CHAPTER

A Multiscale, Stepwise Approximation Approach for Wildlife Conservation Assessment and Planning

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Comprehensive wildlife conservation will be more effective if it incorporates a large area perspective. Different species may have affinities for various ecosystem types, seral stages, and habitat elements at different scales, so conservation planning must consider diverse ecosystems and habitat conditions from a broad-scale perspective (Askins et al. 2007). A planning area must be sufficiently large to accommodate populations of the most wide-ranging species, maintain habitat for area-sensitive species, and provide interspersed habitat types for species that require them. Diverse ownership types and multiple natural resource objectives add to the complexity of wildlife conservation. Therefore, a major challenge for ecologists, resource managers, and policy makers is to develop comprehensive natural resource assessments that integrate current scientific knowledge of the requirements of multiple species. Here, we apply principles of landscape ecology to provide a context for landscape-level wildlife conservation planning and implementation. We begin by discussing limitations of models too specific for general application elsewhere, and review some literature on landscape ecology concepts that could be applied as a general framework for a variety of landscape-level modeling approaches. A broad-scale context is used to help set wildlife goals and objectives for landscape-level planning before choosing modeling objectives, methods, and evaluation criteria. We offer three examples of applying the concepts of multiple scales, stepwise levels of detail, or spatiotemporal heterogeneity in species' occurrences to help set or achieve conservation objectives at successively narrower scales.

There is growing acceptance of the importance of large spatial scales and multiscale interrelationships (i.e., macroecology) in ecology (e.g., May 1994, Brown 1995, Maurer 1999). Ecological systems exhibit domains of scale with hierarchical relationships that vary among levels of the hierarchy of scale (O'Neill et al. 1986), making it difficult to apply models across scales. Ecological heterogeneity within landscapes also makes it difficult to apply locally derived models at higher levels (Pickett and Cadenasso 1995). Many ecological phenomena are mediated by higher level processes (Urban et al. 1987, Wiens 1989), and one cannot predict broad-scale population dynamics by merely scaling up relationships known at finer scales (Bissonette 1997). Therefore, models developed at local scales may not be relevant at broader scales.

Another obstacle to comprehensive integrated assessment is that available information is typically narrow in scope and not uniform among species. Thus, there is an inadequate scientific basis to extrapolate narrowly focused survey and research results to other species, or spatial and temporal scales, geographic areas, or species (Johnson and Herring 1999, Swanson and Greene 1999). For example, even simple species occurrence models frequently fail to accurately predict presence and absence (e.g., Raphael and Marcot 1986), and these shortcomings are usually attributed to inadequate model development, refinement, interpretation, or application (Block et al. 1994, Morrison 2001). However, the problem is often that the models were applied at inappropriate scales or because species habitat associations (Collins 1983, Grzybowski et al. 1996) and ecosystems (Johnson and Herring 1999) are variable in space and time.

Researchers frequently sacrifice generality for precision when choosing to do high-resolution, local-scale research on a narrow, focused problem of limited geographical scope (e.g., May 1994, Brown 1995, Swanson and Greene 1999). Many high-resolution models have limited ability to make predictions for other times and places (e.g., Wiens et al. 1987, Van Horne and Wiens 1991, Levin 1992, Oreskes et al. 1994). The lack of appreciation of temporal variation in populations has been perpetuated because so few studies have been conducted for long time periods (Wiens 1981, Donner 2007). Combining highly detailed, single-species models to predict the cumulative effects of ecosystem change on multiple species becomes impossible because the models are usually parameterized with different variables measured at different spatial and temporal scales. Also, models are developed with varying degrees of rigor, so comparable models are rarely available for all species under consideration for landscape-level planning. Attempts to apply multispecies models are made difficult by several factors: (1) a model designed to optimize predictions from a given data set may lack useful generality; (2) integrating different model forms and data requirements of different species is difficult; (3) many models implicitly assume habitats support populations at carrying capacity, but populations of uncommon species are rarely at carrying capacity; and (4) most species distributions, associations, and biological processes are classified into categories, yet many ecological relationships are best represented by gradients (McGarigal and Cushman 2005).

Many wildlife models are correlative rather than mechanistic (Bissonette 1997), but some have argued that effort should be invested in developing mechanistic models instead (Morrison 2001, Wiens 2002). However, the mechanisms relating multiscale landscape patterns to wildlife ecology processes are not well known (but see Hansen et al. 1993, Thompson et al. 1993, White et al. 1997, Smallwood et al. 1998, Cogan 2002, Cushman et al. 2007), so it would be desirable to frame correlative models in a context of regional distribution or population variability to first separate regional from landscape-habitat effects. The clear majority of “multiscale” studies are actually done at only two scales (Wiens 2002), typically landscape and local or regional and local. Thus, what is needed to provide context for variable patterns in time and space is a series of general to specific models (Van Horne 2002) or a hierarchy of less detailed, or even qualitative models to organize thinking about processes (Rubin 1991). A related solution to these problems is to develop less detailed but more robust models for larger scales (e.g., presence-absence at habitat or landscape scales), and then develop subsequent nested models for smaller areas with more detail (i.e., abundance, productivity, survivorship). Such models can be framed within a hierarchy of general models that lead to an understanding of ecological processes (James and McCulloch 2002, Stauffer 2002, Van Horne 2002). Although coarser-resolution work is typically done at larger geographic scales, it is important to realize that levels of detail are not the same as a hierarchy of spatial scales.

Applying habitat models developed in one landscape to another landscape may be difficult when there is variability in ecosystem composition among landscapes, or when responses of various species to landscape composition and structure vary geographically. Generalizing habitat association models to other species, places, or times than those for which they were developed can be inappropriate because (1) species are distributed unevenly because there is considerable geographic variability in landscapes, ecosystems, biological community composition, and biophysical processes; (2) every species has unique niche and life history characteristics and species may perceive the “grain” of landscape patterns differently; (3) populations vary in time and space, so the assumption that there is always a useful and robust mathematical relationship between habitat and landscape conditions is often not realized; and (4) hierarchical relationships exist among species, ecosystems, and ecological processes. Clearly, ignoring these constraints when applying models violates some basic principles of ecology. If resources are unevenly distributed across gradients in time and space, and there is variation in species distributions and biophysical processes, then it is desirable to establish a multiscale strategy to describe the geographic variability of species’ ecological attributes. We demonstrate how explicitly embracing the concept of hierarchies of scale (e.g., Root and Schneider 1995) and levels of resolution (e.g., Menges and Gordon 1996) allows practitioners to assess conservation issues by a process of stepwise approximation.

