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Birds as a tool in environmental monitoring

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The paper reviews the use of birds as a tool in environmental monitoring by discussing the value of birds as biological indicators and by describing the integrated bird monitoring programme in Finland. The paper emphasizes the central role of the interpretation of data. It is important that environmental authorities are aware of this interpretation.

Birds are useful biological indicators of, for example, broad-scale habitat changes and environmental contaminants. Birds are especially suitable for detecting unexpected changes which cannot be observed by measuring pre-selected physical and chemical parameters, and for monitoring biological, often cumulative and non-linear consequences of many environmental changes acting simultaneously.

In Finland about 15 study projects monitoring the regional population ecology of birds have been integrated to give maximal opportunity for data record linkage across projects. The breeding and wintering resident species are the most important populations for monitoring. The interpretation of results, the most important part of monitoring, tries to confirm cause-effect relationships between birds and their environment. Useful approaches to find the reasons for bird population changes include indicator species, comparison of species with similar ecologies and partitioning the total population change into different population processes. Knowing the reasons for changes is necessary to prevent negative environmental changes, influencing both nature and human well-being.

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1. Introduction

Bird populations have been monitored in many countries in the last few years, because birds are said to be good indicators of environmental changes. There are, however, only few thorough discussions of the use of birds as a tool in environmental monitoring. Morrison (1986) has critically reviewed the validity of birds as environmental indicators, but there remains the need of an integrated plan to solve the practical problems in bird population monitoring.

This paper discusses the suitability of birds as environmental indicators and presents an integrated bird monitoring programme, emphasizing especially the interpretation of data. The paper is based especially on recent research and planning work done in Finland (Koskimies 1987, 1988a). By monitoring is meant continuous and regular quantitative research using standardized methods, which reveal changes and causes of changes in the abundance and ecology of birds (e.g. Tiainen 1985). The changes caused by human activities are of greatest interest to environmental administration, but the natural dynamics must also be studied in order to separate the two from each other. The primary causes of the natural dynamics are climatic changes, geological processes and biological evolution. At least the last two of these influence bird populations many times more slowly than human activities (Salwasser 1986).

The mere recognition of environmental changes and problems can never be the final result of monitoring. Such a recognition must always lead to attempts to define and interpret the problem more precisely and to indicate the importance and kind of counter-measures (Goodman et al. 1986). The data gathered for environmental monitoring can be used also for other purposes, for example for ecological research and conservation of birds.

2. Birds as environmental indicators

2.1. Biological monitoring

Biological monitoring, for example using birds, has two main advantages compared with non-biological monitoring. It is possible, first, to detect environmental changes which cannot be observed or predicted by measuring a limited set of pre-selected physical or chemical parameters, and second, to detect and monitor biological, often cumulative and non-linear consequences of many environmental changes acting simultaneously. In more detail, biological monitoring can be motivated as follows (Zonneveld 1983, Koskimies 1987):

1) environmental changes often concern cumulative processes of strongly fluctuating factors which cannot be measured by one single observation using a chemical or physical method which is selected beforehand;
2) physical and chemical methods may be too time-consuming and/or too costly;
3) the combination of effects is often more important than the single factors and the total effect can be different from the mere sum of all separate actions (synergism);
4) various factors are very difficult to measure with respect to their proper direct and operational action.

A combination of biological and chemical/physical methods is the ideal way of monitoring environmental changes and their effects. By integrated monitoring it is possible to study cause-effect relationships which are of utmost importance in monitoring and in deciding on the actions to be taken.

2.2. Are birds good biological indicators?

Biological indicators are species which are sensitive to a human-caused change in their environment. More precisely: a biological indicator is defined as an organism so strictly associated with particular environmental conditions that its presence is indicative of the existence of these conditions (Morrison 1986).

Birds have been considered useful biological indicators because they are ecologically versatile and live in all kinds of habitats as herbivores, carnivores and omnivores (e.g. Järvinen & Väisänen 1979, Järvinen 1983). The ecology of birds is well known, and census and other study methods are well developed compared with those used for other biological taxa. Furthermore, bird monitoring is relatively inexpensive because voluntary bird watchers can gather the field data.

Although we can safely conclude that birds respond to quantitative and qualitative changes in their environment, they are usually not indicators of the primary cause of this change (Morrison 1986). Birds most often respond to secondary changes brought about by the primary cause, being one to more steps removed from the actual phenomenon.

However, often the changes in the abiotic regime of an ecosystem, or cause variables, may be overlooked, be too subtle, or be of no interest to be monitored directly. Monitoring of bird populations, or effect variables, is necessary for several purposes of describing environmental conditions. Thus far birds have been used most successfully to detect and monitor the effects of environmental contaminants, impacts that in many cases would probably have otherwise gone undetected (e.g. Morrison 1986). Bird data have been shown also to reflect broad-scale habitat changes, such as those due to agriculture and forestry (e.g. Järvinen & Väisänen 1979). The main point then is identifying the most important among the very many factors that can cause changes in bird populations. Interpretation of monitored data tries to solve this problem. It should be noted that all quantitative data, even those obtained with the most subtle chemical and physical methods, are difficult to assess because many actual operative factors are perhaps not reliable for such measurements (Zonneveld 1983).

When using bird species as indicators of certain environmental changes the manager must choose species on the basis of the specific habitat factors which must be monitored (Szaro & Balda 1982). The ecology of the indicator species should be well-known in order to separate the natural dynamics from the effects caused by human activity. Good indicators are specialized in their habitat needs, thus reacting rapidly to changes.

3. Constructing a monitoring programme

3.1. Aims and levels of monitoring

In Finland a large amount of research and planning work has been done to develop a scientifically valid, coordinated programme of bird monitoring in close connection with other environmental monitoring projects (Koskimies 1987). This work has been organized and financed by the Ministry of the Environment.

The basic aim of the programme is general monitoring to detect unexpected environmental changes as they occur, thus birds act as an early warning system for any adverse consequences of human-caused environmental changes. At the same time we try to measure the biological effects of environmental changes on bird populations and to monitor the bird fauna for conservation purposes.

Bird monitoring in Finland can be viewed at three levels:
1) monitoring of species,
2) monitoring of sites, and
3) monitoring of habitats.

The monitoring of species is the basis of all monitoring because it identifies the factors affecting bird numbers. In the present paper I concentrate on this level especially. This monitoring is carried out by cencussing various bird species or species groups. The monitoring of sites focuses on the entire bird fauna of, for example, nature reserves, eutrophic wetlands, peatlands, lush decidious forests, old forests, shore meadows and other important breeding sites. It was started in association with the bird atlas project (Väisänen 1989). The monitoring of habitats is based on the two other levels identifying bird population changes in various habitat types, by grouping species and site data.

3.2. Criteria for a bird monitoring programme

There are several criteria for a bird monitoring programme. It must
1) be continual,
2) be done in the same study areas from year to year, or repeated at regular intervals of a few years,
3) use comparable methods,
4) cover as many species as possible,
5) cover most of Finland,
6) cover all habitats, both optimal and marginal,
7) detect both short-term and long-term population changes,
8) be scientifically valid, and
9) have high efficiency.

The criteria 1–3 and 8–9 are self-evident for all monitoring studies. Other criteria need more explanation.

