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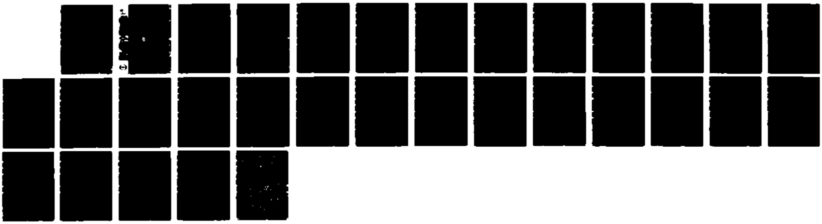

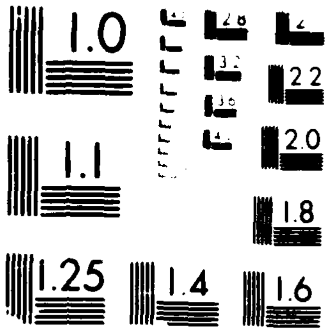

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COMMUNITY HABITAT SUITABILITY MODELS FOR WARMWATER FISHES

by

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Most published habitat suitability index (HSI) models for warmwater fishes have too many variables, many of which are time-consuming and difficult to measure. In addition, suitability index scores are calculated using nonuniform methods that often yield different values for closely related species. Based upon the literature and the results of field studies in the Little Cypress Basin, Texas, and the Yazoo River, Mississippi, closely related species of warmwater fishes were placed into groups. For each group, a community model was developed based on five variables: percent pools, average current velocity, percent cover, pH, and dissolved oxygen. Results are compared with the unmodified models, and methods used to develop and test these models are discussed.

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Preface

This work was conducted under the Environmental Impact Research Program (EIRP), Work Unit 31729, sponsored by the Office, Chief of Engineers (OCE), US Army. Technical Monitors were Dr. John Bushman and Mr. Earl Eiker, OCE, and Mr. Dave Mathis, Water Resources Support Center.

This report was prepared by Dr. Andrew C. Miller, Mr. K. Jack Killgore, Dr. Barry S. Payne, and Mr. Johnny Franklin of the Aquatic Habitat Group (AHG), Environmental Resources Division (ERD), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). Comments were provided by Ms. Jean O'Neil and Mr. David Nelson of WES. This work was performed under the general supervision of Mr. Richard Coleman, AC/AHG, Dr. Conrad J. Kirby, Chief, ERD, and Dr. John Harrison, Chief, EL. Dr. Roger T. Saucier was Program Manager, EIRP. This report was edited by Ms. Jamie W. Leach of the WES Information Products Division.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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Contents

COMMUNITY HABITAT SUITABILITY MODELS FOR WARMWATER FISHES

Introduction

1. Habitat-based evaluation methods such as the Habitat Evaluation Procedures (HEP) are general planning tools used to rate habitat quality for game and nongame species. These methods use suitability index (SI) curves to graphically relate the value of a habitat variable (i.e., percent cover or current velocity) to a species of interest. SI scores range from 0.0 (poor habitat) to 1.0 (optimum habitat). The values from the curves are used to calculate an overall habitat suitability index (HSI). An HSI is a numerical measure of the value of a habitat in terms of important life requisites for a particular species. Thus, a biologist or planner can use a habitat-based method to describe the positive and negative features of project alternatives or to design a resource management program. However, species-specific HSI models and their component SI curves are not proven statements of fact and do not always define ecological relationships. In addition, HSI models do not consider all factors that influence natural populations such as competition, mortality, recruitment, or density-dependent regulation. Gilbert (1984) found that published HSI models performed poorly and did not correlate well with estimated standing crop. HSI models should be considered as qualitative tools to guide general planning.

2. An analysis of more than 20 published HSI models for freshwater fishes revealed two basic problems that hinder model use for general planning studies. First, the data requirements of most models are difficult to meet because they have too many variables, many of which are time-consuming to measure. For example, the HSI riverine model for bluegill (Stuber, Gehart, and Maughan 1982) requires 14 variables. One variable, water temperature, must be measured on multiple dates. Second, different models exist for closely related species that use similar types of habitat. For example, the riverine model for the redear sunfish (Twomey, Gebhart, and Nelson 1984) uses 9 variables, whereas the green sunfish model, a closely related species, requires 15 variables. For most planning purposes, all sunfishes (i.e. lepomids) could be evaluated with a single model built with a minimum number of variables.

3. As part of research on habitat evaluation methods within the

Environmental Impact Research Program, a study was initiated to determine if the number of variables used in published HSI models for riverine fishes could be reduced and if two or more closely related species could be grouped and evaluated with a single model. Field data from two sites in the southern United States were used to evaluate selected fish models, provide information to reduce the number of variables, and place fishes in similar groups. Based upon this work, a set of easy-to-use community models was developed for habitat evaluation studies. These models reduce the complexity and data requirements of the habitat evaluation process and offer an alternate approach to impact assessment, especially when time to complete the project is limited. In addition, the results of this research should provide new insight into use of the HEP and other habitat-based methods.

Methods

4. Data on fish community composition and habitat conditions were obtained from two dissimilar study areas: Little Cypress Bayou, Texas, and the Yazoo River, Mississippi (Killgore and Hathorn 1987 and Killgore and Miller 1985, respectively). The Little Cypress Bayou is a relatively shallow, low gradient stream with abundant instream cover, and the Yazoo River is deep, low gradient, and turbid with little instream cover. The Little Cypress Bayou is relatively undisturbed by water resource development and provides high quality habitat for warmwater fishes. By contrast, the Yazoo River has been negatively affected by agricultural runoff, clearing, and channelization, and is a low quality habitat for most riverine fishes.

5. A boat-mounted electrofishing apparatus was used to determine species composition at representative habitat types at each study area. Chemical and physical data were obtained from the field or published reports to calculate HSI values for fishes common in both study areas. Models developed by the US Fish and Wildlife Service (USFWS) were used for these calculations. Based upon HSI scores calculated for each site, fishes were placed into one of ten possible groups (0.0-0.10, 0.11-0.20, 0.21-0.30, etc.) for each site. Discrepancies among HSI scores for closely related species were identified, and models were examined to determine if these discrepancies were the result of arbitrary differences in individual SI curves, the models, or actual species-specific variation in habitat requirements.

6. Based upon morphological similarities, published information on the ecology of each species, and results of these calculations, fishes were placed into groups. Five variables that were consistently used in the models were chosen to prepare community models: percent cover, water depth, water velocity, pH, and dissolved oxygen. Composite SI curves for each variable and each group of fishes were prepared by averaging individual species curves. Finally, the composite curves for the five variables were used to recalculate HSI scores. These values were then compared with those determined from the original, unmodified models.

