ONLINE APPENDIX

CHAPTER 10

NORTHEASTERN SEASONAL WOODLAND POOLS

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1) Table and 2) Case Study

Appendix Table 10.1

Typical postbreeding habitat requirements of seasonal woodland pool amphibians in northeastern North America

	Postbreeding habitat	**Hibernacula**	**Supporting literature**
Wood frog *(Lithobates sylvaticus)*<Ref>I noted that in references and elsewhere in text the wood frog is called *Rana sylvatica.* Any contradiction here?</Ref>	Forested wetlands, moist lowland forests, or forested ephemeral drainages; a thick and well-distributed deep litter base; complex ground structure; moist but not wet substrates	Often > 100 m from breeding pools; shallow depressions below leaf litter in well-drained soils in deciduous or mixed forests	deMaynadier and Hunter 1999; Regosin, Windmiller, et al. 2003; Regosin, Windmiller, et al. 2005; Baldwin, Calhoun, et al. 2006a,b; Patrick, Hunter, et al. 2006; Rittenhouse and Semlitsch 2007; Blomquist 2008; deMaynadier and Houlahan 2008; Patrick, Harper, et al. 2008; Berven 2009
Spotted salamander *(Ambystoma maculatum)*	Horizontal or vertical small mammal burrows; well-shaded, abundant coarse woody material; thick and well-distributed litter base; > 30% canopy closure; understory vegetation	Small mammal burrows (often short-tailed shrews, *Blarina brevicauda)* in deep, well-drained soils in deciduous or mixed forests	Windmiller 1996; Madison and Farrand 1998; Rothermel and Semlitsch 2002; Faccio 2003; Regosin, Windmiller, et al. 2003; LaVoie 2005; Regosin, Windmiller, et al. 2005; Montieth and Paton 2006; Rothermel and Semlitsch 2006

Blue-spotted complex *(A. laterale)*	Deep litter; cover objects (rocks, logs) within vicinity of breeding wetlands (forested and open canopy); wet meadows; horizontal small mammal burrows associated with fallen tree trunks, logs, or stumps, often found in areas where soils have high sand and loam content	Deep, well-drained soil? Small mammal burrows (often those of *B. brevicauda*)	Minton 1972, 2001; Klemens 1993; Windmiller 1996; Regosin, Windmiller, et al. 2005; Gibbs, Breisch, et al. 2007
Marbled salamander *(A. opacum)*	Under large cover objects on well-drained rocky slopes; dry, friable soils (sand and gravel deposits)	Deep, well-drained soil? Vertical small mammal burrows?	Bishop 1941; Klemens 1993Jenkins, McGarigal, et al. 2006; Rothermel and Semlitsch 2006
Jefferson salamander *(A. jeffersonianum)*	Horizontal mammal burrows; well-shaded, abundant, coarse woody material; small mammal burrows associated with coarse woody material; steep, rocky areas with rotten logs and thick and well-distributed litter base	Small mammal burrows (often those of *B. brevicauda)* in deep, well-drained soils in deciduous or mixed forests	Faccio 2003; Lavoie 2005; Gibbs, Breisch, et al. 2007

Appendix Case Study

Setting Conservation Priorities for Seasonal Woodland Pool-Breeding Amphibians: Comparison of Models

Conservation planning has become a sophisticated new field utilizing mathematical models within geographic information systems (GIS). Beginning with simple overlays of habitats and managed lands to identify gaps in protection (i.e., GAP analysis), conservation planning coevolved with the capacities of computing systems to run spatial analyses and generate graphical outputs. While a decade ago a student in conservation biology had to schedule time in a computer lab to run GIS analyses, now it can be done on a laptop. Concurrently, oversimplified reserve planning debates (e.g., Single Large or Several Small) have matured into a subtle understanding of what it takes to represent an adequate array of habitats to facilitate persistence of biotic communities, natural disturbance regimes, and change (Margules and Pressey 2000). As a result, there is an array of systematic, repeatable methods for prioritizing conservation by answering the questions of where, how much, and when to protect habitat (reviews in Akcakaya, Burgman, et al. 2004; Crooks and Sanjayan 2006).

