Prioritizing Areas for the Conservation of Faunal Species Diversity in the Middle-Atlantic Region

Joshua J. Lawler
National Research Council
U.S. Environmental Protection Agency
NHEERL-WED
200 SW 35th St.
Corvallis, OR 97333

Denis White
U.S. Environmental Protection Agency
NHEERL-WED
200 SW 35th St.
Corvallis, OR 97333

Jean C. Sifneos
Geosciences Department
Oregon State University
Corvallis, OR 97333

Lawrence L. Master
NatureServe
11 Avenue de Lafayette, 5th Floor
Boston, MA 02111

Prioritizing Areas For Conservation Using Site Irreplaceability

Abstract

One of the most basic components of conservation planning involves determining where to concentrate efforts to protect biodiversity. Here we investigated four possible measures for prioritizing sites for conserving species diversity of six animal taxa. We demonstrate patterns of species richness, distributions of at-risk species, sets of sites selected on the basis of complementarity, and an index of irreplaceability. Irreplaceability measures the contribution of a site to sets of sites that include all species. Because it addresses all species, this measure has a distinct advantage over simpler measures of species richness and rarity. Our results highlight some areas of high irreplaceability on the periphery of the study region. These areas are in part influenced by species that are locally rare only because they are at the edges of their geographic ranges. To address this issue we suggest either further analyses that incorporate weights for species based on their relative distribution inside and outside the study region or coordinating conservation analyses over a larger spatial extent.

Data

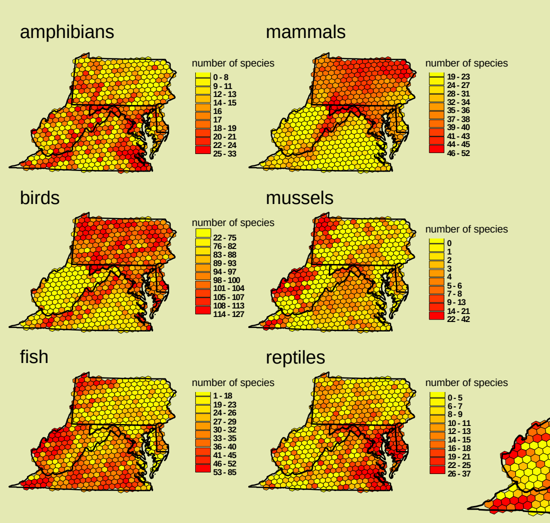
- Species occurrence data were provided by The Nature Conservancy and the Association for Biodiversity Information as part of a cooperative agreement between TNC and the US EPA.
- Occurrences were tallied for 487 650-km^2 hexagonal sampling units (White et al. 1992) across the mid-Atlantic Region.
- We used each of these six taxa as an indicator group. In addition we tested the ability of at-risk species to act as an indictor group for all other species.
- We defined at-risk species using the three most sensitive classes of a five-level global ranking system (Master 1991).

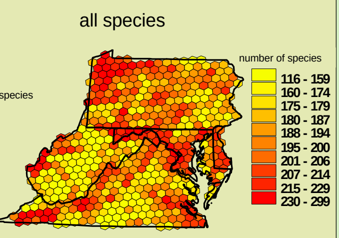
Number of species and at-risk species of six taxa in a database compile for the hexagonal sampling grid in the middle-Atlantic region.

Taxon	Species	At-risk species
Fish	258	37
Birds	208	3
Mussels	96	37
Amphibians	77	6
Mammals	76	4
Reptiles	63	4

Irreplaceability

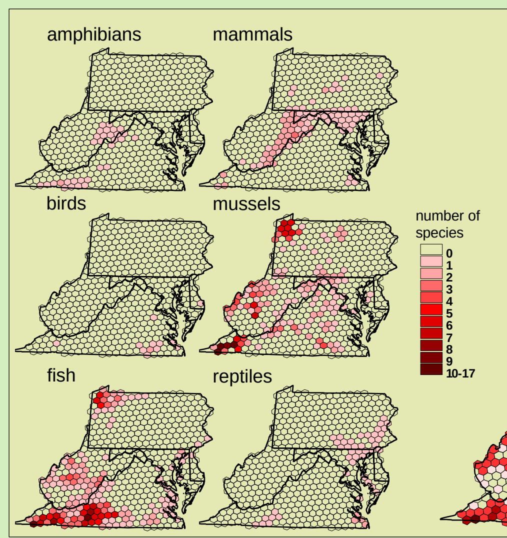
Irreplaceability is a measure of the relative importance of a site for protecting a set of conservation targets. Specifically, the irreplaceability of a site is the proportion of all combinations of sites that achieve the conservation goal for which that site is a critical component. Irreplaceability was calculated for each species and then summed for all species in a hexagon to produce a values of summed irreplaceability. We used C-plan conservation planning software (see Ferrier et al 2000) to calculate summed irreplaceability values.

