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AN OVERVIEW OF GRID-BASED ATLAS WORKS IN ORNITHOLOGY

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ABSTRACT.—Distributional atlas work began in the British Isles in 1950 and in Scandinavia about the same time. These efforts by botanists were very successful, indicating on an area basis not only the occurrence but also frequency of the flowering plants. The British Trust of Ornithology soon followed suit; by 1978 the British, French and Danish Atlases of bird distribution have been published and several others are under way in Europe. The International organisation of European atlas work has its centers in Leeds, England and Gambleaux, Belgium. A survey will be presented telling about the status of these and of the Australian, New Zealand, and USSR atlas works. All above undertakings have in common that they use the 10 km² square, viz. 50 km square, grids. The second half of the presentation will be devoted to discussing the advantages of the grid system for gaining meaningful population estimates on an area basis.

GRID-BASED ATLASES AND BIRD ATLASES

What is a grid-based atlas?—A grid is a "network composed of two sets of uniformly spaced straight lines intersecting in right angles." An atlas is a "collection of maps bound together." The first atlas was published in 1595 by Gerhard Kremer, Flemish geographer. Kremer also introduced the projection of the globe which was named after his Latin pseudonym: Mercator.

The most widespread grid used on maps is the intersection of latitude and longitude (meridian) lines, or smaller, rectangular squares formed by divisions of the latitude/longitude (for short, "latilong") grid. From this grid the geographic position, the "coordinates" of each locality (town, collecting place, study plot, etc.) can easily and accurately be expressed, though the calculation is cumbersome since degrees, and their divisions in minutes and seconds, are used. Latilong-based grids were used lately in the gross mapping of biological localities on large scale maps, e.g., those of the Atlas of Speciation in African Passerine Birds (Hall and Moreau 1970). The Breeding Bird Survey of North America uses 1° and ½° squares (Robbins 1977); the Zambian Bird Atlas project uses 30′ squares (Dowsett 1979).

Long after the introduction of the metric system of measurements by the great majority of the world's political entities, the world atlas has been enriched by a metric grid with its basic unit the 10 km square (or block, but geographers prefer the word *square*). Mercator used his projection with the Equator as base; this way areas up to 15° north and south of the Equator (within which many of the important trade routes of his time were situated) showed true areas without distortion. The transverse Mercator projection uses segments of the globe along the meridians 6° of latitude apart as basic units. The position of a locality in this system is given by its distance, in kilometers, from the Equator, and, latitudinally, from the nearest base meridian. Thus two numerals describe each position e.g., for each 10 km square: the distance, of its southwestern corner, from the sixth meridian east of it (in the Western Hemisphere), and the distance from the Equator.

The Universal Transverse Mercator (UTM) grid is international. Besides uniformity, its main advantage is that it uses the decimal system and its units may be a division or multiplier of the basic unit, i.e., 1, 2, 2½, 5, 10, 50, 100 km etc. all easily converted. The position of any locality on the globe is thus precisely stated. Asilomar, California, for instance, is 595:4053 in Zone 10 of the UTM system: it is situated 595 km east of the zone boundary, the 126° W meridian, and 4053 km north of the Equator. A rare collecting site can be described to the nearest meter on the two axes of the numbering system.

In Canada as in Europe and most other countries the topographic maps are based on the UTM grid. In the USA this grid developed in the years following World War II by the Geological Survey; it is the basic grid of many states, and is used exclusively for military mapping. Many new topographic maps or those recently corrected show the UTM grid either in black, in blue, or at least the metric coordinates are marked on the margins of the map sheets by blue ticks. On the latter the completion of any desired metric grid can be accomplished either by a "master" overlay or by the use of a T-shaped ruler and India ink or pencil.

The first biological use of a metric grid on a wide geographical base known to me (Udvardy 1969) was the Atlas of the Distribution of vascular plants in NW Europe (Hultén 1950). The UTM grid (10 km square grid) was first used by the Atlas of the British Flora (Perring and Walters 1962). One example of its research advantages is demonstrated by Järvinen and Väisänen

