MODELLING THE BIRDSTRIKE RISK FROM HAZARDOUS BIRDS ATTRACTED TO RESTORED MINERAL EXTRACTION SITES.

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Abstract

Mineral extraction for sand and gravel is often concentrated in lowland river valleys near major towns and airports. Where restoration schemes for such sites include open water, they frequently attract large numbers of waterfowl and other hazardous bird species that pose a birdstrike risk to aircraft. There is a need, therefore, to predict the numbers of birds likely to be attracted to a potential restoration and to assess how any movements will impact upon flight safety prior to a site being developed.

Regression analysis was used to determine whether waterfowl count data from over three hundred separate locations in the UK could be related to morphological variables derived from available maps. Variables available for the study included area of open water, length of bank and number of islands. Results showed significant relationships, but suggested that for a truly useful predictive model a number of more detailed measurements would be required. A literature search revealed a range of potential factors that might be included in any model, though little research had been conducted on mineral extraction sites *per se.* A distinction needs to be made between factors that might be measurable in a planning situation before extraction at a site is completed, such as the physical dimensions of a proposed waterbody, and factors that are unpredictable at this time, such as the development of aquatic vegetation or changes in water chemistry over time.

A major study of gravel pit restorations is planned for the UK, incorporating measurements of all potential factors that might influence hazardous bird numbers. Measurements of the number and nature of bird movements generated by the bird populations present on these pits will also be recorded. It is hoped that this will provide an objective measure of the birdstrike risk posed by differing types of restoration.

Key Words: Gravel pit, waterfowl, birdstrike risk, predictive model

Introduction

The UK is committed by international treaty to achieve biodiversity targets and also to preserve air safety. When planning applications are submitted that involve biodiverse restorations (such as restoration of former mineral workings, especially if these involve wetland creation) and are located close to an airport, conflicts can result between the applicants and the safeguarding authorities tasked with preventing any increase in the risk to aircraft from birdstrikes. Henney *et al* (2003) showed that some 44% of the land area of England falls within safeguarded zones around airfields and over 50% of sand and gravel workings either occur within, or are intersected by, these zones. It is therefore in the interests of all parties to understand the impact of site restorations on local hazardous bird populations. A further consideration is that mineral extraction sites rarely occur in isolation. Deposits of sands or gravels are usually worked from a number of pits in close proximity, and the likely effects of restoration must also take into consideration previously existing water bodies nearby. Unfortunately, movements of birds between water bodies are poorly understood on a local scale, and research to establish how flocks of birds move at different times of day, or to show how many birds can be expected to move into an area with a new water body is badly needed.

A number of previous studies have looked at relationships between site characteristics and waterfowl populations. Blomberg (1982) in a study on gravel pits at Fort Collins, Colorado found a strong positive correlation between lake area and mean number of duck in spring. Sillén & Solbreck (1977) found that 54-66% of the variation in bird species richness on natural lakes in Sweden could be explained by area of open water. Suter (1994) in a study of the twenty main natural lakes in Switzerland, had been able to measure a large number of physical variables and found relationships with both the absolute numbers and the numbers of species of waterfowl for factors such as lake size and shoreline morphology. This desk-based study tried to find similar relationships between physical characteristics and waterfowl populations for former mineral extraction sites in the UK. An attempt was made to simulate a planning situation by using only those site characteristics that could be derived from a map, and combining these with publicly available waterfowl count data.

Methods

Assembling the databases

As the starting point for data analysis, the British Geological Survey dataset 'Britpits' was purchased. This comprised G.I.S. point data on approximately ten thousand active and former mineral extraction sites in the UK. For data on waterfowl numbers, the WeBS (Wetland Bird Survey – monthly counts coordinated by the Wildfowl and Wetlands Trust) counts from 1998 to 2001 were selected as the most widespread, consistent and up-to-date. A map was constructed in the ESRI corporation's Arcview™ program combining these two datasets.

