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A Review of the BTO's Nest Record Scheme.

Its value to the Joint Nature Conservation Committee and Country Agencies, and its methodology.

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Summary

(1) The Nest Record Scheme gathers data on the breeding performance of birds in the UK through a network of volunteer ornithologists. These observers complete standard Nest Record Cards for each nest they find, giving details of nest site, habitat, contents of the nest at each visit and evidence for success or failure. Currently the BTO receives a total of *c.* 35,000 records each year, including more than 100 records for *c.* 65 species. Data are computerised according to priorities for population monitoring and for specific research projects. The Nest Record Scheme is the largest, longest running and most highly computerised such scheme in the world and possesses the most advanced and efficient techniques of data gathering, data capture and analyses. There are currently 965,000 records held by the Nest Record Scheme, of which 325,000 are computerised.

(2) The Nest Record Scheme forms part of the BTO's Integrated Population Monitoring programme which monitors the three essential demographic variables; population size, reproduction and survival, and is designed to help determine the causes of population changes by reference to other environmental datasets. Information from the Nest Record Scheme is used by the JNCC and Country Agencies to carry out certain of their statutory duties, both nationally and internationally. The monitoring of reproductive (and survival) rates are essential to allow efficient interpretation of changes in population size and, in the case of long-lived species, to provide early warning of impending changes in population size. There is considerable theoretical and practical evidence to suggest strongly that reliance solely on population sizes and changes could result in inappropriate conservation action. While the Nest Record Scheme cannot measure the breeding productivity per female per year, it can measure success per nesting attempt (in addition to clutch and brood sizes) which for many species is likely to be a useful index of seasonal breeding performance.

(3) The primary aim of the Nest Record Scheme is to monitor annually the breeding performance of a wide range of UK birds as part of the BTO's Integrated Population Monitoring programme, covering major habitat types, foraging guilds and species of conservation interest. Changes in breeding performance are interpreted within the context of (a) the natural variation and long-term trends shown over the past 50 years; (b) population parameters measured by other BTO schemes; (c) weather and other environmental factors and (d) regional and habitat differences.

(4) Annual reports of breeding performance are published in *BTO News* and *Britain's Birds* and notice of significant results sent immediately to JNCC by letter. Recent reports have alerted the JNCC to significant declines in the breeding performance of Raven, Linnet and Reed Bunting, associated with declines in their population size, measured for the seed-eaters by the BTO's Common Bird Census. These reports have also highlighted general trends towards earlier laying (especially in England), generally improving breeding performance, and provided information on the general features of each nesting season.

(5) Monitoring at three levels of detail is undertaken, depending on the numbers of computerised Nest Record Cards available. (a) Measurement of annual changes is currently carried out for 59 species in UK, 47 in England, 15 in Scotland and five in Wales. (b) Measurement of trends based on annual means is currently carried out for 79 species in UK, 73 in England, 36 in Scotland, 23 in Wales and one in

Northern Ireland. (c) Measurement of changes based on means for three-five year periods is carried out for a further six species in the UK, seven in England, 23 in Scotland, 24 in Wales and nine in Northern Ireland. Thus overall, monitoring is carried out for 85 species in the UK, 80 in England, 59 in Scotland, 47 in Wales and ten in Northern Ireland. For many species, analyses show few differences in trends between countries, indicating the value of producing UK statistics for general monitoring purposes.

(6) The 85 monitoring species can be classified as follows; (a) raptors and corvids (20%), waterbirds (18%), resident insectivores (20%), migrant insectivores (23%) and seed-eaters (19%); (b) and as species inhabiting farmland (32%), wood or scrub (30%), wetlands (20%), upland or moorland (13%) and lowland heath (5%). It should be noted that it is only possible to measure breeding peformance up to hatching for nidifugous species (e.g. waders *etc.*).

(7) The Nest Record Scheme receives enough Nest Record Cards annually to monitor the breeding performance of nine species protected under Schedule 1 of the Wildlife and Countryside Act 1981 and 42 species listed on the new List of Species of Conservation Concern (15 *Red*-listed and 27 *Amber*-listed). It also holds sufficient data to allow useful analyses of the breeding ecology for a further six *Red*-listed species and 22 *Amber*-listed species. Thus the Nest Record Scheme covers 70 species on the new List of Species of Conservation Concern.

(8) Another primary aim of the scheme is to undertake detailed analyses of the breeding performance of species of conservation interest. Over 200 scientific papers have been published using Nest Record Cards, including a number of valuable contributions on Schedule 1 or List of Species of Conservation Concern. Recent work at the BTO has concentrated on the breeding performance of lowland buntings (Crick *et al.* 1991, 1994a, in press), moorland birds (Crick 1992a, 1993; Brown, Crick & Stillman 1995) and the use of Nest Records in integrated analyses with other BTO data (Baillie 1990, Baillie & Peach 1992, Peach *et al.* in press).

(9) Site-related information held on Nest Record Cards could be a useful source of information for conservationists. Greater emphasis on the provision of detailed location information has resulted in a steady improvement such that 85% of Nest Record Cards now contain six-figure Grid references. These grid locations will facilitate analyses in relation to grid-based environmental data.

(10) The Nest Record Scheme has benefitted from a number of recent reviews of its operation and function. A major and thorough review was undertaken in 1986-87 by a review group chaired by Dr Ian Newton (Baillie 1988). The main recommendations of the group have been implemented, including a new design for the Nest Record Card to allow more efficient coding and computerisation, a new standard habitat coding system (Crick 1992b) and the development of annual monitoring.

(11) Data is gathered for the BTO's Nest Record Scheme without a formal sampling regime. The problems posed are reviewed in this report and recommendations provided concerning the operation of the scheme, analytical methods for calculations of nesting success, and the need for further validation studies and sensitivity analyses.

(12) The Mayfield method has been developed considerably over the past 30 years and provides a good basis for the analysis of nesting success from Nest Record Cards. The assumptions of the method are reviewed and the need for some further work identified, although none need be considered as high priority.

(13) A review of the effects of nest visiting on nesting success suggests that visits to the nests of solitary nesting birds has little or no effect on nesting success. Repeated visits to colonies of nesting seabirds can have major detrimental effects and it is recommended that such records are not accepted by the Nest Record Scheme. Further research into this aspect would be useful but is not considered essential for the validity of the continued operation of the Scheme.

(14) The seasonal variation in the proportion of nests found by observers has a potentially seriously biasing effect on estimates of breeding performance for many multi-brooded species and some single-brooded species, although any effect is likely to be unimportant for 45% of current monitoring species. The need for further investigations into the importance of this effect for multi-brooded species are highlighted as high priority among the recommendations in the report.

(15) Although there are biases in the distribution of records obtained from different habitats and regions, these can be dealt with analytically by suitable stratification and weighting procedures. To assess whether Nest Record Scheme data are biased with respect to the types of nest recorded, it would be valuable to make comparisons between Nest Record Scheme data and data from intensive autecological studies as opportunities arise.

(16) Support for the Nest Record Scheme represents good value for money for JNCC and Country Agencies in view of the benefits obtained from the high level of dedication provided by volunteers (equivalent to at least 100 full-time staff), funding from BTO of a part-time Scientific Officer and of part of the costs of the JNCC supported SSO and ASO posts, and support from non-JNCC sources to fund additional data processing and analyses. It is the only way in which the JNCC and the Country Agencies could fulfil aspects of their statutory monitoring and other duties so cost-effectively.

(17) This review provides the following general recommendations: (a) to increase communications with JNCC and the Country Agencies so that the Nest Record Scheme can be more responsive to their needs and so that they can be more aware of its capability; (b) data gathering by the Nest Record Scheme would be improved by development of increased cooperation between ringers and nest recorders, the provision of Nest Record Cards by Schedule 1 Licence holders, and the provision of Nest Record Cards by Country Agency staff; (c) to contribute to Integrated Population Monitoring analyses of currently declining species (particularly farmland and other red-listed species) so that the causes of these declines can be identified; (d) to investigate the trends towards earlier laying by a large number of species, given its potential significance for the global warming debate and its implications for biodiversity sustainability; (e) to influence volunteer observers to make more detailed studies in response to analyses undertaken on national Nest Record Scheme datasets. The review also provides a large number of prioritised specific detailed recommendations with respect to validation studies, the analysis of nesting success and fieldwork practice.

1. INTRODUCTION

The conservation of animal populations requires management of those populations and, for management to be targeted properly, the populations need to be monitored accurately. Monitoring allows conservationists to know when to act (because a population has ceased to be sustainable in the long-term) and when action is no longer necessary (because remedial actions have been successful). To increase the value of monitoring, it should be able to reveal the stage of the life cycle that has been affected detrimentally and to suggest possible causes for the declines. This is the basic premise of the BTO's Integrated Population Monitoring programme for UK birds.

Birds have been found to be sensitive bio-indicators of many types of environmental change and pollution (Furness & Greenwood 1994). Birds tend to occur near or at the top of food-chains and are vulnerable to any breaks within a chain or to pollutant bio-accumulation. Thus by monitoring populations of birds it is possible to monitor the functioning of the ecosystems upon which those birds depend. Within the UK, bird population monitoring has been particularly effective because of the large popularity of bird-watching among the public and the considerable interest in birds, as tractable study animals, by the scientific (ecological) community.

The Nest Record Scheme of the BTO forms an essential part of the BTO's Integrated Population Monitoring programme which monitors the three essential demographic variables: population size, reproduction and survival, and is designed to determine the causes of population changes (Baillie 1990). It is particularly cost-effective because it uses data gathered by an extensive network of volunteer birdwatchers from throughout the UK.

The Nest Record Scheme provides an extensive historical database, reaching back over half a century, that is a valuable source of four types of information important to conservation:

(a) trends in breeding performance, to show when any species declines in aspects of breeding performance;

(b) interpretation of trends, allowing an understanding of population processes and how populations should best be managed, through its contribution to the Integrated Population Monitoring programme;

(c) investigations of basic breeding biology;

(d) site-related information, providing precise details of when and where birds have bred, which can be used to help identify places of conservation importance.

It should be noted that the Nest Record Scheme is generally incapable of estimating productivity per female per year because knowledge of repeat nesting by individuals is unobtainable from un-marked birds. However the Nest Record Scheme can obtain information on aspects of breeding performance such as clutch size, brood size, nesting success per nest attempt which can be used as indices of productivity.

Increasingly it is being realised that monitoring population size or density is not enough for conservationists; the monitoring of reproductive and survival rates are essential to allow efficient interpretation of changes in population size and, in the case of long-lived species, to provide early warning of impending changes in population size.

There are good theoretical reasons why population density can be a misleading indicator of habitat quality and population breeding performance (*e.g.* van Horne 1983) and good empirical data that shows how densities are not necessarily related to habitat quality in a linear manner (*e.g.* Vickery *et al.* 1992). Thus, high densities may occur in areas of low breeding performance because there is strong population size regulation on high quality areas (due to processes such as territoriality) leading to relative over-crowding on low quality areas occupied by an essentially non-breeding part of the population (*e.g.* Goss-Custard 1993); or high density areas may be very attractive for breeding birds but the high densities might result in density dependant nest predation that results in low breeding performance (*e.g.* Golden Plovers on limestone areas of the Pennines, Ratcliffe 1976). The theory of population sources and sinks (Pulliam 1988) is based on the relative net breeding performance of subpopulations within a metapopulation, and, to a certain extent, the relative densities of birds in each area is irrelevant. Within regional, country (or European) context, there would be little conservation benefit if apparently high population densities were being maintained in an area purely by population immigration rather than by self-sustaining net breeding performance.

For short-lived species, declines in population size may be due to loss of habitat or a decline in habitat quality (in a very general sense) leading to decreasing breeding performance or survival. Without access to good long-term datasets of breeding performance and survival, remedial conservation action has to be taken without a sound basis or has to wait until some detailed investigative research has been undertaken. The former scenario may provide misjudged action, which is both wasteful of resources and ineffective; the latter scenario defers action, allowing a situation to worsen, increasing the cost of subsequent action or even making restitution impossible.

For long-lived species, declines in population size may only occur after long periods of low survival or reproduction. The classic example is that of the Peregrine, which in the UK suffered from poor breeding performance during the 1940s and 1950s, due to DDT contamination, thereby decreasing the buffering capacity of the non-breeding population to withstand severe mortality of breeding adults due to cyclodiene poisoning from the middle 1950s onwards (Ratcliffe 1993). Monitoring of breeding numbers would not have revealed the problem as efficiently as an "early warning" provided by the monitoring of breeding performance (Pienkowski 1991). Another recent example where declines in breeding performance have preceded declines in population size is provided by the catastrophic breeding failures of seabirds, and particularly Arctic Terns, in Shetland (Monaghan *et al.* 1989).

The aims of this review are twofold: (a) to describe how the Scheme contributes valuable information to the JNCC and Country Agencies and to discuss how such information flow could be increased and more effectively targeted (Chapter 2) and (b) to describe certain aspects of the methodology of data gathering and analysis that are important for the Nest Record Scheme and to outline how such areas of work could be developed further (Chapter 3). Before these chapters we provide a brief outline of the Nest Record Scheme, its background and objectives, recording methods, computerisation and analysis and the implementation of the recommendations of a previous major review by an external group chaired by Professor Ian Newton.

1.1 Outline of the Nest Record Scheme

The BTO's Nest Record Scheme is the largest, longest running and most highly computerised such scheme in the world and possesses the most advanced and efficient techniques of data gathering, data capture and analyses.

The Scheme gathers data on the breeding performance of birds in the UK through a network of volunteer ornithologists. These observers complete standard Nest Record Cards for each nest they find, giving details of nest site, habitat, contents of the nest at each visit and evidence for success or failure. When received by the BTO staff, the cards are checked, sorted and filed away; those for Schedule 1 species are kept under lock and key. Computer programs for the entry and analysis of these data have been developed at the BTO. The programs check the data for errors and calculate first-egg-date, clutch size, nest loss rates at egg and chick stages. Data are computerised according to requirements for population monitoring and for specific research projects. In any year only part of the previous year's cards are computerised (see 2.3.1), together with some part of the historical dataset.

Nest Record Unit products include:

(a) An annual breeding report in *BTO News*, *Britain's Birds* and the *Services in Ornithology* contract report to JNCC;

(b) Contributions to the BTO's Integrated Population Monitoring programme;

(c) Studies of species of conservation interest and of basic breeding biology;

(d) Answers to special requests from JNCC or Country Agencies (*e.g.* the timing of laying of Curlew and Golden Plover to help determine when agricultural stock should be taken off fields in the Peak District ESA);

(e) Assistance to volunteer data analyses.

The Head of Unit (funded under the JNCC contract) is developing standard procedures for measuring breeding performance from nest record data as part of the BTO's Integrated Population Monitoring programme. This work involves maximising data-gathering efficiency, validation and development of analytical methods and the analysis of large datasets within the framework of integrated studies. A part-time Research Officer (funded by BTO) has special responsibility for detailed analysis of datasets for rare or little-studied species, in addition to helping with the routine administration of the Scheme.

The Assistant Nest Records Officer (85% of whose time is supported under the JNCC contract) is responsible for maintaining the Nest Record Card collection and for co-ordinating the computerisation of data, including maintenance of the computer database. She also helps with data analysis and answering data requests.

1.2 Background and objectives of the Nest Record Scheme

The Nest Record Scheme is the oldest such scheme in the world, starting as the Hatching and Fledging Enquiry in 1939 on the initiative of James Fisher and Sir Julian Huxley (The next oldest scheme is New Zealand's, which began in 1950). The aim was to collect comprehensive data on bird breeding biology for the proposed revision of Witherby's

Handbook. Over the years, numbers of Nest Record Cards received have increased to about 35,000 per year for 180-190 species. This is over twice the next largest scheme, the USA's, which receives 12,000 per year. The total number of Nest Record Cards held is 965,000 for 223 species, over twice that of the next largest, the USA's at 400,000. The Nest Record Scheme is the most highly computerised, with over 325,000 on computer, being larger than the total holdings of all other schemes but the USA's, of which only half are computerised.

Over the years, the objectives of the Nest Record Scheme have changed because of changed needs. Today, its objectives are based on the needs of conservationists to monitor the breeding performance of the UK's birds and to analyse current breeding performance in terms of the large historical Nest Record Scheme database. Specifically, the objectives can be stated as follows:

(a) To monitor annually the breeding performance of a wide range of UK birds as part of the BTO's Integrated Population Monitoring programme, covering major habitat types, foraging guilds and species of conservation interest.

(b) To interpret any changes in breeding performance, within the context of:

  (i) the natural variation and long-term trends shown over the past fifty years;

  (ii) population parameters measured by other BTO schemes, *i.e.* changes in population density and in annual survival rates;

  (iii) weather and other environmental factors;

  (iv) regional and habitat differences.

  If such changes and trends are outside the range of normal variation and are potentially detrimental to a population, then the JNCC is alerted.

(c) To provide advice and monitoring information on the breeding of species on Schedule 1 of the Wildlife Countryside Act 1981 and in the *List of Species of Conservation Concern*.

(d) To provide specific information on breeding birds to JNCC and Country Agencies as the need arises, using the long-term nest records dataset.

(e) To investigate long-term trends in the breeding performance in species of conservation interest, within the context of Integrated Population Monitoring analyses and with respect to (b) (i) to (iv) above. As a result of such studies, the JNCC is advised of the need for conservation action or further research.

(f) To undertake methodological studies needed to validate and improve the use of nest records data and to develop appropriate analytical methods.

(g) To investigate the basic biology underlying population processes in European birds, as a means of refining the analysis of nest records data.

1.3 Recording methods

Each Nest Record Card details the history of a single breeding attempt at an individual nest. Observers record species, county, year, their name (or personal code), place name, six-figure grid reference, altitude, dates of each visit, numbers of eggs or young, codes to describe the development of nests, eggs, young, activity of the parents and the outcome of the nest (giving cause of any failure if known). On the reverse of the card are "tick-boxes" to allow a description of the habitat surrounding the nest and a description of the nest site itself; spaces are provided to record the height of the nest above ground and to give floristic or other details of habitat and nest site. To provide linkage with the BTO's ringing scheme database, ringers are asked to record the ring number and EURING age code of male and female parents and the first and last ring numbers of the series used to ring the young.

A time-efficient Colony Nest Record Sheet is available on which location and visit details need only be recorded once to cover visits to all nests in a colony. The same information is recorded on this sheet as on individual Nest Record Cards but, in addition, counts are requested for the estimated peak number of occupied nests and of pairs of birds in the colony, and notes made of other species breeding in the colony.

Each observer is provided with a guide booklet (Crick *et al.* 1994b) that:

(a) explains the value and need for nest recording, emphasising the scheme's valuable monitoring role;

(b) explains how to record observations onto Nest Record Cards;

(c) provides a code of conduct that emphasises the responsibility of recorders towards the safety of the birds that they record and explains their legal responsibilities, especially with respect to species protected under Schedule 1 of the Wildlife and Countryside Act 1981.

When received at BTO HQ, nest records are checked for obvious errors, sorted by species and filed by species and year; those for Schedule 1 species are kept under lock and key. Feedback to volunteer recorders is important to maintain the interest of volunteers and to improve standards and to target special effort towards species within the monitoring programme. Each is thanked by note or letter (depending on the quality and size of their contribution), and sent a free annual newsletter which reports on the scheme's achievements and provides advice and encouragement.

The Nest Record Card has been designed to facilitate ease of recording by volunteers and data capture onto the computer. Much of each record is written in code-form by observers, allowing efficient data capture by commercial data processing companies, and the "tick-box" system for recording habitat and nest site allows data capture by optical mark reader. It is planned to enhance data processing efficiency further by developing a computer program for the input of Nest Record Cards to computer by volunteers for transferral to BTO HQ on disk.

Nest Record Cards which only record one visit to a nest only provide information on nest site details and habitat and the stage of the nest, without allowing the calculation of nest survival rates. In order to promote multiple visits to nests, from 1989 the scheme's annual newsletter to volunteer recorders has highlighted the number of multiple-visit cards sent by each contributor of 100 or more cards. This has resulted in steady improvements in the quality of Nest Record Cards received: the average proportion of multi-visit cards from each contributor is now *c.* 90%.

1.4 Computerisation and analysis

Computer programs for entry and analysis of nest records data have been developed by the BTO. The programs check the data for errors such as mis-ordering of visits and calculate range estimates for first-egg-date, clutch size and other variables. Other programs implement the Mayfield (1961, 1975) method for estimating loss-rates of whole nests and of individual eggs and chicks (providing an estimate of partial losses). The Mayfield programs use the method of Johnson (1979) to estimate variances (see 3.1.2.2.1).

The change to a new recording card in 1990 (see below) necessitated the development of a new inputting program. This has allowed the use of a powerful relational database system ("Prime Information") on the BTO's mini-computer. Access to and manipulation of nest records data has thereby become significantly easier and more rapid, while still allowing use of previously developed checking and analytical programs. Over the course of 1995/1996 the BTO's databases will be transferred to the Oracle system, requiring a period during which program conversion will be required.

In order to monitor the annual breeding performance of a species, the Nest Records Scheme needs to receive at least 100 and preferably more than 150 records of sufficient quality per year. Quality is defined by the accuracy and succinctness (the latter allowing easier transfer to computer) of the data recorded and by the frequency of visits made to each nest (allowing greater precision of the estimation of breeding parameters, such as laying date). Monitoring annual changes and long-term trends in breeding performance require comparison with parameter estimates from previous years, obtainable only from the Nest Records Scheme's historical card holdings, dating back to 1939. Detailed analysis requires:

(a) the use of a powerful statistical package and a computer system which can handle large datasets (currently the BTO uses SAS);

(b) the availability of data sets from other BTO schemes which can allow the calculation of comparable measures of population size and survival rates;

(c) extensive environmental data sets (many of which are held by the BTO on computer).

1.5 Nest Record Scheme Technical Review Group

A major and thorough review was undertaken in 1986-87 by a review group chaired by Dr Ian Newton (Institute of Terrestrial Ecology) and a report was compiled by Dr S R Baillie in 1988. The main recommendations of the review have now been implemented.

In particular, the group recommended that the Nest Record Scheme should have the objectives listed in section 1.2. The scheme has been efficiently redirected and reorganized to pursue these objectives.

Another major recommendation was to re-design the Nest Record Card to allow more efficient coding and computerisation, thereby providing the capacity for the cards to be computerised by external data preparation agencies. A prototype card was tested in 1989, was modified slightly and then brought into full use in 1990. This was well received by the scheme's volunteer contributors and recording rates have been as high as ever in the scheme's history (over 30,000 per year since 1990). Data capture was made especially efficient by the ability to use an optical mark reader for part of the data.

The 1986-87 review group also recommended that habitat recording should be refined, with the aim of producing a coding scheme that could be used throughout the BTO Integrated Population Monitoring programme. A simple-to-use hierarchical coding system was devised and introduced on the new card. It is based on vegetation structure but includes aspects of land management and human activity (Crick 1992b). It is fully compatible both with past BTO habitat coding systems and with the JNCC/RSNC Phase 1 habitat classification system, while possessing several advantages over the latter (especially with regard to the inclusion of farmland habitats and ease of use by birdwatchers with limited botanical knowledge).

Finally, the group discussed the requirements for methodological studies. The key aspects are reviewed in detail in section 2 of this report, covering the estimation of nesting success, the effect of nest visiting, seasonal variation in the proportion of nests found and the distribution of samples between regions and habitats.

2. THE VALUE OF THE NEST RECORD SCHEME TO JNCC AND COUNTRY AGENCIES

2.1 Statutory value

Information from the BTO's Nest Record Scheme is essential to allow the JNCC and Country Agencies to carry out certain of their statutory duties, both nationally and internationally. Accurate information on the conservation status of the majority of wild birds that breed in the UK is only cost-effectively possible through the extensive Integrated Population Monitoring programme of the BTO, of which the Nest Records Scheme is an integral part.

The monitoring of species of conservation interest in the UK was a function transferred to the JNCC by the Environmental Protection Act 1990 (Section 132(1a)) from the NCC Act 1973. Population monitoring is an important requirement to allow the JNCC:

(a) under the Environmental Protection Act 1990, to provide advice on nature conservation policy development and implementation to government at the UK level (Section 133(2b));

(b) under the EU Wild Birds Directive, to attempt to maintain populations of wild birds (Article 2), to apply special conservation measures for species on Annex 1 of the directive (Article 4.1), to undertake studies of the biological status of birds on Annex III/3 (Article 6.4), to ensure the ecologically balanced control of populations of hunted species on Annex II (Article 7), to monitor pest (and other) species that are subject to derogations from the provisions in the Directive (Article 9), to research the role of certain species as indicators of pollution and to study the adverse effect of chemical pollution on population levels of bird species (Article 10.2), and to report to the Commission on the implementation of the Directive (Article 12.1);

(c) under the Ramsar Convention, to underpin management of waterfowl populations (Article 4.4);

(d) under the Bern Convention, to conserve natural fauna (Article 1.1) and to maintain populations of wild fauna (Article 2);

(e) under the Bonn Convention, to determine the conservation status of migratory species (Article 1.1c) and to monitor migratory species of unfavourable conservation status (Article 2).

(f) under the Biodiversity Convention, to monitor through sampling the components of Biological Diversity (Article 7).

In each of the international Directives and Conventions, as well as in the UK's national legislation there is a requirement that research should be encouraged on wild bird populations to increase each nation's understanding of the conservation needs of species and to allow better management of their populations (EU Wild Birds Directive Article 10.1, Ramsar Convention Article 4.3, Bern Convention Article 11.1b, Bonn Convention Article V (5c), Environmental Protection Act 1990 Section 133 (2e), UK Biodiversity Action Plan - Action Points 22, 33, 49). The JNCC's support for research within the BTO's Nest Records Scheme helps to satisfy this requirement in a cost-effective way by taking advantage of the availability of the BTO's unique national data banks and network of volunteer observers.

The Biodiversity Convention (Article 8), EU Habitats Directive (Article 3, incorporating the EU Birds Directive Article 4.1), Ramsar Convention (Article 2.2), Bern Convention (Article 4.3) and Bonn Convention (Article 2) require the designation of sites of conservation value. This depends in many cases on the availability of information on breeding records and distribution patterns. The Nest Records Scheme can supply site-related information which could help in these procedures.

The JNCC is required, under the Environmental Protection Act, Section 133 (2d), to promote the adoption of common standards throughout the UK. This objective is also espoused in Action Point 50 of the UK Biodiversity Action Plan. One way of achieving this objective is to promote extensive standardised population monitoring research and analysis through the UK-wide network of observers contributing to the BTO's Nest Records Scheme.

The Nest Records Scheme is a source of information that is also essential to the Country Agencies, if they are to carry out the functions described in the Environmental Protection Act 1990:

(a) in order to pursue nature conservation and foster the understanding thereof (Section 131(1)), the Agencies are required to take appropriate account of actual or possible ecological changes (Section 131(2));

(b) a duty to monitor species of conservation interest within each country was transferred to the Agencies from the NCC Act 1973 (Section 132(1a));

(c) the Agencies should provide advice to the Government on the development and implementation of policies for or affecting nature conservation in their area (Section 132(1c)).

To fulfil these requirements with respect to breeding birds, the Country Agencies need the extensive population monitoring datasets of the BTO's Integrated Population Monitoring programme and especially the regional breeding performance measures provided by the Nest Record Scheme.

The Nest Record Scheme contains site-specific information that could be used to assist Country Agencies in the establishment, maintenance and management of nature reserves in their areas, as required under Section 132(1b) of the Environmental Protection Act 1990.

Information provided to the JNCC by the Nest Record Scheme allows the JNCC to advise the Agencies on national and international conservation, as prescribed in the Environmental Protection Act 1990, Section 133(3). The conclusions from analyses of the whole UK dataset provide Country Agencies with advice of more general applicability than from studies based on data from one country alone. The UK-wide datasets are larger and cover a wider range of circumstances.

2.2 The Nest Record Scheme as part of the BTO's Integrated Population Monitoring programme

In modern conservation parlance, monitoring involves surveillance - that is, repeated survey using standard methods - plus the following (from Greenwood *et al.* (1994):

(a) A clear understanding of the objectives of the programme.

(b) Assessment of any changes against some standard or target (and relative to the normal range of variation).

(c) The gathering of data in such a way that the reasons for departure from the standard may be illuminated.