Pool-breeding amphibians are largely dependent upon wetlands for breeding and adjacent habitats for fulfilling life-history needs. Consequently, conservation planning for pool-breeding amphibians has focused on defining a functional habitat patch for local populations that include wetlands and surrounding habitats, and has taken into consideration connectivity among these subpopulations (reviewed in Gibbs and Reed 2008). Recent advances in GIS modeling for conservation of wetland fauna have taken into account three primary factors: (1) habitat patches, (2) landscape resistance, and (3) changing land uses (Harper, Rittenhouse, et al. 2008; Compton, McGarigal, et al. 2007: Baldwin and deMaynadier 2009).

This brief overview discusses two approaches to wetland conservation designed to identify clusters of pools and associated habitats that currently have integrity but may be at risk: threat analysis and resistant kernels. These approaches have underlying similarities yet also significant divergence. It is incumbent upon conservation planners to become familiar with how their models are organized before acting upon them. To this end, model assumptions, structure, data sources, outputs, and conservation implications are compared and contrasted for a single study area in this section.

Two Modeling Approaches: Same Place, Different Answers?

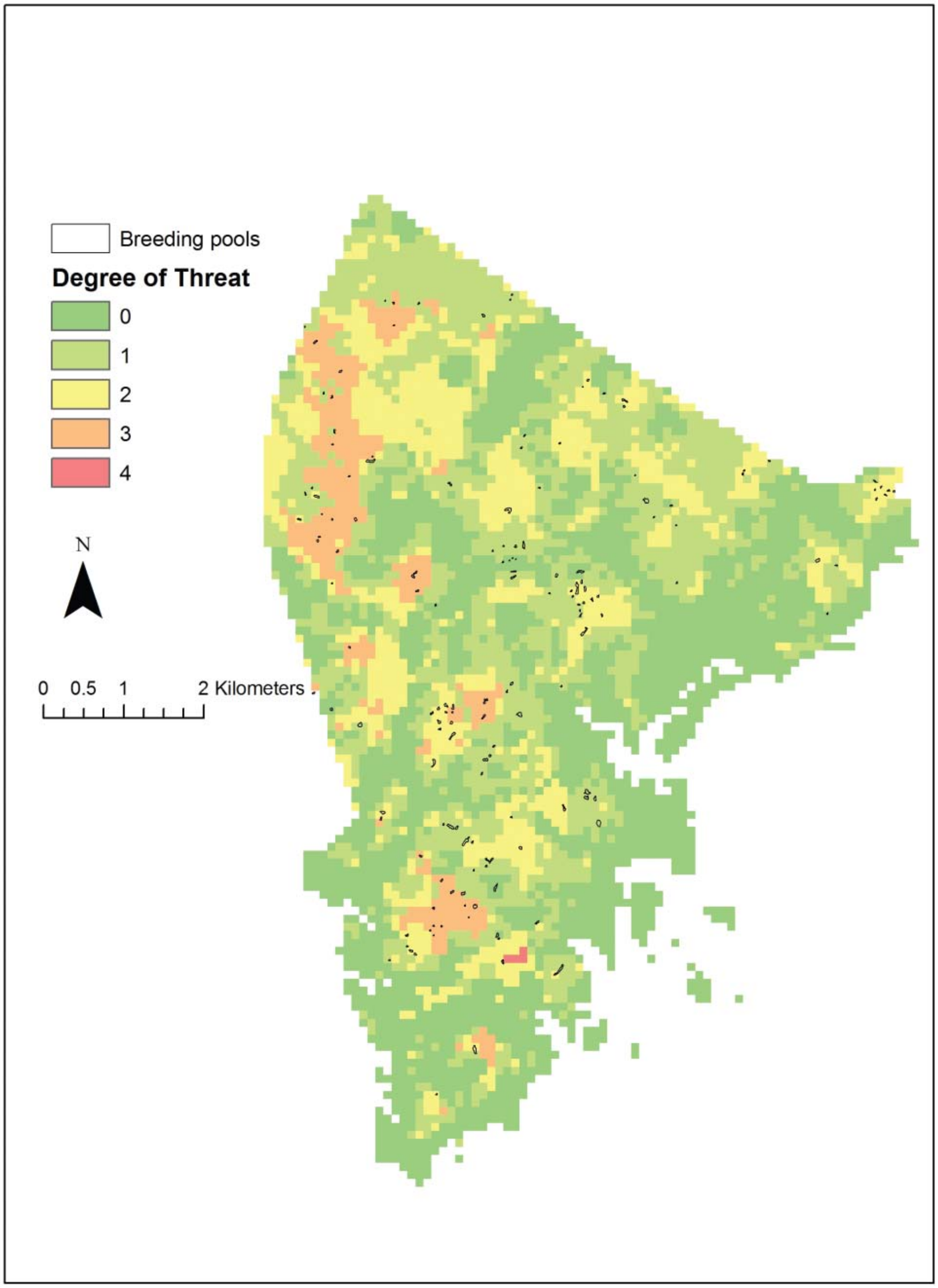
The study area used for these models has a high density of seasonal woodland pools and is experiencing moderate to high levels of habitat conversion for development. Two species of amphibian are the most common breeders in these wetlands, the spotted salamander *(Ambystoma maculatum)* and the wood frog *(Lithobates sylvaticus).*

