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[Article]

Predictive Value of a Lake Sturgeon Habitat Suitability Model

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Abstract.—Although many fish habitat suitability models (HSMs) have been developed and used in wildlife management and conservation planning, comparatively few have been independently validated. Given the importance of such models in habitat management and conservation policy, the extent to which they accurately predict population parameters (e.g., abundance or recruitment) is a critical issue. Here we apply an HSM recently developed for lake sturgeon *Acipenser fulvescens* in northern rivers to three reaches of the Ottawa River, using measurements of the model's key variables (substrate type, water depth, and velocity) to generate spatially explicit predictions of habitat suitability. We then test the predictive power of the model by comparing lake sturgeon catch per unit effort (CUE) when using short-set gill nets in areas predicted to have good (habitat suitability index values >0.6) and poor (values < 0.3) adult and juvenile foraging habitats. Consistent with model predictions, significantly more lake sturgeon were caught at sites within river reaches predicted to be of high quality than at those predicted to be of low quality. Moreover, the average CUE at the reach scale correlated positively with the average predicted habitat foraging quality. On the other hand, the predictive power was generally low, such that most of the variation in CUE was unexplained by the fitted models. These results suggest that although the lake sturgeon HSM developed for northern rivers has some predictive power in other contexts, the uncertainty of its predictions is still rather high. We suggest that (1) considerably more effort be devoted to the independent validation of both existing HSMs and those still in development and (2) in the absence of independent validation and bona fide estimates of their predictive power, such models be used circumspectly in conservation management and planning.

In Canada and the United States, habitat loss and degradation (McAllister et al. 1985; Beamish et al. 1986) are the most pervasive risks to aquatic biodiversity in general and to species of concern in particular. Mitigating these risks requires that we both characterize the habitat requirements of species of concern, and manage human activities so as to maintain habitat of sufficient quality and quantity to ensure the persistence of these species. To this end, habitat suitability models (HSMs) have become increasingly popular: the U.S. Geological Survey (USGS) alone has developed HSMs for 158 species, including 53 species of fish, after a large initiative in the 1980s (U.S. Geological Survey 2007). Many more fish HSMs have been developed independently of the USGS initiative (Threader et al. 1998; Rubec et al. 1999; Guay et al. 2003).

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Habitat suitability models have been developed to evaluate the quality and quantity of habitat for a number of species (O'Neil et al. 1988); to assess the impact of both past or future management activities (O'Neil et al. 1988; Bray 1996; Brooks 1997; Roloff and Kernohan 1999); to assess changes in habitat quantity or quality (Bray 1996); and to link population changes to habitat supply (Chu et al. 2006). The strength of habitat models lies in their potential to explicitly represent limiting habitats that can then be used as concrete targets for conservation action and protection (Boisclair 2001). But whereas HSMs have been used extensively to manage habitat for fish species of interest or concern, comparatively few have been independently validated (Layher and Maughan 1985; Brooks 1997; Rubec et al. 1999; Ortigosa et al. 2000; Morris and Ball 2006; Vinagre et al. 2006) in the contexts in which they were first derived or tested in another context (Fausch et al. 1988).

The issue of validation is critical. Many HSMs were developed on the basis of expert opinion, often using data that were, at best, unsystematically collected

(Rubec et al. 1999). The performance (i.e., predictive power) of the comparatively few HSMs that have been independently validated is underwhelming (Roloff and Kernohan 1999), leading some to question their general reliability (Cole and Smith 1983). In some cases, where predictive power has been assessed, the data used to construct the model were also used in the validation process—a form of pseudoreplication that can lead to the overestimation of model performance (Olden et al. 2002).

Another potential issue with HSMs in wildlife and fisheries management is their spatial scale (Reyjol et al. 2001; Store and Jokimäki 2003). Habitat protection, rehabilitation, or remediation can, at least in principle, be conducted at a wide range of spatial scales: within reaches, among reaches within rivers, or among rivers. Many HSMs have been developed at comparatively large (regional) scales (Threader et al. 1998; Rothley 2001), but conservation and rehabilitation efforts often occur at smaller (local) scales (e.g., Mathys et al. 2006; Vinagre et al. 2006). Thus the question naturally arises as to the extent to which an HSM developed at large scales (e.g., to inform among-river variation in demographic parameters) can be used to define habitat protection or remediation efforts at smaller scales (e.g., among reaches within the same river).

Lake sturgeon *Acipenser fulvescens* are endemic to North America and historically were considered abundant (Harkness and Dymond 1961; Scott and Crossman 1973). However, populations have declined precipitously throughout their ranges and are currently considered at risk in many states and provinces (Williams et al. 1989; Kempinger 1996; Williamson 2003), habitat degradation resulting from dams having been implicated as an important threat. Identifying and evaluating habitat requirements and limiting factors would therefore seem to be an important element in devising conservation strategies and habitat protection measures.