STEPWISE APPROXIMATION STRATEGY

We propose a multiple-level, stepwise strategy that links coarse and fine resolution information to balance the need for generality and specificity for integrated wildlife conservation assessments. By this strategy, local-scale, high-resolution research is interpreted within the context of larger scale, multispecies distribution patterns. The framework can be implemented using existing information and databases, producing time and cost savings, while guiding future research hypotheses and data collection to the most appropriate species and locations.

The key to considering all species while still directing more attention to the most critical issues is to take a general-to-specific perspective on population processes and wildlife habitat relationships. This is best done in a stepwise manner, proceeding from coarse to finer levels of detail (Freemark et al. 1993). We are not recommending a specific protocol for assessing species population dynamics, nor is there a rigid number of steps to an assessment, as each situation will have its own set of relevant scales (Wiens 1989). Nevertheless, we provide a hierarchical strategy for assessing population dynamics by describing seven discretionary levels of analytical resolution for inferring process from pattern based on literature synthesis and empirical data. The analytical levels for conducting a comprehensive population assessment at increasingly finer levels of detail are as follows: (1) delineate the ranges of all species of interest and their range overlaps to identify dissimilar distributions; (2) define or hypothesize species-habitat associations using gradients whenever possible; (3) test these habitat-gradient relationships with species occurrence surveys; (4) evaluate habitat quality by using abundance estimates and its temporal variation in abundance; (5) refine the habitat quality assessment by using indirect productivity inferences or direct productivity measurements, and/or estimate survivorship; (6) synthesize (levels 1–5) using maps and summary models to assess species viability, allowable harvest, conservation plans, or implications of changing conditions; and (7) test the synthesis and its extrapolation to other contexts in space and time through a well-designed strategic monitoring program. Not all levels of this strategy must be used in every conservation assessment, but each level adds understanding to the assessment process because ecological dynamics at each level are better understood when they are related to others (e.g., Urban et al. 1987, Pickett and Cadenasso 1995). Several of the levels can be developed simultaneously as long as generality is not prematurely sacrificed for local, fine-resolution precision. Additionally, adding sequential levels of detail is pragmatic when problem solving because it becomes an application of the scientific Principle of Parsimony (i.e., using the simplest explanations for observed patterns). The steps chosen for this chapter are best suited for wildlife conservation planning and implementation at the landscape level, but we argue that any broad context in space and time can be valuable for most wildlife and natural resource models and planning efforts.

To demonstrate how elements of any stepwise approximation process can be modified, adapted, and reduced for individual situations, we provide three examples of ongoing assessments: (1) a multispecies assessment conducted at multiple scales for prioritizing species for conservation action (Level 1); (2) a multispecies assessment that uses several levels of detail to estimate species' responses to openland management (Levels 1–5); and (3) a single-species range-wide assessment summary model (Level 6) that infers process from pattern using five levels of detail. These examples draw on different avian population studies within and among levels to demonstrate how unconnected research conducted at various scales can be linked within this stepwise framework.

Level of Resolution 1: Broad-Scale Multispecies Ranges

Understanding variability in population distribution among geographic areas and habitats is important when attempting to generalize data from one locality to another. The first prerequisite for aggregating distribution patterns of multiple species is knowledge of species occurrence at several scales to prevent local-scale research on population dynamics from being generalized to places where a species does not occur in its typical habitat. At continental scales, range-wide maps of species distributions are available in field guides or other reviews. Because the geographical extent and sampling intensity of surveys varies by taxa, using general geographic information provides some preliminary comparability among taxa by excluding some distribution details that are important only at finer scales. Large-scale, comprehensive distribution data are available for taxa such as birds (e.g., Price et al. 1995), fish, and trees. Atlases and other comprehensive distribution data are being assembled for other vertebrates, plants, and invertebrates (Johnson and Sargeant 2002).

Because only the most common species are found in all places within their range and suitable habitats (e.g., data in Brewer et al. 1991, Corace 2007), a tabulation of known species presence by regional landforms, ecosystems, cover types (e.g., forest, shrubland, grassland), or disturbance history is an important step in any broad assessment of species conservation status (e.g., Probst and Thompson 1996). At Level 1, species distributions are developed to a degree that might allow them to be matched to land covers from remote sensing and species distribution maps (e.g., Jennings 2000) without supplementary field observation or knowledge of habitat gradients within land cover types. At scales intermediate between regional and local, patterns of presence and absence within a species' geographical range is apparent, and some species may be absent where other species with the same or similar habitat preferences might be present. For example, upland sandpiper (*Bartramia longicauda*) is infrequent in southeast Michigan openlands, whereas grasshopper sparrow (*Ammodramus savannarum*) is not found in a majority of the counties in Michigan's Upper Peninsula (Fig. 7-1). These differences may be due to range limits, landscape structure, or more specific habitat preferences than just "openland" or "grassland" (see Level 2).