Threat Analysis

A threat analysis expands upon the layering approach of GAP analysis to include dynamic, time-dependent processes such as land-use change due to development (Theobald 2003). The purpose of a threat analysis is to identify important habitats that are both unprotected and under threat from land-use change. Therefore, it combines socioeconomic and biological data. The model presented here for pool-breeding amphibians is described in detail elsewhere (Baldwin and deMaynadier 2009), but the basic components of the model are outlined in order to compare them with resistant kernels.

A threat analysis must include at least three variables as layers of information in a GIS: (1) a habitat suitability layer, composed of two parts, potential habitat and actual land use; (2) a layer representing land-use change pressure within a specified time frame; and (3) a layer representing existing protection levels.

The potential habitat in a threat analysis for pool-breeding amphibians adopts the general model of a core terrestrial habitat, represented by possible habitat at a specified radial distance around potential breeding pools (Semlitsch 2008). However, the resulting layer does not yet take into account actual land cover and uses. Thus a habitat suitability layer, which includes existing land use and potential habitat, is produced by weighting the potential habitat lower wherever the land uses are not suitable habitat. The resulting layer is then multiplied by a development pressure index (a layer representing land-use change pressure within a specified time frame), derived from census-based data on how rapidly human populations are growing in the area and how populated (by census or housing density) the area is already. The product of the habitat suitability multiplied by development pressure operation is divided by a final layer representing protection levels that exist across the landscape (e.g., conservation lands, state parks, wildlife refuges, etc.). The greater the protection level (e.g., a national park would be the highest), the lower the urgency to protect a place, and the lower the model output for that area. The resulting raster (appendix fig. 10.1) shows areas of the landscape that (a) have high habitat value, (b) are under development pressure, and (c) are not yet protected.



Appendix Fig. 10.1. Threat analysis for seasonal woodland pools (potential amphibian breeding habitat) in the coastal New England (USA) town of Kennebunkport. Degree of threat is calculated by multiplying resistance-modified core terrestrial habitat zones by development pressure and dividing the product by protection level of existing conservation lands.

