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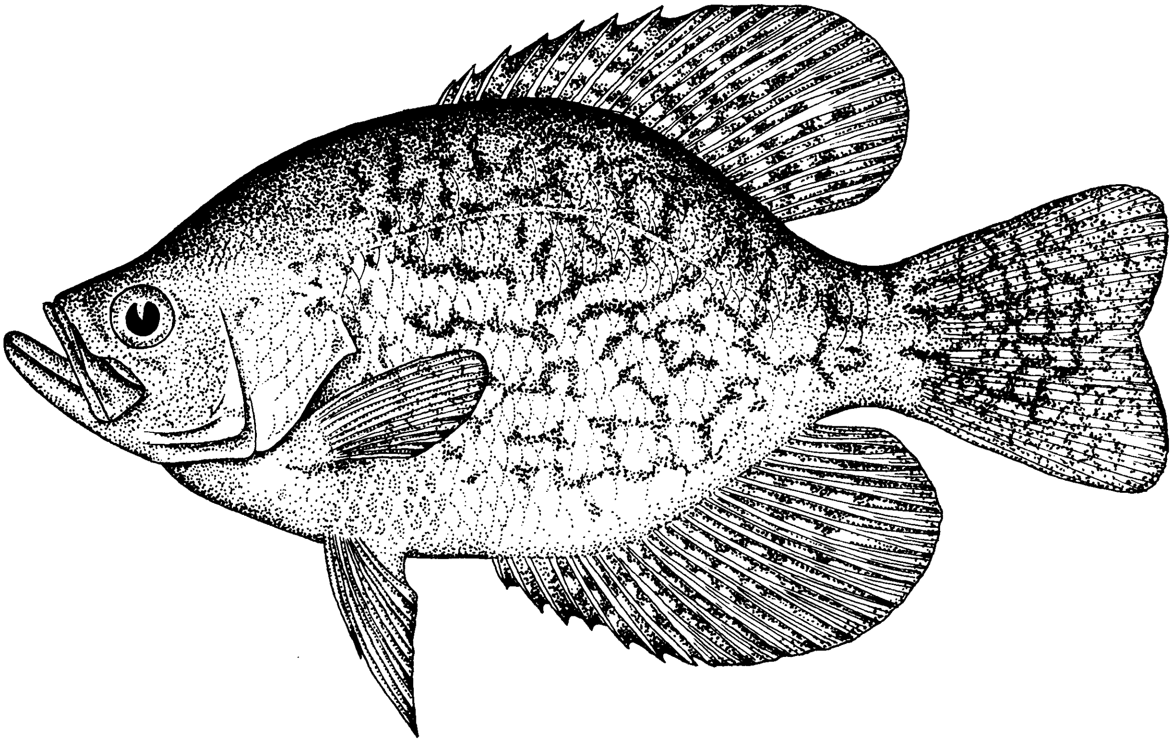
HABITAT SUITABILITY INDEX MODELS: BLACK CRAPPIE



ɩnd Wildlife Service

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HABITAT SUITABILITY INDEX MODELS: BLACK CRAPPIE

by

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PREFACE

The habitat use information and Habitat Suitability Index (HSI) models presented in this document are an aid for impact assessment and habitat management activities. Literature concerning a species' habitat requirements and preferences is reviewed and then synthesized into HSI models, which are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Assumptions used to transform habitat use information into these mathematical models are noted, and guidelines for model application are described. Any models found in the literature which may also be used to calculate an HSI are cited, and simplified HSI models, based on what the authors believe to be the most important habitat characteristics for this species, are presented.

Use of the models presented in this publication for impact assessment requires the setting of clear study objectives and may require modification of the models to meet those objectives. Methods for reducing model complexity and recommended measurement techniques for model variables are presented in Appendix A.

The HSI models presented herein are complex hypotheses of species-habitat relationships, <u>not</u> statements of proven cause and effect relationships. Results of model performance tests, when available, are referenced; however, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, the FWS encourages model users to convey comments and suggestions that may help us increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send comments to:

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CONTENTS

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BLACK CRAPPIE (*Pomoxis nigromaculatus*)

HABITAT USE INFORMATION

General

The black crappie (*Pomoxis nigromaculatus*) is native to freshwater lakes and streams from the Great Lakes south to the Gulf of Mexico, and the southern Atlantic states (Scarola 1973; Scott and Crossman 1973), north to North Dakota and eastern Montana, and east to the Appalachians (Lee et al. 1980). It has been widely introduced outside this range throughout North America.

Age, Growth, and Food

Black crappie can live up to 13 years (Carlander 1977) and reach maximum sizes of 559 mm (Cross 1967) and about 2,270 g (Moyle 1976). Maturation usually occurs at age 2 or 3 (Sigler and Miller 1963; Brown 1971; Moyle 1976), at lengths from 175 to 200 mm (Huish 1954). Growth varies with population size, and productivity and size of the habitat (Scott and Crossman 1973).

Black crappie fry and juveniles feed mainly on microcrustaceans and planktonic insects (Burris 1956; Keast 1968; Scott and Crossman 1973). However, as total length increases, individual diets include more fish (Scott and Crossman 1973; Ager 1976), and adults feed primarily on fish and planktonic insects (Burris 1956; Harmic 1966; Keast and Webb 1966; Keast 1968; Ball and Kilambi 1973). The most important parameter limiting crappie growth and population size is the quantity and quality of available food, particularly small forage fish (Crawley 1954; Goodson 1966). Black crappie commonly forage in open water over deeper areas (Johnson 1945; Keast and Webb 1966; Keast 1968; Moyle 1976).

Reproduction

Male black crappie move into river backwaters or littoral areas in lakes and reservoirs in the spring to establish territories (Ginnelly 1971) and construct nests (Everhart 1966; Brown 1971; Scott and Crossman 1973). Nests are bowl-shaped (Schneberger 1972), shallow depressions (< 60 cm) cleared by the male (Richardson 1913; Scott and Crossman 1973; Moyle 1976) and are usually constructed near or in beds of vegetation on a soft mud (Sigler and Miller 1963; Scott and Crossman 1973; Moyle 1976), sand, or gravel substrate (Breder 1936; Brown 1971; Schneberger 1972; Scott and Crossman 1973). Spawning begins in late March, April, or May depending on geographical location and temperature (Sigler and Miller 1963; Harmic 1966; Brown 1971; Moyle 1976).

Specific Habitat Requirements

Black crappie prefer clear water (Stroud 1948; Hall et al. 1954; Moyle 1976) and grow faster in areas of low turbidity (Hastings and Cross 1962; Neal 1963). Black crappie are less tolerant of high turbidities than are white crappie (Gerking 1945; Trautman 1957; Scott and Crossman 1973) and, as a result, tend to dominate the latter species in clear water areas (Hall et al. 1954; Moyle 1976).