Results and Discussion

Analysis of published models

7. Number and definition of variables. A total of 12 species of fishes were common to both study sites (Table 1). It was determined that a total of 36 habitat variables would be required to calculate HSI scores for these 12 species (Table 2). The largemouth bass required the largest number of variables (20), whereas the redear and spotted bass both required the fewest (9). This list could be reduced if definitions for the same type of variables were uniform and not defined in subtly different ways. For example, in the model for adult bigmouth buffalo, water temperature was considered as "maximum water temperature where species occurs in the summer" (Edwards 1983). Yet for adult smallmouth buffalo, the same variable is defined as "average water temperatures where the species occurs during July-August" (Edwards and Twomey 1982). Also, turbidity was measured in parts per million in some models and Jackson Turbidity Units in others. To minimize the complexity of the data requirements, these variables can be placed into five categories representing depth, velocity, cover, water quality, and "other" (Table 3). However, most applications of the models, as published by the USFWS without modification, require as many as 20 separate variables.

8. Computation of HSI scores. To evaluate relative differences among models, HSI values for all species common to both study sites were calculated using unmodified models. Fishes with the same HSI scores were grouped (Table 4). In the Little Cypress Bayou, HSI scores ranged from 0.11 to 1.00, and fishes were placed into seven groups. In the Yazoo River, the HSI values ranged from 0.0 to 0.80, and six groups were established. The HSI values varied for closely related species because three different methods (arithmetic

mean, geometric mean, and the limiting factor method) were used to calculate the final values. For example, in the Little Cypress Bayou, the HSI for smallmouth buffalo was 0.3, while the HSI for bigmouth buffalo was 0.8, even though these species are commonly found in the same habitat. The HSI value for the smallmouth buffalo was obtained by taking the least of the water quality SI scores, whereas the average of all components was used to calculate the HSI for the bigmouth buffalo. Differences in the way computations were made caused variation in HSI scores for these two closely related species.

9. Suitability index curves. Individual SI curves often varied considerably for closely related species, which caused widely different HSI values. For example, fish in the genus *Lepomis*, which have similar morphometric features and habitat requirements, had HSI scores that ranged from 0.41 to 1.00 in the Little Cypress Bayou and from 0.0 to 0.70 in the Yazoo River. The models for bluegill and green sunfish (genus *Lepomis*) were constructed with similar SI variables, but each had markedly different HSI values in the Yazoo River (Tables 5 and 6). This difference was caused by the variable "average current velocity for embryos." In a current of 15 cm/sec, the bluegill receives an SI of 0.7 while the green sunfish gets a value 0.0; therefore, the reproductive component of the green sunfish model was 0.0 and the overall HSI value was 0.0. Similarly, in a current of 20.0 cm/sec, the adult redear sunfish receives an SI of 0.0, while the SI value for adult warmouth is 0.1, for green sunfish it is 0.4, and for bluegill it is 0.7. As discussed by Payne and Long (1985), SI curves for different species can be conceptually similar, although small differences in the manner in which they were constructed can cause large variation in final values. Carefully designed laboratory experiments or field observations would be necessary to determine if these differences among lepomids actually exist. Currently there is no basis for these large interspecific differences in the *Lepomis* models.

Composite SI curves

10. Although warmwater fishes have similar tolerances to fluctuating water quality conditions (Kelly, Catchings, and Payne 1981), their use of pools, current velocity, and cover is influenced by swimming performance, body shape and fin placement (Gatz 1979a, 1979b, 1981), and their ability to avoid predators (Mittelbach 1984, Webb 1986). Therefore, composite curves for important physical habitat variables were developed for congeneric species with similar morphology. These groups included sunfishes (*Lepomis*), crappies

(*Pomoxis*), black bass (*Micropterus*), catfishes (*Ictalurus*), and buffaloes (*Ictiobus*).

11. Composite SI curves were prepared for each group by taking the average of individual SI curves for the following variables: percent pools, average current velocity, percent cover, dissolved oxygen, and pH. These variables were chosen because they accounted for significant categories in published models (Table 3), are commonly used in riverine habitat analysis, and can be easily measured in the field. This procedure reduced the variation in the models that results from incorporating a large number of variables. However, considering the discrepancies in individual species curves and the use of HEP for general planning purposes, this was considered appropriate. Although water temperature and turbidity were also used in most models, they were defined inconsistently or expressed in different units and were not included. Variables that deal with suitability of habitat for reproduction were not used because they are usually species-specific. However, examination of the pH and dissolved oxygen variables revealed that they were common to all 12 models, regardless of species. The optimum value for dissolved oxygen was ≥6.0 mg/ℓ, and the optimum pH value was approximately 8.0 for all species. Consequently, SI curves for these two variables were prepared by averaging curves from all 12 species models (Figure 1).

