Preliminary Habitat Suitability Index Curves for Sauger

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Abstract: A Delphi exercise conducted on sauger (*Stizostedion canadense*) with a panel of 17 experts resulted in 11 habitat suitability index curves that associate various life stages or activities of sauger with 5 variables: velocity, depth, substrate type, temperature, and cover. The curves are preliminary but should be useful for assessing habitat suitability for sauger until empirical curves are developed and for focusing future research and information exchange.

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Habitat suitability index (HSI) curves, which are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat) are 1 method of representing habitat for fish (and wildlife) species and are necessary components of the instream flow incremental methodology (IFIM) (Stalnaker 1979, Bovee 1986). The IFIM is widely used for the determination of flow regimes necessary to support stream fish populations (Stalnaker 1979, Orth and Maughan 1982, Hunn 1984), and it has been used successfully in negotiations for flow regimes needed to support stream fish populations and to maintain other identified instream values at desired levels (Cavendish and Duncan 1986, Garn 1986).

Many HSI curves used with the IFIM are based largely on the literature or expert opinions and sparse empirical data (Bovee 1986); such curves are preliminary. Empirical HSI curves based on data collected at locations where the species of interest is observed or sampled are preferred for use with the IFIM and should be the goal of the research community and water resource managers. Development of empirical HSI curves, however, requires intensive field sampling, hence they have not been developed for many fish species. In reality, preliminary curves may be the best information available for a species and have to be relied on for a long period of time because of budgetary constraints and limitations on the number of personnel available to perform field sampling required to develop empirical curves.

The sauger is a popular sport fish in the United States (Walburg 1972, Priegel 1983) and is an important sport and commercial species in Canada (Scott and Crossman 1973). Several studies (Walburg 1972; Wrenn 1975; Hess and Winger 1976; Pitlo 1983, 1985) have indicated that habitat suitability for the species is related to flow modifications. Therefore, HSI curves for the major life stages of sauger should be useful for assessing flow alterations in the habitat of the species. However, available information on habitat suitability for the species is meager, and no HSI curves have been published. The purpose of this investigation was to develop preliminary HSI curves for sauger for use with the IFIM.

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Methods

The Delphi technique (Pill 1971, Delbecq et al. 1975, Linstone and Turoff 1975) was used to solicit opinions on sauger habitat suitability. A 4-round Delphi exercise with 17 recognized authorities on sauger biology as panelists (experts) was conducted during January–August 1986. Procedures previously employed (Crance 1987*a*) to develop HSI curves were slightly modified (Crance 1987*b*) and used for the sauger Delphi exercise.

To begin the Delphi exercise, panelists were requested to focus on the relationships between riverine habitat suitability for various life stages and activities of sauger and each of the variables commonly used with the IFIM (i.e., velocity, depth, substrate, cover, and temperature). Questionnaires designed to solicit opinions on HSI's for these variables (Crance 1987*b*) were included in the initial information packet mailed to each panelist. The panelists completed and returned the questionnaires to me. I summarized the responses and drafted a set of preliminary HSI curves based on a composite of the panelists' opinions. This ended Round 1.

I mailed the summary and draft HSI curves to the panelists to begin Round 2. The panelists reviewed the results of Round 1 and indicated agreement or disagreement on each draft HSI curve. If a panelist disagreed, he gave his own version of the curve, commented on why he disagreed, and returned the results. I summarized the responses, modified the draft HSI curves if justified by new information, and returned the summary and curves to the panelists for reconsideration. This ended Round 2.

The process used for Round 2 was repeated for subsequent rounds. The exercise was concluded after Round 4, and residual disagreement, if any, was recorded as part of the results. A completion report that included a summary of each round and the resultant HSI curves was prepared and mailed to each panelist for review and comments.

Summary of Available Empirical Data and Delphi Results

Eleven preliminary HSI curves on habitat suitability for sauger were developed (Figs. 1–4). The panelists reached a consensus on 6 of the curves, and 12 to 16 of the panelists agreed on each of the other curves. Details on the results of the Delphi exercise, including the summary of each round, comments made by the panelists and the final *x,y* coordinate pairs for the end points and the minimum and maximum of the optimum range of each curve, are available from the author.