The monitoring of various bird species forms the skeleton of the monitoring system, because species are units of adaptation to their environment. As many species as possible should be studied (criterion 4) because several studies show the limitations of using a limited number of indicator species to monitor overall, long-term trends in a wildlife community (e.g. Verner 1984, Mannan et al. 1984, Toth & Baglien 1986).

Monitoring the populations of a larger set of species makes it possible to recognize the environmental changes and evaluate their significance more precisely than monitoring only a few species. Although each bird species responds to its environment in an individual way (e.g. Gaud et al. 1986), species with similar ecology are likely to react in a similar manner, and by grouping them data can be interpreted more reliably. By using more species, indication will be sharper and local deviation in behaviour of one of the species will be less relevant (Zonneveld 1983).

Distribution between different geographical scales (criterion 5) is of utmost importance. The regional pattern is a result of complicated dynamics in a mosaic of local populations. On the scale of local communities, changes may not be linked with habitat changes (e.g. Wiens 1981). What happens in a small area over a number of years may be to a great extent stochastic or determined by such factors as site tenacity, weather during winter or migration, fluctuations of food resources, and excess production of young in better habitats (Helle & Järvinen 1986). Adequate geographical spread of monitoring is important since changes may occur on a local scale in response to regional environmental changes (e.g. Wiens 1985, Helle & Järvinen 1986, Väisänen et al. 1986).

Observed patterns and inferred processes must be interpreted with regard to the spatial scale, which also influences duration, methodology, sample sizes or analytical procedures of the studies (Wiens et al. 1987). The scales include
1) biogeographical,
2) regional,
3) local and
4) the space occupied by single individuals.

Many of the resulting patterns and processes in distribution, density, habitat relationships and population ecology of bird populations highly depend on extenct of the study (e.g. Wiens 1981, Rotenberry 1986, Wiens et al. 1987). It cannot be hypothesized that a given process acted to produce a pattern observed within a particular spatial and temporal scale unless this process operates within the very same scale. The studies should be designed to include a nested hierarchy of scales. Emphasis on a single observational scale reduces the ability of the observer to identify patterns only clearly seen within other scales (Maurer 1985).

Clear patterns are most likely to emerge in ecological systems if these systems are relatively closed. In an open system effects from beyond the boundaries of the system as it has been defined may influence both the patterns and processes that go on within the system. For example, populations of migratory birds that breed in a local area may winter in different ecosystem types thousands of kilometres away (Wiens et al. 1987). Every local community is, therefore, likely to differ from every other one in important ways that are difficult to control in comparisons among them. The systems are likely to be effectively closed only over very large areas, or for species occupying highly specific and localized habitats or those populations restricted to islands, and these patterns are thus likely to be derived from processes occurring within the defined area of interest (Wiens et al. 1987, Helle & Järvinen 1986, Väisänen et al. 1986). Controls and replicates are hence very important in monitoring studies (e.g. Stewart-Oaten et al. 1986, Schamberger & O'Neil 1986).

Monitoring bird populations in many geographical areas is expensive. One solution to the problem is that part of the study areas in various geographical regions are studied intensively and the rest extensively. The spread of the changes can be mapped, because the factors identified in the intensively studied areas probably explain the changes in the extensively studied areas.

It has been shown many times since Palmgren (1930) that trends differ between habitats (criterion 6). Even a broad habitat change can remain undetected, if monitoring does not cover most of the habitat range. Particular habitats may be more vulnerable to man-made activities than others. Best & Stauffer (1986) have recently demonstrated the ambiguities that may be generated from incomplete sampling and attested to the drawbacks of extrapolating (or interpolating) from only a subset of the habitat gradient.

Density and population dynamics in optimal habitats may be the same from year to year although the whole population varies strongly. The migration between populations of different habitats is probably intense because a part of these produce excess young (source populations) whereas the rest produce too few young to compensate the losses (sink populations; Wiens & Rotenberry 1981, Helle & Järvinen 1986). In Britain, for example, many analysis have shown that population ecology of various bird species varies from habitat to habitat (e.g. O'Connor 1980a, 1980b, 1981, 1982, 1985a, O'Connor & Mead 1984, O'Connor & Shrubb 1986). Whenever vacancies in more optimal habitats occur, they are filled from the reservoir of the suboptimal habitats, thus keeping the density in the optimal habitat more or less constant at the expense of the suboptimal habitats. In many species there is probably not a single optimal habitat but a broader scale of habitats including many equally valuable solutions for an individual selecting its habitat (Wiens 1985).

The importance of long-term data should be emphasized, because the scarce long-term data on ecological systems collected thus far often show that short-term data collection is misleading or inadequate (criterion 7; e.g. Wiens 1981, 1983, Wiens & Rotenberry 1981). The long-term trends are most interesting in monitoring because they indicate more permanent changes in the environment (e.g. Järvinen & Väisänen 1979). The monitoring methods must be sensitive enough to detect the trend as early as possible. The amplitude of the year-to-year variation must also be measured in order to separate it from the long-term variation.

When, for example, studying wildlife-habitat relationships, short-term studies may suffice for some species but may be totally inadequate for other species. Predictions based on short-term studies can be misleading because of among-year density variation on the same plots (Gaud et al. 1986). Researchers usually have no control over this variation which arises from the vagaries of weather or from other factors affecting the population dynamics of the birds. Long-term, complex and sometimes costly studies are needed to accomplish multifaceted objectives and still a degree of uncertainty will remain to be both accepted and accounted for (O'Neil & Carey 1986).

3.3. Monitoring subject

The main criteria when selecting the monitoring subject are as follows:

1) observed population changes must indicate real environmental changes;
2) monitoring is based on scientifically valid methods and data analyses;
3) populations can be monitored both in natural and man-altered environments;
4) monitoring covers as many species, habitats and study areas as possible;
5) results are representative for larger areas of similar habitats;
6) population size, breeding success, mortality and migratory balance (emigration/immigration) be-

tween populations are monitored at the same time, and

7) bird monitoring can be integrated with other environmental monitoring.

Criterion 6 must be especially stressed. Mere data on population sizes and densities provides no clue as to the causes of observed population changes. An attempt should be made to identify the particular population processes which are affected by environmental effects and which seem to be involved in the recorded change. These population processes include natality, mortality, emigration and immigration. Population ecology of breeding and wintering birds studied in different geographical scales, both regional and national, is the most suitable monitoring subject (see also O'Connor 1985b, Tiainen 1985).

Some studies (e.g. Bezzel 1974, Bezzel & Reichholf 1974, Nilsson & Nilsson 1976) emphasize the use of conglomerative community indices for conservation and monitoring purposes. Many sources of error, however, may affect community indices (see Järvinen 1985). Interpretation of diversity index measures, for example, is extremely difficult (Wiens 1989). Although trends in diversity may sometimes be linked to various environmental conditions, higher diversity has no simple relationship to what might be termed environmental 'favourableness' (Schroeder 1987). Community-level measuring of biological structure do not provide information about the presence or status of particular wildlife species, but rather represent an accumulation of information to yield a measurement at the community level, being more suitable for 'pure' ecological research (Järvinen 1985, Götmark et al. 1986, Schroeder 1987, Koskimies & Pöysä 1989). The use of multivariate analysis in monitoring of ecological communities should be further studied (e.g. Gauch 1982), as well as the relationships between species, the main problem of community ecology.