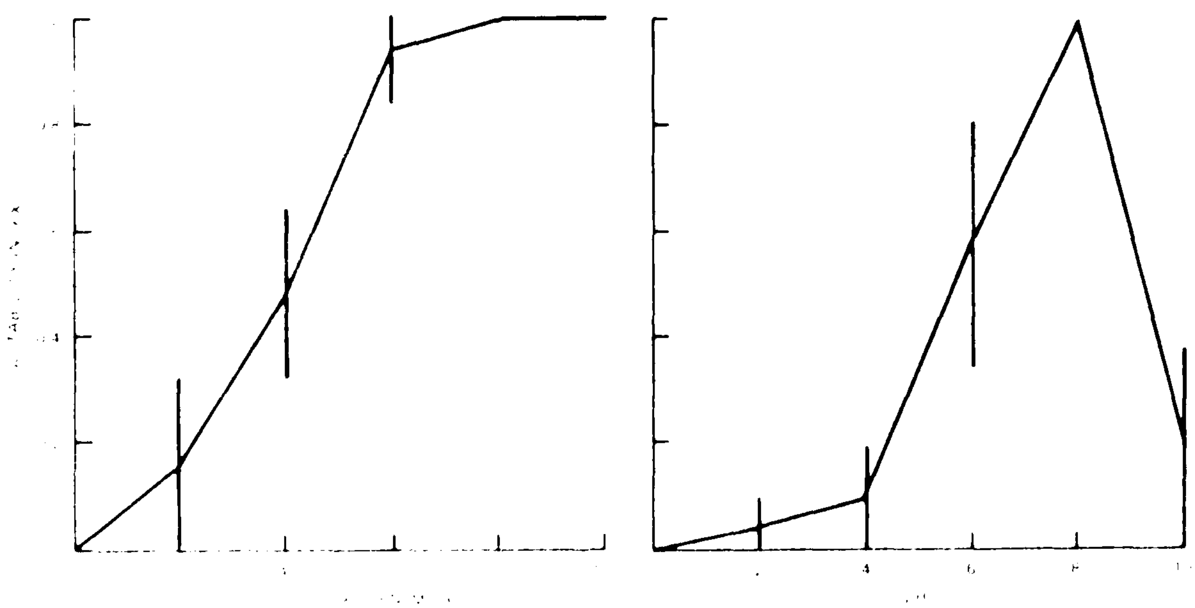


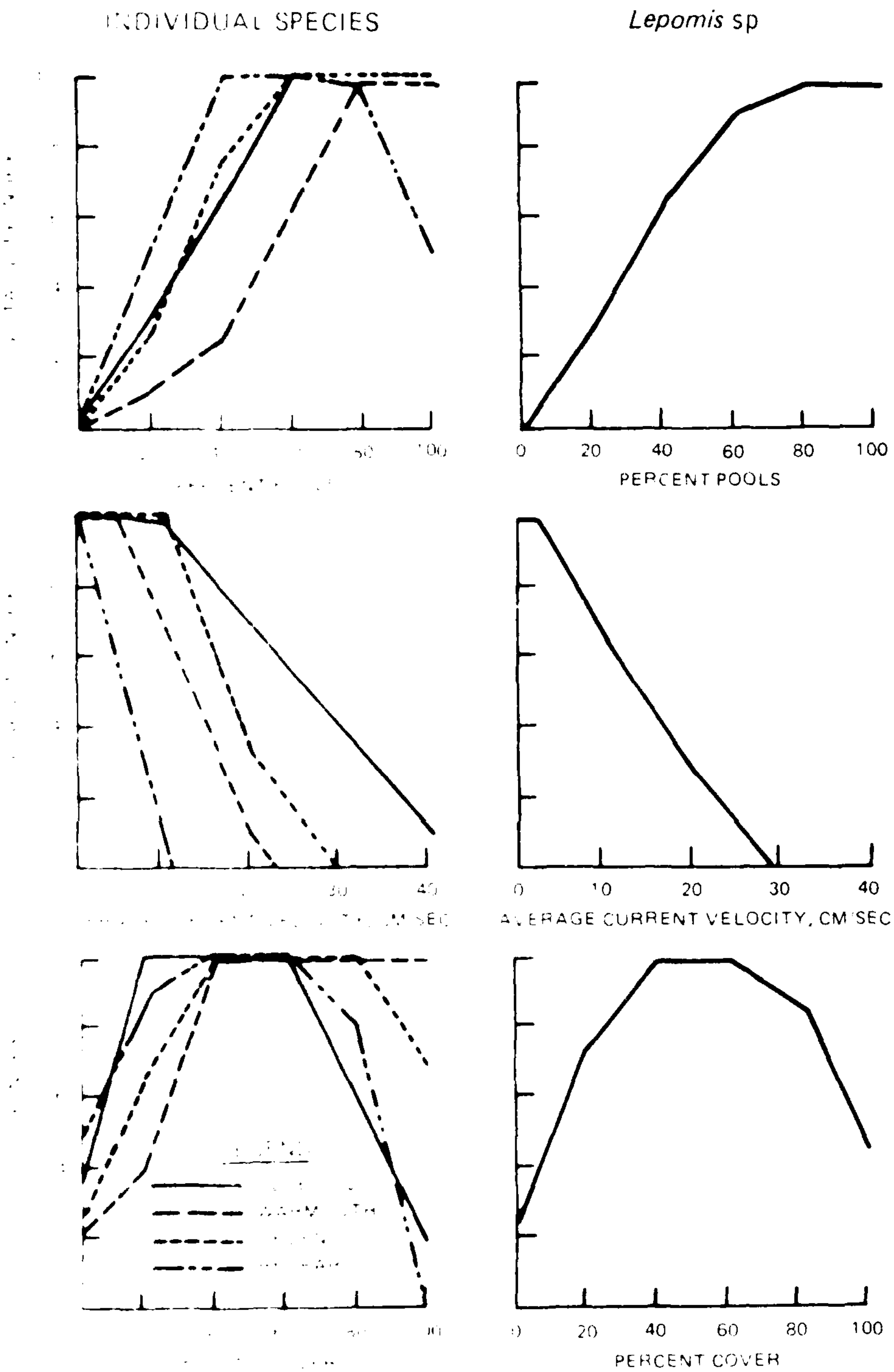
Figure 1. Composite SI curves for pH and dissolved oxygen for 12 species of warmwater fishes

12. Group 1: Bluegill, green sunfish, redear sunfish, and warmouth. These species are members of the sunfish family (Centrarchidae) and are characterized by laterally compressed bodies suitable for low-speed maneuvering in vegetated and other structurally complex areas. They possess small-to-medium-sized mouths with fine teeth and are capable of ingesting aquatic insects, crustaceans, and small fishes. Sunfishes usually inhabit shallow, low-velocity water associated with various types of cover (Scott and Crossman 1973, Pflieger 1975, Becker 1983). Because of their similarities in morphology and habitat utilization, hybridization is common.

13. Individual and composite SI curves of percent pools, average current velocity, and percent cover for each sunfish species for the genus *Lepomis* appear in Figure 2. The optimum percentage of pools for [illegible] was 80 percent. The SI value for the redear decreased when pools exceeded 80 percent, but did not decline for the other species. However, the authors are aware of no information which demonstrates that redear sunfish are less dependent on pools than other lepomids. The optimum SI value for average current velocity occurred at 0 cm/sec for all sunfish and declined to [illegible] at velocities greater than [illegible] cm/sec. Optimum percent cover occurred between [illegible] and [illegible] percent for all sunfishes. If there is little or no vegetation cover, small individuals can be preyed upon, whereas large quantities of cover inhibit growth, movement, and foraging efficiency [illegible] Crowder and Cooper [illegible] and Stein 198[illegible]).

14. Group 2: Black and white crappie. The black and white crappie, members of the [illegible] in the family Centrarchidae, are characterized by strongly compressed bodies that are tallest at the middle and shortened posteriorly. The mouth is large and oblique, and the lower jaw projects slightly beyond the upper. Both species of crappie are carnivorous and feed almost exclusively on [illegible], crustaceans, and small fishes (Becker 1983). The crappie are highly dependent upon the presence of instream cover and are usually found in [illegible] water where there is an abundance of brush, tree stumps, or [illegible].

[illegible] percentage of pools for these fishes was 60 to 100 percent. [illegible] species of crappie have a greater tolerance to elevated current velocities than do the sunfishes. Velocities from 0 to 10 cm/sec were optimum, whereas velocities [illegible] cm/sec or above were considered unsuitable. Both species of crappie have virtually identical curves for percent cover.



... individual and composite SI curves ... , average current velocity, ... cover for sunfishes (Lepomis)