A lake sturgeon HSM for medium-sized, slow-flowing rivers in northern Ontario (e.g., the Moose River basin) was developed by Threader et al. (1998). The objective of this study is to assess the performance of this model on a different river system. Specifically, we develop a spatially explicit form of the lake sturgeon HSM, apply this version to three reaches of the Ottawa River by using measurements of the model's key variables (substrate type, water depth, and velocity) to generate spatially explicit predicted habitat suitabilities, and test the predictive power of the HSM by correlating predicted habitat suitability with observed lake sturgeon abundance, both within and among reaches.

Study Site

This study was conducted in three reaches of the Ottawa River: Upper Allumette Lake, Lower Allumette Lake, and Lac des Chats. The Ottawa River is a large river in eastern Ontario and western Quebec with a watershed of 146,000 km^2 and a mean annual discharge of approximately 2,000 m^3/s; the river has undergone extensive hydroelectric development within the main stem and many tributaries. Upper Allumette Lake and Lower Allumette Lake represent two unimpounded reaches in the Ottawa River. However, in both cases, flows are controlled by hydroelectric dams upstream, whereas Lac des Chats is an impounded reach: a hydroelectric dam was constructed at the outflow in 1932 and another at the main inflow in 1948 (for a more detailed description of these reaches, see Haxton and Findlay 2008). The lake sturgeon populations in Upper Allumette Lake and Lower Allumette Lake appear to be robust (i.e., comparatively large numbers of fish of various sizes were sampled with standard index netting practices [Haxton and Findlay 2008]), whereas the population in Lac des Chats is in a considerably poorer condition (i.e., few large lake sturgeon were sampled in standard index netting [Haxton and Findlay 2008]).

Methods

The lake sturgeon HSM (Threader et al. 1998) has two submodels, one for reproduction and the other for foraging; here we evaluate only the foraging submodel. This submodel includes three habitat variables—bottom substrate, water depth, and water velocity—all of which are considered to affect the distribution and abundance of lake sturgeon in foraging habitats (Threader et al. 1998).

The foraging component (C_F) of the HSM comprises adult ($C_{F\text{-}A}$) and juvenile ($C_{F\text{-}J}$) foraging habitat. Bottom substrate ($V_{\mathrm{bs},A}$) is the only variable in the HSM that determines the quality of adult foraging habitat; it is used as a surrogate for benthos production, the assumption being that the more productive habitat for benthic invertebrates represents better foraging habitat for lake sturgeon (Threader et al. 1998). In the original model (Threader et al. 1998), suitability indices for adult and juvenile foraging were presented for each substrate type (Table 1), suitability ranging from 0 (completely unsuitable) to 1 (most suitable). The substrate suitability index, V_{bs}, is given by

$$V_{\mathrm{bs}};\, j = \sum_{i}^{k} s_{ij} c_i,$$

where j denotes the age-class (adult or juvenile), i is the substrate type, k is the total number of substrate types,

TABLE 1.—Foraging suitability indices for adult and juvenile lake sturgeon, by substrate type (Threader et al. 1998).

Substrate	Adults	Juveniles
Clay	0	0.2
Silt	1.0	1.0
Sand	0.7	1.0
Gravel	0.6	1.0
Cobble	0.5	0.8
Boulder	0.2	0.5
Bedrock	0	0.2
Detritus	0	0

s_{ij} is the suitability index of substrate i for age-class j, and c_i is the proportion of the area under consideration of substrate type i.

Juvenile foraging habitat ($C_{F\text{-}J}$) is based on bottom substrate ($V_{\mathrm{bs},J}$; Table 1; equation 1), water foraging depth (V_d; Figure 1), and juvenile foraging water velocity (V_v; Figure 1). The juvenile foraging habitat score is a geometric mean given by equation (2):

$$C_{F-J} = (V_{\mathrm{bs},J} \times V_d \times V_v)^{1/3}.$$

The overall C_F for a given location (i.e., a pixel in this spatial model) is considered to be the smaller value of $C_{F\text{-}A}$ or $C_{F\text{-}J}$.

The lake sturgeon HSM (Threader et al. 1998) was developed as an aspatial model and therefore has two important limitations for habitat management. First, fish habitat management and conservation are often spatially explicit, that is, designed to mitigate habitat threats or conserve optimal values at particular locations (Rubec et al. 1999). In such circumstances, the practical utility of an HSM is based on its ability to predict habitat suitability and presumably species abundance or likelihood of occurrence at particular sites or locations (Vinagre et al. 2006). Second, an important empirical issue in HSM validation is the extent to which models developed for one spatial scale (e.g., river basins or rivers) can be applied—with reasonable predictive power—at other scales. Habitat suitability models with reasonably good predictive power that are independent of scale over the range of scales pertinent to most habitat management issues are more valuable than those whose predictive power applies only to a narrow range of scales, all else being equal. Only spatially explicit HSMs allow for empirical assessment of predictive performance over a range of