Resistant Kernel

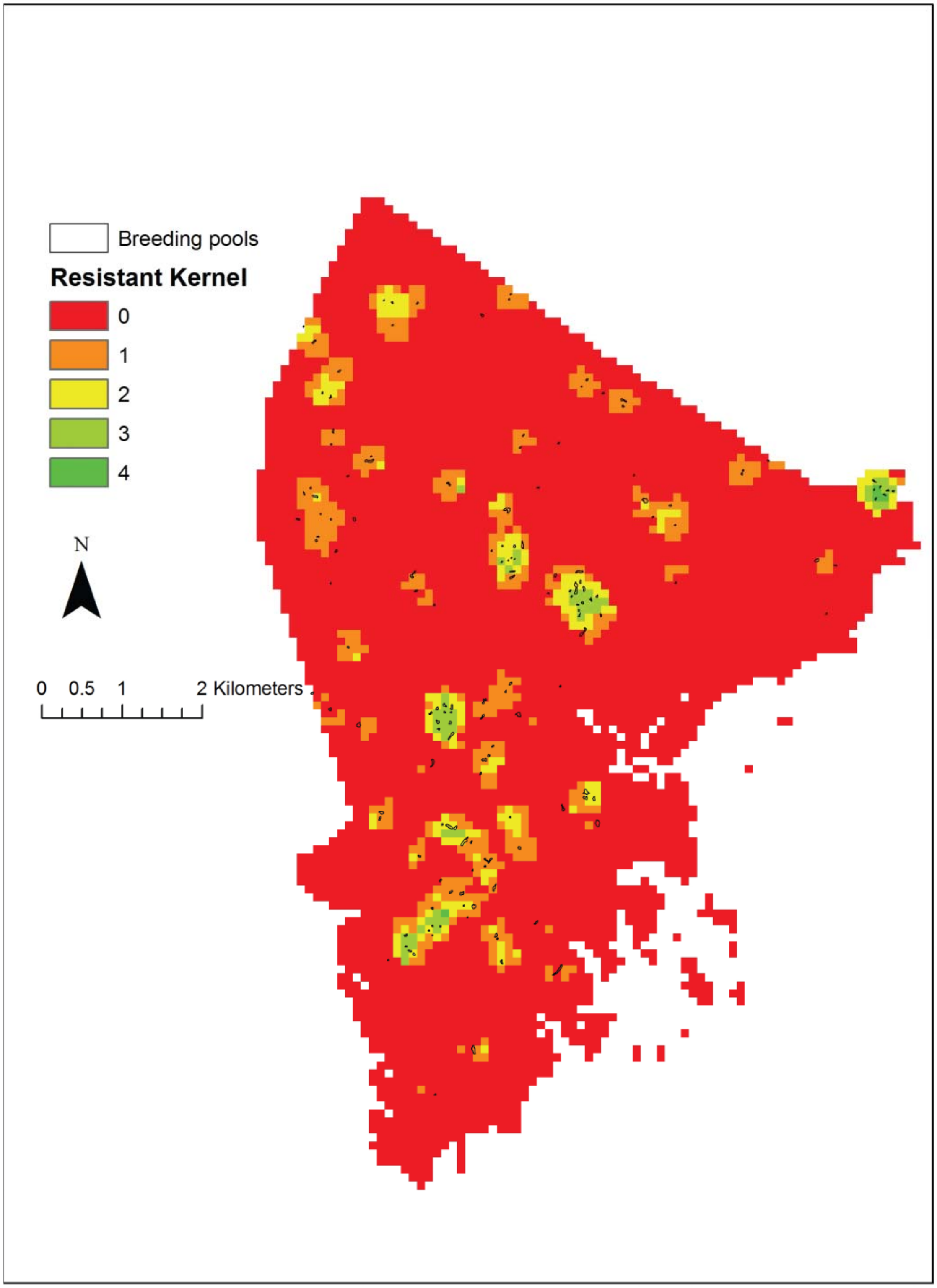
A resistant kernel utilizes the concept of habitat kernels from habitat ecology and modifies those kernels by landscape resistance (Compton, McGarigal, et al. 2007). Landscape resistance is how easily organisms can pass through a habitat matrix of variable quality (Ricketts 2001). The purpose of resistant kernel for wetland fauna is to identify clusters of wetlands in higher-permeability habitat so that larger and more connected clusters might be prioritized for conservation, relative to smaller and more isolated wetland clusters. The model presented here is adapted from Compton, McGarigal, et al. (2007), where the theory and approach are described in detail.

