded. The maximum mean recorded in any kilometre square was 837.1. Flock size varied between 1-3600 birds.

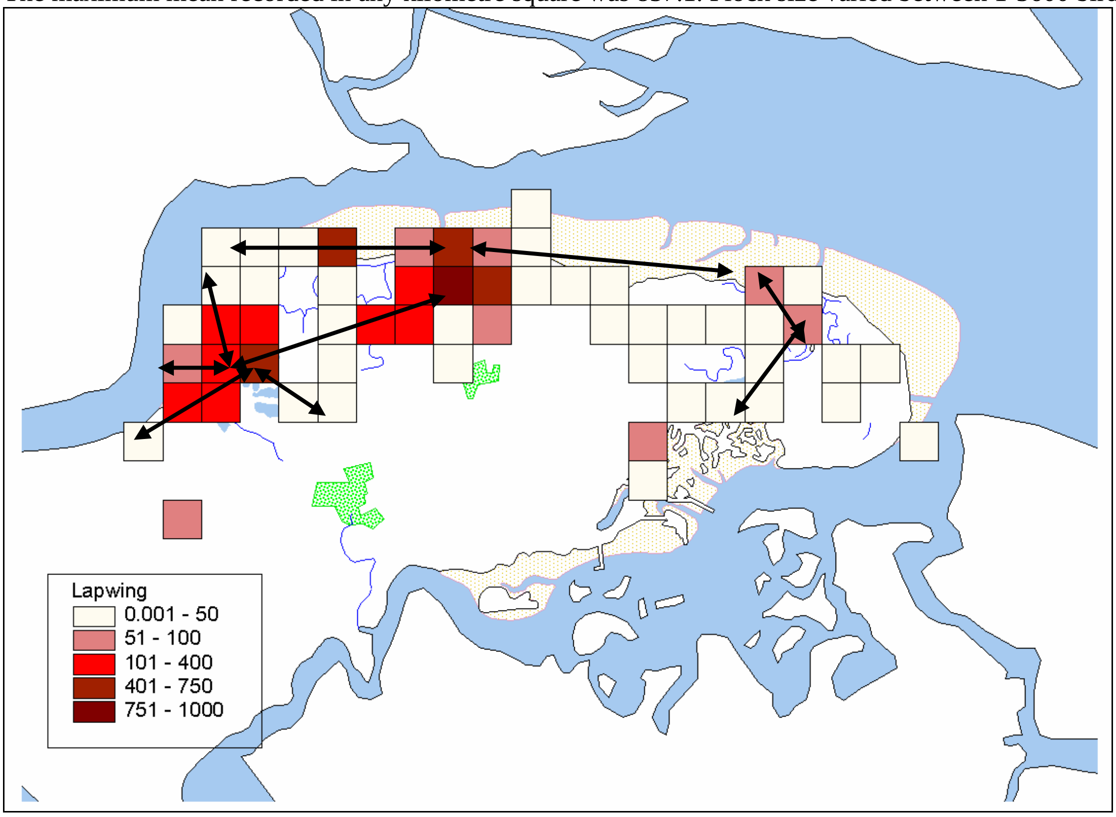


Fig. Appendix 1d . Distribution and movements of Lapwing around the Peninsula.

Lapwings were recorded around Egypt and St Mary's Bay on most surveys. Birds were recorded both on the foreshore and the rough pasture adjacent to the foreshore. Birds were also recorded regularly roosting at Cliffe Pools. Additionally, smaller numbers were recorded using the marshes around Allhallows. Small flocks were also recorded inland, feeding on newly ploughed fields when they were available.

Birds were highly mobile around the study area (Figure Appendix 1d). There were records of birds crossing between Yantlet Creek and Stoke Saltings. Birds also regularly moved to and from Cliffe Pools, and around the marshes adjacent to Egypt and St Mary's Bay.

Lapwings were also active at night, with records of both feeding birds and movements. Activity was noted in all of the main areas where Lapwing were recorded during the day, with large numbers active in the second period of night work.

Implications for Flight Safety

Lapwing have historically been one of the most frequently struck species in the UK (Rochard & Horton 1980, Bell 1999). Airfields can provide suitable roosting, breeding and feeding habitat, although the use of long grass can greatly deter them (Brough & Bridgman 1980).