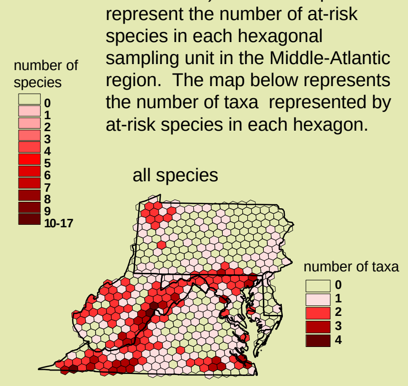




Species Richness

FIGURE 1. Maps of species richness values for six animal taxa and for all six taxa combined





At-Risk Species

FIGURE 2. The distributions of at-risk species (G1-G3 species, Master 1991). The six maps at left represent the number of at-risk species in each hexagonal sampling unit in the Middle-Atlantic region. The map below represents the number of taxa represented by at-risk species in each hexagon.

Complementarity and Irreplaceability

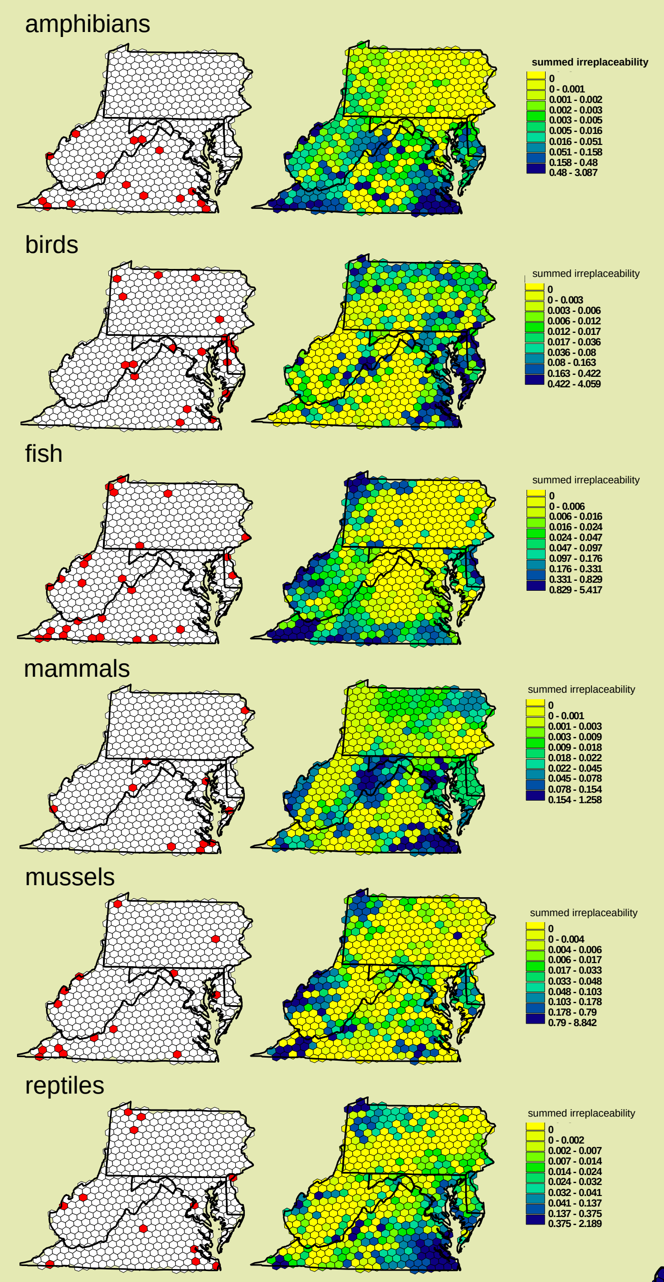


FIGURE 3. Sets of sites selected on the basis of complementarity (left-hand column of maps) and summed irreplaceability values (right-hand maps) for all hexagonal sampling units in the Middle-Atlantic region.