Abundant cover, particularly in the form of aquatic vegetation, is necessary for growth and reproduction (Sigler and Miller 1963; Scott and Crossman 1973; Moyle 1976). Common daytime habitat is shallow water in dense vegetation (Sigler and Miller 1963) and around submerged trees, brush, or other objects (Moyle 1976).

Black crappie are absent from higher gradient streams (> 2 m/km) and are common in base or low gradient streams (< 0.5 m/km) (Trautman 1957). The species is common in shallow areas of larger rivers (Sigler and Miller 1963; Brown 1971; Scott and Crossman 1973), but may not inhabit adjoining tributaries (Finnell 1957). Black crappie prefer low velocity waters (i.e., absence of noticeable current) (Gerking 1945; Whitworth et al. 1968; Pflieger 1975; Kallemeyn and Novotny 1977). Optimum current velocities are < 10 cm/sec, and the species will not tolerate velocities > 60 cm/sec (based on probability-of-use curves developed by Hardin and Bovee 1979). Because of their preference for low velocities, it is assumed that black crappie prefer quiet, sluggish rivers with a high percentage of pools, backwaters, and cut-off areas.

Lacustrine habitat of black crappie may be characterized by large warm-water ponds, reservoirs (Scott and Crossman 1973; Pflieger 1975), and small to medium-sized natural lakes (Sigler and Miller 1963). Although this species does not do well in the main body of large lakes (Hall et al. 1954), it can become abundant in shallow areas and bays (Scott and Crossman 1973). Populations of black crappie have been established in clear, steep-sided California reservoirs that lack vegetation (Moyle 1976), but this situation is not considered optimal.

Lacustrine habitat suitability for adequate food production may be described in terms of total dissolved solids (TDS). Jenkins (1976) reported a significant positive correlation between TDS levels of 100-350 ppm and sport-fish (including black crappie) standing crop. Stroud (1948) discusses the relationship between lacustrine productivity (TDS) and food availability.

Dissolved oxygen (D.O.) requirements for black crappie are assumed to be consistent with those for largemouth bass and freshwater fish in general. Largemouth bass avoid D.O. concentrations as low as 1.5 mg/l but will tolerate 4.5 mg/l for short periods (Whitmore et al. 1960). Levels above 5 mg/l are assumed to be optimum for growth and reproduction of freshwater fish (Stroud 1967; U.S. Environmental Protection Agency 1976). Sigler and Miller (1963) reported that D.O. levels below 1.4 mg/l often cause mortality in black crappie. In a lacustrine environment, oxygen levels must be adequate in the temperature strata that is selected by the species.

Black crappie have been collected in the Mississippi River delta area in waters having salinities of 1.32 ppt (Carver 1966). Louder (1963) reported that black crappie occurred in waters up to 4.7 ppt in North Carolina, but the species was more abundant in the fresher headwaters. Black crappie were rarely found in brackish water in Canada (Scott and Crossman 1973).

A pH range of 5.0-9.0 is considered safe for freshwater fish (European Inland Fisheries Advisory Commission 1969), and a range of 6.5-8.5 is essential for good growth (Stroud 1967; U.S. Environmental Protection Agency 1976).

Adult. In 90% of the streams where adult black crappie were found in the Mississippi Valley and along the East Coast, the mean weekly summer (July and August) temperatures were 23-32° C, with a mean of approximately 26° C (Biesinger, personal communication). It may be inferred that these temperatures are adequate for growth of black crappie; it is assumed that optimum growth occurs near the upper end of the range. Only 5% of all fish in this study were in waters < 20° C.

Embryo. During spawning, temperatures range from 13-21° C (March to July) (Goodson 1966; Scarola 1973; Brungs and Jones 1977; Siefert and Herman 1977; Carlson and Herman 1978), with 17.8-20° C being the most favorable range (Schneberger 1972).

In a laboratory study, successful spawning and survival occurred at dissolved oxygen levels as low as 2.5 mg/l. However, these fish spawned at lower temperatures than at the higher DO levels tested, and earlier spawnings in the natural environment could affect survival of the embryo (Siefert and Herman 1977). In this study and that of Carlson and Herman (1978), successful reproduction at higher temperatures occurred at 3.5 mg/l and 2.7 to 5.7 (diel fluctuating) mg/l, respectively.

In lacustrine ecosystems, receding water levels caused decreased reproductive success (Erickson and Zarbock 1954) and, consequently, population declines because of the loss of shoreline vegetation and increased turbidity (Stroud 1948; Neal 1963). A rise in water level may create more spawning habitat, clearer water, and increased productivity (Neal 1963; Merna 1964).

Fry. Black crappie fry first appear in the spring when water temperature is approximately 15° C (Amundrud et al. 1974). In Wisconsin, larval fish were taken in the limnetic zone in the first part of June to July at temperatures of 18-20° C (Faber 1967). Temperatures from April to July in 90% of the streams where adult black crappie are found in the Mississippi Valley and along the east coast range from 15 to 30° C (Biesinger, personal communication); it is assumed that fry grow best in the middle part of this range. Fry are most abundant in shallow, vegetated areas with cover and food (Gerking 1945; Ball and Kilambi 1973).

Juvenile. Optimal temperature for growth was reported to be 22-25° C; no growth occurred below 11° C or above 30° C (Brungs and Jones 1977). Preferred temperatures of 27-29° C were recorded in a thermal outfall area and in the laboratory (Neill and Magnuson 1974).

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The model is applicable throughout the native and introduced range of the black crappie in North America. The standard of comparison for each individual variable suitability index is the optimum value of the variable that occurs anywhere within the native and introduced regions. Therefore, the model will never provide an HSI of 1.0 when applied to water bodies in the North where temperature related variables do not reach the optimum values found in the South.

Season. The model provides a rating for a water body based on its ability to support a reproducing population of black crappie through all seasons of the year. The model will provide an HSI of 0.0 if any reproduction related variable indicates that the species is not able to reproduce in the habitat being evaluated.

Cover types. The model is applicable in riverine and lacustrine habitats as described by Cowardin et al. (1979).

Minimum habitat area. Minimum habitat area is defined as the minimum area of contiguous suitable habitat that is required for a species to live and reproduce. No attempt has been made to establish a minimum habitat size for black crappie. Although this species prefers larger rivers, it may also live in small lakes.

Verification level. The acceptance goal of the black crappie model is to produce an index between 0 and 1 which has a positive relationship to spawning success of adults and carrying capacity for fry, juveniles, and adults. In order to verify that the model output was acceptable, HSI's were calculated from sample data sets. These sample data sets and their relationship to model verification are discussed in greater detail following the presentation of the model.

