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THE IMPLICATIONS OF STUDIES OF THE REPORTING RATES OF RINGED BIRDS FOR THE INTERPRETATION OF RESULTS FROM THE WILDLIFE INCIDENT INVESTIGATION SCHEME

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EXECUTIVE SUMMARY

Results and discussion

1. The Wildlife Incident Investigation Scheme (WIIS) which operates in England and Wales and similar schemes in Scotland and Northern Ireland investigate wildlife mortality incidents that may have been caused by pesticides. Any system for investigating mortality caused by pesticides must include arrangements for investigating those incidents which are identified and for determining whether pesticides were involved. WIIS performs this function effectively. This study is concerned with the interpretation of incident frequencies measured by WIIS, in relation to differences in reporting probabilities between species, and with the use of this information to identify problems arising from the use of particular pesticides.

2. The WIIS performs two rather different functions. The first is to provide a system for post-registration surveillance of pesticide usage that is designed to detect unexpected problems that may arise from the use of particular chemicals. This covers both correct use according to the manufacturers instructions (use) and situations where there has been an illegal failure to follow the directions properly (misuse). The second function of WIIS is to provide a mechanism for investigating deaths caused by deliberate and illegal poisoning (abuse). The results from this study are relevant mainly to the post-registration surveillance function of WIIS.

3. Some 200-300 incidents involving birds are reported to WIIS each year (Table 1). Raptors are heavily over-represented in the sample, presumably due to their high involvement in deliberate poisoning cases and to high interest in these species from conservationists and others, leading to high reporting probabilities.

4. Recovery data from dead or dying birds reported to the BTO ringing scheme were used to investigate variation in reporting probabilities between species and geographical areas.

5. Reporting probabilities estimated from ringing data are likely to be higher than those for WIIS for three main reasons:
   (1) A ring is a direct request for the bird to be reported.
   (2) WIIS attempts to screen out deaths where pesticide poisoning is unlikely.
   (3) Wildlife incidents occur mainly in rural areas while a substantial proportion of ringing takes place close to inhabited areas where reporting probabilities will be higher.

6. Broad patterns of interspecific and regional variation are likely to be similar between the two schemes. Raptors, owls and corvids are likely to be over-represented in the overall WIIS statistics because they are the species that are mainly involved in cases of deliberate poisoning (abuse).

7. Ring reporting probabilities of 99 species varied by over two orders of magnitude from 0.06% for Chiffchaff to 16.75% for Mute Swan. This very large amount of variation is not just a consequence of a few extreme values, as a 42-fold variation remains if the species with the five highest and five lowest reporting probabilities are omitted. Larger birds had higher reporting probabilities than small ones. Ninety percent of the variation in reporting probabilities between species could be explained by a combination of weight,

association with man, abundance and habitat. Rarer species and those which associated more closely with man had higher reporting probabilities.

8. Six out of eighteen passerines examined showed regional variation in reporting probabilities. Barn Owl, Tawny Owl and Song Thrush all showed significant variation in reporting probabilities at the county level. Regional variation in the reporting probabilities of Tawny Owls and Song Thrushes was related to human population density. Regional variation in reporting probabilities clearly occurs but insufficient data are currently available to establish whether different species show similar patterns.

9. Evidence from field trials and from WIIS itself supports the view that reporting probabilities are low and that they differ greatly between species. The WIIS data show large differences in the frequency of reports between groups (Table 2), the relative incident frequency for raptors being over three orders of magnitude higher than that for passerines.

10. The claim that WIIS probably covers a representative sample of those incidents which occur is now untenable. Pesticide induced deaths of small species with low reporting probabilities are likely to be under-represented while large species and those of special conservation interest will be over-represented. These problems have been recognised by earlier workers but their scale may not have been appreciated fully.

11. The Environmental Panel of the Advisory Committee on Pesticides use WIIS reports to identify potential problems with particular pesticides. Problems are assessed on a case by case basis and there are no formal criteria for identifying problems. Nevertheless it has been suggested that ten incidents per pesticide per year might lead to a presumption against acceptability (Cooke 1990). The use of WIIS data to identify problems implies some form of implicit or explicit threshold system, although this does not necessarily mean that all incidents are weighted equally. Thresholds need to take account of the large variation in reporting probabilities which clearly exists.

Recommendations

1. As far as possible the initial purpose of each investigation, including those where pesticides are not identified, should be classified either as post-registration surveillance or as the investigation of deliberate illegal poisoning (abuse). It should be possible to classify most incidents in this way although there will inevitably be a few that are difficult to categorise. The reporting probabilities of these two types of incidents are likely to be very different and this information is therefore important for the interpretation of incident frequencies.

2. It is important that all potential incidents reported to WIIS should be systematically recorded to provide data on background levels of mortality and coverage. Plans to tighten this aspect of record keeping are in hand.

3. A more refined analysis of the WIIS data than was possible in this study needs to be carried out by MAFF staff to check whether they show similar patterns to the ringing data and to identify species which are over- or under-represented in wildlife incidents relative to their reporting probabilities.

4. Thresholds (whether implicit or explicit) should take account of differences in reporting probabilities between species (Figure 1). They should perhaps also be related to the number of natural deaths which will be expected, which can be calculated from national estimates of the population size and average mortality rate of each species. Many small species have high population sizes and mortality rates which would more than offset their low reporting probabilities under such a system. Further work will be needed to develop a system of this kind. For species with moderate reporting probabilities it should be possible to apply a straightforward threshold system based on reporting probabilities alone. For species with low reporting probabilities in may be necessary to have a threshold of only a few incidents which triggers further investigations. Any such threshold system should be regarded as an aid to decision making and not as a set of rigid criteria.

5. It must be accepted that for those species with very low reporting probabilities (principally small passerines) WIIS alone cannot provide effective post-registration surveillance of pesticide induced mortality. Where further information on the effects of pesticides on these species is needed additional field or laboratory studies would have to be carried out. Approaches for prioritising the needs for such work should be developed. Some work on this topic is already being undertaken by MAFF.

6. Better use should be made of data from national population monitoring schemes for identifying species which may be affected by mortality caused by pesticides. As the effects of pesticides on all species with low reporting probabilities cannot be studied in detail, population monitoring data should focus attention on declining species, or species showing reduced breeding performance or survival rates.

Introduction

The Wildlife Incident Investigation Scheme is operated in England and Wales by MAFF and by the Welsh Office Agriculture Department (WOAD) and a similar scheme is operated in Scotland by the Scottish Office Agriculture and Fisheries Department (SOAFD). An equivalent scheme covering Northern Ireland was introduced by the Department of Agriculture for Northern Ireland (DANI) in 1992[1]. These schemes are concerned with investigating incidents of suspected pesticide poisoning involving wild mammals, wild birds, companion animals, livestock and honeybees. They also investigate incidents involving the illegal use of poisonous baits.

These schemes have two main objectives. The first is to provide post-registration surveillance of the use of pesticides (Hardy 1987, Hardy *et al.* 1987). New pesticides undergo a rigorous series of laboratory and field tests but it would be impossible to test them in all possible conditions and on all species of vertebrates. Therefore it is important to have a scheme in place that will detect any unexpected problems arising from the use of pesticides after they have been approved for general use. Such problems may be resolved through modifications to the conditions of use, or by partial or complete withdrawal. The second objective is to investigate incidents of illegal poisoning. Such poisoning may often involve species and areas that would not be affected by legal pesticide use. The identification of such incidents is likely to lead to enforcement action and to efforts to increase public awareness.

Some 73% of the vertebrate wildlife incidents investigated by WIIS involve wild birds (Fletcher *et al.* 1992, Hardy *et al.* 1986). Major impacts of pesticides on bird populations have been recorded in the past (Risebrough 1986). Effects on the scale seen in the 1950s and 1960s have not been recorded in recent years but with continuing changes in the availability and use of pesticides it is important that vigilance for unanticipated effects of pesticides should be maintained. As birds are often close to the top of food chains and as their populations are relatively well monitored in Britain they provide valuable indicators of wider environmental problems.

This report is concerned with possible biases affecting the use of WIIS data to assess the relative impact of pesticide induced mortality on different bird species. Such bias is likely to arise principally from variation in the probability of incidents involving different bird species being reported. Field tests of search efficiency (Mineau & Collins 1988) and reporting probabilities of ringed birds (Hickling 1988, Baillie & Green 1987, Mead & Clark 1991) suggest that there is a great deal of variation in reporting probabilities between species.

Objectives of the present study

MAFF contracted the BTO to undertake a series of analyses of the reporting probabilities of ringed birds in order to assist in the interpretation of WIIS data. The specific objectives of the study and the location of the results relating to them are as follows:

[1] Throughout the rest of this report these schemes are jointly referred to as WIIS for the sake of convenience.

1. *To measure the reporting rates of dead birds of a wide variety of species.*

Reporting probabilities of individual species are listed in Appendix 3 together with the explanatory variables used for the analysis of interspecific variation in reporting probabilities.

2. *To investigate the effects of body size, conspicuousness and habitat on species-specific variation in reporting rates. This will allow reporting rates to be predicted for species for which few data are available.*

An analysis of interspecific variation in reporting probabilities is presented as a separate manuscript (Baillie, McCulloch & Hart, Appendix 1).

3. *To measure the extent of geographical variation in the reporting rates of selected species and to examine how this is affected by environmental factors, particularly human population density, land-use and agricultural practices.*

An analysis of geographical variation in the reporting probabilities of a range of species at several spatial scales is presented as a separate manuscript (Peach, McCulloch, Baillie & Austin, Appendix 2).

4. *To assess the implications of the results for the interpretation of data gathered under the Wildlife Incident Investigation Scheme (WIIS) operated by the Ministry.*

This is the aim of the main text of this report.

The two main functions of WIIS

WIIS is performing two rather different functions. The first is to provide general surveillance for unexpected mortality caused by the correct use of pesticides or through illegal failure to follow the directions for use properly (referred to as use and misuse, following Greig-Smith 1988). The second is the investigation of incidents thought to involve illegal poisoning (referred to as abuse). It is essential to separate these two functions when reporting rates from ringing are interpreted in relation to WIIS. Such comparisons would be greatly facilitated if WIIS statistics drew clearer distinctions between these two functions, as outlined in the following paragraphs.

Analyses of WIIS data need to separate these two types of incidents clearly. This is usually straightforward where the cause of death is attributed to pesticides and the incident is assigned to one of the three standard categories of use, misuse or abuse, although there will inevitably be a minority of incidents that are investigated because one cause is suspected and which are eventually attributed to another. However the main problem arises with incidents that are not attributed to pesticides. Many such cases appear to be investigated because illegal poisoning is suspected. Criteria need to be developed to separate incidents from agricultural areas, which can be regarded as part of the general surveillance for pesticide mortality, from incidents where the investigation is initiated for special conservation reasons. The fact that a small proportion of cases may be difficult to classify in this way is not a good reason for failing to undertake such a classification as they can always be placed in an "unknown" category.

It would be helpful if the results given in the annual WIIS reports were more clearly separated in this way. This would make clearer the relative effort being put into post-registration surveillance and efforts to combat illegal poisoning. It would also help to show which species groups were most severely affected by these two factors. It is important that proper records should be kept of all potential incidents that are reported, even if they are excluded from detailed investigation at an early stage. Records of all potential incidents should be maintained from the time that they are first reported to an ADAS biologist (below). Such information would provide a better index of background mortality and of the level of surveillance than is currently provided by WIIS. This study is concerned primarily with the use of WIIS data for post-registration surveillance of pesticides.

Incidents of deliberate poisoning are likely to be targeted primarily at a restricted range of species, although many of them (particularly raptors and owls) are of high conservation importance. Patterns of temporal and geographical variation in the incidence of illegal poisoning will have been influenced strongly by the effort which has been put into detecting such incidents and by the activities of conservationists and ornithologists in particular areas.

Methods of data gathering by WIIS

Details within the following account relate to the Wildlife Incident Investigation scheme that operates in England and Wales. The procedures followed in Scotland and Northern Ireland are generally similar. These procedures are outlined in some detail here because a clear understanding of how the WIIS data are gathered is central to the discussion of how data on ring reporting rates might assist in their interpretation.

The WIIS aims to identify mortality incidents that are likely to have been caused by pesticide poisoning or the illegal use of poison baits, and to identify the pesticides involved. The existence of the scheme is widely known amongst conservation organisations and those concerned with animal health, such as RSPB, Country Conservation Agencies, RSPCA, veterinary surgeons and Police Wildlife Liaison Officers. Most incidents arise initially from dead birds found by farmers or members of the public and are fed into the WIIS system via organisations such as those listed above.

An anti-abuse campaign to counter the illegal poisoning of wildlife was launched in 1991 by government departments under the leadership of MAFF. The has included an extensive poster campaign together with events targeted at a range of different groups from veterinary surgeons through to those who use the countryside for recreation. A freephone number which can be used to report incidents has been widely publicised as part of this campaign. This has resulted in an increase in the proportion of incidents that are reported directly to MAFF.

The procedures for investigating incidents are outlined by Hardy *et al.* 1986 and in the annual reports on pesticide poisoning of animals (e.g. Fletcher *et al.* 1992). Potential incidents in England and Wales are investigated initially by a regionally based ADAS biologist. They will usually arrange a field visit and any necessary follow-up investigations to determine the scale and exact circumstances of the problem and to collect relevant information on local pesticide usage.

It is the responsibility of the ADAS biologist to determine whether the incident is appropriate for investigation under WIIS. Written guidelines have been introduced to improve the standardisation of the types of incidents which are investigated under the scheme. The ADAS biologist must determine that the species of animal involved is covered by the scheme and that there is some suspicion of poisoning. Birds which have obviously been shot or killed through collisions with vehicles or stationary obstacles are excluded as are corpses which have been scavenged leaving no tissues for analysis. When one or more birds are found dead with no obvious cause the decision is more difficult. Where several birds are found dead together or where it is known that pesticide applications have taken place recently further investigations would certainly be undertaken. There is also a predisposition to investigate all deaths of rarer birds of prey, such as Red Kites and Golden Eagles, and other groups though to be vulnerable to accidental or deliberate poisoning.

Single dead birds of common species found in areas where pesticides are unlikely to have been used would not generally be investigated. There are inevitably some borderline cases where the decision on whether or not to include them would depend on the judgement of the individual biologist concerned. No statistics on the cases that are excluded at this stage are currently collected but plans to gather such information in the future are in hand (M.R. Fletcher pers comm.).

The next stage of investigation is for any carcases to be taken to a local Veterinary Investigation Centre where a post-mortem examination is undertaken. This may result in bacteriological or virological tests to determine whether disease contributed to the deaths. If it can be demonstrated that trauma or disease was the cause of death then the investigation may be terminated at this stage. In the past some cases where birds had died of disease were not included in the WIIS statistics. Reporting procedures have now been tightened so that all cases which reach the post mortem stage will be included in future statistics (M.R. Fletcher pers comm.).

Where poisoning is still suspected following the post mortem examination, tissue samples are forwarded to the Wildlife Incident Unit at the Central Science Laboratory, where chemical and other analyses of the tissues are carried out.

The results of the field enquiry, post-mortem and tissue analyses are collated and interpreted by the Wildlife Incident Unit to assess the probable cause of the incident and whether any pesticide residues detected contributed to the death or illness of the bird. A written report is compiled on each incident and an annual review of these reports is submitted to the Environmental Panel of the Advisory Committee on Pesticides.

Annual reports on the combined results of WIIS and the related scheme operated by SOAFD have been published for each year since 1986 (Fletcher *et al.* 1988, Greig-Smith *et al.* 1988, 1989, 1990, Fletcher *et al.* 1991, 1992). Statistics on incidents involving birds, taken from these reports, are summarised in Table 1. Between 200 and 300 such incidents are investigated each year, there being little annual variation in the relative proportions of incidents involving different groups of birds or in the percentage of incidents where pesticides are identified as the likely cause of mortality.

Some 44% of the total number of incidents are attributable to raptors and owls alone. This is presumably because conservationists consider that these top predators are particularly vulnerable to both deliberate and accidental poisoning by pesticides and are hence more likely to report such deaths to WIIS. However, the proportion of incidents where death can be attributed to pesticide poisoning is no higher for raptors than for most other groups. The second most common group to be investigated are corvids and here there is clear evidence of a much higher rate of poisoning than for any other group. Most corvids are regarded as pests by farmers and other land-users and may be shot legally throughout the year. The figures suggest that many people resort to illegal poisoning in order to kill these birds. Both corvids and raptors feed on carrion and they are therefore the species that are most likely to take poisoned baits.

There is no significant difference in the percentage of incidents attributable to poisoning between raptors and owls, gulls and plovers, pigeons and doves, gamebirds and passerines. This percentage is lower for wildfowl and waterbirds, perhaps because many of these birds partly or wholly occupy non-agricultural habitats. WIIS is not targeted at marine birds and only a small number of incidents involving such species were investigated. None involved pesticide poisoning.

Methods of data gathering by the BTO Ringing Scheme

The BTO Ringing Scheme organises the ringing of wild birds throughout Britain and Ireland. Some ringing is undertaken by professional biologists but the vast majority is carried out by amateur ringers. All ringers are required to undertake a thorough period of training to ensure that catching and data gathering procedures are carried out to a high standard. There is little direct control over the nature of the ringed sample although ringers are encouraged to ring particular species of conservation interest and to participate in the Constant Effort mist-netting sites scheme through a system of ring subsidies (in Britain and Ireland ringers pay for the rings which they use). The pattern of ringing does not change greatly from year to year. Those changes which do take place are documented in the annual reports on bird ringing (eg Mead & Clark 1991).

Currently about 800,000 birds are ringed in Britain and Ireland each year of which about 20% are ringed as nestling or unfledged chicks (pulli). The vast majority of those ringed as full-grown are caught in mist nets. Cannon nets and a wide variety of traps are also used for particular species. Each bird is marked with a metal ring which carries a unique serial number and the address of the British Museum. The metal rings used on terrestrial and freshwater species will last for the life of the bird.

Ringers return special forms (schedules) which record the species, age, sex, date, place and other details for each bird ringed. These forms are filed by ring number and are used to look up the ringing details when birds are recovered (below). It is recognised that much better use of the ringing data could be made if these data were computerised, and a programme to develop the computerisation of incoming ringing data is currently in progress. Ringers also submit totals lists for each calendar year which record the numbers of each species which they have ringed, split into full-grown birds and pulli. These totals are summarised to provide totals of full-grown birds and pulli of each species ringed each year throughout Britain and Ireland. These data were used to calculate the species-specific estimates of reporting rates.

More detailed information on numbers of birds ringed is only available for a few species. Age-specific totals lists have been gathered for 22 passerines since 1985 (Baillie & Green

1987). These provide annual summer ringing totals for these species split by age and region of ringing. Fully computerised sets of ringing data were available for Song Thrush, Tawny Owl and Barn Owl although these did not necessarily cover all the data held by the BTO.

Recoveries include all records of ringed birds found dead or injured, all records of birds recovered alive by members of the public and all birds recaptured by ringers more than 5 km from the ringing site (a greater threshold distance is used for a few species). The analyses discussed in this paper relate to birds which were dead or dying when recovered, the vast majority of which will have come from members of the public. Bird rings carry the text 'INFORM BRIT. MUSEUM SW7' or similar which is itself a clear request to report the ring. Ringing has been widely publicised through television and radio programmes and both the general and wildlife press. Thus, in Britain and Ireland at least, many people are likely to have some general awareness of bird-ringing that will encourage them to report any ringed birds which they find.

Most recoveries are reported to the ringing office by letter, the remainder being by telephone. Some 14000 recoveries are received each year. With this volume of information it is only possible to send follow up letters if the ring-number has not been reported correctly or if the movement or longevity indicated by the recovery is particularly unusual. For most recoveries the information contained in the letter is coded for cause of recovery, finding county and co-ordinates, accuracy of location, date and accuracy of date. If the finder is imprecise in any aspects of their report this is indicated in the way the recovery is coded.

The ringing and recovery details of each bird which has been recovered are entered into special computer software which performs a large number of checks on the data. After further manual checking printouts of the recovery details are sent to the finder and ringer. These include a general request for the ringing office to be informed of any errors.

All recovery data since the start of the Ringing Scheme in 1909 are held on computer file. Up to the end of 1991 a grand total of 454,155 recoveries had been reported. Many of the birds that are ringed in Britain and Ireland are migrants. Thus although the majority of recoveries come from within Britain and Ireland many are also reported from abroad.

Factors affecting comparisons of reporting probabilities from ringing and from WIIS

Absolute reporting probabilities estimated from ringing data are likely to be higher than those from WIIS for two main reasons. First, ringed birds carry a ring which is, in effect, a request for the bird to be reported. Once a dead bird has been found, the probability that a ring will be found on the body and reported is likely to be higher than the probability that the finder will be aware of the possibility of reporting the incident and will consider it worth reporting (either directly to WIIS or via another organisation). Second, WIIS is concerned only with deaths in places and circumstances where pesticides are likely to have been responsible for the mortality. Deaths of single birds away from areas of obvious pesticide application are unlikely to be investigated, and will therefore not be included in the statistics.

This second point raises the problem that the set of dead birds that might potentially be reported to WIIS is not clearly defined. WIIS deliberately attempts to select birds that are likely to have died from pesticide poisoning. Thus bias towards birds dying in groups or in areas where pesticides are used is introduced deliberately. However, it is not possible to measure the proportion of deaths of different species which occur in circumstances that would warrant reporting to WIIS. Thus it is only meaningful to discuss reporting probabilities to WIIS in relation to all bird deaths except those with obvious causes such as shooting, trauma and predation. Disease and starvation may be identified as a result of WIIS investigations but they are unlikely to be correctly diagnosed by most finders of ringing recoveries.

Both the ringing recoveries selected for estimation of reporting probabilities and the WIIS incidents involve birds found dead or dying with no obvious cause of death. Birds that were reported as shot, killed through collisions with vehicles or obstacles, or killed by domestic animals are excluded. Wildlife incidents which reach the stage of inclusion in the scheme are investigated by ADAS biologists in England and Wales, and it is therefore certain that virtually all such cases are excluded. However, in the case of ringing recoveries there is an unknown proportion of "found dead" records which are attributable to such causes but where the cause of death was not mentioned in the recovery report. This will bias ringing probabilities upwards relative to those from WIIS. In inter-specific comparisons of reporting probabilities based on ringing it would cause positive bias amongst those species for which a high proportion of deaths are attributable to such causes. This is not likely to have caused serious bias to the analysis of interspecific variation in reporting probabilities of ringed birds because reporting probabilities based on all recoveries and on found dead recoveries only are well correlated (Baillie, McCulloch & Hart, Appendix 1).

The analyses of ringing recoveries carried out for this project have demonstrated that ringed birds dying in inhabited areas are more likely to be reported (below). WIIS operates mainly in rural areas as it is targeted primarily at deaths caused by agricultural pesticides. A considerable amount of ringing takes place in urban and suburban areas and many of these ringed birds eventually die in such areas. This will again cause positive bias in the ring-reporting probabilities relative to WIIS. For interspecific comparisons it may cause positive bias to the reporting probabilities of species which inhabit urban and suburban areas. Such bias is not a problem for the analyses presented here because appropriate variables were included to account for it.