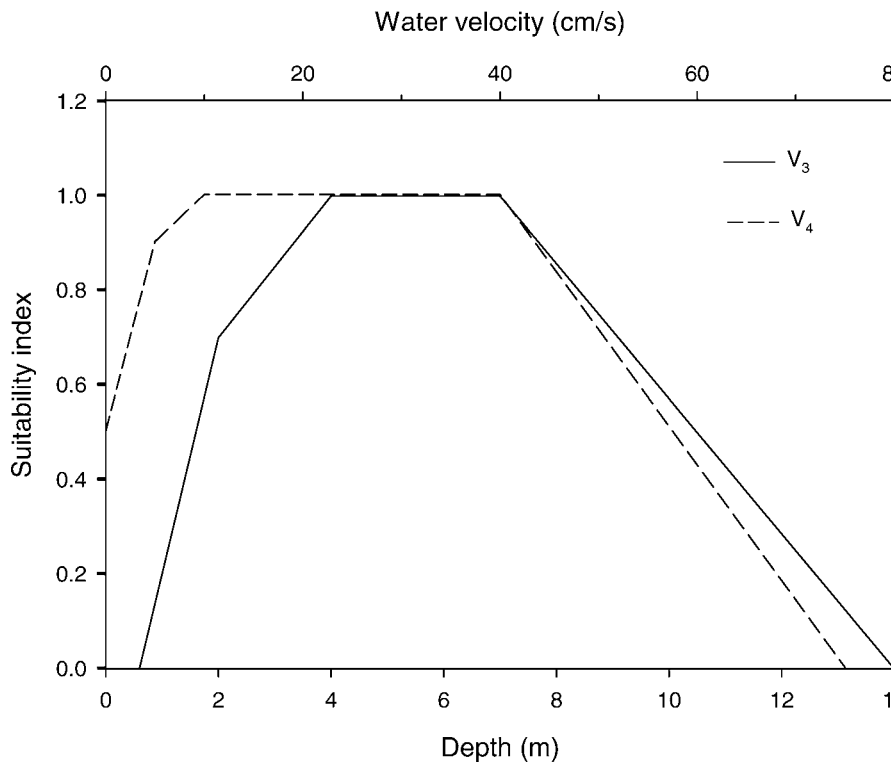


FIGURE 1.—Juvenile habitat suitability in relation to foraging depth (V_3) and water velocity (V_4), as adapted from Threader et al. (1998).

spatial scales. To address these two limitations, we developed a spatially explicit version of the lake sturgeon HSM using ArcMap 9.1 (ESRI [Environmental Systems Research Institute], Redlands, California] to address these two issues, a technique that has been used for other species [e.g., Rubec et al. 1999; Ortigosa et al. 2000]).

Spatial HSM.—The spatial application was developed by generating look-up tables for habitat suitability and substrate class (Table 1) and equations expressing suitability as a function of current velocity and depth (Figure 1; Threader et al. 1998). Rasters at 10-m spatial resolution were developed for each substrate class (e.g., clay, silt, sand, detritus, gravel, rubble, boulder, and bedrock) and water depth. We used this information to calculate a habitat suitability index (HSI) for each pixel and the appropriate elements. For example, when calculating $C_{F\text{-}A}$, we multiplied each pixel in a raster by its corresponding suitability index; the scores for each pixel in each raster were then summed to provide a value for that pixel in the output raster ($0 \leq x \leq 1$, where x is the HSI score for that pixel).

The overall C_F is the mean of all pixels in the reach based on the smaller of $C_{F\text{-}A}$ or $C_{F\text{-}J}$ at a pixel is described by

$$C_F = \frac{1}{n}\left(\sum_{i}^{k} s_{ij}c_i\right),$$

where n is the number of pixels in the area of interest (i.e., river reach), i is the substrate type, k is the number of substrates, $s_i = \min(s_{i,A}, s_{i,J})$ is the suitability index of the ith substrate (taken as the smaller of its suitability for adults or juveniles), and c_i is the proportion of substrate type i in the pixel.

Determination of habitat variables.—Habitat sampling stations were established in each of three Ottawa River reaches: Lower Allumette Lake, Upper Allumette Lake, and Lac des Chats (Figure 2). The distance between stations was initially set at 100 m but was later increased to 300 m because the observed changes in habitat (e.g., relief in bathymetry, vegetative community, etc.) often occurred at scales greater than 100 m. Altogether, 680 stations were sampled in Lac des Chats, 154 in Lower Allumette Lake, and 126 in Upper Allumette Lake, representing sampling densities of 8.9, 4.2, and 4.3 per 100 ha respectively.

At each station, an Aqua Vu (an underwater video camera) was used to describe the bottom substrate (e.g., % boulders, rock rubble, detritus, logs, etc.); in soft bottom locations, a sample of bottom substrate was collected with an Eckmann dredge. Bottom substrate at a sampling station was quantified as percent composition of different substrate types (e.g., 50% clay, 30% sand, and 20% detritus). Data were captured directly into an attribute table on a Pencentra hand-held data logger with Global Positioning System (GPS) capabilities and were downloaded to a personal computer as a point shapefile at the end of each sampling day with Autosync. ArcMap was used on the Pencentra to aid navigation on the water body and facilitate collection of GPS locations for each sampling station. Given the depth and width of the river, current velocity was low and within the suitability range established for juvenile sturgeon (i.e., <40 m^3/s; Figure 1); measurements taken by Ontario Power Generation using an RDI Acoustic Doppler Current Profiler in Lower Allumette Lake (in an area of higher flow at the widening of the river downstream of the rapids) confirmed that flows were generally less than 40 m^3/s during midsummer (Ontario Power Generation, unpublished data). Water velocity measurements were therefore not taken at each sampling site. As such, V_v was set to 1 for all sampling locations (i.e., flows were assumed to be between 10 and 40 m^3/s during periods of low flow from mid- to late July).

