Comparison of Walleye Habitat Suitability Index (HSI) Information with Habitat Features of a Walleye Spawning Stream

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Abstract

The objective of our study was to determine habitat conditions in a stream where walleye successfully produce fry and to compare these conditions with the nationally-applicable Habitat Suitability Index (HSI) model for walleye. During 17-20 day migration periods in April of 1996, 1997 and 2000, walleye were observed spawning; eggs were collected primarily in April and fry primarily in May. Water depths, velocities, and temperatures where walleyes spawned were at the lower end of or below the optimum ranges specified in the HSI for spawning walleye. However, random sampling indicated that optimum HSI conditions for these parameters generally did not exist in the stream. Substrate, dissolved oxygen, and pH were optimal according to the HSI. Our results indicate that predictions using the HSI alone are not sufficient to identify regional tributaries where walleye can successfully establish viable populations.

Introduction

The walleye, Stizostedion vitreum vitreum, is native to the northeastern United States and is one of the most desirable and intensively managed game species. Suitable habitats for walleye are described for large geographic regions, such as New York (Smith 1985), Ohio (Trautman 1981), Canada (Scott and Crossman 1973), and the United States (McMahon et al. 1984). Within each region, walleye spawning and recruitment have been documented in lakes, large rivers and small streams, as well as in marshes (Becker 1983, Priegel 1970).

McMahon et al. (1984) synthesized published and unpublished information to create a Habitat Suitability Index (HSI) model to identify important habitat variables for walleye. Suitability index (SI) curves developed by the authors proposed optimum habitat requirements for spawning walleye. The resulting models are first steps in developing hypotheses about species-habitat relationships (Terrell et al. 1982), which can vary according to geographical area. The approach established in a HSI is broadly applicable across North America, but it may not necessarily present optimum values for all populations or waters in which reproduction and recruitment take place.

Habitat parameters of particular concern for stream-spawning walleye
populations are velocity, depth, water temperature, substrate, dissolved oxygen, and pH. According to McMahon et al. (1984), optimum spawning habitat requirements for these parameters in streams are: 0.6-0.9 m/s velocity, 0.6-1.8 m depth, 6-11 °C water temperature (8 °C preferred), gravel to rubble substrate (2.5-15.0 cm particles), dissolved oxygen >5.0 mg/L, and pH 6.0-9.0.

Recruitment variability is typical in walleye populations because egg and fry survival is highly dependent on environmental conditions (Madenjian et al. 1996). Assessments in eastern Lake Erie show CPUE of age-1 walleye fluctuates widely, and this is reflected in highly variable abundance of year classes within the adult population (Culligan et al. 1995, 1996). Year class strength appears to be established very early in life, and strong year classes in eastern Lake Erie have occurred after long winters with extended ice cover followed by rapidly warming lake temperatures throughout the incubation period (Einhouse 1994). Walleye year class strength in western Lake Erie also has been positively correlated with fast-warming water during egg incubation (Busch et al. 1975, Wolfert 1981). The causal factor for this relationship is hypothesized to be a shorter incubation period, which in turn reduces exposure to sources of mortality such as storms, predators, and siltation.

In recent years, the New York State Department of Environmental Conservation and the United States Fish and Wildlife Service have jointly undertaken efforts to stabilize walleye recruitment in eastern Lake Erie, and to enhance the overall population (Einhouse 1994). One component of this effort includes habitat assessment to determine candidate streams for walleye restoration efforts.

Relative to this, our objective was to determine habitat conditions in a stream where walleye successfully produce fry and to compare those conditions with the nationally-applicable HSI model for spawning walleye. Our null hypothesis was: the walleye population in the study stream exhibits the same preferences for spawning habitat as those described in the HSI model.

Methods and Materials

Dewittville Creek, a tributary of Chautauqua Lake, is located in western New York, southeast of Buffalo. It was selected as the study stream because it is the regional stream closest to eastern Lake Erie with a significant walleye spawning migration. All sampling in Dewittville Creek was below a man-made barrier, impassable to walleye, located 1.75 km upstream from Chautauqua Lake.