The pattern of interspecific variation in the reporting probabilities of birds, which may have died from the use or misuse of pesticides and which are reported to WIIS, is likely to be similar to that for recoveries of ringed birds reported as found dead. Suspected deaths from abuse are superimposed on this pattern. Such causes of death affect primarily raptors, owls and corvids. Reporting probabilities of raptors and owls are likely to be inflated because conservationists and birdwatchers suspect such birds will be poisoned, and dead birds of these species are thus much more likely to be reported to WIIS. The reporting probabilities of these groups are thus likely to be higher, relative to those of other species, for WIIS than in the ring recovery data.

Overall the reporting probabilities for WIIS are likely to be substantially lower than those from ringing recoveries. The pattern of interspecific variation is likely to be similar between the two schemes.

Interspecific variation in the reporting probabilities of ringed birds

This study (Baillie, McCulloch & Hart, Appendix 1) investigated the pattern of interspecific variation in the reporting probabilities of ringed birds that were found dead by members of the public. Reporting probabilities of 99 species varied by over two orders on magnitude, from 0.06% for Chiffchaff to 16.75% for Mute Swan. This wide variation in reporting probabilities is not just a consequence of a few extreme points. Omitting the five highest and five lowest species-specific reporting probabilities gives a 42-fold difference from 0.14% for Treecreeper to 5.87% for Buzzard. Species-specific reporting probabilities are listed in an appendix to the paper.

Body weight alone explained 86% of the variation in reporting probabilities between species. A combination of body weight, species abundance, association with humans (ranked by 15 experienced ornithologists) and habitat explained 90% of the variation in reporting probabilities. Larger birds and those which are more closely associated with man were more likely to be reported. Reporting probability was negatively correlated with abundance, suggesting that rare species were more likely to be reported. These patterns were robust to division of the data according to migration status. Habitat explained only a small percentage of the variance in the all species model and was not significant in the other models. Therefore it did not appear to have an important influence on reporting probabilities.

The main conclusion from this study is that there is a very large amount of variation in reporting probabilities between species and that this is related mainly to body size. Thus, while there may be a reasonably high probability that mortality incidents involving large birds such as swans or geese will be detected and reported, it appears that the chances of detecting incidents involving low numbers of small birds may be negligible.

Regional variation in the reporting probabilities of ringed birds

Regional variation in reporting probabilities was examined on three scales; five large regions of Britain and Ireland, counties and 10km squares (Paper 2, Peach, McCulloch, Baillie & Austin, Appendix 2).

Reporting probabilities of 18 passerines were compared between five large regions; Southern England, Central England and Wales, North England, Scotland and Ireland. The form in which the ringing totals were gathered and the number of recoveries available did not permit a finer regional subdivision of these data. Only six of the 18 species showed statistically significant variation in reporting probabilities between regions and the pattern of regional variation was not consistent across species. These data have only been gathered since 1985 and sample sizes for some species/region combinations remain small. A clearer pattern may emerge once more data have accumulated.

Reporting probabilities for individual counties were calculated for Tawny Owl, Barn Owl and Song Thrush. Statistically significant variation in reporting probabilities between counties could be demonstrated for all three species. Population density accounted for up to 41% of the variation in reporting probabilities between counties for Song Thrush and up to 25% for Tawny Owl. However, the effect of population density was greatly reduced when the small number of conurbations were excluded. In one analysis human population density and the percentage of land under cereals together accounted for 48% of the variation in Song Thrush reporting probabilities. The reporting probabilities of Barn Owls were not correlated with either population density or agricultural land use.

Only the ringing data for Song Thrush were computerised in sufficient detail to allow reporting probabilities to be estimated at the 10km square level. These reporting probabilities were correlated with measures of human population density but not with agricultural or land use variables.

This study shows that within species reporting probabilities vary between regions. However, the pattern of regional variation was not consistent between species. Human population density explained some of this regional variation for two out of three species. These results show that when interpreting the results from passive monitoring schemes for wildlife mortality regional variation in reporting probabilities should be expected. However, they do not establish any general pattern of variation which could be applied to such schemes.

Comparisons between reporting probabilities from ringing, field experiments and WIIS

The reporting probabilities of ringed birds have been shown to vary by over two orders of magnitude and a similar pattern of variation is likely to apply to the reporting of birds killed by pesticides. Thus, while deaths of large birds such as geese will have a high probability of detection, deaths of small birds are very unlikely to be detected.

Data gathered to test the effectiveness of corpse searches, carried out during pesticide field trials or to evaluate mortality from collisions with powerlines and similar structures, provide further evidence that low reporting probabilities should be expected for many species. The proportion of corpses found is determined by search efficiency and by the rate of corpse removal by predators.

In trials where corpses were placed in open habitats without concealment search efficiencies varied enormously from 0% to 100% (Mineau and Collins 1988). In the only study where corpses were concealed, to simulate birds seeking shelter in their preferred habitat, a team of eight experienced observers found none of the 50 duck carcases planted over 40 ha of marsh (Stutzenbaker *et al.* 1984). A series of estimates made in relation to studies of mortality caused by powerlines suggested that the detectability of large and medium sized corpses was high (mean of 11 estimates 86%) but that 69% of small bird corpses went undetected (James & Haak 1979, Beaulaurier 1981, Wildan Associates 1982, Longridge 1986). Thus even intensive searches by experienced observers fail to detect many corpses. Reporting probabilities based on the chance discovery of corpses by members of the public will inevitably be much lower than this.

Corpse removal rates by predators are also extremely variable, ranging from 0% to 93% in the field trials referred to above (Mineau & Collins 1988). Removal rates for passerines appear to be particularly high, contributing further to the low reporting probabilities of these species. Only 7.7% of passerine corpses placed in agricultural fields in Maryland, USA were still present after five days (Balcomb 1986). Three experiments involving House Sparrow corpses distributed under powerlines in Kent, UK similarly showed that almost none were left after four days (Scott *et al.* 1972).

Data from WIIS itself could potentially be analysed to provide further insights into interspecific variation in reporting probabilities within this scheme. A very simple analysis based on the data contained in the published annual reports is presented in Table 2. Numbers of incidents involving each species group were related to the breeding population size of all species in that group, based on the data in Marchant *et al.* (1990). This makes no allowance for the complexities caused by differences in demography and migration patterns. Nevertheless the differences in the frequency of reporting of different species groups are striking. The probability of raptor deaths being reported appears to be over three orders of magnitude higher than for passerines. This difference may be an underestimate because raptors have lower mortality rates than passerines so that a smaller proportion of their population dies each year. The reporting of incidents involving raptors and owls is undoubtedly influenced by conservation awareness of this group. However, the differences in incident rates between passerines and groups with larger body size such as gulls, plovers and pigeons suggest that WIIS reporting probabilities show similar patterns to the ringing data.

Data on WIIS incidents relating to general pesticide surveillance should be analysed in more detail to check that the broad pattern of interspecific variation is similar to that shown by ringing recoveries and to identify species or species groups that appear to be under or over represented. Such an analysis was beyond the scope of the present study and would best be carried out by MAFF scientists who are familiar with the details of the WIIS data set. Numbers of incidents involving each species should be related to an estimate of the number of deaths of the species which occur in Britain each year. This would be based on published estimates of populations size (Lack 1986, Marchant *et al.* 1990, Gibbons *et al.* in press) and demographic parameters (Saether 1989, Dobson 1990). It might be necessary to combine the results for some similar species where the data are sparse. These estimates of WIIS reporting probabilities could then be plotted against those obtained from ringing recoveries in this study. The multiple regression model developed in paper 1 could be used to estimate ring reporting probabilities for species with insufficient ringing data. A strong correlation between these two sets of reporting probabilities would provide further support for the view that the pattern of interspecific variation in ring reporting probabilities is applicable to the WIIS data. Residuals from the line of best fit between these two sets of reporting probabilities would indicate species which were under- or over-represented by WIIS.

The use of WIIS data to identify pesticide problems in the presence of variation in reporting probabilities

The data from this study demonstrate that there are likely to be large differences in the reporting probabilities of different species within the WIIS. It has been suggested previously that although WIIS cannot determine the scale of wildlife mortality incidents it probably covers a representative sample of those incidents that occur (Greig-Smith 1988). In the light of the evidence which is now available this claim is untenable. It is quite clear that pesticide induced deaths of small species with low reporting probabilities will be seriously under-represented in the sample while large species and those of special conservation interest will be over-represented. It has been suggested that WIIS is focused on differences between chemicals rather than differences between species, and that its results may be representative of the types of incidents being caused by different chemicals. However, it seems very probable that species will differ in their susceptibility to different chemicals, and if this is the case differences in the representation of species will inevitably lead to differences in the representation of chemicals. These problems have been recognised by earlier workers (Greig-Smith 1988, Hart 1990) but their scale may not have been appreciated fully.

Some of the small bird species which are vulnerable to pesticides occur in flocks at the times of year when they are at greatest risk of pesticide poisoning. This may increase the probability that poisoning incidents will cause large numbers of deaths within a relatively small area, greatly increasing the chance that such incidents will be noticed and reported. It is certainly true that WIIS has identified a number of incidents of this kind. However, many small birds inhabiting agricultural land do not occur in flocks and whether or not the poisoning of flocks results in conspicuous groups of corpses is likely to depend on the knock down time of the particular chemical and on a range of other factors. While flocking behaviour may, under some circumstances, mitigate the bias caused by the low reporting rates of small species it is very unlikely that it cancels out the major part of such bias.

Information on reporting probabilities could potentially be used to improve the way in which incident data from WIIS are used to identify problems with particular pesticides. Currently an annual summary of incident reports from WIIS is reviewed by the Environmental Panel of the Advisory Committee on pesticides. A number of incidents involving the use or misuse of a particular pesticide may result in a reevaluation of approvals that have been granted previously for that product. They may also affect the progress to full commercial use of a product that currently has provisional approval.

No formal criteria exist for determining the point at which a particular product should be reevaluated, decisions being made on a case by case basis dependent on the numbers and species of birds involved and on the perceived likelihood of recurrence. Possible approaches to identifying unacceptable levels of wildlife mortality are discussed by Cooke (1990). While he makes it clear that rigid criteria would be inappropriate to such a complex decision making process, Cooke does suggest some general criteria that should help to evaluate whether the damage to wildlife that is likely to be caused by a particular product would be unacceptable.

The general premise is that it would be unacceptable for a pesticide to cause a local or more widespread population decline of a non-target vertebrate. Sublethal effects or deaths of small number of individuals have uncertain acceptability while the presence of residues with no demonstrable biological effect is deemed acceptable. The concept of the conservation importance of the species involved is superimposed on this framework, with the presumption that effects on species of high importance are less acceptable. Cooke classified bird species as "common" or "key" species, based on his personal assessment but taking into account the Schedules of the Wildlife and Countryside Act. He suggested that deaths of "key species" would elicit greater concern than those of "common species". The recent publication of Red Data Birds in Britain (Batten *et al.* 1991) provides a framework for this type of assessment. However, the majority of these species do not primarily inhabit agricultural land and are hence at relatively low risk from accidental pesticide poisoning.

Many farmland species are now in long-term decline and any pesticide effects on such species should be evaluated particularly carefully. Major declines of widespread species are likely to have a greater impact on the UK environment and on the public's enjoyment of it than declines of very rare species. In his review Cooke (1990) lists Lapwing, Skylark, Song Thrush, Starling, Tree Sparrow, Linnet and Reed Bunting in his category of "common species". All these species, together with a number of others, are now known to be undergoing long-term declines (Marchant *et al.* 1990) and their conservation status must therefore be re-evaluated. All are widespread inhabitants of agricultural land and their declines almost certainly arise from changes in the agricultural environment. While the precise causes of many of these declines remain to be determined, it is likely that they are due mainly to land-use changes and to reductions in food supplies (perhaps resulting from pesticide use) rather than to direct poisoning.

Assessing the scale of mortality that would cause population effects or otherwise unacceptable mortality is difficult. Cooke (1990) suggests three semi-quantitative criteria which could be applied to the effects of a particular pesticide:

1. Mortality observed following 50% or more of applications

2. Annual mortality of 1% or more of any species in Britain

3. 10 or more wildlife incidents per year

Cooke suggests that these criteria should lead to a "presumption against acceptability" for a particular chemical but that all other relevant information should also be taken into account. The first of these criteria relates to results from field trials and it should be noted that differences in reporting probabilities between species are also likely to apply to this situation, although they may be less marked than for deaths reported by the public. The second is very difficult to assess given the quality of the information available on numbers of deaths that are likely to be caused by pesticides. Such a criterion could usefully be refined by taking account of the mortality rates of different species. The deaths of 1% of the population of a species with an annual mortality rate of 10% would be more serious than for a population with an annual mortality rate of 50%. For common species with high natural mortality rates the level of pesticide induced mortality that would be publicly acceptable is likely to be considerably less than the level that would cause a major population decline.

The proposed threshold level of 10 incidents per year provides a practical suggestion which could be used to assist decision making based on WIIS data. The difficulty is that the number of incidents which had occurred when 10 were detected would differ greatly between species. The following discussion assumes that the reporting probabilities of incidents (which may involve several birds) are linearly related to the reporting probabilities of individual birds. In practice decisions will also need to take account of the circumstances and number of birds killed in each incident, and for this reason any threshold system should only be regarded as an aid to decision making. Figure 1 shows the relationship between reporting probability and the incident threshold assuming the threshold should correspond to a similar number of incidents for all species. The reporting probability used here is taken from the ringing data and the absolute value for WIIS would be lower than this by a substantial but unknown extent. The graph shows that applying the proposed threshold of 10 to a medium sized bird such as the Tawny Owl, thresholds for the same number of pesticide deaths of each species should be 20 for Grey Heron, 2 for Song Thrush and 0.2 for Willow Warbler. These numbers are only intended to provide an example of the general approach. In practice far fewer than 20 Grey Heron incidents attributable to a particular pesticide would give rise to a full review.

This type of calibration could easily be developed to provide thresholds for different species or species groups. It might be necessary to devise a simple system of weighting that would allow the contributions of incidents involving deaths from the same pesticide of species with different reporting probabilities to be combined. A threshold system which incorporated reporting probabilities might lead to the identification of three groups of species as follows:

1. Species with moderate reporting probabilities. Use of the pesticide would be reviewed when the threshold was crossed. Corresponding to Grey Heron and Tawny Owl in Figure 1.

2. Species with low reporting probabilities. After a very small number of incidents (perhaps two or three) further investigations would be initiated, to determine whether a full review was required. The threshold for review of the pesticide based on incidents alone would be set a little higher than that determined by reporting probability. Corresponding to Song Thrush in Figure 1.

3. Species with very low reporting probabilities for which the system was unlikely to be effective. Thresholds would be set as in 2 above, to ensure that action was taken in the unlikely event of mortality from pesticides being detected.

The above approach is based on the premise that any extensive mortality of bird species caused by pesticides is unacceptable. This encompasses the scales of mortality which might cause local population declines.

An alternative approach to setting thresholds would be to adopt a population oriented approach. Thresholds would be set in relation to the probability of detecting the deaths of a certain proportion of the population (equation 1) or a certain proportion of the deaths which normally occur (equation 2).

$$D = P \times X \times R \quad (1)$$
$$D = P \times M \times Y \times R \quad (2)$$

where

D = threshold for number of deaths detected
P = UK population size
R = reporting probability
M = adult mortality rate
X = proportion of population size (perhaps 0.01 following Cooke 1990)
Y = proportion of expected annual mortality (perhaps 0.05)

Equation 2 only considers mortality of breeding adults but it could be extended to all deaths by including estimates of numbers of young fledged and first year survival rates. Because demographic variables tend to be inter-correlated this would make little difference to the ranking of species and might not be justified given the quality of the demographic data available.

This population oriented approach would give a much more complex pattern of thresholds than one related to reporting probabilities alone. Many small species have high population sizes and mortality rates which would more than offset their low reporting probabilities. Such an approach would need to be based on national population sizes. Data which could be used to estimate the proportions of populations which inhabit agricultural land (or other habitats where pesticides are used) exist for most species but new analyses would be needed. Full evaluation of such a system is beyond the scope of the present study.

The population oriented approach is more soundly based from the point of view of the population ecology of the species concerned. If the main aim of post-registration surveillance is to identify problems that could potentially affect the regional or national population sizes of particular species then this would be the most appropriate type of approach to adopt. However, it has the disadvantage that further collation and interpretation of data would be required to provide a comprehensive framework. The simple approach is based on the absolute number of deaths from pesticide incidents and takes no account of the number of deaths that would be expected from natural causes.

Additional approaches to post-registration surveillance

There are a considerable number of small bird species for which WIIS cannot be regarded as an effective means of post-registration surveillance. Any definition of which species should be included in this group will be arbitrary as reporting probability is a continuous variable. An initial suggestion might be all species which have ring reporting probabilities of less than 1.0%, which would include nearly all the smaller passerines weighing less than about 80g but exclude larger species such as Blackbird and Starling. Alternatively, it might be argued that all the small passerines including thrushes and Starlings should be included together with some of the smaller non-passerines such as woodpeckers. A detailed analysis of the WIIS data would provide further information on which species are more poorly covered by the scheme.

Where further evidence on the possible effects of pesticides on species with very low reporting probabilities is required additional methods would need to be used. These might involve counts to monitor population size in treated areas compared with controls (i.e. more extensive field trials), or additional laboratory tests. Mortality searches of treated areas are unlikely to be useful for such species because even experienced searchers may only find a small proportion of corpses (above). Counts are likely to be most useful for populations of small passerines in situations where pesticides are applied in spring and early summer. Even then the replacement of individuals which have died by recruits from a population of non-territorial floaters may make interpretation difficult (Edwards *et al.* 1979). At other times of year populations are often too mobile for counts to have a reasonable chance of detecting the effects of pesticide applications to small areas. Methods for evaluating the effects of pesticides are reviewed by Dingledine and Jaber (1990) and Hart (1990).

All of these alternative methods for investigating possible pesticide effects require substantial resources and it would therefore only be possible to investigate the effects of selected pesticides on a few species groups. Methods may need to be developed to identify priorities for such work. These might attempt to assess likely exposure by combining data from pesticide usage surveys with that on bird numbers and distribution (Sharrock 1976, Lack 1986, Gibbons *et al.* in prep). Priorities should also take account of the conservation status of the species involved, of the size of the British population of that species and of current population trends.

Additional approaches to identifying problems caused by pesticides

One of the strengths of WIIS is that it provides a means of identifying pesticide effects which could not be anticipated from pre-registration trials. Such effects are, by definition, unpredictable making it impossible to target research effort on them. If such effects give rise to widespread reproductive failure or declines in numbers general monitoring schemes for bird populations will be helpful in detecting them. For species with low reporting probabilities population monitoring schemes are likely to be the only general means of detecting unanticipated pesticide problems. These monitoring schemes have the disadvantage that those population changes that are detected may be attributable to a wide variety of causes. However, schemes such as the BTO's Integrated Population Monitoring Programme will increasingly use demographic and environmental variables to provide provisional diagnoses of population changes (Baillie 1990, 1991). Thus population changes that cannot be explained would be prime candidates for the investigation of pesticide effects.

Analyses of population data for birds would provide a more effective tool for identifying possible effects of pesticides if information on pesticide usage could be related more directly to bird monitoring data. MAFF organises pesticide usage surveys (e.g. Davis *et al.* 1990) but these only cover some crop types each year. It may be possible to use these data to compare population trends in areas with different levels of pesticide usage, and a more detailed evaluation of the potential for such analyses is needed. However, such analyses could only provide weak evidence for links between bird population changes and pesticide usage due to the low spatial and temporal resolution of the data, to the large number of pesticides involved and to the further complexity which results from variation in the timing and method of application. Good pesticide usage data from the study areas where birds are monitored would provide a much more powerful tool for identifying problems caused by pesticides.

Conclusions

The limitations of WIIS identified by this study should not be taken to imply that the scheme is not extremely important. Any system for the post-registration surveillance of pesticides must include arrangements for investigating those incidents which are identified and for determining whether pesticides were involved. WIIS performs this function effectively.

All WIIS results should distinguish as clearly as possible data relating to post-registration surveillance from that relating to illegal poisoning. WIIS recording procedures need to be tightened (as is already planned) to ensure that a systematic record of all potential incidents that are reported is maintained. Where such incidents are dropped from further investigation at an early stage a simple record of the reasons for doing so should be kept. Such data are important for assessing the coverage achieved by the scheme and background levels of mortality.

The large amount of variation in the reporting rates of individual species should be taken into account when evaluating the need to review the use of particular pesticides. Greater weight should be given to incidents involving species with low reporting probabilities. Even a few such incidents should lead to the instigation of further field or laboratory investigations. The details of how such a system should be implemented will need to be worked out by MAFF staff.

It should be accepted that for species with very low reporting probabilities WIIS would be very unlikely to identify mortality caused by pesticides unless large numbers of birds were killed in situations where they were flocking. Alternative approaches to post-registration surveillance need to be considered for such species. As resources are limited approaches for prioritising the needs for such additional surveillance need to be developed.

Better use should be made of data from national population monitoring schemes for identifying species which may be affected by mortality caused by pesticides. As the effects of pesticides on all species with low reporting probabilities cannot be studied in detail, population monitoring data should be used to focus attention on declining species, and on species showing reduced breeding performance or survival rates.

