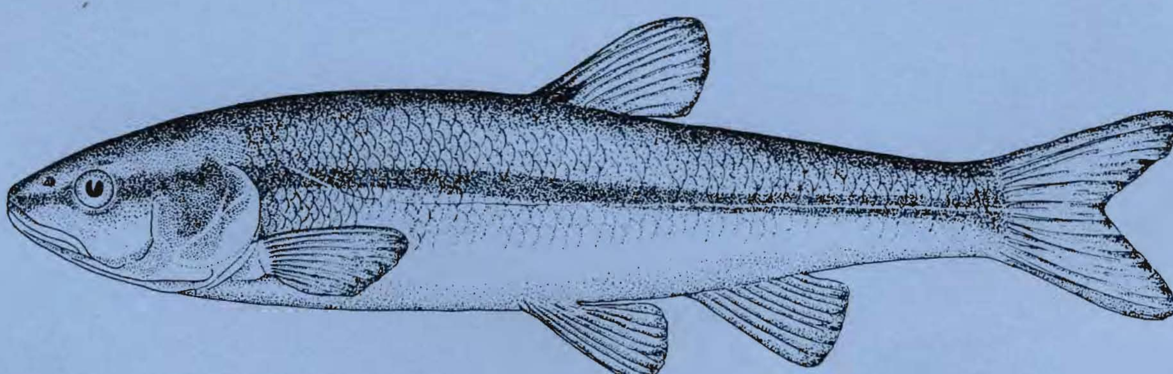
Biological Services Program

FWS/OBS-82/10.4
FEBRUARY 1982

HABITAT SUITABILITY INDEX MODELS: CREEK CHUB



and Wildlife Service

Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.
- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on an analysis of the issues, a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and to determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

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HABITAT SUITABILITY INDEX MODELS: CREEK CHUB

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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CONTENTS

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CREEK CHUB (*Semotilus atromaculatus*)

HABITAT USE INFORMATION

General

The creek chub is a widely-distributed cyprinid ranging from the Rocky Mountains to the Atlantic Coast and from the Gulf of Mexico to southern Manitoba and Quebec (Scott and Crossman 1973). Within its range, it is one of the most characteristic and common fishes of small, clear streams (Trautman 1957).

Age, Growth, and Food

Creek chubs mature at age II-V at lengths of 10.0-20.0 cm (Hubbs and Cooper 1936; Dinsmore 1962; Copes 1978); average life span is 5-7 years (Hubbs and Cooper 1936; Copes 1978). Creek chubs exhibit wide variation in size and growth over their range (Copes 1978).

Fry feed on terrestrial and aquatic insects (Barber and Minckley 1971; Moshenko and Gee 1973; Copes 1978) and amphipods (Copes 1978). Creek chubs consume larger food items as they grow (Scott and Crossman 1973). Juveniles and adults feed on terrestrial and aquatic insects, molluscs, and fish (Barber and Minckley 1971; Moshenko and Gee 1973; Copes 1978). Fish dominate the summer diet of creek chubs > 8 cm (Barber and Minckley 1971; Moshenko and Gee 1973). The flexible food habits of creek chubs may account, in part, for their wide geographical distribution (Scott and Crossman 1973).

Reproduction

Creek chubs spawn in spring (April-July) (Trautman 1957; Pflieger 1975; Copes 1978) as water temperatures approach 14° C (Hubbs and Cooper 1936; Copes 1978). Spawning occurs in gravel nests constructed by the male in shallow areas just above and below riffles (Miller 1964; Pflieger 1975; Copes 1978).

Successful reproduction in creek chubs is adversely affected by water temperatures ≤ 11° C (Miller 1964; Moshenko and Gee 1973; Copes 1978), high turbidity and siltation (Miller 1964), and low flows (Paloumpis 1958).

Specific Habitat Requirements

Optimum habitat for creek chubs is small, clear, cool streams with moderate to high gradients, gravel substrate, well-defined riffles, and pools with abundant cover and abundant food (Trautman 1957; Moshenko and Gee 1973; Hocutt and Stauffer 1975). Small populations occasionally occur in ponds and lakes, but these are not preferred creek chub habitats (Eschmeyer and Clark 1939; Trautman 1957).