Model Description - Riverine

Black crappie habitat quality analysis is based on basic components consisting of food, cover, water quality, and reproduction requirements. Variables that have been shown to affect growth, survival, abundance, or other measure of well-being of black crappie are placed in the appropriate component (Figures 1 and 2).

Food-cover component. Food and cover have been aggregated into one component because the variables within this component describe both food and cover suitability. Species abundance has been positively correlated with percent cover. In pools and backwaters in rivers, cover (V_2) provides resting areas and protection from predation. Cover also provides habitat for insects and small forage fish, important food items for the black crappie. Percent pools and backwater areas (V_5) is included to quantify the amount of food-cover habitat.

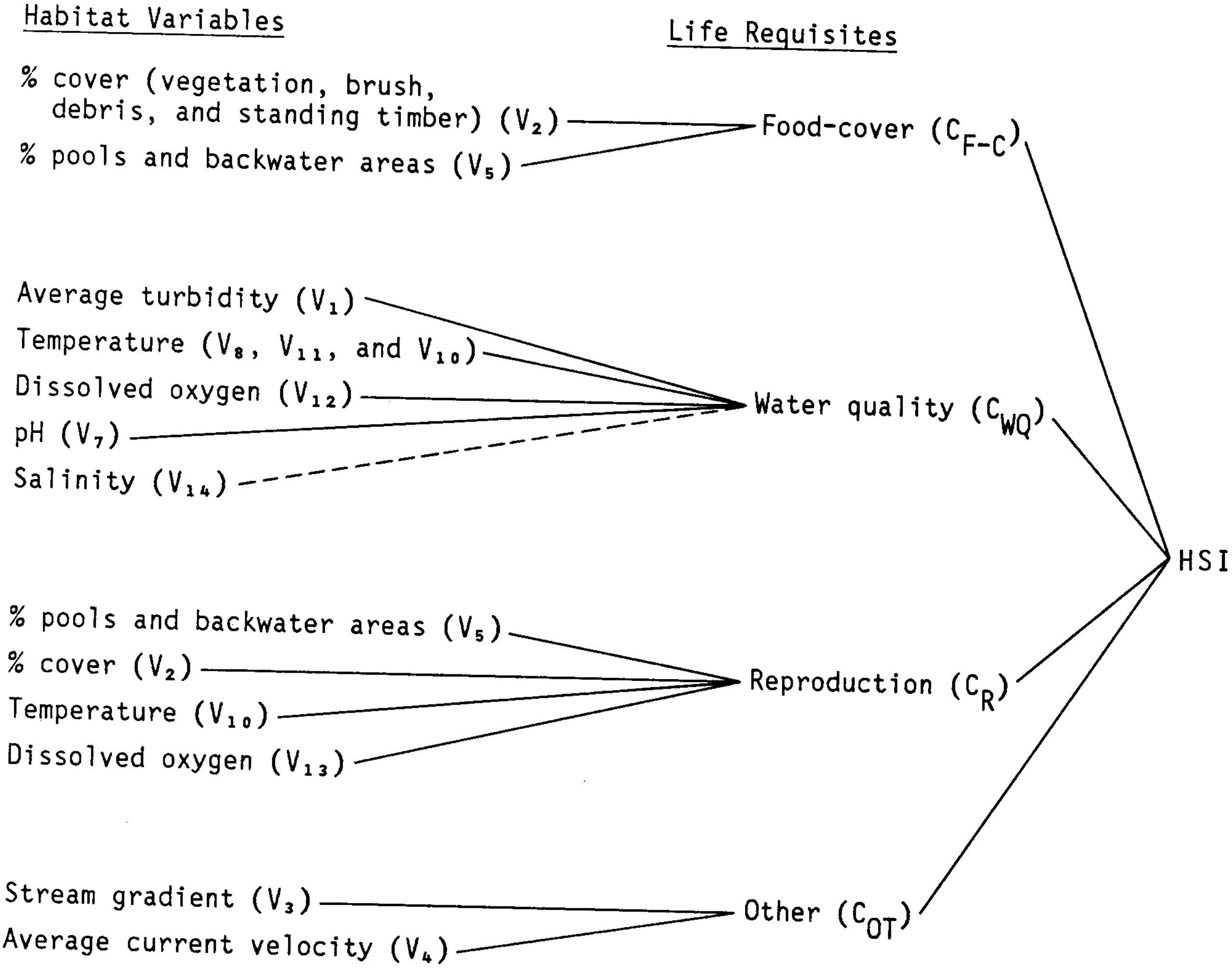


Figure 1. Tree diagram illustrating relationship of habitat variables and life requisites in the riverine model for the black crappie. Dashed line indicates optional variable in the model.