The point shapefiles were interpolated using kriging in ArcInfo 8.3 (ESRI) to calculate rasters for each substrate type at 10-m resolution; a search radius of 12 points and a maximum distance of 750 m were the constraints placed on the kriging process. Existing bathymetry maps of the Ottawa River produced by Canadian Hydrographic Services were georeferenced in ArcMap 8.3, digitized as point files, and interpolated using Topogrid to produce a depth raster. This process produced predicted habitat suitability maps for both juvenile and adult sturgeon from habitat attributes interpolated from the sampling stations in each river reach (Figure 3).

Habitat attribute validation.—The accuracy of the habitat rasters was assessed by means of 156 random test plots in the three reaches. At each plot, habitat variables were measured directly as described above. Universal Transverse Mercator coordinates were obtained at each plot using a Garmin *e*Trex (Garmin International, Inc., Olathe, Kansas), and a point shapefile was created for all test plots. Interpolated (predicted) values for each substrate raster at each test plot were obtained by using Hawth's Analysis Tools version 2.10 (Beyer 2004) in ArcMap. A 100-m-diameter buffer (50-m radius) was created around each plot (sample point) to account for any error with GPS readings. The average HSI value for this area, based on interpolated habitat variables, was calculated by using the zonal statistics procedure in ArcMap. In this manner, for each test plot, we obtained both the observed (as assessed through direct sampling) and predicted (based on spatial interpolation) habitat

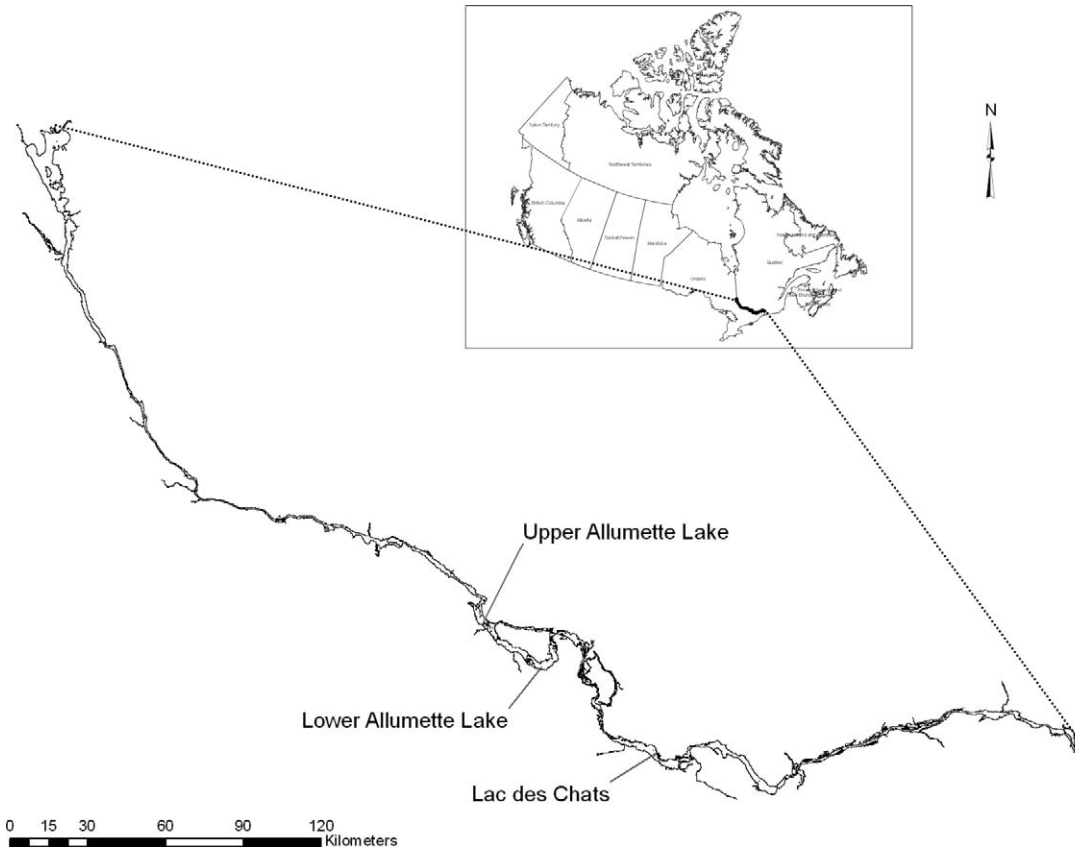


FIGURE 2.—Map depicting the study areas used to validate the habitat suitability model.

