The effectiveness and applicability of indicator species in long-term monitoring of environmental changes in New England forest

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Abstract

With the increase in the occurrence and frequency of forest disturbances, ecologists and conservation biologists are commonly using some selected species, such as amphibians, as indicator species (IS) for monitoring of environmental changes, assessing the efficacy of management, and providing warning signals for impending ecological shifts. However, this method is limited by at least three issues. First, the impacts of the anticipated environmental changes on the abundance and distribution of these indicators species are not fully understood. Second, these simple, non-destructive, and cost-effective sampling methods that are commonly used to evaluate relative abundance of these indicators are not standardized with total population size, which creates problems when monitoring changes and dynamics of these candidate indicators. Finally, when applied to management, there are discrepancies about the limitations of the existing methods these are not fully quantified when assessing the potential of these indicators.

The objective of this study is to assess the potential of two amphibians species, Eastern Red-backed Salamander (*Plethodon cinereus* (Green)) and Eastern Red-spotted Newt (*Notopthalmus viridescens viridescens* Rafinesque), as indicator species of forest disturbances at Harvard Forest, located in Petersham, Massachusetts, United States. Specifically, I 1) assess the impacts of these focal species to decline of hemlock forests in Harvard Forest; 2) calibrate abundance indices of *P. cinereus* based on artificial and natural objects surveys with a population size estimator based on depletion sampling; and 3) assess the potential of these salamanders as indicator species by developing an objective and multimetric method.

My results showed that decline of Eastern Hemlock (*Tsuga canadensis*) forests due to invasive insects has increased the occupancy of *P. cinereus* but significantly reduced its estimated abundance and detection probability. Similarly, the estimated abundance of *N. v. viridescens* also declined dramatically after hemlock decline. The anticipated transition from forests dominated by *T. canadensis* to mixed-hardwood may alter the abundance and detection probability of both salamander species by up to 50%. Abundance indices based on both cover board and natural object surveys were able to be calibrated using density estimates of *P. cinereus* derived from depletion (removal) surveys. The cover-board abundance index was eight times higher than the estimated density of *P. cinereus*, whereas the natural object survey was half the size of the density estimator. I introduced the Indicator Species Potential (ISP) index – a multi-metric method to quantify the efficacy of indicator species in classifying sites, monitoring ecological changes, and assessing desired management conditions. When applied to salamanders as potential indicators of changes in forests in Massachusetts, the ISP suggests that *P. cinereus* is a reasonable indicator for ecological change in hemlock stands whereas *N. viridescens* is a

potential IS in mixed hardwoods. Overall, the ISP shows promise as a method for summarizing ecological and statistical information about potential IS in a single value.