Resistant kernels require two primary sources of data as layers of information in a GIS: (1) points representing wetland locations, and (2) a layer of information representing landscape resistance. This latter layer can be derived from any land-use/land-cover raster source, although for smaller, less mobile organisms, finer-scale data (< typical 30 m resolution) are preferred. Also, landscape resistance values should be carefully assigned based on field studies testing movement patterns of organisms in various landscapes (e.g., deMaynadier and Hunter 2000; Rothermel and Semlitsch 2002).

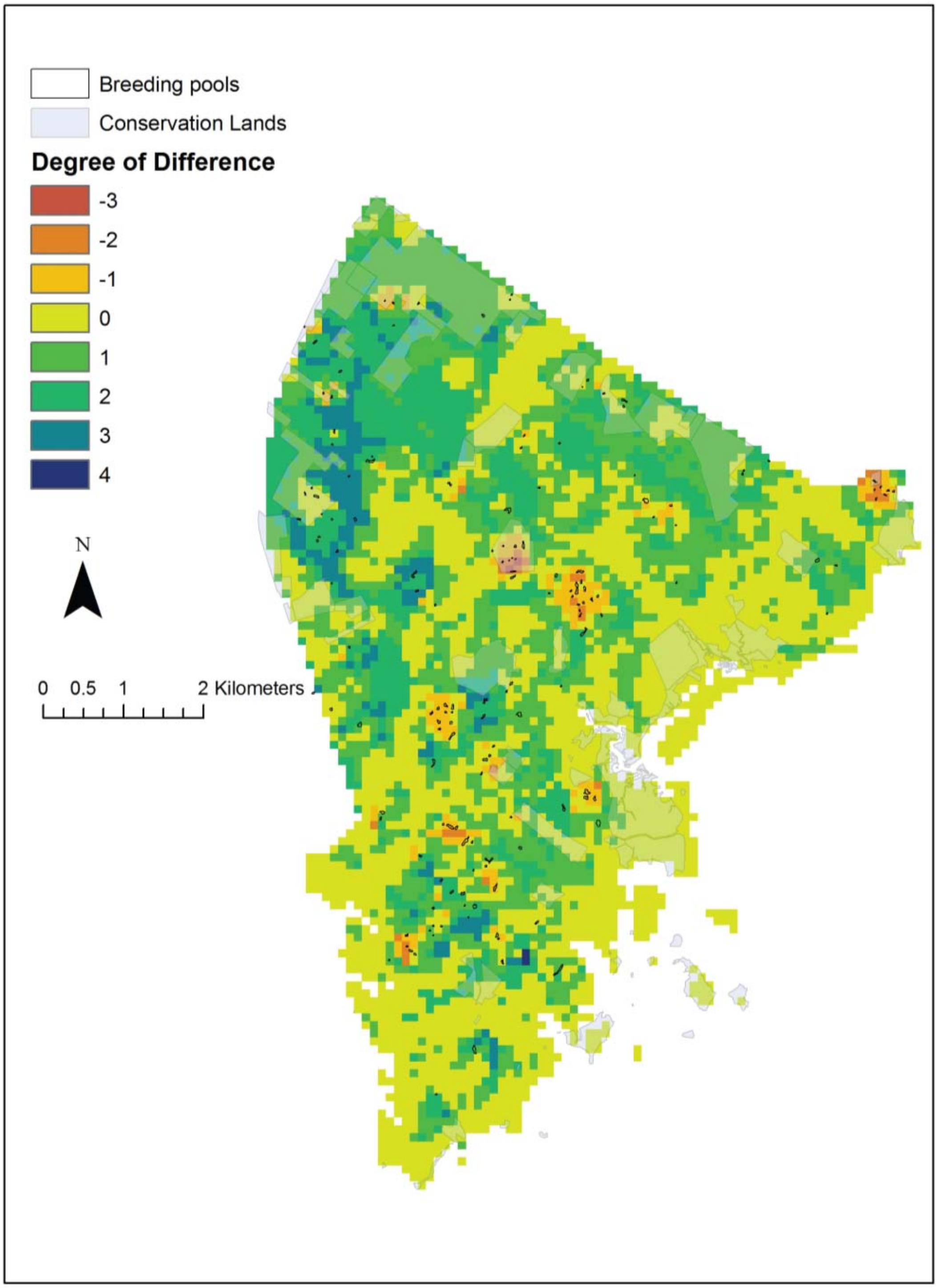
The model presented here adapts resistant kernels to the same study area on which the threat analysis was performed for the purpose of comparing the results. The point file derived from centroids of mapped vernal pools in the study area is converted to habitat kernels using the point density tool (ArcGIS 9.3) with a neighborhood radius of 250 m (the same radius used to produce the potential habitat layer above). The habitat kernel layer produced from points is divided by the landscape resistance raster to produce resistant kernels (appendix fig. 10.2).

