Assessment of stream suitability to round goby invasion based on information from currently invaded Lake Michigan tributaries

Methods as described in Kornis, M.S. and M.J. Vander Zanden. 2010. Forecasting the distribution of the invasive round goby (Neogobius melanostomus) in Wisconsin tributaries to Lake Michigan. Canadian Journal of Fisheries and Aquatic Sciences. **67**(3): 553-562.

Our objectives were to develop a model for round goby presence and absence based on their distribution in Wisconsin (U.S.A.) tributaries to Lake Michigan and to apply model predictions to forecast future invasion potential. We were precluded from using native range data because round gobies are historically limited to large lakes and the lower reaches of large rivers.

Round goby distribution data were obtained from a field survey of all Wisconsin tributaries to Lake Michigan (130 sites on 73 streams). For a given stream, sampling began at or near the mouth and continued at discrete sites (at least 1 km apart) upstream until no round gobies were detected. If round gobies were not present at a sampling site, we assumed they would be absent upstream of that site as well. Two collection methods were required to adequately sample the wide range of stream sizes in our study. Wadeable sites (<1m in depth) also exhibiting high water clarity were sampled using a battery-powered backpack electrofishing unit with pulsed DC current. Such sites were electofished for 20 minutes at a current of 3.5 to 4.0 amps, with special focus on optimal substrate (cobble or boulder). Sites with low water clarity and/or depths greater than 1m were sampled using an overnight set of 10 cylindrical, wire-mesh, Gee-style minnow traps baited with chicken liver. Traps were set near optimal substrate if available to maximize the likelihood of detecting round goby presence. Both methods are recommended for capturing round gobies (Phillips et al. 2003; Diana et al. 2006). Probability of detection for both methods was assumed to be 1 in areas of high round goby abundance. Probability of detection at sites where round gobies were rare was 0.75 for electofishing (determined by repeated sampling of sites where only 1 round goby was initially captured). Probability of detection using minnow traps was not calculated but assumed to be at least 0.75 because round gobies were more frequently detected by minnow traps than electrofishing and traps usually captured high numbers of round gobies if they were present (geometric mean of 9.7 round gobies per set of 10 traps).

We compiled habitat information for Wisconsin streams from various sources. Water temperature, conductivity, bankfull width, stream depth, and percent substrate composition were measured locally at each site by the field survey team. Landscape-scale variables (watershed area, percent land use, stream gradient, watershed slope, soil permeability, base-flow index, and mean July air temperature) and the coordinates of dams were obtained from a global information system (GIS) database provided by the US Geological Survey, Great Lakes Aquatic GAP Analysis Project. Landscape-scale variables were calculated on the scale of confluence-bound stream segments.

We used generalized linear mixed models (using the "logit" or logistic regression function) to model round goby presence/absence based on habitat factors in Wisconsin tributaries to Lake Michigan. Such models output the probability of round goby presence for a given site based on the predictor variables. Models were initially evaluated using the Bayesian information criterion (BIC) to select among models based on predictive ability. Best subsets analysis was used to

extract the 20 best models (based on BIC score) from all possible models (i.e. all possible combinations of predictor variables). To test each of these models on independent data, each model was validated using k-fold cross validation as recommended for presence/absence models by Fielding and Bell (1997). Receiver operating characteristic (ROC) curves were used to determine the probability threshold distinguishing "predicted present" from "predicted absent"; thresholds were selected using the minimized difference threshold (MDT) criterion, which selects the probability value that minimizes the difference between sensitivity and specificity (Jiménez-Valverde and Lobo 2007).

We used Cohen's Kappa, which measures the proportion of agreement between actual and predicted data, as the primary statistic of model performance. This allowed us to evaluate each of the 20 models in our candidate set for their ability to perform on independent data (generated from the k-fold cross validation). This criterion was most appropriate given our goal of using our model to forecast round goby presence/absence at sites yet to be invaded. The best model based on this criterion included watershed area, stream gradient, and watershed slope as predictor variables and was used to generate the forecasted range maps presented on this webpage.

For Wisconsin tributaries to Lake Michigan, the model had a misclassification rate of 20%. The model identified 1369 km of stream downstream of impassable fish barriers (dams) as vulnerable to round goby invasion. Currently, round gobies only occupy 20% (280 km) of these streams, indicating a large potential for continued spread of round gobies in tributaries in the future. The model also identified 7482 km of streams upstream of impassable fish barriers as vulnerable to round goby invasion. To invade these streams, round gobies would need assistance from humans. This illustrates the vast potential for round gobies to invade inland streams and highlights the importance of educational campaigns and species movement regulations in preventing the spread of round gobies (and other invaders) upstream of dams.

References:

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