Population Risk-Based Criteria: Incorporating Habitat and Spatial Information into Ecological Risk Assessments (WQ MYP)

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AED Peer Review '07

Agency Problem

The U.S. EPA recognizes the need for improved methods and information to support its decisions affecting wildlife. The Wildlife Research Strategy outlines an integrated approach for developing scientifically valid methods for assessing risks to aquatic-dependent wildlife and other aquatic populations from multiple stressors in the environment. Central to this approach is the need to consider the risks to spatially structured wildlife populations in a landscape context. A landscape approach informs predictions of population dynamics in spatially heterogeneous landscapes and advances techniques for assessing the combined and relative risks of chemical and non-chemical stressors on wildlife and other populations. This body of research describes methods and models being developed that account for spatial heterogeneity in stressor exposure, and that support delineation of the spatial scales at which wildlife risk assessments should be performed. This research is enhanced by our partnerships with non-government agencies such as the Loon Preservation Committee (LPC) and the state agencies of New Hampshire Department of Environmental Services, Vermont Institute of Natural Science and the Wisconsin Department of Natural Resources.

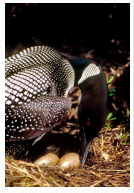
Research Goals

- Develop methods and models to predict population dynamics and evaluate risks from chemical and non-chemical stressors to spatially structured populations
- Evaluate methods and models that account for spatial arrangement of habitat and co-occurring stressors at varying assessment scales
- Incorporate measures of habitat quality as it relates to a species' unique life history traits such as age related survivorship and reproduction
- Integrate tools designed to assess both temporal and spatial scale as it relates to movement and response of wildlife populations to varying conditions of habitat and stressors in a landscape context

Methods/Approach

Multi-scale Habitat and Risk Assessment

The influence of landscape patterns on wildlife and how these relationships vary with scale has become widely recognized in ecological research. Much of this research has resulted in a more 'organism-centered perspective' allowing the study animal to define the scale of analysis. A number of studies have demonstrated avian habitat and nest site selection at multiple spatial scales. The Common Loon is known to use different habitat types for breeding, foraging and rearing young. We analyze habitat variables affecting selection of Loon nest site location at multiple scales to explore the influence of surrounding habitat and stressors relative to the presence and absence of Loon nesting territories. Understanding nest site selection at multiple spatial scales can provide insights into how specific environmental stressors may interact to influence reproductive outcome and inform conservation decisions to prioritize preservation of high quality Loon breeding habitat.



Using geographic information systems (GIS) and relational database software we geographically linked environmental parameters, water quality measures, land use and landscape metrics, human census data, lake morphology and habitat characteristics with a 30 year Loon demographic monitoring productivity database (LPC) across the state of New Hampshire.

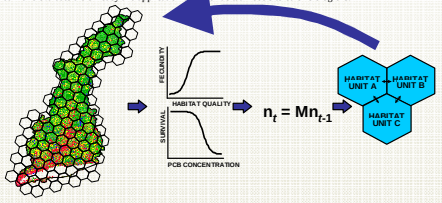
We use logistic and multinomial logistic regression analysis to identify the significant variables at each scale associated with the presence and absence, and productivity of Loon nests. The variables that have the highest significance at each scale are then entered into the multi-scale model. These four models (3 single scale and 1 multi-scale) are then compared using the Akaike's Information Criterion (AIC) framework. AIC is an information theory approach based on the principles of: 1) simplicity and parsimony 2) several working hypotheses 3) strength of evidence. AIC provides a framework for evaluating competing models to identify which models best approximate reality given the data.

Habitat Quality-Heterogeneity Assessment

One of the primary applications of these habitat models will be to examine the differential performance of loons across a gradient of habitat (including varying habitat associated with mercury (Hg) in specific prey). We use a demographic response design to compare loon population demographic parameters across multiple study sites with differing habitat compositions. Analysis of loon productivity associated with habitat quality allows for identification of source and sink habitat.

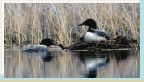
Model Validation-Field Validation

In building these various habitat models we employed both *training* and *testing* data sets for each model. This is accomplished by randomly selecting 60% of the lakes and associated data for the subset of lakes to train or build the model, and use the remaining 40% to test the accuracy of the model predictions. This cross-validation approach reduces a biased assessment of accuracy in the model. Additionally, we are using independently-collected field data sets from the states of Vermont and Wisconsin to "ground-truth" and evaluate the efficacy and application of the habitat models to other bioregions.