(d) A mechanism by which the results of the monitoring are translated into conservation action.

The BTO's Integrated Population Monitoring programme (Baillie 1990) draws together information on population levels from census and ringing schemes, on breeding performance from the nest record and ringing schemes and on survival from the ringing scheme with the aim of producing population models for breeding birds in the UK. The objective of this is to monitor the bird populations in relation to normal population levels and demographic rates and to establish "alert limits" for departures from normality, such that the JNCC and Country Agencies can be made aware of potential problems and take appropriate action. An essential aspect of this programme is to use environmental datasets, particularly weather, to distinguish those changes that might be due to "natural" causes and those due to anthropogenic changes in the environment.

Examples of Integrated Population Monitoring analyses include the following:

(a) Declining Sedge Warbler populations (Peach *et al.* 1991), in which declines were found to be associated with poor over-wintering survival and below average rainfall in the sahel wintering quarters. A subsequent analysis of the population dynamics of Palaearctic-African migrant warblers (Baillie & Peach 1992) showed that over-wintering survival was the most important factor for three other species.

(b) Magpies and songbirds (Gooch *et al.* 1991), in which no evidence was found for a deleterious effect of increasing Magpie densities on songbird populations or breeding success.

(c) Population dynamics of Barn Owl and Tawny Owl (Percival 1990, 1992) which demonstrated improving breeding performance and survival for southern Barn Owl populations. Key factor analysis showed that egg survival could be important in determining population fluctuations for Tawny Owl, although post-fledging mortality was the key factor.

(d) Declining Lapwing populations, which have been shown not to be due to declining survival rates (see section 3.3.1.5 below), but possibly due to poor productivity per nesting attempt.

Although, examples (a) and (c) do not suggest a strong role for breeding performance in determining population levels, they do serve to allow conservationists to allocate resources efficiently towards the non-breeding season, should any have been necessary. The Integrated Population Monitoring programme is still at an early stage of development, with effort having been concentrated on producing systems for integrating the BTO datasets. The BTO is only now getting to the stage when Integrated Population Monitoring data modelling is practical. Further examples will be provided below to indicate the importance of changes in breeding performance, as measured by the Nest Record Scheme, for other species (*e.g.*

Merlin, Golden Plover, seed-eating passerines); these will be important areas in which to implement Integrated Population Monitoring analyses.

2.3 Annual monitoring

The Nest Record Scheme has produced an annual monitoring report since the 1988 breeding season. This has grown in numbers of species covered and in depth and sophistication of analysis. It is published in *BTO News*, *Britain's Birds* and the *Services in Ornithology* contract report to JNCC, and its most important results are highlighted in a letter to JNCC.

The most recent report (for the 1993 season) discussed laying dates, clutch sizes, brood sizes, and daily nest failure rates over incubation and nestling periods and for the whole cycle from egg-to-fledge. The 1993 report covered 49 species of a broad range of ecological types and used 219,315 records from 1962-1993. Such broad-based monitoring provides great strength to the conclusions drawn. A discussion of the possible influence of weather on breeding performance was provided. Analyses were undertaken at UK and country levels and the report provided explicit alerts to the JNCC about species with declining breeding performance in relation to knowledge of population trends.

2.3.1 Species coverage

In 1993, a year typical of the past nine seasons, the BTO received more than 150 Nest Record Cards for 55 species and more than 100 for a further 11 species.

The priorities for inputting are those species for which the BTO monitors breeding performance annually with respect to long runs of data from previous years (generally back to 1962, the start date for the Common Birds Census). The number of "monitoring species" for which the BTO usually receives more than 100 cards per year has increased to 51 and the number of species for which fewer than 100 cards per year are received now numbers 34. The latter are not analysed annually but every three to five years.

Not all monitoring species are covered in each report because of limitations on inputting capacity, although all are computerised before the next season's analysis. For 28 monitoring species more than 150 records are received each year so a sample of 150 Nest Record Cards are computerised initially, these being the Nest Record Cards used in the published annual report and the remaining Nest Record Cards for these species (up to a maximum of 450) are computerised later so that they can be included in subsequent analyses.

Three types of monitoring are undertaken, depending on the numbers of Nest Record Cards available. First, with sufficient Nest Record Cards in any one year (at least 50), it is possible to test for differences between observed and predicted values of breeding performance for that year, based on the trends found over previous years (for details of analytical procedures see 2.3.2.1). For example, mean clutch size in 1993 was compared with a prediction based on regression of clutch size and year, calculated over 1962-1992. Currently this procedure is possible for 59 species at the UK level, for 47 in England, 15 in Scotland and five in Wales (Table 2.3.1a).

Second, with sufficient Nest Record Cards computerised over the monitoring period from 1962 onwards (at least 300), it is possible to measure trends in breeding performance based on annual means. Currently this is possible for 79 species in the UK, 73 in England, 36 in Scotland, 23 in Wales and one in Northern Ireland (Table 2.3.1b).

Third, where there are at least 100 Nest Record Cards computerised over the monitoring period from 1962 onwards, it is possible to assess changes in breeding performance based on means for three-five year periods. Currently this is undertaken for six species in the UK, seven in England, 23 in Scotland, 24 in Wales and nine in Northern Ireland (Table 2.3.1b).

Overall, therefore, monitoring is carried out for 85 species in the UK, 80 in England, 59 in Scotland, 47 in Wales and ten in Northern Ireland. For many species, analyses show few differences in trends between countries, indicating the value of producing UK statistics for general monitoring purposes. While in some cases, regional differences in trends can be very illuminating in the understanding of the causes of change (see below), such differences are relatively infrequent.

Table 2.3.1a List of species for which annual difference monitoring is currently undertaken by the Nest Records Scheme. The species are divided into five very broad ecological groups. Countries are referenced by their initial letters.

Species	No. Nest Record Cards in 1993	Countries covered by annual difference monitoring
(a) "Raptors and corvids"		
Grey Heron	384	UK,E,S
Hen Harrier	57	UK
Sparrowhawk	245	UK,E
Buzzard	177	UK,S
Kestrel	228	UK,E
Merlin	135	UK,E,S
Peregrine	91	UK,S
Barn Owl	308	UK,E,S
Little Owl	48	UK
Tawny Owl	381	UK,E,S
Magpie	319	UK,E
Rook	862	UK,E
Carrion Crow	303	UK,E,W
Raven	87	UK,W
(b) "Waterbirds and waders"		
Red-throated Diver	93	UK,S
Mute Swan	349	UK,E,S
Moorhen	470	UK,E
Oystercatcher	657	UK,E,S,W
Ringed Plover	360	UK,E,S
Lapwing	861	UK,E,S
Curlew	56	UK
Grey Wagtail	190	UK,E,W
Dipper	306	UK,E,S,W
(c) "Resident Insectivores"		
Meadow Pipit	141	UK,E
Pied Wagtail	298	UK,E,S
Wren	369	UK,E
Dunnock	346	UK,E
Robin	361	UK,E
Song Thrush	710	UK,E
Mistle Thrush	141	UK,E
Long-tailed Tit	189	UK,E

	No. Nest Record Cards in 1993	Countries covered by annual difference monitoring
Nuthatch	182	UK,E
Treecreeper	54	UK
Starling	461	UK,E
(d) "Migrant Insectivores"		
Nightjar	58	UK,E
Swallow	1346	UK,S
Redstart	139	UK,E
Wheatear	90	UK,S
Sedge Warbler	81	UK,E
Reed Warbler	253	UK,E
Whitethroat	60	UK,E
Garden Warbler	64	UK,E
Blackcap	62	UK,E
Wood Warbler	71	UK,E
Chiffchaff	52	UK
Willow Warbler	132	UK,E
Spotted Flycatcher	203	UK
(e) "Seed-eaters"		
Stock Dove	224	UK,E
Collared Dove	208	UK,E
Woodlark	96	UK,E
Skylark	72	UK,E
Chaffinch	339	UK,E
Greenfinch	143	UK,E
Goldfinch	80	UK,E
Linnet	340	UK,E
Bullfinch	57	UK,E
Yellowhammer	110	UK,E
Cirl Bunting	62	UK,E
Reed Bunting	48	UK,E

Table 2.3.1b List of species for which trend monitoring is undertaken by the Nest Records Scheme. The species analysed are divided into five very broad ecological groups. Countries are referenced by their initial letters.

Species	Total No. Nest Record Cards	No. Nest Record Cards computerised 1962-1993	Numbers sufficient for trend monitoring	Numbers sufficient for periodic monitoring
(a) "Raptors and corvids"				
Grey Heron	4023	1217	UK,E	S
Hen Harrier	1240	1032	UK,S	W
Sparrowhawk	4376	3690	UK,E,S	W
Buzzard	3674	2997	UK,E,S,W	-
Kestrel	5682	4524	UK,E,S	W
Merlin	2111	1946	UK,E,S	W
Hobby	478	433	UK,E	-
Peregrine	1892	1488	UK,S,W	E,NI
Barn Owl	2730	1941	UK,E,S	W
Little Owl	1472	1181	UK,E	-
Tawny Owl	6137	4786	UK,E,S	W
Long-eared Owl	609	469	UK,E	S
Short-eared Owl	332	239	-	UK,S,E
Magpie	6154	3814	UK,E,W	NI
Rook	9092	3904	UK,E	W,NI
Carrion Crow	5830	3820	UK,E,W	S
Raven	2602	1867	UK,E,W,S	-
(b) "Waterbirds and waders"				
Red-throated Diver	1907	878	UK,S	-
Mute Swan	4431	3243	UK,E,S	-
Moorhen	18559	4736	UK,E,S	W
Oystercatcher	11247	4805	UK,E,S,W	-
Ringed Plover	7090	5841	UK,E,S	W,NI
Golden Plover	804	639	UK,E	S
Lapwing	18642	5357	UK,E,S,W	-
Dunlin	500	381	UK	S
Snipe	1377	1008	UK,E,S	-
Curlew	2474	1763	UK,E,S	W
Redshank	1977	1493	UK,E	S
Greenshank	154	148	-	UK,S
Kingfisher	552	479	UK,E	-
Grey Wagtail	4941	3849	UK,E,S,W	-

Species	Total No. Nest Record Cards	No. Nest Record Cards computerised 1962-1993	Numbers sufficient for trend monitoring	Numbers sufficient for periodic monitoring
Dipper	8003	6095	UK,E,S,W	-
(c) "Resident Insectivores"				
Green Woodpecker	293	219	-	UK,E
Great Spotted Woodpecker	957	825	UK,E	-
Lesser Spotted Woodpecker	156	127	-	UK,E
Meadow Pipit	8265	3485	UK,E,S,W	-
Rock Pipit	654	423	UK	S
Pied Wagtail	8008	4531	UK,E,S,W	-
Wren	12946	7768	UK,E,S,W	-
Dunnock	27982	5972	UK,E,S	W
Robin	17579	11531	UK,E,S,W	NI
Song Thrush	68672	11554	UK,E,S,W	NI
Mistle Thrush	6915	3595	UK,E	S,W
Goldcrest	725	550	UK,E	S
Long-tailed Tit	4176	3198	UK,E	S,W
Marsh Tit	1157	966	UK,E	-
Nuthatch	2394	1930	UK,E,W	-
Treecreeper	2067	1473	UK,E	S,W
Starling	12978	8787	UK,E,S	W,NI
(d) "Migrant Insectivores"				
Nightjar	1205	861	UK,E	-
Sand Martin	994	366	UK	E
Swallow	41471	10471	UK,E,S,W, NI	-
Tree Pipit	1490	1143	UK,E	-
Yellow Wagtail	912	685	UK,E	-
Nightingale	425	337	UK,E	-
Redstart	5124	3863	UK,E,S,W	-
Whinchat	1788	1576	UK,E,S,W	-
Wheatear	3146	2486	UK,E,S,W	-
Grasshopper Warbler	335	260	-	UK,E
Sedge Warbler	4097	3073	UK,E	S
Reed Warbler	9752	7414	UK,E	-
Lesser Whitethroat	772	581	UK,E	-
Whitethroat	5173	3172	UK,E	S,W

Species	Total No. Nest Record Cards	No. Nest Record Cards computerised 1962-1993	Numbers sufficient for trend monitoring	Numbers sufficient for periodic monitoring
Garden Warbler	1583	1249	UK,E	W
Blackcap	2739	2547	UK,E	W
Wood Warbler	1952	1814	UK,E,W	S
Chiffchaff	2159	1650	UK,E	-
Willow Warbler	11117	6331	UK,E,S,W	NI
Spotted Flycatcher	9485	7215	UK,E,S,W	NI
(e) "Seed-eaters"				
Stock Dove	5545	4014	UK,E	S,W
Collared Dove	3216	3063	UK,E	S
Turtle Dove	1834	1492	UK,E	-
Woodlark	686	517	UK,E	-
Skylark	6338	3552	UK,E,S	W
Chaffinch	18940	6203	UK,E,S,W	-
Greenfinch	12721	4186	UK,E,S	-
Goldfinch	2801	2144	UK,E	W
Linnet	24372	5903	UK,E,S	W
Twite	830	664	UK,E	S
Redpoll	1283	1145	UK,E	S
Bullfinch	5016	3828	UK,E	S
Yellowhammer	6218	5005	UK,E	S,W
Cirl Bunting	260	189	-	UK,E
Reed Bunting	7629	3945	UK,E	S,W
Corn Bunting	597	434	UK,E	-

For ease of interpretation, the species are divided into five broad ecological groups. In Table 2.3.1b, there are 17 "raptors and corvids", 15 "waterbirds", 17 "resident insectivores", 20 "migrant insectivores" and 16 "seed-eaters". It is particularly valuable that a large number of raptors be monitored by the Nest Record Scheme because they are not well covered by annual census schemes (although the Breeding Bird survey should provide adequate monitoring in the future). Raptor Study Groups hold good data on some of the rarer species, but lack the capability to carry out rigorous analyses at a country or UK level. The Nest Record Scheme provides such a capability and gathers information on some of the commoner raptors, such as Sparrowhawk and Kestrel, which are valuable country-wide indicator species. It should be noted that for nidifugous species, including most of the waterbirds, the Nest Record Scheme cannot provide information on breeding performance after hatching: the dispersal of chicks away from the nest make chick counts and brood survival almost impossible to record reliably.

If the species are divided into broad habitat categories, then 32% are farmland species, 30% are wood or scrub species, 20% are wetland species, 13% are upland or moorland species and five per cent are lowland heath species.

In *Nest Record News*, which is sent to all participants, we highlight the monitoring species and those for which we particularly need more records by mean of asterisks in the list of Nest Record Card totals. It is now clear that this form of highlighting is ineffective because there is no demonstrable effect on the numbers of Nest Record Cards received for each species. In addition there can be some substantial variations in card receipts for a number of species. For example, in 1993 substantial decreases were recorded for the following species: Hen Harrier (28%), Nightjar (27%), Swallow (33%), Redstart (24%), Greenfinch (20%), and Reed Bunting (49%). Some of these declines in intake rates were worrying because, if persistent, population monitoring of these species may be impaired. While large annual fluctuations in card intake for some species need to be addressed to ensure adequate coverage each year, such variations will not impair the ability to carry out analyses of long-term trends because they are often based on runs of thousands of Nest Record Cards. Long-term trend analyses are conservationally more important than changes in individual years.

2.3.1.1 Candidate monitoring species

There are number of species which are candidates as monitoring species, several which require small amounts of historical data to be input to provide a complete run of data back to 1962 and others which require substantial computerisation (Table 2.3.1.1).

Probably the most important candidate species is the Tree Sparrow which has undergone a population crash on CBC plots (Marchant & Gregory 1995). The BTO currently receives *c.* 200 Nest Record Cards per year for this species and the records have recently been input completely, allowing it to be included in the next annual monitoring report. Similarly, the Stonechat has also recently been input completely.

Six species, for which the BTO receives more than 100 Nest Record Cards per year, have not been computerised at all. House Sparrow would be valuable to monitor as a species with apparently declining populations (Balmer & Marchant 1993). Canada Goose would be useful considering its increasing status as a pest species, although the Country Agencies view this as a low priority. Two species of waterbirds, Great Crested Grebe and Mallard, would provide useful additions to the suite of waterbirds already monitored. Being species in which the nidifugous young are often readily observable and assignable to particular parents, fledging success may be calculable for them in addition to hatching success. Eider as a species for the Nest Record Scheme would only be able to provide information on hatching success. Finally, Coal Tit would provide a valuable monitor of coniferous woodland, a habitat that is largely omitted by the current suite of monitoring species.

Table 2.3.1.1 List of candidate 'Monitoring' Species for the Nest Records Scheme. The numbers of Nest Record Cards needing computerisation assumes 150 Nest Record Cards per year from 1962-1993.

Species	Total No. Nest Record Cards	No. Nest Record Cards in 1993	No. Nest Record Cards computerised	Years computerised	No. Nest Record Cards to be computerised
Great Crested Grebe	2712	168	0	-	2712
Canada Goose	2171	164	0	-	2171
Mallard	7307	217	0	-	4800
Eider	2465	158	0	-	2465
Woodpigeon	20869	744	1976	1962-80	2850
Stonechat	2340	130	2228	1938-93	0
Blackbird	118259	1647	2563	1961-80	2400
Pied Flycatcher	27757	1874	2117	1962-81	4200
Coal Tit	4441	131	0	-	4441
Blue Tit	62093	3337	2019	1962-80	2800
Great Tit	38638	2526	1705	1962-78	3100
House Sparrow	11138	294	0	-	4800
Tree Sparrow	14103	205	4800	1962-93	0

Five further species have been computerised from 1962 until only the early to mid 1980s. Woodpigeon is an important pest species in the UK and there is a case for including this within the monitoring programme as a species that suffers from culling, although the Country Agencies would view this species as a low priority. Pied Flycatcher is a common nestbox species that would be a useful monitor of western and northern woodlands and is not the subject of any long-term academic studies in the UK. One open-nesting species, Blackbird, is widely recorded throughout the country and would provide useful countrywide monitoring in woodland, farmland and urban habitats. Two other common nestbox species, Blue Tit and Great Tit, are also widespread but are of lower priority because they are well-studied as part of long-term academic studies.

A number of these species (Blackbird, Pied Flycatcher, Blue and Great Tits and House Sparrow) are included on the Age Specific Totals lists completed by ringers. These lists allow the calculation of survival rates from the analysis of ringing recovery data. Similarly, Blackbird, Great and Blue Tits are well covered by the Constant Effort Sites (CES) ringing scheme and breeding performance data from the Nest Record Scheme would be valuable for comparison with population changes and survival rates calculated from the CES. Computerisation of the Nest Record Cards of these species would allow their inclusion in Integrated Population Monitoring analyses.

In addition to these species, the BTO receives good numbers of Nest Record Cards or colony sheets for seabirds, including Shag, Gulls (Black-headed, Common, Herring, Great Black-backed), Kittiwake and Terns (Common, Arctic and Little). These are not computerised currently for a number of reasons: (a) the Seabird Colony Register (Lloyd *et al.* 1991) and the JNCC's Seabird Monitoring Programme (Walsh *et al.* 1994) provides good monitoring of seabirds throughout the UK; (b) the data received are often of low quality because of single visits or because nests are not individually marked for identification between visits; (c) the records often report visits that were made at too great an interval to determine fledging success and too little information is provided to allow assessment of the age of the young. The usefulness of these records need to be assessed but this is currently a low priority, considering that seabirds are generally well covered elsewhere.

Finally, there are a number of species for which the BTO needs to encourage more recording as they produce gaps in the monitoring coverage of the Nest Record Scheme. There are four classes of species which are currently under-recorded:

(a) waterfowl, including Little Grebe, Greylag, Egyptian Goose, Shelduck, Mandarin, Wigeon, Gadwall, Teal, Shoveler, Tufted Duck, Red-breasted Merganser, Goosander and Ruddy Duck;

(b) gamebirds and their allies, including Red Grouse, Black Grouse, Capercaillie, Red-legged Partridge, Grey Partridge, Pheasant, Water Rail and Woodcock;

(c) near-passerines and passerines, including Rock Dove, Ring-necked Parakeet, Cuckoo, Swift, Ring Ouzel, Bearded Tit, Crested Tit, Jay, Chough, Hooded Crow, Siskin, Common Crossbill and Hawfinch; and

(d) birds which are monitored (in terms of numbers) by the Rare Breeding Birds Panel, including Slavonian Grebe, Garganey, Pochard, Marsh Harrier, Goshawk, Black Redstart, Cetti's Warbler and Dartford Warbler *Sylvia undata*.

Nearly all of these species pose problems due to relative scarcity, crypsis, susceptibility to disturbance (particularly waterfowl and gamebirds), or inaccessibility of nesting sites. Some groups are well monitored by other organisations (*e.g.* gamebirds by the Game Conservancy Trust and Chough by RSPB), however, some of these species may be sufficiently under-recorded generally to warrant extra efforts by the BTO to encourage increased recording within the Nest Record Scheme (*e.g.* the sawbills, Swift, Ring Ouzel, Jay and Hooded Crow).

2.3.1.2 Schedule 1 & Species of Conservation Concern

The BTO receives good numbers of nest records annually for some species protected under Schedule 1 of the Wildlife and Countryside Act: more than 100 for Hen Harrier, Merlin, Peregrine, Little Tern and Barn Owl, and more than 30 for Red-throated Diver, Goshawk, Little Ringed Plover and Kingfisher *Alcedo atthis*. These species provide enough data to allow monitoring on an annual basis (the first group) or on at least a five-yearly basis (the second group). Such information on rare species in Britain is of great value to the JNCC and Country Agencies.

In *Red Data Birds* (Batten *et al.* 1990), 117 species were listed as being of conservation importance; many because of their breeding populations in the UK. This is now being revised and a provisional classification of species onto *Red* and *Amber* Lists have been produced (Gibbons *et al.* in press). Of the *Red*-listed breeding species (not including those that are listed purely on the basis of their wintering populations in the UK), 14 are Nest Record Scheme Monitoring Species: Hen Harrier, Merlin, Nightjar, Turtle Dove, Woodlark, Skylark, Song Thrush, Spotted Flycatcher, Linnet, Twite, Bullfinch, Cirl Bunting, Reed Bunting and Corn Bunting; one is soon to become a monitoring species: Tree Sparrow; and for six species the Nest Record Scheme has sufficient Nest Record Cards to provide a useful analysis of breeding ecology: Grey Partridge, Stone Curlew, Roseate Tern, Marsh Warbler, Dartford Warbler and Red-backed Shrike.

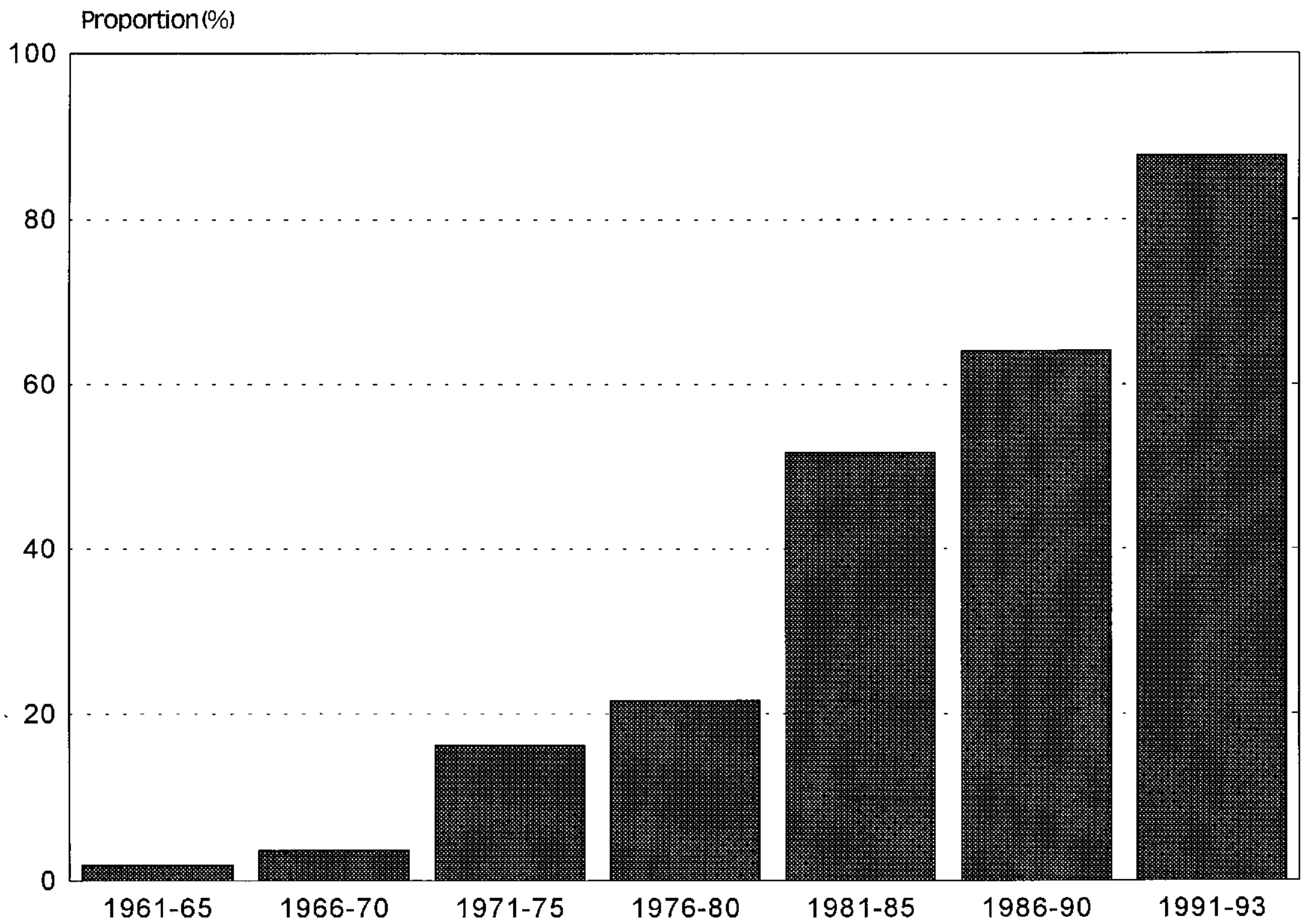
Similarly, of the *Amber*-listed breeding species, 21 are Nest Record Scheme Monitoring Species: Red-throated Diver, Kestrel, Peregrine, Dunlin, Curlew, Redshank, Greenshank, Stock Dove, Barn Owl, Short-eared Owl, Kingfisher, Green Woodpecker, Sand Martin, Swallow, Dunnock, Nightingale, Redstart, Grasshopper Warbler, Marsh Tit, Starling and Goldfinch; one is soon to become a monitoring species: Stonechat; five are candidate monitoring species: Shag, Common Gull, Herring Gull, Arctic Tern, Little Tern and Blackbird; and for 22, the Nest Record Scheme has sufficient Nest Record Cards to provide a useful analysis of breeding ecology: Black-throated Diver, Slavonian Grebe, Shelduck, Goldeneye, Golden Eagle, Avocet, Dotterel, Woodcock, Great Skua, Lesser Black-backed Gull, Sandwich Tern, Guillemot, Razorbill, Black Guillemot, Puffin, Black Redstart, Ring Ouzel, Redwing, Willow Tit, Crested Tit, Chough and Hawfinch.

2.3.1.2.1 Grid references

The provision of six-figure grid references is an important aspect of data quality that affects the uses to which Nest Record Cards can be put. Original versions of the Nest Record Card provided little or no space for grid references but the most recent versions provide well-defined spaces. The Nest Records Unit has put a great emphasis on the provision of such information in recent years, particularly after the Technical Review (section 1.5). As a result, the proportion of Nest Record Cards with six-figure grid references has increased steadily to *c.* 85% in the 1990s (Figure 2.3.1.2.1) and about half of computerised Nest Record Cards now include six-figure references.

The provision of grid references allows better linkage with other BTO datasets and with environmental datasets within the context of Integrated Population Monitoring analyses. Previous analyses have to be based on the county as a geographical unit. Furthermore, six-figure grid references could be useful to conservationists who wish to establish the breeding records that may have occurred within a particular area. This is most valuable with respect to Schedule 1 species, although such information can only be provided after careful consideration of the uses to which it will be put and of the wishes of the contributors of the information.