The monitoring of resident species is especially important because they are affected only by changes occurring in Finland and all of their population processes, at least in theory, can be directly studied throughout the year. When interpreting the results it is important to analyse, among other things, the influence of winter weather on mortality, which is possible, for example, with the help of long-term winter bird censuses. The interpretation of data is greatly enhanced by the site-fidelity of many resident birds, their changes thus reflecting local environmental changes which can be defined. Results can be tied to a specified area which is an essential advantage in environmental monitoring.

Migratory species, however, must be included in the monitoring programme as well. They may indicate other types of environmental changes in their breeding areas compared to the year-round residents. By using migratory birds it is also possible to observe and monitor various environmental changes influencing bird populations in wintering areas and under migration. There are some impressing examples of the global environmental changes indicated by birds (e.g. the Sahel drought, Winstanley et al. 1974). Monitoring migratory birds goes to some extenct towards fulfilling the responsibility for the global environment, accepted by an increasing proportion of the Finnish population.

Monitoring of migratory species in addition to residents has also another important goal. Migrants form an essential part in the breeding bird community, especially in northern latitudes like Finland. Although community indices may not be valid measurements of bird population changes (see above), the communities should also be monitored, not only for the purpose of site and habitat monitoring, but because biological factors such as interspecific competition, intraspecific competition and predation can have an effect on wildlife populations, apart from influences of the habitat or environmental factors (Best & Stauffer 1986, Diehl 1986). By monitoring both resident and migratory species it is possible to compare their changes and try to find out if the cause of the change acts in the non-breeding area.

To conclude, breeding and wintering populations of the numerous species, reflecting most reliably large-scale environmental changes (e.g. Järvinen & Väisänen 1979, 1981), are the most suitable for monitoring. In addition, rare and threatened species indicating special environmental conditions must be included.

3.4. Migrant counts

In many countries, counts or trapping of migrants in the bird stations have been used as a monitoring method (e.g. Edelstam 1972, Hjort et al. 1981, Berthold et al. 1986, Roos 1987). There are many uncontrolled sources of error in these methods, however, and difficulties in interpreting the results. The main source of error when counting migrants is the great variation in migrant numbers, which may not at all indicate real population changes (Svensson 1978, Moritz 1982, Koskimies 1987). In different years the birds may come from different geographical areas due to shifts in migrating routes (e.g. Edelstam 1972, Svensson 1978, Moritz 1982) and defining just the general source area very broadly (e.g. Busse 1983, Liljefors et al. 1985, Berthold et al. 1986) does not fulfill the needs of interpretation, i.e. the identification of populations and environments affected.

Variation in breeding success affects the autumnal numbers of birds markedly, but coastal or archipelagic bird stations are not able to monitor juvenile productivity precisely because landing on these sites may have age-specific variation (Alerstam 1978). In partial migrants the proportion of migrating individuals may vary from year to year. The proportion of migrants which can be seen from observatories, and the proportion of birds landing and trapped varies similarly, depending on uncontrolled factors, especially weather (e.g. Richardson 1978). Various correction coefficients (Hussell 1981) are based on unproven assumptions and can further distort the results. In addition, due to unreliability and high variability from year to year, the efficiency of detecting a long-term trend by counting migrants is lower than by censusing breeding birds (Svensson 1978).

Although the methodological errors listed above could be, at least in theory, corrected or standardized, there remains the vast difficulties in interpreting the data. It is impossible to connect the counted birds definitely to certain geographical areas. An even greater problem is that the breeding habitats of the birds counted are not known. Variations in 'total' population (Busse 1980) cannot be compared with results from monitoring of population ecological parameters and other environmental studies in defined areas and environments.

The monitoring of changes in migrant numbers, whether expressed, for example, as counts of migrants or birds ringed, leads to fairly obvious *a posteriori* explanations in some species in some years, based mostly on guesses derived from autecological or from other knowledge. The argument that counting migrants is measuring something different from breeding time censuses (e.g. Busse 1980) is valid but it is useful in the context of monitoring only if we can know what the counting does actually measure (O'Connor 1984, see also Svensson 1978 and Koskimies 1987). For population monitoring it is necessary that the techniques involved have adequately solved the problems of validation and of interpretation (O'Connor 1984). Although it is perhaps true that counts of migrants reveal the most marked population changes in the long-term (20–30 years?), relying on these does not fulfill the basic requirement of monitoring: the change must be identified early enough to prevent negative effects.

3.5. Monitoring methods

The most important criteria when selecting the monitoring methods are

1) suitability for the species and habitats monitored,
2) the constancy of accuracy and reliability independent of the habitat and bird density,
3) the size of the change to be detected and
4) standardization between habitats, years and observers (e.g. Møller 1983).

There is no single method suitable for monitoring all bird species and habitats. Compromises between the accuracy of results and efficiency of work should be made, but the results must be comparable from year to year. The costs of data analyses after field work vary a lot between methods, and must be taken into account.

It must be kept in mind that there are many sources of error in all census and population ecological methods (e.g. Berthold 1976, Ralph & Scott 1981, Møller 1983, Verner 1985). For monitoring purposes it is not, however, essential to develop methods without errors, but to know the influence of different errors on results and to standardize them. Rapid one-visit census methods are often more suitable than time-consuming multi-visit methods, which voluntary bird watchers may find unattractive. With rapid methods more representative samples from different areas and habitats can be gathered. In Finland over ten different methods to monitor population changes and different population processes are used (Koskimies & Väisänen 1988). The methods are described in the following section.

3.6. The integrated bird monitoring programme in Finland

The Finnish bird monitoring programme covers various environmental types and population ecology of bird groups. A basic feature of the monitoring programme is that different projects are largely integrated to give maximal opportunity for data record linkage across the projects. There are also institutional connections between monitoring projects and basic research activities in various related fields, which is mutually beneficial.

Most projects study population ecology both in an intensive and extensive manner. They have been classified into four groups according to the monitoring subject:

A) projects monitoring size of breeding and wintering populations of land birds,

B) projects monitoring population ecology (population size, breeding success, mortality and emigration/immigration) of different species groups,

C) projects monitoring population ecology of the entire bird fauna, and

D) a project monitoring pesticides in birds.

The most important projects are designated, letters indicating the respective group, followed by a brief mention of other monitoring projects with more definite aims.

A1. Population changes of about a hundred of the most common land birds have been monitored by *line transects* since 1978 (Väisänen et al. 1989). Transects cover representative samples of different habitats in the census region. In the last few years about 30–50 transects (4–6 km each) have been censused by voluntary observers and paid assistants. The interpretation of results will be enhanced by the long tradition of line transects since the 1940s (e.g. Järvinen & Väisänen 1978).

Point counts of land birds started in Finland in 1984. They are easier and more attractive to the amateur bird watchers than line transects, but need to cover a large sample of points to get representative data of all main habitats. About 70–100 routes with 20 points (5 minutes each counting) in each have been censused in the last few years (Väisänen et al. 1989). Both line transects and point counts are made once a season.

A2. *Winter bird censuses* were started in Finland in the winter 1955/56 (e.g. Hildén 1988, Väisänen et al. 1988). The birds are counted along about 500 permanent routes of about 10 km each, three times a winter (early November, late December — early January and late February — early March) to study changes in distribution and abundance of winter birds in various habitats, and in mortality during winter.