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Table 1 Total number of incidents[1] involving bird deaths investigated by MAFF and SOAFD between 1985/86[2] and 1991, and the percentage of these incidents in which pesticides were identified as the likely cause of death

		1985/86	1987	1988	1989	1990	1991	Total
Raptors and owls	n	104	66	80	139	135	155	679
	%	44.2	30.3	32.5	30.9	26.7	18.1	29.3
Wildfowl and waterbirds	n	36	19	23	18	28	22	146
	%	19.4	36.8	0.0	22.2	7.1	0.0	13.7
Gulls and plovers	n	15	10	12	17	11	11	76
	%	33.3	40.0	25.0	29.4	27.3	27.3	30.3
Marine birds	n	5	1	2	7	2	5	22
	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pigeons and doves	n	28	34	31	22	24	17	156
	%	35.7	38.2	38.7	31.8	33.3	47.0	37.2
Corvids	n	46	48	29	53	31	39	246
	%	56.5	77.1	51.7	58.5	64.5	43.6	59.3
Gamebirds	n	15	9	14	11	12	6	67
	%	40.0	44.4	28.6	27.1	41.7	33.3	35.8
Passerines	n	18	25	24	24	28	25	144
	%	44.4	44.4	20.8	25.0	10.7	20.0	26.4
Total incidents		267	212	215	291	271	280	1536

1 Incidents often involve more than one bird. More than one species may be included in a single incident.

2 Date from October 1985 included to standardise reporting periods to calendar years.

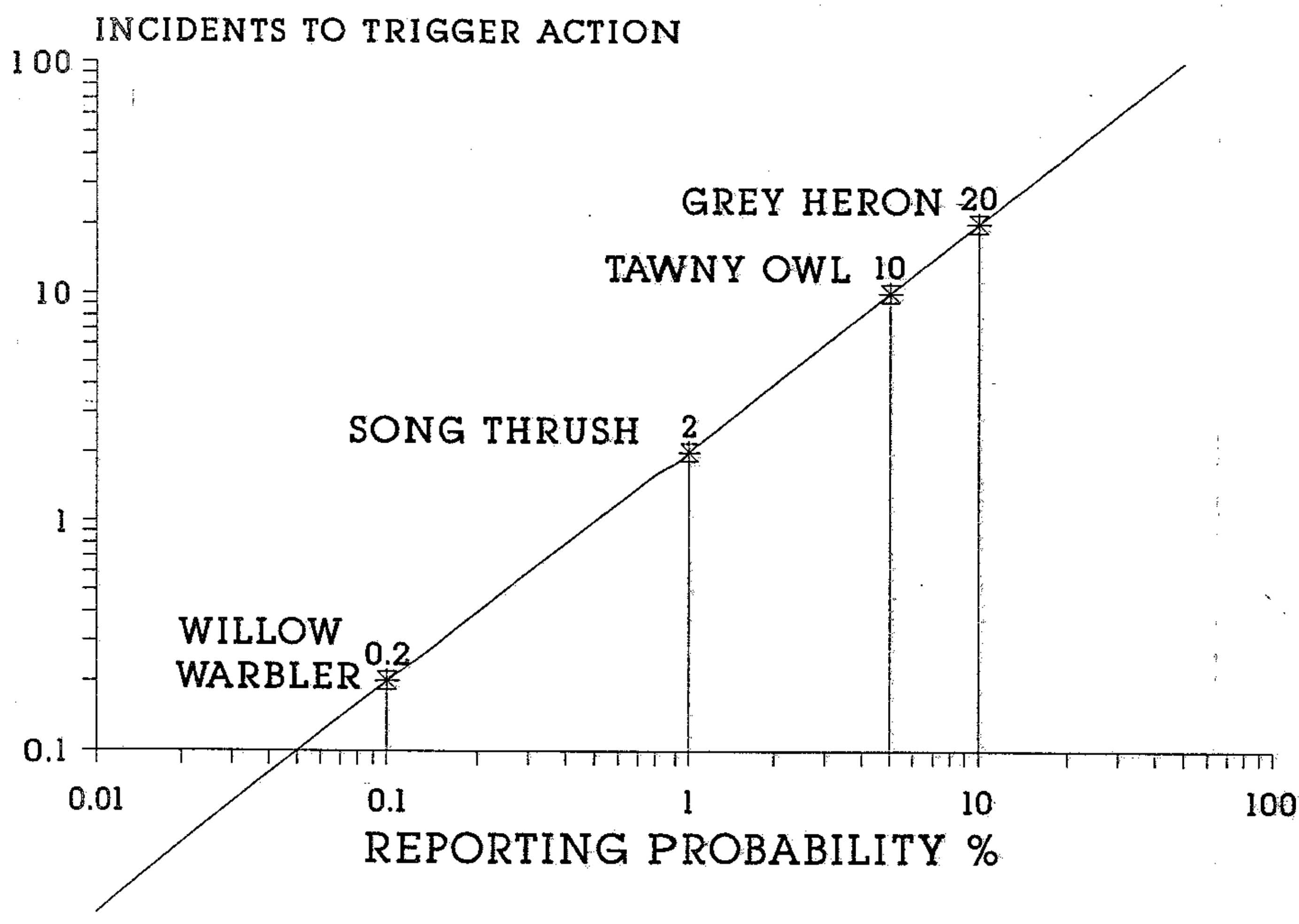
Table 2 Numbers of incidents reported to WIIS in relation to the size of the British breeding population

Species group	Breeding population size [1]	Incidents reported 1985/86-1991[2]	Incidents per 1,000,000 breeding birds
Raptors and owls	422,054	679	1,609
Wildfowl and waterbirds	1,270,974	146	115
Gulls and plovers	1,493,006	76	51
Marine birds	5,640,532	22	4
Pigeons and doves	5,575,000	156	28
Corvids	5,128,100	246	48
Gamebirds	8,036,950	67	8
Passerines	101,010,410	144	1

1 Number of individuals in breeding population (pairs x 2) from Marchant *et al.* 1991.

2 Data from Table 1.

Figure 1 Relationship between reporting probability and number of WIIS incidents required to trigger action. It has been suggested that a level of 10 incidents would be unacceptably high and this is applied to a medium-sized bird such as the Tawny Owl with a reporting probability of 5%. The graph shows the equivalent number of incidents required to trigger action for other species under the assumption that incident frequency is directly proportional to reporting probability. For further discussion see text.



Appendix 1

Interspecific variation in the reporting probabilities of dead birds and its implications for the surveillance of avian mortality

by

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Key-words: conspicuousness, pesticides, post-registration surveillance, ring recoveries, survival modelling.

Running headline: reporting probabilities of dead birds

Summary

1. The probabilities of dead ringed birds being found and reported by members of the public were measured for 99 species which occupy terrestrial or freshwater habitats using ringing and recovery data from Britain and Ireland.

2. Reporting probabilities varied by over two orders of magnitude, from 0.06% for Chiffchaff[1] to 16.75% for Mute Swan.

3. The effects of body weight, colour, plumage pattern, conspicuousness, habitat, species abundance, association with humans and size of rings on interspecific variation in reporting probabilities were investigated.

4. Conspicuousness scores and ring sizes were highly correlated with body weight and the effects of these two variables could not be separated from that of body weight.

5. A quadratic relationship with body weight explained 86% of the variation in reporting probabilities between species. A general linear model with body weight, species abundance, association with humans and habitat explained 90% of variation in reporting probabilities. Habitat had a weak effect and was not selected when various components of the full dataset were analysed separately. None of the other explanatory variables had significant effects.

6. Separate analyses of the data for resident and migratory species showed similar patterns. Once the data for migrants had been corrected for the period when they were absent from Britain and Ireland, and hence not available to be recovered, no residual effect of migration status could be detected.

7. These results have important implications for schemes designed to detect avian mortality through passive surveillance. For many small birds it is unlikely that even quite large scale mortality would be detected. Where additional means of surveillance

[1]Scientific names of the study species are given in Appendix 1

are impractical threshold numbers of reports needed to trigger detailed investigations should be related to the reporting probabilities of the species concerned.

Introduction

Records of numbers of birds found dead have been used to provide assessments of a wide variety of different types of bird mortality incidents, including those caused by severe weather (Dobinson & Richards 1964), oil spills (Stowe 1982), disease (Lloyd *et al.* 1976), lead poisoning (Sears 1988), powerlines (Scott *et al.* 1972) and pesticides (Fletcher *et al.* 1991). The aims of such studies are usually to measure the frequency of particular types of mortality. This approach is different from and complementary to that of studies designed to measure population mortality rates for the purpose of understanding changes in the size and demography of populations (Baillie 1990, Baillie & McCulloch 1993).

Mortality surveillance may either be active, meaning that systematic searches for corpses are organized, or passive, with records being gathered from anyone who voluntarily submits information. Active surveillance schemes generally represent attempts to provide measures of mortality from specific causes such as oil pollution or powerlines. Systematic searches for corpses as part of field trials designed to evaluate the safety of new pesticides (Mineau & Collins 1988) also fall within this category. Passive surveillance schemes often exist to record mortality from a wide range of different causes. Detailed investigation of those incidents which are reported, to identify the diseases or poisons responsible for the deaths, may be a more important function of such schemes than the gathering of systematic information on the frequency with which different species are affected by different types of mortality.

The number of casualties recorded by such schemes will be a function of the number of birds in the area being studied, their mortality rate over the recording period and the probability that corpses are found and recorded. The finding probability incorporates the effects of corpses having a limited lifespan, due to decay and to their being removed by scavengers, as well as the probability that a corpse which is present will be located by an observer. This study is concerned with the probability that corpses are found and recorded, which we refer to as the reporting probability.

It is well known that reporting probabilities are likely to vary widely between species, particularly as a result of information that is available from studies of ringed birds (Hickling 1983, Baillie & Green 1987). However, there have been no systematic studies designed to measure the reporting probabilities of a wide variety of species in a way that gives results comparable with those of schemes for the surveillance of avian mortality incidents. We measured the reporting probabilities of 99 species of ringed birds in Britain and Ireland and investigated factors that are likely to explain differences in these reporting probabilities between species. This information should assist in planning schemes for mortality surveillance and in the interpretation of their results.

Methods

REPORTING PROBABILITIES

Reporting probabilities were estimated using ring recovery data from the British Trust for Ornithology (BTO) ringing (banding) scheme which operates throughout Britain and Ireland (Mead & Clark 1993 and previous annual ringing reports). Under this scheme some 800,000 birds are ringed annually with metal rings, each of which is stamped with an address for reports and a unique serial number. The ringing is carried out by about 2,000 highly trained and licensed ringers, most of whom are amateur ornithologists. Some 14,000 recovery reports of these birds are received annually by the BTO Ringing Unit.

Selection of data

Recoveries of birds ringed between 1950 and 1989 and recovered up to the end of 1990 were analysed. Recoveries of birds which were sick or injured when ringed or which had been moved after death were excluded from the analysis. Records for which ringing or finding dates or locations were not known accurately were also excluded.

The analysis was restricted to birds that were recovered dead. The analyses reported in detail in this paper were based on "found dead" recoveries from which records of birds which were recovered in association with human activities were excluded. The main reported causes of recovery that were excluded were shot or trapped, oiled, human artifacts such as crop protection nets and power lines, vehicles, buildings and domestic animals. These exclusions accounted for between 22% and 94% of all dead recoveries for different species. The highest proportions excluded were for quarry species where large numbers of recoveries were reported as a result of hunting. Thus the "found dead" recovery category included records for which the recovery circumstances corresponded as closely as possible to those which might arise during surveillance schemes for wildlife mortality. Reporting probabilities based on "found dead" recoveries were correlated with those based on all dead recoveries ($r^2=0.632$, $n=99$). This correlation was strengthened substantially when quarry species were excluded from the analysis ($r^2=0.966$, $n=82$).

All terrestrial and freshwater species for which at least 30 found dead recoveries were available were included in the analysis. Marine and fully intertidal species were excluded because their reporting probabilities are likely to be affected by very different factors to terrestrial and freshwater species (Bibby 1981, Stowe 1982). Species which feed in marine or intertidal areas but which also make extensive use of terrestrial habitats, such as Redshank and Herring Gull, were included. Common Sandpiper *Tringa hypoleucos* was excluded because the ringed sample included a high proportion of passage migrants, 48.6% of the found dead recovery sample coming from abroad. A total of 99 species were included in the analysis comprising 40 non-passerines and 59 passerines (Table 1). This sample included 59 species that are predominantly residents, 20 species that are predominantly summer visitors to Britain and Ireland and 5 species that are predominantly winter visitors. There were also 5 species for which the British and Irish population is a mixture of summer visitors and residents (partial summer visitors) and 10 species for which the population is a mixture of winter visitors and residents (partial winter visitors). Unless otherwise stated, partial summer visitors and partial winter visitors were combined with summer visitors and winter visitors respectively for the purposes of analysis. Species occupying all major terrestrial and freshwater habitats were included (Table 2).

Methods of estimation

In order to estimate reporting probabilities it is necessary to know the numbers of birds ringed in each year and the number of subsequent recoveries. Information on numbers ringed was available only as annual totals of each species ringed in the whole of Britain and Ireland in each year, calculated from the annual returns supplied by ringers (e.g. Mead and Clark 1993). Where sufficient time has been allowed to elapse since ringing to ensure that all the birds from a series of ringed cohorts are dead (complete data) then:

$$\text{Reporting probability} = \frac{\text{Number of ringed birds recovered}}{\text{Number ringed}} \qquad (1)$$

The distributions of numbers of years elapsed between ringing and recovery were examined for each species and the number of years within which at least 99% of recoveries had been reported was determined. Records of birds ringed less than this number of years before 1989 were excluded from the data set and the reporting probability was calculated as in equation 1.

An alternative method of estimating reporting probabilities is to use statistical models designed for the estimation of survival and reporting probabilities from ring recovery data (Brownie *et al.* 1985). These models have been developed for the study of survival rates but they also provide estimates of reporting probabilities, which are generally regarded as nuisance parameters. These models can be used to analyse ringing and recovery data which include cohorts from which some birds are still alive and likely to be recovered in the future (incomplete data). Full application of these methods requires more detailed information on numbers ringed than was available for this study (Baillie & Green 1985). However, it was possible to obtain an estimate of the average reporting probability by fitting a model which assumed that survival rates were year-specific and that the reporting probability was constant. This model was used to estimate the reporting probabilities for a sample of 21 species. The resulting estimates were highly correlated with those estimated from complete data (Fig. 1a, $r^2 = 0.95$).

A further check that the reporting probability estimates from complete data were reliable was made by correlating them with reporting probabilities estimated as part of a detailed analysis of the survival rates of 16 passerines (Baillie & McCulloch 1993). These reporting probability estimates included all recovery circumstances and recovery locations and were based on models which provided a satisfactory description of the data as shown by likelihood ratio tests and goodness-of-fit tests. The data concerned birds ringed since 1985 (because detailed ringing totals had not been collected earlier) and were thus independent of those used for the analysis of complete data. The two sets of reporting probability estimates were again very highly correlated (Fig. 1b, $r^2 = 0.94$).

Correction of reporting probabilities for movements outside Britain and Ireland

Even amongst the 59 species which were classified as residents only 18 species had no found dead recoveries from outside Britain and Ireland. The aim of the analysis was to determine the reporting probability within Britain and Ireland. However, if recoveries outside Britain and Ireland were excluded the reporting probability would be an underestimate as part of the ringed population died outside this area. Reporting probabilities outside Britain and Ireland are probably lower than those within these two countries but any such difference could not be measured. Therefore, for resident species, recoveries outside Britain and Ireland were included in the reporting probability estimates. This will have reduced the effect of movement outside Britain on the relative estimates of reporting probabilities but may not have completely eliminated it. Fifty six of the 59 resident species had less than 10% of recoveries from abroad (Table 3), so any such effect is unlikely to have had a major influence on the results of this study.

The situation is more complex for the 40 species of which all or part of the population is absent for part of the year. Tabulations of the numbers of found dead recoveries in each month within and outside Britain and Ireland were examined for each of these species. These tables were used to identify for each species the months when the majority of the population was present within Britain and Ireland. The reporting probability was then calculated using recoveries from these months only, again including recoveries from outside Britain and Ireland. Twenty two of the 40 migratory species had less than 10% of recoveries from abroad while for 10 species more than 15% of recoveries were from abroad. The possibility that general conclusions about the pattern of interspecific variation in reporting probabilities were influenced by the percentage of recoveries from abroad was checked by carrying out separate analyses for species with more or less than 5% of recoveries from abroad.

Having calculated reporting probabilities of migratory species for particular sets of months for each species it was then necessary to convert these to rates for the whole year to give comparable rates for all species. The simplest method was to divide the reporting probability by the number of months included and multiply by 12 (Method 1). However, if there were strong seasonal patterns of variation in reporting probabilities this simple approach might have given misleading results. Therefore an alternative method was devised which scaled up the reporting probabilities of migrant species by assuming that their seasonal pattern of recoveries was the same as that of ecologically similar resident species (Method 2). Thus,

$$R=\frac{\sum_{i=m}^{i=n} r_i}{N}\frac{s}{\sum_{j=1}^{j=s}\sum_{i=m}^{i=n} p_{ij}} \tag{2}$$

where,

R = corrected reporting probability

N = number of birds ringed of the species of interest

r_i = number of recoveries of the species of interest in month i

p_{ij} = proportion of recoveries of resident species j which occurred in month i

m = first month of recovery period for the species of interest

n = last month of recovery period for the species of interest

s = number of comparable resident species included in the analysis

Analysis of monthly variation in the numbers of recoveries of resident species was restricted to 34 species for which less than 5% of recoveries were from abroad and for which there were more than 120 recoveries. Five groups of species were identified from this analysis, within each of which the monthly patterns of variation in the number of recoveries were similar. These groups were waterbirds (n=3, Kendall's coefficient of concordance = 0.72, $P<0.05$), gulls (n=2, $R_s=0.87$, $P<0.001$), medium sized terrestrial species (n=10, Kendall's coefficient of concordance = 0.74, $P<0.001$), small insectivorous passerines (n=7, Kendall's coefficient of concordance = 0.77, $P<0.001$) and finches and buntings (n=6, Kendall's coefficient of concordance = 0.81, $P<0.001$).

The reporting probabilities of migratory species calculated using methods one and two were highly correlated (Fig. 2, $r^2=0.97$) and the simpler method 1 was therefore used in all subsequent analyses.

VARIABLES LIKELY TO INFLUENCE REPORTING PROBABILITIES

Nine variables which might influence the probability of a dead ringed bird being found and reported were considered. These were body weight, ring size, conspicuousness, primary plumage colour, secondary plumage colour, plumage pattern, habitat, association with humans and abundance. The data on numbers ringed did not allow separate reporting probabilities to be calculated for males and females so it was necessary to determine one value of each of these variables for each species, even if the sexes differed markedly in size or plumage. For continuous variables the mean of the values for males and females was taken, while for plumage colours and patterns the values for males were used.

Body weight (g) was taken as the mid-point of the range given by Perrins (1987). Ring size was calculated as the cross-sectional area of the current BTO ring size for the species in question. Cross-sectional area was calculated as:

$$A = (D + 2G) * H \qquad (3)$$

where,

A = cross-sectional area of ring (mm^2)

D = internal diameter of ring (mm)

G = gauge of metal (mm)

H = height of ring (mm).

Both body weights and ring areas were $\log_{10}$ transformed. Ring area was so highly correlated with body weight ($r^2=0.94$, $p<0.001$) that it was not possible to separate the effect of the two variables. It seemed more likely that any causal relationship would be with body weight and therefore only this variable was included in subsequent analyses.

A measure of general conspicuousness was obtained by asking 15 experienced ornithologists to score each species on a scale from 1-10, 1 being the least conspicuous. Respondents were asked to visualise a dead specimen of the species in question lying on grass 100m away. This approach is similar to that used in previous studies (Baker & Hounsome 1983, Baker & Bibby 1987, Hart 1990a) except that, due to the large number of species involved, respondents were asked to assign scores rather than placing all the species in rank order. The respondents showed good agreement in their ranking of species and the mean score was taken as an index of conspicuousness. This measure of conspicuousness was highly correlated with body weight (Fig. 3, $r^2=0.92$, $P<0.001$) and it was therefore not included in the subsequent analyses.

The primary and secondary plumage colours were recorded for each species. Assessment of this and of pattern (below) was based on an adult bird in breeding plumage while at rest. The colour categories used were black, white, grey, brown, blue, green, yellow, and red. Thus, for example, Robin is classified as having brown as its primary plumage colour and red as its secondary plumage colour. Plumage pattern was recorded using the following six categories: all dark, all pale, pied (approximately 50% black, 50% white), patches (small conspicuous contrasting areas such as wing bars and rump patches), colour (large areas of red, blue or yellow), cryptic (all other plumages).

Habitat was taken as that most frequently used by the species in Britain and Ireland (Table 2). Association with humans was assessed by the same 15 respondents who provided the data on conspicuousness. A scale from 1-5 was used, where 5 indicated those species most closely associated with man. The mean scores of the 15 respondents were used.

Abundance was taken as the number of breeding adults (breeding pairs times two) or as the estimated size of the winter population for winter visitors (Lack 1986, Lloyd *et al.* 1991, Marchant *et al.* 1990, Stroud & Glue 1990). As abundance varied by almost four orders of magnitude across the range of study species the approximate nature of many of these population estimates is unimportant. Abundance was $\log_{10}$ transformed in all the analyses presented below.

MODELLING INTERSPECIFIC VARIATION IN REPORTING PROBABILITIES

All reporting probabilities were $\log_{10}$ transformed prior to analysis. A range of other transformations were tested, including the arcsine transformation, but all were less successful at normalising the data. (Shapiro-Wilk statistics (W), which would be 1.0 for a perfect normal distribution: untransformed data, W=0.740; arcsine transformed data, W=0.893, $\log_{10}$ transformed data, W=0.936, all $P<0.001$.) The $\log_{10}$ transformation was successful in correcting the highly skewed distribution of the untransformed data but the transformed distribution remained significantly different from normal due to its bimodal shape (Fig.4). However, regression only requires that the residuals should be normally distributed. For the model for all 99 species (Table 4a) the residuals did not differ significantly from a normal distribution (W=0.977, P=0.376).

Three continuous variables ($\log_{10}$ body weight, association with humans and $\log_{10}$ abundance) and four categorical variables (primary colour, secondary colour, pattern and habitat) were available to explain the pattern of variation in reporting probabilities between species. A few analyses of subsets of the data required some values of the categorical variables to be combined to avoid having categories with very small numbers of species. Migration status was included in some analyses to check that correction of the data for migrant species had not left any residual effect of this variable.

Models using the seven main independent variables were fitted using the general linear modelling procedure of SAS (PROC GLM, SAS 1989). Body weight was always included as a quadratic function because univariate analyses showed a strong curvilinear relationship with reporting probability. A simple backward elimination procedure was employed in which one variable at a time was dropped from the model until all the remaining variables were significant at $P<0.05$. As a further check that a satisfactory model had been selected we attempted to add each of the variables which had been dropped back into the model, but we found no cases in which such variables had a significant effect.

Interactions between variables were not considered because they would have resulted in a large number of complex models which could not have been evaluated satisfactorily given the number of species available for analysis. The results presented below show that in most cases the pattern of variation in reporting probabilities could be explained well without incorporating interaction terms. Overall coefficients of determination (r^2) for each model have been adjusted to allow for the number of variables included in the model (SAS 1989).

Results

DIFFERENCES IN REPORTING PROBABILITIES BETWEEN SPECIES

Reporting probabilities for found dead recoveries varied by about 2.5 orders of magnitude from 0.06% for Chiffchaff to 16.75% for Mute Swan (Appendix 1). The logarithms of the found dead reporting probabilities showed a bimodal distribution with the first peak comprised exclusively of passerines while the second peak was made up largely of non-passerines (Fig. 4). This distribution appears to be related largely to body size rather than to taxonomy. Thus the four passerines with the lowest reporting probabilities were Chiffchaff (0.06%), Sedge Warbler (0.09%), Willow Warbler (0.10%) and Goldcrest (0.10%) while the four with the highest reporting probabilities were Magpie (3.1%), Jay (3.3%), Crow (3.3%) and Raven (5.8%). Within the non-passerines the four lowest reporting probabilities were those of Snipe (0.9%), Stock Dove (1.0%), Woodpigeon (1.1%) and Lapwing (1.1%) while the four highest were those of Kestrel (7.1%), Barn Owl (8.2%), Grey Heron (10.4%) and Mute Swan (16.7%). The high reporting probabilities of Kestrel and Barn Owl relative to their body sizes are probably explained by their close association with human activities, and perhaps also by their high conservation profile.

FACTORS AFFECTING REPORTING PROBABILITIES

The pattern of interspecific variation in found dead reporting probabilities was analysed in relation to seven independent variables; body weight, association with humans, abundance, primary plumage colour, secondary plumage colour, plumage pattern and habitat. Univariate analyses in relation to these variables showed that body weight alone explained 82% of the variation in reporting probabilities across the whole data set. Quadratic regressions of $\log_{10}$ reporting probability against body weight explained 86% of the variance for residents, 79% of the variance for summer visitors and 36% of the variance for winter visitors (Fig.5). There was no significant difference between these three curves (x coefficient $F_{[2,90]}=1.14$, x^2 coefficient $F_{[2,90]}=0.61$, intercept $F_{[2,90]}=2.14$, all $P>0.1$). The weaker relationship for winter visitors may partly reflect the lower range of body weights and partly lower precision of the estimates of reporting probabilities for some species. For species such as Brambling, Redwing and Fieldfare the majority of the wintering population is only present in Britain and Ireland for a few months each winter, and the data are further complicated by some individuals wintering in different countries in different years.