Large numbers of Lapwing occur on the Hoo Peninsula during the winter, but there is also a substantial breeding population to be considered. Birds are likely to attempt to breed on the airfield, so it will be necessary to carry out nest destruction, under the special licence for Lapwing destruction on UK civil aerodromes. It would be necessary to ensure that any new airport is included on this special licence. Lapwings will also continue to breed on the marshes surrounding the airport, and adult birds may attempt to feed on the airfield. Nest control over such a large area will be difficult (and may not be permitted within the conservation designated areas).

However it is outwith the breeding season that Lapwings pose the greatest threat to aircraft, as it is in this period when large flocks occur. The number of bird strikes involving Lapwing peaks in the UK in August, when birds start to leave the breeding grounds. WeBS counts revealed that large numbers occur on the Hoo Peninsula at this time, but that peak numbers occur in the winter. During the fieldwork (which excluded the late summer period), numbers peaked in December, during a period of cold weather following a period of wet weather which may have either brought birds in from continental Europe, or concentrated birds onto the Peninsula.

Currently, Lapwings use the proposed site of the airport extensively, both as a feeding and roost site. If the airport proceeds, then it is likely the birds can be displaced by a combination of habitat management and active control measures. However, the birds are unlikely to be displaced far, and it is probable that they will continue to attempt to use the airfield. Additionally, large numbers will congregate under the approaches, which may be difficult to control even with extensive active control available. If active control is not available off-airfield, then the strike rate is likely to be greater. Lapwings also feed and move at night (Milsom 1984, Milsom *et al* 1985), and were recorded doing so during the fieldwork. Thus, the problems of night-time detection and dispersal described above are valid for this species also.

As a result of this, it is considered that the probability of strikes involving Lapwings is High, possibly even Very High, particularly if no off-airfield control is possible. The probability of damage with this species is Moderate, giving an overall risk rating of High.

Appendix 2: Calculation of the range in predicted numbers of damaging strikes in a year using the example of Lapwing

Likely strike rate:	High
Strike rate range:	3-10 strikes per year[1]
Damage probability:	0.0846

Using Equation 1 in main text:

PDS_i per year	=	$LSR_i \times DP_i$		
Expected no. of damaging strikes per year	=	likely strike rate × damage probability		
(Minimum)	=	3×0.0846	=	0.254
(Maximum)	=	10×0.0846	=	0.846

* To allow comparison with operational airports, the number of strikes per year is calculated from the way that reported bird strikes on operational airports are categorised into bands during risk assessment. For operational airports, the actual strike rate is used.

Appendix 3 – Scientific names of species in the text

English Name	Scientific Name
Red-throated Diver	*Gavia stellata*
Cormorant	*Phalacrocorax carbo*
Little Egret	*Egretta garzetta*
Grey Heron	*Ardea cinerea*
Bewick's Swan	*Cygnus columbianus*
Mute Swan	*Cygnus olor*
White-fronted Goose	*Anser albifrons*
Greylag Goose	*Anser anser*
Canada Goose	*Branta candensis*
Brent Goose	*Branta bernicla*
Shelduck	*Tadorna tadorna*
Wigeon	*Anas penelope*
Gadwall	*Anas strepera*
Pintail	*Anas acuta*
Shoveler	*Anas clypeata*
Teal	*Anas crecca*
Hen Harrier	*Circus cyaneus*
Marsh Harrier	*Circus aeruginosus*
Kestrel	*Falco tinnunculus*
Red-legged Partridge	*Alectoris rufa*
Grey Partridge	*Perdix perdix*
Pheasant	*Phasianus colchicus*
Coot	*Fulica atra*
Oystercatcher	*Haematopus ostralegus*
Ringed Plover	*Charadrius hiaticula*
Golden Plover	*Pluvialis apricaria*
Grey Plover	*Pluvialis squatarola*
Lapwing	*Vanellus vanellus*
Knot	*Calidris canutus*
Dunlin	*Calidris alpina*
Curlew	*Numenius arquata*
Black-tailed Godwit	*Limosa limosa*
Bar-tailed Godwit	*Limosa lapponica*
Redshank	*Tringa totanus*
Black-headed Gull	*Larus ridibundus*
Common Gull	*Larus canus*
Herring Gull	*Larus argentatus*
Great Black-backed Gull	*Larus marinus*
Lesser Black-backed Gull	*Larus fuscus*
Woodpigeon	*Columba palumbus*
Stock Dove	*Columba oenas*
Feral Pigeon	*Columba livia*
Short-eared Owl	*Asio flammeus*
Starling	*Sturnus vulgaris*
Jackdaw	*Corvus monedula*
Carrion Crow	*Corvus corone*
Rook	*Corvus frugilegus*