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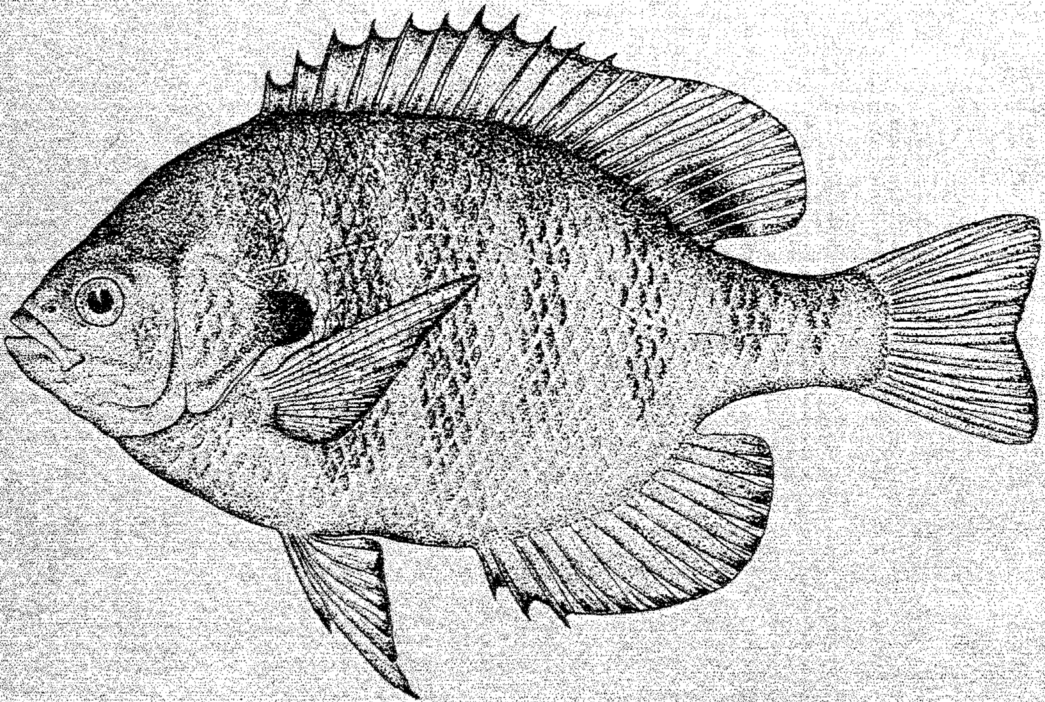
HABITAT SUITABILITY INDEX MODELS: BLUEGILL



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HABITAT SUITABILITY INDEX MODELS: BLUEGILL

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, not 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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BLUEGILL (*Lepomis macrochirus*)

HABITAT USE INFORMATION

General

The bluegill (*Lepomis macrochirus*) is native from the Lake Champlain and southern Ontario region through the Great Lakes to Minnesota, and south to northeastern Mexico, the Gulf States, and the Carolinas (Scott and Crossman 1973). The species has been widely introduced outside its native range (Pflieger 1975). Three subspecies are currently recognized: *L. m. macrochirus* (northcentral United States), *L. m. speciosus* (Texas and northern Mexico), and *L. m. purpurascens* (Atlantic and Gulf States) (Hubbs and Lagler 1958).

Age, Growth, and Food

Bluegills usually mature at age I or II (Schloemer 1939; James 1946; Cross 1951). The maximum known age is 11 years, but most live 1 to 4 years (Schloemer 1939; Carlander 1977). Maximum recorded size is 39 cm and 2.1 kg (Emig 1966).

Bluegills are opportunistic feeders which can alter their diet according to food availability (Keast and Webb 1966). Fry feed primarily on zooplankton and small insects (Werner 1969). Juveniles and adults feed on zooplankton, aquatic and terrestrial insects, and some plant materials (Scidmore and Woods 1960; Emig 1966; Scott and Crossman 1973).

Reproduction

Bluegills are repeat spawners and the spawning season may extend from spring through summer (Anderson, pers. comm.). Spawning occurs from 17 to 31° C, with peak spawning at 24-27° C (Clugston 1966; Emig 1966; Scott and Crossman 1973; Kitchell et al. 1974; Pflieger 1975). Bluegills are guarding, nest building lithophils (Balon 1975). Nests are usually found in quiet, shallow (1-3 m) water (Swingle and Smith 1943). Although spawning will occur over almost any substrate, fine gravel or sand is preferred (Stevenson et al. 1969; Pflieger 1975). Incubation time ranges from 1.5 to 5 days, depending on ambient water temperature (Morgan 1951; Childers 1967; Heckman 1969; Hall et al. 1970; Merriner 1971).

Specific Habitat Requirements

Bluegills are most abundant along shoreline areas in lentic and lentic-type environments such as ponds, lakes, reservoirs, and large low velocity streams (Whitmore et al. 1960). In riverine habitats, bluegills are mostly restricted to areas of low velocity (Hubbs and Lagler 1958). Adult bluegills were captured primarily in backwater areas of the Missouri River (Kallemyn and Novotny 1977). Hardin and Bovee (1978) developed probability of use curves showing that adults prefer current velocities < 10 cm/sec but will tolerate up to 45 cm/sec. Abundance has been positively correlated to a high percent (> 60%) pool area and negatively correlated to a high percent riffle/run area

(Moyle and Nichols 1973). Optimal stream gradient (≤ 0.5 m/km) is based on the preference for low gradient, lentic-type waters (Trautman 1957).

Optimal lacustrine habitat is characterized by fertile lakes, ponds, and reservoirs with extensive (≥ 20% of lacustrine surface area) littoral areas (Emig 1966; Scott and Crossman 1973). However, deeper areas are also required for overwintering and retreat from the summer heat (Scott and Crossman 1973). Jenkins (1976) reported a significant positive correlation between TDS levels of 100-350 ppm and sportfish (including sunfishes) standing crops in a group of predominately southeastern reservoirs.

Cover in both lacustrine and riverine habitats in the form of submerged vegetation or logs and brush is utilized by the species, especially juveniles and small adults (Moyle and Nichols 1973; Scott and Crossman 1973). However, an excessive abundance of vegetation can inhibit utilization of prey by bluegills. Populations of stunted individuals have been associated with an excessive amount of aquatic vegetation which may inhibit the utilization of bluegills as prey (Anderson, pers. comm.). Bluegills also nest in unvegetated areas (Weaver and Ziebell 1976). Lack of cover may also be a problem (Anderson, pers. comm.).