Difference Map: Threat Analysis and Resistant Kernel

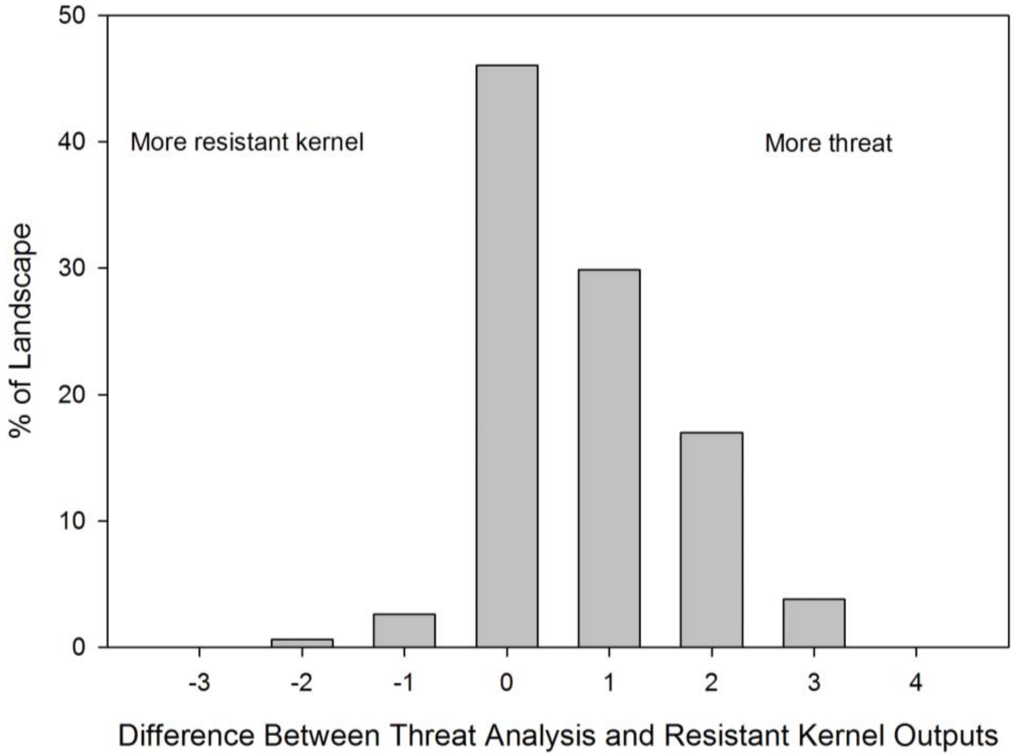
To understand how the model outputs differed, the threat analysis and resistant kernel outputs were reclassified to be on the same scale. Then one was subtracted from the other to create a difference map. The difference map shows those areas where model outputs differed, and by how much (appendix fig. 10.3). These differences are then categorized by percentage of the landscape (appendix fig. 10.4).