Figure 2.3.1.2.1 Proportion of Nest Record Cards with 6-Figure Grid References
Taken from 221,850 Nest Record Cards for 55 "Monitoring Species"



	1961-65	1966-70	1971-75	1976-80	1981-85	1986-90	1991-93
n	14,608	27,211	28,960	32,882	44,764	56,628	22,797

Years

2.3.2 Examples of monitoring results

2.3.2.1 Analytical procedures

Data for laying date, clutch size, brood size and nesting failure rates are analysed in relation to long-term trends measured from 1962. 1962 was chosen as the starting date to provide comparability with results on changes in population size from the CBC which began in that year. Linear and quadratic regressions are put through the annual means, weighted by annual sample size, of all years except the most recent year. The value for the most recent year is then compared with its predicted value (and its confidence limits) from the regression. Quadratic regression is used when it provides a significant improvement over linear.

This procedure is repeated for the UK as a whole and then for its constituent countries. Comparison of trends between the countries being made by analysis of covariance to assess differences of slopes.

2.3.2.2 UK monitoring results

From the 1991 monitoring report onwards (Crick *et al.* 1993a), official "alerts" have been issued to the JNCC to highlight worrying trends in breeding performance among the Nest Record Scheme monitoring species.

High alerts were issued in 1991 for Raven, Linnet and Reed Bunting. They were issued because all (i) show evidence of declining breeding population size and (ii) have trends of declining nest success measured from egg-laying to fledging. Reed Bunting and Linnet are experiencing declining nesting success particularly over incubation. These trends have continued in 1992 and 1993, with Reed Bunting producing the smallest average clutch size for 31 years in 1992 and Raven experiencing a bad year in terms of average clutch size and nestling stage nest losses in 1993. The BTO has suggested that research on these species' declines be concentrated on their breeding performance.

Conservation vigilance has been recommended for seven species because of some aspect of declining breeding performance; the declines may be coupled with declining population size or may be considered worrying in view of a species' status as an indicator of some aspect of the environment. (a) Swallow populations have been in general decline since the early 1970s and suffered a trend of increasing nest failure rates during incubation and three years of very high nest losses during the nestling period from 1990-92. (b) Dippers, valuable indicators of stream water quality, are suffering from increasing nest failure during the nestling stage. (c) Nightjar, a species of conservation concern, was shown to have a trend of increasing nest failures from egg-laying to fledging although its population is currently increasing (Morris *et al.* 1994); (d) Nightingale and (e) Twite both exhibited increasing trends of nest loss during nestling stages. (f) Moorhen was added to the list in 1992 because of a long-term trend of decreasing average clutch size, with especially small clutches from 1989. (g) Although Mute Swan population has shown a good recovery after the banning of lead weights for anglers, it had developed a trend of increasing nest losses which, in 1993, appeared to be most pronounced at the chick stage.

Global warming? One of the most striking patterns to come out of the analyses of over 30 years of Nest Record Scheme data was the finding of a large number of significant trends towards earlier average laying dates for a wide range of species (Crick *et al.* 1993a). Thirty-eight of 82 species showed statistically significant trends, 33 towards earlier distributions of laying dates. Twenty-three of these species had trends that were better described by a convex quadratic curve than a straight line. The peak of these curves occurred at 1976 on average, ranging from 1971 to 1981. The average advancement in laying date was eight days. Trends of earlier laying distributions were significantly more frequent among migrant insectivores and among waterbirds than trends of later laying. These are potentially important findings for conservation and urgently need further analysis.

Generally improving breeding performance. Analyses of long-term trends within Nest Record Scheme data have revealed that many species have been improving their breeding performance since the 1970s. Seventeen species show trends towards larger average clutch sizes and only four towards smaller clutches. Twenty-three show trends towards larger brood sizes and only four towards smaller broods. All increases were greater than those expected from any advancement of average laying date. The improvements in brood size are often related to those in clutch size but a substantial number are better than expected from increases in clutch size. Twenty-six species show trends towards improving nest success from egg-laying to fledging and only four towards declining nest success (see *High Alerts* above). Improvements are particularly apparent among raptors and corvids, but also occur in all other groups.

We believe that this pattern, along with those for improving clutch and brood sizes, may be due to the recovery of these populations from the effects of organochlorine pesticides in the 1950s and 1960s. This is another important result for the conservation bodies because it suggests that the replacement of organochlorines with other biocides in the environment has not resulted in similar sublethal poisoning effects on populations of common birds.

General features of each breeding season. The JNCC and Country Agencies have many projects and programmes that monitor the breeding performance of rare birds and birds on nature reserves or other specially protected areas. For the bodies to gauge whether the performance of birds in a particular year is typical of that year, they need to have access to information on the general features of the breeding season in the wider countryside. The annual reports of the Nest Record Scheme provide such information, without relying on "impressions" but by relying on standardised data collection, properly analysed. Thus 1988, 1989, 1990 and 1993 were relatively early years; 1991 and 1993 were relatively poor breeding seasons, with small clutches and high rates of nest loss; 1992 provided a good breeding season, with large average clutches and high nesting success.

2.3.2.3 Country monitoring results

Part of the annual monitoring procedure involves comparison of data from each of the four countries within the UK. So far, this has been implemented for laying dates, clutch sizes and brood sizes. Due to processing complexities, country comparisons have not yet been implemented for nesting success, but this will be instigated from the 1995 breeding season report.

Comparison of the laying dates in the four countries shows that Scottish birds (in at least 22 species) breed significantly later than those in the other countries, as expected from latitude. Four raptors have average laying dates that are significantly earlier in Scotland than England: Kestrel (four days), Sparrowhawk (three days), Barn Owl (14 days) and Tawny Owl (four days) (corroborating intensive studies of Village (1990), Newton (1986), Shawyer (1994)). Oystercatchers breed earlier (nine days overall) in Scotland and Wales compared with England, as do Rooks (nine days). The differences for the raptors and other species may reflect less intensive management of the countryside in Scotland and Wales compared with England, perhaps producing more favourable foraging and nesting conditions.

Since Lack's (1946) paper on clutch size in the Robin, it has been generally recognised that clutch size increases with increasing latitude. This general principle is borne out by the Nest Record Cards for most of the 82 species analysed in the 1991 report, in which it was found that Scottish birds produce the largest average clutch sizes.

There are several species that appear to contradict this general rule and which warrant further investigation. For example, Chaffinches in Scotland lay smaller and later clutches than in England and Wales, suggesting that the country is generally less suitable for the species. In Wales, Carrion Crows lay relatively small clutches and average clutch size is tending to decrease: perhaps indicating that conditions are poor in Wales or that the population is experiencing density-dependent effects of population increase. Clutch sizes in some species are larger in England than in Scotland, perhaps because the country is warmer and food supplies there increase earlier, for example Lapwing (March); Linnet (July); Reed Bunting (overall) and Song Thrush (April). Oystercatcher clutches are largest in Wales and the Hobby produces significantly larger clutches in the English Midlands than in South England, traditionally held to be its stronghold.

Analyses of the long-term trends of laying dates among a subset of the monitoring species have been made at the country level. While the number of species showing trends towards earlier laying equal the number showing trends to later laying in both Scotland and Wales, in England there are 11 species which have become progressively earlier and none later. This significant result suggests that any effect of global warming appears to be manifesting itself among the birds in the lowlands of south and east UK.

UK trends of increasing clutch size and brood size tended to be found in the countries also. Results of conservation interest include trends of decreasing clutch size in Hen Harrier that have been faster in England than in Scotland (by 0.14 egg per year and 0.05 egg per year, respectively). Clutch size among Kestrels in England is tending to decrease while tending to increase in Scotland, which could be an important result, given that the population trend, as measured by CBC, is currently declining. Similarly, clutch size of Tawny Owls is decreasing in England and Wales while increasing in Scotland.

Table 2.3.1b shows the species for which the Nest Record Scheme can provide trends through annual means of breeding performance variables for each of the countries. The type of analyses reported above show the value of being able to provide country comparisons. However, since trends in the countries are only rarely significantly different, the UK overview trends are important and relevant to each country's conservationists. The extensive networks of volunteer observers in each country that contribute to the Nest Record Scheme enables the provision of such comparative analyses very cost-effectively.

2.3.3 Sensitivity analyses

Although the annual monitoring programme has highlighted various significant trends in laying dates, clutch size, brood size and nesting success, it is unclear how much statistical power is available to the non-significant results. Sensitivity analyses are required to determine the power of each test to detect differences or declines over a range of magnitudes and to determine the degree of decline that would be detected from the datasets given current sample sizes and variances. Such sensitivity analyses would need to be undertaken for each species and for each breeding performance variable and would show where more data was needed or when alternative analytical approaches would be appropriate (for example ANOVA on blocks of years instead of regression through the means of individual years). This would be a substantial piece of work.

2.4 Dissemination of information from the Nest Record Scheme

Information is produced by the Nest Record Scheme in a variety of formats. In addition to providing copies of raw or processed data to analysts or in response to queries from JNCC and Country Agencies, analyses are produced which include the annual reports (see above), scientific publications, reader-friendly summaries, and reports to conferences.

Copies of raw data are available to analysts upon request. Original Nest Record Cards can be consulted within BTO HQ but they are not released outside the building for fear of loss. Photocopies of small datasets can be provided or computerised datasets can be provided as print-out or as ASCII-files on disk.

Examples which show how Nest Record Scheme information has made valuable contributions to analyses of Schedule 1 or the List of Species of Conservation Concern including: Black-throated Diver (Mudge *et al.* 1991), Common Scoter (Ogilvie 1989), Black Grouse (Baines 1991), Little Ringed Plover (Parrinder 1989), Barn Owl (Grant *et al.* 1994), Kingfisher (Peterson 1992), Marsh Warbler (Kelsey 1989), Dartford Warbler (Bibby 1979), Red-backed Shrike (Peakall 1962, Bibby 1973) and Cirl Bunting (Robins 1986, Crick *et al.* 1994a). Such studies are fundamental to the establishment of sound management prescriptions.

Requests for specific pieces of information based on nest records data can be processed quickly as a result of computerised analytical procedures. Recently such requests from JNCC and Country Agencies have required details such as the timing of laying of Yellow Wagtails (to determine silage cropping pattern in the Pennines ESA) and of Curlew and Golden Plover (to determine when stock should be taken off fields in the Peak District ESA). Other requests have been serviced to assist the production of the British List of Species of Conservation Concern and to help JNCC staff advise on reintroductions legislation to control the reintroduction of bird species to the UK and on the timing of breeding of migrant quarry (hunted) species with respect to possible changes in European Law.

222 scientific publications have been produced that use data from the Nest Record Scheme. The first paper published was David Lack's (1946) classic on "Clutch and brood size in the Robin". Since 1946, the numbers of papers published in each decade were: 1940s - four papers; 1950s - 19; 1960s - 36; 1970s - 34; 1980s - 59; and 1990s - 70. The most important journal for publishing Nest Record Scheme papers has been *Bird Study* (73 papers), followed by *British Birds* (24 papers) and *Ibis* (11 papers). There have also been small numbers in *Ardea, Ecography, Evolution, Journal of Animal Ecology, Journal of Applied Ecology, Journal of Zoology, Nature, Ornis Fennica* and *Ornis Scandinavica.* Other places of publication include edited volumes, conference proceedings, BTO Research Reports, and local reports.

User-friendly summaries of scientific publications are produced by the Nest Records Unit in *BTO News* and in *Britain's Birds* and Nest Record Scheme results have featured in articles in the national press (*e.g. Sunday Telegraph, The Independent, New Scientist*), local press and in the popular birdwatching press (*e.g. Birdwatch, Bird Watching*). Contributions are made to national and local radio programmes, including BBC Radio 4's *Natural History Programme.* In addition, the newsletter *Nest Record News* is sent each year to all contributors of the scheme and highlights the value that the Nest Record Scheme has in contributing to studies of conservation importance.

A varying programme of lectures is provided each year by the Nest Records Unit with the aims of reporting results and encouraging participation in the Scheme. Scientific papers have been delivered to international and national conferences (*e.g.* International Ornithological Congresses and meetings of the British Ecological Society and British Ornithologists' Union), in addition to seminars at Universities and Research Institutes. Popular talks are regularly given to BTO members' meetings at Swanwick, to BTO local one-day conferences and to local Bird Club meetings throughout the UK.

2.4.1 Studies of conservation interest

Detailed analyses of datasets of conservation interest are undertaken by the Nest Records Unit as part of the contract to the JNCC. A number of examples are provided below.

2.4.1.1 Causes of nest failure among buntings in the UK (Crick *et al.* 1994a)

Populations of the four lowland buntings that breed in Britain have suffered declines in range and population size in recent decades, some of which have been severe (Gibbons *et al.* 1993). Crick *et al.* (1994a) assessed changes in causes of nest failure by comparison of the relative importance of each cause before and after 1970, as recorded on Nest Record Cards.

Nest predation was found to be the most important cause of failure, accounting for about one third of nests started by Yellowhammers, Cirl and Reed Buntings. For the two commonest buntings (Yellowhammer and Reed), nest predation was a more important factor affecting hatching than before, but agricultural operations were more important before hatching than afterwards.

The data were divided into pre- and post-1970 samples to assess whether there had been any changes in the relative importance of the causes of nest failure. For Yellowhammer and Reed Bunting the differences between the time periods were not significant and there was little change in the proportion of nests recorded from agricultural habitats. Corn Bunting showed a significant change in the relative importance of agricultural damage from 10% to 43% of reported failures. This occurred despite a decrease in the proportion of Corn Bunting nest records from agricultural habitats from 82% to 73%. Changes in the relative importance of each type of failure, as measured from the sample of nests which failed, may not have been the same as changes in the absolute rate of failure, as measured over all nests, if the overall failure rates had changed too. Comparison of measures of absolute proportions of nest failures due to each cause suggested that, while there had been a decline in the proportion of nests lost by predation for Corn Bunting, it had suffered a major increase in losses due to agricultural procedures: from 7% to 21%. However, the overall nest failure rate of Corn bunting was less in the post-1970 period than pre-1970.

Thus, only the Corn Bunting, a *Red List* species has shown any significant change in causes of failure through time, with a sharp increase in losses due to agricultural activities. This species is more likely to nest within cereal fields than Yellowhammer or Cirl Bunting, which prefer to nest in field margins, or than Reed Bunting, which favours areas near wet habitats. It was suggested that the switch from spring to autumn sowing of cereal crops is likely to have been detrimental to Corn Buntings because they have the latest nesting period of the buntings (Crick *et al.* 1991) and their nests are likely to be destroyed during the earlier harvesting period of autumn-sown crops compared with spring-sown crops.

2.4.1.2 The breeding ecology of Twite (Brown *et al.* 1995)

The Twite is the only passerine other than the endemic Scottish Crossbill to breed or winter in Britain in internationally important numbers (Batten *et al.* 1990) and is a *Red List* species. As part of a study of distribution, numbers and habitat usage of Twite in the south Pennines, the species' breeding phenology was investigated by analysis of the BTO's 813 Nest Record Cards from 1944-1991 (Brown *et al.* 1995). The Nest Record Cards were divided into two regions (South Pennines and Scotland) and three habitats (grass moors and pasture; heather moors and heaths; and unspecified moor comprising moorland for which heather or grass was not specified).

Overall daily nest failure rates were not significantly different between the two parts of the country at any stage of nesting: 30% fail during laying and incubation and 22% fail during the nestling period, providing an overall failure rate of 54%. Regression analysis showed a significant increase in losses of nests containing young and a significant decrease in brood size through time.

Comparison of south Pennines Twite nesting in the three major habitat types showed that birds nesting on heather were significantly later than those in the other two habitats. The difference in laying date was due to a much greater proportion of apparently second broods recorded on heather. Nests on heather suffered far fewer losses during the nestling stage than nests on grass. Overall loss rates, measured from egg-laying to fledging, were significantly lower on heather (35%) than on grass (60%) or on unspecified moor (51%).

Overall, the analysis may indicate that, through reduced recruitment, a contraction in the range or size of the breeding population is imminent. Given the international importance of the British population, a detailed autecological investigation into habitat selection, and its possible impacts on the breeding performance of twite was recommended. Aspects of the findings from the analysis of Nest Record Cards will be investigated further during an intensive fieldwork study funded by English Nature.

2.4.1.3 Trends in the breeding performance of Golden Plover (Crick 1992a).

The Golden Plover is a species of particular interest to JNCC and Country agencies because of its inclusion in Annex 1 of the EU Birds Directive and because of its status as a Species of Conservation Concern. Concern has been expressed that the Golden Plover population in Britain and Ireland has declined, with numbers falling from 30,000 pairs in the early 1970s to 23,000 pairs in the late 1980s. Little is known about its breeding in Britain, thus a study was commissioned by JNCC to investigate the BTO's nationwide Nest Record Card dataset, which was carried out contemporaneously with an analysis of population trends undertaken at the JNCC (Boobyer 1992).

Six hundred and sixty nine Nest Record Cards for the years 1943-1989 were analysed. Golden Plovers nesting on heather moorland and bog were found to breed, on average, 11 days earlier than those on grass moorland. Furthermore, clutch size was slightly larger on heather than on grass. This could be due to fewer early partial egg-losses (before observers found them) or due to a real difference in the numbers of eggs laid. Although nest failure rates for Golden Plovers nesting on heather moorland and bog have not changed over the years, they have increased significantly on grass moorland in north-west England and Wales in the 1980s. The report suggests that the fall in nesting success in this region may have been due to increased stocking rates of sheep on upland grass, in response to government subsidies.

The report recommended a comprehensive field study on Golden Plovers to investigate breeding ecology and breeding performance in their three major UK habitats: upland grass, upland heather and blanket bog. Particular attention in such a study should be paid to: (a) the feeding ecology of adults and chicks in relation to their food supplies; (b) the breeding breeding performance of populations in relation to their food supplies; (c) the relationship between sheep stocking rates and nest losses; and (d) the importance of nest predation by crows and other avian predators. (Since Crick's (1992a) report was published, English Nature has funded a three-year intensive study of breeding Golden Plovers in the Pennines, which will include investigation of those factors).

2.4.1.4 Breeding performance of Merlins (Crick 1993)

The Merlin's British population has been in apparent long-term decline throughout the twentieth century. This decline became more marked in the 1950s and 1960s, coincident with the widespread use of organochlorine pesticides. After the progressive decline of organochlorine pesticides in the 1970s and 1980s, populations of other birds of prey, such as Sparrowhawk and Peregrine, have shown significant recovery but Merlins have not. In an analysis of breeding performance to investigate breeding performance in the UK, 1400 Merlin Nest Record Cards from 1943 to 1989 were analysed.

There were no discernible differences between regions or habitats in clutch size, nor any trends through time. After the introduction of organochlorine pesticides in 1947, there was a decline in brood size until the early 1970s and then a recovery. However, while there have been increases in brood size since the early 1970s in Scotland and the English Midlands, brood size in North England and Wales has declined gradually.

The study recommended that the causes of these declines be investigated by comparative studies of Merlins in mainland Scotland and in northern England and Wales. It was also recommended that greater integration of monitoring efforts across be developed to ensure that any worsening of the situation does not go unnoticed.

2.4.1.5 The importance of breeding performance in the decline of the Lapwing

The Lapwing has been shown to have declined in Britain by a number of different sources: the Common Bird Census and Waterways Bird Survey, special national surveys of Lapwings and the Breeding Waders of Wet Meadows Survey (reviewed in Tucker *et al.* 1994). Analysis of Nest Record Cards by a volunteer showed that while clutch size has remained constant, average brood size of Lapwings at hatching has declined, consequent upon greater losses of eggs associated with the switch to autumn cereals and higher stocking rates (Shrubb 1990).

Analysis of ringing recoveries shows that the survival rates of both first-year and adult birds fluctuate greatly in response to winter weather, but that they have not declined in the long-term (Peach *et al.* 1994). The study concludes that the decline in the population is most likely to be a consequence of a decline in reproductive output. In most studies in western Europe the number of fledglings produced per pair was lower than that apparently necessary to balance the mortalities measured by Peach *et al.* Conservation efforts should be directed towards promoting breeding performance rather than over-wintering survival in order to effect a recovery of this species.

2.4.1.6 Studies of basic breeding biology

Nest Record data have been essential in some investigations of basic breeding biology which have an important role in under-pinning conservation work. Such studies include:

(a) descriptions of the nesting biology of rare or understudied species, *e.g.* Grasshopper Warbler (Glue 1990), Ring Ouzel (Tyler & Green 1989), British woodpeckers (Glue & Boswell 1994) for which the information is useful in relation to management of reserves or the wider countryside for the benefit of birds;

(b) analysis of fundamental principles and phenomena of breeding biology, such as patterns of seasonal variation in clutch size among 66 species of British birds (Crick *et al.* 1993c), comparisons of breeding performance and habitat use of resident and migrant passerines in Britain (Fuller & Crick 1992) and analysis of the changing patterns of brood parasitism by Cuckoo (Brooke & Davies 1987);

(c) contributions to distributional studies, such as the New Breeding Atlas (Gibbons *et al.* 1993) and the BTO's special surveys of species such as Peregrine (Crick & Ratcliffe 1995) and Little Ringed Plover (Parrinder 1989).

2.5 Value for money of the Nest Record Scheme

2.5.1 Volunteer fieldwork

Approximately 1000 volunteers contribute 30,000-35,000 nest records each year from all regions of the country. During the course of nest recording, volunteers have to: travel to their study areas, which are often some distance from their homes; travel within their study areas, possibly over difficult terrain; find each nest, which can require a considerable searching and observation time; make return visits to record each nest's progress (88% of records have more than one visit and many have more than four); ring and measure the young (between 10 - 30% of cards per species are completed by BTO ringers); complete and send in a Nest Record Card to BTO HQ. It would be reasonable to suggest, therefore, that the time spent by volunteer nest recorders is in the region of 150,000 hours per year.

2.5.2 Historical datasets

Use of the Nest Records Scheme for population monitoring benefits greatly from the availability of a unique and huge historical nest records database (more than 940,000 records for 223 species, of which 315,000 for 96 species are computerised) and from ready access to other long-term databases held by the BTO, which can provide information on changes in breeding and post-fledging populations and survival rates.

2.5.3 External support

The pursuance of the objectives of the Nest Records Scheme have been assisted greatly by funding and support provided by various bodies in addition to the JNCC and Country Agencies. Examples are:

(a) funding by BTO of (i) a part-time research officer to undertake detailed analyses of small datasets and to assist with servicing the volunteer contributors and (ii) part of the costs of the SSO and ASO posts supported by JNCC;

(b) data computerisation by trainees under government-funded training schemes;

(c) data computerisation by volunteer BTO members;

(d) data analysis by both volunteers and professional scientists (from RSPB, ITE, the universities);

(e) data computerisation and analysis as part of externally funded studies (*e.g.* Barn and Tawny Owls for agrochemical companies), birds of agricultural habitats (for the Environmental Research Fund), Cirl Bunting and Yellowhammer (for RSPB).

(f) the voluntary assistance of expert opinion to guide the development of the Nest Records Scheme through contributions within the Nest Records Scheme Technical Review Group and Integrated Population Monitoring Working Group.

(g) the computer support provided by the BTO, in terms of personnel and equipment.

2.5.4 JNCC support

Currently the JNCC partially supports two posts for work on nest records: Head of Nest Records Unit (Senior Scientific Officer) and Assistant Nest Records Officer (Assistant Scientific Officer). This represents extremely good value for money when compared with the benefits obtained from the high level of dedication provided by volunteers (equivalent to at least 100 full-time staff), funding from BTO of a part-time Scientific Officer and part of the costs of the JNCC supported posts, and support from non-JNCC sources to add to the high-quality extensive data sets. It is the only way in which the JNCC and the Country Agencies could fulfil aspects of their statutory monitoring and other duties so cost-effectively.

2.6 Recommendations for future work

This review has demonstrated in many ways the value of the Nest Record Scheme to the JNCC and Country Agencies. There are a number of aspects in which performance could be improved and there are number of research areas which can be suggested as priorities for future work.

2.6.1 Improving communication between Nest Record Scheme and JNCC and Country Agencies

There is a need to improve the flow of information between Nest Record Scheme and JNCC/Country Agencies. While performance in this area has been improving in recent years, there is still scope to deliver further improvements and this report is part of that process. Recent improvements include the production of timely annual reports of breeding performance, the issuing of specific alerts to JNCC of declining breeding performance among monitored birds and the delivery to JNCC of scientific publications accompanied by covering letters that highlight results of conservation importance.

While the Nest Records Unit has been able to respond to requests from JNCC and Country Agencies to undertake detailed analyses of trends in breeding performance of certain species (*e.g.* Golden Plover (Crick 1992a), Curlew (Austin & Crick 1994), Merlin (Crick 1993) and Twite (Brown *et al.* 1995)), such requests are relatively infrequent. The lack of requests represent a missed opportunity to utilise the extensive historical Nest Record Scheme database in contributing important information to the conservation and research work of the

JNCC and Country Agencies. Suggestions for such requests are provided below but, being relatively extensive pieces of work, they will need careful planning when being inserted into the work-schedules of the Nest Records Unit.

Having provided analyses, alerts and advice to JNCC and Country Agencies the Nest Records Unit rarely hears back how the information has been used. Such feedback is important because it would help the Nest Records Unit gauge whether it is providing the optimal type of information and it would allow the Unit to feedback information to volunteer nest recorders on the value of their efforts, providing encouragement and publicity for the Scheme and the statutory agencies.

2.6.2 Improving data gathering

There are several areas in which Nest Record Scheme data gathering could be improved:

(a) Schedule 1 species reports. Although the BTO receives significant numbers of nest records for species of Schedule 1 of the Wildlife and Countryside Act 1981, we would be able to provide a more comprehensive monitoring of breeding performance of these species if all persons granted licences to disturb birds at the nest of such species were strongly encouraged to complete a Nest Record Card. Data gathered during the review of raptor monitoring (Crick *et al.* 1990) showed, for example, that 85% of Peregrine nests, 82% of Golden Eagle nests, and 73% of Merlin nests that were visited under Schedule 1 licences in one year were not recorded on Nest Record Cards. This represents a significant loss of potentially very valuable monitoring information for JNCC and Country Agencies.

The Nest Records Unit has prepared a single sheet of instructions on how to complete Nest Record Cards for Schedule 1 licence holders. This has been sent out with all licences by the Countryside Council for Wales since 1993 and it is hoped that further collaboration with the other Country Agencies will be possible in the future.

(b) Site-based data. The JNCC and Country Agencies have special responsibilities for monitoring or maintaining the wildlife of particular sites, for example National Nature Reserves and Special Protection Areas. It would be a valuable exercise to investigate the scope for the Nest Record Scheme to produce site-based monitoring information. Currently, the Nest Record Scheme receives relatively little information from Country Agency staff or from other conservation bodies. The Nest Record Scheme's standardised methodology could be used to collate and analyse such data using expertise and facilities for analysis that are available at the BTO. The RSPB have utilized the BTO's expertise to process data for Cirl Bunting and Buzzard.

(c) Ringers. A concerted effort should be made to improve links between nest recorders and ringers. Up to 200,000 pulli are ringed each year, but not all pulli that are ringed are recorded on Nest Record Cards and not all pulli recorded on Nest Record Cards are ringed. This represents a lost opportunity to improve the quality of data gathered for Integrated Population Monitoring. For example, 27% of Sparrowhawk broods ringed were recorded on Nest Record Cards and 53% of Sparrowhawk Nest Record Cards contained broods that were not ringed. Although computerisation of ringing data will soon provide additional information on brood sizes at ringing and on the timing of breeding, more complete data would be gathered if nest recorders and ringers cooperated in recording and ringing all broods.

Another aspect is that of the number of Nest Record Cards in which the identity of the breeding adults is known from ringing. Of the main monitoring species, only relatively small proportions of Nest Record Cards are for ringed breeders. Among the records received for 1991 and 1992, at least 5% of Nest Record Cards reported ringed adults for Barn Owl (23%), Tawny Owl (13%), Dipper (5%), and Nuthatch (13%). Twenty-five species had no Nest Record Cards of ringed breeders. The new Nest Record Card, introduced in 1990, contains special boxes to record the ring, age and sex of parent birds. A concerted effort is needed to improve the marking rates of breeding birds while being careful to ensure that techniques of catching and marking near the nest do not bias the success of the nest (see section 3.2.2.4).

