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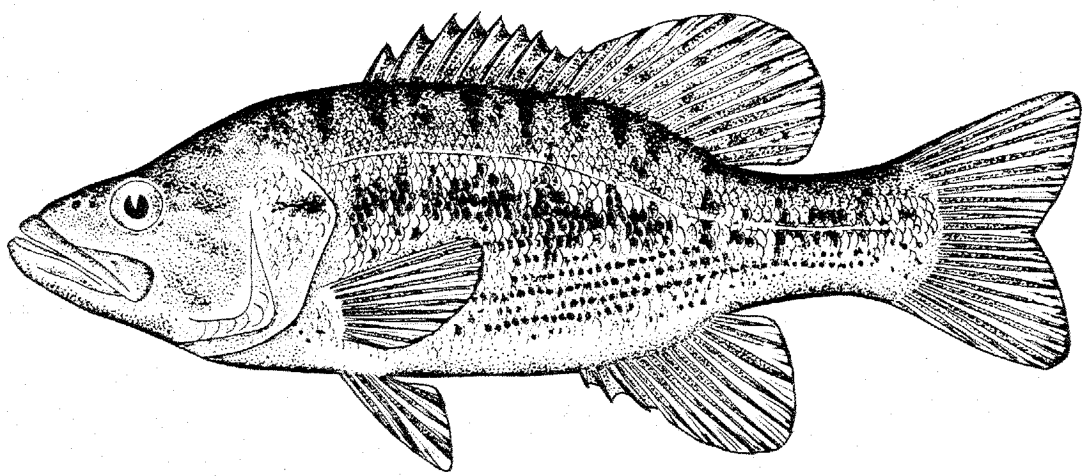
HABITAT SUITABILITY INDEX MODELS AND INSTREAM FLOW SUITABILITY CURVES: SPOTTED BASS



F h and Wildlife Service

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HABITAT SUITABILITY INDEX MODELS AND INSTREAM FLOW SUITABILITY CURVES: SPOTTED BASS

by

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PREFACE

The Habitat Suitability Index (HSI) models presented in this publication aid in identifying important habitat variables. Facts, ideas, and concepts obtained from the research literature and expert reviews are synthesized and presented in a format that can be used for impact assessment. The models are hypotheses of species-habitat relationships, and model users should recognize that the degree of veracity of the HSI model, SI graphs, and assumptions will vary according to geographical area and the extent of the data base for individual variables. After clear study objectives have been set, the HSI model building techniques presented in U.S. Fish and Wildlife Service (1981)[1] and the general guidelines for modifying HSI models and estimating model variables presented in Terrell et al. (1982)[2] may be useful for simplifying and applying the models to specific impact assessment problems. Simplified models should be tested with independent data sets, if possible. Statistically-derived models that are an alternative to using Suitability Indices to calculate an HSI are referenced in the text.

A brief discussion of the use of selected Suitability Index (SI) curves from HSI models as a component of the Instream Flow Incremental Methodology (IFIM) is provided. Additional SI curves, developed specifically for analysis of spotted bass habitat with IFIM, also are presented.

Results of a model performance test in a limited geographical area are summarized, but model reliability is likely to vary in different geographical areas and situations. The U.S. Fish and Wildlife Service encourages model users to provide comments, suggestions, and test results that may help us increase the utility and effectiveness of this habitat-based approach to impact assessment. Please send comments to:

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[1]U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S. Fish Wildl. Serv., Div. Ecol. Serv. n.p.

[2]Terrell, J. W., T. E. McMahon, P. D. Inskip, R. F. Raleigh, and K. L. Williamson. 1982. Habitat suitability index models: Appendix A. Guidelines for riverine and lacustrine applications of fish HSI models with the Habitat Evaluation Procedures. U.S. Fish Wildl. Serv. FWS/OBS-82/10.A. 54 pp.

CONTENTS

ACKNOWLEDGMENTS

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SPOTTED BASS (Micropterus punctulatus)

HABITAT USE INFORMATION

General

The spotted bass is native to the Southeastern United States, its northern range extending into southern Illinois, Indiana, Ohio, and West Virginia (Robbins and MacCrimmon 1974). It has been introduced into streams in Arizona, New Mexico (Robbins and MacCrimmon 1974), California (Shapovalov et al. 1981), and in streams in Missouri and Kansas where it was not native (Cross 1967; Fajen 1975), as well as reservoirs in California (Shapovalov et al. 1981; Aasen and Henry 1981), Kansas, and throughout the Southeast (Robbins and MacCrimmon 1974). A detailed description of its distribution, including maps, is provided by Robbins and MacCrimmon (1975) and MacCrimmon and Robbins (1975).

Three subspecies of spotted bass have been identified (Hubbs and Bailey 1940): the Wichita spotted bass (M. p. wichitae) of West Cache Creek, Oklahoma (Ramsey 1975), the Alabama spotted bass (M. p. henshalli) of the Mobile Bay drainage (Gilbert 1973), and the northern spotted bass (M. p. punctulatus) which occurs throughout the remainder of the range (Ramsey 1975). The wichitae subspecies is presumed extinct (Cook 1979).

Spotted bass is primarily a stream species and generally fares poorly in reservoirs except those having deep, clear, relatively infertile water and steep, rocky shorelines (Jenkins 1975; Vogele 1975a; Webb and Reeves 1975). Spotted bass occupy a wide variety of stream types (Robbins and MacCrimmon 1974; Vogele 1975a). They favor streams with moderate currents, rocky substrates, and alternating pools and riffles (Cross 1967; Vogele 1975a; Smith 1979). Spotted bass occupy stream habitats intermediate to those preferred by largemouth bass (M. salmoides) and smallmouth bass (M. dolomieui). The largemouth frequents backwaters and other slack water areas, the smallmouth prefers fast-moving waters in or near riffles, and the spotted bass favors areas with slow to moderate currents (Ryan et al. 1970; Miller 1975; Vogele 1975a; Trautman 1981). In Missouri, spotted bass are the most abundant of the centrarchid basses in the main channels of larger rivers and in warm, gravelly, relatively turbid streams. In contrast, smallmouth bass predominate in cool, clear, high gradient streams and largemouth prefer clear, weedy, standing waters (Fajen 1975; Pflieger 1975).

Age, Growth, and Food

Spotted bass typically mature at age III-IV (Olmsted 1974; Vogele 1975b). Olmsted (1974) found that in Lake Fort Smith, Arkansas, 34.2% of spotted bass were mature at age II, 85.5% at age III, and 100% at age IV.

Spotted bass fry eat plankton and aquatic and terrestrial insects (Howland 1931; Smith and Page 1969; Mullan and Applegate 1970; Ryan et al. 1970). Larger spotted bass (> 75 mm TL) feed on insects, fish (centrarchids, clupeids), and crayfish to varying degrees, depending on location, season, and availability (Rosebery 1950; Smith and Page 1969; Mullan and Applegate 1970; Aggus 1972), but crayfish often predominate in the diet of spotted bass in streams (Howland 1931; Scalet 1977), and in reservoirs (Aggus 1972; Bohn 1975; Lewis 1976). Numerous researchers have noted a close association between abundance of crayfish and abundance of spotted bass (Cross 1967; Vogele 1975a).

Reproduction

Trautman (1981) and Lewis and Elder (1953) noted that spotted bass in Ohio and Illinois migrate upstream to spawn in tributaries of larger rivers as temperatures warm in the spring. Spotted bass spawn primarily in April and May (Vogele 1975a; Aasen and Henry 1981) as temperatures rise above 14° to 15° C (Ryan et al. 1970; Vogele 1975a,b; Aasen and Henry 1981). Little nest building or spawning occurs at temperatures < 15° C (Vogele 1975b) or > 22° C (Aasen and Henry 1981).

Eggs are laid in nests built and guarded by males (Vogele 1975b). In streams, nests are constructed in areas protected from current, but not in backwaters (Pflieger 1975). Coves and steep shorelines are used for nesting in reservoirs (Olmsted 1974; Vogele 1975b; Aasen and Henry 1981). Spotted bass show a strong preference for nest building on rocky or other firm substrate near cover of logs, brush, or clumps of submerged vegetation (Howland 1932; Olmsted 1974; Vogele 1975b; Vogele and Rainwater 1975; Aasen and Henry 1981). Nest depths generally are greater than other centrarchid basses (Vogele 1975a; Aasen and Henry 1981). The mean depth of nests was reported as 2.3 to 3.7 m in Bull Shoals Reservoir, Arkansas (Vogele 1975b), and 2.7 m in Lake Perris, California (Aasen and Henry 1981).

Embryos hatch within 5 days at temperatures near 15° C (Vogele 1975b). Fry form schools near shoreline cover and are guarded by males until they disperse (Vogele 1975b).

Specific Habitat Requirements

Substrate type and current appear to be major physical determinants of habitat suitability for spotted bass in streams. Streams where spotted bass are most abundant are characterized by rocky substrates; large, deep pools; and well-defined riffles (Howland 1931; Ryan et al. 1970; Robbins and MacCrimmon 1974; Fajen 1975). Large, deep pools provide resting cover and spawning habitat; rocky substrates provide suitable habitat for production of aquatic insects (Hynes 1970) and crayfish (Loring and Hill 1976) used as food by spotted bass. Fajen (1975) reported that stocking success of spotted bass in Missouri streams devoid of centrarchid basses was highest in those streams with the above features and very low in streams with substrates comprised of shifting sand or silt. A decline in spotted bass populations after channelization of streams in Louisiana was noted by Robbins and MacCrimmon (1974). Turbidity appears to be a less significant factor in the suitability of a stream as spotted bass habitat. The spotted bass is more tolerant of turbidity than smallmouth bass (Fajen 1975; Pflieger 1975) and is found in streams of varying turbidity throughout its range. Layher (1983), however, found that standing crops of spotted bass in Kansas were largest in stream sites with low to moderate levels of turbidity (≤ 60 JTU's).

Substrate type, turbidity, fertility, and depth appear to be the major factors affecting habitat suitability of reservoirs for spotted bass (Olmsted 1974; Jenkins 1975; Vogele 1975a). Jenkins (1975) reported that standing crops of spotted bass in reservoirs were positively correlated with mean depth and negatively correlated with total dissolved solids (TDS). Steep, rocky shorelines are a characteristic feature of reservoirs where spotted bass are abundant (Roseberry 1950; Olmsted 1974; Vogele 1975a; Webb and Reeves 1975).

Spotted bass are restricted to fresh water; Bailey et al. (1954) reported that they are absent from waters along the Gulf Coast with salinities exceeding 1 ppt. Based on the pH requirements and tolerances of largemouth and smallmouth bass (Bulkley 1975), a pH range of 6.0 to 9.5 is considered to be suitable for survival of all life stages of spotted bass. Layher (1983) found that adult spotted bass standing crops were highest in those Kansas streams having a pH value between 8.5 and 9.0.

Adult. Adult spotted bass in rivers prefer deep areas with slight to moderate current (Ryan 1970; Vogele 1975a; Trautman 1981). They tend to avoid areas of soft mud substrate, dense emergent vegetation, or fast current (Howland 1931; Fajen 1975; Vogele 1975a). In reservoirs, adult spotted bass are generally found near deep, rocky, littoral areas or reefs (Olmsted 1974; Robbins and MacCrimmon 1974; Vogele 1975b), as well as deep, open water above the thermocline (Dendy 1945; Stroud 1948). As in streams, they tend to avoid reservoir areas with soft mud substrate and dense vegetation (Olmsted 1974). In Lewis Smith Reservoir, Alabama, spotted bass showed a strong attraction to man-made structures added to increase cover in open water (Smith et al. 1980).