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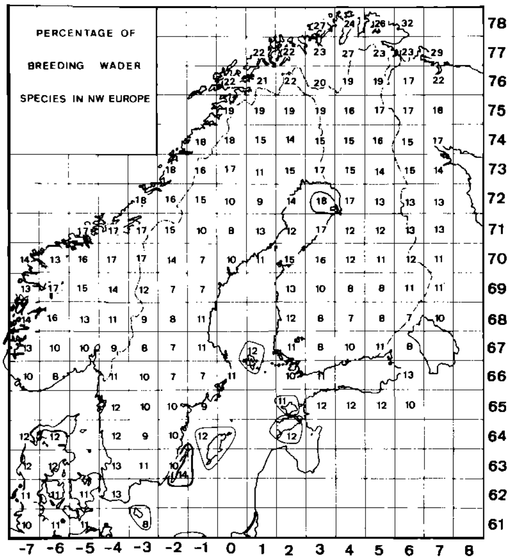

FIGURE 1. Percentage of wader species (of all land birds) in NW Europe. The S to N coordinates of the squares indicate distance, in 100 km, from the Equator. The W to E coordinates indicate, also in 100 km units, the distance from the base meridian of the Finnish National Grid, i.e., 20°E Latitude. Negative 100 km values indicate merely that they are measured westward from the base meridian, an ad hoc procedure for the sake of the wader study only. From Järvinen and Väisänen (1978), (reproduced by permission from Oikos).

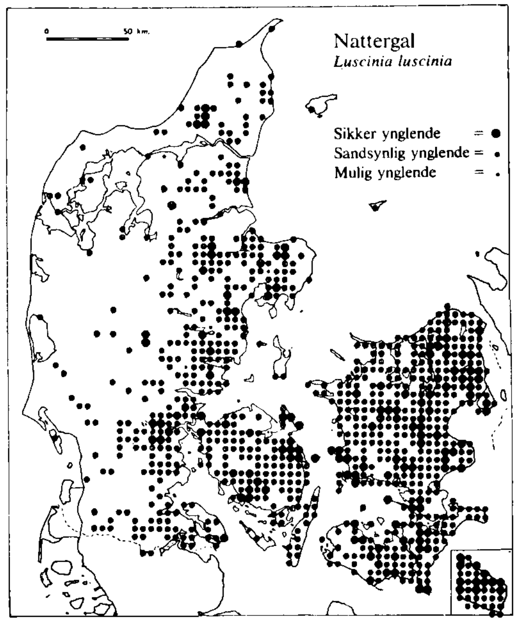

FIGURE 2. Breeding distribution of the Thrush Nightingale in Denmark during 1971–1974. Diminishing dot sizes indicate confirmed, probable, and possible breeding in the 5 km square blocks of the Danish atlas, from Dybbro (1976).

(1978) in their work on the zoogeography of wading birds in Northern Europe (Fig. 1). Several countries are following the British Isles in recording biological data by the UTM grid coordinates rather than latitude and longitude. Coordinates in degrees, minutes and seconds are difficult to compute and compare, and place names change frequently and are restricted locally, as everyone knows who has tried to decipher a specimen label from a foreign collecting locality. Enormous amounts of time, labor and uncertainty are saved by the use of this system and its adoption is a "must" for international science.

The first avian monograph using faunistic maps throughout was the Birds of the Soviet Union (Dementiew and Gladkow 1951–1954). The first avian atlas was that of the European Birds by Voous (1960). These firsts were based on the often scarce and incomplete data of distribution by outlining or shading (Voous) the general area involved. Therefore they often exaggerate distribution (cf. Dybbro 1976: 26). The Palearctic bird distribution atlas initiated by Stresemann and Portenko (1960) connects the distal points of documented breeding localities but rarely shows disjunctions or gaps of the area. Yet there are large expanses of unsuitable habitat where the species cannot and does not live or has died out. Most such atlases use data from various past periods and do not show fluctuations of distribution. Yet these fluctuations may be substantial. In Denmark, for example, 42% of the breeding avifauna of a 110-year period had fluctuating borders; in Hungary, 19% in a 100 year period had fluctuating borders (Udvardy 1970).

The above show clearly that reliable, clear distributional knowledge can only be gained by concentrated effort over relatively large areas during a limited observation period (a few consecutive years) to be repeated at greater time intervals, e.g., several decades. The exploration of any country is haphazard and this applies to breeding bird distribution as well. Willing data collectors have to be organized—enthusiastic amateurs have to be led by scientists to spend their efforts wisely; this can best be achieved by using an uniformized geographic scheme, i.e., a grid.