Creek chubs are found in streams with gradients of 3 to 23 m/km with their greatest abundance in gradients of 7 to 13.4 m/km (Moshenko and Gee 1973;

Hocutt and Stauffer 1975). They are most abundant in small streams 0.5 to 7 m in width (Hocutt and Stauffer 1975) and less than 1 m in average depth (Barber and Minckley 1971; Hocutt and Stauffer 1975). Streams greater than 12 m in width (Starrett 1950; Dinsmore 1962) and greater than 2 m in average depth (Minckley 1963; Powles et al. 1977) are considered marginal habitats.

Creek chubs are most abundant in clear water (Barber and Minckley 1971; Minckley 1963; Scott and Crossman 1973) but can tolerate higher turbidities if areas of clean gravel substrate for spawning are present (Branson and Batch 1972, 1974; Pflieger 1975). Creek chubs are found in moderate abundance in highly turbid streams in North Dakota (Copes and Tubbs 1966).

Creek chubs appear to be more tolerant of acidic conditions than many other species (Smith 1964). F. A. Copes (pers. comm., Mus. of Nat. Hist., Univ. of Wisconsin, Stevens Point) has observed sustaining populations of creek chubs in streams with a pH as low as 5.4. However, a pH range of 6.0 to 9.0 is probably optimum for survival and growth of creek chub populations (McKee and Wolf 1963; Minckley 1963).

Creek chubs are most abundant in streams with alternating pools and riffle-run areas (Trautman 1957; Minckley 1963; Moshenko and Gee 1973). We assume that stream sections with 40-60% pools are optimum for providing riffle areas for spawning habitat (Moshenko and Gee 1973) and pools for cover (Moshenko and Gee 1973; Copes 1978). Rubble substrate in riffles, abundant aquatic vegetation (Hynes 1970), and abundant streambank vegetation (Moshenko and Gee 1973; Cummins 1974) are conditions associated with high production of food types consumed by creek chubs. Streambank vegetation in creek chub habitats is also considered important for stream shading (for water temperature control) and bank stability (for erosion control) (Karr and Schlosser 1978).

Creek chubs are most numerous in deep pools and runs with abundant instream cover of cut-banks, roots, aquatic vegetation, brush, and large rocks (Trautman 1957; Copes 1978). It is assumed that at least 40% pool and run areas with suitable cover is optimum. Deep pools with abundant cover, free access to larger, warmer streams within 5 km, or both, are important for over-wintering habitat (Trautman 1957; Paloumpis 1958; Copes 1978). Creek chubs are found over all types of substrate. Abundance appears to be correlated more with the amount of instream cover than with substrate type (Copes and Tubb 1966; Copes 1970, 1978, pers. comm.).

<u>Adult</u>. The upper incipient lethal temperature for adult creek chubs is near 32° C; the lower lethal level is near 1.7° C (Brett 1944; Hart 1947). They can survive intermittent streamflow in isolated pools for short periods in summer at temperatures of 28° C (Starrett 1950). Creek chubs grow in the temperature range of 12-24° C, with the optimum temperature for growth near 21° C (Miller 1964; Moshenko and Gee 1973).

Dissolved oxygen data are not available for adults. If oxygen requirements are similar to those for other coolwater fishes, concentrations ≥ 5 mg/l should be sufficient for long-term growth and survival (Davis 1975). Creek chubs can survive for short periods in pools with 2.4 mg/l of dissolved oxygen (Starrett 1950). The creek chub is generally not found in lakes, ponds, or streams which experience partial summer- or winter-kills (long-term D.O. deficiency) (Copes, pers. comm.). Adults generally occur in streams with an average velocity of less than 60 cm/sec (Minckley 1963; Moshenko and Gee 1973). They are most abundant in stream sections of deep runs and pools with surface velocities ≤ 30 cm/sec (Moshenko and Gee 1973).