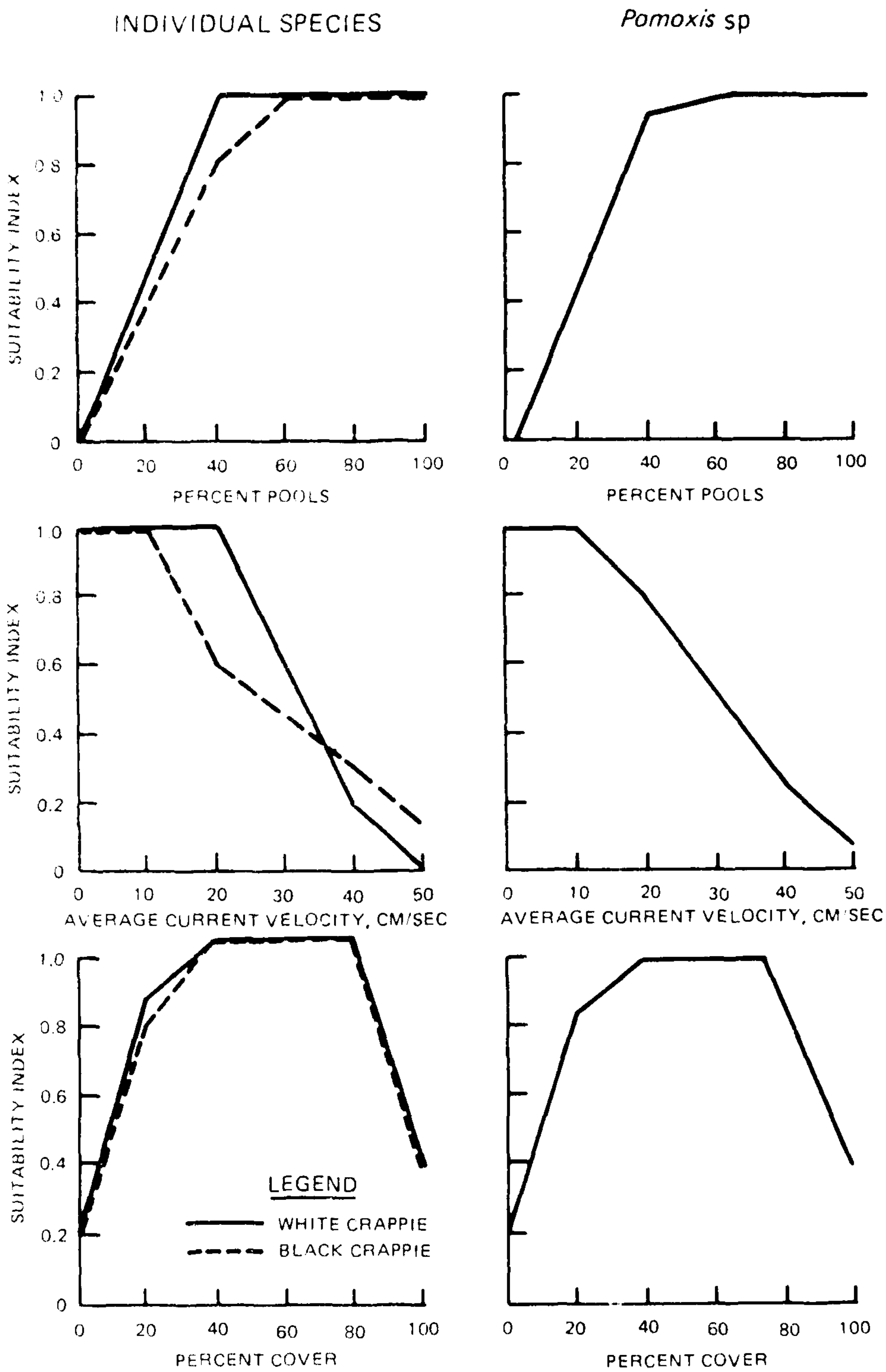


Figure 3. Individual and composite SI curves of percent pools, average current velocity, and percent cover for crappie (*Pomoxis*)

The SI score was 1.0 when cover was between 40 and 80 percent and less than 1.0 when amount of cover was greater than 80 percent or less than 40 percent.

16. Group 3: Largemouth bass and spotted bass. These two centrarchids (genus *Micropterus*) have slightly compressed bodies and large mouths with pointed teeth positioned in brushlike pads on both upper and lower jaws. Adult *Micropterus* are carnivorous and, like other centrarchids, are dependent on cover (Becker 1983).

17. The curve for average current velocity for the spotted bass was prepared from data collected in the Cypress Bayou (Killgore and Hathorn 1987) because the published model did not use this variable. Furthermore, the variable "percent riffle," rather than "percent pool" (used herein) appeared in the published model. Percent pool was calculated by subtracting percent riffles from 100. The optimum quantity of pools for both species was 60 percent (Figure 4). However, the curve for spotted bass decreased when pools exceeded 60 percent, while the value for largemouth bass remained at 1.0. Both species of bass seemed to prefer low-velocity water (less than 10 cm/sec), although spotted bass are often found in higher velocity water than the largemouth bass (Ryan, Avalut, and Smitherman 1970, Trautman 1981). However, when both species of bass occur together, their habitat requirements are similar (Funk 1975, Miller 1975). Optimum percent cover ranged from 40 to 60 percent for both species. The curve for percent cover for the spotted bass indicates that high amounts of cover (60 to 100 percent) are as suitable as intermediate amounts (40 to 60 percent). This is unreasonable since excessive amounts of cover have been shown [illegible] wing efficiency (see references in paragraph 13). Therefore, the [illegible] SI curve was drawn to show reduced suitability when cover exceeded 60 percent.

18. Group 4: [illegible] and black bullhead. This genus [illegible] Ictaluridae) and is characterized by sensory barbels around the mouth, a flattened peduncle, and few pectoral fin [illegible]. [illegible] the bottom when visibility is low [illegible] Becker 1983).

[illegible]