The five years' project dealing with the breeding birds of Britain and Ireland (1968–1972) was the first such accurate project involving over 1500 regular and about 15,000 ad hoc observers covering 3862 grid units of 10 km square (Sharrock 1976). Subsequently France (Yeatman

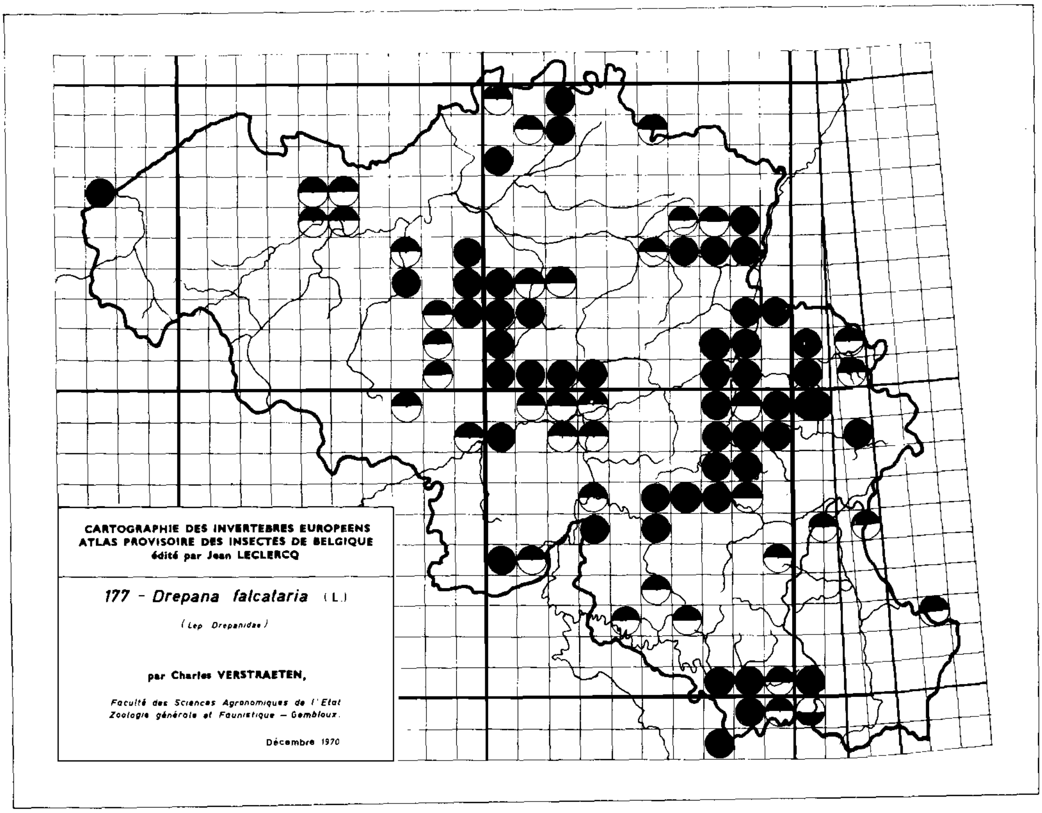

FIGURE 3. Distribution of the butterfly *Drepana falcataria* (L.) (Drepanidae, Lep.) in Belgium as shown by Ch. Verstraeten on the UTM grid map of Europe. Full dots are observations later than 1950, half-dots above are those before 1950, and half dots below are literature data or data from before 1940 where the author has not verified the material. Note that near the eastern border of the country the European grid changes zone to compensate for the earth's curvature. From Leclercq (1970).

1976), Denmark (Dybbro 1976; see Fig. 2), and the Netherlands (Texeira 1980) published, Belgium, Czechoslovakia, Estonia, Lettonia and Lithuania (Kumari in litt. 1980), Finland, Poland, Sweden, Switzerland, West Germany and others started their national breeding bird atlases (Pinowski and Williamson 1974, Pinowski et al. 1977). In the southern hemisphere, New Zealand has published a grid-based provisional atlas (Bull et al. 1978) but breeding occurrence records are still incomplete. This is an important example of the fact, emphasized already by Leclercq (1967), that no matter how spotty the data, they have to be brought together, for documentation of our state of knowledge at the time but chiefly because it spurs interest in further field collecting. The Australians are working in several parts of their large continent on atlas projects, four of which have been completed (van Tets in litt.). There are several atlas projects under way in Africa, notably in Ethiopia, Kenya, Malawi, Rwanda and Burundi, Somaliland, South African Republic, Tanzania, Uganda, and Zambia (Dowsett and Dowsett-Lemaire 1979, Dowsett 1979).