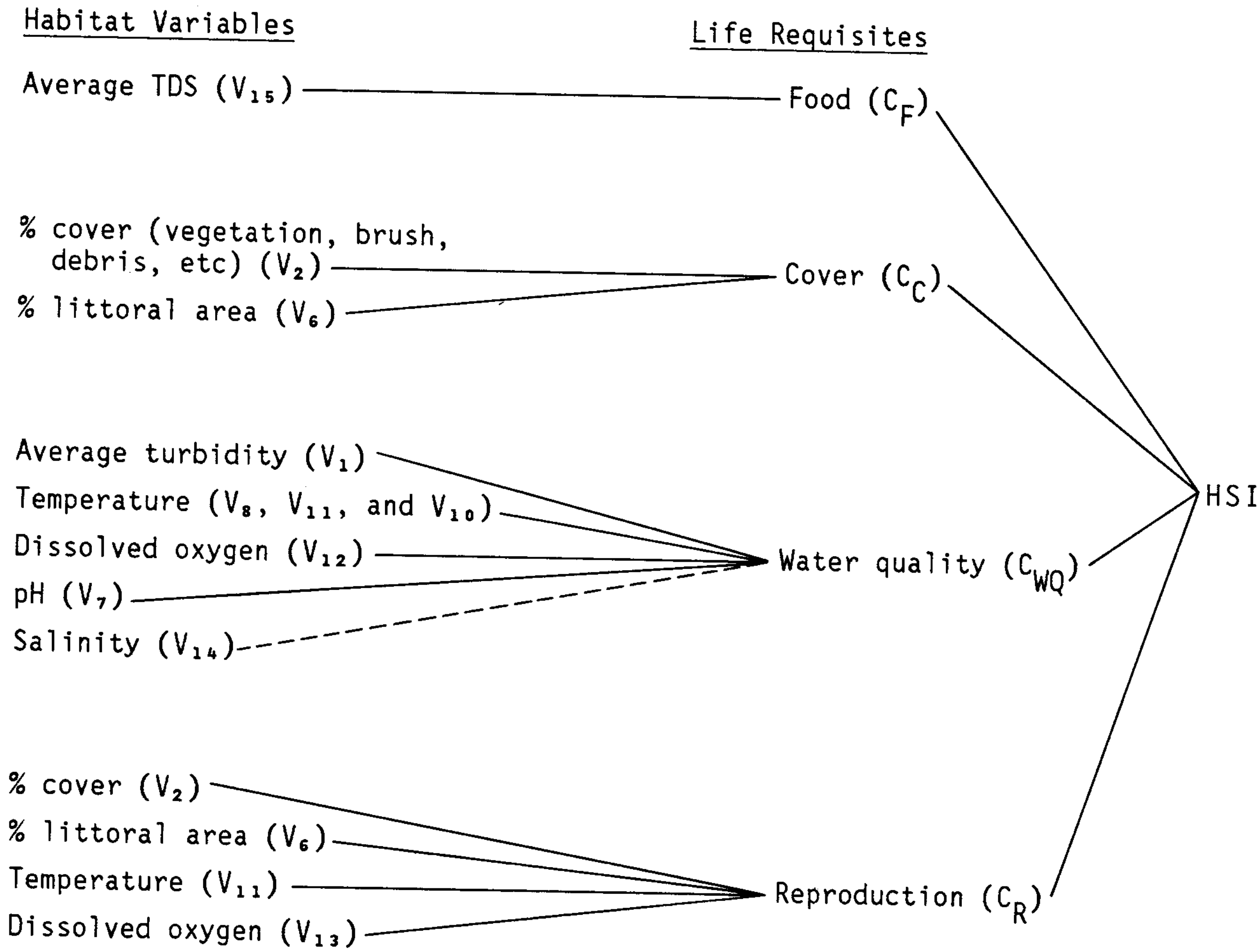


Figure 2. Tree diagram illustrating relationship of habitat variables and life requisites in the lacustrine model for the black crappie. Dashed line indicates optional variable in the model.

Water quality component. Average turbidity (V_1) is important since faster growth rates and high standing crop have been correlated with low turbidities. Temperature (V_8, V_{11}, and V_{10}) and dissolved oxygen (V_{12}) affect survival, development, and growth. The pH (V_7) is included because it has been determined that a certain pH level is necessary for survival and reproduction. Salinity (V_{14}) is included as an optional variable. Salinity can affect growth and survival of the species but is not considered a problem in most areas where black crappie are found. Toxic substances were not considered in this model even though they may interact with pH, temperature, and/or dissolved oxygen to reduce habitat suitability.

Reproduction component. Cover (V_2) is an important reproduction variable since vegetation and/or debris is almost always associated with spawning nests. Percent pools and backwater areas (V_5) is included to quantify the amount of spawning habitat. Temperature (V_{10}) and dissolved oxygen (V_{13}) are included since these are crucial parameters for the initiation of spawning and normal embryonic development.

Other component. The variables within the other component are those which aid in describing habitat suitability for black crappie, yet are not specifically related to the life requisite components already presented. Stream gradient (V_3) is important because black crappie occur only in base or low gradient rivers and streams. Average current velocity (V_4) is included because the species prefers waters with a very low average current velocity.

Model Description - Lacustrine

Food component. Average TDS (V_{15}) is included because TDS is a measure of general lacustrine productivity. Dissolved solids are a vital prerequisite for the development of the food chain.

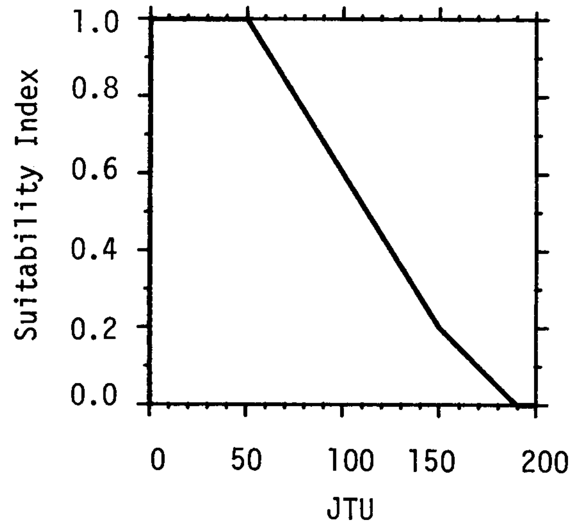
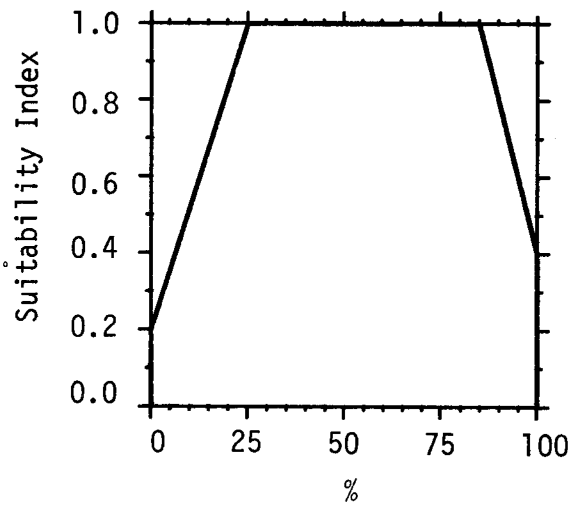
Cover component. Species abundance has been positively correlated with cover. Cover (V_2) in shallower areas of the lacustrine environment provides for protection and resting areas. Percent littoral area (V_6) quantifies the amount of cover habitat.

Water quality component. See riverine model description.

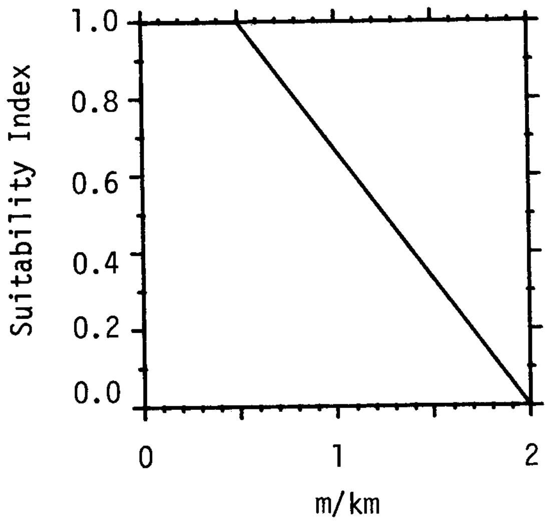
Reproduction component. Cover (V_2), in the form of vegetation or debris, is an important reproductive variable since spawning success is associated with the availability of some cover. Percent littoral area (V_6) quantifies the amount of spawning habitat. A rise in water level may increase the amount of spawning habitat by flooding vegetation. Temperature (V_{11}) and dissolved oxygen (V_{13}) affect survival, development, and growth of the embryo.