B1. Population ecology of *waterfowl* and wetland birds has been the subject of a coordinated nationwide monitoring project since 1986 (e.g. Lammi et al. 1988), although censuses of minor areas have been carried out over 50 years. The breeding populations are censused by point and round count methods, twice in the beginning of the breeding season. In the former, the waterfowl are counted from a fixed point and a standard water area, in the latter by going round the study lake by boat or by foot (e.g. Koskimies & Pöysä 1989). From 1987 to 1988, for example, 608 point counts and 168 round counts were repeated in a comparable way in 148 study squares (10×10 km). The project will become more versatile by integrating studies on, for example, reproductive success (brood counts), on mortality, and on summer-time populations, into the present breeding population censuses (Koskimies & Pöysä 1987).

B2. Monitoring of population changes and reproduction of *archipelago birds* has been going on in a few localities since the early 1900s (e.g. Kilpi 1985). A coordinated project covering about 20 study areas all along the coast was started in 1984 (Hildén 1987). On every study island the observer counts the number of nests and adults and records the content of the nests, preferably three times in a breeding season.

B3. Population changes and breeding success of *birds of prey* have been monitored by searching all nests and territories of different raptor and owl species in 10-km squares since 1982 (e.g. Saurola 1986, Haapala & Saurola 1989a). About 120 squares have been studied. Additional data on reproduction of birds of prey outside the study blocks have been gathered from ringers. Intensive projects mostly carried out by ringers on the Golden Eagle *Aquila chrysaetos*, White-tailed Eagle *Haliaeetus albicilla*, Osprey *Pandion haliaetus* and Peregrine Falcon *Falco peregrinus* have been going on since the 1960s and 1970s by checking all or most of the nests every year.

B4. *Gallinaceous birds* deserve a project of their own because specific census methods are required and because of the commercial value of these birds. Since 1964, counts have been made along 800–900 routes (total length 25 000–30 000 km) once a season in late summer, to monitor population structure and population changes, as well as breeding success (e.g. Lindén & Rajala 1981). From 1988 onwards the census has been done along triangular routes (12 km each), sampling the various habitats randomly (Lindén et al. 1989).

B5. *Box-nesting birds* are in many respects ideal for monitoring: compared with most other species rather accurate measures on the size of the breeding population, reproductive success, mortality and site-tenacity of the birds can be obtained. Migratory balance between populations, irruptions and winter-time mortality can also be monitored in resident species. A special monitoring project of box-nesting passerines has been carried out in Finland since 1975 (Hildén & v. Haartman 1987). The project covers about 20 study areas in different parts of the country, with 50–300 nest-boxes in each area. The project will probably include many other areas in the future.

B6. *Nocturnal singers* (Bittern *Botaurus stellaris*, Rallidae, *Luscinia luscinia*, *Locustella* and *Acrocephalus* spp.) are monitored separately because of a need of a special census method (listening to the nocturnally singing males). All observations (usually 5 000–8 000 singing males in total per year) made by bird watchers in Finland have been gathered since 1980 (e.g. Koskimies 1986). In addition, standardized route censuses were introduced in 1988 to improve the annual comparability. Each route (about 5–30 km long) will be counted three times in early summer.

C1. Breeding success of birds has been monitored since 1954 by gathering *nest-cards* from bird watchers (e.g. v. Haartman 1969). A new card more suitable for coordinated monitoring of bird populations, including, for example, a standardized classification of breeding habitats, was taken into use in 1986 (Tiainen & Väisänen 1986, Koskimies & Väisänen 1988). On average, about 5 000 nest cards have been filled in per year since then. In addition to the general nest card project, breeding success of waterfowl, archipelago birds, birds of prey, gallinaceous birds and box-nesting species are also monitored in their respective projects (see above B1–B5), including, as far as possible, information on post-fledging mortality, which is an important gap in our knowledge of avian populations.

C2. Standardized *mist-netting* for monitoring population ecology of (mostly passerine) birds was introduced in 1986 (Haapala et al. 1987). The method is based on the Constant Effort Sites Scheme of the British Trust for Ornithology (Baillie et al. 1986). The ringer sets up a constant netting site with 5–25 nets. Each ringer uses those nets for certain standardized hours per day per 10-day period between May and August (in total 12 trapping days a summer). All netting routines are highly standardized from period to period and year to year, as in the German MRI-project (Berthold & Scherner 1975). The main aims of the project are to monitor breeding success (juvenile:adult ratio) and mortality of individuals from year to year. In 1988 there were 26 ringing sites in Finland (Haapala & Saurola 1989b).

C3. *General bird ringing* has been going on in Finland since 1913. Ringing data can be used to monitor mortality and to study causes of death, migration routes and wintering areas. However, this requires more data than previously collected from most bird species. More work is needed to develop the mathematical calculation of mortality parameters (see e.g. Wallin 1984, Lakhani 1987). Ringing can be used in monitoring more effectively if ecological data on the ringing site could be in some way coupled with the results of site-related ringing (O'Connor 1984). Koskimies & Väisänen (1988) emphasize the value of long-term and intensive ringing of local populations of various species, to monitor, for example, mortality and site-fidelity (emigration/immigration).

D1. Birds have been successfully used as an object in monitoring *pesticide* levels in biological organisms (reviewed e.g. by Morrison 1986). In Finland there has been no coordinated study programme, but pesticide levels have been analysed in a number of species (e.g. Lindberg et al. 1983, Solonen & Lodenius 1984, Lodenius & Kuusela 1985). This type of monitoring will be activated in the near future.

Atlas studies can also be used in monitoring of subsequent changes in distribution, which for many species probably occur on a time scale of some decades. Thus, the atlas is not a continual annual project as are projects A1 to C3. The first atlas was compiled in Finland in 1974–79 (Hyytiä et al. 1983, Koskimies 1989a), and second one in 1986–89 with greatly improved methodology using a more quantitative basis than previously (Väisänen 1989). Since 1976 atlas information has been enhanced by gathering *faunistically valuable records* of less numerous bird species (e.g. Koskimies 1989b), which are often typical of threatened habitats but poorly sampled in ordinary censuses due to their rarity.

Two monitoring projects having a clear conservation goal deserve special mention: data banks of valuable bird sites and threatened bird species. Data on breeding bird faunas and the environmental conditions of important bird sites (e.g. wetlands, peatlands, open islands with bird colonies, shore meadows, old and decidious forests, etc.) as well as probable threats have been recorded in a special *bird site register* since 1986. Almost one thousand sites have been registered so far for the purposes of nature conservation. Information on each of the 38 *threatened bird species* listed in the Finnish Red Data Book (Rassi & Väisänen 1987) has been gathered from voluntary observers in a coordinated manner during the 1980s (e.g. Koskimies 1989c). The main goal is to monitor the size of the populations and their reproductive success, in order to promote the protection of threatened bird species and their habitats.

In addition to these projects covering the whole of Finland, there is a special study for monitoring population changes of *breeding birds in virgin reference areas*. These are small catchment areas where versatile environmental monitoring will be integrated in the very same site. Breeding birds have been censused by a standard mapping method in 60 ha study plots in four areas since 1987 (Koskimies 1988b). In the early 1990s there will probably be about 10 areas in different parts of Finland.