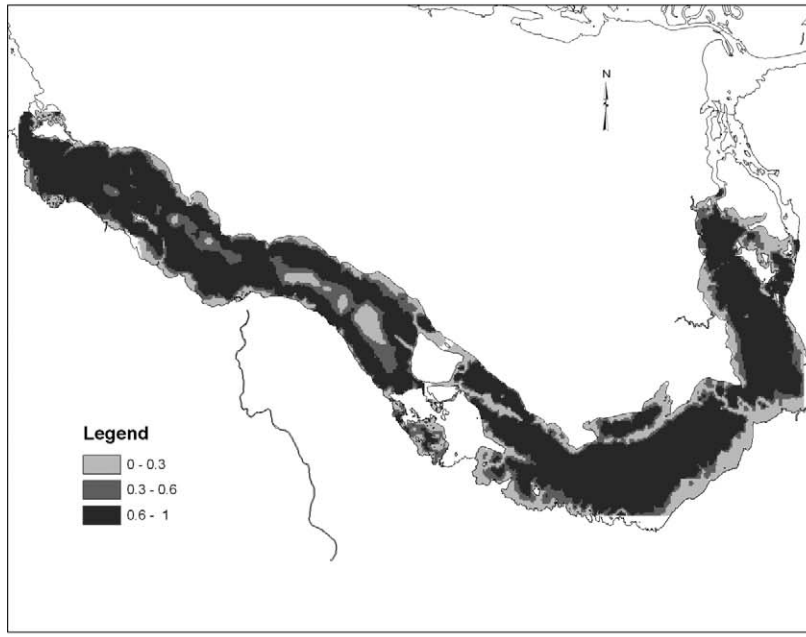
attributes, which provided a direct assessment of interpolation accuracy.

Evaluation of the HSM.—The HSM was evaluated on two Ottawa River reaches with reasonably robust lake sturgeon populations: Lower Allumette Lake and the lower portion of Upper Allumette Lake. Rasters were produced for adult and juvenile foraging suitability based on interpolated habitat characteristics. Data for model validation were obtained by using paired short-set gill nets in sites predicted to represent either low (HSI scores of 0–0.3; hereafter referred to as poor habitat) or high suitability (HSI scores of 0.6–1.0; hereafter referred to as good habitat), based on interpolated habitat characteristics derived separately for both adult and juvenile foraging habitat. We selected the extremes of the interpolated habitat gradient to maximize the chances of detecting a relationship between habitat quality and abundance, keeping in mind that if no differences in abundance are observed at the two extremes of the (predicted) habitat suitability gradient, then the model by definition has little predictive power.

Netting sites in 2004 were chosen based only on interpolated HSIs from the HSM; if on-site measurements indicated that the interpolated HSI was incorrect (e.g., the observed HSI was greater than 0.3 when the HSM predicted the HSI to be less than 0.3), the samples were removed from the analysis (hereafter referred to as incorrectly placed net sets). In 2006, all candidate net sites were evaluated to ensure that the predicted (interpolated) and observed HSI classifications matched or that nets were set in the correct target habitat (e.g., poor versus good, as determined from on-site measurements rather than interpolations).

Juvenile and adult lake sturgeon were sampled with small-mesh (2.5–15.2-cm) and large-mesh (17.8–30.5-cm) gill nets, respectively, both 76 m long. Netting was conducted between 0800 hours and 1800 hours from July 26 to August 11, 2004, and from July 10 to July 21, 2006, to concentrate sampling efforts at times when lake sturgeon are foraging (i.e., not at their spawning grounds). For juvenile or adult habitat, two nets of the same mesh size were set within 500 m of each other for 90–120 min, one in habitat predicted to be poor and the

(a)



(b)

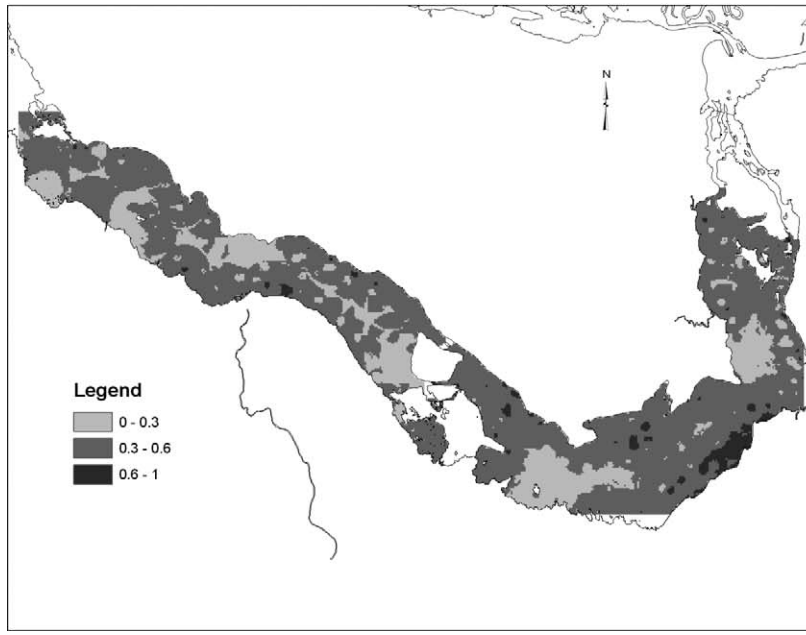


FIGURE 3.—Predicted habitat suitability for **(a)** juvenile and **(b)** adult lake sturgeon on Lower and Upper Allumette lakes derived from the habitat suitability model (Threader et al. 1998) and spatial interpolation of habitat characteristics from 280 sampling locations.

other in habitat predicted to be good. Nets were set for short durations to minimize lethal bycatch and to maximize the likelihood of catching foraging lake sturgeon rather than transients moving between habitats. All lake sturgeon were tagged on the dorsal fin with a numbered Monel tag, measured for TL (cm), and released. Individuals less than 80 cm TL were considered juveniles, individuals greater than 80 cm TL and less than 115 cm TL were considered subadults, and individuals greater than 115 cm TL were considered adults (Haxton, unpublished data).