Embryo. Eggs hatch in 10 days at 13° C (Washburn 1945). Embryos require flowing water for adequate oxygen exchange. Embryo survival and production are highest in gravel substrate in riffle-run areas with velocities of 20-64 cm/sec (Ross 1976; Copes 1978); production is negligible in sand or silt (Washburn 1945; Trautman 1957). Washburn (1945) listed 0.04 m^3/sec (1.25 cfs) as the minimum discharge necessary for successful reproduction. High survival and production of creek chub embryos are associated with temperatures of 15-20° C (Clark 1943; Moshenko and Gee 1973; Copes 1978) and dissolved oxygen levels ≥ 5 mg/l (Davis 1975).

Fry. Fry emerge from nests 20-30 days after spawning (Washburn 1945; Copes 1970; Moshenko and Gee 1973). After emerging from redds, fry are found in shallow areas along the edges of pools with surface velocities ≤ 10 cm/sec (Clark 1943; Minckley 1963; Copes 1978).

The dissolved oxygen and temperature suitability criteria for fry are assumed to be similar to those for adults.

Juvenile. No specific information was found on habitat requirements of juveniles. We assume habitat requirements are similar to those of adults.

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The model provided is assumed to be applicable to any riverine environment within the range of creek chubs. The standard of comparison for each individual variable suitability index is the optimum value of the variable that occurs anywhere within this range. It should be noted, however, that specifying only one set of standards defining optimum habitat for creek chubs is somewhat tenuous since it occurs in such a wide variety of habitats throughout its extensive range (Copes, pers. comm.). Available information on habitat requirements of creek chubs is, however, insufficient at this time to specify more than one set of standards defining optimum conditions in various regions throughout its range.

Season. The model provides a rating for a riverine habitat based on its ability to support all life stages of creek chubs throughout all seasons of the year.

Cover types. This model is applicable in riverine environments, 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 necessary for long-term survival of creek chubs.

Verification level. The acceptable output of this model is an index between 0 and 1 which the author believes has a positive relationship to carrying capacity of a habitat for creek chub populations. In order to verify that the model output was acceptable, sample data sets (described later) were developed for calculating HSI's from the model. These sample data sets and their relationship to model verification are discussed in greater detail following the presentation of the model.

Model Description

The model consists of variables that have an impact on the growth, survival, distribution, abundance, or other measure of well-being of creek chubs, and hence can be expected to have an impact on the carrying capacity of a habitat. Creek chub habitat quality is based primarily on their food, cover, water quality, and reproduction requirements, and the model consists of variables which are thought to be direct or indirect measures of the relative ability of a habitat to meet these requirements (Fig. 1). Variables that affect habitat quality for creek chubs, but which do not easily fit into these four major components, are combined under the "other component" heading (Fig. 1).

Food component. Percent streambank (riparian) vegetation (V_9) is included in the food component since streamside vegetation is habitat for terrestrial insects, an important food source for creek chubs. Substrate type (V_{10}) is included for rating the food component because production potential of aquatic insects (another important constituent in the diet of creek chubs) in a stream is related to amount and type of substrate.

Cover component. Percent pools (V_1) is included since pools are utilized as cover by adults, juveniles, and fry. A pool class rating system (V_2) is included because the depth of a pool affects its suitability for providing cover for creek chubs. Percent cover (V_3) is included in this component to provide a measure of the amount of cover available within a stream. A measure of winter instream cover suitability (V_4) is included since creek chubs require instream cover in pools or free access to larger, warmer streams to provide shelter during winter. A measure of velocities suitable for adults and juveniles (V_{13}) and fry (V_{18}) are included in this component because velocity can affect the quality of a habitat as resting cover.

Water quality component. Turbidity (V_7) is included because abundance of creek chubs is related to turbidity level. Measures of pH (V_8), average water temperature (V_{11}), and dissolved oxygen (V_{12}) are included in this component since these water quality parameters have been shown to affect growth and survival of creek chubs. Any of these latter three variables are assumed to become overriding determinants of overall habitat suitability if the variables approach lethal levels.

Stream shade (V_{19}) is included in this component since the magnitude of daily and seasonal temperature extremes that occur in a small stream are inversely related to the amount of stream shaded from the sun.