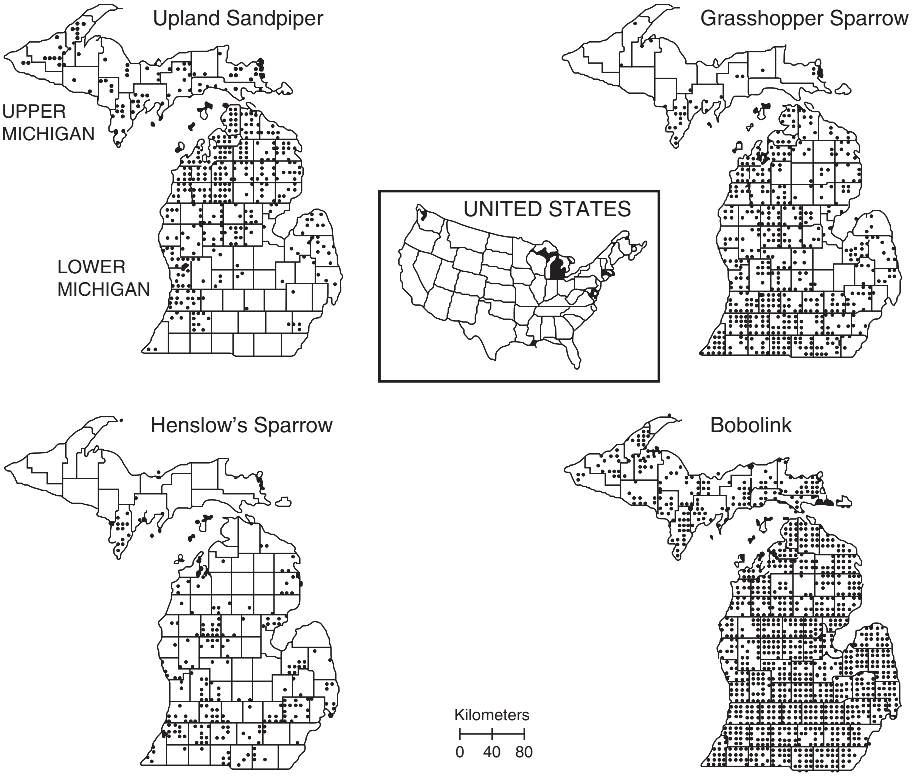
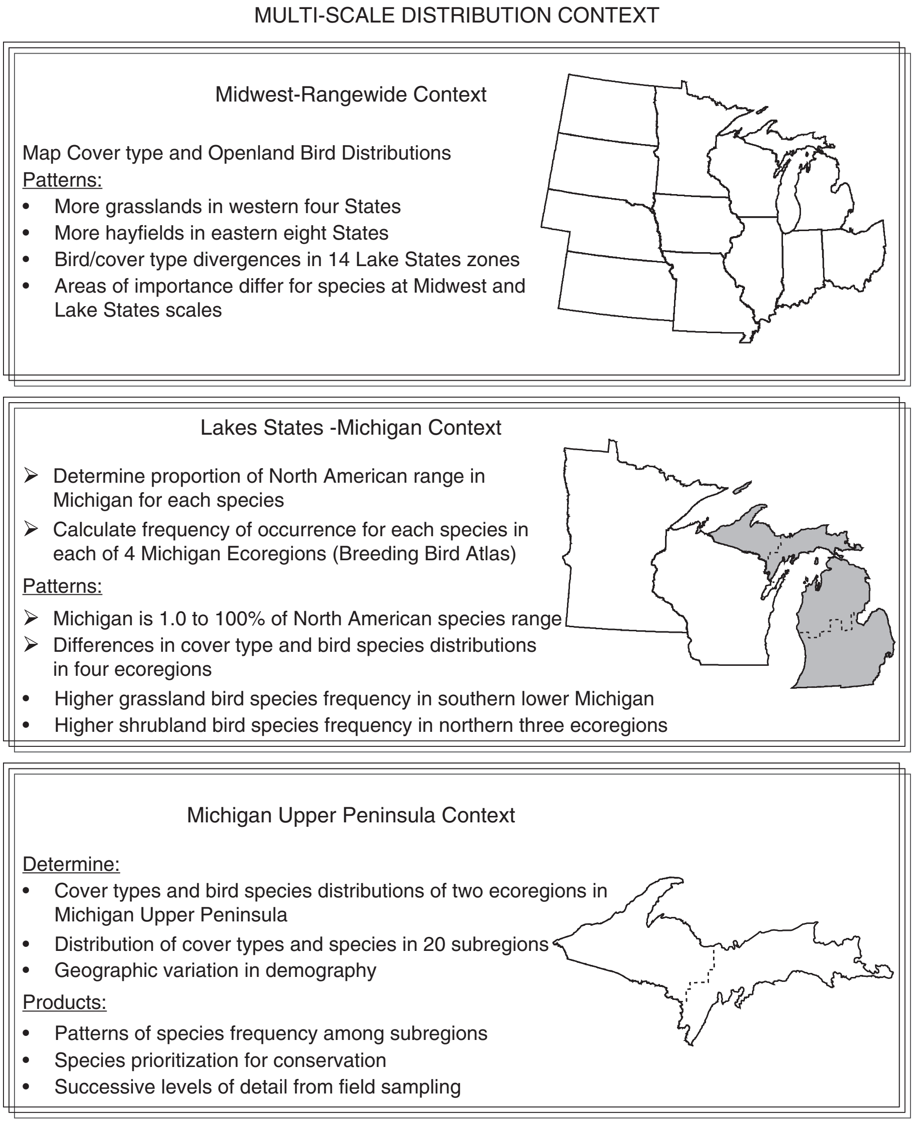


FIG. 7-1

Breeding Bird Atlas distribution of four species of openland birds in Michigan, USA (adapted from Brewer et al. 1991).

Multiscale Bird Distribution Assessment

As an example, we present a conceptual overview of a multiscale assessment of openland cover type and bird species distribution. The assessment is being developed to summarize species distributions at both regional and subregional (1,000–5,000 km^2) political and ecological scales to prioritize species for conservation efforts, and to allocate resources for land acquisition, preservation, restoration, management, mitigation, and easements (Corace 2007). At the Midwestern United States scale (Fig. 7-2), we see a disproportionately large area of grassland cover type in the four most western Midwestern states, and a disproportionately large area of hayfields in Kansas, Missouri, and the three Great Lakes States (Minnesota, Wisconsin, and Michigan). The areas in each cover



MULTI-SCALE DISTRIBUTION CONTEXT

Midwest-Rangewide Context

Map Cover type and Openland Bird Distributions

Patterns:

- More grasslands in western four States
- More hayfields in eastern eight States
- Bird/cover type divergences in 14 Lake States zones
- Areas of importance differ for species at Midwest and Lake States scales

Lakes States -Michigan Context

- ➢ Determine proportion of North American range in Michigan for each species
- ➢ Calculate frequency of occurrence for each species in each of 4 Michigan Ecoregions (Breeding Bird Atlas)