A selection process within Arcview™ identified any minerals extraction site within 1km of a WeBS count location. The resulting eight hundred sites were then checked individually to see whether the WeBS count could be linked to a specific lake. In just over three hundred cases the link was clear and unambiguous, and these lakes formed the basis for all future analysis. The selected sites were located throughout Great Britain (though the majority were in England). There were no sites in Northern Ireland.

The selected sites were then digitized into polygons on Arcview™ using the 1:10,000 scale Ordnance Survey Map as the mapping basis. This process allowed Arcview™ to construct data on morphological characteristics of the lakes such as area of open water, length of perimeter (bank) and number of islands. A further characteristic of sinuosity was added to the database at this point, being calculated as the ratio of the length of perimeter to the length of the smallest possible perimeter for that lake (i.e. the circumference of a circle with the same area).

The WeBS counts provided monthly data for each waterfowl species, so the database was split to produce two separate datasets – one each for summer (April to September inclusive; number of sites n = 302) and winter (October to March inclusive; n = 272). For each dataset a mean monthly value for each species was calculated. Mean total values for five guilds of waterfowl (A guild is an expression used to refer to a set of ecologically related species that use the same kind of resources in a similar way, classified mainly by feeding technique and diet. Guilds used in this study were swans, geese, dabbling duck, diving duck, and sawbills) were calculated for each lake by summing the mean count for the component species of each guild. A value for the total mean number of waterfowl at each site was then produced by summing the five guild values plus the mean value for Coot *Fulica atra*.

Analytical methods

Many of the variables had non-normal distributions, so to facilitate analysis the following data were transformed by calculating their logarithmic values: the total mean number of waterfowl, mean totals for the waterfowl guilds, and the lake morphological characteristics of area and perimeter length. Finally, since the vast majority of lakes had no islands, a number of different grouping variables – from a simple binomial of islands/no islands to different weighting of island numbers – were used in the analysis to try to point up any significance.

Correlations between the total number of waterfowl and the lake morphological characteristics were analysed using the Pearson's product-moment correlation test and the results plotted on scatter graphs. Additionally, correlations between the lake characteristics themselves were analysed using the same test. Principal component analysis (PCA) was used to generate two new uncorrelated factors, to see if these gave a better fit than the measured characteristics. PCA Factor One gave heavier weighting to length of bank, with number of islands and area also well weighted. PCA Factor Two was heavily weighted towards the presence of islands, with area and length of bank negatively weighted.

The likely total number of waterfowl to be found on a given pit was analysed using linear regression, with the numbers of waterfowl as the dependant variable and the lake characteristics plus the two PCA factors as the independent variables. A forward stepwise approach was adopted, with explanatory variables being entered individually and only variables that caused the most significant effects being retained. A regression line and lines representing 95% confidence intervals could then be fitted to the scatter graph for the most important factor.

This process was repeated for the different waterfowl guilds on both summer and winter databases. As a number of sites had zero counts for at least some of the waterfowl guilds, binomial models were tried first. For each guild initial binary logistic regression tests were conducted (with the dependent variable of guild present (1) or absent(0)), using all the measured lake characteristics including different island grouping variables. Similar tests were also conducted using the two new non-correlated variables from the Principal component analysis. Hosmer and Lemeshow Tests were used, and the predicted probabilities plotted on a graph of binomial dependent against principal regression factor. Linear regression analysis was then conducted on only those portions of the database where birds were present (i.e. mean number of guild >0), and the results compared to see if the most significant factor in the presence or absence of a guild was the same as that most significantly correlated to the mean number of birds.