Habitats with detectable water velocities are probably used by all life stages of sauger, but preferred velocities for the species are unknown. Velocities at spawning sites in the Missouri River below Fort Randall Dam ranged from 54.2 to 143.8 cm/sec (Nelson 1968). Velocities at 3 spawning sites in Pool 13 of the upper Mississippi River ranged from 85.3 to 121.9 cm/sec at the surface, 85.3 to 109.7 cm/sec at a depth of 3.0 m, and 42.2 to 88.4 cm/sec near the bottom, which was 6.1 m from the surface (John Pitlo, Jr., Iowa Conserv. Comm., pers. commun.).

Velocities at egg incubation and larval development sites are unknown. The panel agreed that some current is needed to aerate eggs. In laboratory tests, sauger eggs adhered to rock substrate when subjected to velocities up to 33.5 cm/sec (Say-

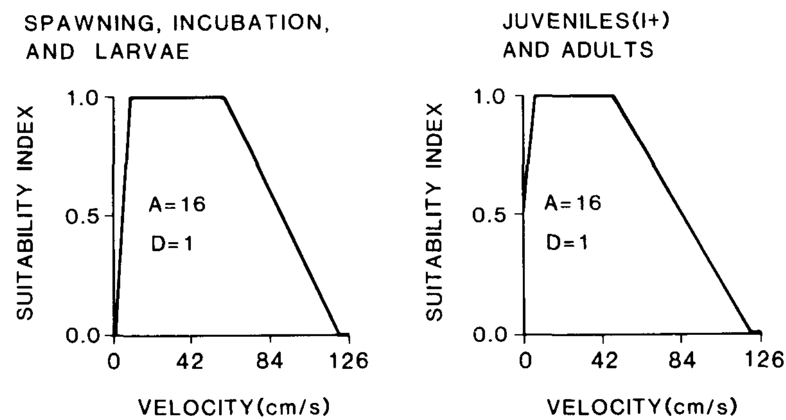

Figure 1. Suitability index curves for water velocity for sauger spawning, incubation, and larvae, and juveniles (I+) and adults; A is the number of panelists who agreed on the curve; D is the number who disagreed.

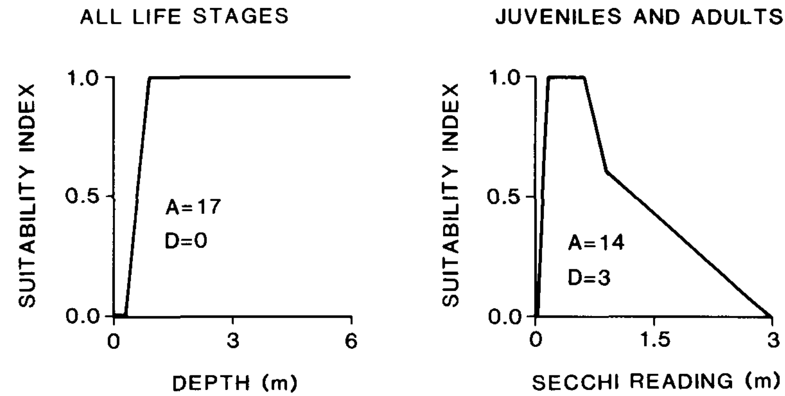

Figure 2. Suitability index curve for water depth for all life stages of sauger, and suitability index curve for monthly average Secchi reading for juvenile and adult sauger habitat with average depth ≤10 m; A is the number of panelists who agreed on the curve; D is the number who disagreed.