Patterns:

- ➢ Michigan is 1.0 to 100% of North American species range
- ➢ Differences in cover type and bird species distributions in four ecoregions
- Higher grassland bird species frequency in southern lower Michigan
- Higher shrubland bird species frequency in northern three ecoregions

Michigan Upper Peninsula Context

Determine:

- Cover types and bird species distributions of two ecoregions in Michigan Upper Peninsula
- Distribution of cover types and species in 20 subregions
- Geographic variation in demography

Products:

- Patterns of species frequency among subregions
- Species prioritization for conservation
- Successive levels of detail from field sampling

FIG. 7-2

A multiscale assessment of cover types and bird species distributions for species prioritization of conservation actions in the Midwestern USA.

type by state and ranked bird cover-type affinities were combined to produce a score for each species in each state. Bird species distribution centroids differ on east-west and north-south axes, and further divergences in cover type and bird species distribution are apparent within the Great Lakes States. These patterns guide initial conservation actions at the state and ecoregion scales within states by developing an initial land cover assessment for each species.

At the Michigan scale, the proportion of the North American range for each species in Michigan was calculated, and the frequency of occurrence of each species in each of four ecoregions in Michigan was tabulated from the Michigan Breeding Bird Atlas (Brewer et al. 1991). In general, grassland bird species were more frequent in southern Michigan and shrubland birds were more frequent in the three northern ecoregions of the state (Corace 2007). However, there were some exceptions that should affect conservation planning in each ecoregion that leads to considerations of grassland maintenance in the Upper Peninsula and management of shrublands in southern Michigan.

At the Michigan Upper Peninsula scale, conservation priority species were identified as (a) those whose proportion of North American range occurring in the Upper Peninsula is above the median (3.6%) for all Michigan species, or (b) species with higher Upper Peninsula breeding-bird atlas block frequency than in Michigan's Southern Peninsula. At this scale, not all species were found in all 20 subregions within the two Michigan Upper Peninsula ecoregions. Species were further prioritized by their breeding bird atlas block frequency by subregion, further refining the geographic specificity of prioritization. Finally, extrapolation errors were illustrated from presence-absence data by calculating the percent area of suitable cover type for a species where it was not found by the breeding-bird atlas, relative to the Upper Peninsula total area for that cover type. Although it is important to acknowledge that "cover types" may not accurately define suitable habitat for a given species, quantification of presence-absence patterns helps estimate errors when relating cover type areas to more detailed demographic attributes at subsequent levels of resolution (see following description). This simple example illustrates how conservation priorities can be identified without detailed population estimates, and the potential difficulties trying to estimate cumulative population sizes resulting from conservation actions.

At all scales, we find that important locations (as indicated by distribution and abundance) are different for each species, and all areas may be important for at least some species. The mix of cover types and bird species varies geographically, so the notion of a "suite of species" for conservation objectives has limited utility. In summary, the broad-scale patterns provide a context for species prioritization and generalization of field measurements, and the finer scales provide detail necessary to interpret the coarser scales. The broad-scale patterns can be used for modifying Partners in Flight prioritization and species rankings, and are being used for state-level landscape planning for Michigan Important Bird Areas. The context of spatial scales and distribution described here can also inform a stepwise approximation process that moves from less-detailed to more-detailed field measurements of bird species demographic parameters to identify specific conservation needs.

Level of Resolution 2: Refine Species Distributions in Terms of Habitat-Gradient Relationships

The next level in the strategy is to refine species distributions at finer scales of species-gradient relationships. At regional or multistate scales, the habitat distribution of vertebrates is available based on field guides, expert opinions, and limited inventories. However, there are questions and biases associated with application of expert opinion to distribution data (e.g., Johnson and Gillingham 2004), as discussed later in Level 3. Typically, species are grouped into habitat categories, vegetation associations or communities, physiographic units, or ecological units for research synthesis, assessment, and planning within the context of coarse filter biodiversity programs (e.g., Pregitzer et al. 2001). Additionally, we can combine information on species' geographic range and habitat affinities to describe geographic variability in continental or regional habitat distributions (e.g., Probst and Thompson 1996). However, individual species respond differently to environmental gradients or changes, so a community association of one species may be a poor predictor of other species distributions (e.g., Graham 1994; Noon et al., this volume). Further, some taxa are too poorly surveyed to reliably place them in either communities or gradients. Although the continuum concept of species (Gleason 1926, Curtis 1959) is basic to general ecology, it is often ignored in conservation plans that use community surrogacy, multispecies taxa, umbrella species (Simberloff 1997), or biophysical units as substitutes for a comprehensive enumeration of the species for which information is currently available.

Classifying species in terms of their response to gradients is a useful classification framework because gradients can accommodate changing species distributions and helps to integrate a variety of new or existing classification systems. Conversely, more arbitrary categorical classification systems can be an impediment to data integration, extrapolation of trends, or cross-agency assessment. For example, species distributions may be arranged on two or more ecological gradients rather than using arbitrary species associations or biological communities, such as habitat types or seral stages (e.g., Fig. 7-3). Gradients are important for understanding limits or boundary conditions (nested within Level 1) and provide context for more-detailed categorical comparisons or models (Van Horne 2002, Probst and DonnerWright 2003), which may be limited to only a part of the total range of potential suitable conditions.

Classification frameworks are an important part of assembling and interpreting distribution data for assessment. Classifying species based on ecological gradients allows scientists to predict changes in species distributions and ecosystem associations as a consequence of changes in the gradient factor(s). Furthermore, the gradient concept allows the formulation of varying management actions across the range of ecosystem conditions. It also allows one to make predictions about habitat suitability within ecosystems that have not been adequately surveyed, and surveys can be designed to test the predictions (Level 7).