2.6.3 Suggestions for future research

The need for bird population monitoring will become increasingly important, to allow conservation of vulnerable birds and to provide a useful, cost-effective bio-indicator of the health of the wider countryside, within a rapidly changing environment. This need will best be provided by monitoring schemes such as the Nest Records Scheme which have long runs of historical data for comparison with current and future trends.

An important consideration with respect to the annual monitoring programme of the Nest Record Scheme is to investigate the sensitivity of the data anlayses to detect long-term declines in breeding performance for each species. This substantial piece of work will be particularly important when null hypotheses are not rejected.

Examples of current and future conservation issues in which the need for Nest Record Scheme data may be important include the following.

(a) It is likely that agricultural practice will continue to be modified over large areas as a result of EU legislation and agro-economics, for example: changes in stocking densities and rapid switches in cropping regimes as subsidies change; changes in drainage policies; changes is set-aside policies; changes in biocide usage.

(b) Recreational use of the countryside has been increasing and is likely to continue to increase with the potential to affect landscapes of high conservation value, for example skiing, climbing and walking in the uplands; disturbance on waterways from water-sports and angling; war-games in woodlands.

(c) The continuing road-building programme may have important effects of bird populations such as Barn Owl and even songbirds such as Willow Warbler (Reijnen & Foppen 1994).

(d) The effects of long-term climate change may be significant in the UK and its significance will only be revealed by analysis of pre-existing long-term datasets such as the Nest Record Scheme.

(e) As raptor populations recover from pesticide-induced population crashes, the JNCC are going to need accurate, objective assessment of their population levels and demography in order to counter the claims of anti-raptor sections of the public, for example some racing pigeon keepers are calling for Peregrines to be culled and some gamekeeping interests would prefer the control of raptors (including those currently protected under Schedule 1 of the Wildlife and Countryside Act) on their estates.

More specific research projects can be identified from current information on species with declining breeding performance. In particular:

(a) Fully Integrated Population Monitoring analyses are urgently needed for four seed-eating species which are in decline: Skylark, Tree Sparrow, Linnet, and Reed Bunting; and a detailed nest records analysis is needed for the carrion-eating Raven. As part of these analyses it might be appropriate to include analysis of non-declining "control species" such as Chaffinch and Carrion Crow.

(b) Fully Integrated Population Monitoring analyses are needed for *Red List* species: Song Thrush, Spotted Flycatcher and Bullfinch; and for *Amber List* species: Kestrel, Barn Owl, Swallow, Redstart, Stonechat, Blackbird, Dunnock, Starling and Goldfinch. Such analyses should make full use of information on numbers and survival and investigate regional and habitat differences in population dynamics where possible.

(c) An in-depth analysis is urgently needed of the possible relationship between global climate change and trends of progressively earlier laying and is in progress.

(d) A detailed analysis of reduced breeding performance in 1950s and 1960s in relation to regional and habitat differences is required to investigate the possible widespread depression of breeding performance due to organochlorine pesticides.

(e) Finally, the Nest Record Scheme holds useful collections of Nest Record Cards for a number of species of conservation concern and Rare Breeding Birds Panel species that have yet to be analysed for habitat, site-location details and breeding performance. Suggestions for immediate analysis include the following (with current numbers of Nest Record Cards available in parentheses).

(i) *Red List* species: Hen Harrier (1240), Grey Partridge (793), Stone Curlew (433), Roseate Tern (660), Rock Dove (268), Turtle Dove (1834), Nightjar (1205), Woodlark (686), Dartford Warbler (427) and Red-backed Shrike (252).

(ii) *Amber List* species: Red-throated Diver (1907), Slavonian Grebe (174), Shag (4348), Shelduck (251), Goldeneye (116), Golden Eagle (422), Peregrine (1892), Avocet (485), Dotterel (248), Woodcock (565), Curlew (2474), Greenshank (154), Arctic Skua (294), Great Skua (341), Common Gull (3216), Herring Gull (4745), Lesser Black-backed Gull (1072), Sandwich Tern (1185), Arctic Tern (4123), Little Tern (4521), Guillemot (1099), Razorbill (717), Black Guillemot (1071), Puffin (208), Short-eared Owl (329), Kingfisher (552), Sand Martin (994), Nightingale (425), Black Redstart (132), Stonechat (2340), Ring Ouzel (1344), Redwing (111), Marsh Tit (1155), Willow Tit (402), Crested Tit (292), Chough (497) and Hawfinch (156).

(iii) RBBP species: Goshawk (318).

The potential value of stimulating BTO volunteers to make special investigations in response to Nest Record Card analyses has been little explored to date. Probably the most recent example was the detailed nest recording requested as part of the BTO Owls Project (Pervical 1992). When the Nest Record Scheme finds a difference in nest success between habitat types or regions, these results could act as a trigger for more detailed and focussed studies to investigate the contrast in question. There is certainly more scope to feed back the "burning questions" to BTO members and to try to set up cooperative investigations of target species in selected study areas.

3. METHODOLOGY

Although the data gathered by the BTO's Nest Record Scheme is extremely straightforward in character, the lack of a systematic sampling regime poses potential problems in data analysis. One aim of this chapter is to review the main sources of potential bias due to non-random sampling of nests, including seasonal variation in the proportion of nests found, due to changes in search effort and nest detectability, and the distribution of Nest Record Cards among different regions and habitats. Nesting success is an important variable to be derived from Nest Record Scheme data but its estimation requires special techniques to cope with the incomplete nature of data on individual Nest Record Cards due to the lack of systematic sampling (visiting) of nests over time. The variety of techniques available are reviewed below and problems associated with their use are discussed. The aim being to provide recommendations about the methodology best suited for Nest Record Card analysis and to suggest where further validation work is necessary. The possibility that nest recording affects nesting success detrimentally is also reviewed, as such effects could potentially bias the Nest Record Scheme results.

3.1 Estimating nesting success

3.1.1 The problem with Apparent Nest Success

Nesting success is a key variable in demographic studies of birds. It is important to know the proportion of nests that succeed in producing at least one fledged young in addition to the average size of broods at fledging. The simplest measure of nesting success is to calculate the proportion of nests that were successful of those that were found. This Apparent Nest Success measure was widely used prior to the 1960's and often used afterwards (*e.g.* Nice 1957, Ricklefs 1969).

The problem with Apparent Nest Success is that it usually severely overestimates success (Snow 1955). In most studies, the majority of nests are found after the first egg is laid. Early losses are missed and not included in the sample used to calculate nesting success. To take the extreme example, if all nests were found on the eve of fledging, then Apparent Nesting Success would be 100%. The method is only reliable if all nests are found before laying begins.

A further problem arises from nests that were not watched to an outcome (Mayfield 1961). If these are discounted, then failure rates increase unrepresentatively because nests which failed quickly are included in the sample while those that existed longer than the observations and were likely to include some successes are excluded. If the outcome-unknowns are included then the nest success will be artificially inflated because of the omission of subsequent failures.

The degree of over-estimation of nest success decreases as observers observe individual nests for longer. This is a potentially important consideration for a scheme that aims to monitor long-term changes in breeding performance because changes in observer behaviour can produce apparent changes in nest success.

3.1.2 The Mayfield Method

3.1.2.1 Basic Model

To overcome the problems outlined above about the Apparent Nest Success, Mayfield (1961, 1975) suggested a method for estimating nest success that was based on the calculation of the daily survival or failure rates of nests. The method allows the inclusion of all nests, so long as they have been visited at least twice. Nest survival rates are based on the "nest-day" as the unit of exposure of nests to mortality factors. Ten nest-days can represent one nest observed twice, ten days apart, or ten nests observed twice each, on two successive days. To calculate a daily nest failure rate, the number of nests that fail during the period of observation are summed and divided by the total number of nest-days over which observations were made. Although we will discuss the assumptions of this approach in detail below, the main assumptions to be aware of here is (a) that daily rates of nest loss are constant over the period of interest (*e.g.* over incubation) and (b) that if a nest fails between two observations then, for the purpose of calculating nest-days, it is assumed to have failed half-way between the two observations.

In summary:

Daily Nest "Mortality" Rate = m = No.Failures/Nest-Days

Daily Nest Survival Rate = s = $(1\text{-}m)$

Survival Rate over period of duration J, = $S = s^J$

The survival rate over two successive periods, for example incubation and nestling periods, will be:

$$S_{Incubation} \cdot S_{Nestling}$$

In calculating survival rates over a period, the need to raise the daily survival rate to the power of the period's length requires caution with regard to the number of decimal places employed. For example:

(a) $0.93^{20} = 0.2342388$

and (b) $0.9333333^{20} = 0.2516142$

the difference between the two = 0.0173753 which means that (a) was 6.9% lower than the less truncated (b). Using binomial theory to produce an approximate standard error for each rate (Price 1990) and using a z-test at z=1.96 to detect a difference between the rates, the sample size required to achieve a significant difference between the two rates would be:

$$N = [z\{(S_a \cdot (1\text{-}S_a)) + (S_b \cdot (1\text{-}S_b))\}]/\text{difference.}$$

In this case $N = (1.96(0.1793709 + 0.1883044))/0.0173753$

$N = 42.$

So if each sample contained at least 42 nests then the difference caused by rounding off decimal places could be enough to produce a spuriously significant result at the 5% level. It is important that Mayfield calculations should be undertaken at the highest precision available and that the precision used should be noted in published studies to permit proper comparisons.

Overall, the Mayfield method provides a straightforward and practical way to overcome the problems associated with the Apparent Nesting Success calculations. It eliminates the bias in overall nest failure rates, produced as a result of missing failures that occur early in a nesting attempt, by using data collected at later stages to extrapolate to earlier stages. Furthermore, it allows the use of incomplete records, including those where the outcome is unknown, and is therefore very suitable for use with data gathered by extensive Nest Record Schemes. However, there are a number of assumptions that have to be met for the Mayfield method to produce completely unbiased estimates and these will be discussed below.

3.1.2.2 Maximum Likelihood Mayfield Model

Subsequent to the production of the basic Mayfield Method, various authors have found that it can be derived as a maximum likelihood estimator (MLE) (Johnson 1979, Hensler & Nichols 1981, Bart & Robson 1982, Hensler 1985). This useful development allows the calculation of estimates of standard errors and significance tests not only for simple daily survival rates but also for products of survival rates.

Prior to the development of significance testing based on MLEs, invalid tests had been proposed by Mayfield (1975) and Dow (1978) based on inappropriate use of X^2 tests (Johnson 1979).

3.1.2.2.1 Variance of Mayfield's Daily Survival Rate

Johnson (1979) calculated the variance (var) of the Mayfield MLE to be

$$1/[exposure^3/(exposure - losses)losses]$$

where *exposure* is the total number of nest-days for the sample and *losses* is the number of nests that failed.

Hensler & Nichols (1981) and Hensler (1985) calculated the variance of the Mayfield MLE to be

$$s(1-s)/(exposure).$$

This is a rearrangement of the Johnson equation and is also the variance for the rate of occurrence of a binomial variable (Price 1990).

3.1.2.2.2 Comparison of daily survival rates

Johnson (1979), Hensler & Nichols (1981) and Hensler (1985) suggest that the appropriate test to use is a *z*-test, assuming a normal distribution:

$$z = (s_1 - s_2)/\mathrm{sqrt}(\mathrm{var}_1 + \mathrm{var}_2).$$

Hensler & Nichols provided some useful tables to show the power of the test to detect a range of differences, for a range of nest periods, sample sizes of nests and daily survival rates, and to estimate the sample sizes required to achieve a certain level of precision. The power of the test tends to increase as the nest period increases, as the daily survival rate increases and as sample size increases. Similar analysis by Bart & Robson (1982) and Beintema (1992) also showed that increasing the frequency of visits to nests is a far less efficient way of increasing precision than increasing the number of nests visited because the latter usually has a greater impact of the sample size of nest-days.

Hensler & Nichols (1981) opine that samples of less than 20 nests would not be appropriate for use in significance testing based on asymptotic theory and Klett & Johnson (1982) recommend that samples of at least 50 nests should be used. Simulation tests by Beintema (1992) suggest that at least 1000 nest-days are required per sample to produce sufficient power to detect differences of the order of 0.01 between daily nest survival rates (which, in his examples, would require 60-80 nests per sample).

3.1.2.2.3 Confidence intervals for survival products

Johnson (1979) suggested that a simple (and conservative) method for calculating the confidence intervals of a survival rate over a period (*i.e.* s^J) is simply to calculate

$$(s+/-(2.\mathrm{se}))^J.$$

These confidence intervals will be approximate and Klett *et al.* (1986) point out that they will be asymmetric because they are derived exponentially.

Hensler (1985) used maximum likelihood theory to show that the variance of s^J ($=S$) is

$$\mathrm{var}_S = \mathrm{var}_s \,.\, (Js^{J-1})^2.$$

Where the variance of the product of two survival rates is required, for example, the variance of the whole nesting period which consists of the product of the survival rate of the incubation and nestling periods, Hensler showed that if it is assumed that there is day-to-day and nest-to-nest independence then

$$S_{nest} = s1^{J1} \,.\, s2^{J2}$$

and

$$\mathrm{var}S_{nest} = (s1^{(2\,.\,J1)} \,.\, \mathrm{var}_{s2}) + (s2^{(2\,.\,J2)} \,.\, \mathrm{var}_{s1}) + (\mathrm{var}_{s1} \,.\, \mathrm{var}_{s2}).$$

Hensler also provided an example of how to calculate the variance for the product of the survival rates for three periods. Approximate 95% confidence intervals can then be calculated from the standard normal distribution as $\pm 1.96(\mathrm{var}_S)$.

3.1.2.3 Other Models

3.1.2.3.1 Johnson's Method

Various other models have been suggested for the estimation of nests survival rates. Johnson (1979) produced another maximum likelihood model which recognizes that the actual destruction date of a failed nest is unknown. Rather than assuming that a loss occurs at the mid-point between observations, the method assumes an exponential decline in the likelihood that a nest continues to survive through the period between observations.

$$1/s \, . \sum (\text{for all } t) \; th_t = \sum (\text{for all } t) \; tf_t s^{t-1}/1\text{-}s^t$$

where h_t is the number of surviving nests over period t and f_t is the number of failed nests.

While being more realistic, unfortunately there is no closed solution for the model and it can be calculated only by reiterated numerical maximisation routines and, as such, has rarely been used. Johnson showed that the Mayfield method produced results that were very close to his method and that standard error estimates were very similar too. Beintema (1992) too provides simulation evidence to suggest that bias due to the use of the mid-point assumption will usually be negligible.

3.1.2.3.2 Bart & Robson's Method

Bart & Robson (1982) devised a model that was again calculable as a maximum likelihood estimate and is based on essentially the same likelihood function as Johnson's method. However, the method requires the separation of the sample of nests into J sub-samples observed over intervals from 1 day to J days. Starting with the Mayfield estimate of daily survival rate, two further functions of the mortality rate are calculated, based on the Mayfield estimate and on the sub-samples of different interval length. The two functions are then divided into each other and added to the original Mayfield estimate. This process can be reiterated to improve the estimate but this only provides a small change in the first calculation. While this method may be more accurate, the difference between Mayfield and Bart & Robson's methods is very small, for two examples in Bart & Robson (1982) the differences were 0.005% and 0.019% (absolute differences were respectively: 0.989535-0.989482 = 0.000053 and 0.980381-0.980198 = 0.000183).

3.1.2.3.3 Pollock & Cornelius' Method

Pollock & Cornelius (1987) proposed a completely different approach to calculating nest survival rates. Their model uses the distribution of age at finding of successful nests to estimate the age distribution of failed nests. A critical assumption is that nest-finding probabilities must be unrelated to subsequent survival probabilities, *e.g.* nests found early in a nesting attempt must not be both easier to find *and* more prone to predation. This method requires the estimation of a considerable number of parameters but is amenable to calculation using the survival analysis program SURVIV (White 1983). However, the survival rates that result appear to biased high compared with the standard Mayfield method (Heisey & Nordheim 1990), although this bias apparently decreases as time between nest-visits decreases (Bromaghin & McDonald 1993).

3.1.2.3.4 Heisey & Nordheim's Method

Heisey & Nordheim (1995) have developed a method of modelling age-specific survival in nesting studies that eliminates the bias they found in Pollock and Cornelius' (1988) method (see 3.1.2.3.3). They use a bivariate contingency table approach to model the age of a nest at recruitment into the study and the age at failure. The method's approach can relatively easily be extended to include covariates by using log-linear techniques. This method, being very new, will need testing to investigate its applicability and value.

3.1.2.3.5 Bromaghin & McDonald's Method

Bromaghin & McDonald (1993) have proposed a model that has similarities to Pollock & Cornelius' model in that it utilizes the probabilities with which nests are included in a sample. However, the assumptions are inappropriate for use with data from Nest Record Schemes because data must be gathered by systematic searches over a certain area, separated by a set interval between searches and all nests must be followed to either success or failure. The estimates of nest success have small errors and may be suitable for use in intensive field studies.

3.1.2.3.6 Conversion methods

Occasionally it is impossible to gather information on the exposure of nests to risks, either because nests are only checked long after success or failure has occurred or because the data concerned are in published studies that provide only the Apparent Nest Success.

Johnson & Klett (1985) produced a simple method for producing a Mayfield-type estimate from an Apparent Nest Success estimate. If nesting attempts normally last J days from egg-laying to fledging and nests are normally found at j days after initiation, then

$$\text{Apparent Success Rate} = S_A = s^{J-j}$$

therefore the daily nest survival rate $= s = J$-jth root of S_A.

This is only an approximate estimate of the Mayfield rate because nests will be found over a range of j, whereas the j in the equation above is a mean. A series of calibration curves is provided by Johnson & Klett, for differing values of mean j.

Green (1989) produced another way of calculating a Mayfield-type estimate, given an Apparent Nest Success estimate. As Johnson (1991) pointed out, Green's method is a mixture of discrete and continuous models which would be better formulated as purely one or the other. (The discrete model assumes that data are collected at discrete time intervals, such as days, whereas a continuous model would assume that exact lifetimes of nests were known and that mortalities operated at a constant rate, day and night). Green's method produces only one calibration curve between Apparent and Mayfield survival rates and does not take into account differing average ages of finding that might occur in different studies because these are often unknown or unreported (he assumes finding is random with respect to nest age and that finding nests does not significantly deplete the population available to be found). Furthermore, Green's method assumes that the number of nests discovered at a particular age is proportional to the numbers surviving to that age, this assumption would be violated if parent birds were particularly likely to draw attention to the nest by their behaviour. Similarly, searching effort must be constant too, otherwise the probability of finding a nest would also change. However, Johnson (1991) tested the two methods on a variety of datasets and found that Green's method usually performed better than Johnson & Klett's.

3.1.2.3.7 Which method should be used?

The methods described above fall into three classes, variants of the Mayfield, methods that utilise encounter probabilities and conversion methods.

The conversion methods are inappropriate for analysing Nest Record Cards, they are only suitable when there is lack of information on exposure (nest-days) and are designed as "quick-and-dirty" tools to provide reasonable estimates of Mayfield-type nesting success given knowledge of Apparent Nesting Success. Although it would seem sensible to prefer Johnson & Klett's method over Green's when the average age of nests when first found is known because it uses more information, Green's method appeared to perform better than Johnson & Klett's when tested on the same datasets.

The methods that utilise encounter probabilities with successful nests to estimate those for failed nests appear to have too many requirements for practical use except in intensive studies. There is doubt as to whether the Pollock & Cornelius method produces unbiased estimates of nesting success and its use cannot be recommended at this time, despite advantages associated with its amenability to analysis within the SURVIV package. The Bromaghin & McDonald method requires systematic nest searches and that all nests be followed to outcome. Clearly, this method is not suitable for use in studies based on an unstructured sampling regime, but may be preferable to the Mayfield method in intensive studies. Further comparisons are needed between the two methods.

Johnson's and Bart & Robson's methods are very similar and provide more accurate models than the standard Mayfield method, by not assuming that losses occur half-way between nest-visits. However, the computational procedures are complex and the results are very similar to those derived from the standard Mayfield calculations (Johnson 1979, Bart & Robson 1982, Beintema 1992). Johnson (1979) recommended the use of his method for detailed analysis of large numbers of nests but later indicated no preference between his method and Mayfield's (Johnson 1991). Given that only minor benefits can be gained from using the more complex procedures and given the body of development work that Johnson, Hensler and co-workers have undertaken, the Mayfield method can be recommended as the basic procedure for calculating nesting success, with incorporation of Johnson's modification when computer intensive facilities are available.

3.1.3 Assumptions of the Mayfield Method

The most basic assumption of any study of nesting success is that all nests found are recorded and included in the analysis. If observers are selective in the nests they record then estimates of nesting success will be biased. It is particularly important that failures are reported and the Nest Record Scheme Handbook (Crick *et al.* 1994b) emphasises to volunteer recorders that these records are of utmost importance if the scheme is to be of value to conservation and to science.

Since Mayfield first formulated his method for calculating nest success, subsequent papers have noted additional assumptions underlying the calculations. We will briefly list the assumptions of the method below, with comments about the problems that may arise from their violation. Not all of these assumptions are specific to the Mayfield method, several are assumptions of any method for estimating nest success by finding and checking nests and others could be described as data requirements.

3.1.3.1 Assumption 1: Nests must be active and have been visited at least twice

Mayfield (1961) noted that exposure to the risk of failure had to be calculated over the period between two visits. If a single visit was counted as showing that a nest had survived for a single day, or from nest initiation to the day of the visit, then survival rates would be biased high because only surviving nests could contribute such exposure (nest-days). Failed nests could not provide a precise estimate of exposure and, in a practical sense were less likely to be found or recorded.

This assumption is met by the Nest Record Scheme because Nest Record Cards are only requested for active nests and single visit records are not included in the analysis of nesting success.

3.1.3.2 Assumption 2: Each individual nest can be relocated at will

First stated by Bart & Robson (1982), this is an assumption of any method for estimating nesting success based on checking. If this assumption is violated then biased survival rate estimates are likely because un-relocatable nests might form a biased sub-sample of nests. Nests which are impossible to relocate may be nests which are most likely to succeed or may be those that have failed. For species with well concealed and/or scanty nests it can be much more difficult to relocate a nest which has failed than one that is still active. In some cases the agent of failure itself makes the nest difficult to relocate, for example trampling of wader nests by cattle.

Nest Record Cards are only included in analysis of Nest Record Scheme data if they have two or more visits, *i.e.* analyses only include those nests that were able to be re-located at will. However, it is recommended that all Nest Recorders should be asked to record whether visits were discontinued to a nest because of difficulty in relocating the nest or in gaining access to a nest. Access may become restricted due to vegetation growth or withdrawal of permission by land-owners. Problems associated with the relocation of failed nests should be emphasised in the *Nest Record Scheme Handbook* (Crick et al 1994b).

3.1.3.3 Assumption 3: The units of exposure are discrete

As noted above, the Mayfield model is most appropriately defined as a discrete time model rather than a continuous time model because the exact times of nest loss are unknown and mortality factors are unlikely to operate at the same rates day and night (Johnson 1991). Although other units could be used, for example two-day units, the nest-day is standard because of its simplicity of calculation and because of its biological significance. The use of nest-days implies that visits to each nest occurs at approximately the same hour of the day, but violation of this assumption would not be likely to produce any systematic bias in a study. Willis (1981) proposed that failures should be ascribed over half-day periods but this was shown to be inappropriate within a system using the nest-day as the discrete measure of time: the use of half-days within such a system could produce mortality rates greater than 1.0 (Johnson 1991)!

This assumption is met by the Nest Record Scheme because the method of analysis employed by the BTO uses the nest-day as the discrete time period with Nest Record Card analyses.

3.1.3.4 Assumption 4: Units of exposure are equivalent and independent between and within nests

Mayfield (1975) realised that survival rate estimates would be biased if the daily survival rate of a nest was affected by its previous survival, the consequences of which would result in a violation of Assumption 8 below (*i.e.* that daily survival rates are constant over each period of calculation).

Furthermore, if different groups or classes of nests have different survival rates then the resultant overall survival rates would be biased depending on how the overall sample was drawn from the two sub-populations. This problem was first discussed by Green (1977) who considered the case of a population consisting of differing proportions of experienced adults and inexperienced first year breeders, all observed from nest initiation. As the proportion of inexperienced breeders increased then the population Mayfield estimate was biased low, such that the apparent nestling production of the population became less than that actually produced by the experienced birds. The experienced part of the population were effectively being ascribed the inexperienced rate of nest success. Green proposed a way of testing for homogeneity of nest survival, but this requires observation of nests from initiation to their outcome to provide a frequency distribution of surviving nests with time for comparison with the expected distribution. This method is impractical for unsystematically collected data such as that gathered by the Nest Record Scheme.

Johnson (1979) considered a contrasting example in which nests were found part-way through each nesting attempt and the resulting Mayfield estimate was biased high. This time it was because the inexperienced nests survived a shorter time and were less likely to be recorded. The importance of this effect is not great so long as (a) the difference in survival rates between the two sub-populations is not large and (b) the proportion of birds exhibiting a low nest survival is not large (Johnson 1979).

Johnson (1979) suggested a test that is more practical than Green's and is based on the fact that samples of nests found at greater ages will be biased toward the higher survival group. He suggested plotting daily mortality rate against age at finding. If there is heterogeneity within the sample then the regression line will tend to decline linearly. He proposed that the intercept on the *y*-axis can be used as an estimate of the daily mortality rate of the entire population, accounting for the disparity between the sub-populations. However, there will be difficulty in separating the effects of heterogeneous samples from genuine declines in mortality rate associated with the age of nests (Klett & Johnson 1982) and therefore in accounting for these effects during analysis. Mortality rates could decline with age of nest if, for example, parental nest defence improved.

Further simulations need to be undertaken to assess the potential bias that could arise from the violation of this assumption within the context of annual monitoring. In practice, it is unlikely that important heterogeneities will arise unless there are clearly distinguishable sub-groups, such as first-year breeders and experienced adults in raptors, or such as birds breeding in marginal habitats, such as urban areas compared with optimal woodland habitats. The annual population monitoring programme of the Nest Record Scheme should attempt to characterise identifiable sub-groups with differing nest survival rates to allow properly stratified and unbiased analysis.

If mortality rates are found to vary with some recognisable feature within a population of birds, such as habitat, then Klett & Johnson (1982) suggests the calculation of stratified Mayfield estimators and their combination within a weighted average to produce an overall survival rate

$$S = [(N_1/(N_1+N_2) \ . \ (s_1)^J] + [(N_2/(N_1+N_2) \ . \ (s_2)^J].$$

This is the survival rate over a period of J days for a population of $(N_1 + N_2)$ nests each with a daily survival rate of s_1 and s_2. Klett & Johnson do not provide an estimate of the variance for such a weighted average, so this would need to be developed. However, such an approach should be adopted within the Nest Record Scheme when appropriate.

Another form of population heterogeneity can occur due to short-term catastrophic events (Klett *et al.* 1986). If agricultural practices cause sudden losses of a large proportion of nests due to tillage or mowing or if the weather produces a sudden snow-fall or flooding then nesting attempts that finish before the event or start after the event will have different success rates to those subject to the event. Ideally the two groups should be treated separately. But even then the Mayfield method can perform less well than the Apparent Survival Rate when describing losses due to catastrophes (Johnson & Shaffer 1990). These sorts of catastrophes are unlikely to affect national Nest Record Schemes but are more likely to affect studies of small and closed populations (*e.g.* Ely & Raveling 1984). However, if a spell of bad weather caused losses throughout the country over the course of a week, then nests under observation during that period should be separated from nests that finished earlier or started later and should be considered as a separate stratum in any analysis.

3.1.3.5 Assumption 5: Visits by observers to nests do not affect nest-survival

This is another critical assumption of any method for estimating nest success based upon checking (Bart & Robson 1982). The most likely way in which nest visiting could affect nest survival would be for observers to make the nest more vulnerable to predation. A nest could be made more exposed by an observer, after parting surrounding foliage for example, predators could determine nest locations by watching observers, mammalian predators might follow human scent trails to nests and, in colonies, observers may scare parents from nests, leaving them vulnerable to predation by other colony members. This is discussed in greater detail below (section 3.2).