It is unknown whether short net sets, such as those used in our study, provide abundance data comparable to that found with nets sets of longer duration. To address this issue, we compared the results obtained from short-term net sets with data from two standard index netting techniques (nearshore community index netting [NSCIN] and fall walleye index netting [FWIN]). The former requires the use of 1.8- and 2.4-m trap nets randomly set (the river shoreline was stratified into 2,000-m sections and numbered; netting locations were determined by randomly selecting a section) for 24 h beginning mid-August until water temperatures fall to 13°C; FWIN requires the use of 2.5–15.2-cm stretched-mesh gill nets randomly set (the river reach was sectioned into 1-km^2 quadrants; netting locations were determined by randomly selecting a quadrant) for 24 h in two depth strata (2–5 m and 5–15 m) during the fall, when water temperatures are between 10°C and 15°C. Both techniques effectively sample lake sturgeon (Haxton 2002). Data from these netting techniques were used to evaluate the efficacy of short set nets and the performance of the HSM at a larger spatial scale (i.e., in predicting the relative abundance of lake sturgeon in relation to overall C_F at the between-reach, rather than the within-reach, scale).

To evaluate the HSM, we fitted Poisson and logistic regression models to adult and juvenile lake sturgeon abundance using habitat suitability (good or poor) based on observed site characteristics as the predictor. In the first case, the dependent variable was the number of individuals captured per net set (i.e., relative abundance); in the latter, the dependent variable was the presence or absence of fish in a set. Regression models were fitted both to paired nets correctly placed (based on observed HSI categories [e.g., good or poor] and to all nets correctly placed (based on observed HSI categories without regard to paired placements [i.e., the criterion of nets being set within 500 m was not applied]). Pseudocoefficients of determination (r^2) values for Poisson regressions were determined by dividing the deviance explained by a variable of interest by the total deviance of the model. Potential overdispersion (i.e., larger variance than would be expected from a Poisson assumption) was examined by dividing the deviance by the degrees of freedom.

To evaluate the predictive ability of the HSM at larger spatial scales, we examined the relationship between lake sturgeon CUE (the number of lake sturgeon caught per trap net–night) obtained from standard index netting to the overall C_F for each river reach. A two-way nonparametric analysis of variance (ANOVA) was conducted to assess the effects of reach and netting technique on the overall CUE of lake sturgeon as estimated from the longer net sets.

Poisson regressions were conducted with S-Plus 6.2 (Insightful Corp., Seattle, Washington). All other statistical analysis was conducted with SYSTAT version 11 (SYSTAT Software, Inc., Richmond, California). Results were deemed significant at $P = 0.05$.

Results

Comparison of the observed and predicted habitat characteristics from the 156 validation sites indicated that with interpolation model accuracy was poor for all habitat variables (r^2 range, 0.001–0.33) except water depth ($r^2 = 0.70$). The HSM evaluation was, as a consequence, based only on net sets for which interpolated and observed (on-site measured) data agreed. A total of 73 lake sturgeon were sampled from 164 short-duration net sets, none of which were recaptured during this study. Lake sturgeon CUE was significantly greater in good habitat for adults (Poisson regression; df = 30, $P = 0.024$; $r^2 = 0.16$) and juveniles (Poisson regression; df = 20, $P = 0.005$; $r^2 = 0.23$; Figure 4) sampled with correctly placed paired nets. When all correctly placed nets were used (i.e., not necessarily paired net placements), adult lake sturgeon CUE was significantly greater in good adult habitat than in poor adult habitat (Poisson regression: df = 64, $P < 0.001$; $r^2 = 0.175$; Figure 4), whereas juvenile sturgeon CUE in good habitat was not significantly greater than in poor habitat (Poisson regression: df = 60, $P = 0.12$; $r^2 = 0.03$). Moreover, the proportion of nets with lake sturgeon catches was greater in good habitat than in poor (Figure 5). Overdispersion of Poisson models was not an issue in the aforementioned analyses. Logistic regression using all correctly placed nets indicated that the probability of capturing at least one sturgeon was significantly greater for nets in good versus poor habitat, for both adults (logistic regression: $G = 5.85$, df = 1, $P = 0.016$; McFadden's rho-squared = 0.091) and juveniles ($G = 6.30$, df = 1, $P = 0.012$; McFadden's rho-squared = 0.077; Figure 6).