An applied, two-visit mapping method has also been used in monitoring the *breeding birds in agricultural habitats* (Tiainen et al. 1985). This project started as a nation-wide status inventory in 1984 and later on included more local and intensive studies on the relationships between the breeding bird fauna and agricultural landscape. Future tasks where a mapping method should be used include monitoring of bird communities in various habitats and at valuable bird sites, and the mapping of the less numerous species in large study areas (Koskimies & Väisänen 1988).

Most projects have been organized by the Zoological Museum of the University of Helsinki with the help of about 3 000 voluntary bird watchers. They form a permanent observer network. The Museum has published detailed standard field instructions and computer forms for all the projects in a special book delivered to all observers (Koskimies & Väisänen 1988). The Finnish Game and Fisheries Research Institute, Game Division, organizes the monitoring of gallinaceous birds. They organize the monitoring of waterfowl together with the Zoological Museum.

4. Interpretation of monitored data

4.1. The relationship between birds and their environment

Interpretation of data is the most important part of monitoring studies, especially for environmental administration. All interpretation should be based on scientifically rigorous analyses of the data; monitoring is basically a scientific, long-term analysis of the relationships between *Homo sapiens* and its environment (Goodman et al. 1986).

Interpretation means searching for cause and effect relationships to assess impacts of various human-caused changes on biological organisms. Efforts should be made to study the mechanisms both of the proposed effect and of any plausible alternative explanation. The differences in the impact of alternative reasons seem often to be of degree, not kind (Stewart-Oaten et al. 1986). Cause and effect can best be inferred by comparing data from disturbed (operational) and undisturbed (control) sites with data collected during baseline studies prior to implementation of land-use practice or to any other change (Graves & Dittberner 1986), but on broad geographical scales controlled experiments may be unfeasible (Väisänen et al. 1986).

Study of habitat correlates is particularly valuable in relation to monitoring because it identifies key elements of habitat on which the various species depend. Population changes detected for different species can then be related to any identifiable changes in the abundance of the habitat elements concerned, whilst changes that are not consistent with known habitat alterations require some other explanation, such as a previously undetected environmental change (O'Connor 1985b).

It is necessary to understand how birds actually utilize their habitats and what habitat components ultimately influence the survivorship and reproductive success of these birds (Holmes 1981). Wildlife-habitat relationships can be obscured when the variables used to characterize habitat are measured too coarsely. Methods of habitat measuring and classification (e.g. Noon 1981, Larson & Bock 1986) must be developed and standardized to fulfill monitoring needs. The relevant parameters must be carefully selected (Wiens 1989).

In recent years, modelling habitat relationships of birds and other vertebrates has been rapidly developed, especially in North America (for a review, see Verner et al. 1986). A habitat relationship model must include a *functional* relation between the nature of the environment and the animal population, and simulate the dynamics of the environment (Shugart & Urban 1986).

Although there are many weaknesses and unproved assumptions in, for example, the Habitat Suitability Index (HSI) models (Verner et al. 1986), based mostly on literature review, they greatly aid in quantifying the species-habitat relationships and are useful for interpreting and predicting the impacts of different land-use practices on wildlife. They should be viewed as the very beginning in modelling the impacts of environmental changes on bird species. The integration of an intensive smaller-scale habitat selection study and an extensive study of bird population changes by Helle & Järvinen (1986) proved to be very fruitful.

Monitoring practioners should recognize when populations respond to something other than changes in their habitats. Biotic and abiotic factors such as weather fluctuations, varying resource bases, philopatry and competition may affect the sizes of populations independently of habitat changes (e.g. Klafs et al. 1981, van Horne 1983, Hejl & Beedy 1986). Weather and food resource fluctuations are probably the most important non-habitat factors which should be considered in bird monitoring work.

4.2. Methods of interpretation

There are many approaches in interpreting the data of bird monitoring studies. The basic goal of these is the separation of the influence of human-caused environmental changes from 'natural' changes. The data base obtainable from virgin areas remains limited because virgin areas are scarce and poorly representative of different habitats. Thus, a comparison between the data base from the virgin areas and that of human-altered habitats is not satisfactory. In addition, bird population changes in (smaller) virgin areas are dependent on the regional changes influenced by human activities (Väisänen et al. 1986).

Suitable approaches to be further developed include
1) single indicator species,
2) grouping species with similar ecologies ('monitoring guild' approach), and
3) partitioning the change in population size to population processes ('population model' approach).

4.3. Indicator species

Birds which are specialised in their life history characteristics may be used as indicators of special habitat needs and changes. In selecting indicator species one should consider
1) residency status,
2) foraging and/or nesting substrate,
3) adequate data base,
4) ease of monitoring,
5) sensitivity to habitat perturbations,
6) sensitivity to environmental fluctuations and
7) the condition or range of conditions a given species will indicate (Szaro & Balda 1982).

Indicator values of various bird species can be evaluated by thoroughly documented case studies where bird populations have been monitored through a measured environmental change. Species sensitive to habitat perturbations will be the best indicators.

There are many problems, however. Any single species can serve as an indicator for only a narrow range of ecological conditions within the habitat type. Some are even too rare to be of any help. The habitat needs of most species are not fully understood and the population level may indicate other changes than those occurring in the study area (e.g. migrants). There has been lively discussion on the use of single or a few species as indicators of other species in the same guild, since Severinghaus (1981). Most authors (e.g. Verner 1983, 1984, Mannan et al. 1984, Szaro 1986) emphasize that the habitat and other needs of different species differ so much that the indicator-guild concept is not relevant in land management and caution is needed when making generalizations to other species.

Restriction to the indicator species of *a priori* known environmental changes diminishes the power of bird monitoring as a biological early warning system of complex and unexpected environmental changes. Important changes may remain unnoticed as in many types of chemical and physical monitoring where the parameters to be measured must be selected beforehand and include only a limited set of the whole. In addition, most of the changes are probably non-linear and not of the type one-cause—one-effect.

4.4. Monitoring guilds

Because many population changes have multiple causes, monitoring specific environmental changes is most rewarding if birds are grouped, for example, by habitat, by main strategy of migrating or feeding. Grouping of ecologically similar species is principally based on the theory of guilds (Root 1967). Verner (1984) developed the concept of 'management guild', or a group of species that respond in a similar way to a variety of changes likely to affect their environment.

By using the above guild concept the land manager tries to predict the presence and abundance of species which will be left after the planned land-use change. In the interpretation of monitoring results we use the same kind of data. This data gives the presence and abundance, as well as trends of different species and species groups through time. Our problem is to find the environmental change(s) which caused the measured population changes. Species having the same sort of population change are clustered and their common or different ecological properties affecting the population-environment relationships are looked for. When guilds are defined more in terms of an animal's associations with zones of its habitat than in terms of diets or foraging manouvres, guild members are more likely to respond alike to changes in habitat.

Short & Burnham (1982) and Short (1983) associated wildlife species with habitat structure, expressed as a (breeding habitat layers) × (foraging habitat layers) matrix. Defining guilds on the basis of habitat layers has limitations, however. Foraging or nesting guilds are less useful as the spectrum of habitats being considered decreases (DeGraaf & Chadwick 1984).