3.1.3.6 Assumption 6: If a nest is lost between two visits then assume the loss occurred half-way between them

Miller & Johnson (1978) found that this assumption of Mayfield (1961) was not appropriate in studies where inter-visit intervals were relatively long. For their duck data, they found that an assumption of failure at 40% of the interval provided more accurate survival rates. Their data was gathered at intervals of three weeks between visits. Where visits are gathered at intervals of less than two weeks, either assumption works well (Johnson 1979). The modification provided by Johnson's (1979) maximum likelihood estimator assumes that losses occur at a constant rate during the inter-visit period, *i.e.* the likelihood that a nest has survived decreases exponentially through the period. The use of this approach is more realistic but does not provide very different results from the standard Mayfield method (see 3.1.2.3.1).

The use of the mid-point assumption is probably valid within Nest Record Scheme analyses because the majority of nest visits recorded on Nest Record Cards probably occur at intervals of less than two weeks. However, this needs checking by the calculation of frequency distributions of visit intervals for each species. If there are a large number of inter-visit intervals of greater than two weeks but less than the nesting period being considered, then it would be appropriate to adopt the more exact methods of Johnson's (1979) maximum likelihood estimator. The species likely to be affected by violations of this assumption, for which incubation or nestling periods (the basic periods analysed within the Nest Record Scheme) are longer than four weeks, are the larger-bodied species such as the crows, raptors, seabirds and waterfowl. The vast majority of passerines are unaffected, as are most near-passerines, terns and waders.

If the discovery of failure occurs at some time after the nest should have fledged, then the estimated fledging date should be substituted for the estimated failure date. This procedure is used in the current Nest Record Scheme analytical programs.

3.1.3.7 Assumption 7: All visits to nests are recorded

Bart & Robson (1982) pointed out that a problem arises if observers do not record visits in which they could see that a nest was still active but in which they did not approach close enough to examine the nest contents. If observers only record visits to nests made when they fear nest failure, then failures will be over-represented in short interval visits and under-represented in longer interval visits. Given Assumption

6 above, the number of nest-days of exposure will be under-counted for failed nests and survival rates will be biased low.

Unfortunately, Bart & Robson (1982) also suggest that there can be difficulty in separating breaches of Assumptions 5 and 7. If nest-visiting tends to result in failure relatively soon after visiting then failures will again tend to be over-represented from short interval visits. If there was no breach of either assumption, a plot of proportion of nests surviving against interval length between two visits should produce a negative exponential. Breaches of Assumption 7 can produce a rising curve at longer intervals whereas breaches of Assumption 5 will always produce a declining curve. A slightly decreasing curve with an intercept on the *y*-axis below 1.0 could be produced by either problem.

Assumption 7 can be satisfied relatively easily within the Nest Record Scheme by requiring nest recorders to record all visits to nests, whether contents are counted or not. This should be easy to bring to the notice of BTO volunteers. Exploratory analysis of a few species to investigate whether the proportion of nests that survive increases with inter-visit interval would be worthwhile. This would be particularly so for common garden species that volunteer observers might easily observe regularly, but from a distance.

3.1.3.8 Assumption 8: Daily survival rate is constant over a period of calculation

If this critical assumption, noted by Mayfield (1961), is violated then the resulting estimates of nest survival can be biased. For example, if nest survival is higher in the early incubation period than later but most nests are found in late incubation, then the survival rate calculated for the whole incubation period will be biased low. Further consideration of problems associated with this assumption are discussed in section 3.1.5 below.

3.1.3.9 Assumption 9: The time-periods used are considered constant for all nests

First noted by Hensler & Nichols (1981), the assumption that periods such as the length of incubation is a population-specific constant has its major effect on the calculation of period survival rates from daily survival rates. As time-periods increase, the difference between period survival rates calculated using slightly different time periods becomes smaller. If the distribution of time-periods, such as incubation length, within a population are normally distributed then there will be no bias in the resultant survival rates. However, if there are discrete sub-populations that exhibit similar daily survival rates but have different standard period lengths, then overall survival rates could be biased by the sampling regime.

The definition of periods within the nesting cycle is an analytical matter. Within the Nest Record Scheme, species-specific durations for incubation and other sub-periods can be culled from the ornithological literature or determined from Nest Record Cards of frequently visited nests. If there is variation in certain periods then it is likely that the variation will be normally distributed. It is possible that identifiable sub-populations might characteristically have different durations for periods such as incubation and it would be important to be aware of this when calculating overall period success rates. For example, experienced birds may lay larger clutches than first-time breeders, extending the risk of loss during the laying period. Conversely, experienced breeders may be able to fledge their young quicker than inexperienced birds and thereby reduce the risk to their nest. The importance of this effect decreases as period length increases and as daily nest survival rate increases. Any differences between sub-populations are likely to be relatively small (say 1-2 days) and not likely to alter the conclusions of comparative studies, however a literature review on period length variation would be useful to check these assumptions.

3.1.3.10 Assumption 10: All time-periods are clearly defined

Although the definition of time-periods, such as for incubation, can be difficult, it is essential that they are clearly defined (Hensler 1985). Difficulties arise when, for example, incubation starts part-way through laying and hatching is asynchronous. How then should laying, incubation and nestling periods be defined? The answer will depend upon the aims of the study, whether there are sufficient samples from each period and whether the periods differ in daily survival rate. Within each study the definition of each period must be clearly stated to facilitate proper comparisons with other studies. Currently the Nest Record Scheme analytical programs define the egg period as beginning with the first egg laid and ending with the first egg hatched or the last egg hatched (the program produces minimum and maximum numbers of nest-days as described in 3.1.5); the nestling period begins with the first young hatched and ends when all young have fledged.

3.1.3.11 Assumption 11: Nest losses must be clearly assignable to a particular period

The clear definition of time-periods (Assumption 10) is also necessary to permit the unambiguous assignment of nest losses to a particular period. Within a study, it is to be hoped that not too many failures occur during observation-intervals that span two periods because they cannot be omitted without biasing survival rates upward. So, Hensler (1985) recommends that each study must employ a rule to allow the placing of such nest losses within adjacent periods. The simplest method would be to assign the nest failure to the period which contains the mid-way point between the two observations. If one period has a considerably higher survival rate than the other, then some other adjustment might have to be made. Hensler suggests that if there are relatively large numbers of nests for which failure could have occurred in either of two periods then the solution is to combine the periods. This problem provides a practical reason why there is a limit to the number of sub-periods that can be used within a Mayfield study: if periods are less than the average inter-visit interval then miss-assignment of failures could be a major problem (Price 1990). The possible impact of this problem could be assessed by measuring the proportion of losses that occur between visits that span two periods.

An extension of this assumption is that visit intervals must not be so long that the observer is unsure whether a particular nest has failed or succeeded (Hensler 1985). Such visits have to be discounted.

Within the Nest Record Scheme, the analytical programs currently omit data on losses which were unassigned definitely to egg or nestling stages, which tends to bias asbolute loss rates low. Modifications need to be made to assign losses according to the rules suggested above. Some further checks on the proportion of failures that occur during intervals that span more than one period are needed. If necessary, programs could be modified to produce sound estimates for combined periods only where necessary. This is not a serious problem for the Nest Record Scheme as it can be resolved by adopting appropriate analytical procedures.

3.1.4 Subdivision of the nesting cycle into periods with constant daily survival rates

Subdivisions of the nesting cycle are required when there are significant changes in nest survival rate during the cycle. The most basic, biologically relevant, division of the nesting cycle is into egg and nestling periods, the latter starting with the hatching of the first egg and ending with the fledging of the last chick. The egg period can be divided into laying and incubation periods. The hatching period may need to be separated out because failure rates then are likely to be high due to the effective accumulation of addled clutches within the sample that are only discovered when they do not hatch. (The practicality of separating out the hatching period will need to be investigated, given its short duration). Division of the nestling period in half may be appropriate if, say, the increased activities of provisioning adults or increased begging by more demanding older chicks makes the nest more apparent to nest predators.

The definition of periods is more difficult for species with asynchronous hatching than those with synchronous hatching. Incubation starts before egg-laying has ended, perhaps improving the daily nest-survival rate due to the continual presence of a parent. Hatching is spread over several days and fledging can extend over an even longer period if environmental conditions tend to produce marked weight hierarchies within each brood. Currently the Nest Record Scheme analytical programs define egg and nestling periods relatively simply (see 3.1.3.10), but more sophisticated developments are planned, which will allow the breakdown of a nesting attempt into a greater number of discrete periods.

The detection of changes in daily nest survival rate during the nesting cycle would be simplest if nests were visited daily, allowing survival rates to be calculated for each day of a nest's existence. With Nest Record Card data, and indeed, within many professional studies, this is not possible because inter-visit intervals are usually longer than one day.

Klett & Johnson (1982) analysed duck nesting data by calculating five-day survival rates. Changes in nest survival rates were investigated using analysis of variance, fitting a variety of models (linear, quadratic, joint linear models that consisted of two straight lines intersecting part-way through the nest cycle) and judging the models by comparing Mean Square Error among them and using the significance level of each effect included in the models. Three data-sets were best described by the joint linear model and the other by the simple linear model. In these cases therefore, five-day sub-divisions of the nesting cycle were found to be necessary. The production of an overall nest survival rate by the product of each subperiod provided a lower value for nest success than the straightforward Mayfield method because samples were biased toward later stages of the nesting period. The intercept method of Johnson (1979), in which the regression lines are extrapolated to the *y*-axis, produced even lower overall survival rates. It is not clear which method is least biased, although the product method would appear to have the soundest basis.

The only other systematic investigation into possible changes of nest survival rate during the nesting cycle was by Price (1990). She analysed Song Thrush *Turdus philomelos* Nest Record Cards from the BTO's Nest Record Scheme to investigate the effect of increasingly sub-dividing the incubation period. First she investigated a model that separated laying, incubation and nestling periods; the second model divided incubation into early and late halves; the third model divided the early incubation in two halves to produce a five-period model. Overall survival rates declined progressively as the incubation period was increasingly split, although not significantly so: the differences between individual sub-periods were not significantly different.

Further analysis of Nest Record Scheme data to assess the importance of changes in nest survival rate through the nest cycle is urgently required. We need to know the magnitude of possible differences between periods, whether survival rates tend to change within periods at constant rates or whether they can be considered to be constant within periods, whether there are different patterns of change between different species and, indeed, whether such changes affect a wide range of species or just a few.

A literature survey of intensive field studies would provide additional valuable information on changes in nest survival through successive nesting stages for comparison with such Nest Record Card analyses.

3.1.5 Further analytical considerations

The analysis of nest survival would be considerably advanced by the adoption of modelling framework similar to that which has been developed in the field of survival rate analysis from ringing data. In particular, the Mayfield method, as adapted by Bart & Robson (1982), has been shown to be amenable to analysis using White's (1983) SURVIV program. White (1983) notes that the variance estimators for the Mayfield method are derived from different assumptions to those used by SURVIV, thus some extensions to SURVIV will be necessary before its use can be implemented. However, the use of a formal modelling framework would allow the incorporation of covariates, such as habitat and region, in analyses in a more flexible and more rigorous way than is possible at present.

Variance estimates of nesting success calculated using the Mayfield method could be calculated using bootstrap resampling techniques (Crowley 1992), bootstrapping on nests. Such methods make no assumptions about the underlying distribution of a dataset and could be used to overcome any problems that might arise due to lack of independence between units of exposure of nests. Such methods are very computer intensive and are only feasible when fast computer facilities are available: they should then be implemented within the Nest Record Scheme.

The Mayfield method can be used to calculate the daily survival rates of eggs and chicks within nests, to provide estimates of partial losses. Mayfield (1961) showed how partial losses from clutches could be calculated in exactly the same way as whole nest losses, but only using egg-days during which whole nest losses did not occur. The Nest Record Scheme has analytical programs available for calculating daily failure rates of eggs and chicks that include both partial and whole nest losses, but the potential problem that eggs or nestlings within broods may not be statistically independent would be better analysed using bootstrap methods to calculate variance estimates. Winterstein (1992) has suggested a method to test for intra-brood independence which uses half a dataset to calculate the expected brood sizes for the other half. Comparison of observed and expected brood sizes for each brood is done by X^2 test.

3.1.6 Recommendations for the operation of the Nest Record Scheme

Currently, the Nest Record Scheme analytical programs use the basic Mayfield methodology and Johnson's variance calculation. The programs calculate estimates for nest failure rates for incubation and nestling periods separately and combined. Sample sizes quoted are number of nests. Maximum and minimum estimates are provided based on maximum and minimum nest-days (exposure-days). Nest-days are known with certainty for nests which neither fledge nor fail during observations and are treated as being known with certainty if a nest fails between two visits (by using the mid-point assumption, see 3.1.3.6). Nest-days are not known with certainty if a nest is successful between two visits: the minimum or maximum nest-days depend on estimates of the fledging date derived from minimum and maximum nestling period lengths culled from the literature. Likewise, nest-days are not known with certainty if a failure occurs between two visits during which fledging could have occurred: the minimum and maximum fledging dates provide the range.

The majority of the assumptions listed above were shown to be relatively easy to accommodate when analysing Nest Record Scheme data. A few were shown to pose more difficult problems and require further investigation as described below (3.1.7).

For the continued operation of the scheme, the following recommendations can be made. (References to the appropriate sections of the report are provided in parentheses).

3.1.6.1 Analytical recommendations

a) Use the Mayfield method and the associated MLE variance estimates (3.1.2.2.1), z-tests (3.1.2.2.2) and variance estimates of survival rate products (3.1.2.2.3). Implement the use of Johnson's (1979) MLE version when practical (3.1.2.3.6).

b) Use the highest precision available for calculating Mayfield survival rates and quote the precision used with published results (3.1.2.1).

c) Use at least 50 nests and preferably >100 nests (1000 nest-days) per sample (3.1.2.2.2).

d) Provide clearly defined period durations for incubation and nestling stages and have clearly defined rules for assigning nest losses to a particular period (3.1.3.10 & 3.1.3.11).

e) Stratify samples when clearly identifiable heterogeneities occur in a population and separate periods of nationally catastrophic losses of nests into separate strata when necessary (3.1.3.4).

3.1.6.2 Recommendations for new fieldwork practice

a) Advise observers of the necessity to record all observations on nests, even when made from a distance (3.1.3.7).

b) Ask observers to note when visits were discontinued because a nest could not be relocated or because continued access to a site was denied (3.1.3.2).

c) Advise observers that, subject to a minimum number of visits required to identify key events in a nesting attempt (laying, hatching, *etc.*), it is more useful for the analysis of Nest Record Cards to receive more records rather than more visits per record (3.1.2.2.2).

3.1.7 Recommendations for further studies

The following studies are recommended to further improve the use of the Mayfield method within the Nest Record Scheme.

3.1.7.1 Validation studies

1) Analysis of daily nest survival rates measured over inter-visit intervals of increasing length to investigate the extent of combinations of adverse effects of nest visiting and inconsistent recording of visits (3.1.3.5 & 3.1.3.7).

2) Analysis to investigate (a) the magnitude of differences in survival rate between different stages of the nest cycle, (b) whether survival rates tend to change within periods or can be considered constant and (c) whether there are differences in patterns of change between species (3.1.5).

3) To examine a relatively minor problem of the application of the Mayfield method by undertaking simulations to analyse the effects of heterogeneous samples on Mayfield estimates (3.1.3.4 & 3.1.4).

4) Investigate the frequency distribution of inter-visit intervals for species with long incubation and nestling periods to check whether the use of the mid-point assumption of Mayfield is valid (3.1.3.6).

3.1.7.2 Analytical developments

1) Over the next few years it would be valuable if a proper modelling framework could be developed for the analysis of Mayfield-type data (3.1.5). The program SURVIV may be a suitable vehicle for such a framework but considerable methodological development will be required.

2) The use of bootstrap techniques should be implemented to allow the calculation of variance estimates based on the distribution of each analysed dataset. The use of such techniques will greatly facilitate the calculation of variance estimates for egg and chick survival rates, allowing for a lack of independence between eggs in a clutch or chicks in a brood (3.1.5).

3.2 The effect of nest visiting

Mayfield (1975), Lenington (1979) and others have referred to this problem as a "Biological Uncertainty Principle": observations may alter the character of the object under observation but there is no way of knowing the undisturbed character of the object.

In addition, there are more general ethical considerations that should be borne in mind during any work involving animals (Cuthill 1991). Cuthill notes that the question of how much "tampering" with wild animals is justifiable depends on issues of welfare, conservation, the sanctity of life and animal rights. Field observations are at the least stressful end of the spectrum of animal research and it is probably only those with extreme anti-science views that would object to such minimal interference. However, the justification for causing any effects depends to a certain extent on the value of the research to humans and to the conservation of the animals themselves. If the effects of field-work can be demonstrated to be minimal at the individual and population levels then, we think there will be few that would criticise the work. The standards required for conservationally important species would need to be more stringent than for those which are relatively common but, overall, standards need to be high in order to convince the general public (including scientists) that the work is justified.

One of the key assumptions of the Mayfield method is that observations at nests do not affect nest survival rates (Assumption 5, see section 3.1.3.5). Indeed, for the study of population dynamics generally, it is important that observers do not affect significantly any aspect of the biology of the species under investigation. Furthermore, any biases that may arise due to investigator activity need to be measured to ensure that corrections are applied to population models.

With regard to nest visiting, the picture is not quite as bleak as the uncertainty principle suggests. It is often possible to observe nests from such a distance that disturbance can be assumed to be zero, comparison can be made to nests which are visited periodically.

3.2.1 Gotmark's review

Gotmark (1992) reviewed the literature on the effects of investigator disturbance on nesting birds. Out of 225 studies included in his review, only 27 involved experimentally disturbed nests in comparison to undisturbed controls, 12 compared three or more levels of disturbance, 33 compared two levels of disturbance. Other papers reported weaker tests such as those involving samples from different years or study areas or even just anecdotal reports, these will be ignored below unless otherwise stated. Many of the studies involved considerable degrees of disturbance.

Gotmark found considerable bias in the distribution of studies among orders, with pelecaniforms, anseriforms and charadriiforms over-represented but passeriforms under-represented. This distribution may reflect both the expectation of effects by investigators and the relative ease with which such studies can be studied among the former groups. Thirty of 58 studies (52%) reported significant effects of visiting on nesting success. Effects were observed particularly among charadriiforms (13 of 15 studies) but were rarely found among passeriforms (two of 11 studies). Gotmark noted that sample sizes were similar among different orders and averaged over 100, concluding that differences in statistical power was not a factor that would explain the differences between orders. Furthermore, studies which showed effects did not involve more visits than those which did not. For six species, conflicting results were found in different studies, probably due to differences in levels of disturbance or predator populations.

Coloniality was an important factor in determining whether a significant effect was found within a study. Thirty-three of 45 studies (including both strong and weak tests, see above) on colonial species (73%) showed effects on nesting success or predation rates compared with eight of 37 studies (21%) on solitary nesters. This is obviously related to the bias in the taxonomic distribution of studies noted earlier.

The size of the effects found by Gotmark (including three studies that were based on relatively weak evidence) ranged from 23-62% reduction in nesting success (mean 39%, eight studies), 11-95% reduction in fledged young per pair (mean 44%, 17 studies), reduction in hatching success by 24% (three studies). Large effects tended to be found among pelicans, cormorants, herons, waders, alcids and gulls (33-95% reductions) and smaller effects in the three studies of passerines (14-35%).

Very few studies were reported by Gotmark to have examined systematically the reasons for reductions in nesting success. Thirty-two of 39 papers suggested predation was responsible (82%), 11 (28%) found nest desertion (some in addition to predation) and smaller numbers reported possible effects from over-heating, cooling, trampling by parents or inadequate parental care after disturbance.

The main predators in 37 studies in which they were not only identified but also found to have a significant effect, were larids (22 studies, seven of which being intraspecific predators), corvids (13 studies), Red-backed Shrike (one study) and man (one study). There was no evidence for other mammalian predators being involved. Three studies specifically looked for the effects of mammalian predator, two found no effect and one found a beneficial effect: close approaches by ornithologists to Piping Plover nests decreased fox predation (MacIvor *et al.* 1990)!

There is even less evidence for nest desertion after nest visiting, although it is often assumed to be more likely at nests during egg-laying or early incubation than later. Five studies were reported by Gotmark to show early-stage desertion as the main cause of reduced breeding success, but five others found no effect of early disturbance. Very few properly controlled studies have investigated this aspect but if all papers showing strong and weak evidence are considered, 59% of 49 studies that started at egg-laying showed effects of nest-visits, but only 46% of 26 studies starting from incubation and 29% of seven after hatching. The difference between the groups was not significant but suggests a trend.

3.2.2 Case studies

Details of a number of case studies are provided below to provide examples of the types of studies undertaken on the effects of nest visiting. Four main categories are considered: studies involving undisturbed control nests, studies that compare frequent with infrequent disturbance, direct observations of the behaviour of nest predators and studies on the effects of marking and handling birds at nests.

3.2.2.1 Undisturbed control nests

The best studies involve the comparison of nests which are completely undisturbed compared with those that were visited by observers. Willis (1973) conducted one of the earliest such studies: Bicolored Antbird behaviour at ant swarms is a good predictor of nesting activity and he found no difference in the survivorship of 16 visited and 61 unvisited nests, although visited nests tended to have higher rates of nest loss during incubation, possibly because they were easier to find, whereas unvisited nests had higher rates of loss during the nestling stage when nestlings were noisy. Galbraith (1987) found no difference in the survival rate of Lapwings nests that were scanned from a distance (n=185), approached for counting (n=65) or approached for handling the eggs (n=136). Hannon *et al.* (1993) studied Red Grouse in the Canadian tundra and found that the number of hens with broods was the same in areas where nests were visited (19%) as in areas where they were not (23%), despite good statistical power to detect a difference. The proportion of robbed nests of Eider Ducks were no different on small islands in south Sweden which were visited or not visited, despite increased gull activity during and after visits; the lack of an effect was probably because nests were covered with down by the observers: uncovered artificial nests suffered higher predation rates than covered ones (Gotmark & Ahlund 1984). Crow predation on a dense population of Coot nests showed no significant effect on whole nest losses after investigator disturbance although sample sizes were relatively small; however the proportion of eggs lost increased from 18% (undisturbed) to 35% (disturbed), suggesting an effect (Salathe 1987). Grier & Fyfe (1987) found no adverse effects of visiting the nests of Bald Eagles, Ospreys, Ferruginous Hawks and Prairie Falcons when compared with unvisited nests. Poole (1989) found similar results for Ospreys in his studies.

A few studies of solitary nesting species have revealed effects of nest visiting. Both Golden Eagle and Red-tailed Hawk but not Prairie Falcon appear more likely to fail if visited early in a nesting attempt in comparison to unvisited nests (Steenhof & Kochert 1982). Newton & Campbell (1975) studied the dense populations of ducks nesting at Loch Leven, searching undisturbed areas after the nesting season for signs of nests: undisturbed areas appeared to have at least 9-14% greater nesting success. Contrary to the results of Nichols *et al.* (1984, see below), Westmoreland & Best (1985) found significant differences in the survival rates of Mourning Dove nests that were visited (15% successful) compared with unvisited nests (29% successful), probably due to higher densities of avian predators in their study area compared with Nichols *et al.* The use of radio-tags to detect the nesting activity of Ring-necked Pheasants and Grey Partridges can result in lower desertion rates compared with intensive nest searches (Carroll 1990), desertion rates were 14% and 8% respectively for pheasants and partridges located by radio-tracking and 64% and 59% for nests located by nest searches.

Studies of colonial birds appear universally to show an effect of disturbance. The inclusion of unvisited control areas in studies has shown that frequent visiting has had the following effects: (a) decreased breeding performance for Brown Pelicans probably due to gull-predation, over-heating, desertion at early stages (Anderson & Keith 1980); decreased breeding performance of Heermann's Gulls due to increased chick movements and intraspecific killing (Anderson & Keith 1980); (c) decreased fledging success from 94% in undisturbed areas of a Tufted Puffin colony to only

18% in a study area together with a delayed start to incubation (Pierce & Simons 1986); decreased chick survival in for Western Gulls (Robert & Ralph 1975); decreased fledging success among Guillemots in daily-disturbed (69%) and undisturbed (94%) colonies, disturbance also apparently caused delayed laying (Harris & Wanless 1984); increases in the proportions of egg and chick death from *c.* ten per cent to *c.*28% for Glaucous-winged Gulls (Gillet *et al.* 1975).

3.2.2.2 Frequent compared with infrequent disturbances

The comparison of nest success between nests that are visited at different frequencies is an easier experimental protocol and, for many species, may be the only feasible protocol, especially if nests are well hidden.

Lack of any effect has been found in the following: (a) between nests of Florida Scrub Jays visited twice daily and nests visited every third day (Schaub *et al.* 1992); (b) between nests of Mourning Dove visited daily and weekly (Nichols *et al.* 1984); (c) between nests of Black Brant visited over a wide range of interval length, randomly assigned (Sedinger 1990). Robertson (1991) analysed Nest Record Cards for Ring-necked Pheasants and found that nest abandonment rates on the day after visiting were four to five times higher than during the subsequent nine days. However, this might not be due solely to an effect of nest visiting but could be a result of observers not recording all visits (see 3.1.3.7 above) or observers not recognising already abandoned nests; the rates of loss due to other causes were not significantly different between the two periods.

Among colonial seabirds, significant effects of increased disturbance again seems the norm. Fetterolf (1983) made some extensive observations of experimental disturbances at a Ring-billed Gull colony and found decreased fledging success, increased adoption rates and increased fights between adults due to disturbance. An island population of Fulmars exhibited lowered breeding success when large groups of field workers visited during the hatching period, but not when visited during early incubation (Ollason & Dunnet 1980). The hatching and fledging success of Least Auklets was severely affected by the level of nest visiting made by observers (Piatt *et al.* 1990). Hatching success but not fledging success (per egg hatched) was adversely affected by daily visits to Black Guillemot nests (Cairns 1980). Daily visits to Black Skimmer colonies were more likely than weekly visits to result in adult dispersal, early nest desertion, decreased hatching success and decreased fledging success (Safina & Burger 1983).

Experiments with artificial nests are a variation of the approach described in this section because all nests have at least one "visit" when they are put into position. Generally, experiments with artificial nests face problems of interpretation because the nests are not guarded by parent birds and they may be placed in locations that are subtly different from the locations of real nests. Gottfried & Thompson (1978) undertook an extensive series of tests involving 240 artificial nests over a two and a half month period in an area of abandoned agricultural fields. The nests were abandoned open-cup nests and were exposed for six days during which they were either visited once or six times. Daily visits did not increase the likelihood that predators would discover the nests. Major (1990) used artificially placed abandoned nests of the White-fronted Chat to find that daily visits over 14 days resulted in significantly higher losses (nine of 20 nests) than nests visited only on the 14th day (two of 20 nests), the losses suspected to be due to corvids. In this case the predation rates were similar between artificial and active nests visited daily, suggesting a real observer effect.

3.2.2.3 Direct observations of nest predators

Sedinger (1990) checked for any immediate effects of nest visitation on Black Brants by immediately revisiting nests once incubating birds had returned after a first visit; only one of 50 eggs in 27 nests were lost at the laying stage and none of 225 eggs in 55 nests during incubation.

Strang (1980) made systematic observation that showed that Arctic Skuas were significantly attracted to areas where observers were actively searching for duck nests in the tundra. Glaucous Gulls and Long-tailed Skuas were not attracted.

Observations of radio-tracked foxes in an area where artificial Piping Plover nests had been laid out showed that foxes did not approach nests by following human trails but seemingly came upon nests randomly as part of their foraging activity (MacIvor *et al.* 1990).

Various fieldworkers have reported that certain specialist individual predators can have large local affects. For example, Gotmark *et al.* (1990) report that one pair of crows learnt to follow field workers to find Black-throated Diver nests. Snelling (1968) found that a predator, probably a Raccoon *Procyon lotor*, systematically destroyed study-nests in a marsh, presumably by following human scent or trails.

3.2.2.4 Marking and handling birds and nests

Calvo & Furness (1992) reviewed the literature on the side-effects of marking wild birds for ecological and behavioural studies. They concluded that marking often has some effect on birds but that this possibility is often left unstudied. We have extracted from their review all reports of the effects of capturing adults at the nest and the effects of marking nestlings. It is important to consider whether records from such nests might provide biased samples for the calculation of nesting success.