Suitability Index (SI) Graphs For Model Variables.

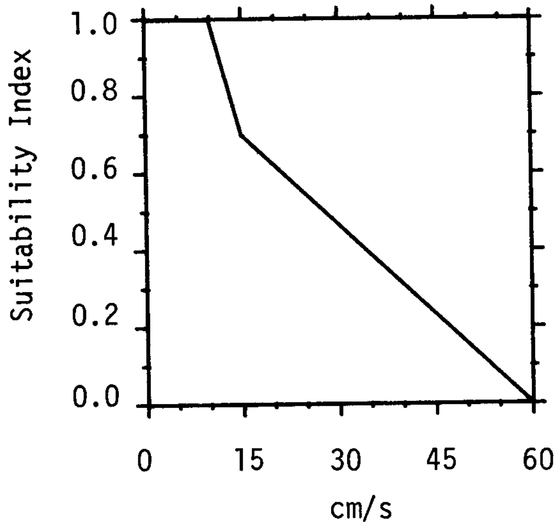
This section contains suitability index graphs for the 15 variables described above and equations for combining selected variable indices into a species HSI using the component approach. Variables may pertain to either a riverine (R) habitat, a lacustrine (L) habitat, or both.

Habitat	Variable		Suitability Graph
R,L	(V_1)	Maximum monthly average turbidity during summer.	
R,L	(V_2)	Percent cover (e.g., vegetation, brush, debris, and standing timber) during mid-summer within pools, overflow areas, and backwaters (R), and the littoral zone (L).	

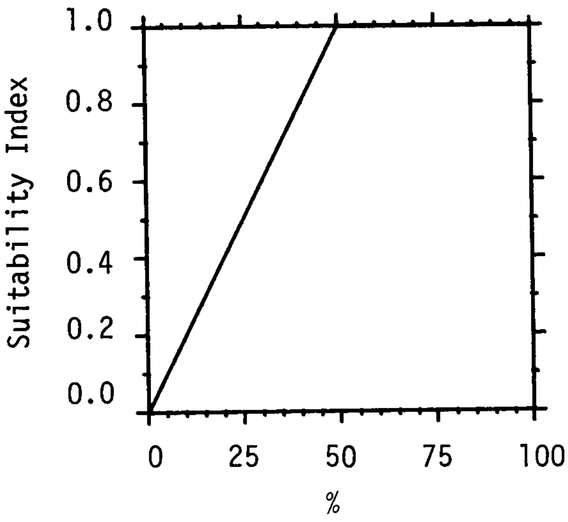
R (V$_3$) Stream gradient within study area.



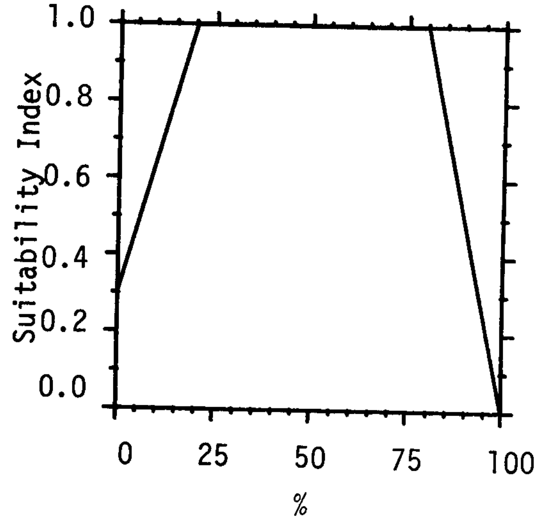
R (V$_4$) Average current velocity in pools and backwater areas during average summer flow.



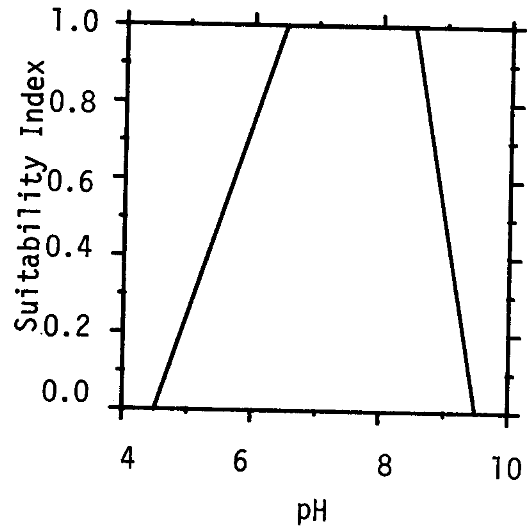
R (V$_5$) Percent pools and backwater areas during average spring and summer flow.



L (V6) Percent littoral area during spring and summer.

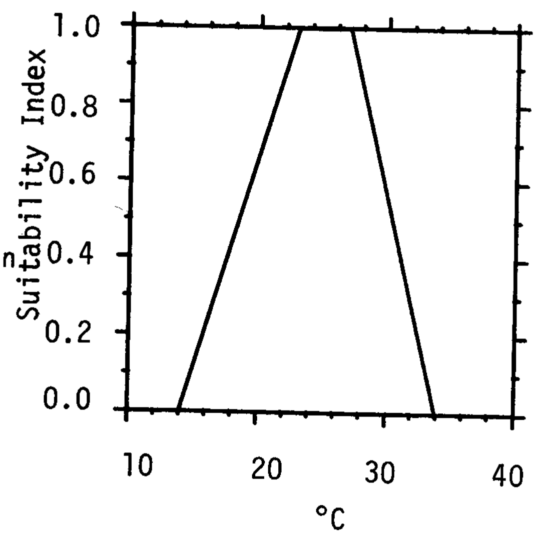


R,L (V7) pH levels during year.



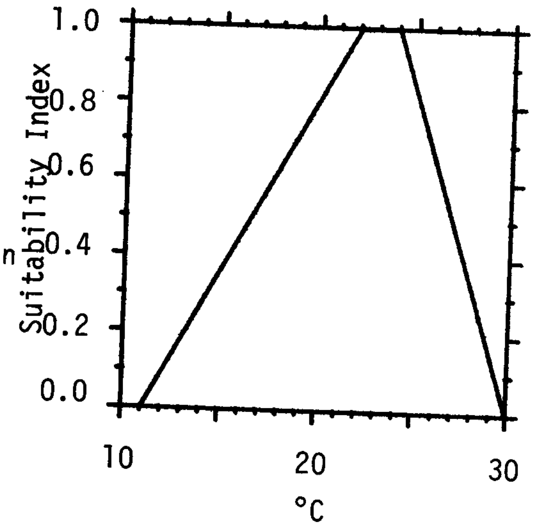
R,L (V8) Most suitable water temperature within the epilimnion (L) or in pools and back-waters (R) during midsummer (adult).