Results

Total numbers of waterfowl

Correlations were found between the mean total number of waterfowl and several of the measured lake characteristics. For example, Pearson product-moment correlation indicated a highly significant positive association between lake area and total number of waterfowl, in both winter (n=272, r = 0.456, P<0.01), and summer (n=302, r = 0.483, P<0.01). Stepwise linear regression analysis confirmed lake area as the most highly correlated variable (winter r^2 = 0.208, P<0.01. summer r^2 = 0.234, P<0.01). The two additional non-correlated explanatory variables produced from the principal component analysis (PCA) did not produce a better result during linear regression (e.g. PCA factor 1 in summer, r^2 = 0.197, P<0.01). The r^2 value was higher in summer than winter for every variable tested. A regression line and 95% confidence intervals were then fitted to the plotted scatter graph of lake area against mean total waterfowl in summer, as shown in Figure 1.

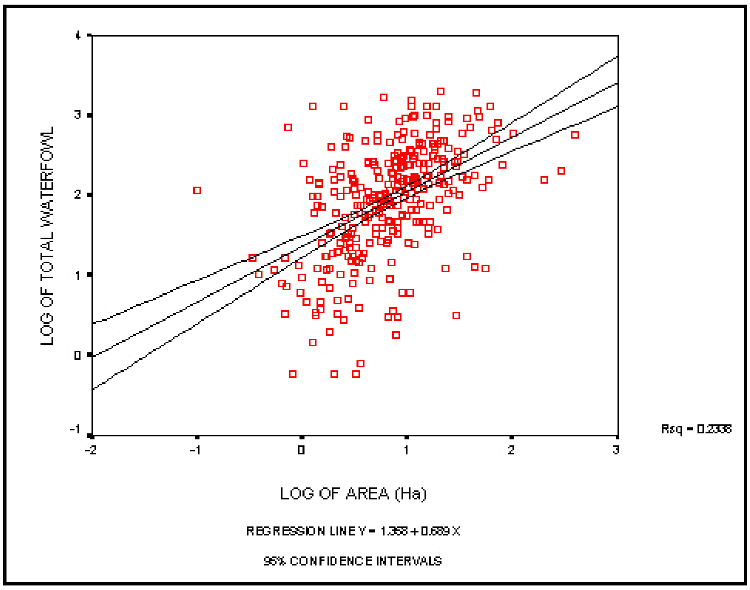

Figure 1. Summer Database: (Regression Line: Log of Mean Total Waterfowl = 0.689Log of area + 1.368)

Waterfowl guilds

The initial binary logistic regression tests for each guild were conducted with all available lake characteristics and the two PCA factors. Although no r^2 values were available, the 'dummy' values generated were well within the expected probability range. Linear regression analysis on sites where the individual waterfowl guilds were actually present found the same main determining factor as the binary logistic regression in every case. The full linear regression analysis results are tabulated below:

Table 1. Winter database

	SWANS	GEESE	DABBLING DUCK	DIVING DUCK	SAWBILLS
n	251	231	269	260	202
Main determining Variable	Perimeter	PCA factor 1	Perimeter	Area	Area
Regression equation	Y=-0.735 + 0.426X	Y=1.001 +0.170X	Y=-1.413 + 0.872X	Y=0.979 + 0.497X	Y=0.223 + 0.345X
r^2	0.083	0.063	0.120	0.186	0.133
P	<0.01	<0.01	<0.01	<0.01	<0.01

Table 2. Summer database

	SWANS	GEESE	DABBLING DUCK	DIVING DUCK	SAWBILLS
n	274	247	298	285	214
Main determining variable	Perimeter	PCA factor 1	Perimeter	Area	Area
Regression equation	Y=-0.919 + 0.483X	Y=0.992 + 0.205X	Y=-1.558 + 0.909X	Y=0.906 + 0.551X	Y=0.207 + 0.339X
r^2	0.110	0.090	0.129	0.216	0.134
P	<0.01	<0.01	<0.01	<0.01	<0.01

In every case the figure for r^2 (the amount of variance in the dependent variable explained by the main determining variable; e.g r^2 =0.083 may be explained as accounting for 8.3% of total variance) was higher in summer. For total number of waterfowl, and the dabbling duck, diving duck and sawbill guilds, the difference between the summer and winter r^2 values (expressed as a percentage) are closely comparable to the difference in the n values. However, for the swan and goose guilds there is a substantially greater difference in r^2 values (see Table 3.)