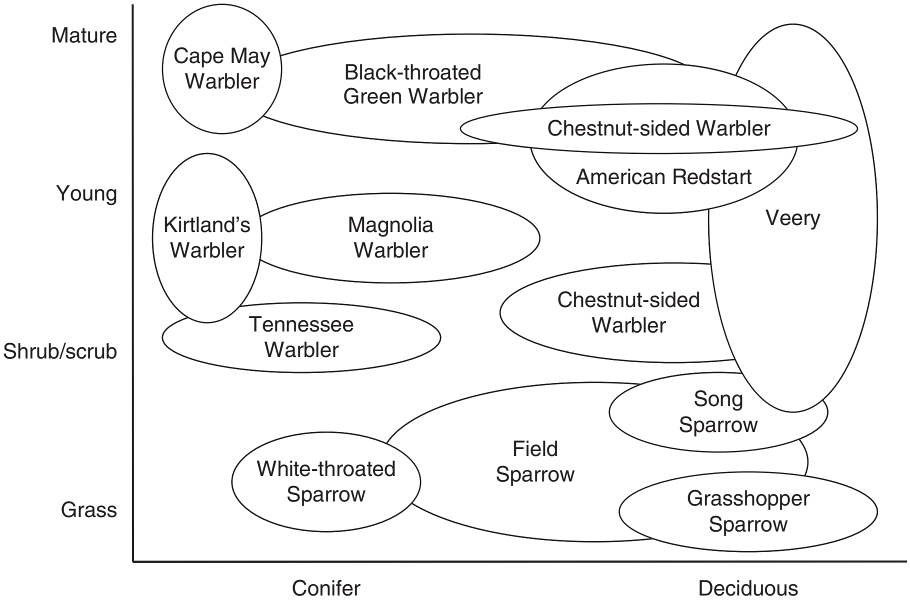


FIG. 7-3

Hypothetical ordination of avian habitat distribution on gradients of seral stage and tree life-form.

The simplest models are usually the best and most robust, and are the most useful to managers (Starfield 1997; Stauffer 2002; Shifley et al., this volume). A direct gradient approach (e.g., Whittaker 1956, Herkert 1991) to conservation biology has far more ability to interpret the effect of disturbances, biological cycles, or directional change than do relationships with indirect multivariate axes. The cumulative effects of global change or management on ecological processes are also more readily assessed by gradients than by arbitrary classification boundaries.

Level of Resolution 3: Test Species Habitat or Gradient Relationships Across Landscapes

Collecting frequency data on species occurrence is less labor intensive than taking measurements of density, biomass, and most demographic variables (Levels 4/5), so survey and monitoring can be planned and conducted in a stepwise manner to infer process from pattern and test hypotheses (Freemark et al. 1993). For example, surveys can be developed to test existing databases as part of stepwise approximation for confirmation of habitat gradient relationships of various species. Species habitat relationships and their spatio-temporal variation can be tested at low resolution (and low expense) by surveys for presence and absence. These surveys may show surprising departures from published field guides, expert opinion, or habitat models (e.g., Avery and van Riper 1990, Short and Hestback 1995) because presence-absence studies further refine our knowledge of species-habitat relationships. Species can be found where not predicted (omission error), absent from where predicted (commission error), or where variable in the same place through time (Raphael and Marcot 1986, Timothy and Stauffer 1991, Block et al. 1994). These surveys have been interpreted without reference to carrying capacity dynamics through time (e.g., Boone and Krohn 2000, Karl et al. 2000), and consequently, unreliable species-habitat model performance might actually be a reflection of populations too small to colonize all apparently suitable habitat (e.g., Donner 2007). Simply extrapolating habitat preference of a species (Levels 2/3) to the area of that habitat on maps can lead to serious population overestimates because most species are not found everywhere within preferred land covers or habitats (e.g., Raphael and Marcot 1986, Smith and Jenks 2002). For example, only 2 of 10 bird species most common in mature oak forests were found in more than 90% of the census plots in a study conducted in oak forests in central Pennsylvania (Probst 1979).

We can infer the dynamics of population processes and their underlying mechanisms when we conduct comparative surveys for presence-absence data in different geographic areas. Initial survey results can help direct subsequent surveys to illuminate the factors that may determine the population distribution. For example, species may have scattered distributions at range borders (Brown 1984) or in rare habitats that can be better understood by studying occurrence patterns in central versus peripheral areas of species' ranges. Species may also have disjunct populations because of area, isolation, or edge effects; so targeted surveys can be designed to document geographic variability in degrees of habitat occupancy and their change through time. Putative favorable landscape conditions can be tested for having higher frequency of occurrence than less favorable ones. Thus, frequency of habitat occupancy may be a useful coarse-resolution variable for evaluating the direction of population trends or geographic variability in populations and habitat preferences.

If planners and scientists have reasonably adequate data through Level 3, they may have enough information to proceed with an iterative planning process without incurring the time and expense of collecting additional field data. The spatial patterns identified by integrating available information may suggest some additional data collection needs, but the need may be for fewer species and locations than would be done in a comprehensive synthesis.

Level of Resolution 4: Evaluate Habitat Quality Through Abundance Estimates and Temporal Change

The next level of resolution considers population size and population variability in different ecosystems through time to make inferences about population dynamics. The focus at this level may be a subset of species and issues of concern identified at Levels 2 and 3. Abundance estimates may be added to presence-absence surveys if resources permit, and abundance data can be ranked to mitigate biases in sampling methods or species detection differences (Smith and Jenks 2002).

Temporal changes in frequency estimates can be used to make preliminary inferences about population dynamics across a species range. We can interpret the direction of population trends based on whether populations have expanded or retracted geographically. For example, variability in geographic distribution and local presence-absence data has been used to infer processes affecting bird population trends, such as sources and sinks (Howe et al. 1991, Probst and Weinrich 1993). Regional and landscape population changes first appear in sink populations, which tend to exhibit more variable dynamics (e.g., Boulinier et al. 1998). This means that degrees of habitat occupancy (i.e., frequency in a land cover or habitat) can be used to understand basic population dynamics and be applied to estimate a realistic carrying capacity for conservation planning purposes. Comparing population variability within breeding seasons (Zimmerman 1982, Lanyon and Thompson 1986, Probst 1988, Howe et al. 1991) or among years (e.g., Probst and Weinrich 1993, Probst et al. 2003) can also provide insight into metapopulation dynamics in relation to habitat quality and its regional population context. Low population variability in a habitat or landscape may imply that an area is a source, whereas annual fluctuations may be seen in overflow sinks. Consequently, monitoring programs (Level 7) could emphasize population variability such as source-sink comparisons, as one example, rather than tracking only relatively stable sources.