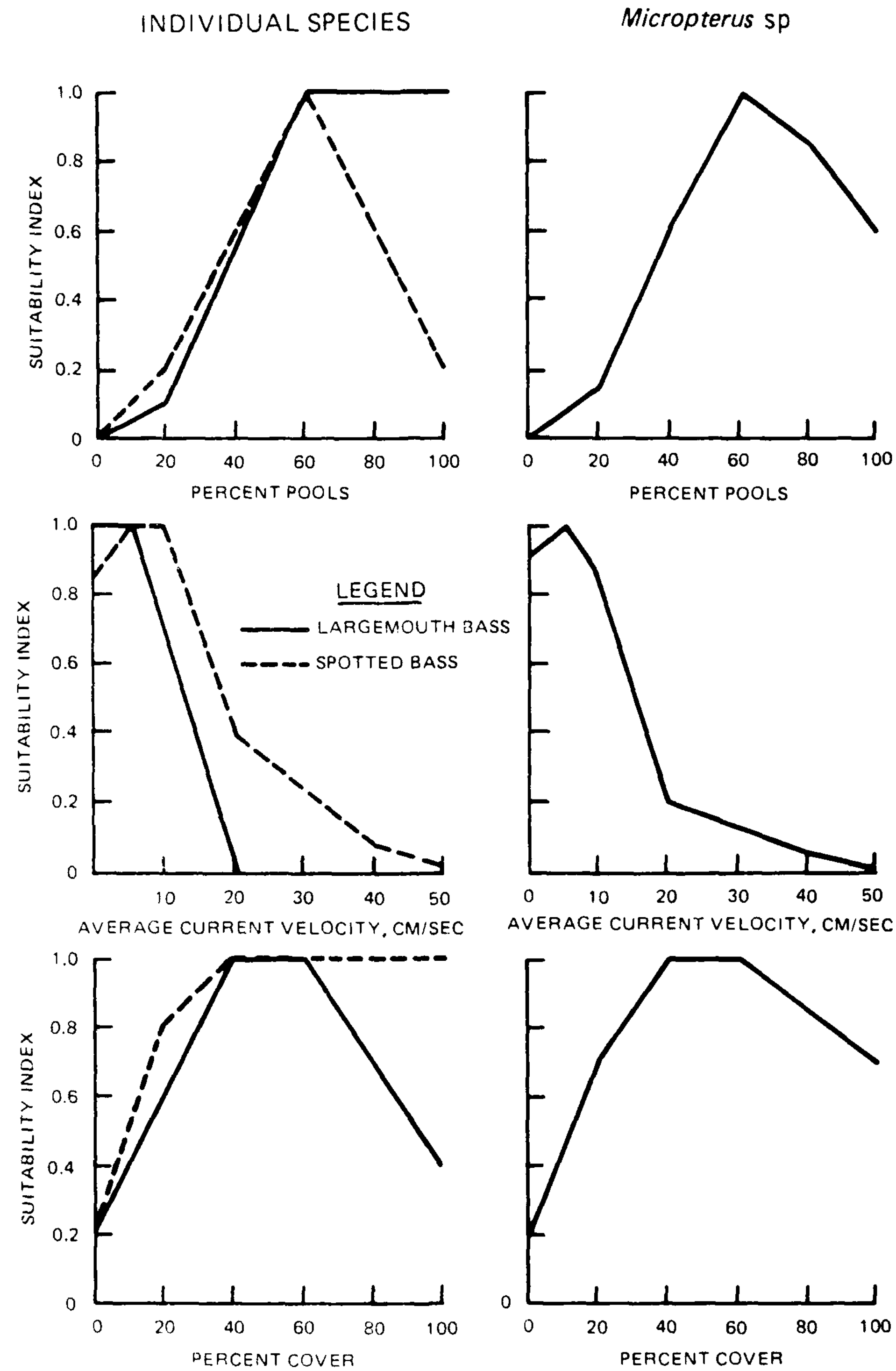


Figure 4. Individual and composite SI curves of percent pools, average current velocity, and percent cover for black bass (*Micropterus*)

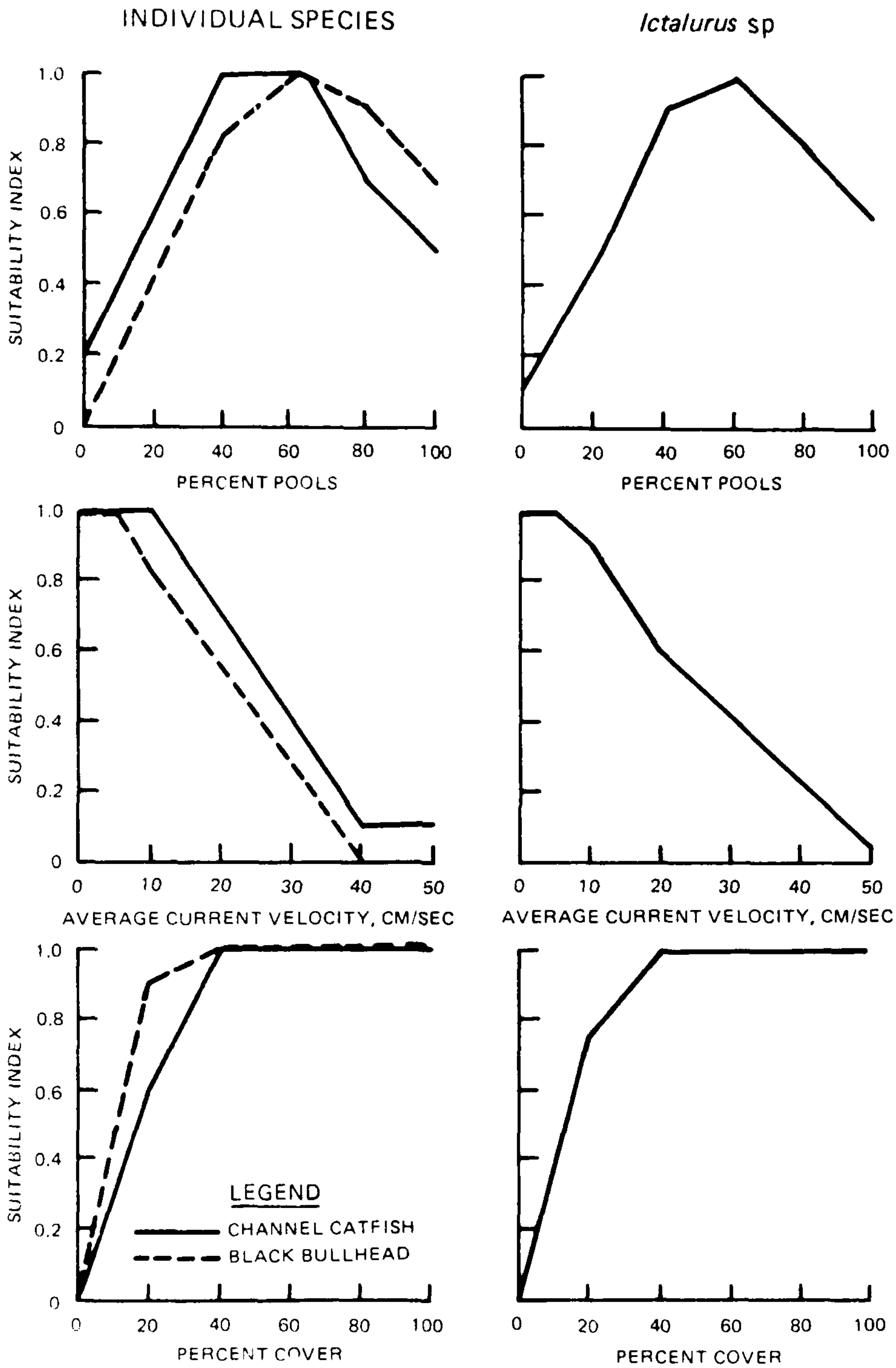


Figure 5. Individual and composite SI curves of percent pools, average current velocity, and percent cover for catfish (*Ictalurus*)

10 cm/sec and decreased to 0.0 at 50 cm/sec. The SI value for cover was 1.0 at 40 percent coverage and greater.

20. Group 5: Smallmouth and bigmouth buffalo. The buffalo are in the genus *Ictiobus*, which is in the sucker family (Catostomidae). Both species of buffalo are characterized by having a heavy head, robust body, and a relatively large mouth. Both species occur in large rivers and are usually found in sloughs, oxbow lakes, and other backwater areas (Becker 1983). Both species feed by searching the bottom for small crustaceans, snails, insect larvae, and other small organisms, as well as algae and certain species of aquatic plants (Clay 1975).

21. The bigmouth buffalo tolerates higher velocities than the other groups (Figure 6). This genus is usually found in water with velocities less than 0.70 cm/sec (Schmulbach, Gould, and Groen 1975), although they can withstand strong current for short periods of time (Kallemeyn and Novotny 1977). Trautman (1981) and Kallemeyn and Novotny (1977) reported that the smallmouth buffalo inhabits streams with currents up to 100 cm/sec, although in all likelihood these fishes avoid high-velocity water for all but short periods of time. The SI curve for current velocity for smallmouth buffalo (prepared by Edwards and Twomey 1982) showed unsuitable habitat at 0 cm/sec, which is not reasonable since this species is found in both lentic and lotic environments. Therefore, this curve was modified based upon data collected in the Yazoo River. The composite curve for current velocity was 1.0 at 0 to 20 cm/sec and declined to 0 at velocities greater than 140 cm/sec. Optimum percent pools occurred at 60 percent. Percent cover did not appear in either species model and was not included.