The botanists of Europe are working on their united plant distribution atlas. The European Invertebrate Survey (e.g., Heath 1970) notes all data previously collected or published as well, though for these different symbols are used on their maps. A typical example is provided by the atlas of Belgian insects (Leclercq 1970) using the UTM grid for that country (Fig. 3). The European Ornithological Atlas (Sharrock et al. 1977) is an undertaking planned and prepared for 1985–88. The UTM grid is to be used with 50 by 50 km squares, since some of the countries are large and have few observers.

The North American bird atlas projects were adequately summarized by Robbins (1977). He mentions nine states of the USA where atlases or mapped quantitative studies are in progress. Since that date several more have started there, and one in Canada. Owing to the use of the "imperial" system of land measurement, the metric grid has generally not been utilized. Consequently few of these are easily comparable with one another or with distribution atlases elsewhere. Two adjacent, smaller areas (counties), however, in the state of Maryland happen to be situated at the latitude of 39°N where the standard size of the U.S. detailed topographic map (scale 1:24,000) i.e., 8′45″ × 7′30″ almost is divisible into six 5 km squares. Here in these counties immediately adjacent to Washington, D.C. a 3-year "pilot project" was carried out and coordinated by Klimkiewicz and Solem (1978), in 60 plots of 10 km square and 136 plots of 5 km square each. So far this project is the only one somewhat comparable with the atlas works elsewhere on the km square basis. Unfortunately, due to the spheroid surface of the earth this method of obtaining 'atlas blocks' is not satisfactory at other latitudes. The 1:24,000 map sheet of Monterey, California, for example (at 36°30′N and 122°00′W) is divisible into six squares, each of the size: 5.61 × 5.3933 km, yielding blocks of 30.2566 km² rather than 25.0000 km² of the 5 km square blocks in the UTM system or the 5 km square ±0.3% as in the case of Montgomery and Howard counties of Maryland in the above mentioned study. To illustrate the discrepancies in using the latitude/longitude based grid system, consider that a 1°00′ distance of two meridians is:

100.93 km at 25°N—about the Florida Keys
85.37 km at 40°N—about Philadelphia, PA
78.82 km at 45°N—about Seattle, WA
47.16 km at 65°N—about Fairbanks, AK

—thus a grid based on one degree distance is more than twice as large at Fairbanks as at the Florida Keys.

BIRD ATLAS PROJECTS USED FOR POPULATION ESTIMATES

An atlas project generally is executed during three, five or more breeding seasons. Observers are assigned to squares, by the planning and supervisory personnel and cover their grid square several times in the field until sufficient coverage is reached. Difficult squares are covered during subsequent years, or new observers cover them again. In Europe criteria for breeding evidence have been agreed upon previously, following international rules. Upon completion of the field seasons, editing personnel scrutinize the data gathered on breeding occurrence.

Population estimates (or counts) can theoretically be obtained in several ways (Table 1). In the following, the categories of Table 1 will be illustrated by examples.

Categories 1a and 1b.—The Polish workers (1976–80, Bogucki 1977) estimated the numbers of breeding pairs of each species in 10 km squares in 5 categories: 1–10, 11–100, 101–1000, 1001–10,000, and over 10,000. Where the actual number of breeding pairs could be estimated, these were also to be recorded. These categories are very wide and inaccurate, but their decimal nature enabled Bogucki and other editing personnel to arrive at average frequencies for larger (50 or 100 km square) units by a simple mathematical formula. So far verification of the validity of these frequency values by comparison with actual censuses is wanting.

The Dutch atlas project (1973–77, Texeira 1980) started a purely qualitative effort, but for the last three years the field workers of the 5 km squares were asked to census the breeding pairs of territories of 50 selected species. This change in goal occurred upon the insistence of the Dutch nature conservation organizations which recognized the value of the atlas project in recognizing and estimating populations of species either themselves potential objects of conservation measures or indicators of threatened habitats. One finds on this list the eight big raptors, 17–18 wetland breeders, 15 songbirds, and some others. Estimated and actually counted pairs were noted by different symbols. The Dutch atlas/census years would also fit into category 2b of Table 1.

Category 1b.—The Danish atlas work (1971–74, Dybbro 1976) in 5 km squares lists the 20 commonest species arrived at in three different ways: species registered in most squares; those registered as sure breeders in most squares; and those 20 species whose registration as sure breeders is highest (percent) of all the squares where they occurred. A total of 30 species comprise the three lists, and, out of 189 breeding species the commonest were the Barn Swallow (*Hirundo rustica*), the House Sparrow (*Passer domesticus*) and the Starling (*Sturnus vulgaris*), followed by the Blackbird (*Turdus merula*) and the Great Tit (*Parus major*).