In 1996 and 1997, walleye activity throughout the entire 1.75 km study reach in Dewittville Creek was viewed by stream-bank and in-stream observation almost daily during the migration season to determine habitat conditions where fish spawned. Walleye were viewed at night with flashlight, spotlight and night-vision scope. However, lights caused walleye to cease spawning and the night-vision scope was unable to distinguish fish in the water. Therefore, all spawning activity was observed during light conditions. Spawning episodes occurred when two or more walleye lay briefly on their sides and agitated their bodies under water, or more commonly, when they were observed breaking the surface. After such episodes, which often included extrusion of eggs, habitat measurements were made exactly where the spawning behavior occurred. There were 14 d of sampling in 1996 (5-22 April) and 16 d in 1997 (3-19 April).
**Habitat Measurements**

Baseline physical data were collected by Lowie (1994, 1995) using modified protocols established by Bain et al. (1985), Davies (unpublished), Meador et al. (1993), and Simonson et al. (1994). Transect sampling occurred every 0.1 km, from the mouth to the impassable barrier. Habitat measurements, including width, depth, water temperature, dissolved oxygen, transparency, and velocity, were collected at 2-3 equidistant points, depending on stream width, across each transect. Habitat type, cover, primary and secondary substrate types, embeddedness, and any notable features that may have influenced the amount of available habitat were also recorded.

In 1994 and 1995, primary and secondary substrate types along sampling transects were recorded qualitatively as estimated percentages. Substrate classes were identified as detritus or muck, sand or silt (<2 mm), gravel or rubble (2-150 mm), cobble (151-256 mm), boulder (>256 mm), and bedrock, (Bain et al. 1985, Meador et al. 1993, Simonson et al. 1994, Davies unpublished). Shale was noted as gravel, cobble, or boulder. Substrate type was converted to a number by multiplying the percent estimated for each type by zero for muck, one for sand or silt, two for gravel, three for cobble, four for boulder, and five for bedrock. The sum of these products described the substrate at a site (Wentworth 1922).

In 1996 and 1997, 40% of the original sites were chosen randomly for habitat sampling. Parameters measured were velocity, depth, and water temperature. Dissolved oxygen and pH were measured in 1997. Substrate composition appeared unchanged since the 1994 and 1995 surveys, and so these measurements were not repeated.

Stream velocity was measured with a flow meter attached to a meter stick at approximately mid-depth. Velocity and depth measurements in 1996 and 1997 were compared to the same measurements in 1995 (P>0.1, Table 1) to establish the similarity of velocity and depth conditions in Dewittville Creek among years. At actual spawning locations, water temperature was determined with a meter. Seasonal water temperatures were measured with two continuous temperature monitors. Temperature was recorded every ten minutes, and a daily average water temperature was calculated. Dissolved oxygen was measured at mid-depth using a meter; pH was recorded with a meter at the surface.

**Egg and Fry Collections**

Peak hatching dates were estimated from observed peak spawning dates and egg development times calculated from daily average water temperatures (Wolfert 1981). In 1996, limited fry sampling was conducted at the mouth of Dewittville Creek during the predicted time of peak hatching. A 0.5-m diameter net with 560 μm mesh and a flow meter was towed behind a small boat for 8-10 min to collect fry. Three tows were made at two sites on each of five days of sampling. In 1997 (11 d) and 2000 (6 d), the same net was placed stationary in Dewittville Creek to collect eggs and fry. CPUE was calculated as the number of eggs and fry collected per 100 m³ and 10,000 m³, respectively.

**Statistics**

Habitat conditions at precise walleye spawning locations were compared to the HSI model and to stream conditions at random sites on the same day to determine
whether habitat selection by spawning walleye differed from general habitat conditions in the stream. We used modified box-and-whisker plots (Moore and McCabe 1993) to compare our data with the optimum habitat ranges identified in the HSI for spawning walleye. One-way ANOVA was used to compare habitat conditions (depth, velocity, etc.) in Dewittville Creek among years (1995, 1996, 1997) and between walleye spawning and random creek locations in each year.