Nest desertion after trapping and handling was excluded from Calvo & Furness' review but they included a few reports that desertion sometimes occurs after the capture and marking of adults at the nest, the effect being more pronounced earlier in the nesting cycle (*e.g.* Lombardo 1989). A questionnaire survey of 250 European ringers by Kania (1992) asked for opinions and observations of desertion rates of parent birds after capture at, or close to, nests or broods. Although no data were provided on desertion rates without capture, the survey suggests that capture at the nest is associated with higher desertion rates the earlier in the nesting cycle it is performed. The proportion of species for which capture is considered safe (by causing <2% desertion) increases from 13% during laying (number of species = 15) to 22% during the first half of incubation (n=40), 51% during the second half (n=63), 62% during hatching (n=24), 72% during the early nestling stages (n=36), 89% during the middle nestling stage (n=44) and 97% during the late nestling stage (n=39). Ringing with metal leg-rings is generally assumed to have no effect on breeding success, although coloured rings on adults can affect reproductive effort in various species (*e.g.* Burley 1981). These aspects of nest disturbance needs to be reviewed, but are outside the scope of the present report.

The marking of nestlings can cause their removal by parents. It is thought that such removals may be a result of parents mistaking the shiny ring as a faecal sac and it is generally considered advisable to darken rings with black ink before attaching to very young nestlings. Coloured leg-rings may also have effects, for example Red-cockaded Woodpecker are less likely to be resighted as fledglings if ringed with red rings. Web-tagging of chicks in pipped eggs did not affect the hatching success or subsequent survival of seven species of duck; toe-banding had no effect on the chicks of Great Northern Divers; patagial tags had no effect on the mobility of Red Grouse chicks; adhesive head-tags had no effect on Pied Flycatcher chicks; while dyes have been shown not to affect the chicks of several species (including Hen Harrier), it has been shown to cause an increase in conspecific predation among South Polar Skuas. Repeated handling of Snowy Egrets to obtain measurements of growth had no effect on their survival in the nest after ringing when compared with chicks that were not handled (Davis & Parsons 1991).

There is a need to examine these aspects further, within the context of breeding performance monitoring using the Nest Record Scheme. A relatively straightforward analysis would compare the nest, egg and chick survival rates of nests in which the parents are caught and ringed at the nest compared with those in which they are not. Similarly, nest and chick survival after chick ringing could be compared with survival of nests from the same age.

Calvo & Furness also reviewed the effects of radio-tags on birds and found eight of 26 studies (31%) recorded an effect on reproductive behaviour, four of 16 (25%) on reproductive success, zero of two on brood size, five of six (83%) on nest or brood desertion and one of four on chick growth rate. Kenward (1987) reported studies that have shown radio-tagging to cause desertion by incubating Herring Gulls and desertion of broods by female Woodcocks.

The use of markers to help relocate nests can attract nest predators. Picozzi (1975 cited in Gotmark 1990) found that corvids were attracted to artificial Lapwing nests marked by canes, although Galbraith (1987) found no effect at real nests. Reynolds (1985) made observations of a Sandhill Crane that obviously became cued onto markers set near wader nests.

Finally, there is an aspect that is unlikely to be an important factor in the UK: the modification of nests to obtain access. A study by Hamilton & Martin (1985) showed that removal of part of the mud entrance tunnel of Cliff Swallow nests had major detrimental effects on breeding performance due to the expenditure of time spent by parents in mending each nest and due to the loss of chicks which fell from the altered nests.

3.2.3 Mayer-Gross' observations

In 1960 and 1961 Henry Mayer-Gross, as Nest Records Officer at the BTO, undertook a series of field observations to examine the effect of nest visiting on the nesting success of open-cup nesting passerines. The studies were never published but were reported to the Nest Records sub-Committee and the Scientific Advisory Committee of the Trust. An outline of these studies and the results are presented below but they are worthy of further analysis to investigate the power of the tests used (no statistical tests were reported by Mayer-Gross, the simple contingency table analysis reported below was undertaken by HQPC).

3.2.3.1 Fieldwork in 1960

In 1960, Mayer-Gross visited the nests of seven species of passerine in five study areas (Song Thrush, Blackbird, Whitethroat, Dunnock, Greenfinch, Linnet and Chaffinch). Nests were only included if found before or during laying. They were divided into two groups, control nests which were only visited to find the date of laying and then at the time of fledging to measure nesting success, and experimental nests which were visited every fourth day. Nests were assigned to each group by the toss of a coin on the day eggs were found.

Sample sizes were not large enough to permit species breakdown by study area. Only two species provided large enough sample sizes to be considered separately. Song Thrush nests suffered a 68% failure rate overall, there being no significant difference between treatments (X^2=0.00), 22 of 32 control nests failed and 32 of 47 experimental nests failed. Blackbird nests suffered a 73% failure rate overall, 21 of 31 control nests failed, 22 of 30 experimental nests failed (X^2=0.23). When all species were grouped together, 72 of 101 control nests failed (71%) and 80 of 115 experimental nests failed (70%), the difference not being significantly different (X^2=0.08).

3.2.3.2 Fieldwork in 1961

In the 1961 field season, Mayer-Gross studied the nests of the same seven species as in 1960 and added the nests of Wren, Bullfinch, Blackcap and Garden Warbler. Field work was carried out in an area of farmland and woodland near Oxford and in the Oxford Botanic Gardens. The experimental protocol was essentially the same as in 1960, but visits were made every three days. Disturbance to vegetation surrounding each nests was varied, some were only slightly disturbed and others were more obviously disturbed to mimic an "average recorder". In addition, nests were classified as exposed or hidden.

The results in Table 3.2.3.2. show little evidence for any effect of nest-visiting, the only significant results for individual species being for a small sample of Bullfinch nests in which nest-visiting was apparently detrimental and the opposite effect for Dunnock, for which nesting success was higher among experimental nests. Over all species there were no differences between treatments, nor between treatments in different habitats. Mayer-Gross was concerned about a possible effect on finches in farmland and, indeed, there was a significant difference in failure rates between control and experimental nests ($P<0.01$). The sample sizes for each for the four species of finch were relatively small, but the effect seemed mainly due to the difference between control and experimental nests for Linnets on farmland (five of 12 control nests failed (42%) compared with eight of nine (89%) experimental nests); if the records of Linnet are subtracted then there is no difference between treatments for the other farmland finches (X^2=2.72). Although the small Linnet sample may have been biased by chance, the possibility of an effect of nest visiting on that species needs further research.

Table 3.2.3.2 Results of Mayer-Gross' experiments in 1961 on the effect of nest visiting

	Controls		Experimental		X^2
	Succeed	Fail	Succeed	Fail	
Wren	12	14	12	15	0.02
Song Thrush					
Garden	6	11	9	7	1.46
Farm	3	15	7	14	1.41
Wood	11	29	11	22	0.29
Total	20	55	27	43	2.34
Blackbird					
Garden	7	9	8	16	0.44
Farm	3	23	6	23	0.84
Wood	4	28	8	19	2.19
Total	14	60	22	58	1.58
Sylvia spp.	8	6	8	5	0.05
Dunnock	8	24	15	15	4.15*
Greenfinch	5	15	3	19	0.88
Linnet	8	8	2	11	3.80
Bullfinch	5	6	1	11	3.80
Chaffinch	0	7	2	6	-
All species	80	195 (71%)	92	183 (67%)	1.22
Garden	17	32 (65%)	23	37 (62%)	0.15
Farm	26	71 (73%)	25	81 (76%)	0.28
Wood	37	92 (71%)	44	65 (60%)	3.59
Farm Finches	16	24 (60%)	5	33 (87%)	7.14**

3.2.4 Recommendations for the Nest Record Scheme

There is only a relatively small body of work on the effect of nest disturbance on nesting success and many of the studies quoted by Gotmark involved quite substantial disturbance, often considerably more than would usually be made by BTO nest recorders. Although simple nest visits often appear to have little or no effect, in some circumstances the effects are marked. Records from nests which have been detrimentally affected by disturbance could provide biased estimates of variables such as nesting success, brood size, clutch size and laying dates. Apart from the ethical reasons for not wanting to receive such records or encourage such disturbance, biased records may be scientifically unwanted because of their effect on population modelling. Monitoring programmes may be able to cope with such biases so long as they do not vary over time. Ideally, potential biases should be identified, measured and preferably eliminated.

One of the most obvious conclusions that should be drawn from this review is that the effects of repeated nest visiting in seabird colonies, reported from many studies, are so severe that it is necessary to ban all but distant observations for nest recording (because it requires repeated visits), on both ethical and scientific grounds. The current Nest Record Scheme Code of Conduct warns that visits to colonies are inadvisable and that visits are best made only near fledging, but visits even at this time may have detrimental effects. Further experimental work on this aspect is urgently needed, but it should be noted that the majority of Nest Record Scheme recording of colonial seabirds is made at a distance and not by entering colonies.

Visits to solitary nesting birds generally have little or no effect on breeding success, particularly to nests of passerines. Recent evidence from radio-tracking has suggested an affect of nest searches on galliform nest desertion, although previous studies have found no effect. Consultation with the Game Conservancy Trust on their experience would be advisable.

There is some evidence that disturbance at early stages of nesting may induce desertion more than disturbance later, although this seems to vary between species and circumstances. Nest recorders should be recommended not to flush birds from nests at early stages until experimental work has been undertaken to investigate its effects.

Surprisingly, mammalian predators appear not to be a problem with regard to the often presumed following of observer trails. The main predator problem arises from corvids. The mechanism by which they can preferentially find visited nests is unclear in some cases but, in at least some cases, corvids have been known to follow observers as they visit nests. Nest recorders are already warned not to visit nests when corvids are present.

It is possible that records from nests where adults or young have been ringed may provide biased estimates of nest or chick survival. It is unlikely that there is any effect of ringing or marking of nestlings on their subsequent survival, although analysis to investigate this further should be undertaken. At the present time, records of nests which contain ringed young should continue to be used in analyses of nest success.

The capture and marking of adult birds at nests needs careful evaluation, species-by-species. It is likely that short-lived species will not be affected by such disturbance but that longer-lived species will be, so the Nest Record Cards of longer-lived species which report the nest-capture of adult birds should not be included in samples used to monitor nest success until such disturbance has been proved to have no effect. The same is necessary for records of nests at which the parents are radio-tagged, the effects of which are often significant. Currently, relatively few species are captured at nests that are recorded on Nest Record Cards; the only monitoring species (Table 2.3.1b) with significant numbers of records of nests at which adults are captured are Barn Owl (23%), Tawny Owl (13%), and Nuthatch (13%). (Captures of adults at or near the nest are recorded by a special code on the Nest Record Card).

3.2.4.1 Ameliorating the effects of nest visiting

Gotmark (1990) suggested a very similar range of actions to be taken by observers to ameliorate the effects of nest visiting as has been laid out in the Nest Record Scheme's code of conduct (Mayer-Gross 1970; Crick *et al.* 1994b). The basic principle being that the observations should not jeopardise the safety of the nest.

Key aspects of the Code include the following: (a) any disturbance to the vegetation surrounding a nest should be kept to a minimum; (b) observers should remain at the nest for as short a period as is necessary to make the observations; (c) approaches to nests should be obvious to sitting parents so that they have time to leave without startling; (d) disturbance should be avoided when eggs and young might be subjected to extremes of temperature; (e) that observers should be especially sensitive to the presence of parents during the early stages of laying and incubation; (f) nests should not be approached when recorders are being observed by avian predators, especially corvids; (g) observers should always make trails that carry on past the nest so as to avoid dead-end trails that end at a nest; (h) observers should not visit close to nests containing large young because they might leave prematurely; (i) wildfowl nests should be covered by down by observers to decrease the likelihood of predation by avian predators; (j) any markers that are used to help relocate nests should be discrete and preferably natural.

3.2.4.2 Literature reviews

It would be useful to undertake a literature review of nest survival rates, including desertion and predation rates, for comparison with figures obtained from the Nest Record Scheme. Although such a comparison would not necessarily reveal which data were biased if there was a difference, similar results would increase confidence in the estimates provided by the Nest Record Scheme.

There is a need for a review of the literature of the effects of capturing and marking adult birds during the breeding season. Capture at the nest is often undertaken in intensive studies and such studies should include an investigation into any side-effects. Capture away from the nest may disrupt the normal nesting activities of breeding birds, possibly due to the stress incurred and less so due to the time lost while captured. The latter affect may be more serious when there is mono-parental care. Capture at the nest is more likely to affect nesting behaviours and nesting success. Adults may desert or be more reluctant to spend time on or at the nest.

3.2.4.3 Analytical work

The apparently straightforward method in which the effects of nest visiting can be assessed from Nest Record Scheme data is that of Bart (1977). He analysed Nest Record Cards, from the US Scheme, of five passerine species by plotting the daily survival rates of nests calculated over inter-visit intervals of differing lengths. He found that daily survival rate was significantly lower on the first day after a visit than on the subsequent five days, for four of the five species. Unfortunately, the same result could have occurred if observers did not record all visits that report continued nest survival but only report visits when a nest has failed (see 3.1.3.7 above), nest failures would then be over-represented during short inter-visit intervals (Bart & Robson 1982). (This approach was used in a valid way by Sedinger (1990) because, in his intensive study, all visits were recorded).

Despite its drawbacks, the test proposed by Bart (1977) should be used to investigate BTO Nest Record Cards. If daily nest failure rates are constant between different inter-visit interval lengths then problems due to adverse observer effects and due to lack of recording of all visits can both be discounted. Bart & Robson's (1982) version of the test, which is to plot proportion of nests surviving against interval length should also be used. If the proportion of nests surviving increases at longer interval lengths then inconsistent recording would be demonstrated as a problem. If the proportion of nests surviving declines gradually, but not exponentially, and regression produces a *y*-axis intercept at less than 1.0, then one or both problems are affecting the data. Such a situation would need the development of a new analytical technique, although this currently seems an intractable problem.

Hannon *et al.* (1993) suggest another approach, which involves comparison of the number of visits made to successful nests and to failed nests over observation periods of equal length. If nest visiting has a cumulative effect then failed nests will have been visited more frequently than successful nests over a given time interval.

It is possible that the act of flushing birds from nests during nest recording may affect nesting success. It would be relatively straightforward to compare the nest success of nests where flushing took place with those where nest contents but no adults were recorded.

The effect of ringing on nest success should be analysed for each species by comparison of nest, egg and chick survival for nests at which the adults have been captured and marked and those at which they have not. Similarly nest and chick survival from the average age at ringing should be compared between nests with and without ringed chicks.

3.2.4.4 Experimental work

Mayer-Gross' experimental study was carried out in the early 1960s when corvids were at low population levels (Gregory & Marchant in press). It would be valuable to repeat his work now that corvid populations have increased substantially. It is possible that nest visits may now result in a greater likelihood of nest failure rates than was found during the 1960s.

There would be great value in attempting to set up experimental fieldwork using BTO volunteer observers. Certain questions could be investigated using simple protocols, similar to the ones used by Mayer-Gross. Simple randomisation of treatments could be undertaken by asking volunteers to flip a coin. Data could be gathered on nests at which (a) adults are flushed from the nest or not flushed, (b) visits are frequent or infrequent, (c) pulli are ringed or not ringed, (d) parents are caught and ringed at the nest or not attempted to be caught. Comparison of various key variables could be analysed to investigate the effects on nest survival rates, egg and chick survival rates, clutch and brood sizes, and laying dates.

It might be possible to develop some intensive fieldwork, using volunteer recorders, who would monitor the success of unfound nests by observing the behaviour of adults. W.J. Peach (*pers. comm.*) has found that the behaviour of Whitethroats can provide accurate indications on the stage of nesting. Similarly, observations of Golden Plover behaviour can be used to prove breeding as it is a species for which the nests are particularly difficult to find (A. Brown, *pers. comm.*)

3.3 Seasonal variation in proportion of nests found

3.3.1 Seasonal variation in search effort

Volunteer nest recorders are known to vary their searching efforts through the year. Fieldwork effort for the Nest Record Scheme is high between April and June, increasing from March and decreasing to October (Figure 3.3.1). For many species, particularly those with relatively synchronised nesting activity occurring during the period of maximum fieldwork effort, the Nest Record Cards gathered should not be biased with respect to season. A problem arises for certain species, mainly multi-brooded, for which the decrease in fieldwork from July results in late nests or second and third broods being under-represented in the samples obtained. This is particularly important if indices of breeding performance over the nesting season is required and late season nests form an important component of breeding performance.

3.3.1.1 Measuring fieldwork effort

Over the past seven years, nest recorders have been asked to record whether they spent "many", "few" or "zero" days nest recording in each month from March to September. The proportion of recorders providing each response for each month has been calculated and reported as a histogram in each year's *Nest Record News*, with a plea for nest recorders to "see the season through". Figure 3.3.1 shows how search effort has remained remarkably constant from year to year. The lack of change is valuable because any bias that arises can be considered essentially constant between years.

The search effort recorded in Figure 3.3.1 combines the records for all nest recorders. Since many nestbox species, such as the titmice, are single-brooded in the UK, the search effort for recorders that concentrate primarily on nestbox species have been separated from those that concentrate on open-nesting species in Figure 3.3.2. As expected, nestbox recorders concentrate their effort in the earlier part of the year, decreasing their effort considerably in July. Recorders that concentrate on open-nesting species, many of which are multi-brooded, show a more extended period of searching effort, with only a slight drop in July, their effort tailing off from August. The decline in search effort for multi-brooded species may not be as severe as has been suspected.

Precise measures of searching effort may be difficult to obtain from volunteer nest recorders because nests can be found incidentally in the course of other activities. However, it might be possible to obtain more detailed information on the four main types of nest finding activities: (a) intensive nest searches; (b) nestbox surveys; (c) nests found and recorded during the course of other fieldwork; (d) incidental nest finding. It would be important to separate specialist fieldwork, concentrating on a particular species, from more general nest recording. Ideally it would be useful to measure habitat coverage by nest recorders as well. Such effort recording would need to be carefully designed and then carried out on a trial basis before general introduction.

3.3.1.2 Number of species affected

Bias due to seasonal variation in search effort is most likely to affect multi-brooded species or single-brooded species with a prolonged or late nesting season. Estimates of the timing of nesting seasons for British species are provided diagrammatically by Campbell & Ferguson-Lees (1972), based on the experience of many nest-finding experts and oologists, and information from the literature. In Table 3.3.1.2 we have divided the species used for the annual monitoring of breeding performance (see 2.3 above) by the Nest Record Scheme into single or usually single-brooded and multi-brooded species. For each species we have provided the duration of the potential nest finding period defined as the main egg-laying period from Campbell & Ferguson-Lees with the addition of the length of the stage of nesting at which 75% of nests are found by nest recorders.

Amongst the single-brooded species, the majority have their potential nest finding period some-time between April and July. Nest Record Card data for these species are unlikely to be biased due to seasonal changes in observer effort. A few species begin egg-laying before this period but they are generally the subject of observations by field-workers who specialise on the species. Only the raptors, Red-throated Diver and Grey Heron extend their main nesting seasons into August.

The majority of multi-brooded species begin the main period of egg-laying during the peak period of activity by observers. Eleven species, have largely finished nesting by the end of July which, is well covered by nest recorders specialising in open nesting species. Only 40 species have nesting seasons extending beyond July; for these species declines in searching effort will provide biased samples, with late nests under-represented. Overall, some 48 monitoring species (55%) have potential nest finding periods that extend beyond July. There is an urgent need to investigate the size and importance of the potential bias in measurements of breeding performance that may occur for the species which are under-recorded late in the season.

3.3.1.3 Measuring the bias due to under-represented late nests

A literature survey of intensive studies of species identified as likely to be affected by declining search effort would reveal the extent of the problem for each species; it would also be useful to review the literature, if any, on variation in renesting and multi-brooding in relation to year, region and habitat. Comparisons with Nest Record Scheme data should use Nest Record Cards gathered from similar geographical areas to avoid complications due to differences in season due to latitude and altitude. Comparisons might allow the calculation of correction factors to compensate for the under-recording of late nests.

The importance of this potential bias would be negligible if nesting success was found not to vary through the season. Analyses of Nest Record Cards should investigate the success of nests started between April and June with those started after June. Inter-annual variation in the difference between early and late periods could be investigated by correlating nesting success between the two periods. If there is a tight correlation between the two periods then nesting success in either period could provide an adequate index of nest success for the whole year.

Consideration should also be given to the possibility that late nests may be relatively unimportant for the population dynamics of a species. Several studies have shown that young produced from late nests have lower survival prospects than those from earlier nests (Dhondt & Olaerts 1981, Perrins 1988); a literature survey would be valuable to gather any evidence from intensive studies. There are good *a priori* reasons why this should be so: late season fledglings have had less time to gain experience and may be less-well developed than early fledglings by the time of the critical over-winter period. A comparison of the post-fledging recovery or survival rates of nestlings ringed in early and late broods would be an important study within this context. Another approach might be to investigate the survival rates of young birds with different moult scores in late summer (indicative of fledging date, C.M. Perrins, *pers. comm.*), although such information is not currently recorded routinely by ringers and would need to be investigated as part of special study.

N.J. Aebischer (*pers. comm.*) has suggested that if the biggest seasonal changes occur at the beginning and at the end of the season, then any problem associated with under-recording such nests would be overcome by omitting the extremes, for example the first and last deciles by date, and calculating survival rates for the relatively constant central period. Analyses based on truncated samples of data would not provide an overall estimate of survival or breeding performance, but will almost certainly give a good index of those two parameters.

Figure 3.3.1

Variation in search effort between months from 1987-1994 (see text)

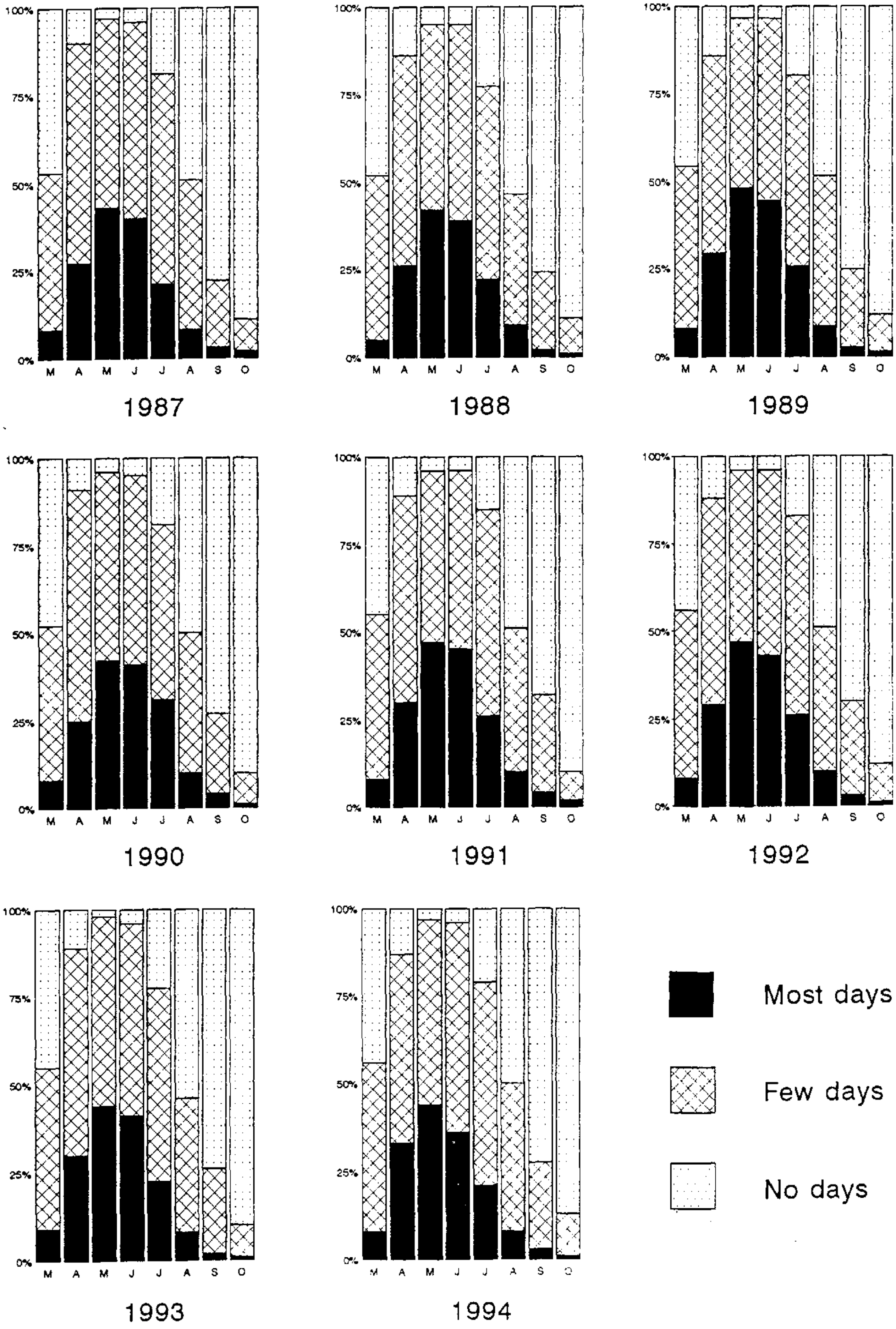
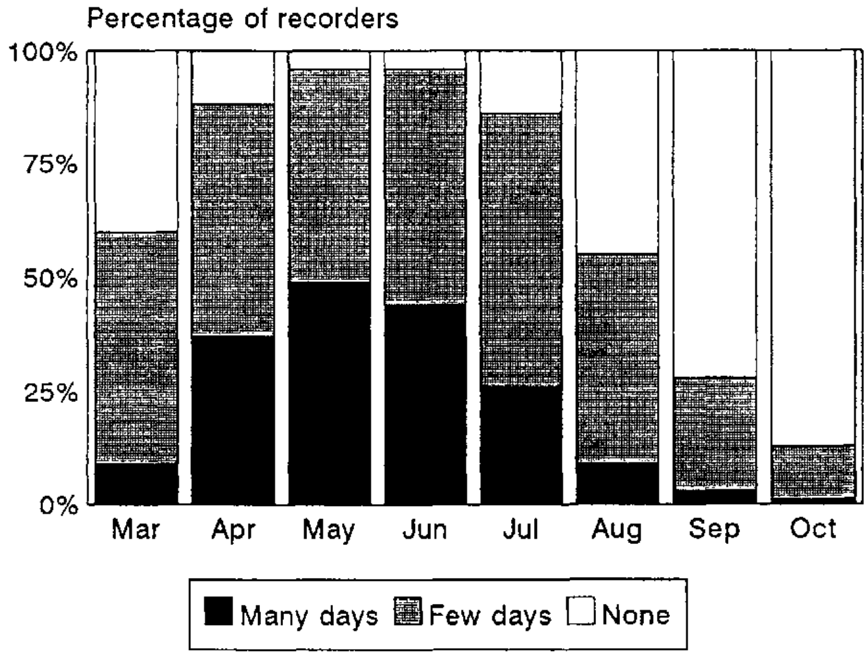


Figure 3.3.2

Search effort for open-nest recorders (n=243)



Search effort for nestbox recorders (n=82)

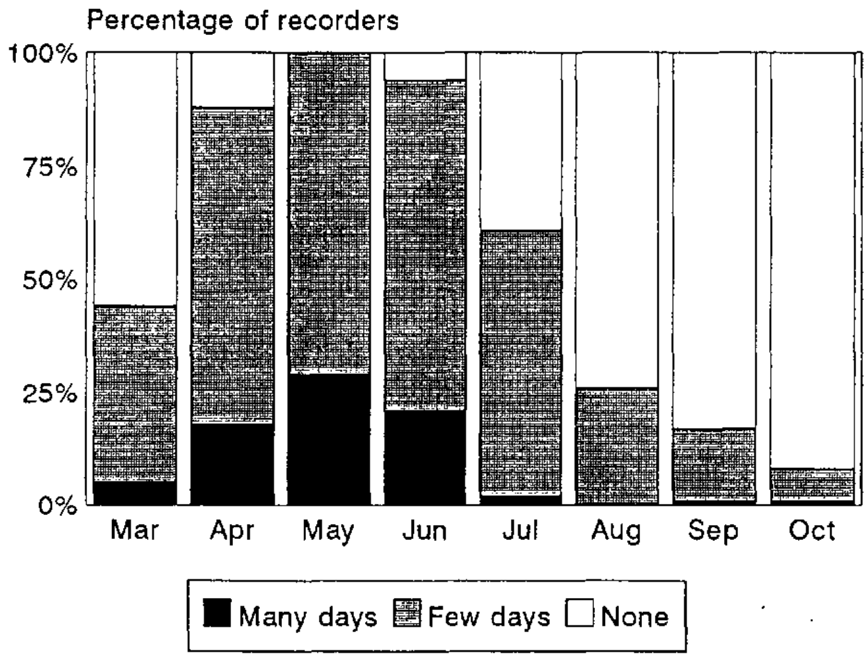


Table 3.3.1.2 The potential nest finding periods of Nest Record Scheme monitoring species (for definition see text): (a) Single brooded or usually single-brooded and (b) multi-brooded species. Species for which seasonal variation in search effort might seriously compromise breeding performance estimates are highlighted in bold.