The guild concept is most useful if species are arranged in guilds that accurately reflect their use of habitats and resources (DeGraaf & Chadwick 1984, Szaro 1986). With the help of manipulative experiments and research on influence of known habitat alterations, we could define indicator species (see 4.3.) and 'response' guilds using a scale that is more closely related to the degree of likely environmental changes (Szaro 1986).

4.5. Population model

The measurements of various population processes (breeding success, mortality and emigration/immigration) should be as thorough as possible. A striking example comes from British farmland (O'Connor & Shrubb 1986). Detailed examination of breeding success of farmland birds in a variety of regional samples with various chemical history suggests that improvements in hatching success are responsible for the improved nesting success. This is as expected if pesticides resulted in generally reduced nesting success in the early 1960s. Of the alternative explanations the most worrying is that average measured success has increased only apparently — if there are fewer birds now they may all breed in the best environments where breeding success is good.

Practical difficulties in monitoring survival of birds are greater than those of reproductive success. The intensification of ringing must be restricted to young birds or older birds whose ages are known accurately, to obtain as reliable data on survival as possible (Lakhani 1987). The same holds true also of the monitoring of emigration/immigration which, at the moment, is possible only for intensively studied populations.

There are some good examples which show the complex of reasons and influences of environmental changes on bird populations. The continuous decrease of the Partridge *Perdix perdix* in Britain was due to increased chick mortality, which is mostly determined by the abundance of their insect food (Potts 1980). The quality and quantity of a chick's diet has been progressively reduced by the use of pesticides and by other modern farming techniques. The net effects of agricultural changes on a population, however, are not straightforward since Partridges are shot to a varying extent throughout their distributional area, and in some areas they also benefit from game conservation techniques such as predator control and re-stocking. These factors are further complicated by the occurrence of a nematode parasite which has been absent in recent years due to an environmental change unrelated to Partridge or even game bird density.

To conclude, interpretation of data is the most important part of monitoring, but seriously neglected thus far. Without knowing the reasons for bird population changes we are not able to find out rapid and effective counter-measures to prevent negative environmental changes influencing both natural surroundings and human well-being. The key to the interpretation is a sound knowledge of the cause-effect relationships between bird populations and the habitat and non-habitat factors of their environment.

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References

Alerstam, T. 1978: Reoriented bird migration in coastal areas: Dispersal to suitable resting grounds. — Oikos 30:405–408.

Baillie, S. R., Green, R. E., Boddy, M. & Buckland, S. T. 1986: An evaluation of the Constant Effort Sites Scheme. — Report of the Constant Effort Sites Review Group to the Ringing Committee of British Trust for Ornithology, Tring.

Berthold, P. 1976: Methoden zur Bestanderfassung in der Ornithologie: Übersicht und kritische Betrachtung. — J. Ornithol. 117:1–69.

Berthold, P., Fliege, G., Querner, U. & Winkler, H. 1986: Die Bestandsentwicklung von Kleinvögeln in Mitteleuropa: Analyse von Fangzahlen. — J. Ornithol. 127:397–437.

Berthold, P. & Schermer, R. 1975: Das "Mettnau-Reit-Illmitz-Programm", ein langfristiges Vogelfangprogramm der

Vogelwarte Radolfzell mit vielfätiger Fragestellung. — Vogelwarte 28:97–123.
Best, L. & Stauffer, D. F. 1986: Factors confounding evaluation of bird-habitat relationships. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 209–216. Univ. Wisconsin Press, Madison.
Bezzel, E. 1974: On the evaluation of waterfowl biotopes. — Int. Conf. Conserv. Wetlands and Waterfowl, Heiligenhafen, FRG, 2.–6.12.1974:294–299.
Bezzel, E. & Reichholf, J. 1974: Die Diversität als Kriterium zur Bewertung der Reichhaltigkeit von Wasservogel-Lebensraüme. — J. Ornithol. 115:50–61.
Busse, P. 1980: Breeding bird censuses contra counts of migrating birds. — In: Oelke, H. (ed.), Bird census work and nature conservation: 55–65. Dachv. Deutsch. Avif., Göttingen.
—"— 1983: Spatial structure of bird populations as a matter of biometry — the method of study on migration. — Ornis Fennica, Suppl. 3:86–88.
DeGraaf, R. M. & Chadwick, N. L. 1984: Habitat classification: a comparison using avian species and guilds. — Environ. Managem. 8:511–518.
Diehl, B. 1986: Factors confounding predictions of bird abundance from habitat data. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 229–233. Univ. Wisconsin Press, Madison.
Edelstam, C. 1972: The visible migration of birds at Ottenby. — Vår Fågelvärld, Suppl. 7.
Gauch, H. G., Jr. 1982: Multivariate analysis in community ecology. — 298 pp. Cambridge Univ. Press, Cambridge.
Gaud, W. S., Balda, R. P. & Brawn, J. D. 1986: The dilemma of plots or years: a case for long-term studies. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 223–227. Univ. Wisconsin Press, Madison.
Goodman, G., Henriksen, A., Järvinen, O., McIntyre, A., Mayer, R., Stalling, D. & Whelpdale, D. 1986: International evaluation of the environmental monitoring programme, PMK. — National Swedish Environmental Protection Board Report 3090:1–25.
Graves, B. M. & Dittberner, P. L. 1986: Variables for monitoring aquatic and terrestrial environments. — USDI Fish and Wildlife Serv. Biol. Rep. 86(5):1–55.
Götmark, F., Åhlund, M. & Eriksson, M. O. G. 1986: Are indices reliable for assessing conservation value of natural areas? An avian case study. — Biol. Conserv. 38: 55–73.
Haapala, J., Koskimies, P. & Saurola, P. 1987: SSP — A mist-netting project for monitoring bird populations in Finland. (in Finnish with English summary) — Lintumies 22:76–79.
Haapala, J. & Saurola, P. 1989a: Breeding and population trends of common raptors and owls in Finland in 1988. (in Finnish with English summary) — Lintumies 24:27–36.
—"— 1989b: Constant Effort Sites Scheme in Finland in 1987–1988. (in Finnish with English summary) — Lintumies 24:76–77.
v. Haartman, L. 1969: The nesting habits of Finnish birds. I. Passeriformes. — Comm. Biol. Soc. Scient. Fenn. 32: 1–187.
Hejl, S. J. & Beedy, E. C. 1986: Weather-induced variation in the abundance of birds. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 241–244. Univ. Wisconsin Press, Madison.
Helle, P. & Järvinen, O. 1986: Population trends of North Finnish land birds in relation to their habitat selection and changes in forest structure. — Oikos 46: 107–115.
Hildén, O. 1987: A new seabird monitoring scheme in Finland. (in Finnish with English summary) — Lintumies 22: 62–67.
—"— 1988: Thirty years of Finnish winter bird censuses. — Sitta 2:21–57.
Hildén, O. & v. Haartman, L. 1987: A decade of population studies in box-nesting small passerines in Finland. (in Finnish with English summary) — Lintumies 22:70–75.
Hjort, C., Lindholm, C.-G. & Pettersson, J. 1981: Bird ringing statistics at Ottenby Bird Observatory 1946–1980 (in Swedish with English summary). — Report Ottenby Bird Station 2:1–191.
Holmes, R. T. 1981: Theoretical aspects of habitat use by birds. — In: Capen, D. E. (ed.), Multivariate statistics in studies of wildlife habitat. USDA Forest Serv. Gen. Techn. Rep. RM 87:33–37.
van Horne, B. 1983: Density as a misleading indicator of habitat quality. — J. Wildl. Managem. 47:893–901.
Hussell, D. J. T. 1981: The use of migration counts for monitoring bird population levels. — Stud. Avian Biol. 6: 92–102.
Hyytiä, K., Kellomäki, E. & Koistinen, J. (ed.) 1983: Finnish bird atlas. (in Finnish) — 520 pp. SLY:n Lintutieto, Helsinki.
Järvinen, O. 1983: How should a Finnish monitoring system of bird populations be implemented? (in Finnish with English abstract)— Ornis Fennica 60:126–128.
—"— 1985: Conservation indices in land use planning: dim prospects for a panacea. — Ornis Fennica 62:101–106.
Järvinen, O. & Väisänen, R. A. 1978: Long-term changes of the most abundant south Finnish forest birds during the past 50 years. — J. Ornithol. 119:441–449.
—"— 1979: Changes in bird populations as criteria of environmental changes. — Holarctic Ecology 2:75–80.
—"— 1981: Methodology for censusing land bird faunas in large regions. — Stud. Avian Biol. 6:146–151.
Kilpi, M. 1985: Archipelago bird populations in Finland: monitoring and recent changes. — Ornis Fennica 62:42–46.
Klafs, G., Müller, H. & Weber, H. 1981: Zum Einfluss der Witterung während der Brutzeit auf grossräumige Abundanzänderungen waldbewohnender Singvogelgruppen. — Arch. Naturschutz Landschaftsforsch. 21:227–240.
Koskimies, P. 1986: The occurrence of night-singers in Finland in 1985. (in Finnish with English summary) — Lintumies 21:146–150.
—"— 1987: Monitoring of Finnish bird fauna. Birds as environmental indicators. (in Finnish with English summary) — Publ. Ministry Environment, Ser. A 49:1–255.
—"— 1988a: Trends in bird populations as environmental indicators. — Statistical J. United Nations ECE 5:231–238.