The Swedish atlas data (1974–83, Svensson 1977, 1979c) are planned to be, and partially already are, evaluated for frequency of occurence by the percentual value of the 5 km squares covering a larger area unit. Svensson's grid frequency map of the Icterine Warbler (*Hippolais icterina*) demonstrates well the usefulness of atlas maps in indicating density of dispersion and distributional limits (Fig. 4).

Bezzel and Utschick (1979), evaluating the German atlas projects, recommend that census would follow upon the atlas field work. As the Swedes, these authors also use grid frequency,

TABLE 1
POPULATION ESTIMATES BASED ON ATLAS PROJECTS

(1) Based on the actual data supplied by the atlas project	(1a)	By atlas contributors themselves: noting onto their field record cards their estimates of numbers breeding in their square
	(1b)	By the editing personnel: Summarized for larger area units which contain several squares
(2) Atlas field work supplementd by simultaneous census work done by the field workers	(2a)	Concerning very common species
	(2b)	Concerning species, usually uncommon, possessing characteristics of their breeding habits which make their censusing easy
	(2c)	Concerning very rare species
(3) Atlas project data are used by the editing personnel in combination with results of previous censuses		
(4) Atlas project followed by census work which is based on atlas results		

e.g., the percentage of squares occupied by one species compared with the total number of surveyed squares. Grid frequency is a value corresponding to the probability of finding a species on an area equal to the grid size: it is determined by the frequency of occurrence and the evenness of dispersion of the breeding pairs, which again is partly dependent on the nature of the habitat. They analyze the relation of grid size and grid frequency with some simple but elegant diagrams, and conclude that the more even the dispersion of the species and its habitat, the smaller is the optimum plot with 100% grid frequency value. Wink (1980) further analyzes the 1974–78 grid-mapping project (very small, 2.2 km squares on an area of 2.400 km^2) for population size estimates and fluctuational trends using the grid frequency concept. A pilot project of this size and intensity proved good for calculations of optimal grid size. Wink concludes that grid frequency values serve population size estimates especially in finding trends in subsequent years and other time periods. It is not usable for too common species (when grid frequency reaches 100, i.e., all squares contain the species, the map shows merely distribution). Likewise when grid frequency is too low, in rare species, such calculations are not feasible.

Category 2a.—The British Breeding Bird Survey, a long-range census project, preceded, paralleled and followed the 1968–72 atlas project years, and its results augmented those derived directly from the atlas data in yielding general estimates about the magnitude of each species' population on the British Isles (Sharrock 1976). *Category 2c.*—Counting of single, rare or endangered species in the grid squares was carried out also by the Danes and Swedes. Both these projects, as can be seen from the Danish atlas and the preliminary Swedish work, seem to have estimates of adequate accuracy of populations of larger raptors, i.e., *Accipiter gentilis* and *Buteo buteo,* over areas as large as Denmark (little less than 44,000 km^2) and Sweden (about 450,000 km^2).

Category 3.—All three major atlases published in the 1970s (the British, French and Danish) gave a population estimate of most breeding species and these were based on a combination of grid frequencies, estimates or accurate counts performed by atlas field workers, and censuses executed previously by various agencies or groups regarding certain single species. All atlases emphasize that such estimates are rough at best, and serve as indicators of the magnitude of population size, to be followed by more accurate censuses.

Category 4.—Grid frequencies, complete atlases or incompletely censused grids all act in stimulating follow-up field work in the form of censuses etc. Because even the oldest published atlases are fairly recent they do not yet provide data for evaluation.

DISCUSSION

How does atlas work serve quantitative population ecological studies? Answers fit into the following objective framework:

Autecology

Population Data Study (statics):

(1) Total population of a species over its whole distribution area (range).
(2) Total population of a species within a certain geographic area (continent, island, mountain chain, country, state, province, etc.).

Study of Population Changes (dynamics)

(3) Trends of population increase/decrease/stability of a species, throughout its distribution area.