Completing data integration and field work through Level 4 for selected species and locations is a potential stopping point. The productivity and survivorship studies of Level 5 are very labor intensive and thus expensive and time consuming, and may not always be necessary.

Level of Resolution 5: Refine Habitat-Quality Evaluations with Productivity and Survivorship Estimates

Inferences about habitat quality and population dynamics developed from distribution patterns usually must be tested using data on other demographic factors such as productivity. Patterns detected from occurrence and abundance surveys can be used to suggest populations that may need research on reproduction or survivorship. Studies can then be initiated to refine habitat quality evaluations for the subset of species and locations identified as problematic by the surveys. Many demographic variables can be approximated for larger areas and smaller sample sizes before doing more standard, fine-resolution studies, such as reproductive studies. These productivity studies can be designed at intermediate resolution to provide indirect productivity measures across a range of species and locations. For example, relative natality can be estimated across space and time from reproductive condition, percentage of adults, the proportion of adults mated or paired (e.g., Verner 1964, Probst and Hayes 1987, Gibbs and Faaborg 1990, Villard et al. 1993), and the proportion of immature individuals to adults during the post-breeding period (e.g., Howe et al. 1991, Bollinger and Linder 1994, Bart et al. 1999). By conducting less intensive relative productivity studies of greater scope and geographical breadth, planners will have a better context for more detailed studies because they will have knowledge of geographic patterns in species' presence, density, and indirect productivity. Conversely, a nested hierarchy of resolution can be used to more reliably extrapolate detailed population dynamics data to a broader multiscale geographic context. Detailed productivity studies will be more effective and efficient if they are designed to test hypotheses developed during coarser-resolution surveys and indirect productivity studies.

Because not all individuals of many species attempt to breed, studies on productivity (Level 5) cannot be directly extrapolated to population density (Level 4), but can be initially approximated by the number of breeding pairs. In cases where productivity is measured directly, abundance is not necessarily well correlated with productivity (Pidgeon et al. 2003). In all situations, failure to understand the context of the varying geographical distribution and abundance developed at Levels 2–4 could lead to gross overestimates of populations and productivity. All field studies described here may be done sequentially in a single field season, so the levels of data need not be confounded by temporal variation across years.

Studies on survivorship are difficult and may take many years to complete, especially for motile organisms. It is often impossible to separate dispersal from mortality (e.g., Brewer and Harrison 1975, Greenwood and Harvey 1982), especially for migratory species (e.g., Probst 1986) or species with long dispersal distances. Often, an estimated survivorship can be calculated from productivity and total population change data (e.g., Probst and Hayes 1987) and tested directly at a more advantageous time.

Openland Bird Assessment Example (Levels 1–5)

This approach was applied to a hierarchical population assessment of openland birds in the Upper Midwest for multispecies, interregional conservation planning (Fig. 7-4). Researchers summarized where species or habitats were common, uncommon, or both, at three scales. At each level, a context was developed to facilitate interpretation at the next finer level of detail, and the number of species under consideration was narrowed based on the patterns observed (e.g., species rarity or distribution of habitats used).

Bird species occurrence and openland area (shrub-grasslands, hayfields, etc.) were compared at three spatial scales: 12 Midwestern states, 3 Upper Great Lakes states (Michigan, Wisconsin, and Minnesota) and 14 subregions (40,000–50,000 ha) (Level 1). Results confirmed that species' distributions and large-scale abundance patterns differed geographically, suggesting that many species-habitat models could not be transferred reliably to ecoregions with different habitat

STEPWISE CONSERVATION ASSESSMENT: OPENLAND BIRDS[A]

Upper Midwest (Level 1): Document species' ranges (4 X 10^6 km^2)

- ➢ Michigan (Level 1): Record frequency distribution using 10.4 km^2 breeding bird atlas blocks (37 species)
  - ➢ Northern Lower Michigan Barrens[B] (Level 3): Record frequency distribution at landscape scale using road point count transect (20,000 km^2) (20 species)
    - ➢ Landscape Scale (Level 4): Determine abundance in 1-4 year clear-cuts by walking transects through landscapes (1000 km^2) (12 species)
      - ▪ Landscape-local (Level 5): Determine number of pairs present (9 species)
      - ▪ Landscape-local (Level 5): Determine pair productivity by finding fledged young (6 species)

Result: Broad distribution context of most openland birds established for regional population assessment. Documentation of abundance and status of selected species, and further refined by productivity estimates at the landscape-local level.

[A] Grass-shrubland birds

[B] Xeric shrublands and clearcuts

FIG. 7-4

A framework for stepwise population assessment of openland birds in the Upper Great Lakes States, USA. At finer scales level, a successively smaller pool of species is examined at more detailed levels of resolution based on information available at the previous levels.

relationships or population levels. The 4 Northern Great Plains states contained most of the openlands and grasslands in particular. The 893,000 km^2 of open lands in the Great Lakes states represented only 16% of the openlands in the 12 states context, but represented 25% of the hayfield habitat, and included the majority of the total range for some bird species of population concern

(Crow et al. 2006, Corace 2007). Published landscape-level abundance information (Price et al. 1995) at the mid-scale 3-states level was used to identify zones of species presence and absence. At the scale of one state (approximately 250,000 km^2), existing frequency data were tabulated from a Breeding Bird Atlas (Brewer et al. 1991) for all openland types (Corace 2007) and within barrens and shrublands only (Fig. 7-4).