Adult spotted bass grow best at temperatures near 24° C (Mohler 1966). Dendy (1945) and Stroud (1948) reported that spotted bass in Norris Reservoir, Tennessee, were most abundant in epilimnetic areas with temperatures of 23.5 to 24.4° C. The upper lethal temperature range for spotted bass is undetermined, but is probably near 34° C (Robbins and MacCrimmon 1974). Spotted bass growth is greatly reduced at temperatures ≤ 15.5° C and ceases at temperatures ≤ 10° C (Mohler 1966). Adult spotted bass can survive dissolved oxygen (D.O.) levels near 1 mg/l for short periods, but D.O. levels ≥ 6 mg/l are optimum for long term survival and growth (Mohler 1966).

Embryo. Because nests in reservoirs are often built in relatively deep water (Vogele 1975b; Aasen and Henry 1981), spring reservoir drawdown may be less detrimental to reproduction of spotted bass than it is to other centrarchid basses which construct much shallower nests (Aasen and Henry 1981). The strong preference shown by spotted bass for nest building on firm substrates near cover (Olmsted 1974; Vogele 1975b; Aasen and Henry 1981) suggests that substrate type and cover are important features in determining suitability of habitat for reproduction of spotted bass.

The temperature and dissolved oxygen (D.O.) requirements for embryos are unknown. Presumably, temperatures of 18 to 21° C are optimum for growth and survival of embryos, because these temperatures occur during peak spawning activity (Ryan et al. 1970; Vogele 1975a,b; Aasen and Henry 1981). D.O. requirements are likely to be similar to those of smallmouth bass (Siefert et al. 1974); thus, D.O. levels of ≥ 6 mg/l may be considered optimum for survival and growth, and D.O. levels ≤ 1.5 mg/l would be lethal.

Fry. Little is known about the distribution or habitat requirements of spotted bass fry. In reservoirs, fry seek shoreline cover after leaving nests (Vogele 1975a). The amount of cover available to spotted bass for spawning and as fry habitat may directly effect reproductive success and year-class strength in reservoirs (Vogele and Rainwater 1975). Oxygen and temperature requirements of spotted bass fry are unknown but are assumed to be similar to those of adults.

Juveniles. Little is known about specific habitat requirements for juvenile spotted bass as their requirements are rarely differentiated from those of adults in the literature. In Center Hill Reservoir, Tennessee, Jahnke (1979) did not observe substrate preferences for either age 0 or age I juvenile bass. Age 0 fish also showed no location preference but age I bass were most abundant in inner cove habitats. Thus, juvenile spotted bass do not appear to show the strong preference for rocky substrates as reported for adults (Olmsted 1974; Vogele 1975a; Roussel 1979).

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The models were designed to evaluate the suitability of water bodies within the native and introduced range of spotted bass. The standard of comparison for each suitability index is the optimum value of the variable that occurs anywhere within this geographic range. Users of these models should use the Habitat Use Information section of this model, as well as local information, to adapt this model to local conditions.

Season. The models are designed to rate a riverine or lacustrine habitat on its ability to support a self-sustaining population of spotted bass throughout the year.

Cover types. Models are applicable to riverine and lacustrine habitats, as defined by Cowardin et al. (1979).

Verification level. These models have not been tested against habitats of known quality. Layher and Maughan (1982) tested an earlier version of a riverine model for spotted bass having gradient, substrate, temperature, and average velocity as model variables. HSI (computed as the geometric mean of suitability index values for each variable) was not significantly ($p > 0.10$) correlated with standing crop of spotted bass in 46 stream sites in Kansas, but a trend towards increasing standing crops of spotted bass with higher HSI values was evident. Suitability index (SI) graphs for substrate and temperature were found to closely approximate SI curves derived by transforming spotted bass standing crop values to SI's as described in USFWS (1981). Failure of the tested model was attributed to the use of the geometric mean to calculate HSI's and to the absence of limiting variables from the model. Layher (1983) found that mean width, minimum width, percent riffle, pH, turbidity, temperature, and nitrates accounted for most of the variation in standing crop of spotted bass in Kansas streams. This information was used in developing SI graphs for the riverine HSI model presented here. Mean width, minimum width, and nitrates were excluded as model variables since they were considered either correlates of other model variables or would not be useful in evaluating habitats under future conditions.

Model Description - Riverine

Overview. The HSI model is an attempt to condense information on habitat requirements of spotted bass into a set of habitat evaluation criteria. The model includes those variables with a known impact on the growth, survival, distribution, abundance, standing crop, and/or preferences of spotted bass, and thus could be expected to have an impact on the carrying capacity of a habitat. The model is structured to produce a relative index of the ability of a present or future habitat to meet the food and cover, water quality, and reproductive requirements of spotted bass. The hypothetical relationship between habitat variables, model components, and HSI is illustrated in Figure 1.

The following sections document why a particular set of habitat variables were chosen for each model component. The definition and justification of the suitability levels of each model variable are described in the Suitability Index Graphs section.

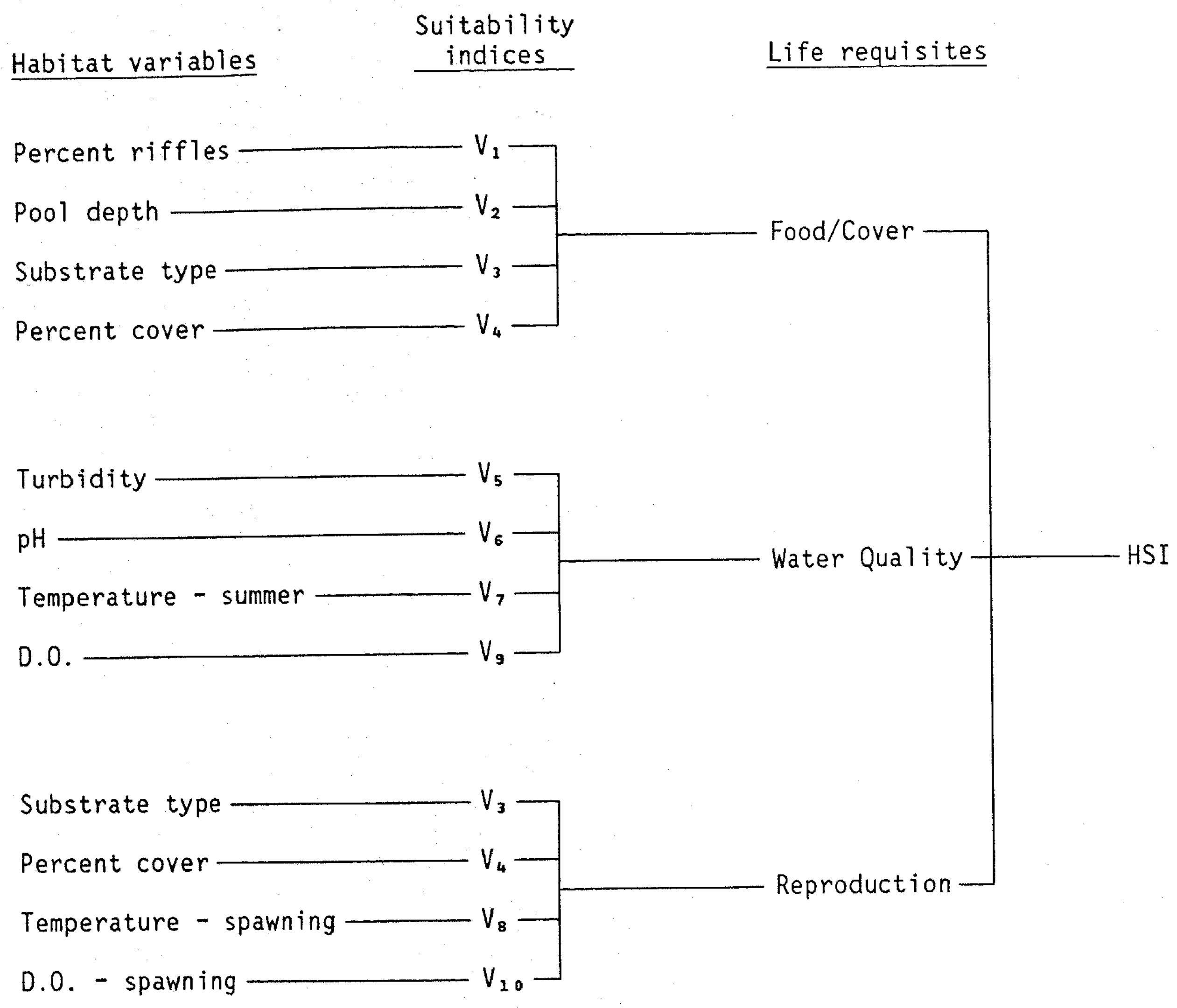


Figure 1. Diagram illustrating habitat variables in the riverine HSI model and the aggregation of the corresponding suitability indices (SI's) into an HSI. HSI = the lowest of the 9 suitability index ratings.

Food/cover component. The literature documents a wide variety of food types eaten by spotted bass, but crayfish are often reported as a primary component of the diet. Percent rocky substrate (V_3) was included in this component because crayfish are most abundant in rocky substrates which they require for shelter (Loring and Hill 1976). V_3 should also provide an index of aquatic insect availability, a seasonally abundant food item for spotted bass in at least some streams (e.g., Smith and Page 1969), because aquatic insect production is highest on rocky substrates (Hynes 1970). V_3 also was included in this component because numerous sources document that spotted bass are most abundant in gravel-bottomed streams. Layher and Maughan (1982) provided data that standing crop of spotted bass is proportional to the amount of rocky substrate present.

Percent riffles (V_1) was included in this component because (1) spotted bass streams commonly have alternating pools and well-defined riffles, and (2) Layher (1983) found that standing crop of spotted bass in Kansas streams varied with percentage of riffles present. Similarly, pool depth (V_2) was included because spotted bass are most abundant in streams with large, deep pools (Howland 1931; Ryan et al. 1970; Fajen 1975).

Structural cover (V_4) of logs, boulders, and brush are common in streams where spotted bass are found and thus was included in this component. Also, it seems that increased cover provides more suitable habitat for forage fishes eaten by spotted bass in streams (i.e., cyprinids and centrarchids).

Water quality component. Turbidity (V_5) was included as a variable in this component because spotted bass are most abundant in clear to moderately turbid conditions (e.g., Pflieger 1975) and are intolerant of conditions associated with high turbidity (e.g., high siltation) (Smith 1979).

This component includes pH (V_6) because pH is a known limiting factor of fish populations. In addition, Layher (1983) found evidence that standing crop of spotted bass in streams varies with pH level.

Spotted bass occur over a wide latitudinal range, but seem to prefer temperatures (V_7) somewhat intermediate to those preferred by smallmouth bass and largemouth bass. Standing crop of spotted bass in Kansas streams was highest at summer temperatures of 24 to 27° C.

Relatively little is known about D.O. (V_9) requirements of spotted bass. As with the other centrarchid basses, they are probably tolerant of short term decreases in D.O. to 2 mg/l, but long term D.O. levels below 3 mg/l are probably limiting. Layher (1983) did not find spotted bass in Kansas streams with D.O. levels below 4 mg/l.

Reproduction component. Spawning requirements of spotted bass appear relatively flexible, although they do exhibit preferences for building nests on firm substrates near cover (Vogele 1975b). V_3 and V_4 were included in this component as measures of these preferences. Measurements of temperature (V_8) and D.O. (V_{10}) are included in this component in as much as nesting success will depend on the suitability of these variables' values during the spring spawning period.

