Fish species of greatest conservation need in wadeable Iowa streams: relative importance of spatial scales

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Conservation of freshwater ecosystems is a common goal of resource managers, and understanding species distributions and habitat requirements greatly increases the probability of successful ecosystem restoration or preservation. Furthermore, understanding species-habitat relationships can provide insight on the effects of land use practices, habitat alterations, and climate change on species distributions (Rowe et al. 2009). As habitat loss and degradation continue to threaten fish biodiversity in North America, species distribution models are playing an increasingly important role in conservation. Nonetheless, predicting the distribution of fish species is challenging because fish species occurrences are influenced by a combination of abiotic and biotic processes acting across multiple spatial and temporal scales.

In Iowa, 68 of approximately 144 fish species are classified as species of greatest conservation need (SGCN), and protecting and enhancing habitats to improve their status is priority. However, the distribution and habitat associations of many Iowa stream fish species are poorly understood. Therefore, understanding factors influencing the occurrences of stream fauna at multiple spatial scales is important for guiding conservation efforts. The objectives for this study were to 1) develop models to predict the occurrences of fish SGCN using habitat variables measured at a large scale, small scale, and at multiple scales, 2) identify important large- and small-scale habitat features that influence species occurrences, and 3) evaluate the relative influence of large- and small-scale habitat variables on species occurrences.

During spring and summer 2009 and 2010, fish assemblages and instream habitat characteristics were sampled from 84 wadeable (i.e., 2nd - 5th order) stream reaches located in the Mississippi River drainage of Iowa. We took an exploratory approach to identify habitat variables measured at multiple spatial scales that influence the occurrences of seven selected fish SGCN using multiple logistic regression analyses. An information-theoretic approach was used (Burnham and Anderson 2002). Specifically, models were created to predict the occurrences of each species using all possible combinations of five large-scale (i.e., GIS-measured) variables, thirteen small-scale (i.e., instream) variables, and all eighteen variables measured at both scales. Confidence model sets were selected from all possible variable combinations based on Akaike information criterion (AIC) and used to create model-averaged models. All models with a ΔAIC ≤ 6 were included in a confidence model set, and model-averaged parameters were calculated by weighting coefficient and intercept values for each model in the confidence model set by their respective Akaike weight to account for model selection uncertainty. Model-averaged predictions of species presence and absence were compared to actual presences and absences to calculate Cohen's kappa (κ) value as the primary measure of model performance (Cohen 1960). Kappa value is an index used to assess correct classification of occurrences relative to what would be expected by random chance. Kappa values equal to or less than zero indicate model performance no better than random chance, whereas a kappa value of one indicates perfect model performance. Kappa values were used to assess the performance of models, and evaluate the relative influence of habitat variables measured at each spatial scale on species occurrences. Furthermore, we used an independent dataset from a previous study (Rowe et al. 2009) to validate our species occurrence models and test model generality.

Table 1. Cohen's kappa values for seven fish species occurrence models.

	Large-scale		Small-scale		Multiple-scale	
Species	κ	*P* -value	κ	*P* -value	κ	*P* -value
Banded darter	0.54	<0.001	0.60	<0.001	0.64	<0.001
American brook lamprey	0.14	0.118	0.21	0.041	0.27	0.011
Ozark minnow	0.27	0.007	0.39	0.001	0.51	<0.001
Blackside darter	0.37	0.001	0.33	<0.001	0.54	<0.001
Southern redbelly dace	0.51	<0.001	0.40	<0.001	0.58	<0.001
Longnose dace	0.75	<0.001	0.77	<0.001	0.88	<0.001
Central mudminnow	0.47	0.047	0.74	<0.001	0.70	<0.001