Note: Choose the epilimnion with highest SI rating for water temperature.

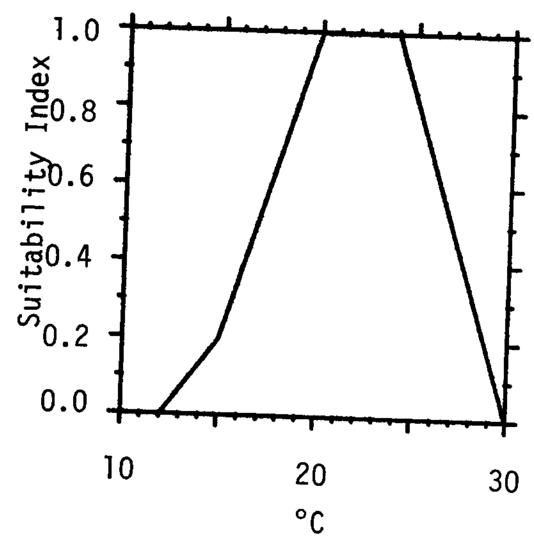


R,L (V$_9$) Most suitable water temperature within the epilimnion (L) or in pools and backwaters (R) during midsummer (juvenile).

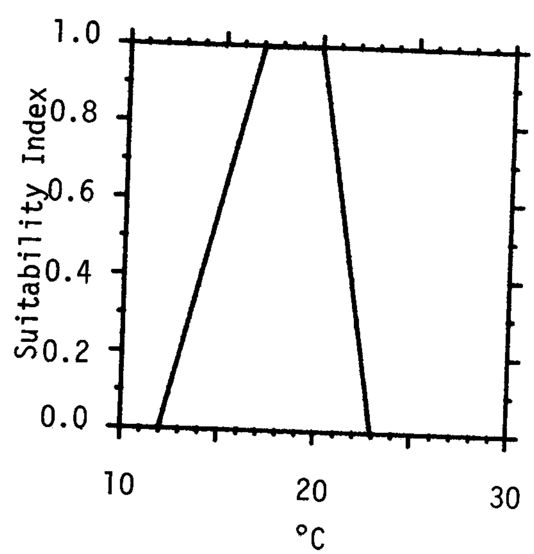
<u>Note</u>: Choose the epilimnion with highest SI rating for water temperature



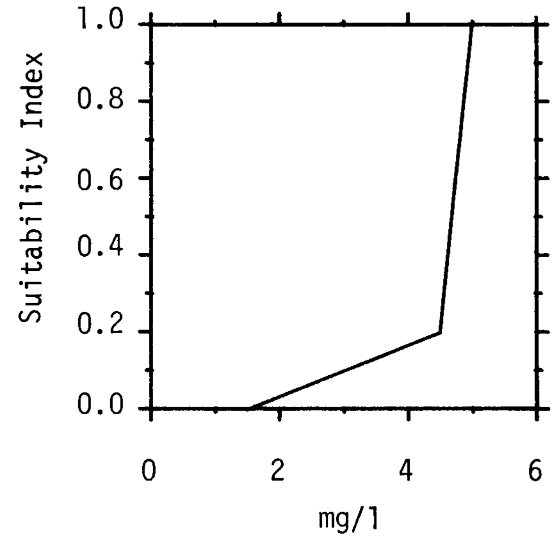
R,L (V$_{10}$) Average water temperature within littoral areas (L) or in pools and backwaters (R) during midsummer (fry).



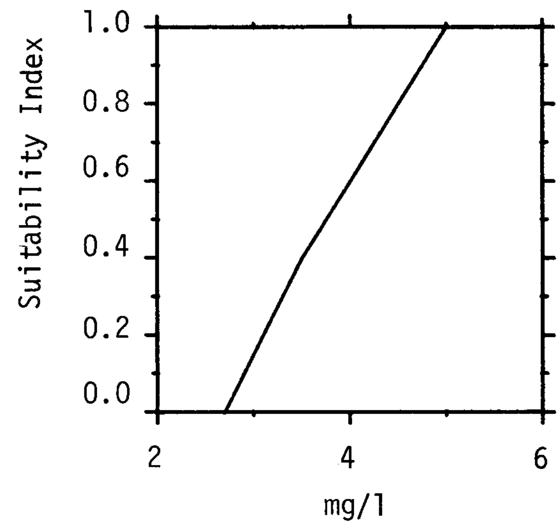
R,L (V$_{11}$) Average water temperature within littoral areas (L) or backwaters (R) during spawning (embryo).



R,L (V_{12}) Minimum dissolved oxygen levels within temperature strata selected above (V_8, V_9, and V_{10}) during midsummer (adult, juvenile, fry).

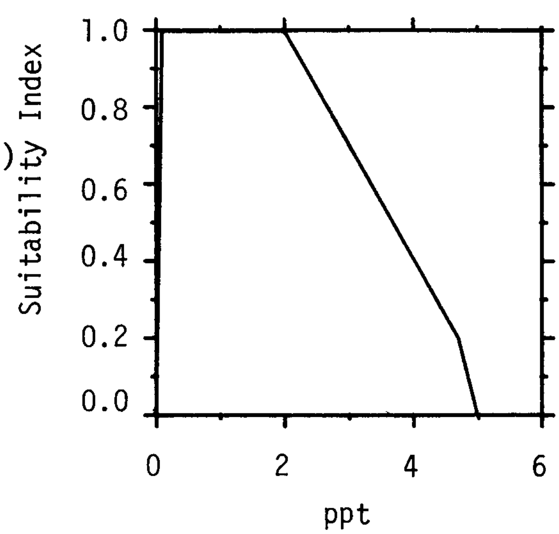


R,L (V_{13}) Minimum dissolved oxygen levels within littoral areas (L) or backwaters (R) during spawning (embryo, fry).