Multivariate analysis of the full data set revealed that 90% of the variance in reporting probabilities could be explained by a combination of body weight, association with humans, abundance and habitat (Table 4). Larger size and greater association with humans increased the probability that a dead ringed bird would be reported while more abundant species were less likely to be reported than less abundant ones. The significant effect of habitat was brought about by a higher than expected mean for coniferous woodland and a lower than expected mean for human habitation. Two of the four species associated with coniferous woodland (Coal Tit and Siskin) are largely ringed in gardens and are likely to have inflated reporting probabilities for this reason. Amongst the six species associated with human habitation, Swallow, House Martin and Collared Dove all had lower than expected reporting probabilities. Although the first two species nest on buildings they spend much of their foraging time elsewhere. All three species have short tarsi which will make rings more difficult to detect. Thus the significant effect of habitat appears to be explained largely by the biology of the individual species involved.

Very similar models, but without a significant effect of habitat, were obtained for species with less than 5% of recoveries from abroad and for those with more than this (Table 4). Thus the inclusion of recoveries from outside Britain and Ireland did not have any important effect on the results. Each of these models was rerun with migration status as an additional variable but in no case did it have a significant effect (all species $F_{[2,84]}=0.83$, n.s.; less than 5% abroad $F_{[2,49]}=0.98$, n.s.; greater than 5% abroad $F_{[2,36]}=2.43$, n.s.).

Body weight, association with humans and abundance were also selected when the data for residents and summer visitors were analysed separately (Table 5). These models accounted for 91% of the variance for both residents and summer visitors, the parameter estimates from the two models being similar. Body weight was the only variable which had a significant effect on the reporting probabilities of the small sample of 15 winter visitors, accounting for 36% of the variance.

The data were also divided into two size classes to check whether effects of any other variables might be detected within broad size classes. Analyses were carried out for the 49 species with weights between 10 and 99g and for the 37 species with weights between 100 and 999g (Table 6). The 10-99g sample showed similar results to the analyses presented above with 80% of the variance in reporting probabilities accounted for by body weight, association with humans and abundance. However, body weight had no significant effect within the 100-999g size class and only 30% of the variance in reporting probabilities could be accounted for by a combination of association with humans and abundance. None of the other independent variables had significant effects. Results from a model including body weight, association with humans and abundance are also presented for the 100-999g size category (Table 6). This model explained 35% of the variation in reporting probabilities, the effect of body weight being only marginally non-significant ($P=0.054$). Inclusion of a quadratic rather than a linear relationship between reporting probability and body weight in this model did not explain any more of the variance. The body weight term became less significant due to the loss of an additional degree of freedom. The lack of a strong relationship between reporting probability and body weight within the 100-999g weight class is almost certainly accounted for by the quadratic relationship between reporting probability and body weight. The curve is less steep within the 100-999g weight class than with the 10-99g weight class (Fig. 5).

Discussion

The reporting probability is the product of the probability that a dead bird is found, the probability that the ring is located and the probability that the finder of a ring reports it to the ringing office. These component probabilities could only be separated by field experiments, which would be difficult and costly to carry out on an adequate scale. However, there are a few studies that give clues as to their likely magnitudes.

A striking feature of ring recovery data is that for most species only a very small proportion of ringed birds are recovered dead. It seems that the main reason for this is that most dead birds are never found. Even in well studied areas, where ornithologists search all the corpses they find for rings, reporting probabilities remain low. Trials in which experienced searchers have attempted to locate corpses previously distributed within a defined study area have also found remarkably low finding probabilities, partly due to the removal of corpses by scavengers (Mineau & Collins 1988).

Little information is available on the probability that the ring will be located when a dead ringed bird is found. Many birdwatchers will be interested in finding rings and will turn over corpses in search of them but most members of the public are unlikely to do so. A comparison of the reporting probabilities of Herring and Lesser Black-backed gulls with and without colour-rings in addition to a metal ring showed that birds with colour rings were almost twice as likely to be recovered (Shedden *et al.* 1985). This suggests that the metal rings were not noticed on at least half of the dead gulls that were found, although an alternative interpretation is that the colour rings made the corpses themselves more conspicuous. Rings are very likely to be noticed when the cause of recovery normally results in the bird being handled, such as birds which are shot or brought in by cats. However, such records were excluded from the main analyses presented above.

A proportion of those rings that are located may not be reported. This study is concerned mainly with recoveries within Britain, where there should be no difficulty in finders reading the ring inscription. All BTO rings carry the inscription "INFORM BRIT. MUSEUM SW7" or similar in addition to a unique serial number. A ring address experiment was carried out in the early 1970s which involved Starlings being fitted with rings that carried either the British Museum address or "BTO TRING ENGLAND" (Sales 1973). This was designed to test the advisability of changing the address to that of the BTO's headquarters. The results showed that use of the BTO address resulted in a 45% reduction in the number of recoveries reported from Britain although, perhaps surprisingly, there was no reduction in the number of recoveries reported from Europe. This difference in reporting probabilities arising from the use of different ring inscriptions suggests that a substantial proportion of those rings that are located by finders of ringed birds may not be reported.

Despite the above evidence that some rings are not located when corpses are found, and that some of those rings that are found are not reported, the main factor responsible for low reporting probabilities appears to be that most dead birds are not found by people. This interpretation is supported by the high correlations between body size and reporting probability. Body size would be expected to have a strong influence of the probability of a corpse being found, and is highly correlated with our independent measure of conspicuousness. These results confirm those of an earlier study based on a much smaller number of species (Hart 1990a). There is little reason to suppose that the probability of a ring being located would depend on body size. It is also unlikely that the probability of a ring that has been found being reported is related to body size, except that a few people might find the smallest ring sizes more difficult to read.

Interspecific variation in reporting probability was also related to association with humans and negatively related to abundance. Birds dying close to human habitation are more likely to be encountered by people. Thus most of the variation in ring reporting probability appears to be caused by variation in the probability that dead birds will be found. The negative relationship with abundance is unlikely to be related to finding probability. Corpses of uncommon species may be more likely to be examined than those of common ones, increasing the probability that rings will be located. It is also possible that finders think that reports of rare birds will be of more interest to the ringing scheme, or that they are themselves more interested to learn of the origins of such birds.

A multiple regression model was able to explain 90% of the variation in reporting probabilities in terms of body weight, association with humans, abundance and habitat. This model was generally robust to various subdivisions of the data, except into weight classes due to non-linearity. The relationship between reporting probability and body weight followed a quadratic function on the log-log scale, with the slope decreasing for larger birds. It seems likely that this is due to differences in size having more influence on finding probabilities amongst small birds than amongst large ones.

The marginally significant effect of habitat in the all species model was apparently due to special factors which influenced the mean reporting probabilities of two habitat classes. None of the other analyses detected any effect of habitat. It might be anticipated that birds dying in open habitats would be more likely to be found than those dying in densely vegetated ones. However, any such effect may be counteracted by the relatively remote location of more open habitats such as moorland. Furthermore, even in quite open habitats there are usually many places where small or medium sized birds could hide, and birds which are about to die may often feel ill and seek cover. Unless birds poisoned by pesticides die very quickly then they are likely to do this (Mineau & Peakall 1987, Hart 1990b). Birds occupying urban and suburban habitats and areas around farmsteads would be expected to have increased finding probabilities but this effect will be accounted for by the association with humans variable. Intraspecific variation in the reporting probabilities of Tawny Owls and Song Thrushes is positively related to human population density (Peach, McCulloch, Baillie & Austin unpublished m/s), providing further evidence that birds dying close to human habitation are more likely to be found.

No effects of colour or pattern on reporting probabilities were detected by the multiple regression analyses. Furthermore, inspection of the residuals from these regressions did not suggest that failure to detect significant effects of these categorised variables was due to small sample sizes or too many classes. This failure to detect significant effects is presumably because any effect of these variables is swamped by the effects of body size, which itself accounted for 92% of the variance in the independent conspicuousness scores. Two other factors may help to explain the lack of strong effects related to these variables. First, many particularly conspicuous plumage features such as white rumps or wing bars show up best in flight and will be much less obvious when a bird is lying dead on the ground. Second, the conspicuousness of many patterns and colours will depend on the background. For example, a dead pied bird might be very conspicuous on a lawn but much less so against dense vegetation.

This study has established a clear pattern of variation in the reporting probabilities of ringed birds. It is important to consider the extent to which this pattern can be applied to other monitoring schemes for avian mortality. We are concerned here with detecting mortality caused by pesticides, environmental pollution and of natural mortality agents such as severe weather. Thus the corpses of such birds may be found anywhere in the countryside and are unlikely to show any obvious signs of the cause of death. It is also of interest to consider whether the results are applicable to field trials where deliberate searches for corpses are made in order to evaluate the safety of new pesticides. In field trials all corpses found will be recorded so reporting probability is only dependent on the probability of the corpse being found. Absolute reporting probabilities of ringed birds will underestimate this rate due to failures to find and report rings.

The probability of dead birds being reported to passive monitoring schemes will be the product of the finding probability and the probability that a dead bird will be reported. The latter probability is likely to be substantially lower than the probability that the ring of a dead ringed bird will be reported. The ring constitutes a specific request for a report to be made and gives an address where it should be sent.

To report a dead bird to a passive monitoring scheme the finder must be aware of the scheme and must consider the incident to be of sufficient interest to merit reporting. Thus single corpses of common species are unlikely to be reported but it is more likely that a group of such corpses would be. The extent to which birds dying from causes of particular interest, such as pesticide poisoning or severe weather, are more likely to be found in groups is currently unknown. Rare species and species such as raptors and owls, which are known to be at risk from poisoning and have in the past been affected extensively by pesticides, are more likely to be reported than other species. For example, the WIIS and a similar monitoring scheme in Scotland reported that of 256 incidents involving birds investigated in 1990, 53% involved raptors and owls and only 11% involved small passerines (Fletcher *et al.* 1991). This could partly reflect a real difference in the frequency with which these groups are affected by pesticides, but it is likely to be at least partly due to differences in reporting probabilities. Even for species such as raptors and owls reporting probabilities for passive monitoring schemes are likely to be much lower than those of ringed birds.

The reporting probabilities of ringed birds reported in this paper are underestimates of the true reporting probabilities of ringed birds dying from apparently natural causes. This is because recoveries of birds killed as a direct result of human activities have been excluded but it has not been possible to adjust the number of ringed birds at risk to take account of this. Birds dying from such causes may often have very high reporting probabilities which result in such reported causes of death being greatly over-represented in the recovery sample. Thus the reporting probabilities estimated using all recoveries are often a considerable overestimate of the reporting probabilities for birds dying of apparently natural causes. Nevertheless such reporting probabilities are rarely more than a few percent. Reporting probabilities estimated from all dead recoveries and from found dead recoveries only are well correlated, so the above problem is unlikely to affect the patterns of variation shown by this study.

Despite problems of low reporting probabilities schemes for passive monitoring of wildlife mortality have had some success in identifying unanticipated mortality of larger species caused by pesticides. For example, the WIIS has identified mortality of Greylag (*Anser*

anser) and Pink-footed (*Anser brachyrhynchus*) Geese caused by carbophenothion seed treatments and mortality of black-headed gulls caused by aldicarb, a granular nematicide used on potatoes and sugar beet (Hardy *et al.* 1987). In both cases it was possible to find solutions which prevented further mortality. Nevertheless it is recognised that such schemes cannot determine the scale of avian mortality caused by pesticides, although it has been suggested that they may provide a representative sample of those incidents which do occur (Greig-Smith 1988).

The present study has demonstrated that there are very large differences between the reporting probabilities of different species, with large birds having much higher reporting probabilities than small ones. This conclusion, based on an analysis of data on ringed birds, almost certainly applies to all situations in which involve active or passive recording of mortality. Thus while passive monitoring of wildlife mortality is likely to detect major problems involving large birds such as swans and geese, and perhaps some problems involving flocks of smaller species, it could very easily miss widely dispersed but nevertheless substantial mortality of small birds. It is extremely unlikely that passive monitoring schemes provide a sample of mortality incidents that is representative with respect to species composition. Where mortality of small birds is of interest attempts to record mortality directly need to be supported by other data such as population censuses. Species specific reporting probabilities need to be taken into account when considering the number of incidents needed to trigger detailed investigation of a particular problem. It has been suggested that the safety of a pesticide should be reviewed if it causes more than about 10 incidents per year (Cooke 1990). Whatever levels are set for such thresholds, it would be appropriate to set them lower for smaller species than for larger ones.

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Table 1 **Numbers of species for which reporting probabilities were estimated, by taxonomic group and migration status. For explanation of the partial summer visitor and partial winter visitor categories see text.**

	Residents	Summer Visitors	Partial Summer Visitors	Winter Visitors	Partial Winter Visitors	Total
Waterfowl	3	0	0	2	2	7
Raptors	6	0	0	0	0	6
Waders	0	0	1	0	4	5
Gulls	3	1	0	0	1	5
Owls	5	0	0	0	0	5
Woodpeckers	2	0	0	0	0	2
Other non-passerines	7	3	0	0	0	10
Swallows and martins	0	3	0	0	0	3
Wagtails and pipits	3	1	1	0	0	5
Thrushes and chats	4	2	1	2	0	9
Warblers and crests	1	8	0	0	0	9
Flycatchers	0	2	0	0	0	2
Tits	6	0	0	0	0	6
Corvids	6	0	0	0	0	6
Finches and buntings	4	0	2	1	2	9
Other passerines	9	0	0	0	1	10
Total	59	20	5	5	10	99

Table 2 **Numbers of species for which reporting probabilities were estimated by habitat and migration status. For explanation of partial summer visitor and partial winter visitor categories see text.**

	Residents	Summer Visitors	Partial Summer Visitors	Winter Visitors	Partial Winter Visitors	Total
Coastal	3	1	0	0	3	7
Freshwater	7	1	0	2	2	12
Marsh or reedbed	3	2	0	0	1	6
Agricultural land	14	1	2	2	1	20
Scrub or hedgerow	3	3	1	0	0	7
Deciduous woods	19	8	1	1	1	30
Coniferous woods	3	0	0	0	1	4
Upland heath or montane	5	1	1	0	0	7
Human habitation	2	3	0	0	1	6
Total	59	20	5	5	10	99

Table 3 **Numbers of species for which reporting probabilities were estimated by percentage of recoveries from abroad and migration status. Abroad refers to recoveries outside Britain and Ireland. The percentage of recoveries from abroad refers only to the sample of found dead recoveries that was used for the reporting probability calculations. For explanation of partial summer visitor and partial winter visitor categories see text.**

Percentage of recoveries from abroad	Residents	Summer Visitors	Partial Summer Visitors	Winter Visitors	Partial Winter Visitors	Total
<5%	49	3	3	0	1	56
5%-10%	7	8	1	0	6	22
10%-15%	2	4	1	1	2	10
>15%	1	5	0	4	1	11
Total	59	20	5	5	10	99

Table 4 **Multivariate models of $\log_{10}$ (reporting probability) for (a) all species, (b) species with less than 5% of recoveries from abroad and (c) species with greater than 5% of recoveries from abroad. Models were selected by backward selection starting with the seven independent variables described under methods. Body weight was always included as a quadratic function. Only variables with P<0.05 were included in the final model. *** P<0.001 ** P<0.01, * P<0.05.**

	Regression coefficient	Standard Error	Partial r^2	Sig.
(a) All species (n = 99, model r^2 = 0.903 *)**				
$\log_{10}$ body weight	1.718	0.149	0.804	***
$(\log_{10}$ body weight$)^2$	-0.260	0.036		
Association with humans	0.222	0.034	0.327	***
$\log_{10}$ abundance	-0.201	0.033	0.301	***
Habitat:			0.198	*
Coastal	-4.203	0.189		
Freshwater	-4.335	0.176		
Marsh or reedbed	-4.279	0.168		
Agricultural land	-4.270	0.185		
Scrub or hedgerow	-4.200	0.182		
Deciduous woods	-4.180	0.172		
Coniferous woods	-3.946	0.174		
Upland heath or montane	-4.175	0.177		
Human habitation	-4.436	0.220		
(b) Species with <5% recoveries from abroad (n = 56, model r^2 = 0.901 *)**				
$\log_{10}$ body weight	1.576	0.171	0.858	***
$(\log_{10}$ body weight$)^2$	-0.227	0.039		
Association with humans	0.179	0.033	0.362	***
$\log_{10}$ abundance	-0.179	0.039	0.292	***
Intercept	-4.025	0.192	-	-
(c) Species with >5% recoveries from abroad (n = 43, model r^2 = 0.875 *)**				
$\log_{10}$ body weight	2.075	0.350	0.816	***
$(\log_{10}$ body weight$)^2$	-0.372	0.090		
Association with humans	0.187	0.043	0.332	***
$\log_{10}$ abundance	-0.218	0.054	0.299	***
Intercept	-4.365	0.319	-	-

Table 5 **Multivariate models of $\log_{10}$ (reporting probability) for (a) residents, (b) summer visitors and partial summer visitors, and (c) winter visitors and partial winter visitors. Models were selected by backward selection starting with the seven independent variables described under methods. Body weight was always included as a quadratic function. For winter visitors selection started with $\log_{10}$ body weight, association with humans and $\log_{10}$ abundance only due to the limited sample size. Only variables with $P<0.05$ were included in the final model. *** $P<0.001$ ** $P<0.01$, * $P<0.05$.**

	Regression coefficient	Standard error	Partial r^2	Sig.
(a) Residents (n = 59, model r^2 = 0.906 *)**				
Log_{10} body weight	1.545	0.159)	0.854	***
(Log_{10} body weight)^2	-0.224	0.037)		
Association with humans	0.191	0.036	0.338	***
Log_{10} abundance	-0.188	0.037	0.321	***
Intercept	-3.981	0.183	-	-
(b) Summer visitors and partial summer visitors (n = 25, model r^2 = 0.909 *)**				
Log_{10} body weight	1.640	0.468)	0.890	***
(Log_{10} body weight)^2	-0.216	0.126)		
Association with humans	0.170	0.032	0.586	***
Log_{10} abundance	-0.193	0.066	0.300	**
Intercept	-4.162	0.437	_	_
(c) Winter visitors and partial winter visitors (n = 15, model r^2 = 0.360 *)				
Log_{10} body weight	0.837	0.774)	0.451	*
(Log_{10} body weight)^2	-0.128	0.182)		
Intercept	-3.060	0.772		

Table 6 **Multivariate models of $\log_{10}$ (reporting probability) for (a) species weighing 10-99g and (b) species weighing 100-999g. Models were selected by backward selection starting with the seven independent variables described under methods. Body weight was included as a quadratic function except for the second model for species weighing 100-999g (see text). Only variables with $P<0.05$ were included in the final model. For species weighing 100-999g a model including body weight is also given. *** $P<0.001$ * $P<0.05$.**

	Regression coefficient	Standard error	Partial r^2	Sig.
(a) Species weighing 10-99g (n = 49, model r^2 = 0.800 *)**				
Log_{10} body weight	0.236	0.939)		
		)	0.687	***
(Log_{10} body weight)^2	0.242	0.320)		
Association with humans	0.209	0.026	0.585	***
Log_{10} abundance	-0.165	0.038	0.298	***
Intercept	-3.243	0.671	-	-
(b) Species weighing 100-999g (n = 37)				
Model from backward elimination (model r^2 = 0.298 ***)				
Association with humans	0.132	0.053	0.156	*
Log_{10} abundance	-0.206	0.050	0.336	***
Intercept	-1.396	0.106	-	-
Model including $\log_{10}$ body weight, association with humans and $\log_{10}$ abundance (model r^2 = 0.354 ***)				
Log_{10} body weight	0.243	0.122	0.108	P=0.054
Association with humans	0.133	0.050	0.174	*
Log_{10} abundance	-0.201	0.048	0.351	***
Intercept	-2.013	0.325	-	-

Figure Legends

Figure 1 $\quad$ Log_{10} reporting probability from complete data as used in this study against:

(a) Log_{10} reporting probability estimated from survival modelling of incomplete data for 21 species, using recoveries of birds ringed between 1950 and 1989. $\log_{10} y = 0.896 \log_{10} x - 0.234$, $r^2 = 0.948$.

(b) Log_{10} reporting probability estimated from detailed survival modelling of incomplete data for 16 species, using recoveries of birds ringed between 1985 and 1990. $\log_{10} y = 0.967 \log_{10} x - 0.152$, $r^2 = 0.938$, $P<0.001$.

For further details of how reporting probabilities were estimated from incomplete data see text and Baillie & McCulloch (1993).

Figure 2 $\quad$ Relationship between the reporting probabilities of migratory species estimated from two alternative methods of correcting the data for the period when the majority of these populations are absent from Britain and Ireland. $n = 40$, $\log_{10} y = 1.072 \log_{10} x + 0.140$, $r^2 = 0.970$. For details of methods see text.

Figure 3 $\quad$ Mean conspicuousness score (from 15 experienced ornithologists) against $\log_{10}$ body weight for all 99 species included in the study. $y = 2.933 \log_{10} x - 1.476$, $r^2 = 0.916$, $P<0.001$.

Figure 4 $\quad$ Frequency distribution of $\log_{10}$ reporting probability for the 40 non-passerines and 59 passerines included in this study.

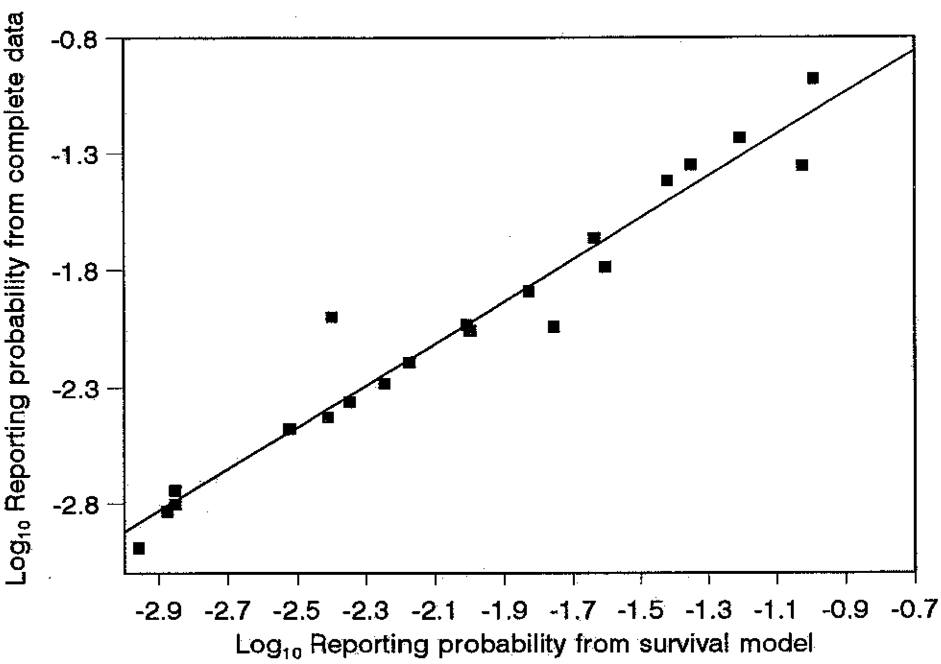
Figure 5 $\quad$ Log_{10} reporting probability against $\log_{10}$ body weight for:

(a) Residents $n = 59$
$\log_{10} y = 1.501 \log_{10} x - 0.192 (\log_{10}x)^2 - 4.006$, $r^2 = 0.857$, $P<0.001$.