Table 3. Comparison of winter and summer results

	Total waterfowl	Swans	Geese	Dabbling duck	Diving duck	Sawbills
Winter/summer n (as %)	90.1	91.6	93.5	90.2	91.2	94.4
Winter/summer r^2 (as %)	88.0	75.4	70.0	93.0	86.1	99.0

Discussion

Limitations of the data

This study was conducted with the best dataset available, but certain limitations need to be acknowledged. The data for numbers of birds were taken from WeBS counts, which are monthly counts undertaken by volunteers and coordinated by the Wildfowl and Wetlands Trust. Counts are conducted on specific weekends each month, and the accuracy of the data collected is inevitably influenced by such factors as the weather and the skill of the observer. WeBS counts were selected as being the most comprehensive counts of waterfowl available, before any attempt was made to match counts to specific mineral extraction sites, but it is unlikely that any other data source would have given better coverage at a national scale.

A degree of inaccuracy was also introduced into the data for lake characteristics by the nature of the digital mapping process. Working from the 1:10,000 scale map layer, lakes were digitised into polygons by hand, and this process would tend to underestimate characteristics such as total length of bank (perimeter) particularly. Since the measurement for sinuosity was a function of the two other measured characteristics lake area and length of perimeter, this variable would also be subjected to a level of inaccuracy. This situation was considered acceptable, as any degree of inaccuracy was consistent across the entire dataset, but it needs to be borne in mind in the consideration of the most important determinant characteristic arrived at through regression analysis.

Implications of the results

All the waterfowl guilds produced highly significant results when subjected to linear regression analysis in both summer and winter. The slightly more significant results from the summer database can be attributed to the larger n values in most cases. However, the data provides evidence that for swans and geese there is a step-change in the significance of the named factor in summer. This may indicate that these guilds choose to frequent lakes in summer with different morphological characteristics to those frequented in winter, or that these characteristics become more important in summer, perhaps because of the requirements of their breeding ecology.

The two non-correlated characteristics generated from the Principal component analysis, which weighted all the measured characteristics in different ways, failed to account for more of the variance in numbers than individual lake characteristics, except in the case of geese. This slightly surprising result may stem from the inevitable inaccuracies involved in the digital mapping process, and it would be interesting to see if a study based at individual sites where the measurements like length of perimeter could be taken more accurately would give the same result. That the one waterfowl guild where a PCA-derived factor was the most significant should be geese is itself of great interest, since current thinking on reduction of bird strike risk from created water bodies stresses islands as likely to result in greater numbers of geese. Although the variables for islands alone were not the most significant for this guild, the PCA factor that was most significant did carry a heavy weighting towards numbers of islands and length of bank. This fits in well with goose ecology, since the birds prefer islands as nest sites and feed largely by grazing on land.

The strong positive correlation between lake area and total number of waterfowl in this study had also been found in previous scientific papers, e.g. Blomberg (1982), Suter (1994). However, in the present study analysis showed that only 23.4% of the variance in total waterfowl numbers could be explained with reference to lake area, even in summer. An explanation for over three-quarters of the variance must therefore be sought in factors not included in this dataset, such as age of the water body, depth, vegetation, height of bank, other water bodies in the area and so on. Some of the physical factors may be available in advance in a planning situation, since more detailed large-scale maps of proposed water bodies would normally include data on water depth, bank profiling and proposed planting regimes for both bank and occasionally emergent vegetation. Blomberg (1982) found a negative relationship between total numbers of species and mean bank height-to-surface area ratio, which strongly suggests that ducks find closely surrounding steep banks unattractive, for example.