HSI determination. It was assumed that the most limiting factor (i.e., lowest SI score) defines carrying capacity for spotted bass in rivers; thus, the HSI equals the minimum value of any of the suitability indices V_1 to V_{10}.

Model Description - Lacustrine

Overview. Spotted bass usually are a minor component of centrarchid bass standing crop in reservoirs (largemouth bass are more prevalent), except in reservoirs characterized by deep, clear, relatively infertile water and steep, rocky shorelines. Model variables were chosen that provide measures of these reservoir habitat characteristics for spotted bass. The relationship between lacustrine habitat variables, model components, and HSI is illustrated in Figure 2. The "other" component comprises a variable that affects habitat suitability for spotted bass, but which does not fit easily into food/cover, water quality, or reproduction components of the model.

Food/cover component. The literature characterizes spotted bass as most abundant in reservoirs with rocky substrates and as avoiding reservoir sections with mud substrate and dense emergent vegetation; thus, percent rocky substrate (V_3) was included in this component. Aggus (1972) found that crayfish, a primary food item of spotted bass in reservoirs, were closely tied to rocky substrates in Bull Shoals Reservoir, Arkansas. Percent cover (V_4) was also included in this component since spotted bass are attracted to rocky outcroppings and man-made midwater structures. Again, it seems that more available cover indicates a more suitable habitat for forage fishes utilized by spotted bass.

Water quality component. Turbidity (V_5) was included in this component because reservoirs with high populations of spotted bass are commonly characterized in the literature as having clear water. For the model variables of pH (V_6), temperature (V_7), and D.O. (V_9), see the explanations presented in the water quality component of the riverine HSI model.

Reproduction component. Spotted bass in reservoirs prefer rocky substrates (V_3) near log or brush cover (V_4) as nest sites. Due to this preference and deeper nest depths, spotted bass appear to do better than other centrarchid basses in reservoirs that have fluctuating water levels in spring and/or rocky, relatively barren substrates predominating along the shoreline as in Lake Perris, California (Aasen and Henry 1981) and Lewis Smith Reservoir, Alabama (Webb and Reeves 1975; Smith et al. 1980).

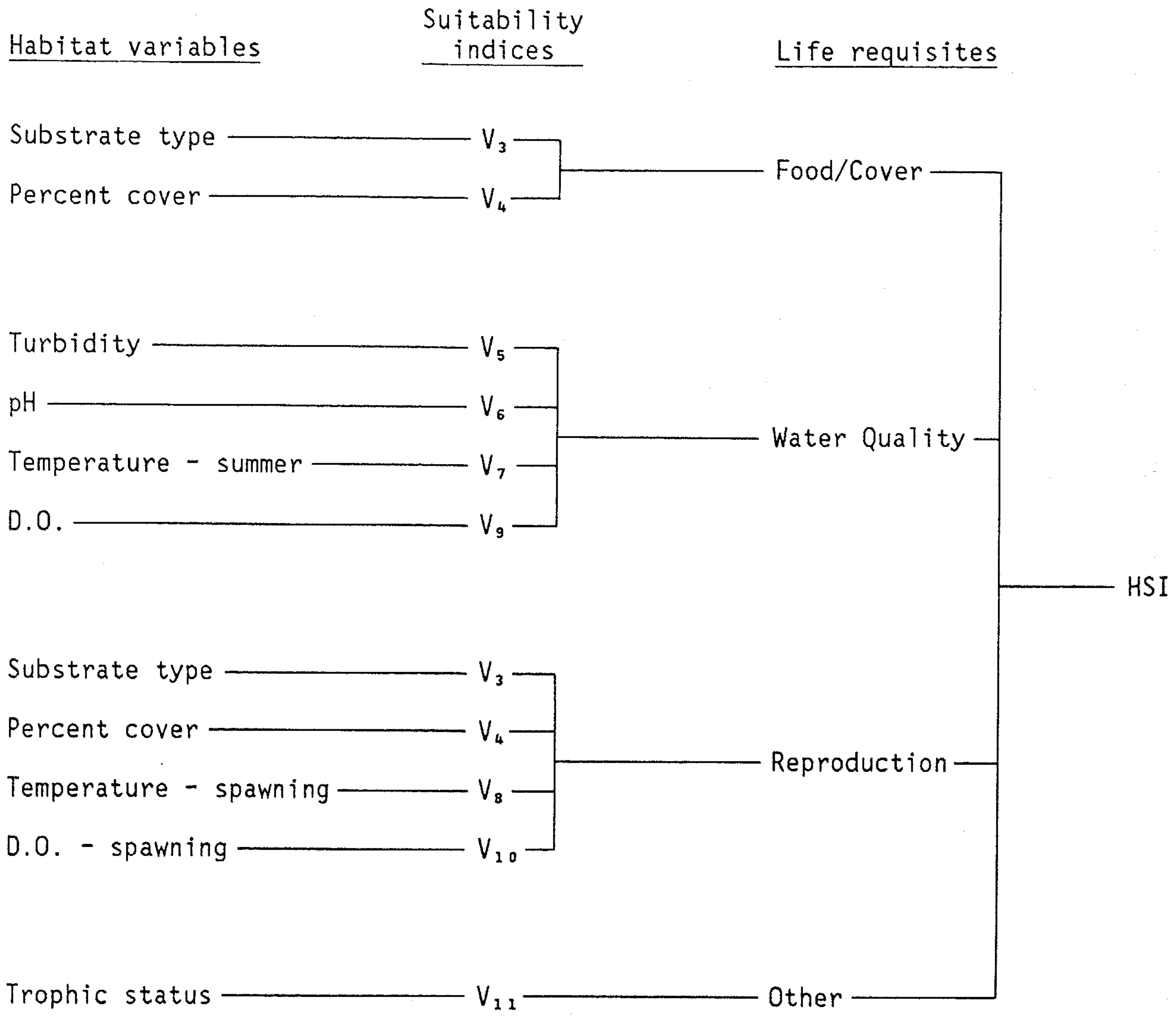


Figure 2. Diagram illustrating habitat variables in the lacustrine HSI model and the aggregation of the corresponding suitability indices (SI's) into an HSI. HSI = the lowest of the 10 suitability index ratings.

For explanations on why temperature (V_8) and D.O. (V_{10}) were included in this component, see the water quality component of the riverine HSI model.

Other component. Trophic status (V_{11}) was included as a measure of habitat suitability for spotted bass because fertility and mean depth have been identified by regression analyses and observation as variables highly likely to affect the population abundance of spotted bass in reservoirs (see Habitat Use Information section). A general trophic class rating system is thought to be a more representative and useful system of rating than specific SI graphs for TDS and mean depth because available information is only of a general nature. Deep, relatively oligotrophic reservoirs define the optimum lacustrine habitat for spotted bass. Examples of reservoirs with these characteristics, and that have high standing crops of spotted bass, are:

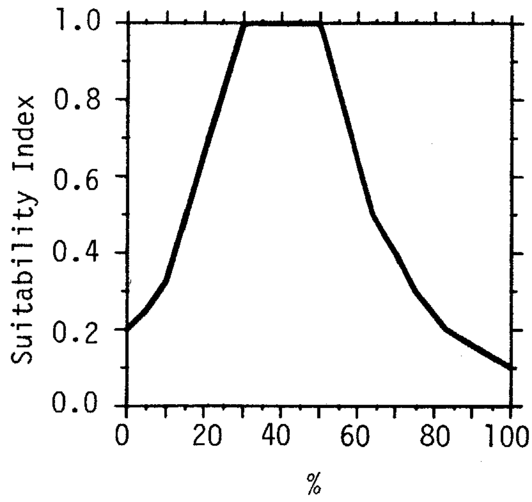
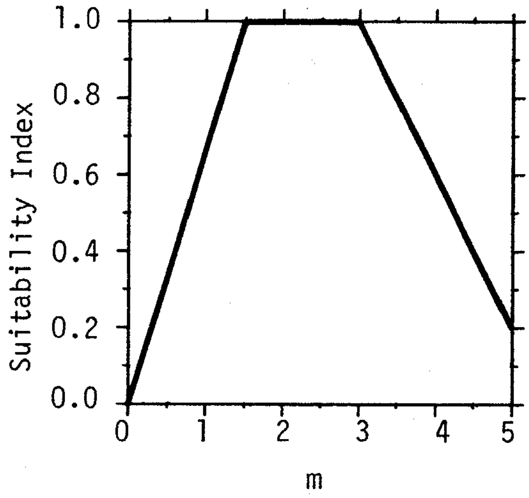
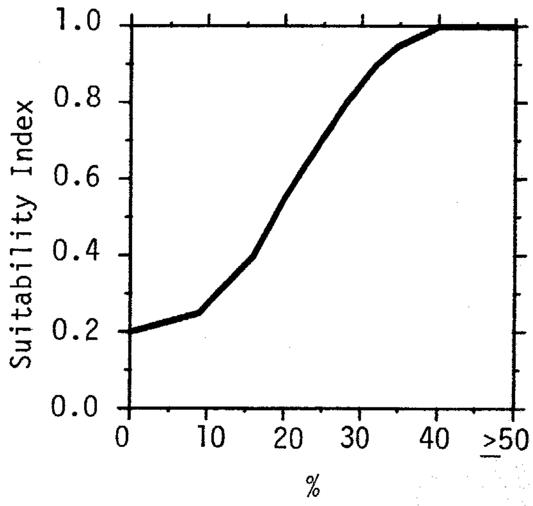
Reservoir/location	Fertility	Mean depth	References
Center Hill, Tennessee	TDS = 115 mg/l (MEI = 4.8)	24 m	Hargis 1965; Leidy and Jenkins 1977
Bull Shoals, Arkansas*	TDS = 150 mg/l (MEI = 6.8) *Secchi depth = 8.4 m	22 m	Leidy and Jenkins 1977; Vogele 1975a
Allatoona, Georgia	TDS = 40 mg/l (MEI = 3.9)	10.3 m	Kirkland 1965; Leidy and Jenkins 1977
Lewis Smith, Alabama	low	30 m	Webb and Reeves 1975
Claytor, Virginia	low	high	Roseberry 1950

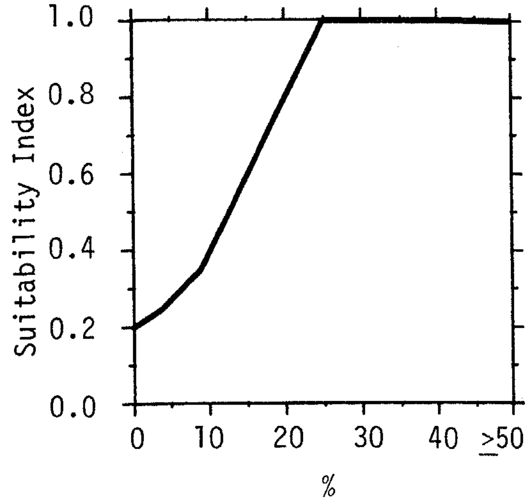
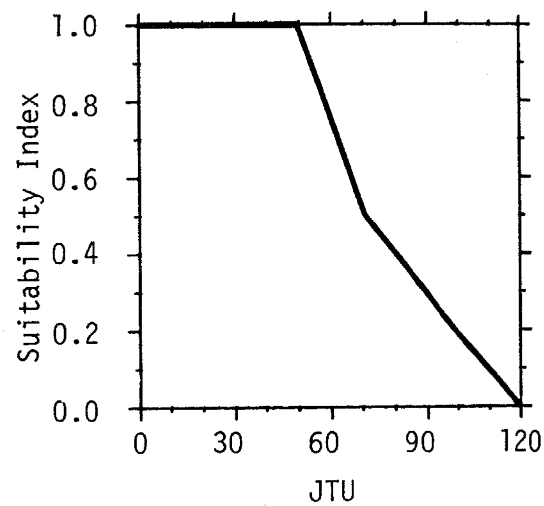
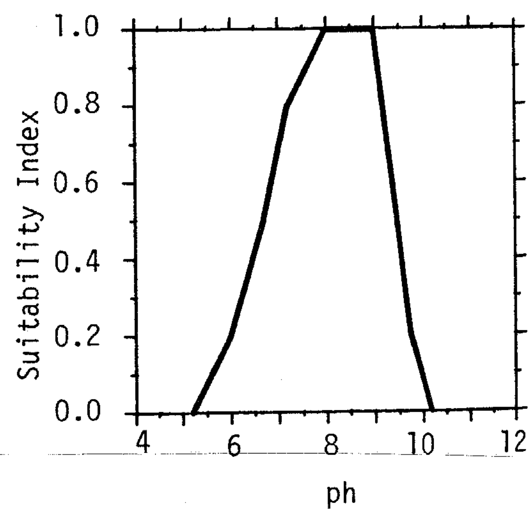
In contrast, spotted bass populations do poorly in shallow, eutrophic impoundments even if they were common in the stream prior to impoundment (Patriarche 1953; Vogele 1975a).