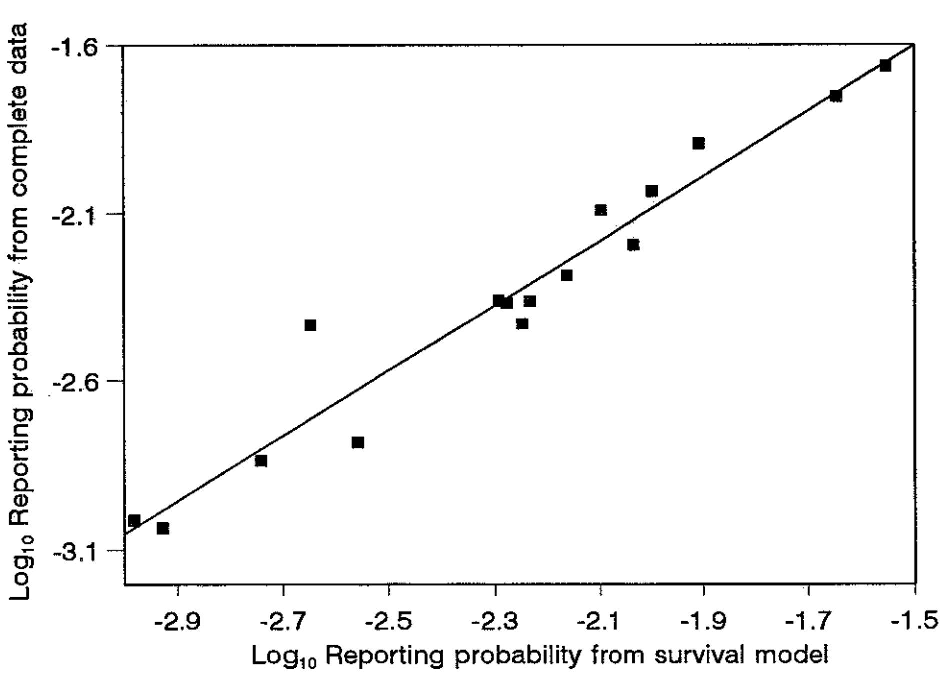
(b) Summer visitors and partial summer visitors $n = 25$
$\log_{10} y = 2.315 \log_{10} x - 0.381 (\log_{10}x)^2 - 4.900$, $r^2 = 0.792$, $P<0.001$.

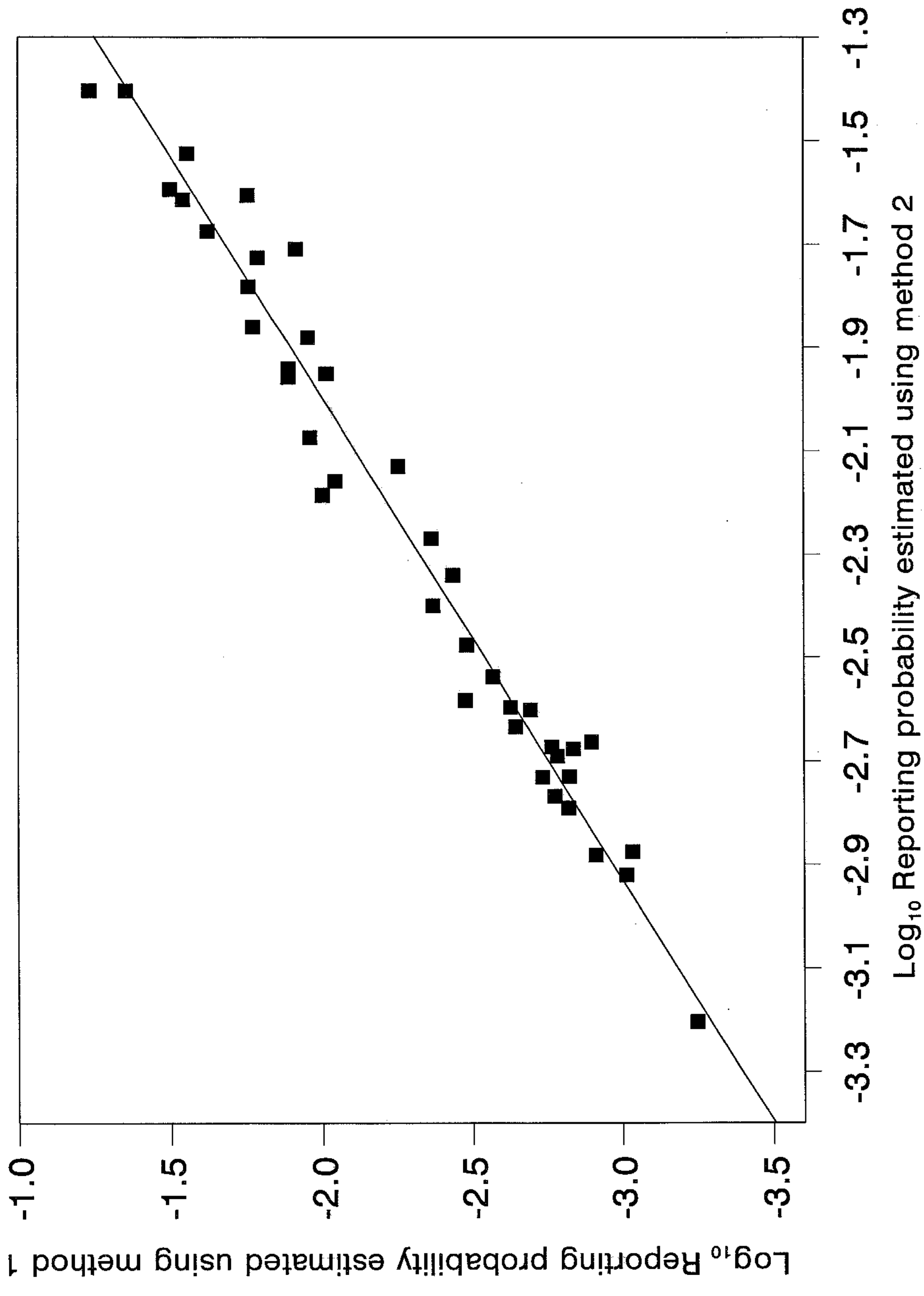
(c) Winter visitors and partial winter visitors $n = 15$
$\log_{10} y = 0.837 \log_{10} x - 0.128 (\log_{10}x)^2 - 3.060$, $r^2 = 0.360$, $P<0.05$.

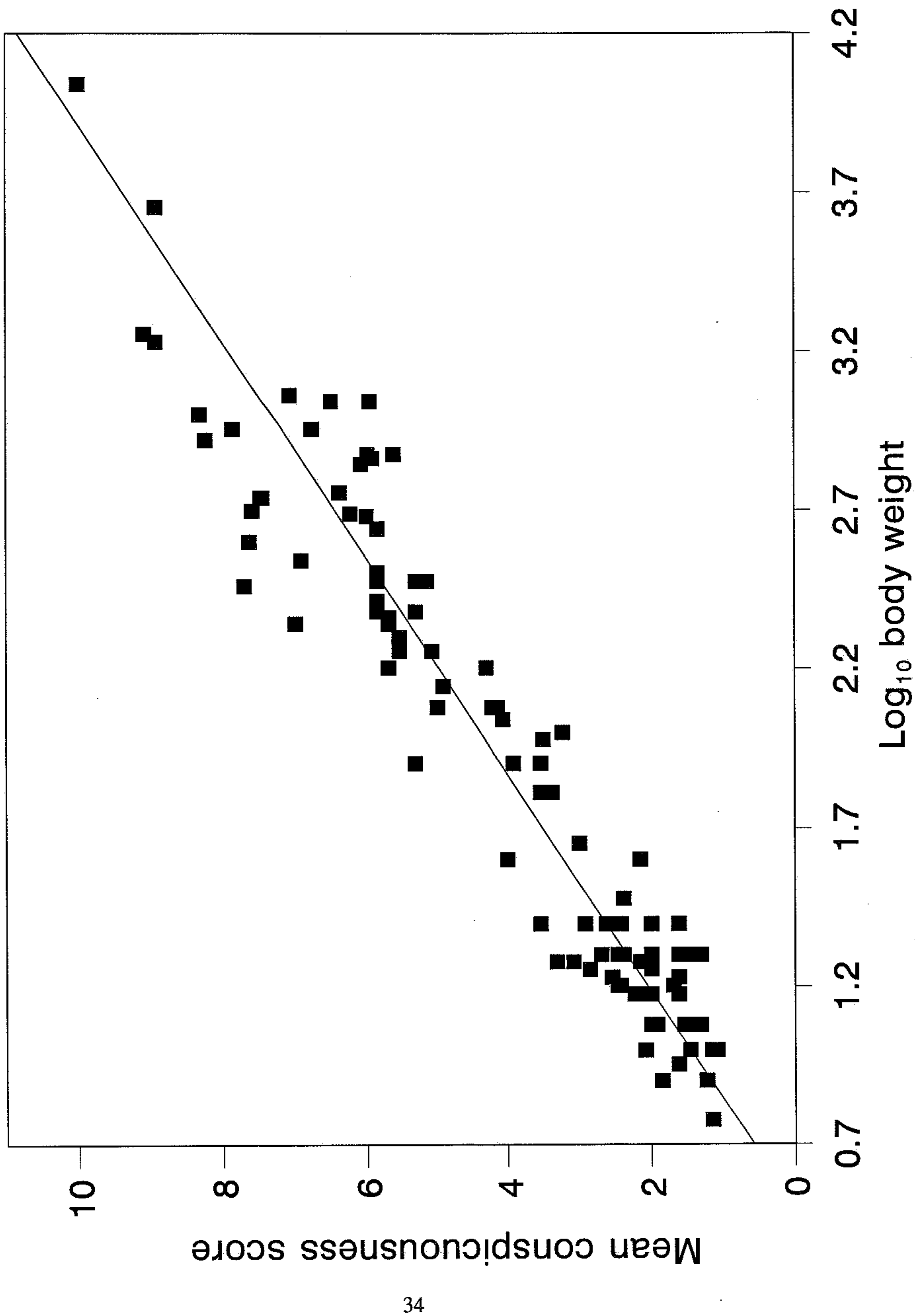
(a) Modelling of data for birds ringed between 1950 and 1989



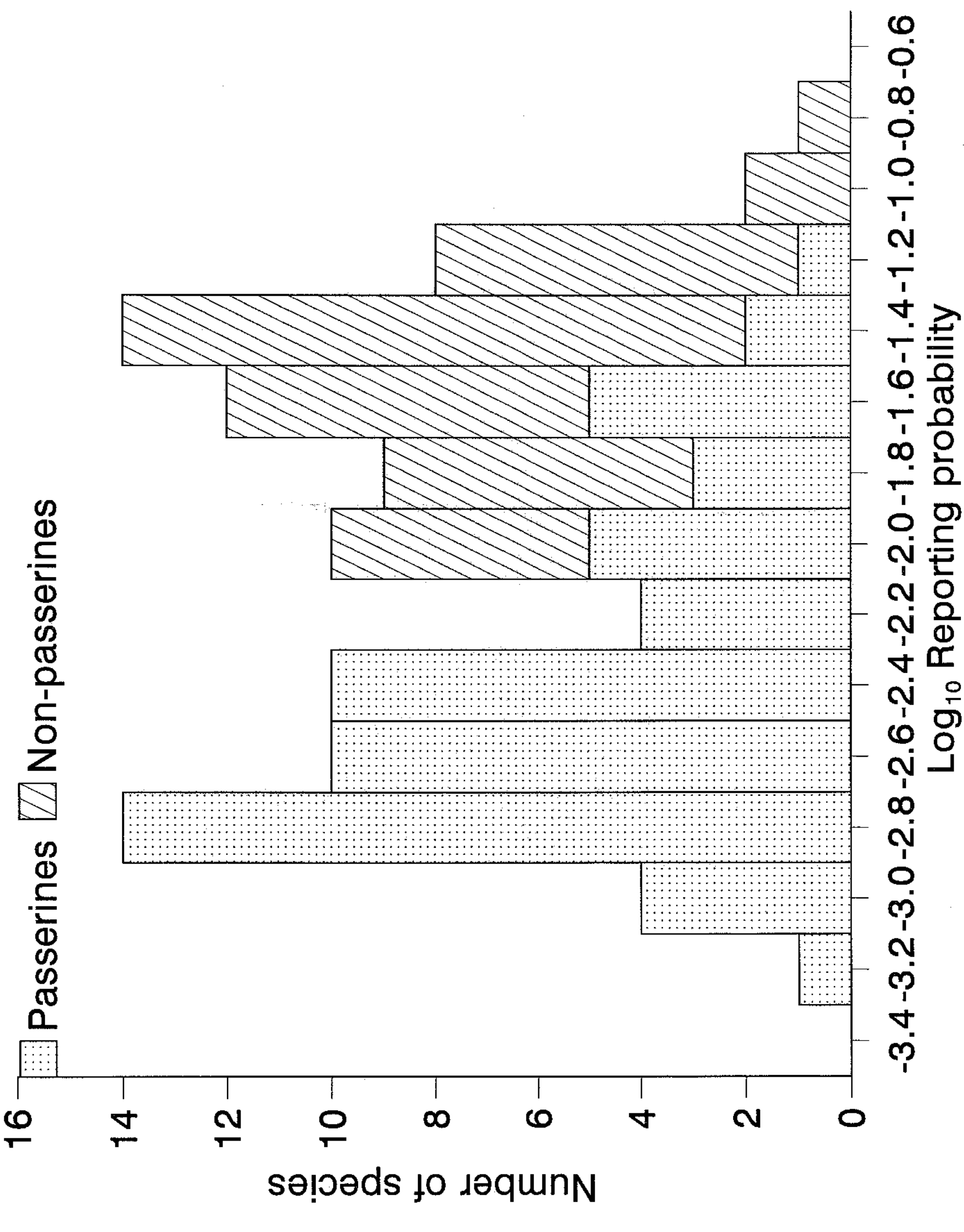
(b) Detailed modelling of data for passerines ringed between 1985 and 1990



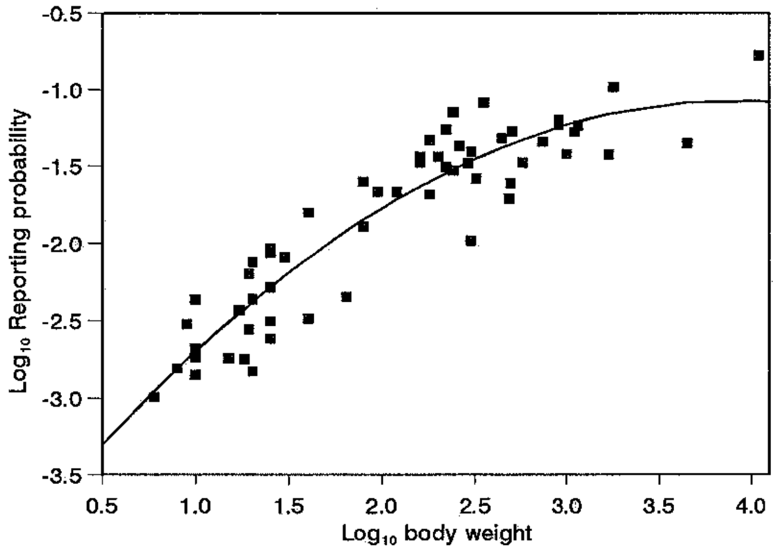

Log10 Reporting probability estimated using method 2
-3.3
-3.1
-2.9
-2.7
-2.5
-2.3
-2.1
-1.9
-1.7
-1.5
-1.3
Log10 Reporting probability estimated using method 1
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5



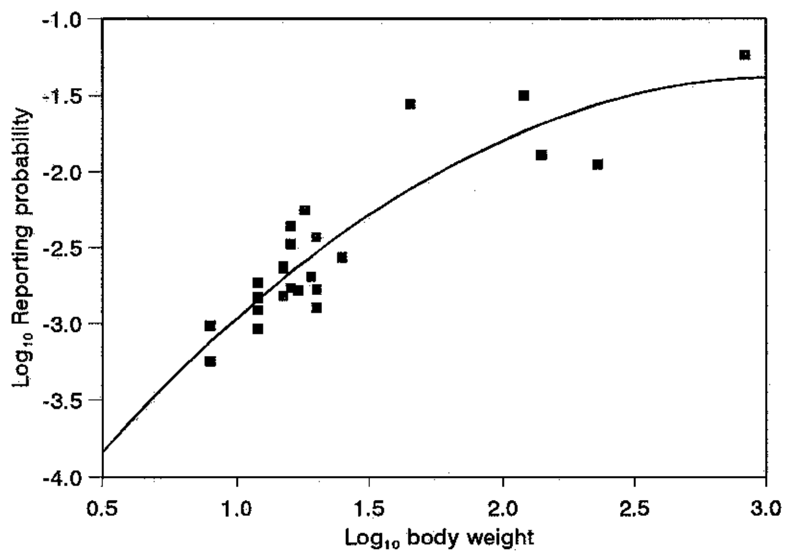
Mean conspicuousness score
0
2
4
6
8
10
Log$_{10}$ body weight
0.7
1.2
1.7
2.2
2.7
3.2
3.7
4.2


Passerines
Non-passerines
Number of species
0
2
4
6
8
10
12
14
16
-3.4 -3.2 -3.0 -2.8 -2.6 -2.4 -2.2 -2.0 -1.8 -1.6 -1.4 -1.2 -1.0 -0.8 -0.6
Log10 Reporting probability

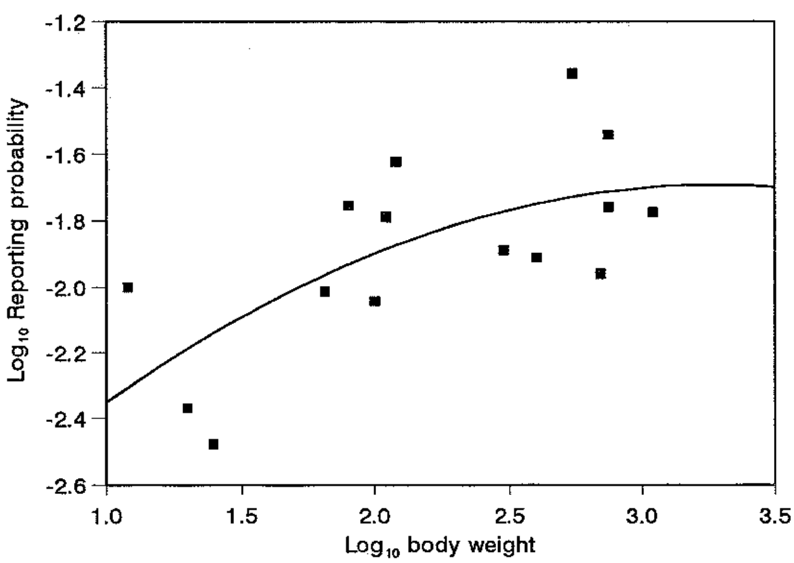
(a) Residents



(b) Summer Visitors



(c) Winter Visitors



APPENDIX 1 FOUND DEAD REPORTING PROBABILITIES (%) OF THE SPECIES INCLUDED IN THIS STUDY

Reporting probabilities were estimated from cohorts for which no further recovery reports were expected (complete data). These probabilities have been corrected for recoveries outside Britain and Ireland using method 1 as described in the text.

English name	Latin name	Reporting probability (%)
Grey Heron	*Ardea cinerea*	10.41
Mute Swan	*Cygnus olor*	16.75
Canada Goose	*Branta canadensis*	4.45
Wigeon	*Anas penelope*	1.10
Teal	*Anas crecca*	1.30
Mallard	*Anas platyrhynchos*	1.68
Tufted Duck	*Anas fuligula*	2.87
Goosander	*Mergus merganser*	5.31
Hen Harrier	*Circus cyaneus*	5.33
Sparrowhawk	*Accipiter nisus*	5.50
Buzzard	*Buteo buteo*	5.87
Kestrel	*Falco subbuteo*	7.08
Merlin	*Falco columbarius*	4.67
Peregrine	*Falco peregrinus*	6.36
Moorhen	*Gallinula chloropus*	2.63
Coot	*Fulica atra*	4.55
Oystercatcher	*Haematopus ostralegus*	4.41
Lapwing	*Vanellus vanellus*	1.12
Snipe	*Gallinago gallinago*	0.91
Curlew	*Numenius arquata*	1.75
Redshank	*Tringa totanus*	2.38
Black-headed Gull	*Larus ridibundus*	3.31
Common Gull	*Larus canus*	1.23
Lesser Black-backed Gull	*Larus fuscus*	5.79
Herring Gull	*Larus argentatus*	3.80
Great Black-backed Gull	*Larus marinus*	3.79
Stock Dove	*Columba oenas*	1.04
Woodpigeon	*Columba palumbus*	1.96
Collared Dove	*Streptopelia decaocto*	2.08
Turtle Dove	*Streptopelia turtur*	1.29
Cuckoo	*Cuculus canorus*	3.16
Barn Owl	*Tyto alba*	8.18
Little Owl	*Athene noctua*	3.65
Tawny Owl	*Strix aluco*	4.79
Long-eared Owl	*Asio otus*	4.29
Short-eared Owl	*Asio flammeus*	3.93
Swift	*Apus apus*	2.78
Kingfisher	*Alcedo atthis*	1.59
Green Woodpecker	*Picus viridis*	3.63
Great Spotted Woodpecker	*Dendrocopos major*	2.51
Skylark	*Alauda arvensis*	0.33
Sand Martin	*Riparia riparia*	0.15
Swallow	*Hirundo rustico*	0.37
House Martin	*Delichon urbica*	0.56
Meadow Pipit	*Anthus pratensis*	0.17
Rock Pipit	*Anthus petrosus*	0.31

English name	Latin name	Reporting probability (%)
Yellow Wagtail	*Motacilla flava*	0.20
Grey Wagtail	*Motacilla cinerea*	0.28
Pied Wagtail	*Motacilla alba*	0.93
Dipper	*Cinclus cinclus*	0.45
Wren	*Troglodytes troglodytes*	0.18
Dunnock	*Prunella modularis*	0.44
Robin	*Erithacus rubecula*	0.64
Redstart	*Phoenicurus phoenicurus*	0.17
Stonechat	*Saxicola torquata*	0.23
Wheatear	*Oenanthe oenanthe*	0.27
Blackbird	*Turdus merula*	2.16
Fieldfare	*Turdus pilaris*	1.63
Song Thrush	*Turdus philomelos*	1.28
Redwing	*Turdus iliacus*	0.97
Mistle Thrush	*Turdus viscivorus*	2.16
Sedge Warbler	*Acrocephalus schoenabaenus*	0.09
Reed Warbler	*Acrocephalus scirpaceus*	0.15
Lesser Whitethroat	*Sylvia curruca*	0.15
Whitethroat	*Sylvia communis*	0.24
Garden Warbler	*Sylvia borin*	0.13
Blackcap	*Sylvia atricapilla*	0.16
Chiffchaff	*Phylloscopus collybita*	0.06
Willow Warbler	*Phylloscopus trochilus*	0.10
Goldcrest	*Regulus regulus*	0.10
Spotted Flycatcher	*Muscicapa striata*	0.43
Pied Flycatcher	*Ficedula hypoleuca*	0.12
Bearded Tit	*Panurus biarmicus*	0.18
Long-tailed Tit	*Aegithalos caudatus*	0.16
Marsh Tit	*Parus palustris*	0.21
Willow Tit	*Parus montanus*	0.21
Coal Tit	*Parus ater*	0.30
Blue Tit	*Parus caeruleus*	0.43
Great Tit	*Parus major*	0.37
Nuthatch	*Sitta europaea*	0.76
Treecreeper	*Certhia familiaris*	0.14
Jay	*Garrulus glandarius*	3.33
Magpie	*Pica pica*	3.12
Jackdaw	*Corvus monedula*	2.97
Rook	*Corvus frugilegus*	2.45
Carrion Crow	*Corvus corone*	3.34
Raven	*Corvus corax*	5.81
Starling	*Sturnus vulgaris*	1.76
House Sparrow	*Passer domesticus*	0.87
Tree Sparrow	*Passer montanus*	0.15
Chaffinch	*Fringilla coelebs*	0.43
Brambling	*Fringilla montifringilla*	0.33
Greenfinch	*Carduelis chloris*	0.81
Goldfinch	*Carduelis carduelis*	0.33
Siskin	*Carduelis spinus*	1.00
Redpoll	*Carduelis flammea*	0.18
Bullfinch	*Pyrrhula pyrrhula*	0.52
Yellowhammer	*Emberiza citrinella*	0.24
Reed Bunting	*Emberiza schoeniclus*	0.18

Appendix 2

Regional Variation in the Reporting Rates of Ringed Birds

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SUMMARY

Reporting rates of ringed birds are estimated at the regional (18 passerine species), county (2 owls and 1 passerine) and 10 km square (1 passerine) levels within the UK. There was evidence of regional variation in reporting rates for 5 passerine species although regional differences in reporting rates were not consistent across species. Reporting rates varied significantly between counties and between 10km squares. Reporting rates for Tawny Owl *Strix aluco* and Song Thrush *Turdus philomelos*, but not Barn Owl *Tyto alba*, were significantly related to the density of the human population. There was some evidence that reporting rates were related to agricultural practices, particularly the extent of cereal production. Implications of spatial heterogeneity in reporting rates for the estimation of survival rates from ring recovery data and for schemes concerned with the surveillance of avian mortality are discussed.