Water quality criteria for bluegills in both riverine and lacustrine habitats are outlined as follows: optimal growth and reproductive potential occurs in waters of low to moderate turbidities (< 50 ppm) (Buck 1956; Hastings and Cross 1962; Shireman 1968). Bluegills can tolerate a pH range of 4.0 to 10.3 (Trama 1954; Ultsch 1978) but pH levels at these extremes have caused at last partial kills (Calabrese 1969). Optimal levels are 6.5-8.5 based on Stroud's (1967) criteria for freshwater fish. Bluegills can tolerate dissolved oxygen levels < 1.0 mg/l for short durations (Baker 1941; Cooper and Washburn 1946; Moss and Scott 1961; Petrosky and Magnuson 1973) but will avoid levels of 1.5-3.0 mg/l (Whitmore et al. 1960). Optimal levels are > 5.0 mg/l (Petit 1973). Bluegills will not tolerate salinities > 5.6 ppt (Kilby 1955), and prefer salinity levels < 3.6 ppt (Tebo and McCoy 1964; Carver 1967).

Adult. Optimal growth of adult bluegills occurs near 27° C (Anderson 1959). No growth occurs below 10° C or above 30° C (Anderson 1959; Emig 1966). The reported ultimate upper incipient lethal temperature for bluegill is 35° C (Reynolds and Casterlin 1976).

Embryo. Optimal temperatures for successful embryo development are 22-27° C, and development will occur from 22-34° C (Banner and Van Arman 1973). Optimal current velocities are < 7.5 cm/sec, and embryos are not found at current velocities > 30 cm/sec (Hardin and Bovee 1978). Because bluegill spawn at 1-3 m depth (Swingle and Smith 1943), reservoir drawdown during spawning should not exceed 3 m during spring and summer.

Fry. Optimal temperatures for fry are 25-32° C (Hardin and Bovee 1978). Fry will not survive temperatures below 11° C or above 34° C (Banner and Van Arman 1973). Optimal current velocities are < 5 cm/sec; fry are not found in areas with velocities greater than about 7.5 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978).

Juvenile. The highest specific growth rate of juvenile bluegill occur in waters of 30° C and the growth range is 22-34° C (Lemke 1977). Preferred current velocities are < 5 cm/sec; juveniles are not found in areas with velocities greater than about 15 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978).

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The model is applicable wherever bluegills occur in North America. The standard of comparison for each individual variable suitability index is the optimum value of the variable that occurs anywhere within this region. 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 riverine or lacustrine habitat based on its ability to support all life stages of bluegills through all seasons of the year.

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 population to live and reproduce. No attempt has been made to establish a minimum habitat size for survival and growth of a bluegill population.

Verification level. The acceptance goal of the 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

Variables which have been shown to affect growth, survival, abundance, or other measure of well-being of bluegill are placed in the appropriate component (Figs. 1 and 2).

Food component. Percent cover (logs and other objects) (V_2) is included because this type of cover in pools is favorable prey habitat. Percent cover (vegetation) (V_3) is included as a separate variable because vegetation density can influence both feeding ability of bluegills and abundance of food. Percent pools (V_1) is included to quantify the amount of food habitat.

Cover component. Percent cover (logs and other objects) (V_2) and percent cover (vegetation) (V_3) are included because bluegills exhibit cover-seeking behavior. Percent vegetative cover is separate from other cover because too much vegetation can cause a habitat problem, while logs, brush, and other debris provide good cover.

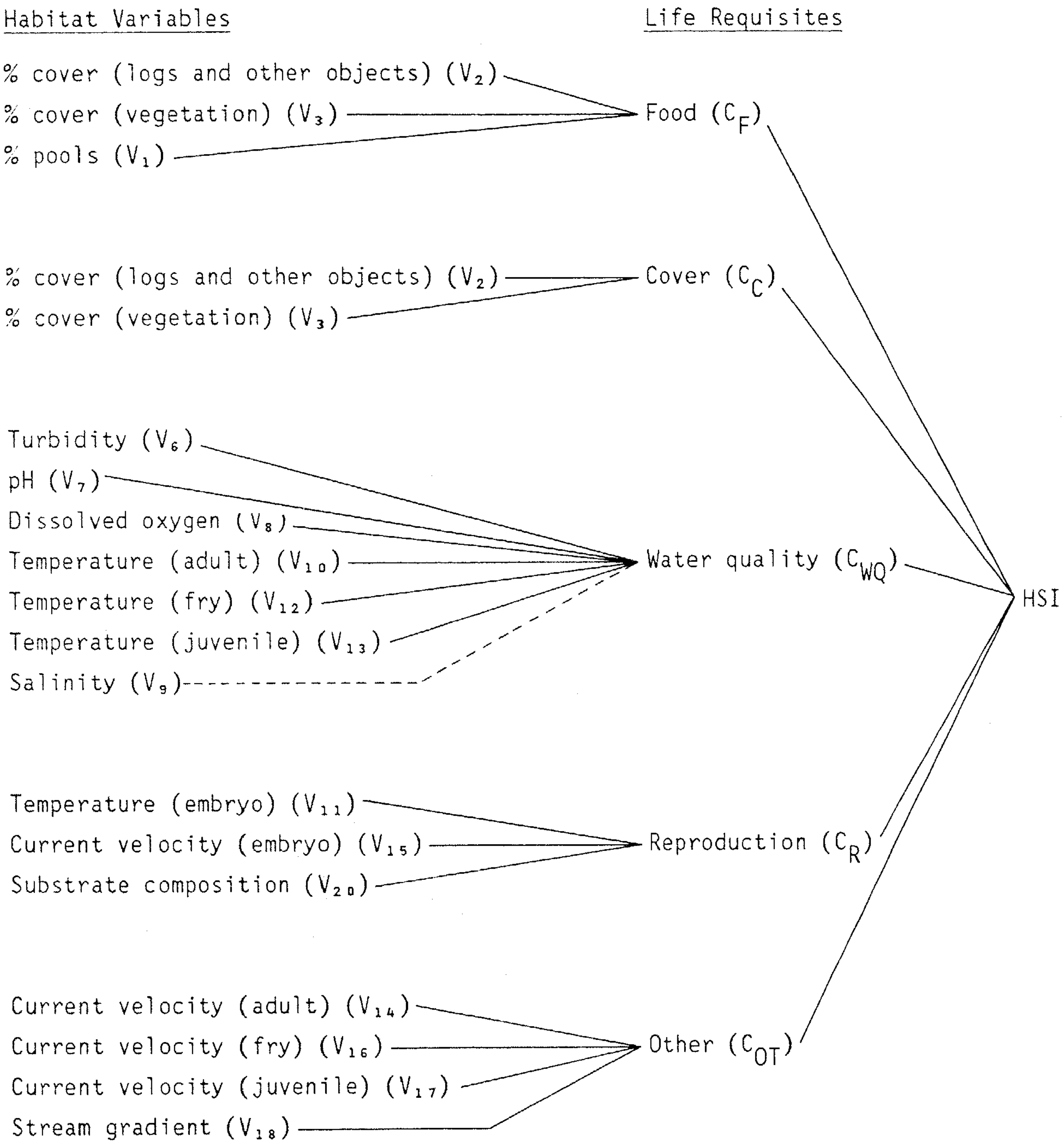


Figure 1. Tree diagram illustrating relationship of habitat variables and life requisites in the riverine model for the bluegill. Dashed line indicates optional variable in the model.