Results and Discussion

Spawning Habitat Conditions in Dewittville Creek and HSI Comparisons

Spawning. Walleye were first seen in Dewittville Creek on 3 April in 1996; they were last seen on 22 April 1996. In 1997, walleye were also first seen on 3 April, and the migration ended on 19 April. Despite daily observations, and visibility to the stream bottom, we observed spawning walleye on only four days in 1996 and 1997 combined, and none were confirmed spawning at night. In 1996, 15 spawning episodes were observed on 16 April at six locations in the 1.75-km of stream available for spawning. Because of the numerous episodes observed, we believe this was the peak of the spawning period. In 1997, spawning was observed on three days: 5, 6, and 16 April, all in one 50-m section of the creek. As a result of all spawning episodes, 23 sets of habitat measurements, including velocity, depth, water temperature and substrate, were recorded at spawning locations.

Table 1. Comparison of mean physical habitat variables (SE) in Dewittville Creek, 1995-1997 at sites where walleye were observed spawning (Walleye) and at other randomly selected sites (Random).

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<tr>
<td>Velocity (m/s)</td>
<td>0.6-0.9</td>
<td>0.50 (0.07)</td>
<td>0.55 (0.04)</td>
<td>0.54 (0.04)</td>
<td>0.46 (0.06)</td>
<td>0.38 (0.05)</td>
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<tr>
<td>Depth (m)</td>
<td>0.6-1.8</td>
<td>0.46 (0.04)</td>
<td>0.54 (0.03)</td>
<td>0.52 (0.03)</td>
<td>0.53 (0.03)</td>
<td>0.48 (0.06)</td>
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<td>Water Temperature (°C)</td>
<td>6.0-11.0</td>
<td>6.8 (0.4)</td>
<td>6.0 (0.4)</td>
<td>3.9 (0)</td>
<td>5.8 (0.4)</td>
<td>6.9 (0.4)</td>
</tr>
<tr>
<td>Dissolved Oxygen (mg/L)</td>
<td>&gt;5.0</td>
<td>9.4 (0.5)</td>
<td>-- (0)</td>
<td>-- (0)</td>
<td>10.8 (0.1)</td>
<td>10.5 (0.2)</td>
</tr>
<tr>
<td>PH</td>
<td>6.0-9.0</td>
<td>-- (0)</td>
<td>-- (0)</td>
<td>-- (0)</td>
<td>8.1 (0.1)</td>
<td>8.2 (0.1)</td>
</tr>
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Substrate

| % detritus/muck | 0 | 0 | 0 | 0 |
| % silt/sand     | 24.2 (4.2) | 0 | 0 | 0 |
| % gravel        | 73.7 (4.0) | 100 | - | 100 |
| % cobble        | 0 | 0 | 0 | 0 |
| % boulder       | 2.2 (1.2) | 0 | 0 | 0 |
| % bedrock       | 0 | 0 | 0 | 0 |
Water Velocity. Average velocities at random sites in Dewittville Creek did not differ among years (P>0.4, Table 1). Velocities used by spawning walleye were lower in 1997 than 1996 (P<0.01). On 16 April 1996, the average velocities at spawning sites and random sites in Dewittville Creek were 0.54 m/s (Figure 1) and 0.59 m/s, respectively. Average velocities at spawning sites on 5, 6, and 16 April 1997 were 0.43, 0.27, and 0.39 m/s, respectively (Figure 1), and 0.47, 0.42, and 0.44 m/s, respectively, at random sites. With the possible exception of 6 April 1997, spawning walleye did not appear to select velocities different than those generally available in midstream in Dewittville Creek on the same dates.

Interestingly, at one spawning location on 16 April 1996, many non-spawning walleye were present on either side of the spawning fish at average velocities of 0.21 m/s and 1.05 m/s. Differences in velocities selected by spawning and non-spawning walleye at this location and time suggest the possibility that some walleye select spawning microhabitats in relation to stream velocity or another factor associated with velocity (e.g., see substrate section below) or, perhaps, that the non-spawning walleye on either side of the spawners were not ripe.