Community models

22. Community models were constructed for each congeneric group by taking the arithmetic mean of the five composite SI variable scores. As discussed in paragraph 8, there are several methods available to determine the relationship among variables, and each method will result in different HSI scores. The arithmetic mean is used when there is a compensatory relationship among variables. The geometric mean is a similar mathematical function, but is used when the compensatory relationship is considered weak (USFWS 1981). The limiting factor method is also commonly used in describing variable relationships and assumes that the lowest SI score is limiting. The five variables used in the composite HSI calculations were considered to equally

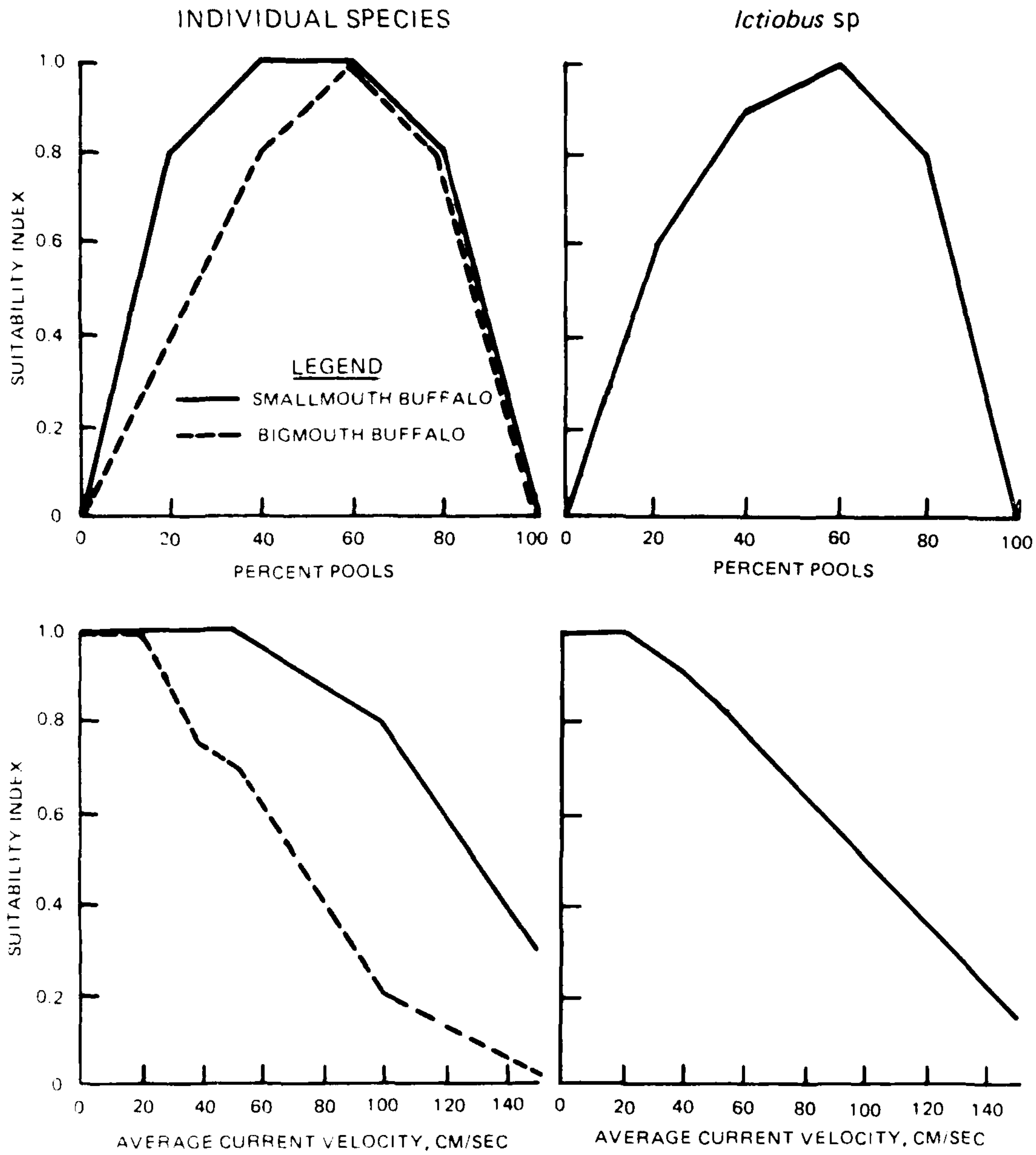


Figure 6. Individual and composite SI curves of percent pools and average current velocity for buffalo (*Ictiobus*)

influence all species. Therefore, the arithmetic mean was used in HSI calculations.

23. HSI values were calculated using the community models for the Yazoo River and Little Cypress Bayou and compared with values obtained from the unmodified models. HSI values calculated from both types of models were similar for most species in the Yazoo River except spotted bass, redear sunfish, and green sunfish (Figure 7). For these species, the HSI scores calculated with the unmodified models were 0.0, while the community models produced a value less than 0.5. The discrepancy between techniques was caused by the manner in which final HSI scores for the unmodified models were obtained. Turbidity was the limiting variable* in the unmodified model for spotted bass, and current velocity was limiting to the redear and green sunfish. Since the arithmetic mean was used in these models, final HSI scores were quite different from the published models. At the Little Cypress Bayou, the HSI scores calculated from the composite models differed substantially from those obtained using the unmodified models for redear sunfish, warmouth, spotted bass, largemouth bass, smallmouth buffalo, and channel catfish. The limiting factor method was used in the unmodified models for redear, warmouth, and spotted bass, resulting in low HSI scores due to one limiting variable (usually a water quality variable) and no compensatory influence from other variables in the model. Either low water quality or poor habitat for reproduction caused reduced HSI values in the unmodified models for smallmouth buffalo and channel catfish.

24. The community models produced values that differed for selected species and were similar for others, with no apparent trends with regard to taxonomic status. As discussed above, HSI scores obtained using unmodified models for closely related species (such as small and bigmouth buffalo, the sunfishes, etc.) were often quite different. There are no ecological reasons for these discrepancies. Differences are the result of the manner in which curves were drawn and data in the literature were evaluated, or calculations performed. However, these differences illustrate the problem of using the published models for closely related species. The community models described in this report have reduced differences among closely related species while still retaining important biological information.

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* In this case the final HSI score was equal to the value of the lowest SI value. If the value for turbidity equals 0.0, then the HSI equals 0.0.