HSI determination. The most limiting factor (i.e., lowest SI score) was assumed to define carrying capacity for spotted bass in reservoirs; thus, HSI equals the minimum value for suitability indices V_3 through V_{11}.

Suitability Index (SI) Graphs for Model Variables

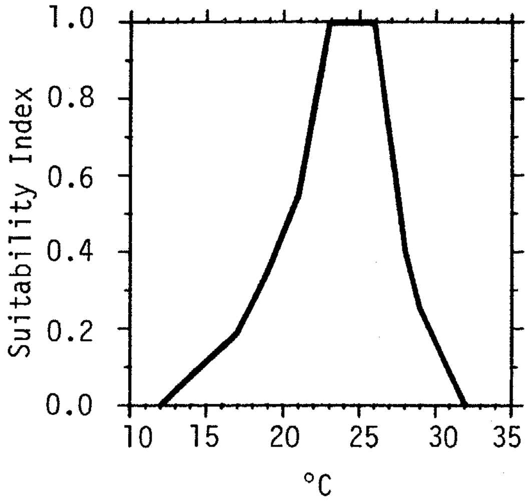
Table 1 lists the rationale and assumptions used in constructing each SI graph. Graphs were constructed by converting available information on the habitat requirements of spotted bass into an index of suitability from 0.0 (unsuitable) to 1.0 (optimum). Descriptors for each habitat variable were chosen to emphasize limiting conditions for each variable. This choice reflects our assumption that extreme, rather than average, values of a variable most often limit the carrying capacity of a habitat. (R) refers to Riverine and (L) to Lacustrine model variables.

Habitat	Variable		
R	V_1	Percent riffles during low summer flow period. (Riffle = areas where substrate projects above water surface or where flow is turbulent.)	
R	V_2	Average pool depth during low summer flow period. (Suggested measurement = average of pool depths at 1 m intervals across transects.)	
R,L	V_3	Percent of substrate in streams (R) or reservoirs (L) comprised of gravel, cobble, boulders, or bedrock.	

R,L	V_4	Percent cover (boulders, brush, log piles, or other structure) in pools (R) or above thermocline in reservoirs (L).	
R,L	V_5	Average turbidity during summer.	
R,L	V_6	Annual maximum or minimum pH. (Use measurement with lowest SI value.)	

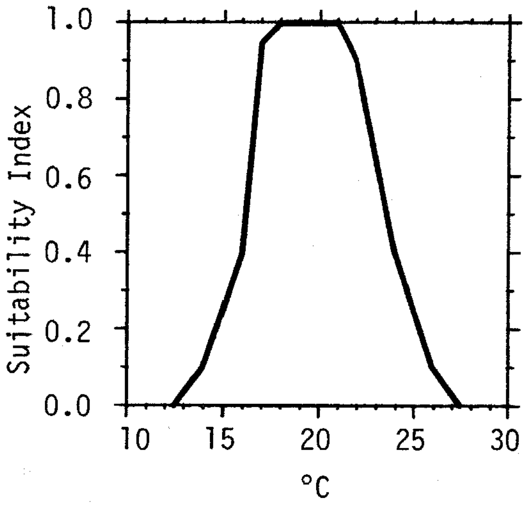
R,L V_7

Average maximum daily temperature during warmest summer month. (For lacustrine applications (L), the SI value is the most suitable temperature above the thermocline during the month.



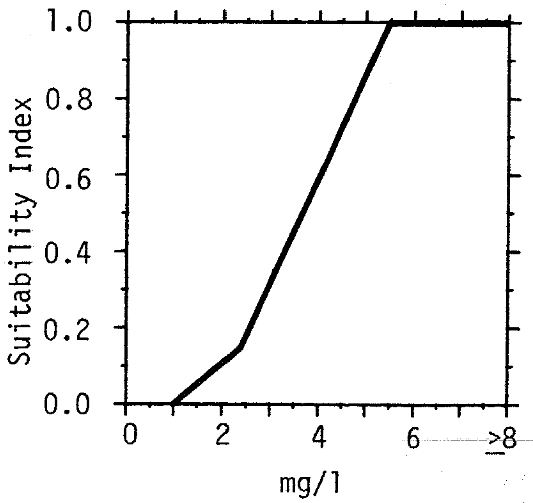
R,L V_8

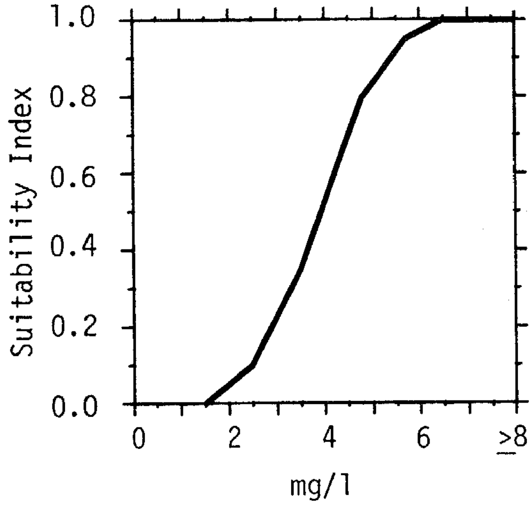
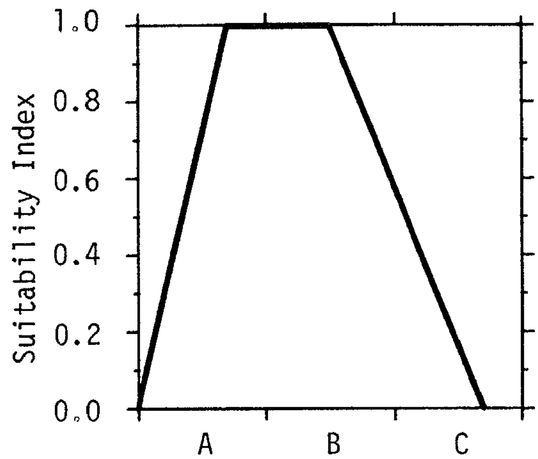
Minimum temperature during spawning (April to May). For example, if temperature declines to 15° C when bass are spawning, then SI = 0.2.



R,L V_9

Minimum dissolved oxygen levels during summer, fall, and winter in pools (R) or at location selected for most suitable temperature for variable V_7 (L).



R,L	V_{10}	Minimum dissolved oxygen level determined at same time and location as for V_8.	
L	V_{11}	Trophic status/ productivity of lake or lake section.	

Parameter[1]	A (Oligotrophic)	B (Mesotrophic)	C (Eutrophic)
Productivity	low	medium	high
Sedimentation rate	low	medium	high
Nutrient levels (mg/m³-P)	< 9	9-18	> 18
Morphoedaphic Index (MEI)[2]	< 6.0	6-7.2	> 7.2
Transparency (Secchi depth)	> 6 m	1-6 m	< 1 m

[1]Table adapted from Leach et al. (1977).

[2]MEI = TDS (mg/l)/mean depth (m).

Table 1. Sources of information and assumptions used in construction of the suitability index graphs. "Excellent" habitat for spotted bass refers to an SI of 0.8 to 1.0, "good" an SI of 0.5 to 0.7, "fair" 0.2 to 0.4, and "poor" habitat 0.0 to 0.1.

Variable	Assumptions and sources
V_1	Spotted bass are most abundant in streams with well-defined riffles and deep pools (Howland 1931; Lewis and Elder 1953; Ryan et al. 1970; Fajen 1975; Trautman 1981), therefore, a mixture of riffles and pools is considered excellent. Zero percent riffles is considered poor habitat because spotted bass are rare in backwaters and other areas lacking at least some current (Fajen 1975; Vogele 1975a; Ryan et al. 1970). High percent riffles is also poor because: (1) spotted bass in streams occupy large, deep pools (Howland 1931; Fajen 1975); (2) channelization adversely affects spotted bass populations (Robbins and MacCrimmon 1974); and (3) stocking success of spotted bass was very poor in rivers with extensive channelization (Fajen 1975). The general shape of the graph for V_1 was based on the following standing crop data from Kansas streams (Layher 1983):

Percent riffles	No. of stream sites	Mean standing crop	Fraction of maximum mean standing crop = SI
< 15	302	0.82	0.25
15-30	62	2.09	0.62
30-45	26	3.35	1.00
45-60	5	0.00	0.00
60-75	-	-	-
75-90	3	0.00	0.00
> 90	1	0.00	0.00

V_2	Shallow pools are deemed poor because stocking success (Fajen 1975) and abundance of spotted bass (Howland 1931; Trautman 1981) is low in streams where shallow pools predominate. Average pool depths ≥ 1 m are rated good to excellent because spotted bass are most abundant in large, moderately deep pools (Howland 1931; Ryan et al. 1970; Robbins and MacCrimmon 1974; Fajen 1975; Trautman 1981) and standing crop of spotted bass was highest in Kansas streams having mean depths 1.2 to 1.8 m (Layher 1983). Spotted bass prefer areas with some current, which is most characteristic of small- to moderate-sized streams (< 30 m wide) (Ryan et al. 1970; Robbins and MacCrimmon 1974; Vogele 1975a; Layher 1983), thus, the suitability of depths ≥ 5 m was determined to be only fair.

Table 1. (continued).