Appendix Fig. 10.2. Resistant kernels for seasonal woodland pools (potential amphibian breeding habitat) in the coastal New England (USA) town of Kennebunkport. Kernels are calculated using point density with a 250m radius, modified by landscape resistance values derived from fine-scale classification of aerial photos.



Appendix Fig. 10.3. Difference map comparing outputs of threat and resistant kernel models. Difference model is created by subtracting resistant kernel output from threat analysis output. Negative values are areas where resistant kernel values were higher than threat analysis values, positive values are the opposite, and zero values represent no difference between the models outputs.



Appendix Fig. 10.4. Summary of differences between models as a function of percent area occupied for each difference level.

A Comparison of Models

Nearly half of the study area (46%) had exactly the same outputs for threat analysis and resistant kernel (difference = 0), and 80% of the landscape had very similar outputs (difference –1 > < +1). Differences between the two outputs arise from how the models were constructed. For example, several of the areas with the strongest negative difference values (resistant kernels were identified, but areas of high threat were not) were on lands already protected, which is a component of the threat analysis (appendix fig. 10.3). In addition, threat analysis outputs were much more inclusive; 97% of the difference values were neutral or positive, indicating that more of the landscape was included in the threat analysis (appendix fig. 10.4). This is because threat analysis includes the future development pressure index.

Six clusters of seasonal woodland pools were identified as resistant kernels but not identified as important to protect by the threat analysis (and were not already protected). These represented 20.4% of the total kernel area (2.6% of the study area). Because threat analysis has a temporal dimension (i.e., focuses on both high habitat values and high development pressure), it excludes areas that have high habitat values but are subject to lower development pressure. Resistant kernels, on the other hand, do not make this judgment. Rather, they simply select those clusters of pools that are currently the most connected and thus probably the most viable for wildlife populations.

Conclusions: Models and Conservation Planning

Seasonal woodland pools and other short-hydroperiod aquatic systems are underprotected by regulations, and thus the conservation of the fauna that depend upon them is likely to hinge, at least in the short term, on actions taken by land trusts, wildlife conservancies, and other grassroots conservation efforts (Oscarson and Calhoun 2007; Baldwin and deMaynadier 2009). Deciding where and when to protect habitat is the realm of the rapidly expanding field of conservation planning: such tools should be applied to identifying critical wetland habitats and assessing their exposure to risk.

GIS is a decision-support system that can provide valuable guidance for setting conservation priorities. Yet, as a decision-support system for wetland conservation, priority setting using GIS is only as useful in as far as the models employed match the problems at hand. No one model is correct, but some models may fit the goals better than others. It is of utmost importance, then, that conservation planners understand the construction of the models they are using. This includes model assumptions, data quality, model structure (e.g., the math), and presentation of outputs (issues such as choosing color ramps can influence visual interpretation).

Models for conservation planning other than the ones presented here include those for representation and reserve selection (e.g., MARXAN); for modeling connectivity among pairs of patches (e.g., CorridorDesigner) or multiple patches (e.g., Circuitscape, FunConn); and for modeling viability of populations of selected species (e.g., RAMAS GIS). Each one has unique applications that should be understood prior to embarking on any priority-setting exercise. As an emerging science, conservation priority setting is dynamic, and wetland conservationists and planners should collaborate with biologists who are familiar with the structure and function of these models and can help interpret and adjust conservation scenarios.

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