Lake sturgeon CUE based on standard index netting (FWIN and NSCIN) was greater than that obtained from short-term sets (Figure 7) and was related to both

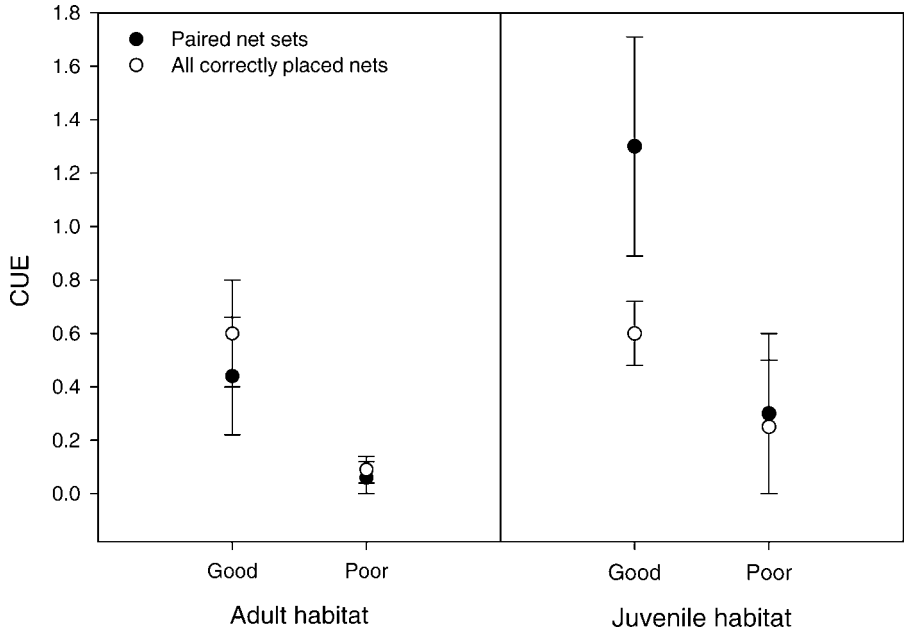


FIGURE 4.—Mean ± SE juvenile and adult lake sturgeon catch per unit effort (CUE [number of lake sturgeon captured per net set]) based on paired net sets and all correctly placed nets in good and poor habitat.

netting technique and reach (two-way nonparametric ANOVA: $H_{2,\ 350} = 33.5$ $P < 0.001$; $H_{2,\ 350} = 15.0$, $P < 0.001$); however, there was no significant interaction between the two factors ($H_{4,\ 350} = 2.1$, $P = 0.077$).

Discussion

The within-reach spatial variation in the observed lake sturgeon abundance correlated with habitat suitability as assessed at a comparatively coarse resolution (poor versus good quality). Similarly, at a larger spatial scale, reaches with higher overall habitat suitability had higher average CUE than did reaches with lower habitat suitability. In both cases, however, the predictive power was low, the explained variation in CUE generally being less than 20%.

Several potential sources of error may be responsible for the comparatively poor performance of the HSM in this study. First, measurement error in habitat variables or sturgeon CUE may be substantial. Accuracy in

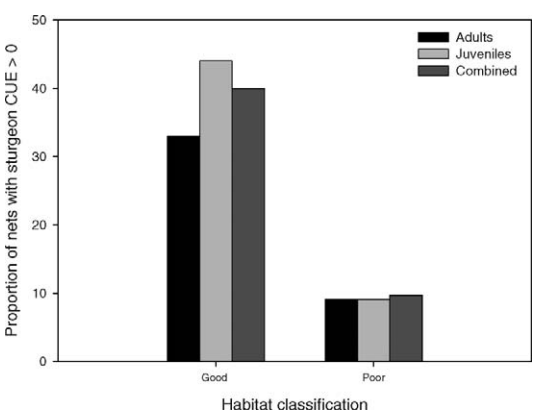


FIGURE 5.—Proportion of nets for which the catch per unit effort (CUE [number per net]) of adult or juvenile lake sturgeon was greater than 0 in locations with observed poor or good habitat quality.

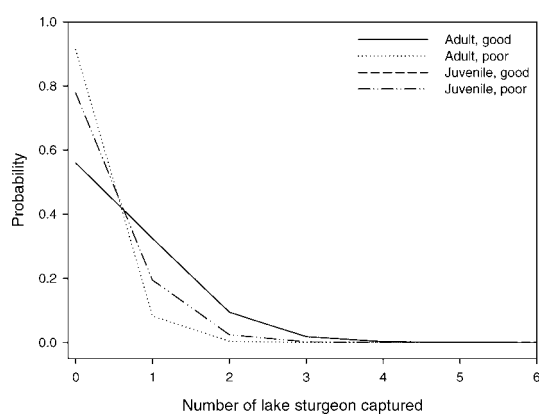


FIGURE 6.—Probability of capturing adult and juvenile lake sturgeon in short net sets in good and poor habitat, as derived from mean observed CUE and Poisson distributions.