All models explained the occurrence of species significantly better would be expected by random chance ($\kappa > 0$, $P \leq 0.05$), except the large-scale model for American brook lamprey *Lampetra appendix* (Table 1). On average, multiple-scale models performed better than large- or small-scale models, and small-scale models performed better than large-scale models (Figure 1). Comparisons of model performance for each species revealed that large-scale variables were noticeably more effective for explaining the occurrence of southern redbelly dace *Phoxinus erythrogaster* than small-scale variables. In contrast, small-scale models explained the occurrences of American brook lamprey, Ozark minnow *Notropis nubilus*, and central mudminnow *Umbra limi* noticeable better than large-scale models. Ultimately, the inclusion of both large- and small-scale variables in multiple-scale models resulted in the greatest model performance for six of the seven evaluated species, including banded darter *Etheostoma zonale*, blackside darter *Percina maculata*, and longnose dace *Rhinichthys cataractae*. When applied to an independent dataset, large-scale models predicted the occurrences of four species significantly better than random chance (Table 2). Small-scale models only predicted the occurrences of two species better than chance with the independent dataset, but were more accurate than the large-scale models. Nonetheless, multiple-scale models exhibited the greatest generality and predicted the occurrences of three species better than single-scale models with the

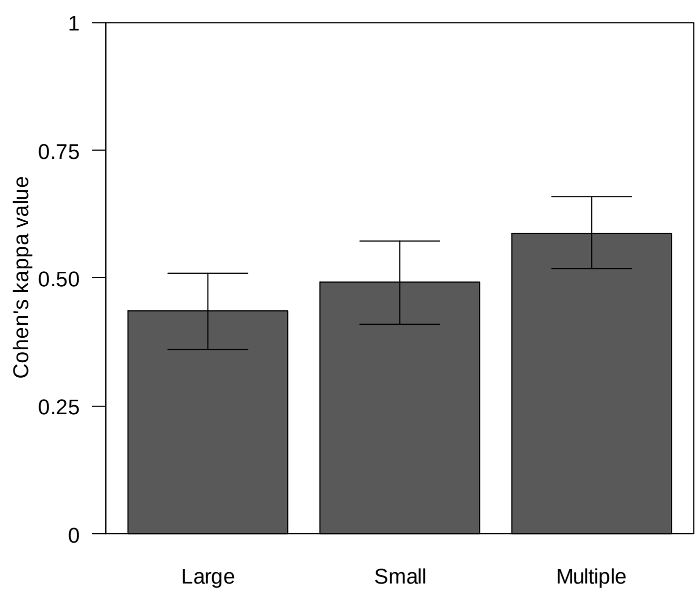

Figure 1. Mean Cohen's kappa value for large-scale, small-scale, and multiple-scale species occurrence models.

independent dataset. In addition to evaluating the relative influence of large- and small-scale habitat variables on species occurrences, our results showed that each species exhibiting a unique set of associations with both large- and small-scale habitat variables.

Table 2. Cohen's kappa values for seven fish species occurrence models applied to an independent dataset.

	Large-scale		Small-scale		Multiple-scale	
Species	κ	*P*-value	κ	*P*-value	κ	*P*-value
Banded darter	0.33	0.021	0.48	0.016	0.66	0.004
American brook lamprey	0.52	0.006	0.08	0.309	0.41	0.026
Ozark minnow	0.06	0.363	0.07	0.353	0.24	0.242
Blackside darter	0.19	0.105	0.17	0.152	0.18	0.169
Southern redbelly dace	0.35	0.009	0.10	0.236	0.44	0.002
Longnose dace	0.40	0.019	0.53	0.018	0.68	0.002
Central mudminnow	0.44	0.167	-0.14	0.764	0.25	0.236

Understanding factors that constrain the distribution of fish species across spatial scales is vital to conservation success. Although factors measured at large scales are likely to influence habitat conditions and thus biota at smaller scales, these factors only represent the average of small-scale conditions. The performance of our models compliments other studies that have found large-scale features to explain variability in species occurrences. However, we also showed that the most influential spatial scale and habitat variables are species-specific. Thus, the most appropriate approach for addressing serious conservation and management questions is to gain an understanding of the factors that constrain the distribution of species at multiple spatial scales pertaining to the specific species and system. Furthermore, fish SGCN exhibited a wide variety of habitat associations across spatial scales. Therefore, conservation of biodiversity requires managing for habitat complexity across a broad spectrum of landscapes and environmental gradients.

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