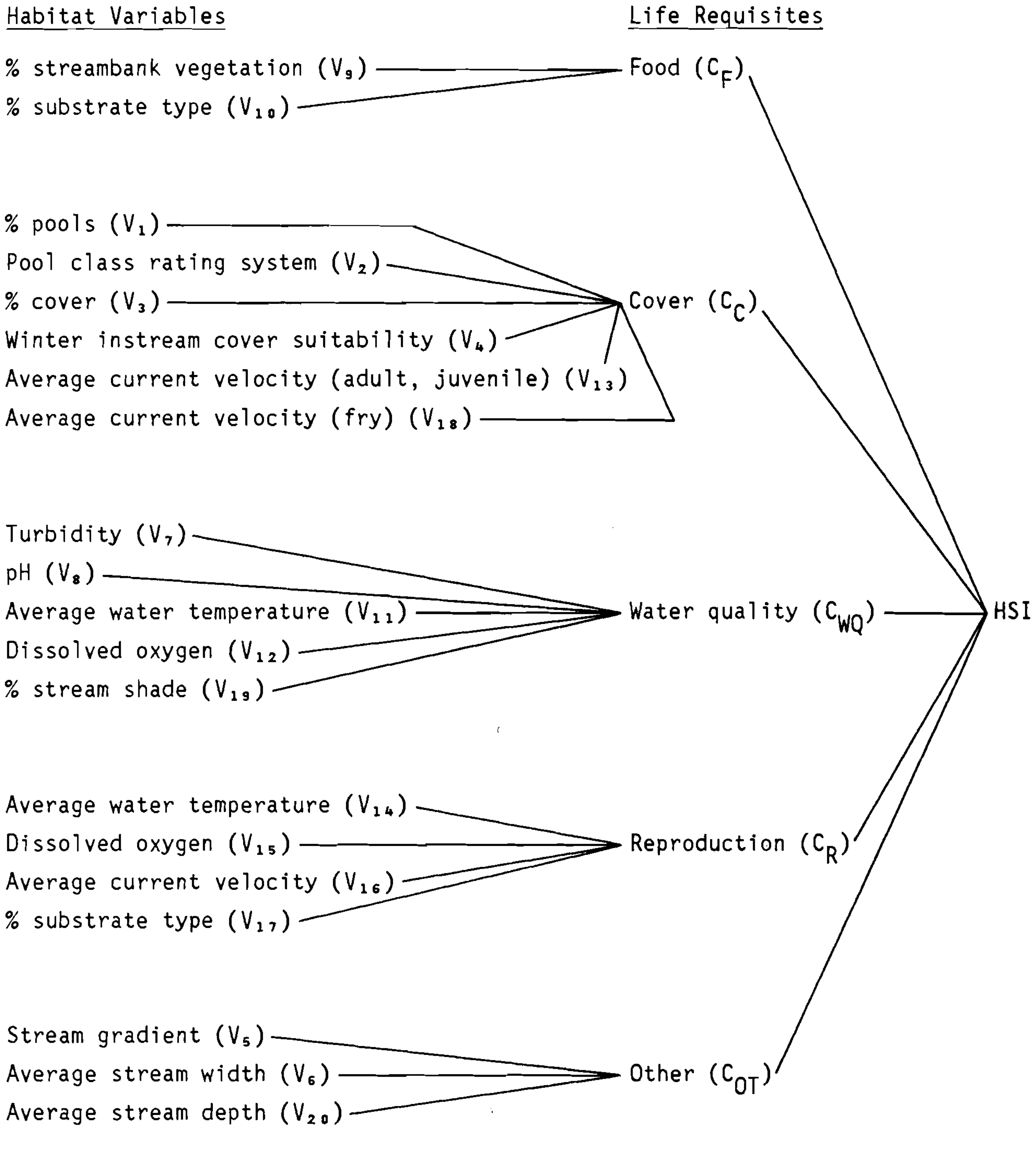


Figure 1. Tree diagram illustrating relationship of habitat variables and life requisites in the creek chub model.