Variable	Assumptions and sources
V_3	It is assumed that habitat suitability is proportional to the amount of rocky substrates present in streams and reservoirs because: (1) spotted bass are most abundant in streams (Howland 1931; Lewis and Elder 1953; Cross 1967; Fajen 1975; Layher and Maughan 1982), reservoirs (Roseberry 1950; Aasen and Henry 1981), and reservoir sections (Olmsted 1974; Roussel 1979) with rocky substrates; (2) spotted bass prefer rocky substrates as spawning sites (Olmsted 1974; Vogele 1975b; Aasen and Henry 1981); (3) crayfish are a primary component of the diet of spotted bass and crayfish are most abundant in rocky substrates that provide them shelter (Aggus 1972; Emery 1975; Loring and Hill 1976); and (4) spotted bass, especially juveniles (e.g., Smith and Page 1969), eat aquatic insects and production of aquatic insects is highest on gravel-cobble substrates (Hynes 1970). Spotted bass are absent from areas of dense emergent vegetation and mud bottom (Olmsted 1974), and stocking was unsuccessful in Missouri streams with shifting sand substrate (Fajen 1975), therefore these substrate types are deemed poor.
V_4	The strong preference of spotted bass for building their nests near brush or other forms of cover (Vogele 1975b; Vogele and Rainwater 1975; Aasen and Henry 1981), the use of cover by fry after leaving their nests (Vogele 1975b), the attraction of spotted bass to man-made midwater structures (Smith et al. 1980) and rocky outcroppings in reservoirs (Robbins and MacCrimmon 1974), and the common listing of abundant cover as a habitat characteristic of spotted bass streams (e.g., Viosca 1932; Ryan et al. 1970), suggests that some cover is necessary for optimum conditions. Zero percent cover is assigned an SI of 0.2 because a stream or reservoir may still be able to support spotted bass, although at a much reduced level. The selection of ≥ 25% cover as optimum is our best estimation based on available information.
V_5	Although spotted bass are found over a wide range of turbidities (Robbins and MacCrimmon 1974; Vogele 1975a), low turbidities are considered excellent because spotted bass are most abundant in clear streams and reservoirs (e.g., Lewis and Elder 1953; Cross 1967; Olmsted 1974; Vogele 1975a; Webb and Reeves 1975). The SI graph was constructed primarily on the basis of the following standing crop data from Kansas streams (Layher 1983):

Table 1. (continued).

Variable	Assumptions and sources

Turbidity (JTU's)	No. of stream sites	Mean standing crop (Kg/ha)	Fraction of maximum mean standing crop = SI
0-30	161	1.77	1.00
30-60	49	1.54	0.87
60-90	18	0.61	0.35
90-120	10	0.01	0.01
120-570	15	0.00	0.00

V_6 Levels of pH in the range of 6.0 to 9.5 are generally considered suitable for centrarchid basses (Bulkley 1975). The general shape of the graph was based on the following standing crop data from Kansas streams (Layher 1983):

pH	No. of stream sites	Mean standing crop (Kg/ha)	Fraction of maximum mean standing crop = SI
< 6.5	3	0.00	0.00
≥ 6.5-6.99	10	0.88	0.38
≥ 7.0-7.49	39	0.21	0.09
≥ 7.5-7.99	114	0.61	0.27
≥ 8.0-8.49	149	1.01	0.44
≥ 8.5-8.99	72	2.30	1.00
≥ 9.0-9.49	14	0.00	0.00

Unsuitable pH levels were determined by the levels that were lethal to largemouth bass in laboratory experiments [< 4.2 and > 10.3 (Calabrese 1969)].

Table 1. (continued).

Variable	Assumptions and sources
V_7	Temperatures associated with highest growth in laboratory experiments [24° C (Mohler 1966)], highest abundance in reservoirs [23.5 to 24.4° C (Dendy 1945; Stroud 1948)], and highest standing crops in Kansas streams (see below) are rated excellent. Temperatures that (1) are assumed lethal to spotted bass [≥ 34° C (Robbins and MacCrimmon 1974)], (2) are avoided [> 34° C (Cherry et al. 1975)], or (3) corresponded to an absence of spotted bass in Kansas streams (≥ 32° C), are deemed poor as are temperatures associated with little or no growth [< 15° C (Mohler 1966)] and very low standing crops [< 12 to 16° C (Layher 1983)]. The shape of the graph between optimum and no suitability was based on the following standing crop data from Kansas streams (Layher 1983):

Temperature interval	No. of stream sites	Mean standing crop (Kg/ha)	Fraction of maximum mean standing crop = SI
≥ 12-15	27	0.02	0.01
≥ 16-19	45	0.45	0.20
≥ 20-23	98	1.10	0.50
≥ 24-27	129	2.15	1.00
> 28-31	41	0.89	0.40
≥ 32-35	3	0.00	0.00
≥ 36-39	1	0.00	0.00

Variable	Assumptions and sources
V_8	Temperatures coinciding with highest incidence of spawning [17 to 21° C (Ryan et al. 1970; Olmsted 1974; Vogele 1975a,b; Aasen and Henry 1981)] are excellent. Temperatures above [> 23° C (Vogele 1975a,b; Aasen and Henry 1981)] or below [< 15° C (Olmsted 1974; Vogele 1975a,b; Aasen and Henry 1981)] the range where nesting has been observed are poor.
V_9	D.O. levels coinciding with highest growth and survival of spotted bass [≥ 6 mg/l (Mohler 1966)] are excellent. Levels that are lethal to spotted bass [< 1 mg/l (Mohler 1966)] or that elicit avoidance in largemouth bass [< 1.5 mg/l (Whitmore et al. 1960)] are poor. D.O. levels < 5 mg/l are less than optimum because swimming speed (Dahlberg et al. 1968) and production (Warren et al. 1973) of largemouth bass decreases below this level.

Table 1. (concluded).

Variable	Assumptions and sources
V_{10}	No information was available on D.O. requirements of spotted bass embryos. D.O. levels lethal to smallmouth bass embryos in the laboratory [< 2.5 mg/l (Siefert et al. 1974)] are therefore used here, and are considered to be poor. Levels coinciding with a reduction in survival of smallmouth bass embryos are rated fair [< 4 mg/l (Siefert et al. 1974)]. Levels ≥ 6 mg/l are assumed to be excellent for spawning and embryo survival of spotted bass.
V_{11}	Spotted bass are most abundant in deep, relatively infertile reservoirs (Roseberry 1950; Jenkins 1975; Webb and Reeves 1975; Vogele 1975a), therefore, oligotrophic-mesotrophic conditions are considered to be excellent. Eutrophic conditions are considered to have fair-poor suitability because largemouth bass are more abundant than spotted bass under these conditions (Patriarche 1953; Olmsted 1974). Because growth of spotted bass in highly oligotrophic Lake Fort Smith, Arkansas (total alkalinity = 10 to 30 ppm) was very low (Olmsted 1974), we assumed that reservoirs with very low fertility would be less suitable.

Interpreting Model Outputs

The riverine and lacustrine models described above are generalized descriptors of habitat requirements of spotted bass and thus the model output should not be expected to discriminate among different habitats with a high degree of resolution (Terrell et al. 1982).

A spotted bass HSI determined by application of the models may not reflect the population level of spotted bass in the study area since other variables may have a more significant influence in determining spotted bass abundance. A positive relationship between HSI's generated by these models and the measureable indices of population abundance (e.g., standing crop) is assumed, but this hypothesized relationship has not been tested other than by inferences drawn from the literature during the model-building process. The proper interpretation of the HSI is one of comparison. If two areas have different HSI's, the area with the higher HSI should have the potential to support more spotted bass than the one with the lower HSI. Outputs of these models should be interpreted as indicators (or predictors) of excellent (0.8 to 1.0), good (0.5 to 0.7), fair (0.2 to 0.4), or poor (0.0 to 0.1) habitat for spotted bass.

The models should be useful as a basic framework for formulating revised models that incorporate site-specific or project-specific factors affecting habitat suitability for spotted bass (see Terrell et al. 1982). The individual suitability indices may also be useful for identifying habitat variables that may be limiting, without aggregating the SI's into an HSI. Results of testing an earlier version of a riverine HSI model for spotted bass (Layher 1983) suggest an important point. That is, if a more precise index of population abundance is required, use of the HSI models derived from suitability indices aggregated by nonstatistical methods may not be appropriate or should be preceded by evaluating the model in the field. Testing the model will better define which variables are important descriptors of habitat quality in the proposed area of model application or under the post-project conditions.

ADDITIONAL HABITAT MODELS

Descriptive Models

The following models are simplified descriptions of optimum habitat for spotted bass as detailed in the Habitat Use Information section of this summary. These models should be useful for "reconnaissance-grade" applications where the relative quality of habitats for spotted bass must be judged using minimal data.

Riverine model. Optimum riverine spotted bass habitat (assuming water quality is not limiting) is characterized by:

1. Average summer temperatures in the range of 20 to 24° C;

2. Rocky substrates;

3. An approximate 3:2, pool:riffle ratio; and

4. Cover present in pools.

$$HSI = \frac{\text{number of attributes present}}{4}$$

Lacustrine model. Optimum lacustrine spotted bass habitat (assuming water quality is not limiting) is characterized by:

1. Summer water temperatures in the range of 20 to 24° C, with adequate D.O. levels are available;

2. Rocky substrates;

3. Low turbidity (> 5 m Secchi depth);

4. Deep (mean depth > 15 m); and

5. Low fertility (TDS < 125 but > 50 mg/l).

$$HSI = \frac{\text{number of attributes present}}{5}$$

Regression Models

Layher (1983) developed regression equations to predict standing crop of spotted bass in streams in Kansas and Oklahoma. In Kansas, habitat variables of turbidity, mean depth, minimum width, mean width, pH, percent riffles, and temperature accounted for the significant variation in standing crop. Mean width, pH, turbidity, temperature, nitrates, mean depth, and minimum width explained the variation in standing crop in Oklahoma streams. Layher (1983) reports the methods of analysis and provides guidance on potential use of the models to predict standing crop. The regression equations utilize SI's derived from SI graphs as the independent variables. Graphs and equations are presented in Layher (1983). Further information on their use may be obtained from: William G. Layher, Environmental Services Section, Kansas Fish and Game, Pratt, Kansas 67124.

Aggus and Morais (1979) developed regression equations to predict standing crop of spotted bass in reservoirs from easily obtainable preconstruction data. These authors discuss procedures for converting measured or predicted standing crop values for spotted bass to HSI's.

Discriminant Analysis Models

Layher (1983) used discriminant analysis to determine the relationships between habitat variables and presence or absence of spotted bass in streams in Kansas and Oklahoma. The discriminant analysis models showed high reliability for predicting presence or absence of spotted bass within each data set. When the Kansas model was applied to Oklahoma streams, however, many misclassifications resulted, suggesting that the models are reliable only over limited, homogeneous geographical areas. Further information on use of these discriminant models can be obtained by contacting William G. Layher at the address listed in the Regression Models section.

INSTREAM FLOW INCREMENTAL METHODOLOGY (IFIM)

The U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (IFIM), as outlined by Bovee (1982), is a set of ideas used to assess instream flow problems. The Physical Habitat Simulation System (PHABSIM), described by Milhous et al. (1984), is one component of IFIM that can be used by investigators interested in determining the amount of available instream habitat for a fish species as a function of streamflow. The output generated by PHABSIM can be used for several IFIM habitat display and interpretation techniques, including:

1. Optimization. Determination of monthly flows that minimize habitat reductions for species and life stages of interest;

2. Habitat Time Series. Determination of the impact of a project on habitat by imposing project operation curves over historical flow records and integrating the difference between the curves; and

3. Effective Habitat Time Series. Calculation of the habitat requirements of each life stage of a fish species at a given time by using habitat ratios (relative spatial requirements of various life stages).

Suitability Index Graphs as Used in IFIM

PHABSIM utilizes Suitability Index graphs (SI curves) that describe the instream suitability of the habitat variables most closely related to stream hydraulics and channel structure (velocity, depth, substrate, temperature, and cover) for each major life stage of a given fish species (spawning, egg incubation, fry, juvenile, and adult). The specific curves required for a PHABSIM analysis represent the hydraulic-related parameters for which a species or life stage demonstrates a strong preference (i.e., a species that only shows preferences for velocity and temperature will have very broad curves for depth, substrate, and cover).