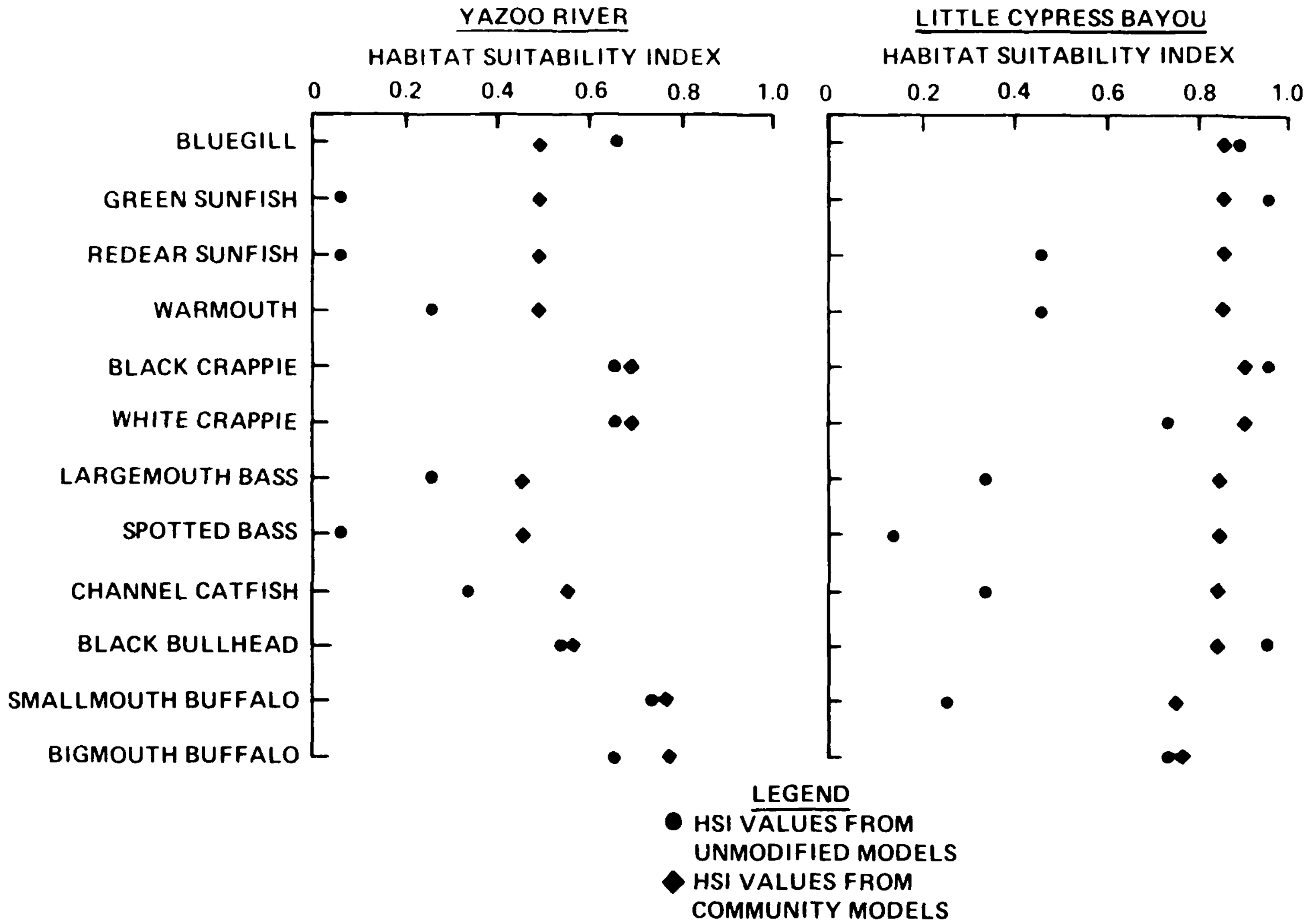

Figure 7. Comparison of HSI values calculated using unmodified and community models. There are five communities in this figure (i.e., the first community consists of bluegill, warmouth, green sunfish, and redear sunfish). See Figures 2-6

Summary

25. Published HSI models for warmwater fishes are difficult to use in habitat evaluation studies for two major reasons. First, models have too many variables, many of which are difficult and time-consuming to measure. The number of variables could be reduced if definitions for the same variable category (temperature, turbidity, etc.) were defined with uniform terminologies and units of measurement. Second, models are often constructed differently for closely related species with inconsistent methods of calculating the final HSI value. As a result, species that are closely related taxonomically and use similar habitat frequently yield different SI scores. The HEP is a general planning tool and should be based only on variables that are important in structuring community composition. To be most useful, the HEP should be accurate as well as easy to use.

26. Based upon habitat preferences determined from field studies and a review of the literature, warmwater fishes from the Little Cypress Bayou, Texas, and the Yazoo River, Mississippi, were placed into the following groups: sunfishes (*Lepomis*), black bass (*Micropterus*), crappie (*Pomoxis*), catfish (*Ictalurus*), and buffalo (*Ictiobus*). Community models, which were much less complex than species models, were developed for each group of warmwater fishes. The community models were based only on five composite SI curves (pH, dissolved oxygen, percent cover, average current velocity, and percent pools) that characterize major habitat requirements of these species. The community models presented in this report are applicable to general planning studies and can be modified if site-specific data are available.

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Table 1

Species Used in Developing Riverine Community Models

Common Name	Scientific Name
Spotted bass	*Micropterus punctulatus*
Largemouth bass	*Micropterus salmoides*
Bluegill	*Lepomis macrochirus*
Warmouth	*Lepomis gulosus*
Redear sunfish	*Lepomis microlophus*
Green sunfish	*Lepomis cyanellus*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Smallmouth buffalo	*Ictiobus bubalus*
Bigmouth buffalo	*Ictiobus cyprinellus*
Channel catfish	*Ictalurus punctatus*
Black bullhead	*Ictalurus melas*

[illegible]

Variable No.	Habitat Variable	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] backwaters [illegible] summer flow		X					X	X	X	X	X	X
[illegible]	Average [illegible] depth [illegible] summer flow												
[illegible]	Average [illegible] summer [illegible]												
[illegible]	[illegible]												
[illegible]	Average water [illegible] during growing [illegible] (adult, juvenile)		X										
[illegible]	Maximum water [illegible] during spawning (embryo)		X								X		
[illegible]	Average water level fluctuation during growing [illegible]		X										
8	Average current velocity at [illegible] m depth during summer (adult, juvenile)*		X	X	X	X	X	X	X	X	X	X	X
[illegible]	Maximum current velocity at [illegible] m depth within pools or backwaters during spawning (May-June) (embryo)		X										
[illegible]	Average current velocity at [illegible] m depth during summer (fry)		X	X			X			X			
[illegible]	Average current velocity within pools during spawning (June-July) (embryo)			X			X						
[illegible]	Percent cover within pools and backwaters (adult, juvenile)**	X	X	X	X	X	X	X	X	X	X	X	X
[illegible]	Percent bottom cover within pools and backwaters (fry)		X										X
14	Substrate composition within riverine pools and backwaters or lacustrine littoral areas (embryo)		X	X			X				X		X
15	Percent of substrate in streams or reservoirs composed of gravel, cobble, boulders, or bedrock	X											
16	Food production potential in river by substrate type present during average summer flow											X	
17	Minimum dissolved oxygen (mg/ℓ) levels during midsummer within pools	X	X	X	X	X	X	X	X	X	X	X	X
18	Minimum dissolved oxygen (mg/ℓ) levels during spawning (embryo)							X	X	X			
19	pH range during growing season	X	X	X	X	X	X	X	X	X	X	X	X

(Continued)

Note: X indicates that an SI curve appears in the published model.
* Published models separate juveniles and adults into two variables resulting in a higher number of variables than appears in this table.
** Some published models express cover as percent bottom cover, cover composed of logs and other objects, or cover composed of aquatic vegetation. However, this table combines all types of cover into one category and may result in a lower number of variables than appear in the published models.