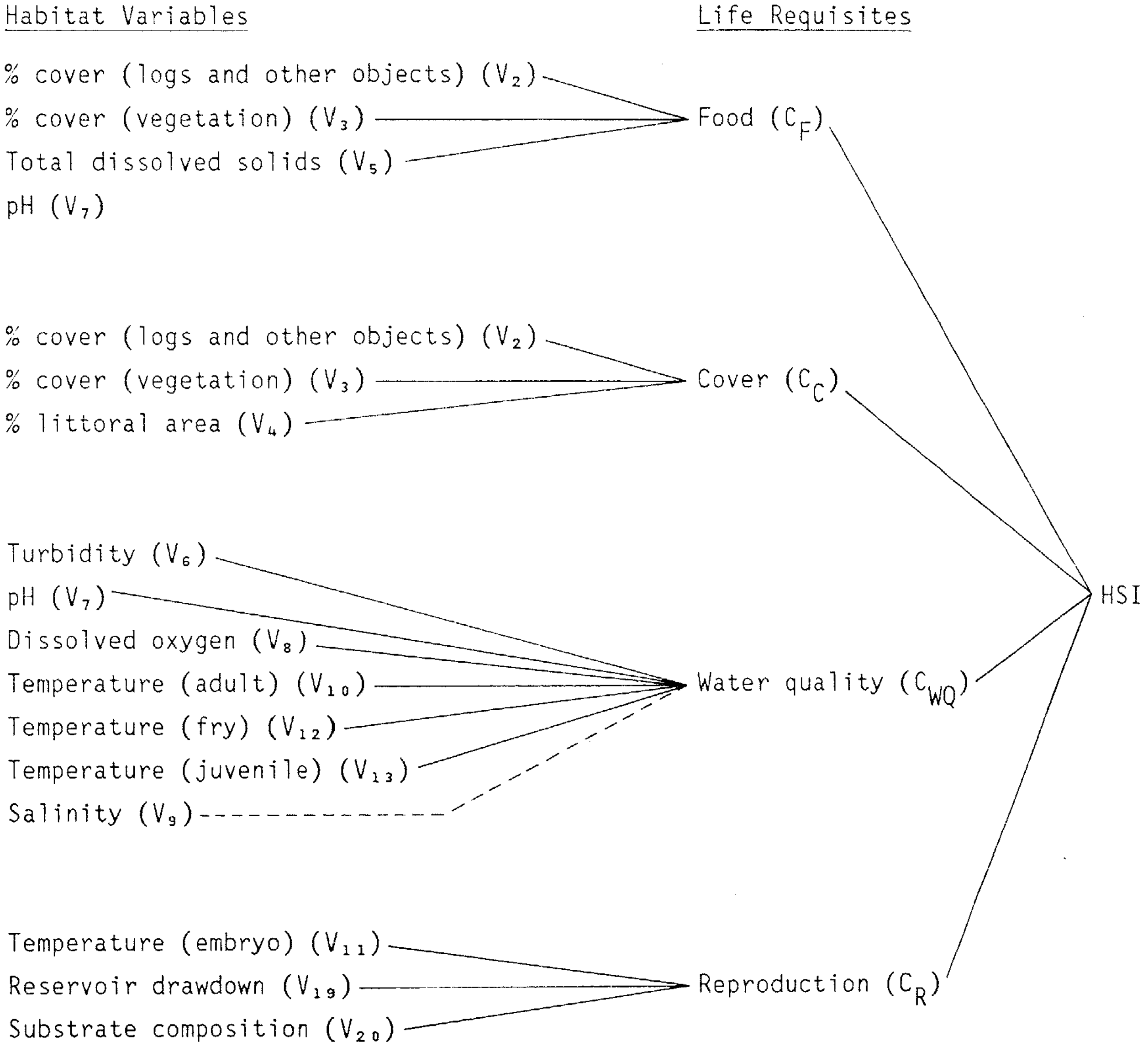


Figure 2. Tree diagram illustrating relationships of habitat variables and life requisites in the lacustrine model for the bluegill. Dashed line indicates optional variable in the model.

Water quality component. Turbidity (V_6), pH (V_7), dissolved oxygen (V_8), and temperature (V_{10}, V_{12}, and V_{13}) are crucial parameters that affect development, growth, and survival. Dissolved oxygen and temperature are weighted in the model and are considered to be limiting factors. Salinity (V_9) is an optional variable since it is not considered to be a problem in most areas where bluegills are found.

Reproduction component. Temperature (V_{11}) is included because embryo survival and development depends on the temperature being warm enough for incubation and hatching. Current velocity in spawning areas (V_{15}) is included because the embryo will not survive in areas of higher velocities. Substrate composition (V_{20}) is included since bluegill show a preference for spawning over fine gravel and sand.

"Other" component. The variables in the "other" component are those which aid in describing habitat suitability for bluegills, yet are not specifically related to life requisite components already presented. Current velocity for the different life stages (V_{14}, V_{16}, and V_{17}) is included because all stages cannot tolerate swifter velocities. Stream gradient (V_{18}) is included because bluegills are most often found in lower gradient streams.

Model Description - Lacustrine

Food component. Percent cover (logs and other objects) (V_2) is included because this type of habitat promotes good habitat for foraging and food organisms. Percent cover (vegetation) (V_3) is included because, though vegetation can be a measure of lacustrine productivity, too much vegetation can seriously reduce foraging capabilities. Total dissolved solids (TDS) (V_5) is included because TDS is a measure of general lacustrine productivity and dissolved solids are a vital prerequisite for the development of the food chain. Bluegills are opportunistic feeders on whatever is abundant. pH (V_6) is included in the food component because a low pH may indicate low alkalinity and low productivity.