Four categories of SI curves are described below. All species curves for HEP and IFIM are referred to collectively as suitability index (SI) curves or graphs. The designation of a curve as belonging to a particular category does not imply that there are differences in the quality or accuracy of curves among the four categories.

Category one curves are the most common type presently available for use with HEP or IFIM. Usually category one curves have as their basis one or more literature sources. Some SI curves may be derived from general statements made in the literature about fishes (i.e., rainbow trout spawn in gravel; fry prefer shallow water). Some category one curves may come from literature sources which include variable amounts of field data (i.e., from a sample size of 300, fry were observed in velocities ranging 0.0 to 3.0 ft/sec, and 80% were found in velocities less than 1.0 ft/sec). Other category one curves may be based entirely on professional opinion, by using the Delphi technique or educated guesswork (i.e., an expert believes that velocities ranging 1.0 to 8.0 ft/sec are necessary for successful spawning of striped bass). Most category one curves are the result of a combination of sources; the final curve may include information from the literature, combined with field data, and smoothed or modified using professional judgement. Category one curves usually are intended to reflect general habitat suitability throughout the entire geographic range of the species and throughout the year, unless they are identified as being applicable only to a given area or season. In the latter case, curves developed for a specific area or stream may not accurately reflect habitat utilization in other areas. Curves meant to describe the general habitat suitability of a variable throughout the entire range of a species may not be as sensitive to small changes of the variable within a specific stream (i.e., rainbow trout will generally utilize silt, sand, gravel, and cobble for spawning substrate, but utilize only cobble in Willow Creek, Colorado).

Category two curves are derived from frequency analyses of field data, and are basically curves fit to a frequency histogram. Each curve describes the observed utilization of a habitat variable by a life stage. Category two curves unaltered by professional judgement or other sources of information are referred to as utilization curves. When modified by judgement they then become category one curves. Utilization curves from one set of data are not applicable for all streams and situations (i.e., a depth utilization curve from a shallow stream cannot be used for the Missouri River). Category two curves, therefore, are usually biased because of limited habitat availability. An ideal study stream would have all substrate and cover types present in equal amounts; all depth, velocity, and percent cover intervals available in equal proportions; and all combinations of all variables in equal proportions. Utilization curves from such a perfectly designed study theoretically should be transferable to any stream within the geographical range of the species. Curves from streams with high habitat diversity, then, are generally more transferable than curves from streams with low habitat diversity. Users of a category two curve should first review the stream description to see if conditions are similar to those present in the stream segment to be investigated. Some variables to consider might include stream width, depth, discharge, gradient, elevation, latitude and longitude, temperature, water quality, substrate and cover diversity, fish species associations, and data collection descriptors (time of day, season of year, sample size, sampling methods). If one or more deviate significantly from those of the proposed study site, then curve transference is not advised, and the investigator should develop his own curves.

Category three curves are derived from utilization curves which have been corrected for environmental bias and therefore represent preference of the species. To generate a preference curve, one must simultaneously collect habitat utilization data and habitat availability data from the same area. Habitat availability should reflect the relative amount of different habitat types in the same proportions as they exist throughout in the stream-study area. A curve is then developed for the habitat frequency distribution in the same way as for fish utilization observations, and the equation coefficients of the availability curve are subtracted from the equation coefficients of the the utilization curve, resulting in preference curve coefficients. Theoretically, category three curves should be unconditionally transferable to any stream, although this has not been validated. At present, very few category three curves exist because most habitat utilization data sets are without concomitant habitat availability data sets. In the future, the need to collect habitat availability data will be impressed upon investigators.

Category four curves (conditional preference curves), describe habitat requirements as a function of interaction among variables. For example, fish depth utilization may depend on the presence or absence of cover; or velocity utilization may depend on time of day or season of year. Category four curves are just beginning to be developed by IFASG.

HSI models generally utilize category one curves for habitat evaluation. IFIM analyses may utilize any or all categories of curves, but category three and four curves yield the most precise results in IFIM applications; and category two curves will yield accurate results if they are found to be transferable to the stream segment under investigation. If category two curves are not felt to be transferable for a particular application, then category one curves may be a better choice.

For an IFIM analysis of riverine habitat, an investigator may wish to utilize the curves available in this publication; modify the curves based on new or additional information; or collect field data to generate new curves. For example, if an investigator has information that spawning habitat utilization in his study stream is different from that represented by the SI curves, he may want to modify the existing SI curves or collect data to generate new curves. Once the curves to be used are decided upon, then the curve coordinates are used to build a computer file (FISHFIL) which becomes a necessary component of PHABSIM analyses (Milhous et al. 1984).

Availability of Graphs for Use in IFIM

All curves available for IFIM analyses of spotted bass habitat are category one (Table 2). Investigators are asked to review the curves (Figs. 3 to 7) and modify them, if necessary, before using them.

Spawning. For IFIM analyses of spotted bass spawning habitat, use curves for the time period (generally 4 to 6 weeks) during which spawning occurs (sometime between April and June, depending on locale). Spawning curves are broad and, if more accuracy is desired, investigators are encouraged to develop their own curves which will specifically reflect habitat utilization at the selected site.

Spawning velocity. No quantitative information was found concerning spawning velocity requirements of spotted bass. The SI curve for spawning velocity (Fig. 3) was based on observations of spotted bass spawning in lentic environments, and in areas protected from currents in lotic environments.

Table 2. Availability of SI curves for IFIM analyses of spotted bass habitat.

	Velocity[a]	Depth[a]	Substrate[a,b]	Temperature[a]	Cover[a]
Spawning	Use SI curve, Fig. 3.	Use SI curve, Fig. 3.	Use SI curve, Fig. 3.	Use SI curve, Fig. 3.	No curve necessary.
Egg incubation	Use SI curve, Fig. 4.	Use SI curve, Fig. 4.	Use SI curve, Fig. 4.	Use SI curve Fig. 4.	No curve necessary.
Fry	Use SI curve, Fig. 5.	Use SI curve, Fig. 5.	Use SI curve, Fig. 5.	Use SI curve Fig. 5.	Use SI curve, Fig. 5.
Juvenile	Use SI curve, Fig. 6.	Use SI curve, Fig. 6.	Use SI curve, Fig. 6.	Use SI curve Fig. 6.	Use SI curve, Fig. 6.
Adult	Use SI curve, Fig. 7.	Use SI curve, Fig. 7.	Use SI curve, Fig. 7.	Use SI curve Fig. 7.	Use SI curve, Fig. 7.

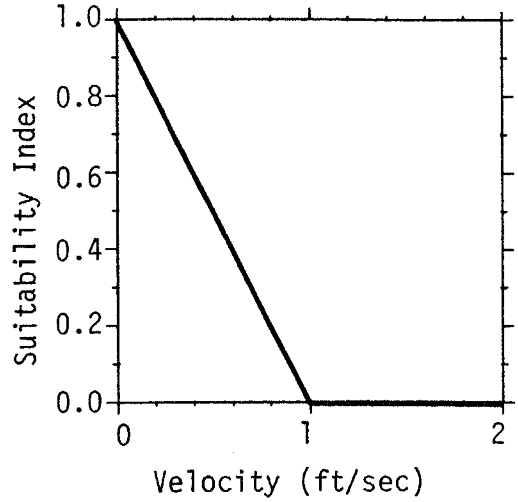
[a]When use of SI curves is prescribed, refer to the appropriate curve in the HSI or IFIM section.

[b]The following categories may be used for IFIM analyses (see Bovee 1982):

1 = plant detritus/organic material
2 = mud/soft clay
3 = silt (particle size < 0.062 mm)
4 = sand (particle size 0.062- 2.000 mm)
5 = gravel (particle size 2.0-64.0 mm)
6 = cobble/rubble (particle size 64.0-250.0 mm)
7 = boulder (particle size 250.0-4000.0 mm)
8 = bedrock (solid rock)

Coordinates

x	y
0.0	1.0
1.0	0.0
100.0	0.0



x	y
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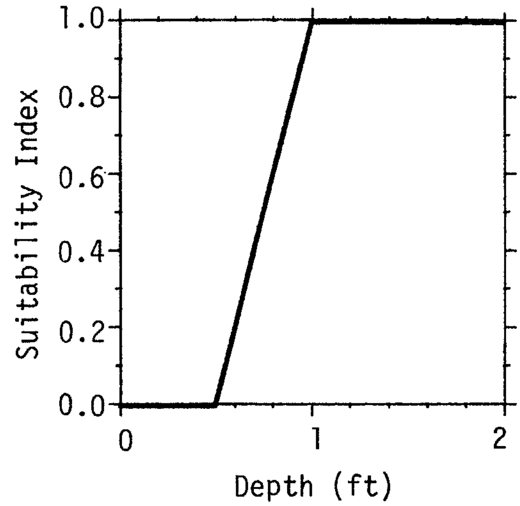
0.5	0.0
1.0	1.0
100.0	1.0



x	y
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4.9	0.0
5.0	1.0
100.0	1.0

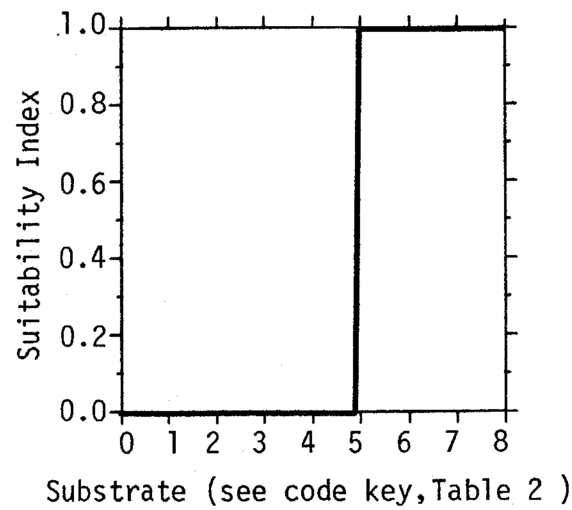

Figure 3. SI curves for spotted bass spawning velocity, depth, substrate, cover, and temperature.

No curve available for spawning cover utilization.

x	y
0.0	0.0
54.0	0.0
61.0	0.4
63.0	1.0
70.0	1.0
75.0	0.4
81.0	0.0
100.0	0.0

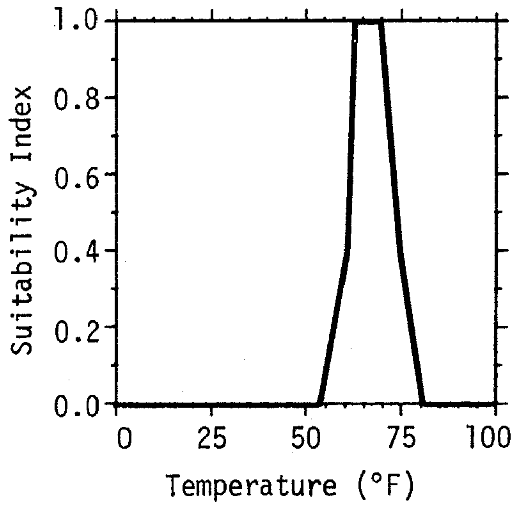

Figure 3. (concluded).