INTRODUCTION

Records of numbers of birds found dead have been used to provide assessments of a wide variety of different types of bird mortality incidents, including those caused by severe weather (Dobinson & Richards 1964), oil spills (Stowe 1982), disease (Lloyd *et al.* 1976), lead poisoning (Sears 1988), powerlines (Scott *et al.* 1972) and pesticides (Fletcher *et al.* 1991). The aims of such studies are usually to measure the frequency of particular types of mortality. This approach is different from and complementary to that of studies designed to measure population mortality rates for the purpose of understanding changes in the size and demography of populations (Baillie 1990, Baillie & McCulloch 1993).

Mortality surveillance may either be active, meaning that systematic searches for corpses are organised, or passive, with records being gathered from anyone who voluntarily submits information. Active surveillance schemes generally represent attempts to provide measures of mortality from specific causes such as oil pollution or powerlines. Systematic searches for corpses as part of field trials designed to evaluate the safety of new pesticides (Mineau & Collins 1988) also fall within this category. Passive surveillance schemes often exist to record mortality from a wide range of different causes. Detailed investigation of those incidents which are reported, to identify the diseases or poisons responsible for the deaths, may be a more important function of such schemes than the gathering of systematic information on the frequency with which different species are affected by different types of mortality.

The number of casualties recorded by such schemes will be a function of the number of birds in the area being studied, their mortality rate over the recording period and the probability that corpses are found and recorded. The finding probability incorporates the effects of corpses having a limited lifespan, due to decay and to their being removed by scavengers, as well as the probability that a corpse which is present will be located by an observer. This study is concerned with the probability that corpses are found and recorded, which we refer to as the reporting rate.

It is well known that reporting probabilities are likely to vary widely between species particularly as a result of information from studies of ringed birds (Hickling 1983, Baillie & Green 1987) and a study investigating interspecific variation in reporting rates has recently been completed (Baillie *et al.* in prep). Reporting rates might also vary geographically perhaps in relation to human population density or other land-use features although as far as we know there have been no studies of such variation. Recoveries of ringed birds provide a means of measuring reporting rates of dead birds in the wider countryside. In this paper we estimate regional reporting rates for 22 passerine species and for Barn Owl *Tyto alba* and Tawny Owl *Strix aluco* using United Kingdom and Ireland ringing and recovery data. Regional variation in reporting rates is considered in relation to variation in human population density and a range of land-use and habitat variables which might potentially influence reporting rates of dead birds.

METHODS

Bird ringing in the UK is organised by the British Trust for Ornithology (BTO) which issues rings and collects and computerises information on recoveries. More than 800,000 birds are currently ringed and more than 13,000 found and reported (i.e. recovered) each year in the UK (Mead & Clark 1991). Since the start of ringing in 1909, more than 21 million birds have been ringed and approximately 460,000 recovered.

Species-specific reporting rates can be estimated using national ringing totals (McCulloch & Baillie 1993), and a detailed breakdown of the composition of the ringing data is not essential. The estimation of region-specific reporting rates requires as a minimum a regional breakdown of ringing totals. Because UK ringing data are not yet computerised routinely, regional reporting rates can only be estimated for a number of species for which either regional ringing totals are available (as is the case for 22 passerine species since 1985) or for which a significant proportion of the ringing data have been computerised (this is the case for Barn Owl, Tawny Owl and Song Thrush *Turdus philomelos*).

Spatial variation in reporting rates was investigated at three geographic scales : 'regions' (Scotland, Ireland, southern England, central England and Wales and northern England as defined according to age-specific totals (Baillie & Green 1987), counties and 10 km squares.

1. Regions

Since 1985 annual summer (April-September inclusive) ringing totals have been collected for 22 passerine species according to region and age (Baillie & Green 1987; Baillie & McCulloch in press). Prior to analysis the following categories of recoveries were excluded from the dataset as being unreliable : birds which were sick when ringed, transported after ringing, held in captivity, involving the finding of a ring only (or leg and ring only) or for which the finding date was not known to within 50 days. The remaining recoveries were then tabulated by finding year (taken as 1 July to 31 June), age at ringing and region, and ringing-recovery matrices generated of the type described by Brownie *et al.* (1985). In the cases of four species (Sand Martin *Riparia riparia*, Pied Flycatcher *Ficedula hypoleuca*, Reed Bunting *Emberiza schoeniclus* and Redpoll *Carduelis flammea*) there were fewer than 10 recoveries from birds ringed in three or more of the five regions, and no attempt was made to model such sparse data sets. Maximum likelihood estimates of regional reporting rates were generated from a series of models fitted to the ringing and recovery data using program SURVIV (White 1983). All models were parameterised in terms of survival rate (S) and reporting rate (λ). For each species an initial model was fitted to the ringing and recovery data in which both survival and reporting rates varied with age and with region ($Sar,\lambda ar$). Note that the effects of region and age are only considered interactively and not using additive models. Attempts were then made to fit a series of simpler models in which the regional component of the model was removed first from the survival term ($Sa,\lambda ar$), then from the reporting rates part of the model (Sar,λa) and finally from both survival and reporting rate (Sa,λa). The fit of each model was assessed using goodness-of-fit tests and the relative suitability of different models by likelihood ratio tests (LRTs) between models. The latter constitute formal tests of regional variation in survival and reporting rates. Data for Ireland were generally sparse and estimates of Irish reporting rates were only possible for Willow Warbler *Phylloscopus trochilus*, Blackbird *Turdus merula* and Starling *Sturnus vulgaris*. There were also no data for Reed Warbler *Acrocephalus scirpaceus* in Scotland.

In the case of species for which none of these four models provided an adequate description of the data, two further models both incorporating time-specific reporting rates (Sar,λart and Sar,λat) were fitted to the data. In cases where these models also failed to provide an adequate description of the data, separate analyses were carried out for each region. These latter analyses do not involve any formal statistical test for regional variation in reporting rates.

2. Counties and 10 km squares

2.1 Ringing data

For most species of birds ringed in the UK, details of ringing (date, species, ring number, place of ringing and age at ringing) are not available in computerised form. For three species (Barn Owl, Tawny Owl and Song Thrush) a proportion of the total ringing data are available in computerised form. Details of 8,307 ringings of Barn Owl and 11,587 ringings of Tawny Owl have been computerised covering the period 1964 to 1989. Comparison with published annual ringing totals (e.g. Mead & Clark 1991) suggests that the computerised ringing data were almost complete for the years 1971-87 inclusive, and all subsequent analyses of Barn Owl and Tawny Owl are based on this time period. All ringings and recoveries of captive-bred owls (mainly Barn Owls) were excluded from the county ringing totals because ring recovery rates of captive-bred birds might well be higher than those for wild owls (Percival 1990). Recoveries reported up until the end of 1991 are included in the analysis, and although recovery data for owls are not complete, we estimate (using recovery data for the period 1960-85) that 81% of recoveries from Tawny Owls ringed in 1987 and 90% of all expected recoveries of Tawny Owls ringed in 1984, would have been reported by 1991. Similarly, in the case of Barn Owl we estimate that 91% of recoveries of birds ringed in 1987 can be expected to have been reported by 1991 and 97% of recoveries of birds ringed in 1984.

In the case of Song Thrush, details of 84,879 ringings were available in computerised form covering the years 1976-91 inclusive. This represents less than half of all Song Thrushes ringed in Britain and Ireland during these years (approximately 188,000 ringed in total). As details of Song Thrush ringings have been computerised from all years 1976-91, all analyses of reporting rates are based on the sample of ringings computerised (i.e. only those recoveries relating to birds whose ringing details have been computerised are considered). Ringings of Song Thrushes in Ireland were not computerised. In order to maximise sample sizes no attempt has been made to exclude recoveries of birds ringed in years for which the recovery data are incomplete (i.e. 1991). Consequently it is necessary to assume that during the latter part of the study period (for birds ringed in 1987 recovery data are probably more than 90% complete) there has been no regional variation in the age (of the bird) at which ringed dead Song Thrushes are reported.

2.2 Recovery data

Only recoveries of birds ringed in Great Britain and found dead are considered here. All ring recoveries are computerised with codes indicating the accuracy with which the date of the birds' death was recorded and all inaccurate and unreliable recoveries were excluded from all analyses. These included birds which were sick or injured when released, transported before release, held more than 24 hours before release, instances in which only the ring (or leg and ring) were found and recoveries for which the finding date was not known to within 50 days. It was also necessary to exclude recoveries involving relatively long-distance movements because such recoveries will have been dependent on the reporting rate in the area of recovery not the area of ringing, variation which we are aiming to quantify and explain. In the case of Barn Owl, 95% of all reliable (n=884) recoveries were within 81 km of the ringing place, whilst in the case of Tawny Owl, 95% of all reliable recoveries (n=723) were within 23 km. All recoveries of owls involving movements of more than 100 km were therefore excluded from the analysis with relatively little loss of data. In the case of Song Thrush, 95% of all reliable recoveries (n=2124 for the years 1976-91) were within 155km of the ringing place and 90% within 56km. Because analyses of Song Thrush reporting rates were planned at a finer scale than those of owls (i.e. 10km squares), all recoveries of Song Thrushes more than 50km from the ringing place were excluded from subsequent analyses of reporting rates. In those analyses which were restricted to Song Thrushes ringed and recovered during the period April-September inclusive, 90% of all recoveries were within 16km of the ringing place.

The finding circumstances of ringed birds found dead were tabulated for Tawny Owl, Barn Owl and Song Thrush. The main finding circumstances for the owls were 'found dead' (i.e. no known cause) (36% of Barn Owls and 37% of Tawny Owls), road casualties (36% of Barn Owls and 32% of Tawny Owls), railway casualties (6% of Barn Owls and 8% of Tawny Owls) and 'entered man-made structures' (6% of Barn Owls and 3% of Tawny Owls). No other finding circumstance accounted for more than 5% of all dead recoveries. The main finding circumstances for Song Thrush were 'found dead - no cause' (40%), road casualty (19%), hit glass window (7%) and killed by cat (22%). No other finding circumstance accounted for more than 2% of all dead recoveries.

For each of three species analyzed two sets of county-specific reporting rates were calculated. The first was the total number of dead recoveries divided by the number ringed in each county and the second was the number of 'found dead - no known cause' recoveries divided by the numbers ringed. In the case of Song Thrush a further category of county-specific reporting rates were calculated, derived from birds which were both ringed and recovered during the period April-September inclusive. British breeding Song Thrushes are known to be partial migratory with some birds moving to France and other areas in southern Europe in winter (Ashmole 1972). Birds ringed in Britain during winter may not therefore be caught in their breeding areas. The inclusion of Song Thrushes either ringed or recovered in winter might therefore exacerbate the effects of widescale phenomena such as weather and migration on reporting rates, rather than the possible local effects of human population density and land-use characteristics in which we are interested here. For this reason four sets of reporting rates were calculated for Song Thrush using different sets of recoveries as follows: (i) all dead recoveries, all year round (n=1923); (ii) all dead recoveries, ringed and recovered April-September inclusive (n=741); (iii) 'found dead recoveries - no known cause', all year round (n=830) and (iv) 'found dead recoveries - no known cause', ringed and recovered April-September inclusive (n=310). All counties or 10 km squares in which there were computerised records of fewer than 10 birds ringed were excluded from all analyses.

2.3 Relationships between reporting rates and human population density and land-use variables

In an attempt to identify factors which influence reporting rates of ringed birds, county- and 10km square-specific reporting rates were treated as dependent variables in multivariate analyses. A range of possible independent variables were available from five main sources : (i) the 1981 national population census statistics for human populations by county, (ii) the MAFF/DAFS June Agricultural Statistics for agricultural land-use statistics by county for Great Britain, (iii) the ITE Land Characteristics Data Bank for a variety of topography, climate and land-use statistics measured from Ordinance Survey maps by 10 km squares in Great Britain (Ball *et al.* 1983), (iv) the Edinburgh University Data Library conversion of MAFF/DAFS parish agricultural statistics into 10 km square data in Great Britain and (v) the density of BTO members in different counties and 10 km squares.

A number of variables were selected for inclusion in stepwise multiple regression analyses (by forward selection) of county-specific reporting rates (Barn Owl, Tawny Owl and Song Thrush) and stepwise logistic regression analyses (by backward exclusion following Bowden (1988) and SAS Institute Inc. (1989)) of 10 km square-specific reporting rates (Song Thrush only) as described in Table 1. The density of the human population and of BTO members in counties and in 10 km squares were obvious independent variables to include in these analyses. The land-use and agricultural variables were selected from larger sets of variables without any objective prior information regarding likely relationships with reporting rates of ringed birds. The independent variables selected were those thought to be most likely to directly influence reporting rates (i.e. the number of main roads might affect the numbers of ringed owls reported because many are killed by vehicles) or which best represent the major agricultural land-uses (i.e. proportion of the land area devoted to arable crops).

In all multiple regression analyses reporting rates were arcsine transformed. Reporting rates for six major conurbations (Greater London, Greater Manchester, Merseyside, West Midlands, West Yorkshire and South Yorkshire) were found to be considerably higher than those from other counties, and were exerting a strong influence on multivariate analyses. For this reason two sets of stepwise multiple regression analyses were carried out, one including conurbations and one excluding conurbations.

Logistic regression was considered more appropriate for the 10 km square analysis because there were no recoveries for more than 60% of all squares analysed. For the purposes of logistic regression, 10 km squares were categorised either as having generated recoveries (1) or as not having generated recoveries (0). As the number of birds ringed in a square is likely to be an important determinant of the likelihood of recoveries being generated, the number of birds ringed in any 10 km square was forced to be included as an independent variable in all logistic regression models. Other independent variables (listed in Table 1b) only remained in the logistic model if they accounted for a significant amount of the variation in the occurrence/non-occurrence of recoveries in squares after that explained by the numbers of birds ringed in the square had been accounted for. Two sets of logistic regressions were carried out, one including all independent variables and one excluding the six agricultural land-use variables listed in Table 1b.

RESULTS

1. Region-Specific Reporting Rates

Models providing the best fit to each of the passerine data sets for which summer ringing totals are available since 1985, are presented in Table 2. In the cases of Greenfinch *Chloris chloris*, Song Thrush, Blackcap *Sylvia atricapilla* and Willow Warbler there was strong evidence of regional variation in reporting rates (i.e. the national model (Sar,λa) or (Sa,λa) was rejected in favour of the regional model (Sar,λar) or (Sa,λar) respectively by LRTs). In the case of Greenfinch all attempts to simplify the full regional model failed. In the cases of Dunnock *Prunella modularis*, House Sparrow *Passer domesticus*, Wren *Troglodytes troglodytes* and Reed Warbler either survival and/or reporting rates varied significantly between regions, but the analysis was unable to distinguish between the two (i.e. model (Sar,λa) fitted the data just as well as model (Sa,λar) and the national model (Sa,λa) was conclusively rejected by LRTs). In the cases of Bullfinch *Pyrrhula pyrrhula*, Chaffinch *Fringilla coelebs* and Great Tit *Parus major* there was no evidence of regional variation in either reporting rates or survival rates (Table 2).

No age and region dependent models fitted the data for Swallow *Hirundo rustica*, Pied Wagtail *Motacilla alba*, Robin *Erithacus rubecula*, Blackbird, Blue Tit *Parus caeruleus* and

Starling. Further attempts to model these data (with age-, region- and time-dependent reporting rates) failed to provide models which adequately described the data in all cases except Pied Wagtail the data for which fitted the time-dependent reporting rates model (Sar,λart).

To test for consistent regional patterns in reporting rates across species Kendall's coefficient of concordance (W) was calculated using ranked reporting rates for the four regions of Britain for 17 species (Reed Warbler was excluded because data were only available for three regions). Coefficients of concordance were calculated separately for adults and young and for (i) all species (ii) migrant species and (iii) resident species. In the case of the five species for which none of the models described above provided an adequate description of the data, regional estimates of reporting rates were taken from the full regional model (Sar,λar).

There was no significant concordance in the reporting rates of either age class for all species or for migrants across regions (Table 4). There was also no evidence of concordance in the reporting rates of adult residents across regions, although there was for juvenile residents ($W=0.316$, $P<0.01$, Table 4). In the latter case, reporting rates were generally highest in central England & Wales and southern England, and lowest in northern England and Scotland.

2. County-specific reporting rates

The numbers of counties for which there were computerised records of at least 10 ringed birds (excluding captive-bred birds) were 44 for Barn Owl, 48 for Tawny Owl and 50 for Song Thrush. A list of county-specific reporting rates is listed in the Appendix. Contingency table tests showed that reporting rates varied significantly across counties for all three species (chi-square = 169.1, 35df, $P<0.001$ for Barn Owl, chi-square=120.6, 35df, $P<0.001$ for Tawny Owl and chi-square=234.2, 38df, $P<0.001$ for Song Thrush).

Similarities in county-specific reporting rates between species were assessed using weighted correlation, in which the weighting factor was the square root of the sum of the county ringing totals for the two species being considered. County-specific reporting rates for Barn Owl were uncorrelated with those for both Tawny Owl ($r=0.16$, $n=61$, for 'found dead, no known cause' recoveries only and $r=0.09$, $n=62$, for all recoveries) and Song Thrush (r=-

0.03, n=63 and r=-0.12 respectively). There was, however, a significant correlation between the county-specific reporting rates of Tawny Owl and Song Thrush based on all recoveries (r=0.32, n=62, P<0.02), although not between reporting rates based on 'found dead, no known cause' recoveries only (r=0.23, n=61, P>0.05).

Results of stepwise multiple regressions of county-specific reporting rates against a range of environmental and human demographic variables are summarised in Tables 5 and 6. None of the five variables listed in Table 1a could explain a significant proportion of the variation in Barn Owl reporting rates (Table 5), although the number of BTO members in each county approached significance for 'found dead -no known cause' recoveries excluding conurbations (P=0.1; and see below).

In the case of Tawny Owl, 25% of the variation across counties in reporting rates based on 'found dead' recoveries only, could be explained by the density of BTO members therein and this remained a highly significant explanatory variable when the six main conurbations were excluded from the analysis (Table 5). The proportion of the county land area under cereal production in 1981 explained 13% of the variation in reporting rates based on all recoveries after conurbations had excluding (Table 5), reporting rates being higher in counties with a relatively large amount of cereal production.

In the case of Song Thrush, human population density accounted for a large proportion of the variation in reporting rates across all counties (up to 48%, in the case of all dead recoveries from all months, Table 6). However, the six main conurbations were highly influential on this relationship, and following their exclusion, little, if any, of the variation in reporting rates in the wider countryside could be explained (Table 6). It is notable, however, that, as in the case of Tawny Owl, reporting rates were weakly but significantly related to the extent of cereal production in each county.

In the case of Song Thrush the exclusion of recoveries from outside the period April-September only served to decrease the proportion of the variation in reporting rates explained by the multiple regression models (Table 6). Human population density was positively related to reporting rates based on summer recoveries only but this relationship was also strongly dependent upon the six major conurbations (Table 6).

It should be noted that the extent of cereal production within counties was strongly correlated with the extent of total arable crops ($r=0.98$, $P<0.0001$) and negatively correlated with the extent of old (>4yrs) grass ($r=-0.44$, $P<0.002$). The analyses described here cannot therefore distinguish between the possible influence of cereal production on reporting rates with the possible influence of total arable production.

The nature of the relationship between county reporting rates derived from 'found dead' only recoveries and human population density is shown in Figure 1 for each of the three species considered. For Song Thrush and Tawny Owl weighted regression analyses show the significant effect of population density on reporting rates even when the six large conurbations are excluded from the analysis (Figure 1). In the case of Barn Owl there was no evidence of any relationship between reporting rates and human population density.

To summarise, there was strong evidence to suggest that county-specific reporting rates of Song Thrush and Tawny Owl were positively related human population density (and/or the density of BTO members) and weaker evidence that reporting rates were positively related to the extent of cereal production. Reporting rates of Barn Owls were not related to any of the independent variables available for analysis. County-specific reporting rates for Tawny Owl were weakly correlated with those for Song Thrush, whilst reporting rates for Barn Owl were uncorrelated with those for either Tawny owl or Song Thrush.

3. Ten-kilometre square reporting rates for Song Thrush

The numbers of 10km squares for which there were computerised records of at least 10 Song Thrushes ringed was 752 when all recoveries were used, and 613 when only those birds ringed and recovered during summer were used. Of these, agricultural land-use and human demographic data were also available for 651 and 537 squares respectively.