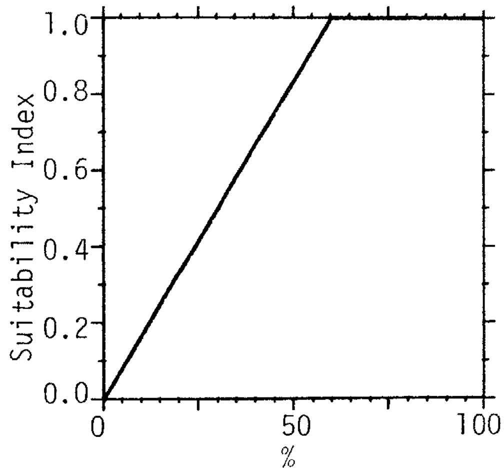
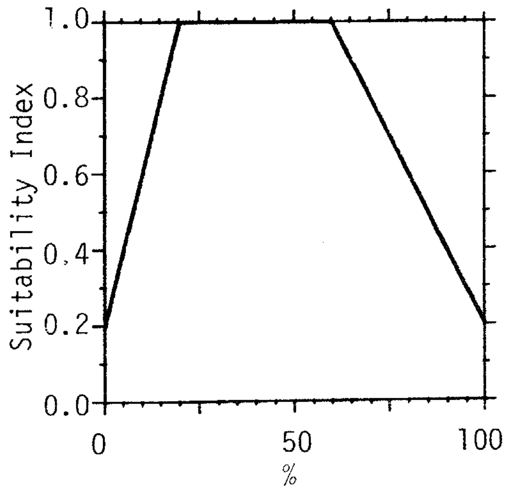
Cover component. Percent cover (logs and other objects) (V_2) and percent cover (vegetation) (V_3) are important since cover-seeking behavior indicates that some cover must exist for good habitat. Too much vegetative cover may indicate poor habitat. Percent littoral area (V_4) is included to quantify the amount of cover habitat.

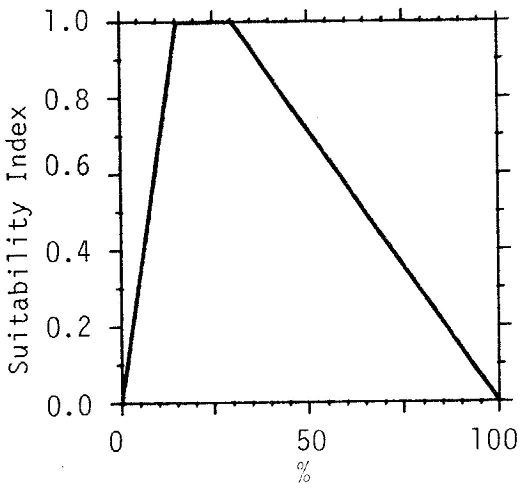
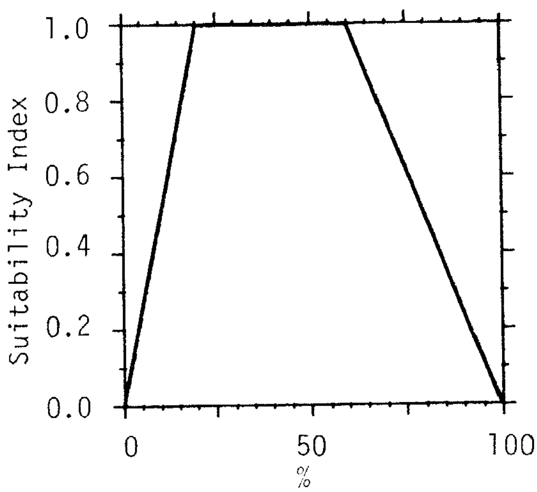
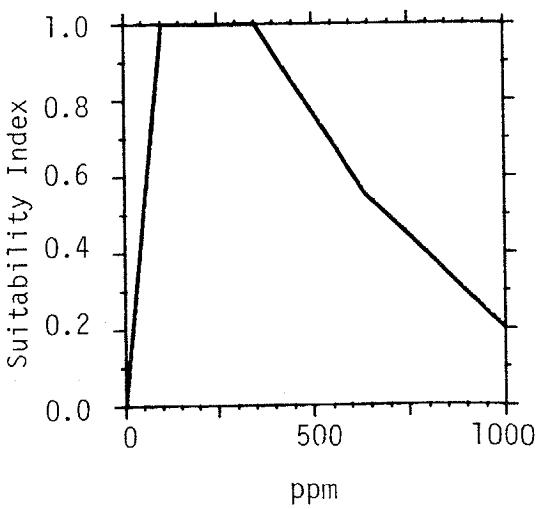
Water quality component. See description for riverine water quality component.

Reproduction component. Temperature (V_{11}) is included because embryo survival and development is related to temperature. Reservoir drawdown (V_{19}) is included because bluegills spawn at a certain depth and eggs may be exposed if water levels drop too low (this variable is excluded in a natural lake or pond). Substrate composition (V_{20}) is included because bluegill show a preference for spawning over fine gravel and sand.

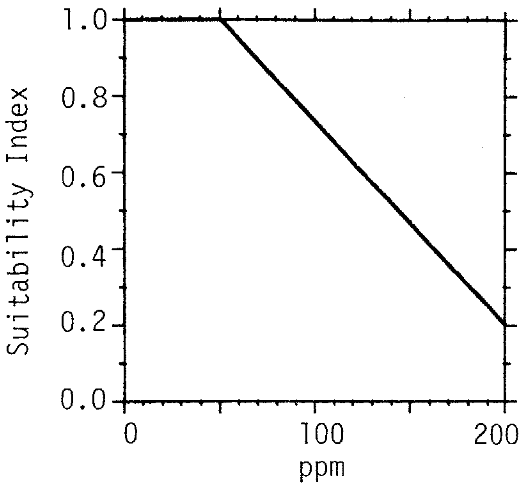
Suitability Index (SI) Graphs for Model Variables

This section contains suitability index graphs for the 20 variables described above. The "R" pertains to riverine habitat variables, and the "L" refers to lacustrine habitat variables.

Habitat	Variable		Suitability Graph
R	(V_1)	Percent pool area during average summer flow.	
R,L	(V_2)	Percent cover (e.g., logs, brush, and debris) within pools or littoral areas during summer.	

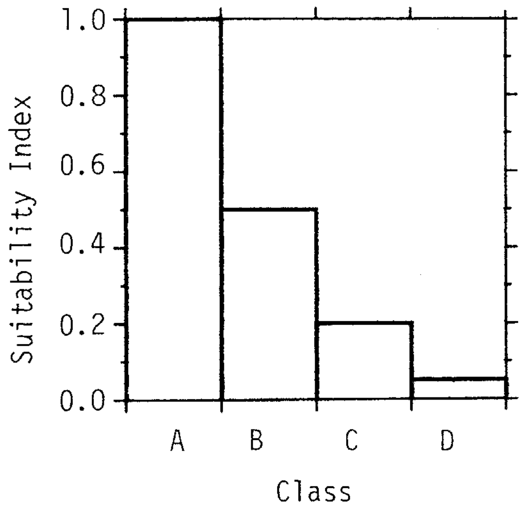
R,L	(V_3)	Percent cover (aquatic vegetation, submersed, dense stands, finely divided leaves).	
L	(V_4)	Percent littoral area during summer stratification.	
L	(V_5)	Average TDS level during growing season. Note: SI values should be lowered about 0.2 if ionic concentration of sulfate-chlorides exceeds that of carbonate-bicarbonates.	