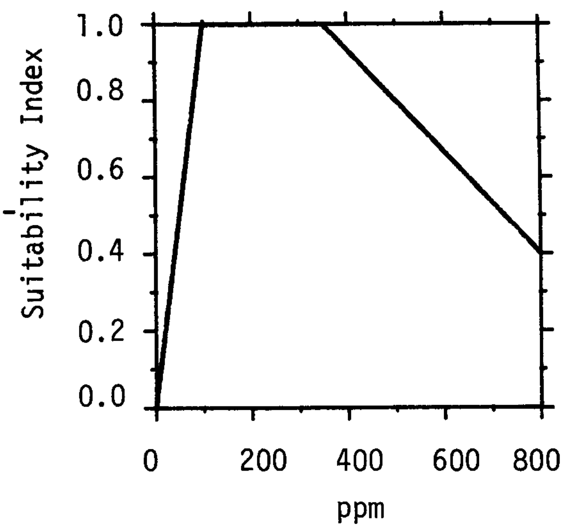
L (V_{14}) Maximum salinity during growing season.

Note: (optional variable) V_{14} may be omitted if salinity is not considered to be a potential problem within the study area.



L (V$_{15}$) Average TDS level during the growing season.

Note: SI value should be lowered 0.2 if ionic concentration of sulfate-chlorides exceeds that of carbonate-bicarbonates.



Riverine Model

These equations utilize the life requisite approach and consist of four components: food-cover, water quality, reproduction, and other.

Food-Cover (C_{F-C}).

$$C_{F-C} = (V_2 \times V_5)^{1/2}$$

Water Quality (C_{WQ}).

$$C_{WQ} = \frac{2[(V_8 \times V_9 \times V_{10})^{1/3}] + 2V_{12} + V_7 + V_1}{6}, \text{ or}$$

If $(V_8 \times V_9 \times V_{10})^{1/3}$ or V_{12} is ≤ 0.4, C_{WQ} equals the lowest of the following: $(V_8 \times V_9 \times V_{10})^{1/3}$, V_{12}, or the above equation. If either V_8, V_9, or V_{10} is ≤ 0.4, then $(V_8 \times V_9 \times V_{10})^{1/3}$ equals the lowest rating.

Note: If V_{14} (optional salinity variable) is added,

$$C_{WQ} = \frac{2[(V_8 \times V_9 \times V_{10})^{1/3}] + 2V_{12} + V_7 + V_1 + V_{14}}{7}$$

Reproduction (C_R).

$$C_R = (V_2 \times V_5 \times V_{11}^2 \times V_{13}^2)^{1/6}$$

Other (C_{OT}).

$$C_{OT} = \frac{V_3 + V_4}{2}$$

HSI determination.

$$HSI = (C_C \times C_{WQ} \times C_R \times C_{OT})^{1/4}, \text{ or}$$

If C_{WQ} or C_R is ≤ 0.4, then HSI equals the lowest of the following: C_{WQ}, C_R, or the above equation.

Lacustrine Model

This model utilizes the life requisite approach and consists of four components: food, cover, water quality, and reproduction.

Food (C_F).

$$C_F = V_{15}$$

Cover (C_C).

$$C_C = (V_2 \times V_6)^{1/2}$$

Water Quality (C_{WQ}).

See riverine water quality equation.

Reproduction (C_R).

$$C_R = (V_2 \times V_6 \times V_{11}^2 \times V_{13}^2)^{1/6}$$

HSI determination.

$$HSI = (C_F \times C_C \times C_{WQ} \times C_R)^{1/4}, \text{ or}$$

If C_F, C_C, C_{WQ}, or C_R is ≤ 0.4, the HSI equals the lowest of the following: C_F, C_C, C_{WQ}, C_R, or the above equation.

Sources of data and assumptions made in developing the suitability indices are presented in Table 1.

Sample data sets for the above riverine and lacustrine HSI models are listed in Tables 2 and 3. The data sets are not actual field measurements, but represent combinations that could occur in a riverine or lacustrine habitat. We believe the HSI's calculated from the data reflect what the carrying capacity trends would be in riverine and lacustrine habitats with the listed characteristics. Thus, the model meets the acceptance goal of producing an index between 0 and 1 which is believed to have a positive relationship to the spawning success of adults and carrying capacity for fry, juvenile, and adult black crappie.

Interpreting Model Outputs

Habitats with an HSI of 0 may contain some black crappie; habitats with a high HSI may contain few. The black crappie HSI determined by use of these models will not necessarily represent the population of black crappie in the study area. This is because the standing crop does not totally depend on the ability of the habitat to meet all life requisite requirements of the species. If the model is a good representation of black crappie riverine or lacustrine habitat, it should be positively correlated with long term average population levels in areas where black crappie population levels are due primarily to habitat related factors. However, this relationship has not been tested. The proper interpretation of the HSI is one of comparison. If two habitats have different HSI's, the one with the higher HSI should have the potential to support more black crappie than the one with the lower HSI, given that the model assumptions have not been violated.

Table 1. Data sources for black crappie suitability indices.

Variable and source		Assumption
V_1	Gerking 1945 Hall et al. 1954 Trautman 1957 Hastings and Cross 1962 Scott and Crossman 1973 Moyle 1976	Turbidity levels associated with high standing crops and faster growth rates are optimum. Turbidity levels associated with slowed growth rates are suboptimum.
V_2	Gerking 1945 Sigler and Miller 1963 Ball and Kilambi 1973 Scott and Crossman 1973 Moyle 1976	Since black crappie are found in greater numbers in areas with cover, it is assumed that the percent cover associated with high species abundance is optimum. Too little cover can affect survival. Too much cover is assumed to be suboptimum.
V_3	Finnell 1957 Trautman 1957 Sigler and Miller 1963 Brown 1971 Scott and Crossman 1973	Stream gradients where the species is most often found are optimum.
V_4	Gerking 1945 Whitworth et al. 1968 Pflieger 1975 Hardin and Bovee 1979	Current velocities associated with high species abundance are optimum.
V_5	Gerking 1945 Finnell 1957 Whitworth et al. 1968 Pflieger 1975	Since black crappies are abundant only in pools and backwaters of the main river channel, it is assumed that the percentage of these areas associated with high numbers is optimum.
V_6	Sigler and Miller 1963 Scott and Crossman 1973 Pflieger 1975	Since black crappies are most abundant in shallow areas, the percent littoral area associated with high numbers of fish is optimum. Little or no littoral area is assumed to be suboptimum. Since black crappie need deeper, open water to forage, too much littoral area is suboptimum to unsuitable.