Coordinates

x	y
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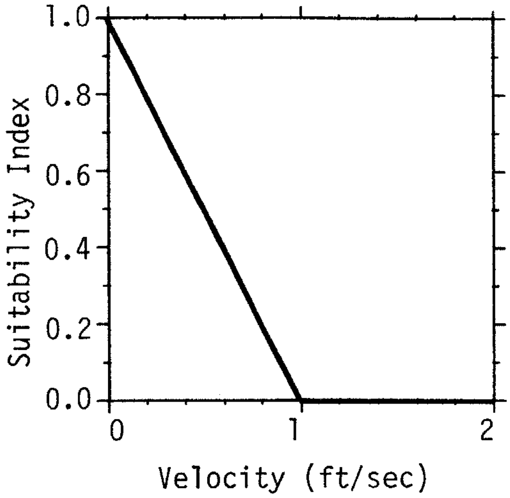
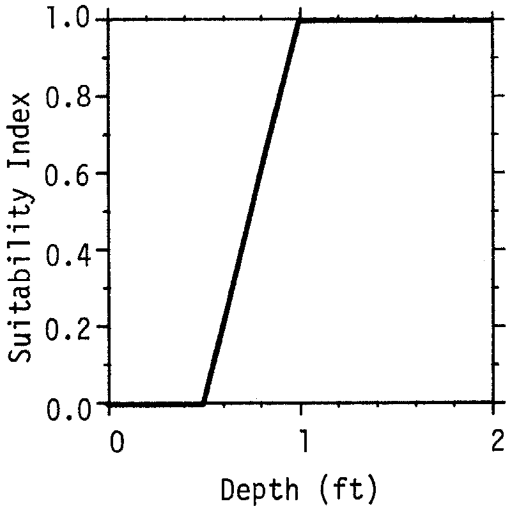
1.0	0.0
100.0	0.0



x	y
0.0	0.0
0.5	0.0
1.0	1.0
100.0	1.0



x	y
0.0	0.0
4.9	0.0
5.0	1.0
100.0	1.0

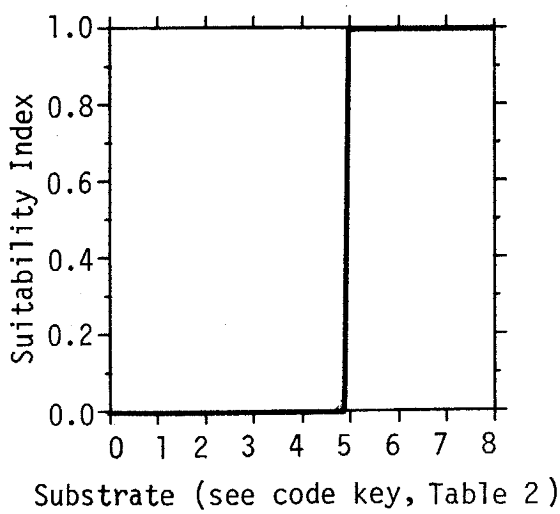


Figure 4. SI curves for spotted bass egg incubation, velocity, depth, substrate, cover and temperature.

No curve available for egg incubation cover requirements.

x	y
0.0	0.0
54.0	0.0
61.0	0.4
63.0	1.0
70.0	1.0
75.0	0.4
81.0	0.0
100.0	0.0

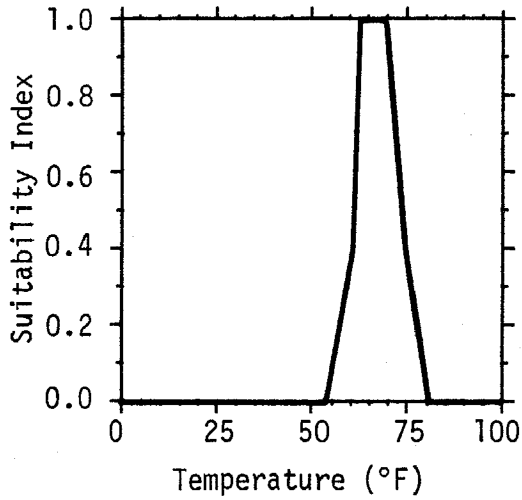


Figure 4. (concluded).

Coordinates

x	y
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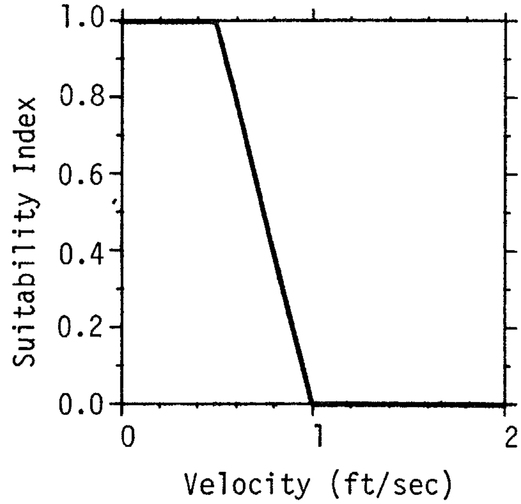
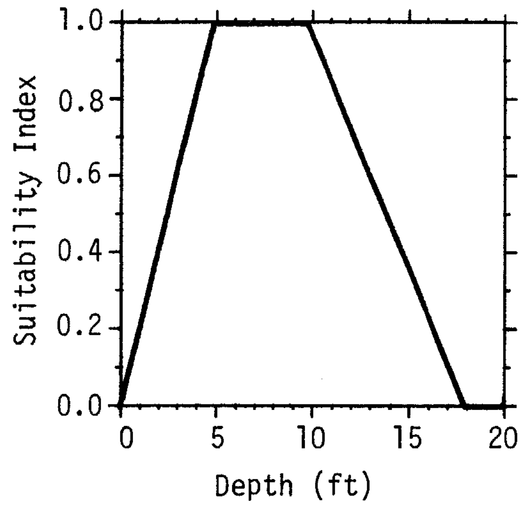
0.5	1.0
1.0	0.0
100.0	0.0



x	y
0.0	0.0
4.9	1.0
9.8	1.0
81.0	0.0
100.0	0.0



x	y
0.0	0.0
1.5	0.0
3.0	1.0
100.0	1.0

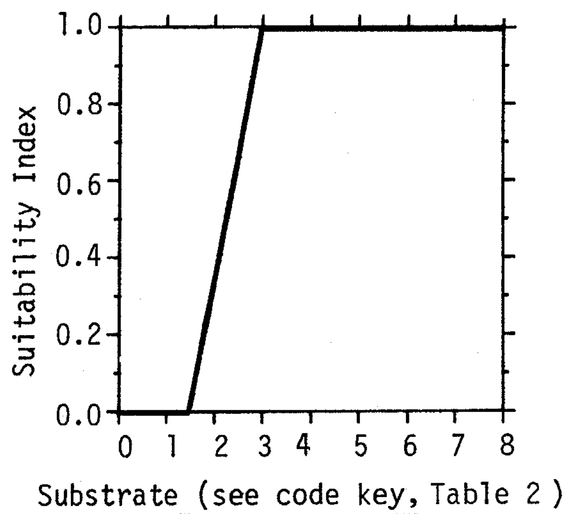
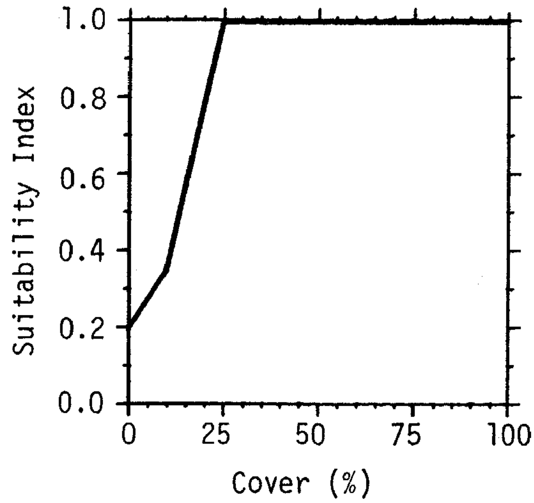


Figure 5. SI curves for spotted bass fry velocity, depth, substrate, cover and temperature.

Coordinates

x	y
0.0	0.20
10.0	0.35
25.0	1.00
100.0	1.00



x	y
0.0	0.0
54.0	0.0
63.0	0.2
70.0	0.5
73.4	1.0
78.8	1.0
84.2	0.2
90.0	0.0
100.0	0.0

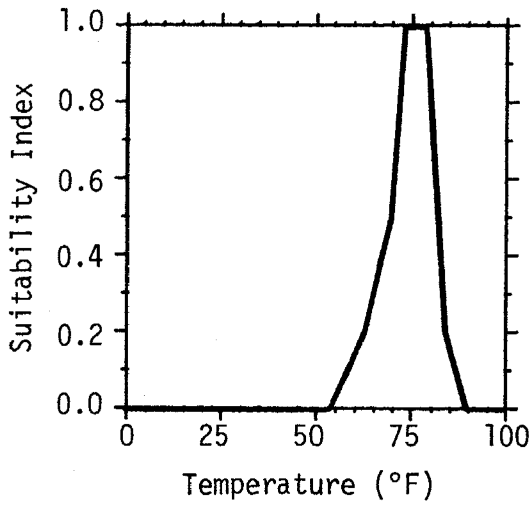
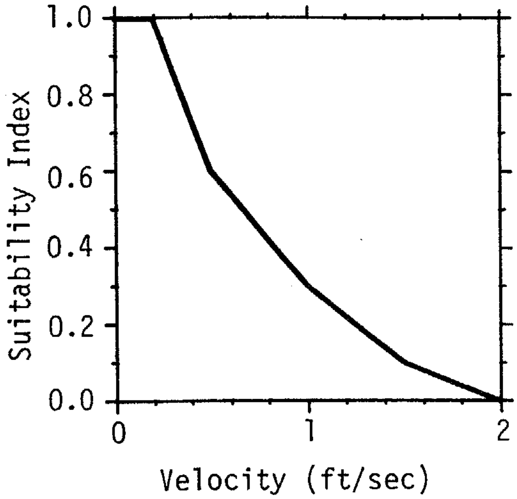


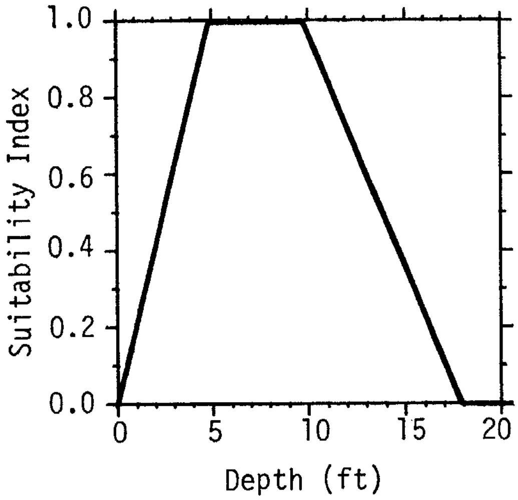
Figure 5. (concluded).