R,L (V_6) Maximum monthly average turbidity during average summer flow or summer stratification.



R,L (V_7) pH range during growing season.

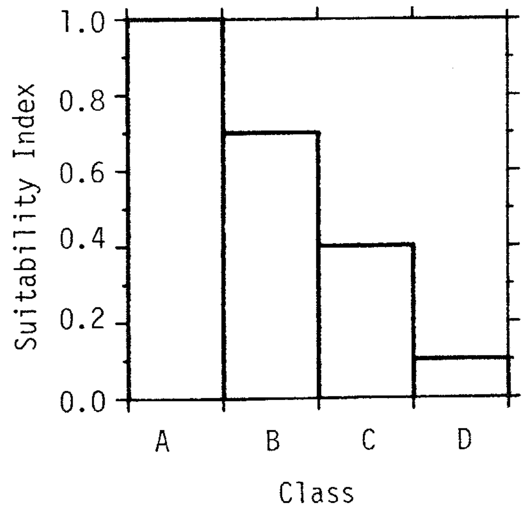
A) 6.5-8.5
B) 6.0-6.5 or 8.5-9.0
C) 5.0-6.0 or 9.0-10.0
D) < 5.0 or > 10.0

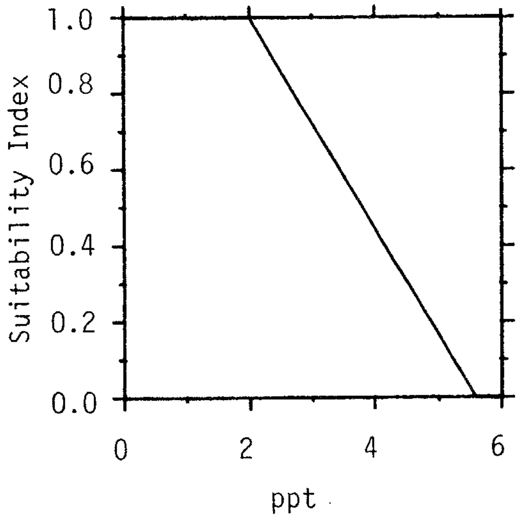
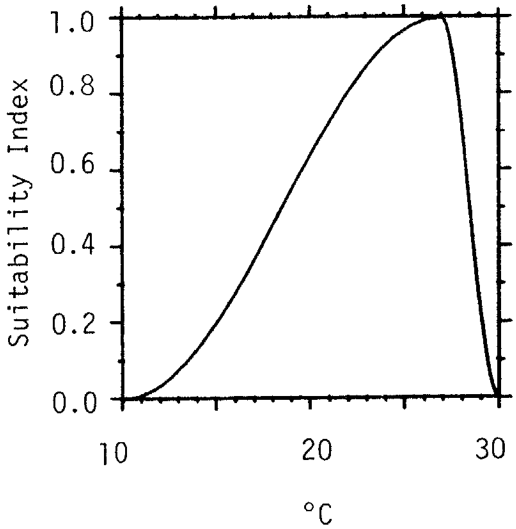
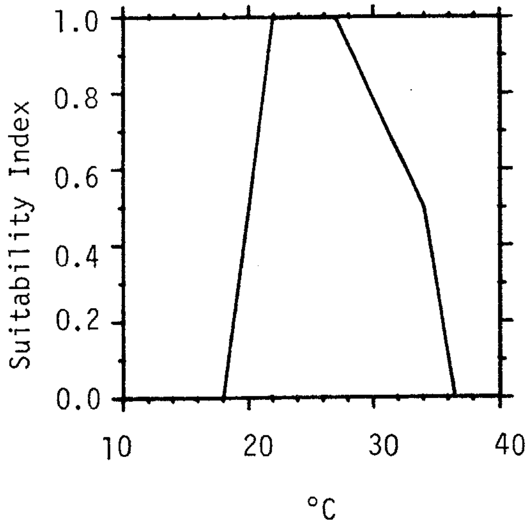


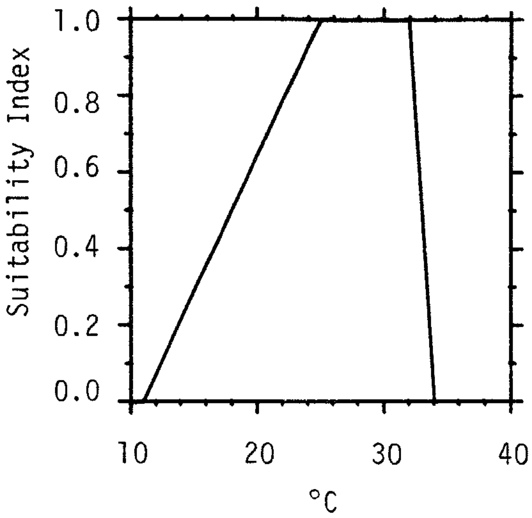
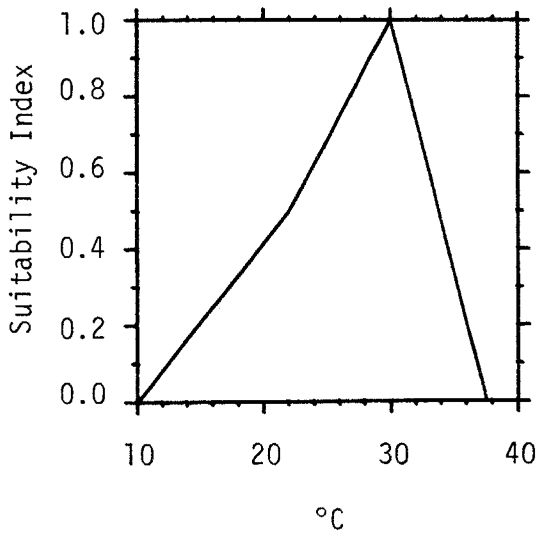
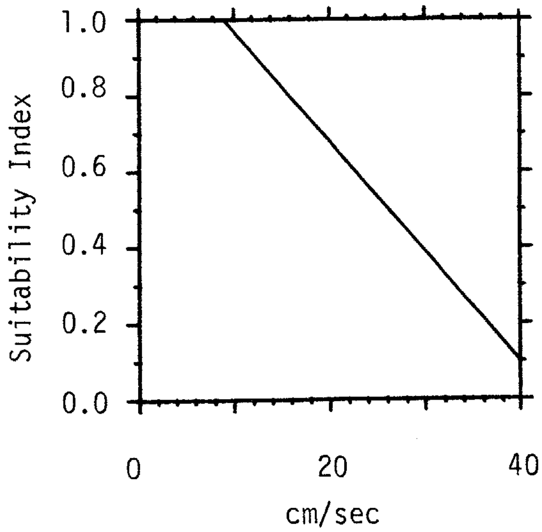
R,L (V_8) Minimum dissolved oxygen range during summer.