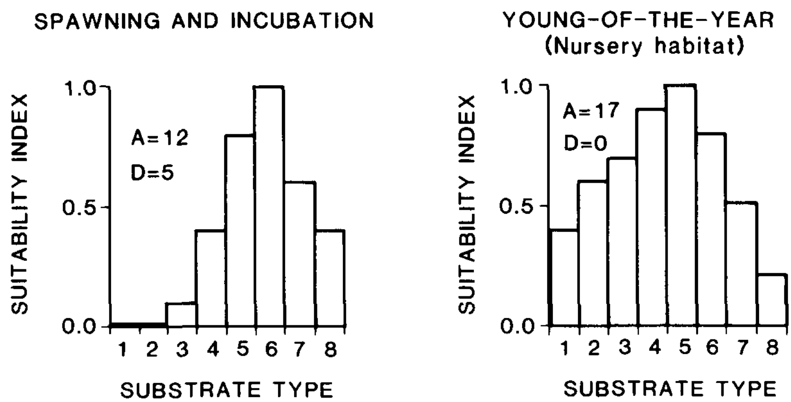

Figure 3. Suitability index graphs for substrate type for sauger spawning and incubation, and young-of-the-year juveniles; A is the number of panelists who agreed with the graph; D is the number who disagreed. Substrate types are: 1, plant detritus or organic material; 2, mud or soft clay; 3, silt (<0.062 mm diameter); 4, sand (0.062–2.0 mm); 5, gravel (2–64 mm); 6, cobble-rubble (64–250 mm); 7, boulder (25–400 cm); and 8, bedrock (solid rock).

lor et al. 1983). Newly hatched larvae are probably subject to transport by velocities >3.0 cm/sec (Houde 1969). Young-of-the-year sauger were collected at 6 stations in Pools 16 and 18 of the Mississippi River where the velocity ranged from 21.3–85.3 cm/sec, but were not found at 1 station where the velocity was 0.0 cm/sec or at another station where the velocity was 33.5 cm/sec (A. V. Van Vooren, Iowa Conserv. Comm., unpubl. rep., 1982).

The panel agreed that 1 HSI curve for velocity could represent spawning, incubation, and larvae and another curve could represent Age I+ juveniles and adults