Table 1. (Continued)

Variable and source		Assumption
V_7	Stroud 1967 (freshwater fish) European Inland Fisheries Advisory Commission 1969	pH values that are adequate for freshwater fish are assumed to be adequate for black crappie.
V_8	Sigler and Miller 1963 Neill et al. 1972 Biesinger 1980	Average midsummer temperatures where black crappie are found are adequate for growth. Optimum growth occurs at the upper end of the temperature range for warmwater fish. Temperatures associated with few or no fish are suboptimum to unsuitable. Individuals acclimated at higher temperatures, thus having a higher tolerance level, are assumed to reflect other than natural conditions.
V_9	Neill and Magnuson 1974 Brungs and Jones 1977	Maximum growth occurs when temperatures are optimum. Temperatures must reach levels that permit growth in order for habitat to be suitable. Preferred temperatures in a thermal outfall area are suboptimal.
V_{10}	Faber 1967 Amundrud et al. 1974 Biesinger 1980	Average water temperatures where fry are found are adequate for growth.
V_{11}	Goodson 1966 Harmic 1966 Schneberger 1972 Siefert and Herman 1977 Brungs and Jones 1977	Normal development and maximum survival occur when temperatures are optimum. Temperatures that result in little or no survival are unsuitable.
V_{12}	Sigler and Miller 1963 Stroud 1967 U.S. Environmental Protection Agency 1976 Siefert and Herman 1977	Dissolved oxygen levels that are optimum for freshwater fish are assumed to be optimum for black crappie. Dissolved oxygen levels that reduce growth and feeding are suboptimal.
V_{13}	Sigler and Miller 1963 Stroud 1967 Siefert and Herman 1977 Carlson and Herman 1978	Dissolved oxygen levels that are optimum for freshwater fish spawning are assumed to be optimum for black crappie. DO levels that limit survival and retard development are suboptimum to unsuitable.

Table 1. (Concluded)

Variable and source		Assumption
V_{14}	Stroud 1948 Crowley 1954 Goodson 1966 Ryder et al. 1974	Salinity levels associated with high standing crop are considered optimum. Levels that slow growth or cause death are suboptimum to unsuitable.
V_{15}	Stroud 1948 Jenkins 1976	Average TDS levels that are associated with abundant food organisms are optimum. TDS levels that limit food production are suboptimum to unsuitable.

Table 2. Sample data sets using riverine HSI model.

Variable		Data set 1 Data	Data set 1 SI	Data set 2 Data	Data set 2 SI	Data set 3 Data	Data set 3 SI
Turbidity (JTU)	V_1	10	1.0	75	0.8	110	0.5
% cover	V_2	35	1.0	15	0.7	10	0.5
Gradient (m/km)	V_3	0.3	1.0	1.1	0.6	1.8	0.1
Velocity (cm/s)	V_4	4.0	1.0	9.0	1.0	15	0.7
% pools	V_5	60	1.0	35	0.7	60	1.0
pH	V_7	7.3	1.0	8.4	1.0	8.9	0.6
Temperature-adult (°C)	V_8	24	1.0	20	0.7	18	0.4
Temperature-juvenile (°C)	V_9	19	0.7	17	0.5	16	0.4
Temperature-fry (°C)	V_{10}	19.5	0.9	19	0.8	16	0.3
Temperature-embryo (°C)	V_{11}	15.5	0.7	18	1.0	14.5	0.5
D.O.-midsummer (mg/l)	V_{12}	6.3	1.0	5.4	1.0	8.6	1.0
D.O.-spring (mg/l)	V_{13}	8.8	1.0	6.2	1.0	9.4	1.0
Salinity (ppt) (optional)	V_{14}	1.0	1.0	0.5	1.0	1.5	1.0
Component SI							
C_{F-C} =			1.00		0.70		0.71
C_{WQ} =			0.95		0.85		0.36[a]
C_R =			0.89		0.89		0.71
C_{OT} =			1.00		0.80		0.40
HSI =			0.96		0.81		0.36[b]

[a] $(V_8 \times V_9 \times V_{10})^{1/3} = 0.36$.

[b] The HSI equals C_{WQ}.

Table 3. Sample data sets using lacustrine HSI model.

Variable		Data set 1 Data	Data set 1 SI	Data set 2 Data	Data set 2 SI	Data set 3 Data	Data set 3 SI
Turbidity (JTU)	V_1	6	1.0	70	0.8	110	0.5
% cover	V_2	40	1.0	20	0.8	60	1.0
% littoral	V_6	18	0.9	12	0.7	8	0.6
pH	V_7	7.3	1.0	8.9	0.5	9.3	0.1
Temperature-adult (°C)	V_8	28	0.9	29	0.7	31	0.4
Temperature-juvenile (°C)	V_9	24	1.0	25	0.9	25.5	0.8
Temperature-fry (°C)	V_{10}	25	0.9	19	0.8	26.5	0.6
Temperature-embryo (°C)	V_{11}	16.5	0.9	19	1.0	20	1.0
D.O.-midsummer (mg/l)	V_{12}	7.4	1.0	6.0	1.0	4.6	0.4
D.O.-spawning (mg/l)	V_{13}	8.6	1.0	8.0	1.0	7.6	1.0
TDS (ppm)	V_{15}	40	0.5	80	0.8	200	1.0
Component SI							
C_F =			0.50		0.80		1.00
C_C =			0.95		0.75		0.77
C_{WQ} =			0.98		0.82		0.40[a]
C_R =			0.94		0.87		0.84
HSI =			0.81		0.81		0.40[b]

[a] V_{12} = 0.40.

[b] The HSI equals C_{WQ}.

ADDITIONAL HABITAT MODELS

Model 1

Optimal riverine habitat for black crappie is characterized by the following conditions: moderately clear water (< 50 JTU), a gradient less than 0.5 m/km, at least 50% pools, greater than 25% vegetative cover, and warm (20-26° C) summer temperatures.

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

Model 2

Optimal lacustrine habitat for black crappie is characterized by the following conditions: lakes and reservoirs with warm water strata available (maximum summer temperature, 20-26° C), adequate dissolved oxygen (> 5.0 mg/l), abundant cover in littoral areas (> 50% but < 90% of total littoral area), stable water levels during spawning (May to July), moderately low turbidities (< 50 JTU), and TDS levels between 100 and 350 ppm.

$$HSI = \frac{\text{number of above criteria present}}{6}$$

Model 3

Use a crappie standing crop model for reservoirs presented in Aggus and Morais (1979).

Model 4

Use the black crappie model for reservoirs presented in McConnell et al. (1982).

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

Characteristics and habitat requirements of the black crappie (Pomoxis nigromaculatus) are described in a review of the literature. This information is then used as a basis for the development of Habitat Suitability Index models.

This is one in a series of publications developed to provide information on the habitat requirements of selected fish and wildlife species. Numerous literature sources have been consulted in an effort to consolidate scientific data on species-habitat relationships. These data have subsequently been synthesized into explicit Habitat Suitability Index (HSI) models. The models are based on suitability indices indicating habitat preferences. Indices have been formulated for variables found to affect the life cycle and survival of each species. Habitat Suitability Index (HSI) models are designed to provide information for use in impact assessment and habitat management activities. The HSI technique is a corollary to the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures.

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