A) Seldom below 5.0 mg/l
B) Usually between 3.0 and 5.0 mg/l
C) Usually between 1.5 and 3.0 mg/l
D) Often below 1.5 mg/l

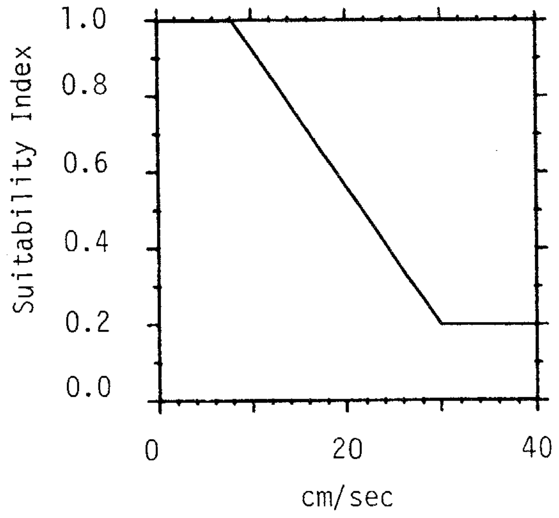
<u>Note</u>: Lacustrine D.O. levels refer to littoral areas; riverine, pools.



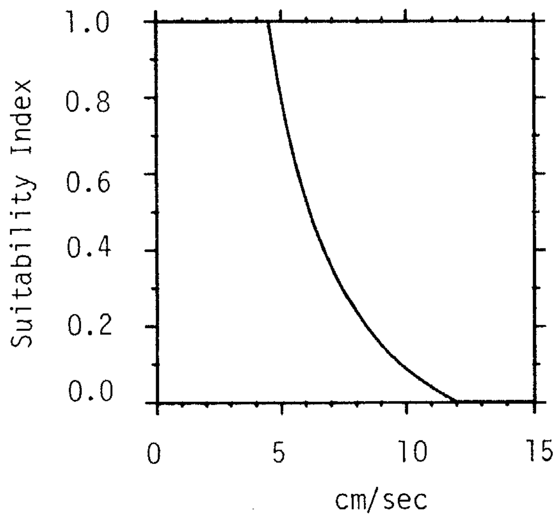
R,L	(V_9)	Maximum monthly average salinity during growing season (optional).	
R,L	(V_{10})	Maximum midsummer temperature within pools or littoral areas (adult).	
R,L	(V_{11})	Average of mean weekly water temperature within pools or littoral areas during spawning (embryo).	

R,L	(V_{12})	Maximum early summer temperature within pools or littoral areas (fry).	
R,L	(V_{13})	Maximum midsummer temperature within pools or littoral areas (juvenile).	
R	(V_{14})	Average current velocity in pools and backwater areas during growing season (adult).	

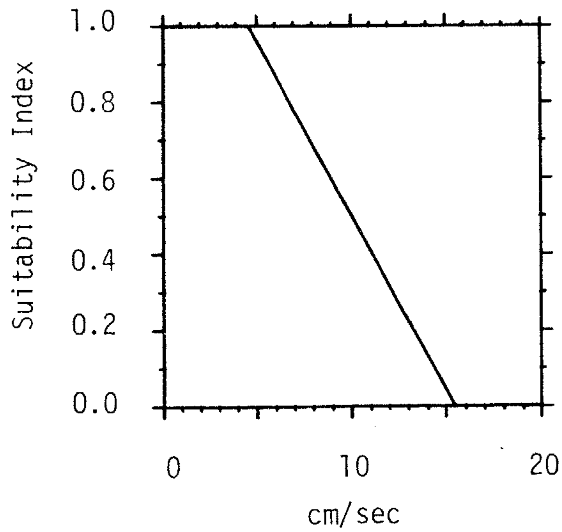
R (V$_{15}$) Average current velocity in spawning areas (embryo).



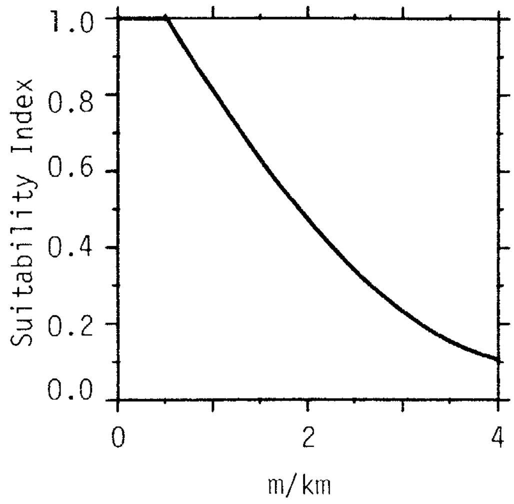
R (V$_{16}$) Average current velocity in pools and backwater areas during early summer (fry).



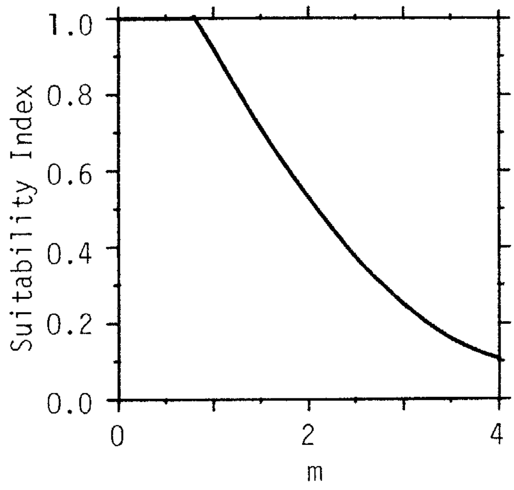
R (V$_{17}$) Average current velocity in pools and backwater areas during growing season (juvenile).



R (V$_{18}$) Stream gradient within representative reach.