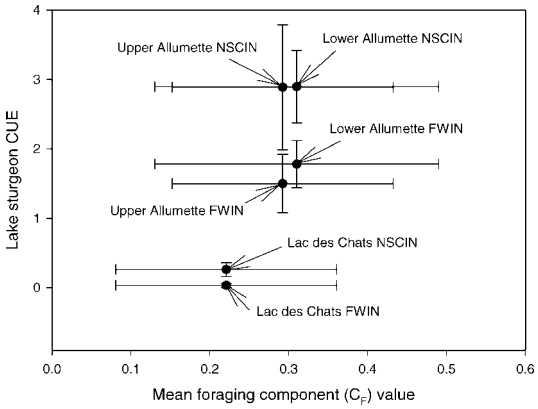


FIGURE 7.—Mean ± SE catch per unit effort (CUE) of lake sturgeon with standard index netting techniques (fall walleye index netting [FWIN] and nearshore community index netting [NSCIN]) and short-term net sets in relation to the mean foraging component value for three Ottawa River reaches.

measuring habitat variables is often hampered by observer bias and natural changes over time (Fausch et al. 1988). Our evaluation of predictive power within reaches is based on 90-min net sets; our intent was to target lake sturgeon actively feeding at those locations, avoid capturing individuals migrating between habitats, and avoid increases in mortality rates associated with sampling. Longer net sets resulted in greater average CUE and greater interset variation (Figures 4, 7) than shorter net sets; these differences might indicate that longer net sets more accurately reflect any spatial variation in abundance arising from spatial variation in habitat quality. Longer net-set data could not be used to validate the HSM at the within-reach scale because habitat data were not collected as part of the study from which the data were obtained (Haxton and Findlay 2008).

Diel movements of lake sturgeon represent another possible source of error. Lake sturgeon have been found to inhabit deeper waters during the day and then move to shallower water at night to feed (Holtgren and Auer 2004). As such, the spatial variation in diurnal abundance may be less reflective of variation in habitat quality than nocturnal abundance is. Morse et al. (1997), however, observed no differences in diel and nocturnal habitat selection. Different techniques such as baited set lines (e.g., Thomas and Haas 1999) or trawls may be a better technique because such gear targets feeding lake sturgeon and may reduce the measurement error associated with fish presence unrelated to the quality of foraging habitat.

The lake sturgeon HSM was initially developed for medium-sized, slow-flowing rivers in northern Ontario (Moose River basin; Threader et al. 1998). Differences in populations or variability in habitats across geographical areas (Pajak and Neves 1987; Fausch et al. 1988; O'Neil et al. 1988; Glozier et al. 1997; Vismara et al. 2001; Strakosh et al. 2003) may also account for the low predictive power of adult and juvenile sturgeon foraging in the Ottawa River. Adult and juvenile foraging habitats are based primarily on substrate, which we used as a surrogate for prey (i.e., macroinvertebrates). Although the abundance and distribution of sturgeon have been correlated with preferred prey availability (Chiasson et al. 1997; Hayes and Werner 2004), another study suggests that the presence of juvenile lake sturgeon aggregates cannot be fully explained by their food habits (Nilo et al. 2006).

Moreover, there is some evidence of variation in habitat selectivity among lake sturgeon populations. For example, juvenile lake sturgeon preferred clay in the Moose River (Chiasson et al. 1997), whereas silt was the predominant substrate utilized by juveniles in the St. Lawrence River (Hayes and Werner 2004). Adult lake sturgeon in the St. Lawrence River used areas dominated by boulders, and to a lesser degree, areas dominated by silt (Hayes and Werner 2004), whereas lake sturgeon in the Groundhog River preferred organic or coarse substrate (sand–organic, sand–gravel, gravel, rubble; Seyler 1997). In the Sturgeon River, lake sturgeon were found over mud during the day and over mud–sand during the night (Holtgren and Auer 2004). Morse et al. (1997) found that sand was the preferred habitat in the Kettle River except during low-water periods, when sand, muck, and detritus were all, apparently, equally attractive. Such variation in habitat selectivity among populations in different regions will substantially reduce the transferability of HSMs among systems, as has been demonstrated in other species (Glozier et al. 1997; Guay et al. 2003; Strakosh et al. 2003; Hedger et al. 2004). Although transferability appears to improve when the systems in which the HSM was developed, and the system to which is applied, are in close proximity (Rubec et al. 1999), close proximity does not guarantee transferability (e.g., Fausch et al. 1988).

Considerable effort has been devoted to the development of fish HSMs. As of 2007, 53 fish HSMs posted on the USGS website has been cited 169 times in the scientific literature. Yet only two attempts at validating any one of these HSMs have been published; in one instance the model was refuted (Lowie et al. 2001), and in the other there was little correlation between HSI and species biomass (Layher and Maughan 1985). Our results suggest that the lake sturgeon HSM developed for northern rivers has at best modest predictive power (i.e., significantly greater

catches in good habitat but a low coefficient of determination) when applied in a different context.

The apparently limited effort devoted to independent validation of fish HSMs—and the comparatively poor performance of the few for which independent evaluations have been conducted—are troublesome, especially in light of the widespread use of HSMs in wildlife management and planning decisions. We suggest that considerably more effort be devoted to the independent validation of existing HSMs and that in the absence of such validation and bona fide estimates of predictive power these models be used circumspectly in conservation management and planning.

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