Table [illegible] (concluded)

Variable No.	Habitat variable	[illegible] Bass	[illegible] Bass	Bluegill	[illegible]	[illegible]	[illegible]	[illegible]	Black Crappie	[illegible] Bullhead	[illegible] Bullhead	Channel Catfish	[illegible]
[illegible]	Average water temperature within pools, backwaters, or littoral areas during growing season		X		X			X		X		X	
21	Average weekly mean temperature within pools or littoral areas during spawning and incubation (embryo)		X	X	X	X		X	X	X		X	X
22	Average water temperature within pools, backwaters, or littoral areas during the growing season (fry)		X					X	X	X		X	
23	Average maximum daily temperature during warmest summer months	X											
24	Minimum temperature during spawning (April-May)	X											
25	Maximum midsummer temperature within pool or littoral areas (adult, juvenile)*			X		X	X				X		X
26	Maximum midsummer temperature within pools or littoral areas (fry)			X			X						
27	Maximum temperature within pools or littoral areas during spawning (June-July) (embryo)						X			X			
28	Most suitable water temperature within [illegible] (adult)								X				
29	Maximum monthly average turbidity during growing season		X(ppm)		X(JTU)**	X(ppm)	X([illegible])	X([illegible])	X([illegible])	X([illegible])	X([illegible])	X(ppm)	X(ppm)
30	Average turbidity during summer	X([illegible])		X(ppm)									
31	Maximum salinity during summer (adult, juvenile)		X	X		X	X	X		X	X	X	X
32	Maximum salinity during summer (fry)		X									X	
33	Maximum salinity during spawning and incubation (embryo)		X									X	X
34	Average stream width within representative reach						X			X			
35	Stream gradient within representative reach		X	X	X		X	X	X				
36	Length of agricultural growing season											X	

* Published models separate juveniles and adults into two variables resulting in a higher number of variables than appear in this table.
** JTU = Jackson Turbidity Units.

Table 3

Categories Used To Describe the Same General Habitat Condition

Category	Composite Variable	HSI Variable Number*	Total Number of Variables
Depth	Percent pools	1, 2, 3, 4	4
	Water level fluctuation	5, 6, 7	3
Velocity	Velocity	8, 9, 10, 11	4
Cover	Percent cover	12, 13	2
	Substrate	14, 15, 16	3
Water quality	Dissolved oxygen	17, 18	2
	pH	19	1
	Temperature	20, 21, 22, 23, 24 25, 26, 27, 28	9
	Turbidity	29, 30	2
	Salinity	31, 32, 33	3
Other	Stream width	34	1
	Stream gradient	35	1
	Growing season	36	1

* Variable numbers refer to Table 2.

Table 4

HSI Scores Calculated From Unmodified Species Models for Warmwater Fishes in Little Cypress Bayou and Yazoo River

HSI Value (Range)	Species at Indicated Location: Little Cypress Bayou	Species at Indicated Location: Yazoo River
0.00-0.10	--	Spotted bass Redear sunfish Green sunfish
0.11-0.20	Spotted bass	--
0.21-0.30	Smallmouth buffalo	Largemouth bass Warmouth
0.31-0.40	Largemouth bass Channel catfish	Channel catfish
0.41-0.50	Warmouth Redear sunfish	--
0.51-0.60	--	Black bullhead
0.61-0.70	Bluegill	Bluegill White crappie Black crappie Bigmouth buffalo
0.71-0.80	Bigmouth buffalo White crappie	Smallmouth buffalo
0.81-0.90	--	--
0.91-1.00	Black bullhead Green sunfish Black crappie	

Table 5

Habitat Data and SI Values for Bluegill, Collected in the Little Cypress Bayou and Yazoo River

Variable No.*	Habitat Variable	Cypress Bayou Data	Cypress Bayou SI	Yazoo River Data	Yazoo River SI
1	Pools, %	75	1.0	25	0.4
12	Percent cover (logs, brush, and vegetation)	50	1.0	10	0.6
30	Maximum average turbidity, ppm	10	1.0	125	0.6
19	pH	6.5	1.0	7.2	1.0
17	Minimum dissolved oxygen, mg/ℓ	4.0	0.7	5	0.7
31	Salinity, ppt	0.0	1.0	0	1.0
25	Maximum temperature for adults and juveniles, °C	29	0.1	28	0.6
21	Average temperature for embryos, °C	19	1.0	19	1.0
26	Maximum temperature for fry, °C	22	1.0	22	1.0
8	Average current velocity for adults and juveniles, cm/sec	5	1.0	22	0.5
11	Average current velocity for embryos, cm/sec	5	1.0	15	0.7
10	Average current velocity for fry, cm/sec	5	1.0	10	0.1
35	Substrate gradient, m/km	0.5	1.0	0.5	1.0
14	Substrate composition for embryos	Sand	0.7	Silt/clay	0.7
	Life Requisites				
	Food		0.4		0.6
	Cover		0.8		0.6
	Water quality		0.5		0.7
	Reproduction		0.4		0.8
	Other		1.0		0.6
	HSI		0.7		0.7

* Variable number corresponds to Table 2.

Table 6

Habitat Data and SI Values for Green Sunfish Collected in the Little Cypress Bayou and Yazoo River

Variable No.*	Habitat Variable	Cypress Bayou Data	Cypress Bayou SI	Yazoo River Data	Yazoo River SI
12	Percent cover	50	1.0	10	0.4
1	Percent pools	75	1.0	25	0.4
35	Stream gradient, m/km	0.5	1.0	0.5	1.0
17	Minimum dissolved oxygen, mg/ℓ	4	0.7	5	0.7
29	Maximum turbidity, JTU	20	0.9	150	0.7
19	pH range	6.5	1.0	7.2	1.0
25	Maximum temperature for adults and juveniles, °C	30	1.0	28	1.0
26	Maximum temperature for fry, °C	30	0.6	28	0.8
27	Maximum temperature for embryos, °C	20	1.0	20	1.0
14	Substrate for embryos	Sand	0.8	Silt/clay	0.8
8	Average current velocity for adults and juveniles, cm/sec	5	1.0	22	0.1
10	Average current velocity for fry, cm/sec	10	1.0	10	0
11	Average current velocity for embryos, cm/sec	5	1.0	15	0
34	Average stream width, m	15.0	1.0	40	0.6
31	Maximum salinity, ppt	0	1.0	0.0	1.0
	Life Requisites				
	Food/cover		1.0		0.4
	Water quality		0.7		0.7
	Reproduction		0.9		0.0
	Other		1.0		0.5
	HSI		0.9		0.0

* Variable number corresponds to Table 2.

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