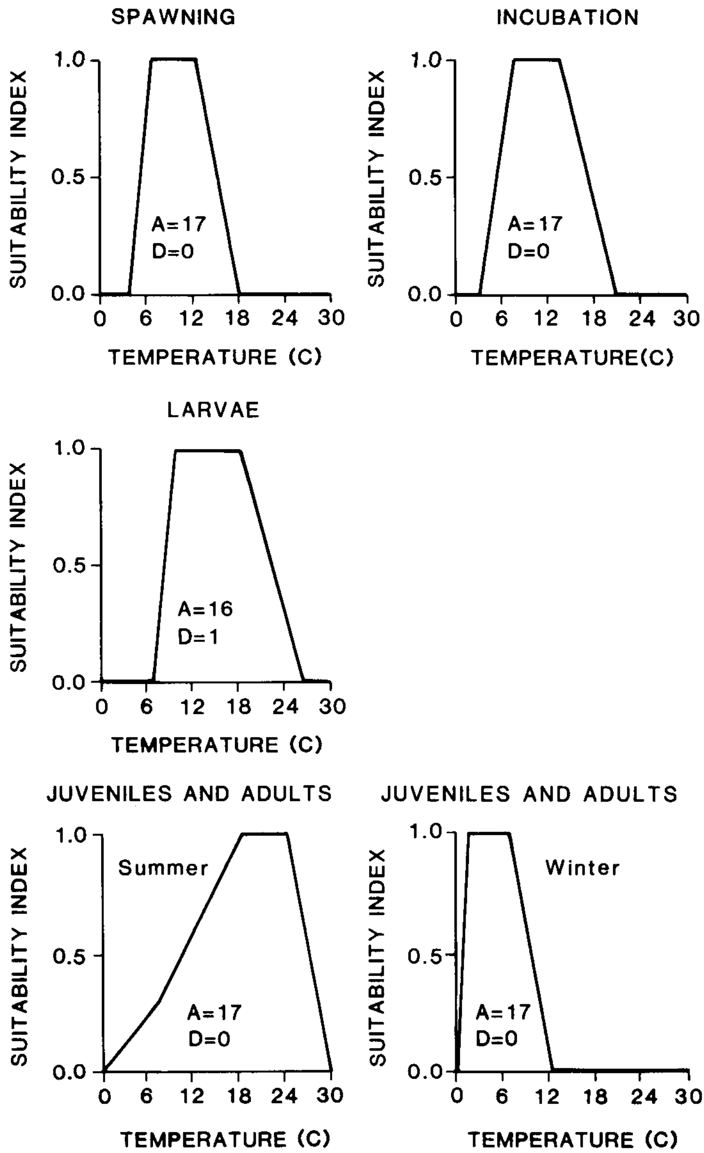

Figure 4. Water temperature suitability index curves for sauger spawning, egg incubation, larvae, and juveniles and adults (shown separately for summer and winter); A is the number of panelists who agreed on the curve; D is the number who disagreed.

(Fig. 1). One panelist believed that the low end of the optimum range in the former curve should be 30 cm/sec instead of 9 cm/sec. The panelist who disagreed with part of the later curve believed that velocities of 122 cm/sec and 183 cm/sec would result in HSI = 0.2 and HSI = 0.1, respectively.

Water depth likely plays an important role in habitat suitability for sauger, but precise depth preference for various life stages and activities of the species are unknown. The panel agreed that all life stages of sauger may use a wide range of depths (Fig. 2). They agreed that the optimal depth is ≥ 1 m, but they did not reach a conclusion on the upper limit of the optimum depth range or the upper threshold depth where HSI = 0. Running-ripe males and a partially spent female were collected in water <0.6 m deep (Nelson 1968). Spawning has been reported to occur in water 0.6 to 3.7 m deep in the Missouri River (P. J. Graham and R. F. Penkal, Mont. Dep. Fish and Game, unpubl. rep., 1978), and up to 1.2 m deep in Lake Winnebago (Priegel 1963). Sauger eggs have been collected at water depths ranging from 0.3 to 6.4 m (Nelson 1968) and 3.0 to 7.5 m (Saylor et al. 1983). Nelson (1968) collected sauger larvae at depths more than 6.1 m, but highest catches of larvae were at a depth of 3.0 m.

The Delphi panelists were asked if they considered cover to be important to sauger. The general response was that turbidity, as a measure of cover, is a factor in relation to habitat suitability. Several panelists pointed out, however, that sauger have adapted well to areas of some reservoirs where Secchi readings of 5 to 10 m are common. The cover HSI curve for juvenile and adult sauger (Fig. 2) was based on the monthly average Secchi reading for habitats with an average depth ≤ 10 m. Comments by each of the 3 panelists who disagreed with the Secchi reading curve were as follows: 1) "the optimum Secchi reading should be 0.15 to 1.0 m"; 2) "the optimum Secchi reading should be 0.1 to 0.6 m"; and 3) "Secchi readings where we find all sizes of sauger are normally less than 0.15 m."

Sauger spawn over substrate consisting primarily of rubble (Nelson 1968); sand, fine gravel, and rubble (Priegel 1963); pebble-cobble (Graham and Penkal 1978); and rock and cobble (Pitlo 1985). Saylor et al. (1983) reported that spawning occurred and eggs were collected over gravel-cobble substrate. Pitlo (1985) collected eggs over sand and cobble. Information on the association of other life stages with specific substrate types was unavailable.

Two substrate HSI graphs resulted from the Delphi exercise (Fig. 3). Five panelists disagreed with the substrate SI graph for spawning and incubation. They all felt that the HSI for silt should be 0.0 instead of 0.1. Substrate type is probably more important for egg incubation than other life stages; eggs deposited on mud or silt would likely suffocate. There was agreement on all HSI values for the substrate HSI graph for young-of-the-year sauger. Substrate use and suitability for juvenile and adult sauger are so poorly known that no HSI graphs were developed for these life stages. Substrate type may not be very important to larvae because they are generally pelagic. Most young-of-the-year sauger are likely associated with substrate types that yield the greatest amount of food.