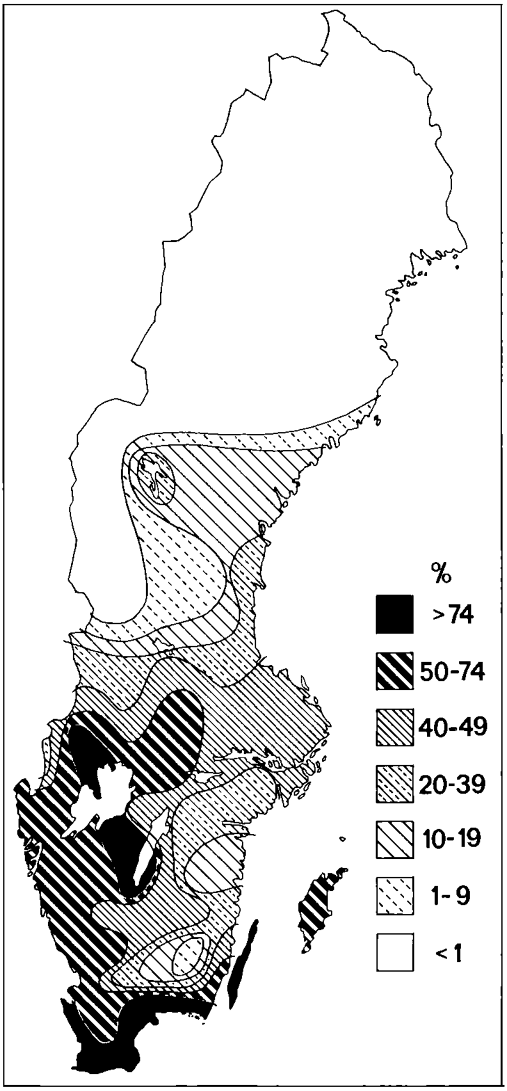

FIGURE 4. Grid Frequency classes of the Icterine Warbler based on the 1974–78 data of the Swedish breeding bird atlas project. The percent values indicate percentual occurrence in the 5 km square blocks of larger area units. From Svensson (1979).

(4) Local trends of the dynamics of species populations.

Synecology (Comparative population dynamics from the point of view of)

(5) The total breeding bird population of a geographic area.

(6) The numerical relations of "bird communities," "guild," etc. within certain habitat types and ecosystems.

The most accurate estimates come from census works based on area units. Censusing any larger area (conforming to points (1) and (5) above) necessitates the use of smaller samples and project their results, proportionately, to larger areas. In a summarizing paper, Merikallio (1961) applied this method first to bird population estimates of large areas, in his case, the total bird population of species nesting in Finland.

The only efforts made to count or estimate the total (world) population of species, objectives (1) and (2), concern dwindling, rare populations of endangered species on the brink of extinction; these usually are populations ranging from less than 100 to some 10,000's of breeding pairs. Game birds (galliforms and anseriforms) are censused mainly for managemental purposes, by indirect methods, and not necessarily over their total area but usually over the area of managemental responsibility.

For population ecological as well as conservational reasons (widespread agreement is found in the atlas literature here reviewed about the role of birds as biological indicators) the early clarification of objective (1) is a "must." Whereas the primary task is achieved by censuses, the subject of this symposium, the geographic aspect can only be achieved by accurate distribution mapping of *species* and habitat. I would suggest that the combined goal of *all* census and atlas projects should be to clarify by the year 2000: What is a common, uncommon, scarce, or rare passerine, or nonpasserine bird?

In objective (3) the atlas initiatives and their theoretical foundations, as we have narrated above, would enable the ornithologist of the area to read population dynamical trends from the grid frequency data of subsequent time periods: direct estimates by the field workers serve the same end and since these mainly include conspicuous and large, therefore often endangered species, the goals of the ornithologist-scientist and of the ornithologist-conservationist often coincide and enhance one another. The same applies to objective (4), local trends.

Objectives (5) and (6) suggest the same problems as the previously treated ones, but in a synthetic way. Area-based censuses preferably preceded by area mapping and habitat mapping are the answer. In this respect again, the goals of the avian scientist and of the "environmentalist" coincide. A good example might be the California subspecies of the Yellow-billed Cuckoo (*Coccyzus americanus*). By 1972 it was apparent that this bird was rare (Leach et al. 1974). It has been studied, together with other rare species (Gaines 1977) and these studies show that the total habitat needs to be studied (R. E. Warner unpubl. MS).

In North America the U.S. Geological Survey recently issued a series of large-scale (1:250,000) special maps which show "land use and land cover." Thirty-seven types of land use/cover are superimposed on a 10 km square UTM grid, and on the network of water, roads, boundaries and villages or towns. These maps could provide the common and uniform basis of coast-to-coast census and atlas work of the breeding birds of North America. Avian biology, biogeography and ecology as well as local and global conservational goals would benefit from such cooperation.

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