(a) Single or usually single-brooded	
Red-throated Diver	late May - mid August
Grey Heron	late Feb - early August
Mute Swan	April - July
Hen Harrier	May - August
Sparrowhawk	May - August
Buzzard	April - early August
Kestrel	April - July
Merlin	May - mid August
Hobby	June - early September
Peregrine	April - mid August
Oystercatcher	mid April - July
Golden Plover	April - July
Lapwing	late March - early July
Dunlin	May - July
Curlew	mid April - mid July
Redshank	mid April - June
Greenshank	May - early July
Common Sandpiper	May - July
Little Owl	April - July
Tawny Owl	March - June
Long-eared Owl	March - mid July
Green Woodpecker	late May - mid July
Great Sp Woodpecker	May - mid July
Lesser Sp Woodpecker	late April - July
Nightingale	May - June
Redstart	May - mid July
Wood Warbler	mid May - July
Willow Warbler	May - July
Long-tailed Tit	April - mid June
Marsh Tit	April - June
Nuthatch	April - June
Magpie	April - June
Rook	mid March - mid June
Jackdaw	mid April - June
Crow	April - June
Raven	mid February - May
Chaffinch	mid April - mid July

(b) Multi-brooded	
Moorhen	late March - August
Ringed Plover	mid April - July
Snipe	April - July
Stock Dove	April - September
Collared Dove	April - October
Turtle Dove	May - mid September
Barn Owl	April - September
Short-eared Owl	late March - August
Nightjar	late May - mid September
Kingfisher	April - early September
Woodlark	mid March - August
Skylark	mid April - mid August
Sand Martin	mid May - August
Swallow	mid May - September
Tree Pipit	May - mid August
Meadow Pipit	mid April - early August
Rock Pipit	mid April - mid August
Yellow Wagtail	May - mid August
Grey Wagtail	April - July
Pied Wagtail	mid April - August
Dipper	early March - June
Wren	mid April - mid August
Dunnock	April - mid August
Robin	April - mid July
Whinchat	mid May - mid August
Stonechat	April - mid August
Wheatear	late April - early August
Song Thrush	mid March - mid August
Mistle Thrush	mid March - early July
Grasshopper Warbler	May - mid August
Sedge Warbler	early May - August
Reed Warbler	late May - August
Lesser Whitethroat	May - mid August
Whitethroat	May - mid August
Garden Warbler	May - mid July
Blackcap	May - July
Chiffchaff	May - July
Goldcrest	mid April - August
Spotted Flycatcher	late May - August
Treecreeper	mid April - mid July
Starling	April - mid July
Greenfinch	late April - mid August
Goldfinch	May - August
Linnet	late April - mid September
Twite	May - mid August
Redpoll	May - mid August
Bullfinch	May - August
Yellowhammer	late April - August
Cirl Bunting	mid May - August
Reed Bunting	May - August
Corn Bunting	June - August

3.3.2 Seasonal variation in nest detectability

The detectability of nests is thought to vary markedly through the breeding season. In the early part of the season vegetative cover is less than later on, making nests easier to detect, not only for nest recorders but also possibly for predators. There is a substantial body of work on the effect of nest cover on the survival probability of nests (*e.g.* Dwernychuk & Boag 1972, Yahner & Cypher 1987), this would be worth reviewing to assess the available evidence on the importance of changes in nest cover.

Analyses of nesting success would become biased if nest recorders tend to under-record well hidden nests. The problem would be more severe if the degree of under-recording increased through the season as vegetative cover increased. Measurement of this potential problem would appear to be difficult, but several alternative lines of evidence might shed light on the potential importance of the effect, if it occurs.

The Nest Record Card that was introduced in 1990 contains a section that describes the degree of exposure of each nest in three categories: hidden, partly hidden and exposed. Analysis of these records could involve a description of how the proportions of Nest Record Cards that fall into each category change through the season, and a comparison of nest survival rates of nests in each class, perhaps divided into early and late season nests. A further analysis could compare the stage at which nests with different levels of exposure were found. Nests with lower detectability should be found at a later stage of nesting; the changes in stage of finding through the season could also be assessed. However, this analysis would have to be designed carefully to avoid the confounding effects of seasonal changes in nest survival: if late season nests survive better, then the proportion found at later stages of nesting will necessarily be greater than for early season nests. R.E. Green (*per litt.*) suggests that such an analysis should be restricted to those nests which survive to the end of the breeding stage under consideration; *i.e.* examine the stage of incubation of which all nests which survived to hatching had been first located with respect to time of year and nest concealment score. It is even possible that this method could be used to produce correction factors to allow for seasonal variation in nest detectability.

Further evidence might be produced from the comparison of the predation rates of nests recorded on general Nest Record Cards with those obtained from specialist studies, or with predation rates obtained from a review of the literature. A literature review might also reveal information on the location of nests for comparison with Nest Record Card data. Although not related to seasonal changes in detectability, the height of a nest is often a determinant of its predation risk. It is possible that Nest Record Cards may be biased toward lower nests, a factor that could be revealed from a literature survey. A method of obtaining direct information on this latter possibility would be to ask nest recorders to note all nests that were found too inaccessible to record.

A final analytical possibility, originally suggested by Dr M.W. Pienkowski (Baillie 1988), would be to compare the late predation risk of nests that were found at an early stage with those found later. For example, nests found early in incubation might be relatively easy to find, whereas those found when young are being fed might be better hidden. The comparison of nest survival of these nests over the last half of the nestling stage would reveal whether degree of exposure was an important factor.

3.3.3 Comparison of Nest Record Scheme and Constant Effort Sites ringing

If there are biases due to the under or over-reporting of certain classes of nest, then the estimates of nesting success and brood size derived from Nest Record Scheme data might be very different from the breeding performance estimates obtained from the Constant Effort Sites (CES) ringing scheme (Baillie *et al.* 1986). The CES produces annual counts of numbers of juveniles caught each year and an index of breeding performance from ratios of numbers of juveniles to adults caught. It would be worthwhile to see whether the annual estimates obtained from Nest Record Scheme and CES are correlated over the years. Furthermore, it might be possible to use juvenile to adult ratios from general ringing once computerised ringing schedules become the norm. There are some problems involved in interpreting such an analysis, especially because of the restricted habitat distribution used by the CES (scrub and reedbeds) and the fact that CES measures the juvenile population after some post-fledging mortality has occurred. This factor could be taken into account if estimates of post-fledging survival were obtained using the Age-Specific Totals data gathered from ringers over the past ten years (Baillie & Green 1987). Post-fledging mortality would be calculated as the ratio of the proportion of ringed pulli recovered after a threshold date to the proportion of ringed juveniles recovered after the same threshold date. Although such information on post-fledging survival may be only precise enough for a few species, it would allow a more powerful comparison of Nest Record Scheme and CES data. Significant correlations will be more likely for species which have undergone large changes in breeding performance since the CES began. If there is a lack of correlation between the two schemes, this might have simply to be interpreted as evidence that they measure different aspects of the population dynamics of the species or sample different sub-populations.

One detailed study has compared the results of nest recording and CES ringing at a particular site (Du Feu & McMeeking 1991). The numbers of juvenile Blackbirds, Song Thrushes, Blue Tits and Great Tits caught during CES mist-netting were compared with the numbers of nestlings of these species ringed during the years 1979-1990 in Treswell Wood, Notts. There was a significant relationship between the numbers of juveniles captured and the numbers of nestlings ringed for Blackbirds, Blue Tits and Great Tits. The lack of a relationship for Song Thrush was ascribed to the low proportion of nests found in relation to the number of known territories (from Common Bird Census work).

Within the context of the comparison of Nest Record Scheme and CES, it should be borne in mind that the Nest Record Scheme has no measure of the number of nesting attempts made per pair during a nesting season. Although a small number of records are received each year which report successive nesting attempts of individual pairs, these are inadequate to provide a measure of the proportion of pairs attempting relays after failure, or second, third and fourth broods. Comparison could be made with intensive studies but it is unlikely that they would continue for many years or would provide sufficient geographical coverage to be representative. From the point of view of national monitoring, the Nest Record Scheme can only produce an index of success for multi-brooded species that reflects the production from a nesting attempt rather than from an individual. In terms of interpretation it must be borne in mind that a lack of annual change in an index can hide considerable change in breeding performance if the output per nest remains constant but the number of nesting attempts changes.

It is possible that CES ringing, and maybe other ringing activities, could provide independent data on the length of each year's nesting season. Naylor & Green (1976) describe how the timing of egg-laying of Reed Warblers could be precisely measured by recording the dates of capture of gravid females. The distribution of laying dates was similar to the distribution of captures of short-winged juveniles, having been out of the nest for only a few days and likely to have been locally bred. (The catching of gravid females might damage uncalcified oviducal eggs, so this method may be undesirable - C.M. Perrins, *pers. comm.*). The proportions of birds with engorged brood patches might also be useful in this regard, although the state of a brood patch is less closely tied to a particular stage of nesting than the measures used by Naylor & Green. A trial study at a few sites could be made to assess the potential of this method to describe the nesting season of other species. It would be preferable if such sites were also subject to intensive nest recording.

3.3.4 Recommendations for further work

Seasonal variation in the proportion of nests found by observers is a potentially serious bias for some multi-brooded species. Although the effect is likely to be slight for 86% of species that are monitored currently, the need to investigate the importance of any effect for the remaining species should be considered a high priority.

3.3.4.1 Validation work

(1) Literature surveys of (a) the extent of late season nesting by monitoring species and those species likely to become monitoring species, with a view to providing correction factors for biased Nest Record Scheme samples (3.3.1.3); and (b) seasonal variation in nest success (3.3.1.3).

(2) Comparison of nesting success of samples from April-June with those from July-October to see if late nests form a biased sample. This would be a relatively quick analysis to answer the problem raised in section 3.3.1.3. This perhaps should be extended to see if there was any annual variation in the relative success of early and late season nests; correlation of annual estimates of nesting success between early and late season nests would help to show whether any differences between the two periods were at a constant ratio. A more thorough analysis would attempt to divide nesting seasons into shorter lengths, such as months, to determine whether there was any evidence for progressive changes.

(3) Correlation of Constant Effort Sites and Nest Record Scheme datasets, incorporating estimates of post-fledging survival derived from Age-Specific ringing totals (3.3.3).

(4) To investigate various aspects of seasonal changes in the detectability of nests: (a) analysis of late-stage nest predation risk for nests found early and nests found at a later stage (3.3.2); (b) analysis of seasonal changes in nest detectability by investigation of the stage at which nests are found, taking into account the possible confounding effects of seasonal changes in nest survival (3.3.2); (c) literature survey of the effect of cover on nest survival rates (3.3.2); (d) literature survey of the nest location frequency distributions from intensive studies for comparison with Nest Record Scheme data (3.3.2); (e) analysis of nesting success in relation to degree of exposure recorded on new Nest Record Card (3.3.2).

(5) To examine the importance of late-season nests: (a) literature survey of the reproductive value of late season nests (3.3.1.3); (b) comparison of post-fledging survival rates of early and late broods (3.3.1.3).

(6) Investigate the use of truncated data to analyse changes in breeding performance for multi-brooded species from the central part of the nesting season when observer effort is relatively constant (3.3.1.3).

3.3.4.2 Fieldwork

(1) Investigation of the feasibility of using ringing measurements for assessing the length and timing of nesting seasons annually after analysis of any existing suitable Constant Effort Sites data (3.3.3).

(2) Ask observers to record search effort more systematically (3.3.1).

(3) Ask observers to record details of nests that were too inaccessible to record normally (3.3.2).

3.4 Distribution of samples between regions and habitats

The use of Nest Record Cards for national monitoring of nesting success for a wide range of species requires the distribution of records not to be biased with respect to any differences in performance that might occur between different regions or habitats. This aspect has to be approached analytically by suitable stratification and weighting of subsets of the data. Where differences occur, results should also be reported separately for appropriate regions and habitats.

The general distribution of Nest Record Cards is locally patchy but relatively even over larger regions of the UK. Figure 3.4.1 shows the geographical distribution of grid-referenced Nest Record Cards by 10 km square for 87 species, covering the period 1988-90. Some of the gaps in coverage are almost certainly due to individuals and groups who do not record grid reference: a map of the distribution of Nest Record Cards for 41 monitoring species in 1989 shows that some areas in Figure 3.4.1 were under-reported, for example Norfolk (Figure 3.4.2). Figure 3.4.2 shows that counties which are under-represented are often adjoined by counties which are relatively over-represented. Overall, Scotland is under-represented and England over-represented, but about a third of Scotland's area occurs in Highland Region and Western Isles, which have very low densities of observers (Table 3.4.1).

Table 3.4.1 Relative proportions of UK Nest Record Cards received from each country in 1990 in relation to the relative areas of each country.

	England	Scotland	Wales	Northern Ireland
All NRCs	72%	17%	8%	2%
Monitoring NRCs	67%	19%	12%	1%
Area	54%	32%	9%	6%

The habitat coverage of Nest Record Cards used for monitoring in 1989, based on the coding scheme of Crick (1992b), was as follows:

A:	Wood	22%
B:	Scrub	2%
C:	Grass & Marsh	5%
D:	Heath & Bog	4%
E:	Farm	33%
F:	Human Sites	18%
G:	Fresh Water	10%
H:	Coastal	2%
I:	Inland Rock	1%
J:	Miscellaneous	4%

Changes between years in the proportion of records coming from different regions and habitats need investigation on a species-by-species basis. There will be a need for a stratified analysis of Nest Record Cards for monitoring purposes which will be developed over the next few years. Habitat and region should be incorporated as factors in monitoring analyses after the appropriate divisions have been chosen for each species from the results of exploratory investigations. A major analysis of trends over time in various aspects of breeding performance found relatively few differences between major regions in the UK, when analysed by analysis of covariance (Crick *et al.* 1993a). Where trends differ between regions or habitats, then contributions to the national trend will have to be weighted according to the population's distribution measured from the New Breeding Atlas (Gibbons *et al.* 1993). The relative importance of different habitats to a species may be measurable from the results of the Breeding Bird Survey (Marchant 1994).

Within any analysis, it is possible that records are only obtained from areas or habitats where a species flourishes. Such data collection would mask reduced success in areas or habitats of decline. While such a problem can never be ruled out, analyses which break the data down by both region and habitat should detect declines in breeding performance at medium spatial scales. When resources for conservation-related research are limited, such analyses should provide useful pointers to where resources for more detailed studies should be spent.

Figure 3.4.1

Number of grid-referenced Nest Record Cards submitted for 87 species (1988-1990)

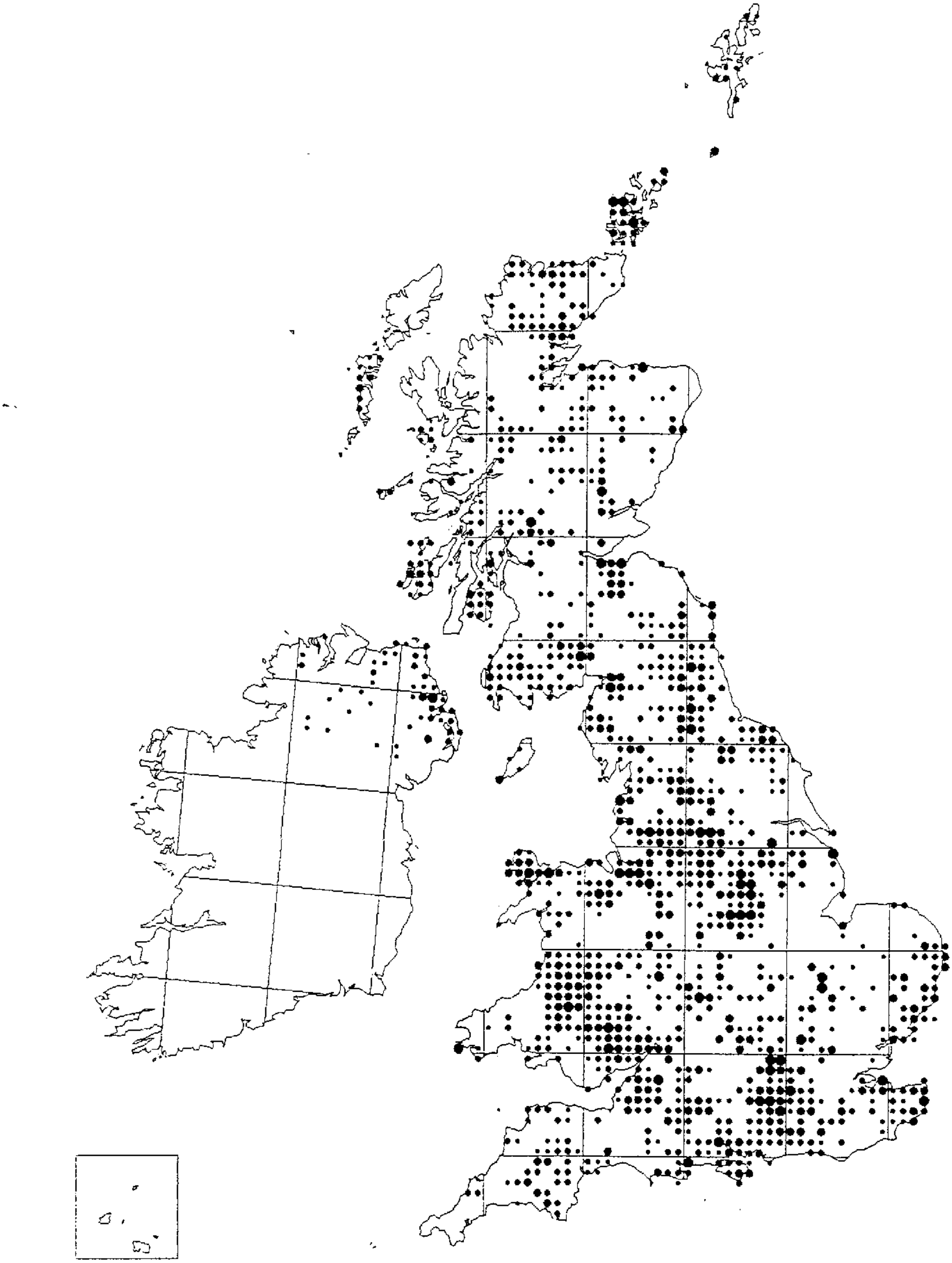
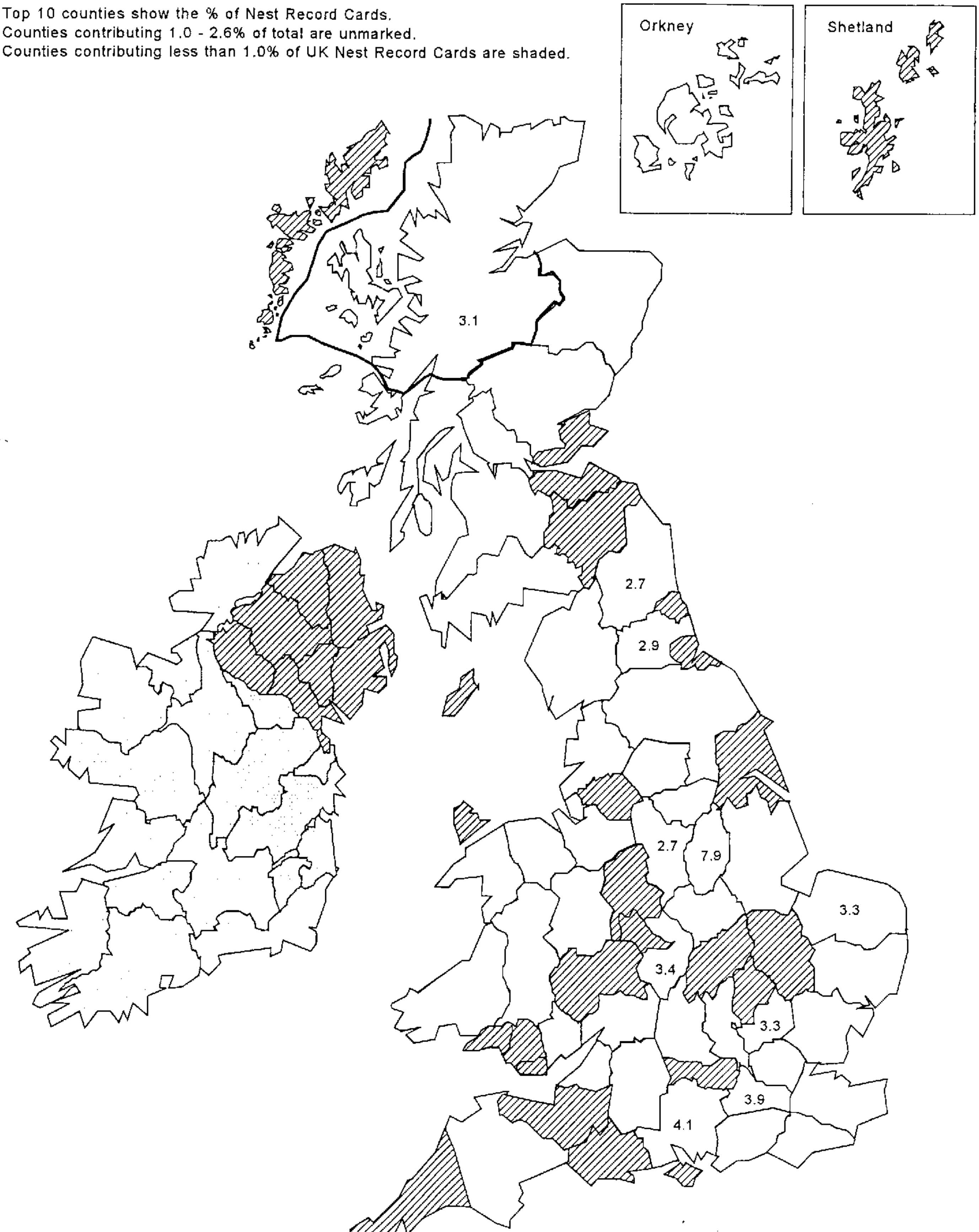


Figure 3.4.2. 1989 Nest Record Cards for 41 monitoring species.

Top 10 counties show the % of Nest Record Cards.
Counties contributing 1.0 - 2.6% of total are unmarked.
Counties contributing less than 1.0% of UK Nest Record Cards are shaded.



3.4.1 Constant Nest-monitoring Plots

There may be a case for investigating the viability of developing a system of Constant Nest-monitoring Plots along the lines suggested by Martin & Guepel (1993) in North America. Such plots would be fixed in location and studied each year to record as many nests as possible (Martin & Guepel recommend at least 20 per species per plot). Standardised nest-searching regimes should be used to allow comparability between plots and between years, Martin & Guepel provide a good set of instructions for such a regime, including the use of Cornell Nest Record Cards for recording the nests. They also recommend detailed recording of habitat and vegetation in each plot recording the changes that occur each year. (It should be noted that the system devised by Martin & Guepel is carried out by teams of research assistants that work on nest finding and monitoring for the entire breeding season.)

There may be benefits from linking the location of such plots with the plots used within the BTO's Breeding Bird Survey, although the feasibility of this would need testing. This concept would only work if all randomised squares were surveyed by nest recorders, non-random omissions would invalidate the design. Nest recording requires intensive and more invasive fieldwork than census work and the permissions required are more exacting and more likely to be refused by land-owners in the randomised squares than those needed by census workers. In the particular case of BBS squares, there would be particular concern that an increase in the number of fieldworkers requiring access permissions in survey squares led to land-owner dissatisfaction and the refusal of the original BBS surveyors to enter the squares.

Non-random sampling at the habitat scale is relatively easy to deal with analytically by treating habitat as a factor. The BBS will allow the assessment of habitat use by bird species which can be compared with habitat coverage for each species in the Nest Record Scheme. Such comparisons will allow the identification of habitats that are poorly covered by the Nest Record Scheme, permitting analytical adjustments and the targeting of recorder effort toward these areas. The BTO has a long-term aim of developing a system of long-term Integrated Population Monitoring study plots and nest recording should be incorporated within these when they are developed.

However, the use of a randomised sample of Constant Nest-monitoring Plots is only likely to affect any bias that may arise due to non-random sampling at a habitat spatial scale. Non-random sampling at the nest-site scale will only occur if *all* nests within these plots are monitored. This is very unlikely to be achieved with volunteer observers because of the time-costs involved. Since there have been a reasonable number of studies that show that Nest Record Scheme data is unbiased (except when late-season nesting is a factor) when compared with intensive studies (Crick *et al.* 1993c; Crick in press vs papers in Donald & Aebischer in press; Brown *et al.* 1995 vs McGhie *et al.* 1994; Rodrigues and Crick in prep; Bibby 1978; Kelsey 1989; Murton 1966), the problem may be relatively small. Further studies that compare data from intensive studies with that from the Nest Record Scheme would be very valuable in this respect.

3.4.2 The effect of specialist recorders

Within large datasets, there may be hundreds of observers that have contributed records. Within small datasets, perhaps of rarer species, significant proportions of the records may have been contributed by a small number of observers whose identity and location changes over time. This may bias analyses of time trends and differences in trends among habitats. To avoid confounding the effects due to specialist observers with other variables of greater biological interest, such as habitat, "observer" should be included as a factor in analyses although this may not be practical in many cases because the data may be too unbalanced if observers enter and leave the scheme over time. Bootstrapping across observers would only be helpful if there were a reasonable number of observers from which to resample and if the number of cards they contribute does not vary greatly. Another solution suggested by R.E. Green (*per litt.*) might be to group observers into sets so that each set includes a similar number of cards. Thus a set might include data from one specialist observer or 20 casual observers. These sets might then be used as units for bootstrapping or perhaps for the jack-knife. Some statistical advice should be obtained on this problem but, before analyses begin, preliminary inspection of datasets is necessary in order to avoid drawing unjustified conclusions.

3.4.3 Recommendations for the Nest Record Scheme

(1) Differences in breeding performance between regions and habitats should be dealt with analytically by suitable stratification and weighting of subsets of the data. Subsets that are significantly different from each other should be reported separately in addition to being combined within an overall analysis (3.4).

(2) The use of Breeding Bird Survey data to assess the representativeness of samples of Nest Record Cards from different habitats should be investigated (3.4.1).

(3) Where it is suspected that specialist observers might bias a dataset, then "observer" should be included as a variable in analyses, to avoid confounding effects with other variables of greater biological interest (3.4.2). Further statistical advice should be obtained on how to cope with this potential problem.

3.5 Recommendations for future work priorities

The review of methodological aspects of the BTO's Nest Record Scheme highlights some areas in which further work is required with respect to the operation of the scheme, analytical methods for calculations of nesting success, and the need for further validation studies. (Numbers in parentheses refer to sections in the report).

3.5.1 Recommendations for Nest Record Scheme fieldwork procedures

(1) Continue to emphasise to fieldworkers that it is essential to minimise disturbance at nests, for both ethical and scientific reasons (3.2.4.1).

(2) Ban all but distant monitoring of colonial seabirds for the Nest Record Scheme (3.2.4).

(3) Advise observers to avoid flushing birds from nests at early stages of nesting (3.2.4).

(4) Advise observers that it is essential to record on Nest Record Cards all observations on nests, even when made from a distance (3.1.3.7).

(5) Ask observers to note when visits were discontinued because a nest could not be relocated or because continued access to a site was denied (3.1.3.2).

(6) Emphasise the need for observers to record when parent birds are trapped at or near a nest (3.2.4).

(7) Advise observers that, subject to a minimum number of visits required to identify key events in a nesting attempt (laying, hatching, *etc.*), it is more useful for the analysis of Nest Record Cards to receive more records rather than more visits per record (3.1.2.2.2).