Water temperature associated with sauger habitats and activities has been studied more than any other variable. Sauger, with temperature requirements essentially the same as those for walleye (*Stizostedion vitreum*), is generally recognized as a coolwater species (mesothermal), particularly on the basis of spawning temperature (Hokanson 1977, Kendall 1978). However, based on revised temperatures for optimum growth (26° C) and lethal limits (34° C) for walleye (Hokanson and Koenst 1986), the sauger is quite similar to eurythermal or warmwater species. Spawning may occur at temperatures as low as 5.6° to 6.1° C (Priegel 1963, Nelson 1968) and as high as 15° to 16° C (Fletcher 1977). Information summarized by Hokanson (1977) indicates that spawning temperatures for sauger range from 4.0° C to 14.4° C. Sauger in some populations may not reach sexual readiness to spawn until the water warms to above 10° C (E. M. Scott, Tenn. Valley Authority, unpubl. rep., 1985). Hokanson (1977) noted that percids, in general, show a greater difference in spawning time at geographical extremities of their range than for any given stock.

Sauger eggs were collected when water temperatures ranged from 5.0° to 8.3° C (Pitlo 1983, 1985). The duration of the incubation period varies with temperature. Eggs hatch in 21 days at an average temperature of 8.3° C (Nelson 1968) and in 25 to 29 days at 4.5° to 12.8° C (Scott and Crossman 1973). Newly-hatched larvae were found when the water temperature was 13.4° C, and were subsequently collected for 3 weeks, by which time the water temperature had reached 17.1° C (Scott 1985). The greatest number of sauger larvae were collected when the water temperature reached 15° C (Hess and Winger 1976).

Adult and subadult sauger were collected from a discharge basin in the Tennessee River when the water temperature ranged from 7.2° to 29° C (Wrenn 1975). Adults and juveniles apparently avoid temperatures above 29° to 30° C (Gammon 1971, Wrenn 1975). The summer temperature preference for sauger in Norris Reservoir was about 20° C (Dendy 1948). A thermal preference range of 22.2° to 27.8° C was determined for sauger in the Wabash River, Indiana (Gammon 1971).

There was unanimous agreement on 4 of 5 temperature HSI curves (Fig. 4). For the larvae HSI curve, 1 panelist disagreed because he felt that it did not make sense for HSI = 0 at 7.2° C for larvae, if HSI = 1 at 7.8° C for incubation. There was no disagreement with the temperature HSI curve for juveniles and adults. Summer and winter temperature HSI curves for juvenile and adult sauger were developed separately based on a report by Hokanson (1977) that indicated a winter temperature of 10° C was near the upper limit for maturation of gonads in percids.

Discussion

The Delphi technique is not a substitute for scientific methods traditionally used to determine habitat suitability for fish species; rather, it is an alternate method for developing HSI curves in the absence of field data. Few Delphi-derived HSI curves for a fish species have been compared to HSI curves developed from data obtained by sampling the species in its habitat. HSI curves for spawning pink salmon (*Oncorhynchus gorbuscha*) generated by professional judgement were very similar to HSI curves subsequently generated from data obtained by sampling the species in its spawning habitat (Baldridge 1981).

I included all HSI curves resulting from the sauger Delphi exercise regardless of the degree of disagreement by panelists because in most cases of disagreement it was over only a portion of a curve. For example, the disagreement on the velocity HSI curve for Age I+ juveniles and adults (Fig. 1) was over the HSI value for the high end of the curve only; there was no disagreement on the optimum range or the low end of the curve. Each of the 5 disagreements over the suitability index graph for substrate for spawning and incubation (Fig. 3) was over the suitability of silt only; there was unanimous agreement on the other 7 substrate types. Delphi-derived HSI curves represent "average" values of habitat quality for a species and will be useful only for predicting "average" HSI's. Potential users of any HSI curve should scrutinize the information used to develop the curve and then judge the adequacy of the curve for a specific need. The HSI curves resulting from the sauger Delphi exercise are preliminary. However, most of the curves should be useful with the IFIM until empirical curves are developed and for focusing future research related to habitat of sauger.

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