The assessment documented which species occur within subdivisions of their geographic range with Breeding Bird Atlases (e.g., Fig. 7-1), but focused on just two habitat-types (barrens and xeric shrublands) within an age-gradient in a single ecosystem (Level 2) to document multiple bird species' use of young, jack pine (*Pinus banksiana*) regeneration. Field surveys documented landscape-level (1500–6000 ha) spatial variability in species-habitat relationships (Level 3). Not all species found in Levels 1 or 2 were found in the sampled habitats of landscapes, so the pool of species under consideration was reduced at each level. At the landscape level, it was possible to choose study sites where a species of interest, especially rare species, actually occurred, before conducting finer resolution investigations. In this example, we selected nine species of conservation interest, five of which were area-sensitive openland species. Thus, the landscape-local studies on abundance (Level 4) and reproduction (Level 5) could be generalized to larger-scale areas of habitat more reliably, because it was documented beforehand where species actually occur in respect to geography, hierarchical ecosystems, and habitat. Ultimately, we should achieve an understanding of multispecies response to openland management at the levels of frequency, abundance, and indirect productivity measurements. Such information has been incorporated into state-level planning such as Important Bird Areas and to document multispecies use of an ongoing endangered species management program for Kirtland's warblers (*Dendroica kirtlandii)*.

APPLICATIONS TO PLANNING

Level of Resolution 6: Synthesize Levels 1–5 with Maps and Summary Models

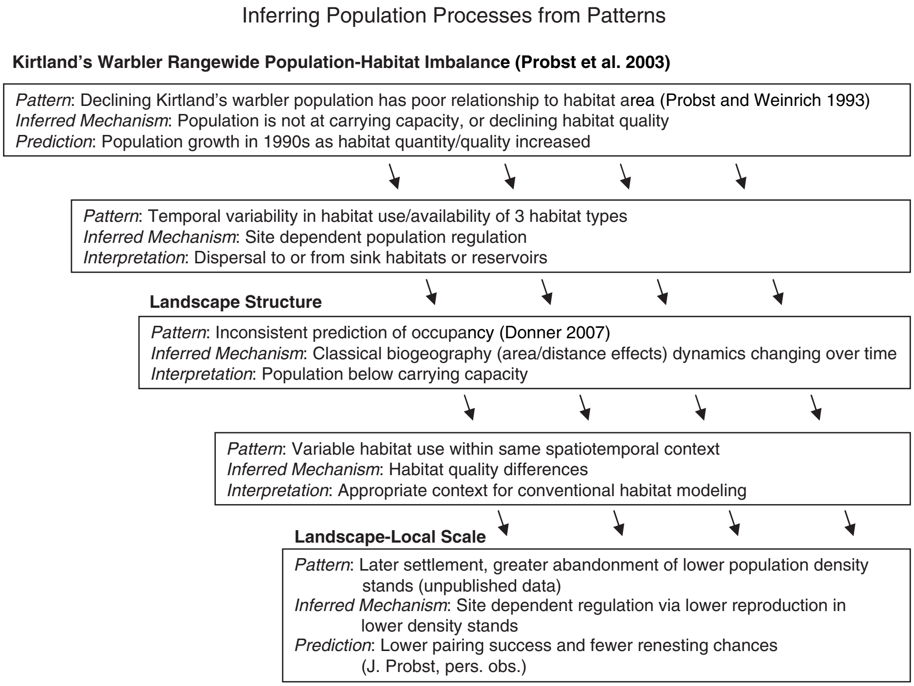
One major application of syntheses of population dynamics is in the development of conservation plans, including species viability assessments (e.g., Beissinger and Westphal 1998). Once ecological processes and their multiscale interactions are better understood, range-wide or other broad-scale assessments are more useful. Many times viability is inferred based on minimum population size needed to withstand demographic uncertainty, or to conserve genetic diversity (e.g., Shaffer and Samson 1985), but rarely is range-wide or even regional information considered. For example, an exhaustive habitat assessment for the northern goshawk (*Accipiter gentilis*; Reynolds et al. 1992) initially did not address the entire species' range, but a more comprehensive geographic scope has been added and is ongoing. Conversely, a range-wide study on black-capped vireo (*Vireo atricapillus*) showed regional differences in habitats and their relative use by different age classes of birds (Grzybowski et al. 1996), which is vital to understand how geographic differences may affect species viability throughout its range. Thus, habitat models using information from part of the species' range could not be transferred uncritically to other places in the range. In the initial northern spotted owl (*Strix occidentalis*) conservation plans, the single species assessment was followed by, rather than preceded by, the multispecies considerations in the Forest Ecosystem Management Assessment Team (Thomas 1994). Because the context for application was lacking in the initial single-species focus, the management plan for Pacific Northwest forests had to be modified.

Similarly, comprehensive assessments of neotropical migrant bird populations have proposed programs focused on subareas of species ranges, with planning conducted for subregional physiographic units (Williams and Pashley 2000). We advocate improving conservation planning by beginning with less-detailed, broader-scale steps at the level of many physiographic units (e.g., Probst and Thompson 1996; Fig. 7-2), before examining subregional or landscape issues. For example, assessment across the entire known range of Kirtland's Warbler has given practitioners a realistic framework of possibilities and limitations for the total habitat and population potential and its distribution in time and space. This understanding was generated by a general-to-specific examination of patterns (Fig. 7-5), where each level was constrained by the level before. In particular, Kirtland's Warbler cannot be expected to occupy habitat classes predictably when the context of the regional population and habitat area are so dynamic. The regional population may simply be insufficient to fill one or more habitat types. Thus, a temporal component is often necessary to evaluate the significance of current species population densities (Probst et al. 2003). Although the Kirtland's Warbler has a smaller range than that of many bird species, a stepwise approach can still be used for larger-scaled multispecies assessments (Fig. 7-2). A grassland plan for prairie grouse (Vodehnal and Haufler 2007) incorporates most of the ranges of four species and can interface with state-level planning for these species and others in or adjacent to the interregional planning area.