—"— 1988b: The mapping censuses of breeding bird fauna in the areas of integrated monitoring. (in Finnish) — Publ. Ministry Environment, Ser. D 45:1–38.

—"— 1989a: Distribution and numbers of Finnish breeding birds. Appendix to Suomen lintuatlas. — 76 pp. SLY:n Lintutieto, Helsinki.

—"— 1989b: Faunistical report 1987. (in Finnish with English summary) — Lintumies 24:12–20.

—"— 1989c: The occurrence of threatened bird species in Finland in 1987. (in Finnish with English summary) — Lintumies 24:81–87.

Koskimies, P. & Pöysä, H. 1987: Methods for monitoring and census of waterfowl in Finland. (in Finnish with English summary) — Suomen Riista 34:31–41.

—"— 1989: Waterfowl censusing in environmental monitoring: a comparison between point and round counts. — Ann. Zool. Fennici 26:201–206.

Koskimies, P. & Väisänen, R. A. 1988: Monitoring bird populations in Finland: a manual. (in Finnish with English summary) — 2nd edn, 144 pp. Zoological Museum, Univ. of Helsinki

Lakhani, K. H. 1987: Efficient estimation of age-specific survival rates from ring recovery data of birds ringed as young, augmented by field information. — J. Anim. Ecol. 56:969–987.

Lammi, E., Väisänen, R. A. & Koskimies, P. 1988: Population monitoring of the Finnish waterfowl in 1987–88. (in Finnish with English summary) — Lintumies 23:138–145.

Larson, D. L. & Bock, C. E. 1986: Determining avian habitat preference by bird-centered vegetation sampling. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 37–43. Univ. Wisconsin Press, Madison.

Liljefors, M., Pettersson, J. & Bengtsson, T. 1985: Recruitment areas for migrants trapped at Ottenby Bird Observatory. (in Swedish with English summary) — Report Ottenby Bird Station 5:1–127.

Lindberg, P., Odsjö, T. & Wikman, M. 1983: Mercury in feathers of the peregrine falcon Falco peregrinus in Finland. — Ornis Fennica 60:28–30.

Lindén, H. & Rajala, P. 1981: Fluctuations and long-term trends in the relative densities of tetraonid populations in Finland 1964–77. — Finnish Game Res. 39:13–34.

Lindén, H., Wikman, M. & Helle, E. 1989: Tetraonid populations in Finland in 1988: A comparison between the route censuses and the wildlife triangles. (in Finnish with English summary) — Suomen Riista 35:36–42.

Lodenius, M. & Kuusela, S. 1985: Mercury content in feathers of the kestrel Falco tinnunculus L. in Finland. — Ornis Fennica 62:158–160.

Mannan, R. W., Morrison, M. L. & Meslow, E. C. 1984: Comment: the use of guilds in forest bird management. — Wildl. Soc. Bull. 12:426–430.

Maurer, B. A. 1985: Avian community dynamics in desert grasslands: observational scale and hierarchical structure. — Ecol. Monogr. 55:295–312.

Møller, A. P. 1983: Methods for monitoring of bird populations in Nordic countries. (in Danish with English summary) — Nordic Council of Ministers, Environmental Report 1/1983:1–185.

Moritz, D. 1982: Langfristige Bestandsschwankungen ausgewählter Passeres nach Fangergebnissen auf Helgoland. — Seevögel, Sonderband:13–24.

Morrison, M. L. 1986: Bird populations as indicators of environmental change. — Current Ornithol. 3:429–451.

Nilsson, S. G. & Nilsson, I. N. 1976: Valuation of South Swedish wetlands for conservation with proposal of a new method for valuation of wetlands as breeding habitats for birds. (in Swedish with English summary) — Fauna och Flora 71:136–144.

Noon, B. R. 1981: Techniques for sampling avian habitats. — In: Capen, D. E. (ed.), The use of multivariate statistics in studies of wildlife habitat. USDA Forest Serv. Gen. Techn. Rep. RM-87.

O'Connor, R. J. 1980a: Population regulation in the Yellowhammer Emberiza citrinella in Britain. — In: Oelke, H. (ed.), Bird census work and nature conservation: 190–200. Dachv. Deutsch. Avif., Göttingen.

—"— 1980b: Pattern and process in great tit (Parus major) populations in Britain. — Ardea 68:165–183.

—"— 1981: Habitat correlates of bird distribution in British census plots. — Stud. Avian Biol. 6:533–537.

—"— 1982: Habitat occupancy and regulation of clutch size in the European kestrel Falco tinnunculus. — Bird Study 29:17–26.

—"— 1984: Science and ringing scheme: a prospective. — Ringing & Migration 5:6–14.

—"— 1985a: Behavioural regulation of bird populations: a review of habitat use in relation to migration and residency. — In: Sibly, R. M. & Smith, R. H. (ed.), Behavioural ecology: 105–142. Blackwell, Oxford.

—"— 1985b: Long-term monitoring of British bird populations. — Ornis Fennica 62:73–79.

O'Connor, R. J. & Mead, C. J. 1984: The stock dove in Britain, 1930–1980. — Brit. Birds 77:181–201.