Results of stepwise logistic regressions of 10 km square reporting rates against a range of environmental and human demographic variables are summarised in Table 7. As expected the numbers of birds ringed in each square was a highly significant determinant of whether recoveries were likely to be reported from a square (Table 7). Squares giving rise to reports of any category of dead bird tended to be those with relatively large numbers of towns or relatively few hamlets or, for birds ringed and recovered in summer, with a relatively high human population density (Table 7). Squares giving rise to reports of dead Song Thrushes for which there was no known cause of death, tended to be those either with a low proportion of land devoted to farming (cereals and non-cereals) or with a relatively large number of towns and small number of hamlets (Table 7).

The exclusion of Song Thrushes either ringed or recovered outside the summer period, resulted in rather simpler models with slightly improved predictive powers (Table 7). After allowing for the numbers of birds ringed, human population density and, in the case of recoveries with no known cause of death, the proportion of the square devoted to total grass were selected as highly significant factors affecting the likelihood of a 10 km square giving rise to reports of dead Song Thrush recoveries. The area of total grass within a square was negatively correlated with human population density ($r=-0.28$, $P<0.0001$) suggesting that the apparent relationship with total grass may actually reflect population density.

It also seems likely that the relative numbers of towns and hamlets in squares might be reflecting human population density in some of these models (for population size and number of towns $r=0.21$, $P<0.0001$, whilst for population size and number of hamlets $r=-0.34$, $P<0.0001$). Similarly, the extent of total grass in 10km squares is strongly correlated with several other agricultural variables (e.g. the extent of old grass $r=0.98$, the extent of non-cereal crops $r=-0.45$, the extent of total cereals $r=-0.33$, and the extent of total farmland $r=0.42$) as well as with human population density (above). Logistic regression analyses of the type described here will have only limited power to distinguish between the effects of inter-correlated independent variables on reporting rates.

To summarise, there is strong evidence that the likelihood of ringed Song Thrushes being reported when dead depends upon the numbers of birds ringed and the human population density in the locality. There was weaker evidence that the likelihood of dead Song Thrushes being reported as 'found dead - no known cause' is related to agricultural land-use.

DISCUSSION

Whilst the regional analyses of ring recovery data provided evidence of regional variation in reporting rates for 6 of the 18 species considered, the data were sparse for individual regions and some of the analyses will therefore have lacked statistical power. There was however evidence of concordance across regions in the estimated reporting rates of first-year birds for resident species. These regional differences in reporting rates may be partly related to human population density (low reporting rates in Scotland and higher rates in southern and central England). The power of analyses of this kind will increase as the amount of available data increases with time.

The multivariate analyses summarised above are subject to a number of limitations. First, the independent variables used in the analyses (listed in Table 1) relate to individual years or time periods which differ between variables and generally cover only a small fraction of the period over which ring recoveries were being reported. Probably the worst example of this is the 10 km square human population data which relate to 1971 whilst the owl data relate to the period 1971-87 and the Song Thrush data to the period 1976-91. Second, the land-use and agricultural variables used in the stepwise analyses were selected from larger sets of variables without any objective prior information regarding likely relationships with reporting rates of ringed birds. The independent variables selected were those thought to be most likely to directly influence reporting rates (i.e. the number of main roads might affect the numbers of owls ringed reported because many are killed by vehicles) or which best represent the major agricultural land-uses (i.e. proportion of the land area devoted to arable crops). Third, only a limited number of human demographic and land-use variables were available and it is likely that a higher proportion of the total variation in reporting rates could have been explained if a larger number of possible explanatory variables had been available. For example, it is possible that the socio-economic composition of the human population might affect the likelihood that dead birds are reported.

The main findings of the analyses described here are that there is significant geographical variation in reporting rates of ringed birds and that in the case of Tawny Owl and Song Thrush some of this variation is related to human population density, the density of BTO members and agricultural land-use. However, a large proportion of the variation in reporting rates across counties could not be explained by the available environmental variables.

The significant positive relationships between reporting rates and human population density and the density of BTO members (in the case of Tawny Owl) are not unexpected and probably reflect the likelihood that dead birds will be encountered by members of the public, and more particularly well-informed members of the public like BTO members. It should be noted that there is a strong correlation between the density of BTO members in 1992 and both human population density in 1981 across counties (r=0.84, n=59) and human population in 1971 across 10km squares (r=0.75,n=651) and therefore the analyses presented here will have only limited power to distinguish between the relative importance of each with respect to reporting rates.

The apparent influence of agricultural practices on reporting rates of Tawny Owls and Song Thrushes requires cautious interpretation both because of the statistical weakness of most of the relationships and because of inter-correlations between agricultural variables and human population density. The extent of cereal production was positively associated with county-specific analyses of reporting rates of both Tawny Owl and Song Thrush, but only when reporting rates were based on all dead recoveries. This suggests that the relationship is dependent upon recoveries for which the cause of death was known. In the cases of Tawny Owl and Song Thrush the major reported causes of death were road and rail casualties (both species) and killed by cats (Song Thrush). It is possible, therefore, that in areas where a high proportion of the land area is devoted to cereal production (rather than woodland or natural wetlands, for example) birds like Tawny Owls and Song Thrushes might be forced to utilise habitats such as road-side verges, parks and gardens where, when they die, they are more likely to be found by humans. It is also possible that in areas dominated by cereal production where natural and semi-natural habitats are rare, a relatively high proportion of ringing activities are carried out in habitats close to human habitations.

In the 10 km square analyses of the Song Thrush data it is notable that, contrary to the findings of analyses at the county level, agricultural variables were only retained in predictive models when reporting rates were based upon 'found dead, no known cause' recoveries (Table 7). However, the positive relationship between the extent of cereal production and county reporting rates (Table 6) is broadly supported by the negative relationship between the area of total grass and 10 km square reporting rates (Table 7), because these two agricultural variables are negatively correlated with each other (r=-0.33, P<0.0001).

Unlike Tawny Owl and Song Thrush, reporting rates of Barn Owls were unrelated to either human population density or any other human demographic or agricultural land-use variables. In the case of Barn Owl it is likely that factors other than human population density and farming practices are more important determinants of reporting rates. Two factors which might affect regional variation in the reporting rates of Barn Owls are the abundance of captive-bred birds and the availability of farm buildings suitable for nesting. Captive-bred Barn Owls which are released into the countryside might have lower survival rates (Percival 1990) and perhaps higher reporting rates than wild birds. Although all known captive-bred birds were excluded from the ringing and recovery data, some may not have been identified as having been captive-bred on ringing schedules, and this might have introduced spurious geographical heterogeneity into the observed reporting rates. Barn Owls which nest in buildings are likely to be both conspicuous and of great interest to landowners and local people. The proportion of Barn Owls which build nests in buildings is known to vary markedly within the UK, with a high proportion of nests occurring in buildings in the west and a low proportion in the east where most nests are in trees (Shawyer,1989). This is likely to result in marked geographic heterogeneity in reporting rates across counties and any future analyses of the kind presented here should consider variation in the availability of farm buildings within the UK.

The evidence presented here for regional variation in reporting rates has implications for both future analyses of ring recovery data and for mortality monitoring schemes such as the Wildlife Incidents Investigation Scheme (WIIS) of the Ministry of Agriculture, Fisheries and Food (MAFF). Future analyses of ring recoveries (usually for the purpose of survival rate estimation) should where the data allow, test for regional differences in reporting rates rather than assume regional homogeneity as has generally been the case in the past. These findings also emphasize the need to have regional breakdowns of the ringing data in order to avoid drawing spurious conclusions about regional variation in survival rates.

Mortality monitoring schemes such as the WIIS investigates cases of mortality of vertebrate wildlife caused by pesticides in England and Wales (Greig-Smith 1988). Most of incidents of wildlife mortality investigated by the WIIS are initially reported by members of the public. Inter-specific and regional variation in reporting rates will therefore complicate the interpretation of such mortality incidents and if possible should be taken into account. The results of this study suggest that reporting rates are higher in areas of high human population density than in areas of lower human population density (Figure 1), such as rural areas where any effects of agricultural pesticides on wildlife are likely to occur. It follows therefore, that average reporting rates estimated using all ring recovery data for a single species (as in

Baillie *et al.* 1993) will underestimate reporting rates for ringed birds in habitats where pesticides are being used. Reporting rates for unringed casualties are probably even lower than those for ringed birds.

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TABLE 1: Independent variables used in multivariate analyses of reporting rates (abbreviations in brackets).

(a) COUNTY ANALYSES	
Human Population Density in 1981	(POPT)
Density of BTO Members in 1992	(BTOMEM)
Proportion of county under cereals in 1981	(PCER)
Proportion of county under old (>4yrs) grass in 1981	(POGRASS)
Proportion of county under arable crops in 1981	(PARABLE)
(b) 10km^2 ANALYSES	
Number of birds ringed in each 10km^2	(NRING)
Human Population Density in 1971	(POPT)
Density of BTO Members in 1992	(BTOMEM)
Number of main roads (from OS maps)	(NMROADS)
Number of towns (from OS maps)	(NTOWNS)
Number of hamlets (from OS maps)	(NHAMLETS)
Proportion of the square devoted to farmland in 1988	(PFARM)
Proportion of the square devoted to crops and fallow land in 1988	(PCROPFAL)
Proportion of the square devoted to old grass in 1988	(POGRASS)
Proportion of the square devoted to total grass in 1988	(PTGRASS)
Proportion of the square devoted to total cereals in 1988	(PTCEREAL)
Proportion of the square devoted to non-cereal crops in 1988	(PNCER)

TABLE 2: Models providing the best fit to ringing and recovery data for birds ringed during summer (April-September inclusive) during the period 1985-90 and recovered 1986-91. Initially age (a) and region (r) dependent models were fitted to the data and attempts were made to simplify regional survival (S_r) and reporting rates (λ_r) to national rates. In cases where none of these models provided an adequate description of the data time-dependence was introduced into the reporting rates (λ) term, but this only provided an adequate description of the ring-recovery data for one species (Pied Wagtail). Brackets indicate species for which the analysis could not distinguish between models (S_{ar}, λ_a) and (S_a, λ_{ar}).

SIMPLEST MODEL PROVIDING AN ADEQUATE DESCRIPTION OF THE DATA	SPECIES
Full Regional Model (S_{ar}, λ_{ar})	Greenfinch
Regional Reporting Rates Model (S_a, λ_{ar})	Song Thrush, Sedge Warbler, Blackcap, Willow Warbler (House Sparrow, Dunnock)
Regional Survival Rates Model (S_{ar}, λ_a)	(Wren, Reed Warbler)
Full National Model (S_a, λ_a)	Chaffinch, Bullfinch, Great Tit
Full Regional Model with time-dependent reporting rates (S_{ar}, λ_{art})	Pied Wagtail

No model provided an adequate description of the data from all regions for the following species: Swallow, Robin, Blackbird, Blue Tit and Starling

TABLE 3: Estimated Regional Reporting Rates (%) for adult (Ad) and juvenile (Juv) passerines during the period 1985-91. * Indicates species for which no model provided an adequate description of the data, and estimates from the "least bad" model are presented. Species in bold are those for which there is statistically significant variation in reporting rates between regions.

Model	Species		Regional Estimates (standard errors)				
			Scotland	N England	C England & Wales	S England	Ireland
S_{ar}, λ_{ar}	**Greenfinch**	Ad	0.79 (0.17)	1.21 (0.15)	1.21 (0.08)	1.22 (0.08)	- -
		Juv	0.57 (0.47)	0.30 (0.10)	0.52 (0.13)	0.75 (0.13)	- -
S_a, λ_{ar}	**Song Thrush**	**Ad**	**0.59** **(0.25)**	**1.44** **(0.30)**	**1.41** **(0.23)**	**1.022** **(0)**	- -
		Juv	**0.53** **(0.28)**	**0.92** **(0.29)**	**1.77** **(0.37)**	**1.41** **(0.29)**	- -
S_a, λ_{ar}	**Sedge Warbler**	**Ad**	**0.05** **(0.05)**	**0.13** **(0.06)**	**0.07** **(0.03)**	**0.09** **(0)**	- -
		Juv	**0.16** **(0.04)**	**0.14** **(0.05)**	**0.13** **(0.04)**	**0.07** **(0.01)**	- -
S_a, λ_{ar}	**Blackcap**	**Ad**	**0.63** **(0.32)**	**0.21** **(0.07)**	**0.16** **(0.04)**	**0.38** **(0)**	- -
		Juv	**0** **(6.12)**	**0.35** **(0.11)**	**0.19** **(0.05)**	**0.29** **(0.05)**	- -
S_a, λ_{ar}	Great Tit	Ad	0.82 (0.24)	0.46 (0.11)	0.54 (0.09)	0.38 (0)	- -
		Juv	0.30 (0.17)	0.51 (0.11)	0.70 (0.11)	0.61 (0.08)	- -
S_a, λ_{ar}	House Sparrow	Ad	1.38 (0.51)	1.09 (0.42)	1.15 (0.27)	1.12 (0)	- -
		Juv	0.50 (0.27)	0.92 (0.57)	0.72 (0.30)	1.00 (0.42)	- -
S_a, λ_{ar}	Wren	Ad	0.31 (0.16)	0.07 (0.04)	0.17 (0.05)	0.33 (0)	- -
		Juv	0.14 (0.10)	0.22 (0.07)	0.28 (0.06)	0.27 (0.05)	- -
S_a, λ_{ar}	**Dunnock**	**Ad**	**0.45** **(0.16)**	**0.36** **(0.10)**	**0.59** **(0.9)**	**0.45** **(0)**	- -
		Juv	**0.51** **(0.20)**	**0.47** **(0.10)**	**0.61** **(0.9)**	**0.54** **(0.08)**	- -
S_a, λ_{ar}	Reed Warbler	Ad	- -	0.16 (0.11)	0.14 (0.04)	0.15 (0.03)	- -
		Juv	- -	0.08 (0.06)	0.14 (0.03)	0.11 (0.02)	- -

S_a, λ_{ar}	**Willow Warbler**	**Ad**	**0 (1.36)**	**0 (0.65)**	**0.06 (0.02)**	**0 (0)**	**0 (1.32)**
		Juv	**0.12 (0.04)**	**0.14 (0.03)**	**0.11 (0.03)**	**0.07 (0.02)**	**0.22 (0.10)**
S_a, λ_{ar}	Chaffinch	Ad	0.53 (0.11)	0.48 (0.10)	0.63 (0.10)	0.67 (0)	- -
		Juv	0.19 (0.12)	0.62 (0.20)	0.61 (0.21)	0.45 (0.16)	- -
S_{ar}, λ_{ar}	Bullfinch	Ad	0.28 (0.28)	0.46 (0.17)	0.59 (0.11)	0.56 (0.10)	- -
		Juv	99.9 (67550)	0.81 (0.49)	0.52 (0.17)	1.29 (0.74)	- -
The following estimates are derived from models which do not provide an adequate description of the data							
S_a, λ_{ar}	* Pied Wagtail	Ad	1.38 (0.33)	0.41 (0.24)	1.11 (0.31)	1.944 (0)	- -
		Juv	0.60 (0.17)	0.59 (0.23)	0.84 (0.24)	1.20 (0.29)	- -
S_a, λ_{ar}	* Swallow	Ad	0.33 (0.09)	0.35 (0.07)	0.18 (0.04)	0.19 (0)	- -
		Juv	0.19 (0.05)	0.21 (0.04)	0.17 (0.03)	0.16 (0.03)	- -
S_a, λ_{ar}	* Robin	Ad	0.30 (0.10)	1.11 (0.23)	0.81 (0.15)	0.82 (0.14)	- -
		Juv	0.77 (0.20)	0.77 (0.13)	1.37 (0.38)	1.02 (0.19)	- -
S_{ar}, λ_{ar}	* Blackbird	Ad	1.34 (0.22)	3.27 (0.54)	2.56 (0.19)	2.81 (0.23)	0.52 (0.23)
		Juv	4.73 (3.74)	2.98 (0.98)	3.68 (0.73)	2.61 (0.37)	6.82 (38.62)
S_{ar}, λ_{ar}	* Blue Tit	Ad	0.63 (0.19)	0.54 (0.12)	0.48 (0.07)	0.51 (0.07)	- -
		Juv	0.87 (0.30)	0.54 (0.09)	0.59 (0.09)	0.73 (0.12)	- -
S_{ar}, λ_{ar}	* Starling	Ad	6.59 (2.38)	3.43 (0.77)	1.59 (0.18)	2.98 (0.30)	3.30 (1.13)
		Juv	1.28 (0.22)	1.67 (0.27)	2.10 (0.39)	2.15 (0.26)	0.54 (0.39)

TABLE 4: Regional * concordance amongst reporting rates from best fitting region-specific, time-independent models. (W = Kendall's coefficient of concordance)

STATUS	AGE CLASS	NO SPECIES	df	W	P
ALL SPECIES	AD 1Y	16 16	3 3	0.026 0.081	>0.05 >0.05
RESIDENTS	AD 1Y	13 12	3 3	0.031 **0.316**	>0.05 **<0.01**
MIGRANTS	AD 1Y	3 4	3 3	0.422 0.575	- >0.05

* excluding Ireland
- too few species to compute significance levels

TABLE 5: Results of stepwise multiple regressions of Tawny Owl and Barn Owl county-specific reporting rates. Independent variables available for selection are listed in Table 1. "+" indicates a positive relationship and "-" indicates a negative relationship.
(*** P<0.001; ** P<0.01; * P<0.05)

	ALL DATA		EXCLUDING SIX CONURBATIONS	
	All Dead Recoveries	"Found Dead" only	All Dead Recoveries	"Found Dead" only
TAWNY OWL	+POPT ** +PCER * $R^2 = 0.22$ n = 48	+BTOMEM *** $R^2 = 0.25$ n = 48	+PCER * $R^2 = 0.13$ n = 42	+BTOMEM ** $R^2 = 0.19$ n = 42
BARN OWL	All N.S. n = 44	All N.S. n = 44	All N.S. n = 38	All N.S. n = 38

TABLE 6: Results of stepwise multiple regressions of Song Thrush county reporting rates. Independent variables available for selection are listed in Table 1. "+" indicates a positive relationship and "-" indicates a negative relationship. (*** P<0.001; * P<0.05).

	ALL DATA (n = 50)		EXCLUDING SIX CONURBATIONS (n = 44)	
SEASON	All Dead Recoveries	"Found Dead" Only	All Dead Recoveries	"Found Dead" Only
Recoveries from all months	+POPT *** +PCER* $R^2 = 0.48$	+POPT *** $R^2 = 0.41$	+PCER* $R^2 = 0.13$	All N.S.
Recoveries of birds ringed and recovered in April-Sept inclusive	+POPT *** $R^2 = 0.38$	+POPT *** $R^2 = 0.26$	All N.S.	All N.S.

TABLE 7: Results of stepwise logistic regression of Song Thrush 10km^2 reporting rates. 10km squares were excluded from the analysis if records of fewer than 10 Song Thrushes were available or if greater than 50% of the area of the square was taken up by sea. Independent variables available for selection are listed in Table 1. The percentage of all observations successfully predicted by each model is given at the bottom of each box. (*** P<0.001; ** P<0.01; * P<0.05).

	All Independent Variables (from Table 1b)		Human populations, inhabitations & BTO members only	
	All Dead	"Found Dead" only	All Dead	"Found Dead" only
Recoveries from all seasons (n=651 10km squares)	+ NRING *** + NTOWNS* 75% pred.	+ NRING *** - PFARM *** + PCROPFAL * - PNCER * - PTCEREAL * 84% pred.	+ NRING *** - NHAMLETS ** 76% pred.	+ NRING *** + NTOWNS * - NHAMLETS * 84% pred.
Recoveries of birds ringed and recovered during April-Sept inclusive (n=537 10km squares)	+ NRING *** + POPT ** 79% pred.	+ NRING *** - PTGRASS ** 88% pred.	+ NRING *** + POPT ** 79% pred.	+ NRING *** + POPT ** 88% pred.

Appendix: County-specific reporting rates for Barn Owl, Tawny Owl and Song Thrush for all recoveries and for "found dead, no known cause" recoveries only.