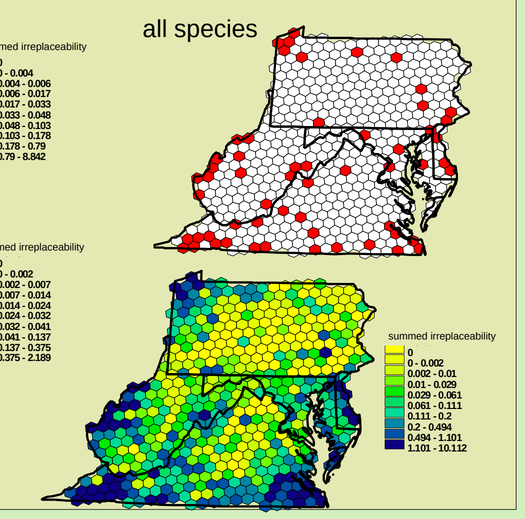
Complementary Sets:

The sets of sites in the maps at the far left represent one possible solution to the set coverage problem. The number of hexagons required to cover all species ranged from 10 for mammals to 26 for fish. When all six taxa were considered together, 53 hexagons were required to cover all 782 species.

Summed Irreplaceability:

Summed irreplaceability is a measure of the contribution that any one site makes to the universe of possible solutions of the set coverage problem.

An irreplaceability index calculated for species of all six taxa combined, indicated high levels of irreplaceability in the northwest, southwest, and southeast corners of the region, as well as the a portion of the Appalachian Mountains and much of the Delmarva peninsula.



Translating Results to Different Frameworks

(an example using 8-digit HUCs)

MAXIMUM

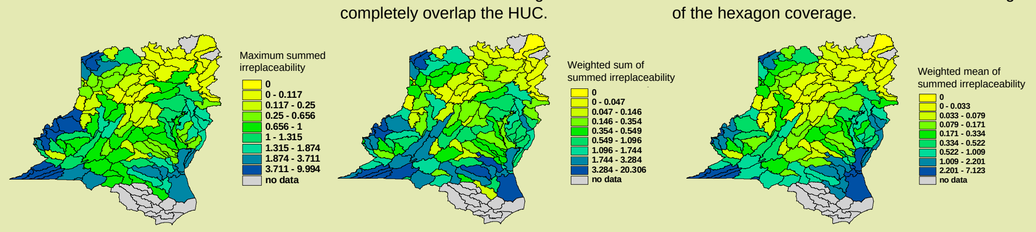
The maximum summed irreplaceability value in any hexagon that intersects a HUC.

WEIGHTED SUM

The sum of all summed irreplaceability values weighted by the area of the hexagon that overlaps the HUC. Thus hexagons with small overlaps contribute less to the value than hexagons that completely overlap the HUC.

WEIGHTED MEAN

The weighted sum (at left) is standardized for the area of the HUC for which hexagon data were available. This amounts to dividing weighted sums by the area of internal HUCs and by a smaller number for HUCs that occur on the edge of the hexagon coverage.



Conclusions

- Although hot spots of species richness (fig. 1) show some spatial coincidence with areas containing rare or threatened species (fig. 2), not all rare species are contained in areas of high species richness.
- High irreplaceability values in peripheral regions result in part from locally rare species that are at the edge of their geographic ranges and in part from the presence of globally rare species. Depending on the goals of the analysis, locally rare but globally common species can be dealt with by employing weighting factors or by coordinating planning efforts at larger spatial scales

Testing Indicators of Species Diversity

Abstract

Indicator groups have been proposed as one tool for selecting areas for conservation when information about species distributions is lacking. The indicator concept involves selecting sites based on groups of easily monitored species that represent more broadly defined patterns of biodiversity. Although tests of the concept have produced varied results, sites selected to cover indicator groups on the basis of complementarity can include a high proportion of other species. Because they are inherently rare, however, species threatened with extinction are not likely to be well covered by indicator groups. Here we show that although sites selected using each of six taxonomic indicator groups included relatively large percentages of other species, they included relatively few at-risk species. Furthermore, the probability of inclusion in selected sites was related to the area of a species' range, as evidenced by thresholds above which species were included, but below which the probability of inclusion was variable. Although rare species were not well covered by indicator taxa, they performed well as an indicator group, covering a relatively large proportion of all other species.