Other key factors are impossible to predict in advance, but have been shown in other studies to have an influence on waterfowl numbers. Tydeman (1982) found a good relationship between bird species diversity and habitat diversity for eleven gravel pit sites in the Thames Valley from 1973-75. Hoyer & Canfield (1994) report in a study on 46 Florida lakes that annual average bird numbers and species richness were positively correlated to lake trophic status as assessed by total phosphorous, total nitrogen and chlorophyll concentrations. Since the habitat diversity and trophic status would be expected to change over time as a newly-flooded gravel pit gradually matures, the only way to predict their potential influence on likely bird numbers would be to analyse data from lakes of similar size but varying ages.

Future research

Any project attempting to assess the likely birdstrike risk from proposed gravel pit restoration schemes needs to incorporate the measurement of a large number of physical and botanical factors, in order to provide data on the maximum number of potential influences on waterfowl numbers. In addition, data needs to be collected on human influences on the site: from disturbance through watersports or sailing activities, to fish-stocking to improve conditions for anglers, since all these have a potentially large impact on the future usage of the site by hazardous bird species.

Although critiques of mineral extraction restoration plans often concentrate on the numbers of birds that they are likely to attract, it is the behaviour of those birds that will actually govern the risk to aircraft. For this reason, the juxtaposition of features such as feeding and roosting sites in the environment strongly influences the birdstrike risk that will result from a development, and two apparently identical proposals could result in two different responses from the aviation regulators at different airports. Unfortunately, the way in which birds move around the environment is poorly understood. The average distance that common species such as pigeons, corvids and waterfowl fly on a daily basis from roosting or nesting sites to feeding grounds, for example, remains largely unknown. Similarly the altitude, time of day and influence of factors such as weather conditions on these movements are also not properly documented. This results in the regulators adopting a precautionary approach, assuming that birds will move between a new site and any other suitable site in the area. A better understanding of the routine movements of common birds in relation to features in the environment would allow more precise predictions of risk levels to be made and ensure that only those developments that will actually increase the risk will attract an objection.

A key aim for a future study would be to use specialist techniques such as bird detection Radar, as well as more conventional methods such as direct observation and radio/satellite tracking to obtain behavioural data on hazardous birds around a number of existing restored mineral extractions. The ideal would be to quantify and describe the bird movements generated by observed populations in particular environments. The combination of these measurements – e.g. a population of *x* hazardous birds generates *y* movements per day in an environment with *z* water bodies within a given distance – would provide the basis for an objective numerical risk assessment to be developed.

References

Blomberg, G.E.D. (1982) Duck use of gravel pits near Ft.Collins, Colorado. In Sverdarsky, W.D. & Crawford, R.D. Eds. Wildlife Values of Gravel Pits – symposium proceedings

Henney, P.J., Cameron, D.G., Mankelow, J.M., Spencer, N.A., Highley, D.E. & Steadman, E.J. (2003) Implications of CAA Birdstrike Safeguard Zones for River Sand and Gravel Resources in the Trent Valley. A report for the CBI Minerals Committee and Quarry Products Association. Keyworth, Nottingham.

Hoyer, M.V. & Canfield, D.E. (1994) Bird abundance and species richness on Florida lakes: influence of trophic status, lake morphology, and aquatic macrophytes – *Hydrobiologia* 279/280: 107-119.

Sillén, B. & Solbreck, C. (1977) Effects of area and habitat diversity on bird species richness in lakes – *Ornis Scandinavia* 8: 185-192

Suter, W. (1994) Overwintering waterfowl on Swiss lakes: how are abundance and species richness influenced by trophic status and lake morphology? – *Hydrobiologia* 79/280: 1-14

Tydeman, C.L. (1982) Gravel Pits as Wildlife Habitat in Great Britain. In Sverdarsky, W.D. & Crawford, R.D. Eds. Wildlife Values of Gravel Pits – symposium proceedings.