Figure 1. Distribution of 1996 and 1997 velocity data from Dewittville Creek at observed walleye spawning locations (single dates) and at random sites during the entire spawning/migration period (5-22 April 1996 and 3-19 April 1997). Also shown is the range of velocity reported from the HSI. For the stream data, the horizontal, dashed lines on the box plot correspond to the 25th (lower bound), 50th, and 75th (upper bound) percentiles. The plus sign represents the mean. The whiskers represent 1.5 interquartile ranges of the distribution. A zero corresponds to values in the 1.5-3.0 interquartile ranges (minor outliers). The interquartile range is the difference between the 75th and 25th percentiles. For the HSI, the horizontal, dashed lines represent the 0, 50th, and 100th percentiles.
Stream Depth. Average depths at random sites in Dewittville Creek did not differ among years (P>0.1, Table 1). There was no difference in depths used for spawning in 1996 and 1997 (P>0.4). The average depths at spawning locations and at random sites on 16 April 1996 were 0.52 m (Figure 2) and 0.68 m, respectively. On 5, 6, and 16 April 1997, average depths were 0.45, 0.44, and 0.61 m, respectively at spawning sites, while average depths at random sites were 0.49, 0.56, and 0.54 m, respectively. Thus, spawning walleye did not appear to select depths different than those generally available in Dewittville Creek on the same dates.

Water Temperature. Average water temperatures at random sites in Dewittville Creek did not differ among years (P>0.9, Table 1). Because of substantial daily and weekly temperature variations in the shallow study stream and because of differences in water temperature measurement methods (daily averages of continuous recorders vs. point measurements at walleye spawning locations), water temperatures when walleye spawned were often quite different from the average temperatures available to them (Figure 3). Water temperatures at spawning locations and at random sites on 16 April 1996 were 3.9 °C and 4.0 °C, respectively. On 5, 6, and 16 April 1997, water temperatures at spawning locations were 6.6, 8.4, and 5.2 °C, respectively, and at random sites they were 6.8, 8.3, and 5.7 °C, respectively. Thus, because no other temperatures were available to them, water temperature appeared to play little, if any, role in spawning habitat selection by walleye in Dewittville Creek.

In our study, water temperature appeared to be responsible for ending the migration period. In 1996 and 1997, as temperatures approached 9.0 °C, walleye were
Water temperature (°C)

Figure 3. Distribution of 1996 and 1997 water temperature data from Dewittville Creek at observed walleye spawning locations (single dates) and at random sites during the entire spawning/migration period (5-22 April 1996 and 3-19 April 1997). Also shown is the range of water temperature reported from the HSI. See Figure 1 caption for explanation of the box and whisker plots.

no longer seen in the creek. During the peak spawning period in 1997, thousands of walleye eggs were caught in each 100 m$^3$ of water sampled, but in 2000, when our primary focus was fry sampling, we did not begin sampling until 18 April and egg drift was already very low (2.0-14.4/100 m$^3$). Water temperatures in Dewittville Creek were 8-9 °C from 16-28 April 2000, thus the egg drift and temperature data from all years suggests that walleye leave the creek as water temperatures approach 9 °C. However, because the migration seasons were so similar in all three years, the possibility of a photoperiod-induced beginning or end to the migration and spawning period can not be dismissed. Photoperiod is known to play a critical role in the gonadal development and, possibly, in the spawning/migration period of walleye (Beamish 1990). Ciereszko et al. (1997) found that photoperiod and water temperature both modify the onset of spawning in yellow perch (Perca flavescens).

Substrate, Dissolved Oxygen and pH. Spawning walleye in Dewittville Creek were always over gravel substrate. Although no spawning was observed at random sites, the primary substrate at these locations also was gravel (Table 1). Within 1-2 m of one spawning location over gravel in 1996, many non-spawning walleye were present over cobble or sand substrates (see related discussion, velocity section above).