Questions

- *How well do sites selected to cover indicator groups cover non-indicator species?*
- *Is there cross-taxon concordance of at-risk species distributions?*
- *How well do indicator groups cover at-risk species?*
- *Is there a relationship between the extent of a species' range and its probability of inclusion in a set of sites selected to cover an indicator group?*
- *How well do at-risk species perform as an indicator group?*

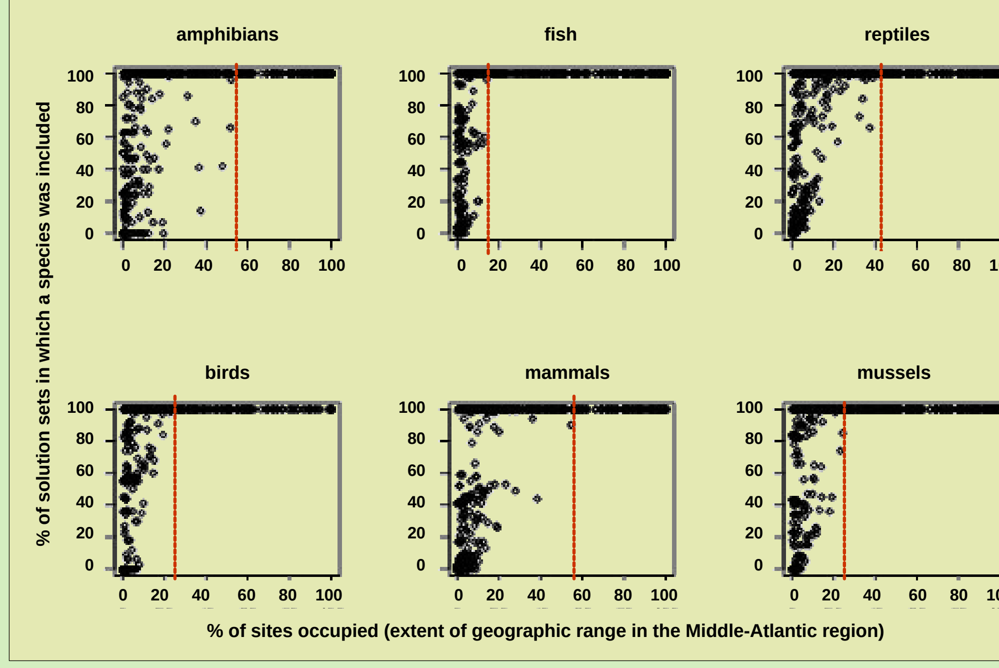
Analyses

- We used simulated annealing (Kirkpatrick et al. 1983) to solve two formulations of the reserve selection problem.
  - First we selected the minimum number of sites necessary to cover all members of each indicator group. This analysis provided an evaluation of the best performance of which an indicator group was capable.
  - Next we selected the 10 sites that best covered each indicator group. This analysis allowed for comparisons of indicator performance to be made across groups by holding the number of sites used constant.
- For both types of analysis, we used a combination of SITES (Andelman et al. 1999) and our own program to select 100 sets of sites for each indicator group. We computed the proportion of all non-indicator, and all at-risk non-indicator group species included in the sites selected to cover each indicator group. Our results represent the means of each set of 100 analyses.

Results

- Sites selected to cover each of the six taxonomic groups covered a high percentage of all other species (Fig. 4).
- The distributions of at-risk species showed little cross-taxon correspondence (Fig. 2). The distributions of at-risk fish and mussels were the most similar.
- Sites selected to cover each of the six taxonomic indicator groups covered relatively small percentages of non-indicator at-risk species (Fig. 5).
- Species whose geographic range covered smaller proportions of the study area were less likely to be included in sets of sites selected to cover an indicator group (Fig. 6). We found thresholds in range area above which species were included in sets of sites and below which inclusion was variable.
- Sites selected to cover at-risk species covered a relatively large percentage of all other species (Fig. 7).

FIGURE 6. The relationship between the probability of inclusion in a set of sites selected to cover each of six indicator groups (represented by the percent of solutions containing the species), and the extent of a species' range within the study area. Each point represents one species. Red lines represent possible thresholds in range area, above which species were included in sets of sites and below which the probability of inclusion was variable.