3.5.2 Recommendations for the analysis of nesting success

(1) Use the Mayfield method and the associated maximum likelihood estimators of variance (3.1.2.2.1), of z-tests (3.1.2.2.2) and of variance of survival rate products (3.1.2.2.3). Implement the use of Johnson's (1979) maximum likelihood estimator version of Mayfield when practical (3.1.2.3.6).

(2) Use the highest precision available for calculating Mayfield survival rates and quote the precision used within published results (3.1.2.1).

(3) Use at least 50 nests and preferably >100 nests (1000 nest-days) per sample (3.1.2.2.2).

(4) Provide clearly defined period durations for incubation and nestling stages and have clearly defined rules for assigning nest losses to a particular period (3.1.3.10 & 3.1.3.11).

(5) Stratify samples when clearly identifiable heterogeneities occur in a population and separate periods of nationally catastrophic losses of nests into separate strata when necessary (3.1.3.4). Differences in breeding performance between regions and habitats should be dealt with analytically by suitable stratification and weighting of subsets of the data. Subsets that are significantly different from each other should be reported separately in addition to being combined within an overall analysis (3.4).

(6) Where it is suspected that specialist observers might bias a dataset, then "observer" should be included as a variable in analyses, to avoid confounding effects with other variables of greater biological interest (3.4.2).

(7) Over the next few years it would be valuable to develop a modelling framework for the analysis of Mayfield-type data (3.1.5). Although the program SURVIV is a suitable vehicle for such a framework, considerable methodological development will be required.

(8) The use of bootstrap techniques should be implemented to allow the calculation of variance estimates based on the distribution of each analysed dataset. The use of such techniques will greatly facilitate the calculation of variance estimates for egg and chick survival rates, allowing for a lack of independence between eggs in a clutch or chicks in a brood (3.1.5).

3.5.3 Recommendations for validation studies

Recommendations for further work fall into three main categories, literature survey, analysis and fieldwork. The subjects are listed, in order of priority, providing reference to the relevant section in this report. Staff time required is indicated in parentheses for high and medium priority items.

3.5.3.1 High priority (Necessary within the next 12-18 months).

(1) Literature survey of the extent of late season nesting by monitoring species and those species likely to become monitoring species, with a view to determine its importance and to provide correction factors for biased Nest Record Scheme samples (3.3.1.3). (Three weeks).

(2) Literature survey of seasonal variation in nest success, to assess the difference (if any) between early and late season nests (3.3.1.3). (Three weeks).

(3) Comparison of nesting success of samples from April-June with those from July-October to see if late nests form a biased sample. This would be a relatively quick analysis to answer the problem raised in section (3.3.1.3). This perhaps should be extended to see if there was any annual variation in the relative success of early and late season nests; correlation of annual estimates of nesting success between early and late season nests would help to show whether any differences between the two periods were at a constant ratio. A more thorough analysis would attempt to divide nesting seasons into shorter lengths, such as months, to determine whether there was any evidence for progressive changes. (Three weeks for the short analysis, a further 3 weeks for the longer analysis).

(4) Correlation of Constant Effort Sites and Nest Record Scheme datasets, incorporating estimates of post-fledging survival derived from Age-Specific ringing totals, to assess compare indices of breeding performance between the two schemes (3.3.3). (Eight weeks, four weeks if not using Age-specific totals).

(5) To investigate the feasibility of using ringing measurements for providing a measure of the length and timing of nesting seasons on an annual basis (3.3.3). (Eight weeks).

(6) To ask observers to record search effort more systematically, to obtain a measure of the potential bias in the recording of late season nests (3.3.1). (0.5 week).

3.5.3.2 Medium priority (Necessary within the next two to three years).

(1) To assess the appropriate division of periods in analyses of nest survival rates (3.1.5): (a) a literature survey of changes in nest survival rate during a nesting attempt in intensive studies (three weeks); (b) analysis to investigate (i) the magnitude of differences in survival rate between different stages of the nest cycle, (ii) whether survival rates tend to change within periods or can be

considered constant and (iii) whether there are differences in patterns of change between species (six weeks).

(2) Analysis of daily nest survival rates measured over inter-visit intervals of increasing length to investigate the extent of a combination of the potentially adverse effects of nest visiting and of inconsistent recording of visits (3.1.3.5, 3.1.3.7 & 3.2.4.3). (Four weeks).

(3) Analyse late-stage nest predation risk for nests found early and nests found at a later stage to investigate the possibility that nests found at early stages are more prone to predation (3.3.2). (Four weeks).

(4) Analyse seasonal changes in nest detectability by investigation of the stage at which nests are found, taking into account the possible confounding effects of seasonal changes in nest survival (3.3.2). (Four weeks).

(5) Ask observers to record details of nests that were too inaccessible to record normally to gain a measure of the under-recording of such nests (3.3.2). (0.5 week).

(6) To make comparisons between Nest Record Scheme data and data from intensive autecological studies as opportunities arise.

(7) The use of Breeding Bird Survey data to assess the representativeness of samples of Nest Record Cards from different habitats should be investigated (3.4.1).

(8) Obtain statistical advice on how to ensure that specialist observers do not bias analyses of nest record cards (3.4.2).

3.5.3.3 **Low priority** (Desirable, but not necessary to justify current uses of Nest Record Scheme data).

(1) To examine the effects of nest visiting on nest survival rates: (a) literature survey of predation rates from intensive studies for comparison with Nest Record Scheme data, as an indication of any effect of nest visiting (3.2.4.2 & 3.3.2); (b) comparison of the numbers of visits made to successful and unsuccessful nests that were observed for the same length of time (3.2.4.3); (c) ask volunteers to assign randomly nests upon finding to the treatments of flushing or not flushing adults (3.2.4.4); (d) investigate the possibility of asking volunteers to monitor nest success remotely by observing the behaviour of nesting adults.

(2) To examine the effects of ringing on nest survival rates: (a) literature survey of the effects of capturing adults at the nest on subsequent nest, egg and nestling survival (3.2.4.2); (b) analysis of differences between nest and nestling survival rates between (i) ringed and unringed broods (3.2.4 & 3.2.4.3) and (ii) nests at which an adult was or was not caught (3.2.4.3); (c) ask volunteers to randomly assign nests upon finding to the following pairs of

treatments: (i) ringing vs not ringing pulli, (ii) capturing vs not capturing adults at the nest (3.2.4.4).

(3) To examine the importance of late-season nests for recruitment of young into the next generation: (a) literature survey of the reproductive value of late season nests (3.3.1.3); (b) comparison of post-fledging survival rates of early and late broods (3.3.1.3).

(4) To examine aspects of the problems of detectability of nests: (a) literature survey of the effect of cover on nest survival rates (3.3.2); (b) literature survey of the nest location frequency distributions from intensive studies for comparison with Nest Record Scheme data (3.3.2); (c) analysis of nesting success in relation to degree of exposure recorded on new Nest Record Card (3.3.2).

(5) To examine relatively minor problems of the application of the Mayfield method by undertaking (a) simulations to analyse the effects of heterogeneous samples on Mayfield estimates (3.1.3.4 & 3.1.4); (b) a literature review of variation in the length of incubation and nestling periods for monitoring species (3.1.3.9); and (c) an investigation of the frequency distribution of inter-visit intervals for species with long incubation and nestling periods to check whether the use of the mid-point assumption of Mayfield is valid (3.1.3.6).

4. THE FUTURE OF THE NEST RECORD SCHEME

4.1 General considerations

This review discusses the key issues concerning the BTO's Nest Record Scheme, its methodology and its value to the statutory conservation bodies. Throughout the body of the report a number of specific detailed recommendations are made to investigate particular aspects but, in this chapter, we wish to draw together several threads that pertain to the four main questions that need to be considered with respect to the future of the Nest Record Scheme. First, is it necessary to monitor nesting success when the UK has a good system of monitoring bird population sizes? Second, if it is necessary to monitor nesting success, is the Nest Record Scheme a reliable source of information? Third, if the Nest Record Scheme is a reliable source of information, is the volume of data that it collects necessary for its analytical needs? And fourth, what are the main priority areas for future work?

4.2 Is it necessary to monitor nesting success?

Considerable empirical and theoretical evidence strongly suggests that monitoring population size alone is an inadequate tool for conservationists (Goss-Custard 1993). As discussed in the Introduction (Section 1.), the monitoring of reproductive and survival rates are essential to allow efficient interpretation of changes in population size (Temple & Wiens 1989) and, in the case of long-lived species, to provide early warning of impending changes in population size (Pienkowski 1991). Population densities change due to the combination of birth and death rates, and immigration and emigration rates. By modelling changes in these intrinsic (or proximate) causes of population change with changes in external environmental factors, such as land-use change or climate change, the likely ultimate causes of population change can be identified. High population densities can provide very misleading evidence for good population health when they occur in areas of low breeding performance and poor survival rates. For example high density populations of Shelduck in the Montrose Basin (Pienkowski & Evans 1982), Golden Plovers on limestone areas of the Pennines (Ratcliffe 1976) and Golden Eagles in western Scotland (Watson *et al.* 1987), have a low production of young compared with lower density areas elsewhere. Conservation of the high density areas alone would be dangerous for these species. It is very likely that such effects could occur at a regional sale or a European scale.

The whole theory of metapopulation dynamics (Hanski & Gilpin 1991) that underpins much of current ecological thinking is based on the ideas of source and sink populations with different net productivities (Pulliam 1988). Conservation management decisions based solely on changes in population size will have a high chance of being inappropriate (Lawton 1993). It is absolutely essential to have a body of evidence on breeding performance readily available for consultation in order to ensure that conservation research and management decisions are effective. The Nest Record Scheme provides a unique source of such information for the Country Agencies, being nationally extensive, covering all major habitats and providing information that would otherwise be unavailable on at least 85 species. While it is true that seasonal productivity is unobtainable from the Nest Record Scheme, the measures of breeding performance that it can provide have substantial value in helping to assess the possible causes of any decline in bird populations.

To take a current and very important example, the severe declines in 10-20 farmland birds in recent years has identified a major problem for conservationists in the wider countryside

(Fuller *et al.* in press). While the problem has been identified, the proximate cause of these declines could be changes in breeding performance or in survival. Autecological studies of these 10-20 species would be very costly. Such studies would not necessarily be representative of the wider countryside because intensive study plots would be small. They would not produce any reliable or consistent results for three to five years. The Nest Record Scheme has been able to show relatively quickly that every measured aspect of Corn Bunting breeding performance has increased markedly during its population decline (Crick in press) and that only Linnet and Reed Bunting show performance declines in parallel to population declines (Crick *et al.* 1995). In this way the Nest Record Scheme has been able to direct conservation research towards investigating survival rates outside the breeding season for species such as Corn Bunting, but towards the nesting season for Linnet and Reed Bunting (cf. RSPB Action Plans for these species). Similarly, Integrated Population Monitoring studies of the Lapwing population have shown that it is likely that breeding performance declines and not changes in survival have driven the population decline (Peach *et al.* 1994). Analyses of the Nest Record Scheme has suggested that research on declining Golden Plover (Crick 1992a) and Twite (Brown *et al.* 1995) populations in England should be concentrated on breeding performance studies; the results of these studies are now being followed up as part of some more intensive fieldwork studies funded by English Nature. Given scarce resources for conservation research the Nest Record Scheme is able to increase the likelihood of those resources being used wisely.

Such considerations will be particularly important when the conservation agencies consider the plight of species listed on the list of Bird Species of Conservation Concern (Gibbons *et al.* in press). The Nest Record Scheme will be able readily to provide monitoring information or analyses for 21 Red-listed species and 49 *Amber*-listed species (2.3.1.2). The value of its historical database in helping to diagnose the problems facing these species will be invaluable and more cost-effective than initiating 70 comprehensive individual autecological studies.

The value of such information is such that many other countries are now seeking to develop their Nest Record Schemes. Advice has been sought from the BTO by Australia, Estonia, Netherlands, Finland, Poland, South Africa, Spain, USA and Zimbabwe because the BTO's scheme has increasingly shown its value in recent years. The BTO Nest Record Scheme currently leads the world in this field, which is due in no small part to the cost-effective support provided by the UK government since the 1960s. Furthermore, the data in the UK are gathered by volunteers, so that approximately 100 person-years of fieldwork is supplied *gratis* each year.

4.3 Is the Nest Record Scheme a reliable source of information?

The review of the Nest Record Scheme's methodology (chapter 3) shows that there are a number of potential biases in the data collected. It has highlighted the need for various methodological studies to investigate these further, particularly with respect to seasonal variation in the proportion of nests found due to changes in observer effort and in nest detectability. However, the review shows that 45% of monitoring species are unlikely to be seriously affected by seasonal changes in observer effort (3.3.1.2).

Potential problems due to non-random sampling can occur at two spatial scales. The first is based on the broad habitats in which nests are recorded and could be tackled analytically or by asking volunteers to conform to a randomised study plot design, perhaps linking to the randomised squares used by the Breeding Bird Survey (BBS). The latter concept would only work if all randomised squares were surveyed by nest recorders, non-random omissions would invalidate the design. Nest recording requires intensive and more invasive fieldwork than census work and the permissions required are more exacting and more likely to be refused by land-owners in the randomised squares than those needed by census workers. In the particular case of BBS squares, there would be particular concern that an increase in the number of fieldworkers requiring access permissions in survey squares led to land-owner dissatisfaction and the refusal of the original BBS surveyors to enter the squares.

Non-random sampling at the habitat scale is relatively easy to deal with analytically by treating habitat as a factor. The BBS will allow the assessment of habitat use by bird species which can be compared with habitat coverage for each species in the Nest Record Scheme. Such comparisons will allow the identification of habitats that are poorly covered by the Nest Record Scheme, permitting analytical adjustments and the targeting of recorder effort toward these areas.

The second aspect of non-random sampling is at the spatial scale of habitats or nest sites. It is possible that the nests sampled do not include those which are difficult to find or that poor quality habitats are undersampled because of low densities of birds in such areas. There is little evidence to support the suggestion of such biases (except when late-season nesting is a factor) and, indeed, comparison of Nest Record data with that from intensive study areas show close similarity between the two datasets (*e.g.* Blackbird and Great Tit: Crick *et al.* 1993c; Corn Bunting: Crick in press vs papers in Donald & Aebischer in press; Twite: Brown *et al.* 1995 vs McGhie *et al.* 1994; Chiffchaff: Rodrigues and Crick in prep; Reed and Sedge Warblers: Bibby 1978; Marsh Warbler: Kelsey 1989; Stock Dove: Murton 1966). Furthermore, the concept of randomised study plots will not tackle this aspect unless *all* nests are found in each plot, which is very unlikely. It is important for more comparisons with intensive studies to be made so that the extent of any such biases can be determined.

To conclude then, such comparisons as are readily available suggest that the Nest Record Scheme provides relatively unbiased data for most species and is reliable as a source of information for conservationists. However, more detailed and thorough comparisons of Nest Record and intensive datasets would be very valuable for showing where any weaknesses might lie.

4.4 Nest Record Scheme data volume

The Nest Record Scheme collects 35,000 Nest Record Cards per year for 200 species of which 15,000 are used for monitoring 85 species. Some species are recorded too infrequently for anything but analysis in blocks of three to five years whereas a few are recorded in numbers that are beyond the BTO's current capacity for computerisation. Is there any scope for trying to be more selective in the records which the BTO collects? Do we receive records for too many species? Would it be more cost-effective to limit the number of species for which we receive records?

There are four aspects which pertain to these questions: (a) the psychology of the volunteers, (b) the time-costs of administering different aspects of the Nest Record Scheme; (c) the analytical needs for monitoring purposes and (d) the need for data to investigate unforseen environmental problems.

The majority of volunteer nest recorders are generalist recorders who do not specialise on a particular species. The main source of enjoyment for them is to find a wide range of nests and to record each one; the possibility that their records can be of value and will be held in a national archive provides an extra motivation and source of pride. The concept that we will not accept records for certain species is likely to provide a general disincentive that may well lead to fewer records being received for the conservation target species. Consideration has been given to the idea of not accepting single-visit Nest Record Cards (for all but the very under-recorded species). It was found that the majority of single-visit cards come from volunteers who send in over 100 records each year. Inevitably, when finding a large number of nests, circumstances will increase the absolute number of single visit records sent by these volunteers, but the overall contribution of these volunteers is very important and the BTO would benefit little from antagonising them by placing strictures on their *modus operandi.*

The time costs of filing effectively unwanted records are small compared with the costs of administering each individual volunteer. Decreasing the types of records accepted by the scheme (in terms of species or number of visits) would not necessarily decrease the number of volunteers which have to be administered. A far more effective way of increasing the number of records for target species or improving the standard of recording is by targeted encouragement. This has proved very successful in increasing the proportion of multi-visit cards sent to the BTO and recent indications suggest that the prominent targeting of specific species will be effective in increasing the volume of data received for those species.

Currently, the Nest Record Scheme attempts to computerise at least 150, and up to 450, records for each monitoring species (2.3.1) to provide adequate samples of data for annual analysis. While this number appears to provide adequate power to detect significant trends in breeding performance, the BTO has not undertaken a sensitivity analysis to determine the power of the monitoring analyses to detect changes of different magnitude. This might identify species for which a more cost-effective computerisation programme could be designed, thereby targeting analytical effort in response to the requirements of the statutory agencies.

The restriction of data collection to a small number of 'indicator species' would limit the ability of the Nest Record Scheme to investigate conservation problems as they arise. While some species can be said to be broadly indicative of others, each actually has their own particular niche and is unique. It is very difficult to pick the 'correct' indicator species and this option should only be considered when the ability to monitor species is restricted. Given that a large number of species within the Nest Record Scheme can be monitored for approximately the same cost as a smaller number of species, there would be little benefit in restricting the number of species for which the Nest Record Scheme would accept records. Furthermore, it is impossible to predict which species will show population declines in the future and will need to be investigated by the Integrated Population Monitoring programme. For example, in the 1960s and 1970s, relatively common species such as Tree Sparrow, Song Thrush, Linnet and Lapwing would not necessarily have been chosen as indicator species, but the availability of historical data for these species now is invaluable for helping to diagnose the causes of their declines. If data collection ceased for certain species, then future analysis of their records, should a population decline be detected, would have fundamental *lacunae* covering the periods of decline.

In summary, there is little benefit to be gained in decreased administration time and costs from receiving fewer records, but there are substantial potential costs in terms of lost information that could be important in the future. Furthermore, the placing of restrictions is likely to have a negative impact on volunteer motivation and may lead to decreases in the numbers of records of conservation target species instead of the desired increases. The best way forward will be to use encouragement and persuasion to increase the numbers of records of these target species.

The alternative problem of whether the Nest Record Scheme receives enough information to be sufficiently powerful to detect declines in breeding performance can only be assessed by a series of sensitivity analyses (see section 2.3.3). This is an important but substantial piece of which would need to be undertaken for each species individually although it is possible that some general rules of thumb could be elucidated after investigating just a few species.

4.5 Priorities for future work

This review has identified four major areas which are the most important priority areas for future work within the Nest Record Scheme. These are: (1) to increase communications with JNCC and the Country Agencies so that it can be more responsive to their needs and so that they can be more aware of its capability; (2) to undertake validation studies to investigate further the representativeness of the Nest Record Scheme, particularly by comparison with results from intensive studies; (3) to contribute to IPM analyses of currently declining species (particularly farmland species) so that the causes of these declines can be identified and (4) to investigate the trends towards earlier laying by a large number of species, given its potential significance for the global warming debate and its implications for biodiversity sustainability. Summaries of more detailed priorities for future work are provided at the end of each chapter in this report.

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Appendix: Alphabetical list of scientific names of birds mentioned in the text.

Arctic Skua *Stercorarius parasiticus*

Arctic Tern *Sterna paradisaea*

Avocet *Recurvirostra avosetta*

Bald Eagle *Haliaeetus leucocephalus*

Barn Owl *Tyto alba*

Bearded Tit *Panurus biarmicus*

Bicolored Antbird *Gymnopithys bicolor*

Blackbird *Turdus merula*

Black Brant *Branta bernicla nigicans*

Blackcap *Sylvia atricapilla*

Black Grouse *Tetrao tetrix*

Black Guillemot *Cepphus grylle*

Black-headed Gull *Larus ridibundus*

Black Redstart *Phoenicurus ochruros*

Black Skimmer *Rhynchops niger*

Black-throated Diver *Gavia arctica*

Blue Tit *Parus caeruleus*

Brown Pelican *Pelecanus occidentalis*

Bullfinch *Pyrrhula pyrrhula*

Buzzard *Buteo buteo*

Canada Goose *Branta canadensis*

Capercaillie *T. urogallus*

Carrion Crow *Corvus corone*

Cetti's Warbler *Cettia cetti*

Chaffinch *Fringilla coelebs*

Chiffchaff *Phylloscopus collybita*

Chough *Pyrrhocorax pyrrhocorax*

Cirl Bunting *Emberiza cirlus*

Cliff Swallow *Hirundo pyrrhonota*

Coal Tit *Parus ater*

Collared Dove *Streptopelia decaocto*

Common Gull *Larus canus*

Common Scoter *Melanitta nigra*

Common Tern *Sterna hirundo*

Coot *Fulica atra*

Corn Bunting *Miliaria calandra*

Crested Tit *Parus cristatus*

Common Crossbill *Loxia curvirostra*

Corn Bunting *Miliaria calandra*

Cuckoo *Cuculus canorus*

Curlew *Numenius arquata*

Dartford Warbler *Sylvia undata*

Dipper *Cinclus cinclus*

Dotterel *Charadrius morinellus*

Dunlin *Calidris alpina*

Dunnock *Prunella modularis*

Egyptian Goose *Alopochen aegyptiacus*

Eider *Somateria mollissima*

Ferruginous Hawk *Buteo regalis*

Florida Scrub Jay *Aphelocoma c. coerulescens*

Fulmar *Fulmarus glacialis*

Gadwall *Anas strepera*

Garden Warbler *Sylvia borin*

Garganey *Anas querquedula*

Glaucous Gull *Larus hyperboreus*

Glaucous-winged Gull *Larus glaucescens*

Goldcrest *Regulus regulus*

Golden Eagle *Aquila crysaetos*

Goldeneye *Bucephala clangula*

Golden Plover *Pluvialis apricaria*

Goldfinch *Carduelis carduelis*

Goosander *Merganser merganser*

Goshawk *Accipiter gentilis*

Grasshopper Warbler *Locustella naevia*

Great Black-backed Gull *Larus marinus*

Great Crested Grebe *Podiceps cristatus*

Great Northern Diver *Gavia immer*

Great Tit *Parus major*

Great Skua *Stercorarius skua*

Great Spotted Woodpecker *Dendrocopos major*

Greenfinch *Carduelis chloris*

Greenshank *Tringa nebularia*

Green Woodpecker *Picus viridis*

Grey Heron *Ardea cinerea*

Greylag *Anser anser*

Grey Partridge *Perdix perdix*

Grey Wagtail *Motacilla cinerea*

Guillemot *Uria aalge*

Hawfinch *Coccothraustes coccothraustes*

Heerman's Gull *Larus heermanni*

Hen Harrier *Circus cyaneus*

Herring Gull *Larus argentatus*

Hobby *Falco subbuteo*

Hooded Crow *Corvus corone*

House Sparrow *Passer domesticus*

Jay *Garrulus glandarius*

Kestrel *Falco tinnunculus*

Kingfisher *Alcedo atthis*

Kittiwake *Rissa tridactyla*

Lapwing *Vanellus vanellus*

Least Auklet *Aethia pusilla*

Lesser Black-backed Gull *Larus fuscus*

Lesser Spotted Woodpecker *Dendrocopos minor*

Lesser Whitethroat *Sylvia curruca*

Linnet *Carduelis cannabina*

Little Grebe *Tachybaptus ruficollis*

Little Owl *Athene noctua*

Little Ringed Plover *Charadrius dubius*

Little Tern *Sterna albifrons*

Long-eared Owl *Asio otus*

Long-tailed Skua *Stercorarius longicaudus*

Long-tailed Tit *Aegithalos caudatus*

Magpie *Pica pica*

Mallard *Anas platyrhynchos*

Mandarin *Aix galericulata*

Marsh Harrier *Circus aeruginosus*

Marsh Tit *Parus palustris*

Marsh Warbler *Acrocephalus palustris*

Meadow Pipit *Anthus pratensis*

Merlin *Falco columbarius*

Mistle Thrush *Turdus viscivorus*

Moorhen *Gallinula chloropus*

Mourning Dove *Zenaida macroura*

Mute Swan *Cygnus olor*

Nightingale *Luscinia megarhynchos*

Nightjar *Caprimulgus europaeus*

Nuthatch *Sitta europea*

Osprey *Pandion haliaetus*

Oystercatcher *Haematopus ostralegus*

Peregrine *Falco peregrinus*

Pheasant (Ring-necked) *Phasianus colchicus*

Pied Flycatcher *Ficedula hypoleuca*

Pied Wagtail *Motacilla alba*

Piping Plover *Charadrius melodus*

Pochard *Aythya ferina*

Prairie Falcon *Falco mexicanus*

Puffin *Fratercula arctica*

Raven *Corvus corax*

Razorbill *Alca torda*

Red-backed Shrike *Lanius collurio*

Red-breasted Merganser *Merganser serrator*

Red-cockaded Woodpecker *Picoides borealis*

Red Grouse *Lagopus lagopus*

Red-legged Partridge *Alectoris rufa*

Redpoll *Carduelis flammea*

Redshank *Tringa totanus*

Redstart *Phoenicurus phoenicurus*

Red-tailed Hawk *Buteo jamaicensis*

Red-throated Diver *Gavia stellata*

Redwing *Turdus iliacus*

Reed Bunting *Emberiza schoeniclus*

Reed Warbler *Acrocephalus scirpaceus*

Ring-billed Gull *Larus delawarensis*

Ringed Plover *Charadrius hiaticula*

Ring-necked Parakeet *Psittacula krameri*

Ring Ouzel *Turdus torquatus*

Robin *Erithacus rubecula*

Rock Dove *Columba livia*

Rock Pipit *Anthus petrosus*

Rook *Corvus frugilegus*

Roseate Tern *Sterna dougallii*

Ruddy Duck *Oxyura jamaicensis*

Sandhill Crane *Grus canadensis*

Sand Martin *Riparia riparia*

Sandwich Tern *Sterna sandvicensis*

Scottish Crossbill *Loxia scotica*

Sedge Warbler *Acrocephalus schoenobaenus*

Shag *Phalacrocorax aristotelis*

Shelduck *Tadorna tadorna*

Shoveler *Anas clypeata*

Short-eared Owl *Asio flammeus*

Siskin *Carduelis spinus*

Skylark *Alauda arvensis*

Slavonian Grebe *Podiceps auritus*

Snipe *Gallinago gallinago*

Snowy Egret *Egretta thula*

Song Thrush *Turdus philomelos*

South Polar Skua *Catharacta maccormicki*

Sparrowhawk *Accipiter nisus*

Spotted Flycatcher *Muscicapa striata*

Starling *Sturnus vulgaris*

Stock Dove *Columba oenas*

Stonechat *Saxicola torquata*

Stone Curlew *Burhinus oedicnemus*

Swallow *Hirundo rusticus*

Swift *Apus apus*

Tawny Owl *Strix aluco*

Teal *Anas crecca*

Treecreeper *Certhia familiaris*

Tree Pipit *Anthus trivialis*

Tree Sparrow *Passer montanus*

Tufted Duck *Aythya fuligula*

Tufted Puffin *Fratercula cirrhata*

Turtle Dove *Streptopelia turtur*

Twite *Careduelis flavirostris*

Water Rail *Rallus aquaticus*

Western Gull *Larus occidentalis*

Wheatear *Oenanthe oenanthe*

Whinchat *Saxicola rubetra*

White-fronted Chat *Ephthianura albifrons*

Whitethroat *Sylvia communis*

Wigeon *Anas penelope*

Willow Tit *Parus montanus*

Willow Warbler *Phylloscopus trochilus*

Woodcock *Scolopax rusticola*

Woodlark *Lullula arborea*

Woodpigeon *Columba palumbus*

Wood Warbler *Phylloscopus sibilatrix*

Wren *Troglodytes troglodytes*

Yellowhammer *Emberiza citrinella*

Yellow Wagtail *Motacilla flava*