In 1997, average dissolved oxygen concentrations were 10.5 (0.2 SE) mg/L at spawning sites and 10.8 (0.1 SE) mg/L at random sites (Table 1). Both values were
far above the >5.0 mg/L standard recommended in the HSI. The pH meter was inoperable on all spawning dates except 16 April 1997 when average measurements of 8.2 and 8.1 were recorded at spawning and random sites, respectively.

Summary of Spawning Habitat Conditions in Relation to the HSI Model.

None of the habitat parameters used in the HSI (velocity, depth, temperature, dissolved oxygen, pH) were distinguishable between microhabitats where walleye were observed spawning in Dewittville Creek and at randomly chosen sites on the same dates. Substrate used by walleye for spawning and pH were well within the HSI range, and dissolved oxygen concentrations were well above the minimum requirement (Table 1). In general, the ranges of velocity, depth and water temperature conditions where walleye spawned, and in Dewittville Creek as a whole, were at the lower end of or below the ranges specified in the HSI (McMahon et al. 1984). Parameters measured at random sites in Dewittville Creek fell in the HSI ranges on only 36% or fewer of the days sampled.

**Egg and Fry Collections**

In 1996, ichthyoplankton (Family Catostomidae) were collected at the mouth of Dewittville Creek on 5 May (n=1), 9 May (n=4), and 12 May (n=6), 19-26 days after the peak walleye spawn on 16 April. No walleye were collected, but according to the regression formula of Wolfert (1981), peak hatch (100% of walleye egg development) should have occurred by approximately 14 May. No ichthyoplankton were caught on 15 and 20 May, so sampling ended. Walleye fry may not have been collected due to inappropriate time or place of sampling, low sampling effort or low abundance, or walleye fry not being produced in the creek in 1996. In 1997, daily egg collections in Dewittville Creek showed the highest egg drift between 11 April (6,200/100 m³) and 14 April (4,300/100 m³), suggesting a peak spawning period. We did not attempt to collect fry in 1997. According to Jirka (1997), velocity, depth, water temperature, and substrate conditions were sub-optimum to optimum for egg incubation in Dewittville Creek following the peak spawning times in 1996 and 1997. Therefore, although we are aware of no specific HSI criteria for walleye fry, some fry should have been produced in both years.

In 2000, we looked intensively for fry. Local residents first reported adult walleye in Dewittville Creek on 22 March 2000, and temperature monitors were placed in the creek on 29 March. Eggs (study total = 2,543) were caught beginning on 18 April, the first sampling date, and catches declined thereafter until a sharp peak was observed on 12 May. The peak (200/100 m³) was 2 d after a major rainfall on 10 May that apparently flushed many, mostly inviable eggs out of the benthos and into the water column.

According to the temperature monitors, 100% of walleye eggs in the creek before 15 April (24 days after adult walleye were first reported), experienced enough degree-days to complete their development and hatch by 6 May. Larval captures (study total = 36) began on 29 April (66% of predicted development time) and peaked (220/10,000 m³) on 7 May, one day after the predicted hatching peak and three days before the rain event. In summary, walleye fry successfully hatched in Dewittville Creek, and they probably recruited to Chautauqua Lake to sustain the annual walleye migration in the creek.
**Summary**

Walleye utilized spawning habitats (velocities, depths and temperatures) in Dewittville Creek that did not differ from conditions at random locations. As water temperatures approached 9.0 °C, the migration period came to an end. Spawning walleye were always observed over gravel substrate, which was the primary substrate type in Dewittville Creek.

Our hypothesis was “the walleye population in the stream exhibits the same spawning habitat preferences as those described in the nationally-applicable HSI model.” Although many walleye spawn in Dewittville Creek each year, and fry are produced, our results indicate that velocities, depths, and water temperatures at walleye spawning sites are generally sub-optimum compared to the HSI. However, optimum HSI conditions for these variables generally do not exist in Dewittville Creek. The extensive gravel substrate in Dewittville Creek is optimal and is likely the important variable contributing to walleye reproductive success. Dissolved oxygen and pH also are optimal. The HSI model is a hypothesis of walleye-habitat relationships that may vary by region. By rejecting our hypothesis, our results support the need to identify suitable regional habitat conditions for walleye rather than relying only on the national HSI.

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