O'Connor, R. J. & Shrubb, M. 1986: Farming and birds. — 290 pp. Cambridge Univ. Press, Cambridge.

O'Neil, L. J. & Carey, A. B. 1986: Introduction: when habitats fail as predictiors. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 207–208. Univ. Wisconsin Press, Madison.

Palmgren, P. 1930: Quantitative Untersuchungen über die Vogelfauna in den Wäldern Südfinnlands mit besonderer berücksichtigung Ålands. — Acta Zool. Fennica 7:1–218.

Potts, G. R. 1980: The effects of modern agriculture, nest predation and game management on the population ecology of partridges Perdix perdix and Alectoris rufa. — Adv. Ecol. Res. 11:1–82.

Ralph, C. J. & Scott, J. M. (ed.) 1981: Estimating numbers of terrestrial birds. — Stud. Avian Biol. 6:1–630.

Rassi, P. & Väisänen, R. (ed.) 1987: Threatened animals and plants in Finland. — 82 pp. Ministry of the Environment, Helsinki.

Richardson, W. J. 1978: Timing and amount of bird migration in relation to weather: a review. — Oikos 30:224–272.

Roos, G. 1987: Bird migration in Falsterbo. (in Swedish) — National Swedish Environmental Protection Board Report 3342:1–30.

Root, R. B. 1967: The niche exploitation pattern of the blue-gray gnatcatcher. — Ecol. Monogr. 37:317–350.

Rotenberry, J. T. 1986: Habitat relationships of shrubsteppe birds: even "good" models cannot predict the future. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 217–221. Univ. Wisconsin Press, Madison.

Salwasser, H. 1986: Modeling habitat relationships of terrestrial vertebrates — the manager's viewpoint. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 419–424. Univ. Wisconsin Press, Madison.

Saurola, P. 1986: The raptor grid: an attempt to monitor Finnish raptors and owls. — Vår Fågelvärld, Suppl. 11:187–190.

Schamberger, M. L. & O'Neil, L. J. 1986: Concepts and constraints of habitat-model testing. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 5–10. Univ. Wisconsin Press, Madison.

Schroeder, R. L. 1987: Community models for wildlife impact assessment: a review of concepts and approaches. — USDI Fish and Wildlife Serv. Biol. Rep. 87(2):1–41.

Severinghaus, W. D. 1981: Guild theory development as a mechanism for assessing environmental impact. — Environ. Managem. 5:187–190.

Short, H. L. 1983: Wildlife guilds in Arizona desert habitats. — USDI Bur. Land. Manage. Techn. Note 362:1–258.

Short, H. L. & Burnham, K. P. 1982: Technique for structuring wildlife guilds to evaluate impacts on wildlife communities. — USDI Fish Wildl. Serv. Spec. Sci. Rep. — Wildl. no 244:1–34.

Shugart, H. H. & Urban, D. L. 1986: Modeling habitat relationships of terrestrial vertebrates — the researcher's viewpoint. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 425–429. Univ. Wisconsin Press, Madison.

Solonen, T. & Lodenius, M. 1984: Mercury in Finnish sparrowhawks Accipiter nisus. — Ornis Fennica 61:58–63.

Stewart-Oaten, A., Murdoch, W. W. & Parker, K. R. 1986: Environmental impact assessment: "pseudoreplication" in time? — Ecology 67:929–940.

Svensson, S. 1978: Efficiency of two methods for monitoring bird population levels: breeding bird censuses contra counts of migrating birds. — Oikos 30:373–386.

Szaro, R. C. 1986: Guild management: an evaluation of avian guilds as a predictive tool. — Environ. Managem. 10: 681–688.

Szaro, R. C. & Balda, R. P. 1982: Selection and monitoring of avian indicator species: an example from a Ponderosa Pine forest in the Southwest. — USDA Forest Serv. Gen. Techn. Rep. RM-89:1–8.

Tiainen, J. 1985: Monitoring bird populations in Finland. — Ornis Fennica 62:80–89.

Tiainen, J., Pakkala, T., Piiroinen, J. & Ylimaunu, J. 1985: Changes and status of avifauna of farmland in Finland: background and general methods. (in Finnish with English summary) — Lintumies 20:23–29.

Tiainen, J. & Väisänen, R. A. 1986: The renewed Finnish nest record scheme. (in Finnish with English summary) — Lintumies 21:58–59.

Toth, E. F. & Baglien. J. W. 1986: Summary: when habitats fail as predictors — the manager's viewpoint. — In: Verner, J., Morrison, M. L. & Ralph, C. J. (ed.), Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates: 255–256. Univ. Wisconsin Press, Madison.

Verner, J. 1983: An integrated system for monitoring wildlife on the Sierra National Forest. — Transact. North Amer. Wildl. Nat. Res. Conf. 48:355–366.

—"— 1984: The guild concept applied to management of bird populations. — Environ. Managem. 8:1–14.

—"— 1985: Assessment of counting techniques. — Current Ornithol. 2:247–302.

Verner, J., Morrison, M. L. & Ralph, C. J. (ed.) 1986: Wildlife 2000. Modeling habitat relationships of terrestrial vertebrates. — 470 pp. Univ. Wisconsin Press, Wisconsin.

Väisänen, R. A. 1989: Renewal of methodology in the second bird atlas of Finland. — Ann. Zool. Fennici 26:167–172.

Väisänen, R. A., Hildén, O. & Koskimies, P. 1988: The Finnish winter bird censuses: present state, future possibilities and results from the winter 1987/88. (in Finnish with English summary) — Lintumies 23:202–213.

Väisänen, R. A., Hildén, O. & Pulliainen, E. 1989: Monitoring of Finnish land bird populations in 1979–88. (in Finnish with English summary) — Lintumies 24:60–67.

Väisänen, R. A., Järvinen, O. & Rauhala, P. 1986: How are extensive, human-caused habitat alterations expressed on the scale of local bird populations in boreal forests? — Ornis Scand. 17:282–292.

Wallin, K. 1984: Methods for estimating survival rates from band recovery data. (in Swedish with English summary) — Vår Fågelvärld 43:231–239.

Wiens, J. A. 1981: Scale problems in avian censusing. — Stud. Avian Biol. 6:513–521.

—"— 1983: Avian community ecology: an iconoclastic view. — In: Brush, A. H. & Clark, G. A. (ed.), Perspectives in ornithology: 355–403. Cambridge Univ. Press, Cambridge.

—"— 1985: Habitat selection in variable environments: shrubsteppe birds. — In: Cody, M. L. (ed.): Habitat selection in birds: 227–251. Academic Press, Orlando.

—"— 1989: The ecology of bird communities. 1. Foundations and patterns. — 539 pp. Cambridge Univ. Press, Cambridge.

Wiens, J. A. & Rotenberry, J. T. 1981: Censusing and the evaluation of avian habitat occupancy. — Stud. Avian Biol. 6:522–532.

Wiens, J. A., Rotenberry, J. T. & van Horne, B. 1987: Habitat occupancy patterns of North American shrubsteppe birds: the effects of spatial scale. — Oikos 48:132–147.

Winstanley, D., Spencer, R. & Williamson, K. 1974: Where have all the whitethroats gone? — Bird Study 21:1–14.

Zonneveld, I. S. 1983: Principles of bio-indication. — Environ. Monitoring Assessment 3:207–217.

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