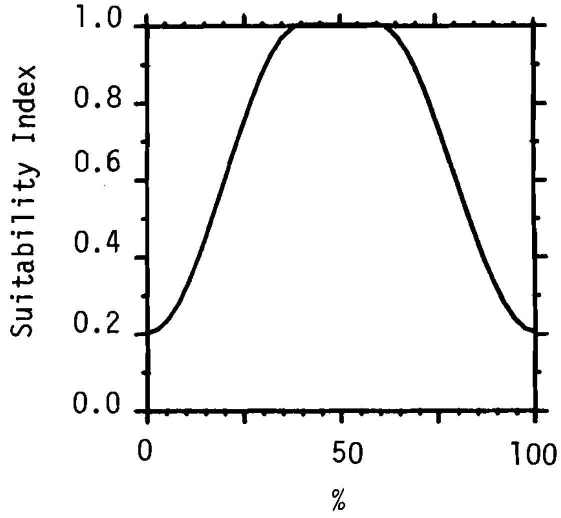
Reproduction component. Average water temperature (V_{14}) and dissolved oxygen (V_{15}) are included since they affect survival and production of creek chub embryos. A measure of velocity in riffle-run sections during spawning (V_{16}) is included because current velocity affects the water exchange rate in creek chub redds. Substrate type (V_{17}) in the same areas is included in this component since reproductive success of creek chubs varies with type of spawning substrate available.

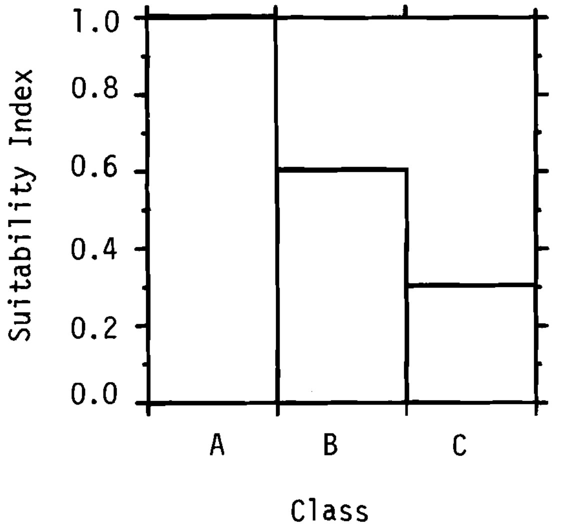
Other component. Stream gradient (V_5), average stream width (V_6), and average stream depth (V_{20}) are included in this component since the abundance of creek chubs has been observed to vary with these three parameters.

Suitability Index (SI) Graphs for Model Variables

This section contains suitability index graphs for the 20 variables described above, and equations for combining the suitability index (SI) of each variable into a species HSI using the component approach. All variables pertain to a riverine (R) habitat.

Habitat	Variable		Suitability Graph
R	(V_1)	Percent pools during average summer flow.	
R	(V_2)	Dominant (> 50%) pool class rating during average summer flow.	



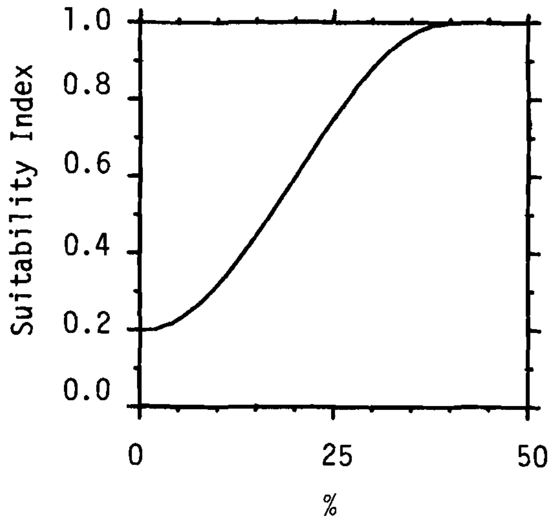


A) First-class pools (large and deep): Pool depth and size is sufficient to provide a low velocity resting area for numerous creek chubs. More than 30% of the pool bottom is obscured due to surface turbulence, depth, or the presence of structures, e.g., logs, debris piles, boulders, or overhanging banks and vegetation.