Coordinates

x	y
0.0	1.0
0.2	1.0
0.5	0.6
1.0	0.3
1.5	0.1
2.0	0.0
100.0	0.0



x	y
0.0	0.0
4.9	1.0
9.8	1.0
18.0	0.0
100.0	0.0



x	y
0.0	0.0
1.5	0.0
2.0	0.2
3.0	1.0
100.0	1.0

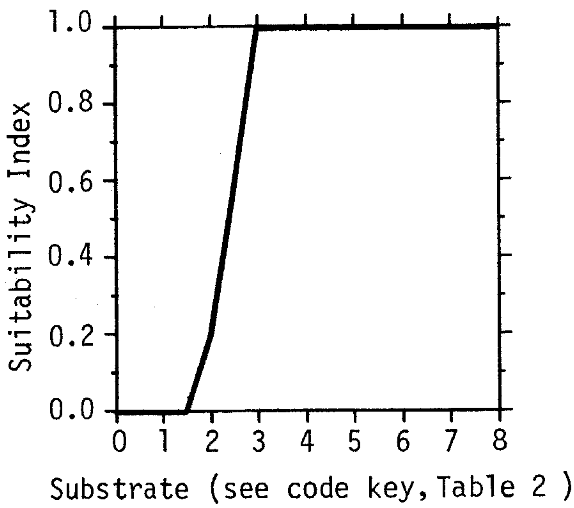
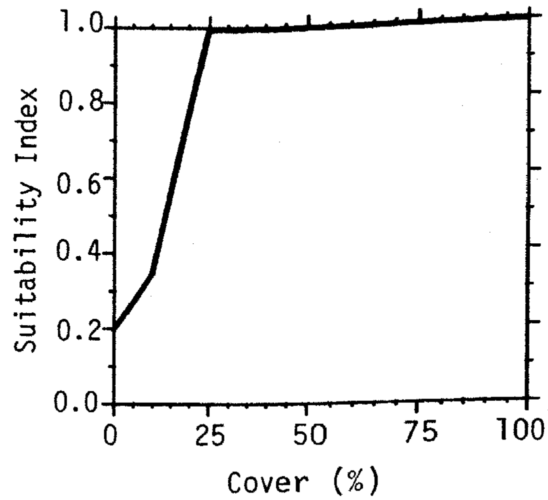


Figure 6. SI curves for spotted bass juvenile velocity, depth, substrate, cover, and temperature.

Coordinates

x	y
0.0	0.20
10.0	0.35
25.0	1.00
100.0	1.00



x	y
0.0	0.0
54.0	0.0
63.0	0.2
70.0	0.5
73.4	1.0
78.8	1.0
84.2	0.2
90.0	0.0
100.0	0.0

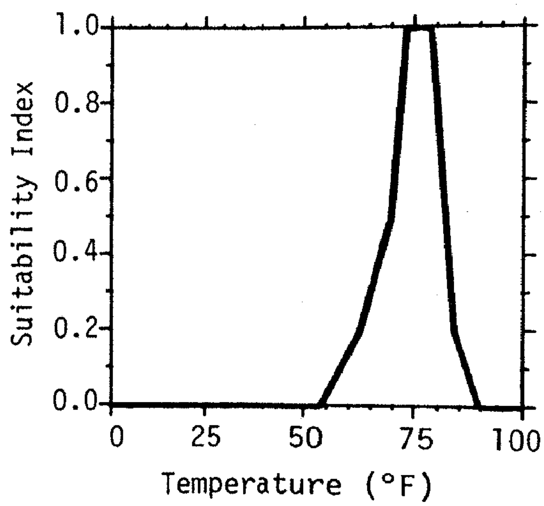
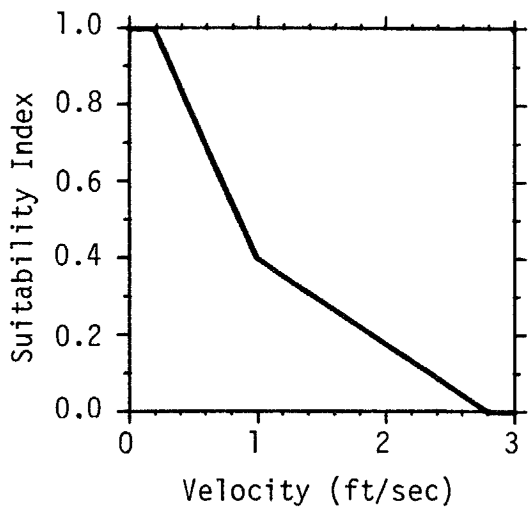


Figure 6. (concluded).

Coordinates

x	y
0.0	1.0
0.2	1.0
1.0	0.4
2.8	0.0
100.0	0.0



x	y
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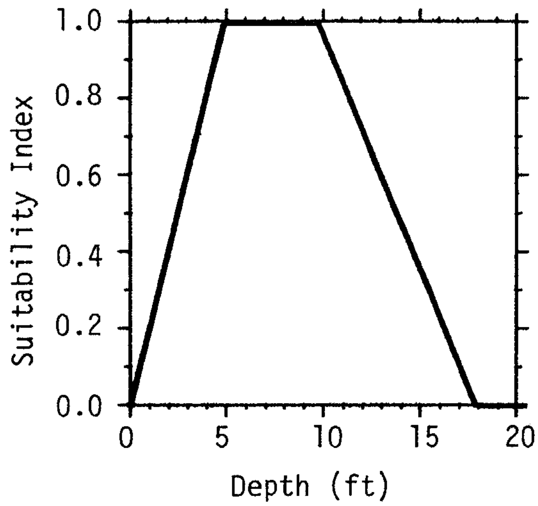
9.8	1.0
18.0	0.0
100.0	0.0



x	y
0.0	0.0
1.5	0.0
2.0	0.2
3.0	1.0
100.0	1.0

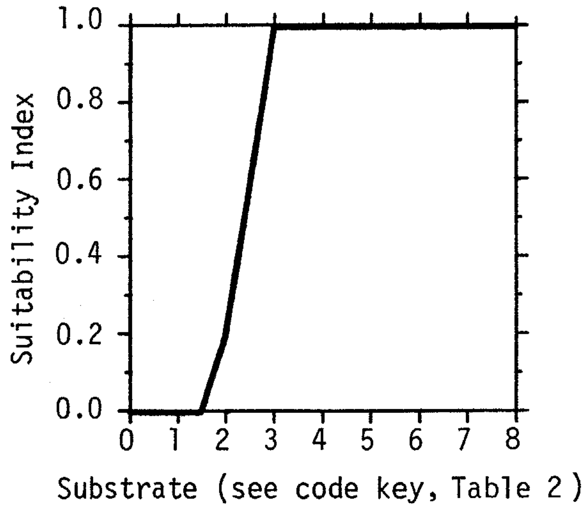
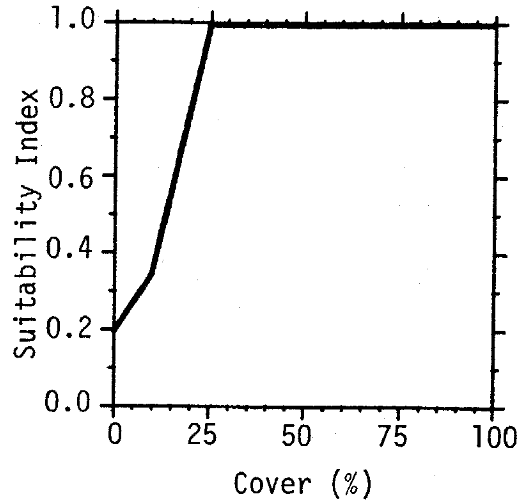


Figure 7. SI curves for spotted bass adult velocity, depth, substrate, cover, and temperature.

Coordinates

x	y
0.0	0.20
10.0	0.35
25.0	1.00
100.0	1.00



x	y
0.0	0.0
54.0	0.0
63.0	0.2
70.0	0.5
73.4	1.0
78.8	1.0
84.2	0.2
90.0	0.0
100.0	0.0

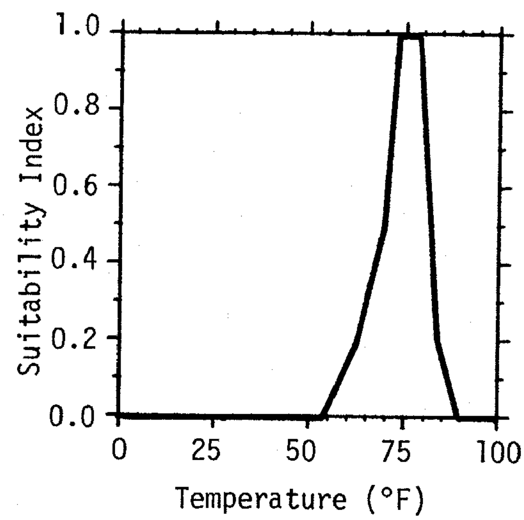


Figure 7. (concluded).

Spawning depth. Vogele (1975a) observed spotted bass nests in depths ranging from 13 to 29 inches in a Missouri stream. Nests in Bull Shoals Reservoir, Arkansas, were located in depths to 22 feet (Vogele 1975b). The SI curve for spawning depth (Fig. 3) is based on the assumption that depths greater than 1.0 feet are suitable for spawning.

Spawning substrate. Spotted bass spawned over gravel, rubble, broken rock, large flat rocks, and solid rock ledges in Bull Shoals Reservoir, Arkansas (Vogele 1975b). The SI curve for spawning substrate (Fig. 3) was based on that information.

Spawning cover. No curve is available for spotted bass spawning cover. Spotted bass often spawn near cover, but also spawn in the absence of cover. An investigator may wish to develop his own curve for spawning cover requirements in his area.

Spawning temperature. Spotted bass are known to spawn at temperatures ranging from 55° F to 73° F (Vogele 1975b; Carlander 1977). The SI curve for spawning temperature (Fig. 3) was taken from the HSI model section (V_8); assumptions and sources are listed in Table 1.

Egg incubation. For IFIM analyses of spotted bass egg incubation habitat, use SI curves for the time period from the beginning of spawning to one week beyond the end of spawning. The duration of egg incubation has been found to range from 2 days at 70° F to 5 days at 58 to 60° F (Fig. 4). The SI curves and assumptions for egg incubation velocity, depth, substrate, and cover (Fig. 4) are the same as those for spawning (Fig. 3).

Fry. For IFIM analyses of spotted bass fry habitat, use SI curves (Fig. 5) for the time period from two weeks after the onset of spawning to six weeks beyond the end of spawning. The length at which fry become juveniles is assumed to be approximately 1.0 inches. The SI curves for fry velocity, depth, and substrate (Fig. 5) are the result of professional guesswork, and investigators may wish to develop their own curves. The SI curves for cover and temperature (Fig. 5) came from the HSI model section (V_4, V_7); assumptions and sources may be found in Table 1.

Juveniles. Spotted bass juveniles are assumed to range in lengths from approximately 1.0 to 8.0 inches (Carlander 1977). SI curves for juvenile depth, cover, and temperature were taken from the HSI model section (V_2, V_4, V_7). Curves for velocity and substrate were based on information from Cross (1954), Minckley (1963), McKechnie (1966), and Carlander (1977).

Adults. Adult spotted bass are assumed to be greater than 8.1 inches in length (the approximate length at sexual maturity; ages II-III). SI curves for adult depth, cover, and temperature were taken from the HSI model section (V_2, V_4, V_7). Curves for velocity and substrate were based on information in Shurrager (1932), Cross (1954), McKechnie (1966), and Carlander (1977).

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16. Abstract (Limit: 200 words)

The Habitat Suitability Index (HSI) models presented in this publication aid in identifying habitat variables important to the growth and survival of spotted bass (Micropterus punctulatus). Facts, ideas, and concepts obtained from the research literature and expert reviews are synthesized and presented in a format that can be used for impact assessment. The models are hypotheses of species-habitat relationships, and model users should recognize that the degree of veracity of the HSI model, SI graphs, and assumptions will vary according to geographical area and the extent of the data base for individual variables.

A brief discussion of selected Suitability Index (SI) curves as used in the Instream Flow Incremental Methodology (IFIM), and a discussion of SI curves available for the IFIM analysis of Spotted bass habitat are also included.

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Micropterus punctulatus
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