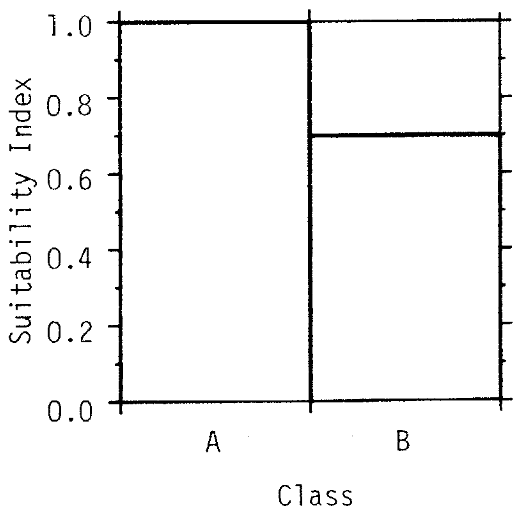


L (V$_{19}$) Reservoir drawdown during spawning (embryo).



R,L (V$_{20}$) Substrate composition within pools or littoral areas during spawning (embryo).

A) Fines and gravel present
B) Fines and gravel scarce



Riverine Model

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

Food (C_F).

$$C_F = (V_1 \times V_2 \times V_3)^{1/3}$$

Cover (C_C).

$$C_C = \frac{V_2 + V_3}{2}$$

Water Quality (C_{WQ}).

$$C_{WQ} = \frac{V_6 + V_7 + 2V_8 + V_9 + 2[(V_{10} \times V_{12} \times V_{13})^{1/3}]}{7}$$

If V_8 or $(V_{10} \times V_{12} \times V_{13})^{1/3} \leq 0.4$, C_{WQ} equals the lowest of the following: V_8, $(V_{10} \times V_{12} \times V_{13})^{1/3}$, or the above equation.

Note: V_9 may be dropped and the denominator changed to 6 if salinity is not considered to be a problem or potential problem in the study area.

Reproduction (C_R).

$$C_R = (V_{11} \times V_{15} \times V_{20})^{1/3}$$

Other (C_{OT}).

$$C_{OT} = \frac{\frac{V_{14} + V_{16} + V_{17}}{3} + V_{18}}{2}$$

HSI determination. If all component ratings > 0.4,

$$HSI = (C_F \times C_C \times C_{WQ}^2 \times C_R \times C_{OT})^{1/6}$$

If C_{WQ} or C_R are ≤ 0.4, use lowest component rating as the species HSI.

Lacustrine Model

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

Food (C_F).

$$C_F = (V_2 \times V_3 \times V_5 \times V_7)^{1/4}$$

Cover (C_C).

$$C_C = (V_2 \times V_3 \times V_4^2)^{1/4}$$

Water Quality (C_{WQ}).

$$C_{WQ} = \frac{V_6 + V_7 + 2V_8 + V_9 + 2[(V_{10} \times V_{12} \times V_{13})^{1/3}]}{7}$$

If V_8 or $(V_{10} \times V_{12} \times V_{13})^{1/3} \leq 0.4$, C_{WQ} equals the lowest of the following: V_8, $(V_{10} \times V_{12} \times V_{13})^{1/3}$, or the above equation.

Note: V_9 may be dropped and the denominator changed to 6 if salinity is not considered to be a problem or potential problem in the study area.

Reproduction (C_R).

$$C_R = (V_{11} \times V_{19} \times V_{20})^{1/3}$$

Note: If the lacustrine environment is a natural lake or pond, V_{19} will not be applicable. Thus,

$$C_R = (V_{11} \times V_{20})^{1/2} \text{ in a natural lake or pond}$$

HSI determination. If all component ratings > 0.4,

$$HSI = (C_F \times C_C \times C_{WQ}^2 \times C_R)^{1/5}$$

If C_{WQ} or $C_R \leq 0.4$, use lowest component ratings as the species HSI.

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. 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 of fry, juvenile, and adult bluegill.

Interpreting Model Outputs

Habitats with an HSI of 0 may contain some bluegills; habitats with a high HSI may contain few. The bluegill HSI determined by use of these models will not necessarily represent the population of bluegill 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 bluegill riverine or lacustrine habitat, the model should be positively correlated with long term average population levels in areas where population levels are determined primarily by habitat related factors. However, this has not been tested. The proper interpretation of the HSI produced by the model is one of comparison. If two habitats have different HSI's, the one with the higher HSI should have the potential to support more fish than the one with the lower HSI, given the model assumptions have not been violated.

ADDITIONAL HABITAT MODELS

Model 1

Optimal riverine habitat for bluegills is characterized by the following conditions, assuming water quality is adequate: large, low gradient (< 0.5 m/km) streams; warm water temperatures (> 20° C); sluggish current velocities (< 5 cm/sec); clear water (< 50 ppm suspended solids); and an abundance of bottom cover within pool areas.

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

Table 1. Data sources for bluegill suitability indices.

Variable and source		Assumption
V_1	Moyle and Nichols 1973	The amount of pool area that is correlated to a high abundance of bluegills is optimum.
V_2	Moyle and Nichols 1973 Scott and Crossman 1973 Pflieger 1975	The percent cover (logs and other objects) where bluegill are most abundant is optimum.
V_3	Moyle and Nichols 1973 Scott and Crossman 1973 Weaver and Ziebell 1976 Anderson, pers. comm.	The percent cover (vegetation) that is associated with abundant fish is optimum. Not enough vegetative cover or too much vegetative cover are suboptimum, since the former restricts the food availability and the latter restricts foraging capabilities.
V_4	Emig 1966 Scott and Crossman 1973	Since the bluegill inhabits shallow vegetated areas, a certain percentage of littoral area must exist for habitat to be suitable. Since bluegills require deeper water in winter and to get away from summer heat, too much littoral area would be suboptimum to unsuitable.
V_5	Jenkins 1976	TDS levels associated with high standing crops are optimum. Levels that reduce food availability are suboptimum to unsuitable.
V_6	Buck 1956 Trautman 1957 Hastings and Cross 1962 Shireman 1968 Pflieger 1975	Turbidity levels where growth rates are fastest are optimum. Levels that retard growth and development and that adversely affect reproduction are suboptimum to unsuitable.
V_7	Trama 1954 Stroud 1967 Calabrese 1969 Ultsch 1978	pH levels that promote good production and maximum survival are optimum. Levels that reduce reproductive capabilities and feeding are suboptimum to unsuitable.
V_8	Cooper and Washburn 1946 Whitmore et al. 1960 Doudoroff and Shumway 1970 Petit 1973	D.O. levels where survival is maximum and development is normal are optimum. Levels causing stress reactions are suboptimum. Levels that are tolerated for short durations are unsuitable.