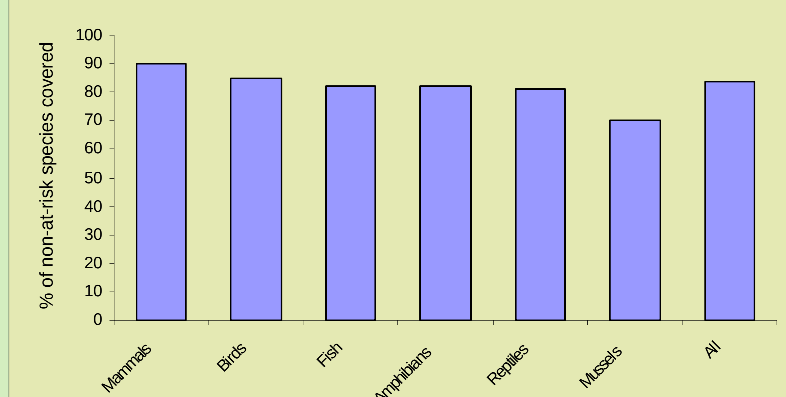
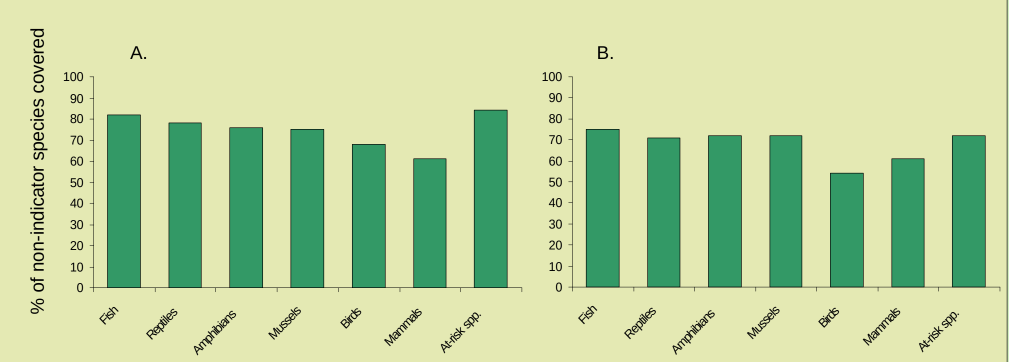


FIGURE 5. Percentage of all (non-at-risk) species of six animal taxa included in sets of sites selected to cover all at-risk species. Bar heights represent means of 100 simulated annealing runs. Standard deviations were 2% for mammals, fish, amphibians, and reptiles; 1% for birds and all taxa combined; and 6% for mussels.

FIGURE 1. Percentage of all non-indicator species included in A) the minimum number of sites required to cover all members of each of seven indicator groups and B) 10 sites selected to best cover all members of each indicator group. Bar heights represent means of 100 simulated annealing runs. Standard deviations ranged from 1%-5%.



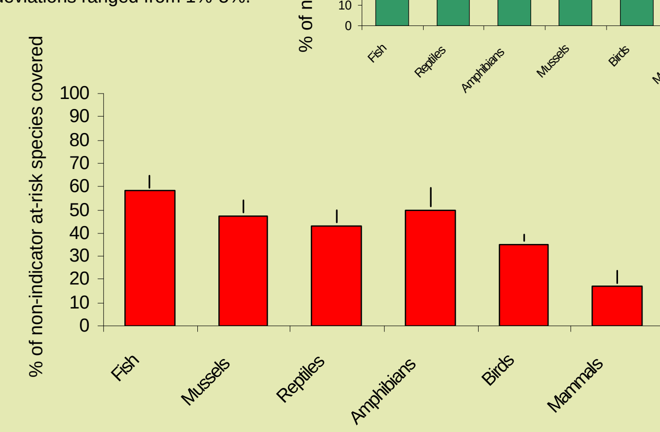


FIGURE 3. Percentage of non-indicator group at-risk species covered by each of six taxonomic indicator groups. Bar heights represent means of 100 runs of the simulated annealing algorithm. Error bars represent standard deviations.

Conclusions

- In areas where data on rare species are available, these species may be useful indicators for selecting areas to preserve species diversity.
- Unless planners can explicitly include information on the distributions of rare species into the selection process, these species are not likely to be included in conservation areas selected using specific indicator taxa.

Literature Cited

Andelman, S., I. Ball, F. Davis, and D. Stoms. 1999. Sites version 1.0. An Analytical Toolbox for Designing Ecoregional Conservation Portfolios. Manual prepared for The Nature Conservancy, December 1999. University of California,Santa Barbara, CA, 55 pp.

Ferrier, S., R. L. Pressey, T. W. Barrett. 2000. A new predictor of the irreplaceability of areas for achieving a conservation goal, its applicability to real-world planning, and a research agenda for further refinement. Biological Conservation 93: 303-325.

Kirkpatrick , S., C. D. Gelatt Jr., and M. P. Vecchi. 1983. Optimization by simulated annealing. Science 220: 671-680.

Master, L. L. 1991. Assessing threats and setting priorities for conservation. Conservation Biology 5: 59-563.

White, D., A. J. Kimmerling, and W. S. Overton. 1992. Cartographic and geometric components of a global sampling design for environmental monitoring. Cartography and Geographic Information Systems 19: 5-12.