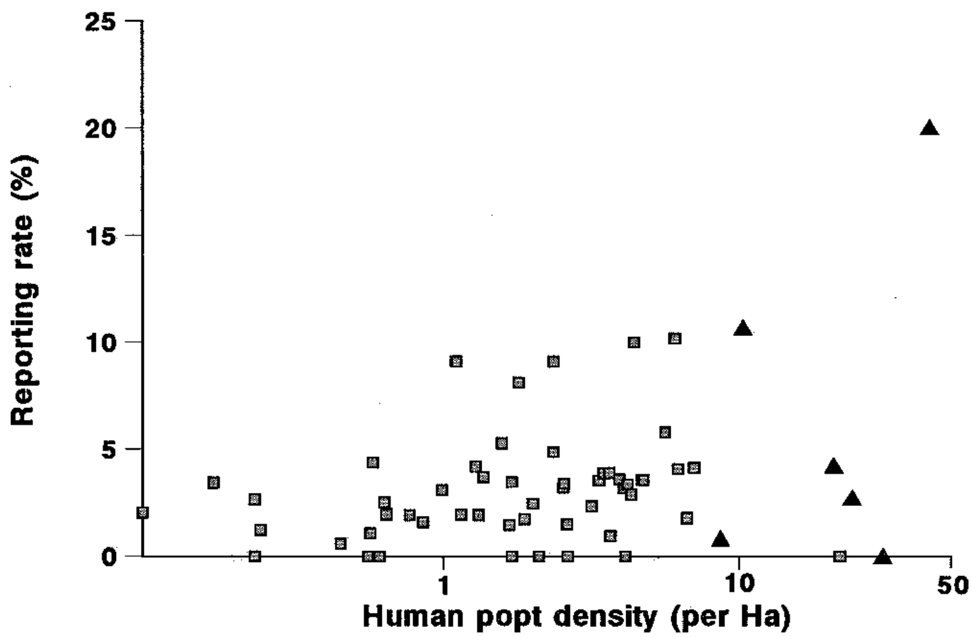
County	Barn Owl		Tawny Owl		Song Thrush	
	All	Found Dead	All	Found Dead	All	Found Dead
Anglesey	19.5	7.4	20.0	-	3.2	0.0
Avon	24.2	4.8	7.0	4.0	1.0	0.3
Buckingham	16.9	8.5	7.0	2.3	1.1	0.3
Bedford	22.2	11.1	20.0	2.9	0.9	0.5
Berkshire	0.0	0.0	13.5	5.8	1.1	0.2
Border Region	44.4	8.3	5.3	2.6	0.0	0.0
Cambs & Huntingdon	18.8	0.0	32.4	8.1	0.6	0.2
Cheshire	23.5	11.8	8.0	3.3	0.9	0.6
Cornwall	13.2	4.8	4.2	4.2	0.7	0.0
Central Region	1.0	0.0	18.2	9.1	0.0	0.0
Cumbria	22.3	7.0	7.3	19.0	0.3	0.1
Cleveland	7.7	0.0	8.9	17.7	1.1	0.6
Clwyd	22.2	11.1	33.3	0.0	0.0	0.0
Derby	17.5	7.8	11.1	3.9	0.7	0.2
Dorset	22.4	11.9	18.2	9.1	0.1	0.0
Dumf & Gall	13.7	4.4	5.3	1.2	0.3	0.0
Durham	0.0	0.0	4.5	1.5	0.9	0.5
Devon	19.6	6.0	4.5	3.4	0.8	0.4
Dyfed	6.0	4.0	0.0	0.0	0.0	0.0
Essex	18.8	10.6	11.5	5.8	0.9	0.2
Fair Isle	-	-	-	-	0.8	0.9
Fife Region	0.0	0.0	2.9	0.0	0.1	0.0
Gwynedd	3.8	0.8	15.0	2.5	0.0	0.0
Gloucester	12.0	0.0	4.9	2.4	0.2	0.0
Glamorgan	0.0	0.0	5.9	0.0	0.3	0.3
Grampian Region	45.8	25.0	15.1	4.3	1.1	0.7
Gwent	27.3	9.1	7.9	3.5	0.4	0.0

Hampshire	25.9	9.3	11.3	3.1	1.4	0.7
Hereford & Worcs	50.0	0.0	9.0	3.4	1.4	0.7
Highland Region	16.7	0.0	13.8	2.0	0.8	0.3
Herts	17.6	0.0	14.8	10.2	1.0	0.3
Humberside	7.0	0.0	5.6	3.4	0.7	0.2
Isle of Man	100.0	100.0	-	-	0.1	0.0
Isle of Wight	12.0	7.2	-	-	-	-
Kent	35.9	2.6	5.0	0.0	0.1	0.4
Lancashire	23.5	10.7	11.3	3.5	1.1	0.3
Leics & Rut	21.4	0.0	11.5	3.8	0.8	0.4
Lincoln-shire	22.0	5.7	10.1	3.1	0.8	0.4
London (Gtr)	15.4	7.7	30.0	20.0	2.4	1.2
Lothian Region	5.6	5.6	12.5	10.0	0.6	0.2
Manchester	27.4	12.9	13.9	4.2	1.6	0.4
Merseyside	10.4	6.3	9.5	2.7	1.2	0.5
Northants	11.1	3.7	13.6	4.9	1.2	0.1
Norfolk	33.0	16.5	8.3	3.7	0.6	0.1
Northumber land	12.9	2.7	8.1	2.0	0.6	0.0
Nottingham shire	15.6	5.5	11.4	3.5	0.7	0.2
North Yorkshire	16.7	10.0	6.0	1.6	0.5	0.1
Orkney	0.0	0.0	0.0	0.0	0.6	0.3
Oxford	20.0	4.0	4.9	0.0	1.1	0.3
Powys	11.7	5.9	2.3	0.0	0.0	0.0
Salop	26.9	4.4	9.7	1.9	0.8	0.1
Strathclyde Region	6.6	2.3	4.0	1.7	0.3	0.0
Shetland	0.0	0.0	0.0	0.0	0.0	0.0
Scilly Isles	-	-	-	-	0.8	0.3
Suffolk	23.5	8.8	7.4	1.5	0.4	0.1

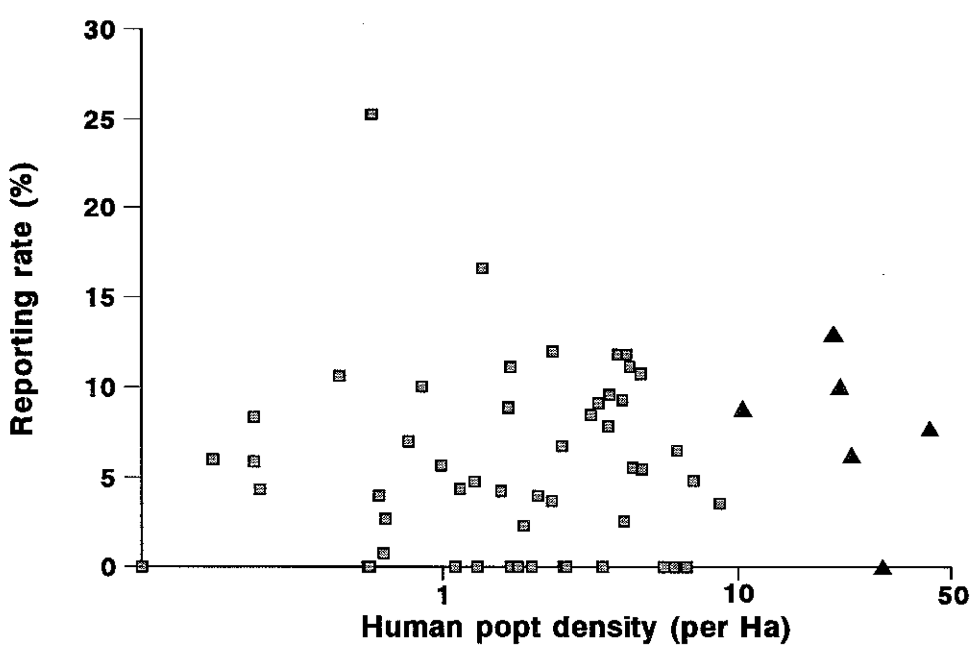
Somerset	66.7	0.0	2.9	1.9	0.4	0.2
Surrey	20.8	6.5	11.1	4.0	0.6	0.2
Stafford-shire	29.4	11.7	25.0	3.5	0.7	0.0
Sussex	27.9	9.6	8.4	0.9	1.1	0.3
South Yorkshire	73.2	3.6	2.5	0.8	0.8	0.4
Tayside Region	4.0	0.0	4.7	1.1	0.3	0.1
Tyne & Wear	30.0	10.0	0.0	0.0	0.3	0.0
Western Isles	-	-	-	-	0.0	0.0
Warwick-shire	43.2	6.8	12.2	3.2	0.4	0.0
West Midlands	10.0	0.0	8.3	0.0	1.7	1.7
Wiltshire	25.5	4.3	8.8	5.3	0.5	0.5
West Yorkshire	21.0	8.8	18.9	10.7	1.0	0.1

Figure 1: County-specific reporting rates (%) derived from all "found dead" (no known cause) recoveries only for (a) Tawny Owl, (b) Barn Owl and (c) Song Thrush in relation to human population density. Reporting rates for the six main conurbations are represented by triangles. Regression statistics are presented as a footnote.

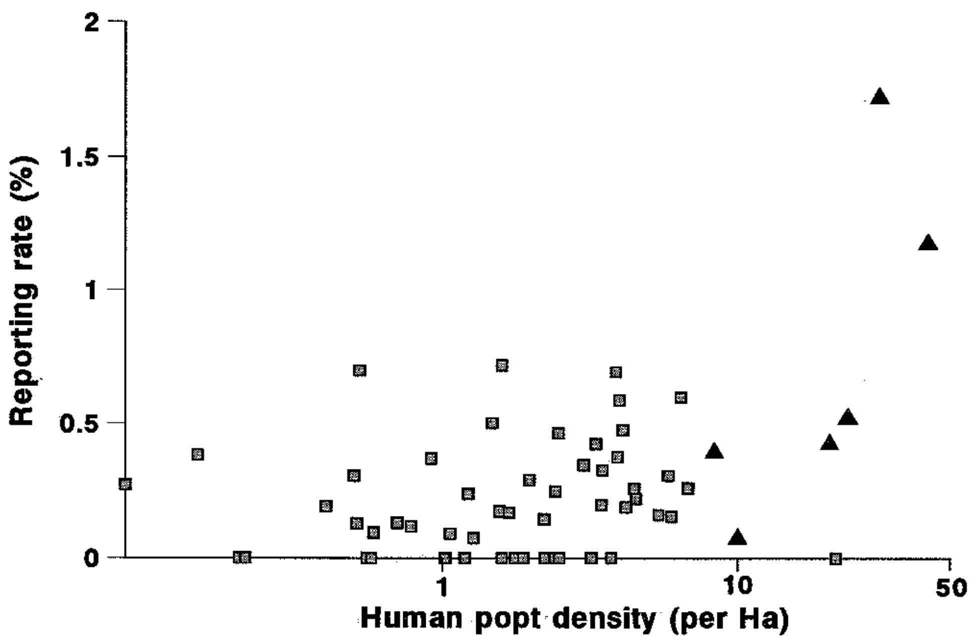
(a) Tawny Owl



(b) Barn Owl



(c) Song Thrush



Footnote:

Summary statistics for the regression of population density on the arcsine transformation of the reporting rate, weighted according to the square root of the numbers of birds ringed in each county, are given below for (i) all data and (ii) excluding conurbations.

Tawny Owl: (i) $R^2=15.5\%$, $P<0.005$
(ii) $R^2=5.5\%$, $P=0.05$

Barn Owl: (i) $R^2=0.0\%$, NS
(ii) $R^2=0.0\%$, NS

Song Thrush: (i) $R^2=33.5\%$, $P<0.001$
(ii) $R^2=6.4\%$, $P<0.05$

Appendix 3

Appendix 3 Species specific estimates of ring reporting probabilities and some potential co-variates

Species	Status	Found dead reporting probability (%)	Found dead reporting probability corrected by method 1 (%)	Found dead reporting probability corrected by method 2 (%)	Body weight (g)	Abundance (thousands)	Association with humans	Primary plumage colour	Secondary plumage colour	Plumage pattern	Habitat	Conspicuous-ness	Ring area (mm^2)
Grey Heron	R	0.1041	0.10415	0.10415	1800	20	2.31	GY	WH	1	3	9.08	190.800
Mute Swan	R	0.1661	0.16746	0.16746	11000	19	3.31	WH	WH	1	3	10.00	236.640
Canada Goose	R	0.0445	0.04452	0.04452	4500	50	3.15	BR	BK	6	5	8.92	250.800
Wigeon	W	0.0148	0.01098	0.00843	700	200	1.38	GY	RD	5	3	6.08	91.872
Teal	W	0.0113	0.01298	0.01101	300	200	1.46	GY	RD	5	3	5.15	56.840
Mallard	PW	0.0139	0.01682	0.01383	1100	500	3.23	GY	GR	5	3	5.96	114.300
Tufted Duck	PW	0.0230	0.02869	0.02435	750	60	2.23	BK	WH	3	3	5.99	91.872
Goosander	R	0.0531	0.05314	0.05314	1100	5	1.20	WH	GR	5	3	6.50	127.800
Hen Harrier	R	0.0532	0.05325	0.05325	500	1	1.08	BR	BR	6	9	7.58	73.312
Sparrowhawk	R	0.0547	0.05495	0.05495	220	80	2.38	GY	BR	6	7	5.69	50.960
Buzzard	R	0.0587	0.05873	0.05873	900	25	1.31	BR	BR	6	5	7.85	114.300
Kestrel	R	0.0706	0.07085	0.07085	240	140	2.38	BR	WH	6	5	5.85	56.840
Merlin	R	0.0467	0.04669	0.04669	180	1	1.15	GY	WH	6	9	5.08	50.960
Peregrine	R	0.0616	0.06362	0.06362	900	2	1.15	GY	WH	6	9	6.77	114.300
Moorhen	R	0.0261	0.02628	0.02628	320	600	2.77	BK	WH	4	3	5.85	91.872
Coot	R	0.0455	0.04548	0.04548	730	150	2.61	BK	BK	2	3	5.92	114.300
Oystercatcher	PW	0.0220	0.04407	0.03940	550	300	1.31	BK	WH	3	2	7.46	91.872
Lapwing	PS	0.0033	0.01117	0.01316	230	1500	1.77	GR	WH	3	5	5.69	44.590
Snipe	PW	0.0040	0.00906	0.00695	100	60	1.15	BR	WH	6	4	3.23	37.100
Curlew	PW	0.0084	0.01749	0.01653	750	70	1.23	BR	WH	6	2	5.62	91.872
Redshank	PW	0.0135	0.02381	0.02114	120	70	1.15	BR	WH	6	2	4.23	44.590
Black-headed Gull	R	0.0330	0.03307	0.03307	290	400	3.31	WH	GY	1	5	7.69	56.840
Common Gull	PW	0.0221	0.01226	0.01956	400	100	2.31	WH	GY	1	5	7.62	56.840
Lesser Black-backed Gull	S	0.0255	0.05790	0.03939	830	170	2.23	WH	GY	1	2	8.23	114.300
Herring Gull	R	0.0379	0.03796	0.03796	1000	250	3.00	WH	GY	1	2	8.31	114.300
Great Black-backed Gull	R	0.0378	0.03790	0.03790	1700	38	1.92	WH	BK	1	2	8.92	127.800

Species	Status	Found dead reporting probability (%)	Found dead reporting probability corrected by method 1 (%)	Found dead reporting probability corrected by method 2 (%)	Body weight (g)	Abundance (thousands)	Association with humans	Primary plumage colour	Secondary plumage colour	Plumage pattern	Habitat	Conspicuous-ness	Ring area (mm^2)
Stock Dove	R	0.0104	0.01040	0.01040	300	200	2.23	GY	GY	6	5	5.31	56.840
Woodpigeon	R	0.0195	0.01961	0.01961	480	5000	3.23	GY	RD	4	5	6.00	91.872
Collared Dove	R	0.0208	0.02080	0.02080	180	200	4.23	GY	BR	6	10	5.54	56.840
Turtle Dove	S	0.0064	0.01293	0.01144	140	200	1.85	BR	RD	6	6	4.92	45.150
Cuckoo	S	0.0129	0.03161	0.02546	120	50	1.69	GY	WH	6	7	5.00	45.150
Barn Owl	R	0.0810	0.08179	0.08179	350	9	3.08	BR	WH	6	5	6.92	114.300
Little Owl	R	0.0362	0.03650	0.03650	160	20	1.69	BR	WH	6	7	4.31	56.840
Tawny Owl	R	0.0479	0.04786	0.04786	440	150	2.46	BR	WH	6	7	5.85	114.300
Long-eared Owl	R	0.0429	0.04290	0.04290	260	12	1.15	BR	WH	6	8	5.85	114.300
Short-eared Owl	R	0.0393	0.03930	0.03930	300	10	1.00	BR	WH	6	9	5.85	114.300
Swift	S	0.0079	0.02782	0.02983	45	200	4.69	BR	BR	2	10	3.00	13.040
Kingfisher	R	0.0159	0.01594	0.01594	40	14	1.38	BL	RD	5	4	4.00	13.040
Green Woodpecker	R	0.0363	0.03630	0.03630	200	25	1.61	GR	YW	5	7	5.54	45.150
Great Spotted Woodpecker	R	0.0251	0.02511	0.02511	80	70	2.00	BK	WH	3	7	5.31	37.100
Skylark	R	0.0033	0.00329	0.00329	40	4000	1.46	BR	WH	6	5	2.15	20.900
Sand Martin	S	0.0006	0.00152	0.00162	15	600	1.38	BR	WH	6	3	2.00	16.830
Swallow	S	0.0015	0.00368	0.00457	20	1000	4.38	BL	WH	5	10	2.69	16.830
House Martin	S	0.0023	0.00557	0.00742	18	900	4.76	BL	WH	4	10	2.85	16.830
Meadow Pipit	PS	0.0030	0.00168	0.00171	20	2000	1.15	BR	WH	6	9	1.62	16.830
Rock Pipit	R	0.0031	0.00315	0.00315	25	100	1.15	BR	WH	6	2	1.62	15.620
Yellow Wagtail	S	0.0011	0.00203	0.00251	19	200	1.31	YW	GR	5	5	3.08	16.830
Grey Wagtail	R	0.0027	0.00280	0.00280	19	75	1.31	GY	YW	5	3	3.31	16.830
Pied Wagtail	R	0.0092	0.00926	0.00926	25	600	3.31	WH	BK	3	5	3.54	16.830
Dipper	R	0.0045	0.00452	0.00452	65	60	1.15	BR	WH	4	3	3.38	27.500
Wren	R	0.0018	0.00185	0.00185	10	6000	3.38	BR	BR	6	6	1.15	15.180
Dunnock	R	0.0043	0.00436	0.00436	20	4500	3.69	BR	GY	6	6	1.31	16.830
Robin	R	0.0064	0.00642	0.00642	19	7000	4.08	BR	RD	5	7	2.15	16.830
Redstart	S	0.0010	0.00172	0.00213	16	280	1.38	GY	RD	5	7	2.42	16.830
Stonechat	PS	0.0030	0.00227	0.00233	15	90	1.23	BR	RD	5	5	2.12	16.830
Wheatear	S	0.0015	0.00271	0.00291	25	160	1.15	GY	BR	4	9	2.92	16.830

Species	Status	Found dead reporting probability (%)	Found dead reporting probability corrected by method 1 (%)	Found dead reporting probability corrected by method 2 (%)	Body weight (g)	Abundance (thousands)	Association with humans	Primary plumage colour	Secondary plumage colour	Plumage pattern	Habitat	Conspicuous-ness	Ring area (mm^2)
Blackbird	R	0.0216	0.021632	0.021632	95	9000	3.92	BK	BK	2	7	3.50	37.100
Fieldfare	W	0.0048	0.016288	0.018802	110	1000	1.77	BR	GY	6	5	4.07	37.100
Song Thrush	R	0.0128	0.012816	0.012816	80	3000	3.31	BR	WH	6	7	3.54	24.750
Redwing	W	0.0030	0.009698	0.011195	65	1000	1.92	BR	WH	6	5	3.54	24.750
Mistle Thrush	R	0.0215	0.021584	0.021584	120	600	2.61	BR	WH	6	7	4.15	37.100
Sedge Warbler	S	0.0005	0.000925	0.001336	12	600	1.08	BR	WH	6	4	1.31	16.830
Reed Warbler	S	0.0008	0.001458	0.002107	12	120	1.08	BR	WH	6	4	1.38	16.830
Lesser Whitethroat	S	0.0008	0.001503	0.001863	12	100	1.38	GY	WH	6	6	1.54	16.830
Whitethroat	S	0.0009	0.002368	0.002539	15	900	1.62	BR	WH	6	6	1.62	16.830
Garden Warbler	S	0.0007	0.001269	0.002173	20	400	1.69	BR	BR	6	7	1.46	16.830
Blackcap	S	0.0008	0.001647	0.002042	17	1600	2.23	GY	WH	6	7	1.62	16.830
Chiffchaff	S	0.0003	0.000566	0.000626	8	900	2.23	GR	WH	6	7	1.23	15.180
Willow Warbler	S	0.0005	0.000970	0.001202	8	5000	2.23	GR	WH	6	7	1.23	15.180
Goldcrest	R	0.0010	0.001019	0.001019	6	1100	2.46	GR	WH	6	8	1.15	15.180
Spotted Flycatcher	S	0.0014	0.004345	0.005386	16	400	2.46	BR	WH	6	7	1.69	18.150
Pied Flycatcher	S	0.0004	0.001226	0.001314	12	40	1.38	BK	WH	3	7	1.92	16.830
Bearded Tit	R	0.0018	0.001817	0.001817	15	1	1.00	BR	WH	6	4	2.23	16.830
Long-tailed Tit	R	0.0016	0.001566	0.001566	8	500	2.38	WH	BK	3	7	1.85	15.180
Marsh Tit	R	0.0021	0.002098	0.002098	10	290	1.92	BR	WH	6	7	1.46	16.830
Willow Tit	R	0.0019	0.002069	0.002069	10	150	1.92	BR	WH	6	7	1.46	16.830
Coal Tit	R	0.0030	0.003018	0.003018	9	1200	2.85	GY	WH	6	8	1.62	16.830
Blue Tit	R	0.0043	0.004341	0.004341	10	7000	4.08	BL	YW	5	7	2.08	16.830
Great Tit	R	0.0037	0.003716	0.003716	17	4000	4.00	GR	YW	5	7	2.54	16.830
Nuthatch	R	0.0076	0.007613	0.007613	20	100	2.69	GY	RD	5	7	2.46	20.900
Treecreeper	R	0.0014	0.001420	0.001420	10	450	2.23	BR	WH	6	7	1.08	15.180
Jay	R	0.0326	0.033339	0.033339	160	200	2.31	RD	BK	5	7	5.69	45.150
Magpie	R	0.0308	0.031209	0.031209	220	500	3.69	BK	WH	3	7	7.00	56.840
Jackdaw	R	0.0294	0.029724	0.029724	240	1000	3.31	BK	BK	2	5	5.31	56.840
Rook	R	0.0242	0.024544	0.024544	490	1700	2.31	BK	BK	2	5	6.23	56.840
Crow	R	0.0331	0.033414	0.033414	570	2000	2.69	BK	BK	2	5	6.38	91.872
Raven	R	0.0573	0.058126	0.058126	1150	10	1.15	BK	BK	2	9	7.08	127.800

Species	Status	Found dead reporting probability (%)	Found dead reporting probability corrected by method 1 (%)	Found dead reporting probability corrected by method 2 (%)	Body weight (g)	Abundance (thousands)	Association with humans	Primary plumage colour	Secondary plumage colour	Plumage pattern	Habitat	Conspicuous-ness	Ring area (mm^2)
Starling	PW	0.0222	0.017603	0.024841	80	7000	4.62	BK	BK	2	10	3.92	37.100
House Sparrow	R	0.0087	0.008705	0.008705	25	11000	5.00	BR	WH	6	10	2.00	20.900
Tree Sparrow	R	0.0015	0.001496	0.001496	20	570	1.92	BR	WH	6	5	2.00	16.830
Chaffinch	PW	0.0040	0.004286	0.003981	20	10000	3.77	RD	BR	5	7	2.38	16.830
Brambling	W	0.0013	0.003347	0.002620	25	500	1.85	BR	RD	5	7	2.62	16.830
Greenfinch	R	0.0081	0.008136	0.008136	30	1600	3.38	GR	YW	5	6	2.38	20.900
Goldfinch	PS	0.0031	0.003317	0.003343	16	600	2.46	BR	BK	5	6	2.46	16.830
Siskin	PW	0.0042	0.009994	0.006536	12	60	2.31	GR	YW	5	8	2.00	16.830
Redpoll	PS	0.0015	0.001848	0.001862	12	290	1.69	BR	RD	5	7	1.54	16.830
Bullfinch	R	0.0052	0.005195	0.005195	25	650	2.69	RD	BK	5	7	2.58	16.830
Yellowhammer	R	0.0024	0.002432	0.002432	25	3000	1.92	YW	BR	5	5	2.42	16.830
Reed Bunting	R	0.0018	0.001794	0.001794	18	800	1.69	BR	WH	6	4	2.00	16.830

KEY:
For further explanation of these variables and how they were derived see Baillie, McCulloch & Hart, Appendix 1.

Status

R	Resident	W	Winter visitor
S	Summer visitor	PW	Partial winter visitor
PS	Partial summer visitor		

Association with humans
Rank score from 1 (lowest association) to 5 (highest association) calculated as the mean of the scores assigned by 15 experienced ornithologists.

Primary and secondary plumage colours

BK	Black	RD	Red
WH	White	BL	Blue
GY	Grey	GR	Green
BR	Brown	YW	Yellow

Plumage patterns

1	All dark	4	Patches
2	All pale	5	Colour (Red, Yellow or Blue)
3	Pied	6	Cryptic

Habitat

2	Coastal
3	Freshwater
4	Marsh/Reedbed
5	Agricultural land, including pasture
6	Scrub/Hedgerow
7	Deciduous woodland
8	Coniferous woodland
9	Upland heath/montane
10	Urban

Conspicuousness
Rank score from 1 (least conspicuous) to 10 (most conspicuous) calculated as the mean of the scores assigned by 15 experienced ornithologists.

Ring area
Estimated cross-sectional area of ring.