Table 1. (continued)

Variable and source		Assumption
V_9	Kilby 1955 Tebo and McCoy 1964 Carver 1967	Salinity levels that promote successf reproduction and good growth are opti- mum. Levels where the species does n reproduce are unsuitable.
V_{10}	Anderson 1959 Emig 1966	Temperatures that promote maximum gro are optimum. Temperatures where no growth occurs are unsuitable.
V_{11}	Clugston 1966 Emig 1966 Banner and Van Arman 1973 Scott and Crossman 1973 Kitchell et al. 1974 Pflieger 1975	Temperatures where embryo development is successful and normal and survival is maximum are optimum. Temperatures where survival is reduced but develop- ment may occur are suboptimum. Tempe atures where no development occurs ar unsuitable.
V_{12}	Banner and Van Arman 1973 Hardin and Bovee 1978	Temperatures that reach levels where maximum growth occurs are optimum. Temperatures where the species does not survive are unsuitable.
V_{13}	Lemke 1977	Temperatures that reach levels where maximum growth occurs are optimum. Temperatures where feeding is reduced but where growth still occurs are sub- optimum. Temperatures that cause no growth or death are unsuitable.
V_{14}	Kallemyn and Novotny 1977 Hardin and Bovee 1978	Current velocities where bluegills ar most often collected are optimum. Velocities where the species is seldo or never found are suboptimum to unsuitable.
V_{15}	Same as V_{14}	Same as V_{14}
V_{16}	Same as V_{14}	Same as V_{14}
V_{17}	Same as V_{14}	Same as V_{14}
V_{18}	Trautman 1957	Stream gradients where bluegills are collected in abundant numbers are optimum. Gradients where the fish occur in fewer numbers or are absent are suboptimum to unsuitable.

Table 1. (concluded)

Variable and source		Assumption
V_{19}	Swingle and Smith 1943	Because bluegill spawn at specific depths, stable water levels are optimum. Any reservoir drawdown would be suboptimum to unsuitable.
V_{20}	Stevenson et al. 1969 Pflieger 1975	Substrates that the species prefers are optimum. Almost any other substrate has high suitability.

Table 2. Sample data sets using riverine HSI model.

Variable		Data set 1		Data set 2		Data set 3	
		Data	SI	Data	SI	Data	SI
% pools	V_1	20	0.3	35	0.6	70	1.0
% cover (logs, brush)	V_2	5	0.4	10	0.6	20	1.0
% cover (vegetation)	V_3	5	0.3	10	0.6	25	1.0
Turbidity	V_6	140	0.5	70	0.9	110	0.7
pH	V_7	Class A	1.0	Class A	1.0	Class A	1.0
Dissolved oxygen (mg/l)	V_8	Class C	0.4	Class A	1.0	Class B	0.7
Salinity (ppt)	V_9	1.2	1.0	2.0	1.0	0.8	1.0
Temperature - adult (°C)	V_{10}	24	0.9	26	1.0	27	1.0
Temperature - embryo (°C)	V_{11}	18.5	0.1	22	1.0	24	1.0
Temperature - fry (°C)	V_{12}	22	0.8	24	0.9	27	1.0
Temperature - juvenile (°C)	V_{13}	22	0.5	24	0.6	27	0.8
Current velocity - adult (cm/sec)	V_{14}	20	0.7	30	0.4	9	1.0
Current velocity - embryo (cm/sec)	V_{15}	28	0.3	30	0.2	14	0.8
Current velocity - fry (cm/sec)	V_{16}	20	0.0	30	0.0	10	0.1
Current velocity - juvenile (cm/sec)	V_{17}	20	0.0	30	0.0	9	0.6
Stream gradient (m/km)	V_{18}	2	0.5	2.7	0.3	0.7	0.9
Substrate comp.	V_{20}	Class B	0.7	Class A	1.0	Class A	1.0

Table 2. (concluded)

Variable	Data set 1		Data set 2		Data set 3	
	Data	SI	Data	SI	Data	SI
Component SI						
C_F =		0.33		0.60		1.00
C_C =		0.35		0.60		1.00
C_{WQ} =		0.67		0.93		0.85
C_R =		0.28		0.58		0.93
C_{OT} =		0.37		0.22		0.73
HSI =		0.28		0.58		0.89

Table 3. Sample data sets using lacustrine HSI model.

Variable		Data set 1		Data set 2		Data set 3	
		Data	SI	Data	SI	Data	SI
% cover (logs, brush)	V_2	100	0.2	10	0.6	50	1.0
% cover (vegetation)	V_3	5	0.4	35	0.9	25	1.0
% littoral area	V_4	8	0.4	17	0.8	60	1.0
TDS (ppm)	V_5	50	0.4	10	0.1	200	1.0
Turbidity (ppm)	V_6	15	1.0	10	1.0	90	0.8
pH	V_7	Class A	1.0	Class A	1.0	Class A	1.0
Dissolved oxygen (mg/l)	V_8	Class A	1.0	Class A	1.0	Class A	1.0
Salinity (ppt)	V_9	0.4	1.0	0.2	1.0	0.5	1.0
Temperature - adult (°C)	V_{10}	24	0.9	24	0.9	21	0.7
Temperature - embryo (°C)	V_{11}	19	0.3	21	0.7	24	1.0
Temperature - fry (°C)	V_{12}	21	0.7	22	0.8	28	1.0
Temperature - juvenile (°C)	V_{13}	20	0.4	22	0.5	28	0.9
Reservoir drawdown (m)	V_{19}	4	0.1	-	-	-	-
Substrate	V_{20}	Class B	0.7	Class A	1.0	Class A	1.0
<u>Component SI</u>							
C_F =			0.42		0.48		1.00
C_C =			0.34		0.77		1.00
C_{WQ} =			0.89		0.87		0.93
C_R =			0.28		0.84		1.00
HSI =			0.28		0.77		0.97

Model 2

Optimal lacustrine habitat for bluegill sunfish is characterized by the following conditions, assuming water quality is adequate: fertile lakes, reservoirs, and ponds (TDS levels 100-350 ppm); extensive littoral areas ($\geq$ 20% surface area); maximum water temperature > 20° C; and clear water (< 50 ppm suspended solids).

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

Model 3

Use the regression models for bluegill standing crop in reservoirs presented by Aggus and Morais (1979) to calculate an HSI.

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16. Abstract (Limit: 200 words)

A literature review encompassing habitat and species characteristics of the bluegill (*Lepomis macrochirus*) is followed by a discussion of the relationship of habitat variables and life requisites of this species. These data are then incorporated into Habitat Suitability Index models for the bluegill.

This is one in a series of publications describing 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 Habitat Suitability Index (HSI) models. The models are based on suitability indices formulated for variables found to affect the life cycle and survival of the species. The models are designed to be modified to evaluate specific habitat alterations using the HSI model building techniques presented in the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures.

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