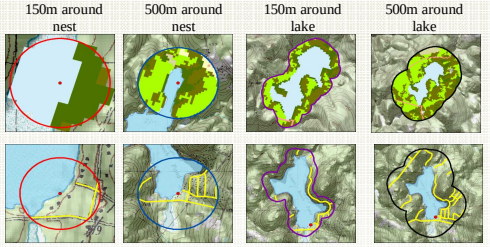
GIS-referenced habitat and exposure data | exposure-response habitat-response relationships | extrapolation population models | spatially explicit models

Conceptual Model



Results and Conclusions

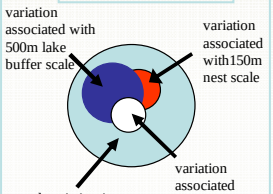
Land Cover and Road Density at varying scales



Habitat Model Selection using Information-Theory

Model ID	Significant factors	AIC	Explained Deviance (%)	Delta AIC (Δ_i)	Akaike weights (ω_i)
Nest Scale	lake area (+) p/a ratio (+) dist to loon (-)	120.41	90	2.00	0.25
150 m lake buffer	dist to loon (-) pH (+)	180.98	65	62.57	0.00
500 m lake buffer	Residential (-) Deciduous (+) lake area (+) human census (-)	123.01	89	4.6	0.07
Multi-scale*	Agriculture (-) Deciduous (+) lake area (+) human census (-)	**118.41**	**92**	**0.00**	**0.68**

Variance Decomposition



* Results from AIC demonstrate that the multi-scale model best explains the available data and loons are selecting habitat hierarchically:

- Explained variance of 3 single scale and full multi-scale models. Lowest AIC value is the full multi-scale model
- The model with the lowest AIC value is considered the best approximating model given the data set.
- Delta AIC: </= 2.0 is a model with substantial support for explaining the variance in the data; Delta > 3-7 less support; Delta > 10- basically useless.
- Akaike weights can be viewed as probabilities for the best model relative to the other competing models.

Landscape Context:
Spatial arrangement of habitat and stressors

Lake Distance grid

Model Rank
Spatially-explicit population models accounting for spatial variation

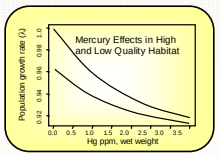
One of the unique aspects of Loon ecology is their dispersal patterns. In field observations, Loons tend to be on clusters of lakes and are more likely to occur on a lake if there is a Loon on a nearby lake.

Loons exhibit high nest site fidelity with an 80% return rate for nesting pairs to previously occupied nests. Loons also select nest sites within 20 km of their natal lake. This creates a clustering pattern of nesting loons which causes an increase in competition for territories. The proximity metrics allow us to evaluate the relationship between nest site locations relative to nearby lakes and nest proximity.

Impact and Outcome

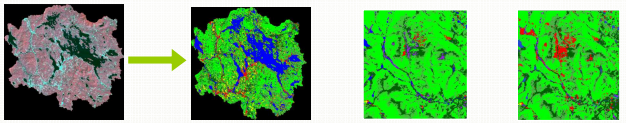
Incorporating habitat models and considering habitat quality in Ecological Risk Assessments enhances ecological realism by addressing effects of habitat alteration and species' preferences in tandem with chemical stressors. This research demonstrates a collaborative and integrative approach to quantify relative risks to wildlife populations from toxic compounds, habitat alterations, and other stressors. Results are being extended into large scale spatially-explicit population projections and are providing the scientific foundation for regulatory wildlife criteria at the state, regional or national levels.

Predicted effects of multiple stressors on population growth rate



Temporal Scale-Change Analysis

Land-Cover Products



Southern Subset Displayed 4,3,2 RGB | 1990 Land-Cover Map | 1990 | 1999

Urban Disturbed Cleared | Agriculture | Deciduous Forest | Coniferous Forest | Mixed Forest | Water | Forested Wetland | Bedrock

A pilot study performed with satellite imagery and NH GRANIT land cover GIS data from two sub regions of NH demonstrated differential change in land use land cover (LULC) rates over a ten year period (1990-99). Statistical analyses are being performed to determine if changes in land cover are related to changes in the spatial distribution of loons over time.

Future Directions

- Habitat modeling is also being applied to assess temporal changes by using satellite imagery to compare recent and historical landscapes with corresponding loon populations. Land use change detection models will be developed to further assess the effects of human disturbance and multiple stressors on loons. These results will be used to identify and prioritize critical habitat for the Common Loon for future conservation and protection.
- Future applications to geographic areas of increasing size (watershed to state to bioregional levels) and collaborations with partners will permit independently-collected data sets for model validation and comparisons between large regions of the US (*i.e.*, New England and the Mid-West), contributing to a better understanding of broad scale risks and providing scientific support for regional and national environmental regulations.

References

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