FUTURE DIRECTION

Level of Resolution 7: Testing Syntheses: Integrating Monitoring into Science

Traditionally, monitoring is conducted principally to document trends, while research is done to explain mechanisms determining the trends. In contrast, we propose that monitoring be used to test hypotheses so that the scientific method becomes an integral part of monitoring conservation strategies. From this perspective, monitoring is logically delayed within a stepwise approach



Inferring Population Processes from Patterns

Kirtland's Warbler Rangewide Population-Habitat Imbalance (Probst et al. 2003)

Pattern: Declining Kirtland's warbler population has poor relationship to habitat area (Probst and Weinrich 1993)
Inferred Mechanism: Population is not at carrying capacity, or declining habitat quality
Prediction: Population growth in 1990s as habitat quantity/quality increased

Pattern: Temporal variability in habitat use/availability of 3 habitat types
Inferred Mechanism: Site dependent population regulation
Interpretation: Dispersal to or from sink habitats or reservoirs

Landscape Structure

Pattern: Inconsistent prediction of occupancy (Donner 2007)
Inferred Mechanism: Classical biogeography (area/distance effects) dynamics changing over time
Interpretation: Population below carrying capacity

Pattern: Variable habitat use within same spatiotemporal context
Inferred Mechanism: Habitat quality differences
Interpretation: Appropriate context for conventional habitat modeling

Landscape-Local Scale

Pattern: Later settlement, greater abandonment of lower population density stands (unpublished data)
Inferred Mechanism: Site dependent regulation via lower reproduction in lower density stands
Prediction: Lower pairing success and fewer renesting chances (J. Probst, pers. obs.)

FIG. 7-5

Stepwise inferences about mechanisms controlling patterns of Kirtland's Warbler habitat occupancy. Each inference about process leads to examination of another pattern, so detailed habitat modeling is deferred until processes are elucidated.

until early inferences are made from survey data. Initial surveys are essentially the observation phase of the scientific method, and targeted surveys and long-term monitoring data structured in time and space are used to test hypotheses. Sequential surveys (Levels 3, 4) can target processes such as source-sink interactions before long-term monitoring is established.

Past approaches to resource management monitoring tended to consider only a few species or resources as indicators. However, the indicator approach is unlikely to cover the range of biodiversity concerns, and surrogate representation of other species by ecological indicators is questionable (Mannan et al. 1984; Verner 1984; Landres et al. 1988; Noon et al., this volume). Monitoring groups of species, or guilds, may moderate some of the problems of an indicator approach (Verner 1984, Tilghman and Verner 1989), but even monitoring several representative guilds may not provide a comprehensive evaluation of cumulative management effects. Another improvement is to consider as many species as possible at lower resolution before initiating intensive field studies. Once population sizes are estimated initially and population dynamics and interrelationships are postulated using a stepwise approximation strategy, developing monitoring plans to test hypotheses becomes possible.

Survey and monitoring applications in past approaches are frequently separated from the scientific process. Some established monitoring work should certainly be continued to maintain long-term baselines, but new surveys could be planned within a conceptual framework designed to document resource conditions by stepwise approximation. Such a framework is likely to direct surveys to specific, contrasting locations rather than a random, systematic, or stratified sampling scheme. Any monitoring that is distributed randomly or evenly may be suboptimal if not based on less-intensive sampling. Surveys might be short-term initially, but can be replaced by specific higher resolution work as needed. Indeed, sequential surveys, carefully planned in space and time, can be powerful tools for understanding the mechanisms of environmental change and drivers of population dynamics. In fact, there is a need to develop surveys, targeted toward areas or species groups that are dynamic in time, and that are not permanent monitoring plots and projects. Such mid-resolution surveys could be extremely incisive, using lower sampling intensity, and might best be assembled by interagency partnerships.

CONCLUSIONS

Researchers and managers often approach integrated wildlife management by using bottom-up applications of an indicator species approach, a pilot project, an ecosystem management demonstration area, or other narrowly focused but detailed approaches. Most detailed analyses must be repeated when placed in a broader context of space, time, and other resource issues. In contrast, solving problems using stepwise approximation strategies with nested, general models (Rubin 1991, Van Horne 2002) is a useful first step to achieve large-scale, integrated objectives, especially across academic disciplines.

In summary, the key concepts of a stepwise approximation approach for linking coarse scale and finer scale species population patterns are

1. Employ more than two spatial scales or several levels of resolution over a large geographic spatial context.
2. Consider most well-known species or several taxa at some common level of resolution before conducting detailed research or modeling.
3. Set ranges of environmental conditions (i.e., gradients) to establish context before doing categorical comparisons in research or modeling.
4. Initially use less precise models to facilitate geographic comparisons and integration across spatial scales.
5. Infer processes from presence-absence patterns in space and time to generate and test hypotheses about mechanisms driving observed patterns.

6. Assume that species are not at carrying capacity so that spatiotemporal heterogeneity can be captured and evaluated for its explanatory value.
7. Employ a hierarchy of simple or even qualitative models rather than overly precise predictive or correlative models until there is an adequate understanding of controlling processes or finer-scale mechanisms.

The stepwise approximation strategy can help produce better, more integrated conservation plans for multiple species at reduced cost, by deferring more detailed analyses until it has been determined that it is necessary.

SUMMARY

A major challenge for ecologists, resource managers, planners, and policy makers is the development of comprehensive wildlife conservation assessments that synthesize current scientific knowledge. We presented a stepwise approximation approach that incorporated a broad consideration of population patterns by emphasizing a larger geographic context before integrating more detailed studies at successively finer scales. Although there are various approaches to establishing context for assessments, we described one that integrates multiple levels of resolution in a stepwise manner to (1) delineate multispecies ranges to identify range overlaps and dissimilar distributions; (2) refine species distributions in terms of habitat-gradient relationships; (3) test species habitat-gradient relationships with species occurrence surveys; (4) evaluate habitat quality through abundance estimates and temporal change; (5) further refine habitat-quality evaluations with productivity and survivorship estimates; (6) synthesize levels 1–5 using maps and summary models to assess viability, conservation plans, or changing conditions; and (7) design monitoring strategies to test the validity of the synthesis. Stepwise approximation can connect coarse and fine scales using general to detailed species population patterns and can help produce more integrated conservation plans for multiple species at reduced cost, by deferring more detailed analyses until it has been determined that it is necessary.

ACKNOWLEDGMENTS

We thank Greg Corace, Tom Crow, Russell Graham, Peter Landres, Pam Nankervis, Anna Pidgeon, Brian Sturtevant, and several anonymous referees for critical reviews of the manuscript drafts. Deahn Donner edited and improved numerous manuscript and figure drafts and contributed valuable ideas. Sue Lietz provided technical assistance. The approaches and strategies presented here benefited from interactions with practitioners and land managers from government, industrial, and conservation organizations.

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