B) Second-class pool (moderate size and depth): Pool depth and size are sufficient to provide a low velocity resting area for some creek chubs. From 5 to 30% of the bottom is obscured due to surface turbulence, depth, or the presence of structures. Typical second-class pools are large eddies behind boulders and low velocity, moderately deep areas beneath overhanging banks and vegetation.

C) Third-class pool (small or shallow or both): Pool depth and size provide a low velocity resting area for only a very few creek chubs. Cover, if present, is in the form of shade, surface turbulence, or very limited structure. Typical third-class pools are wide, shallow pools or small eddies behind boulders. Virtually the entire bottom of the pool is discernible.

R (V_3) Percent cover during summer within pools and runs.



R (V_4) Winter instream cover suitability.

A) If access to larger, warmer streams is > 5 km from study area, then

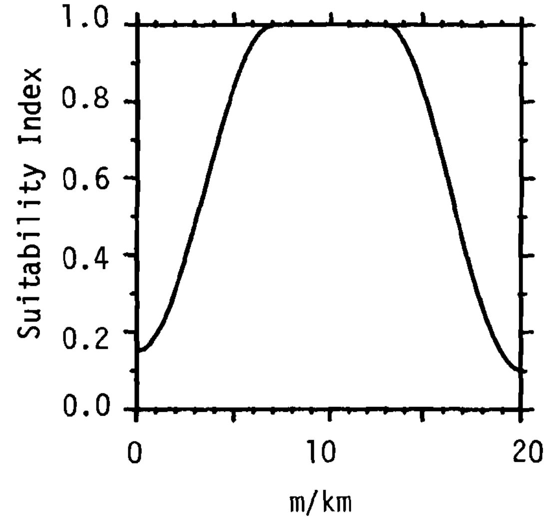
$$V_4 = (V_1 \times V_2 \times V_3)^{1/3} - 0.2$$

B) If access is within 5 km, then

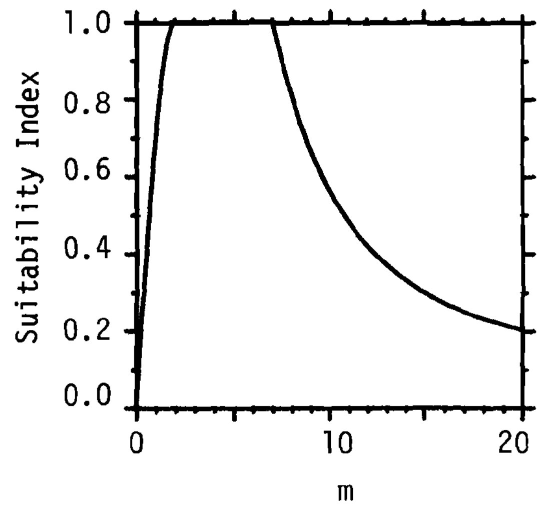
$$V_4 = (V_1 \times V_2 \times V_3)^{1/3} + 0.2,$$

or 1.0, whichever is smaller

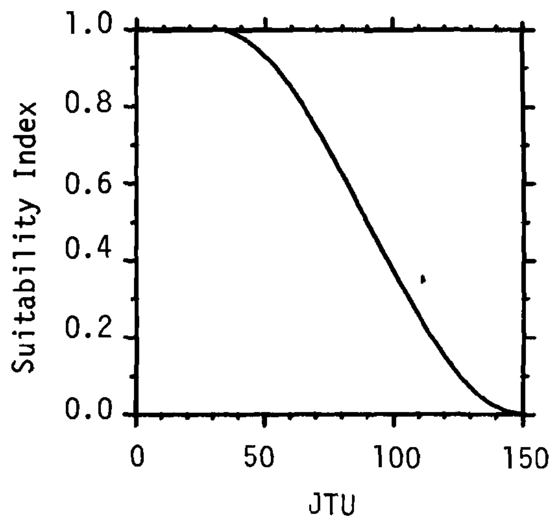
R (V$_5$) Stream gradient within sampling reach.



R (V$_6$) Average stream width during average summer flow.

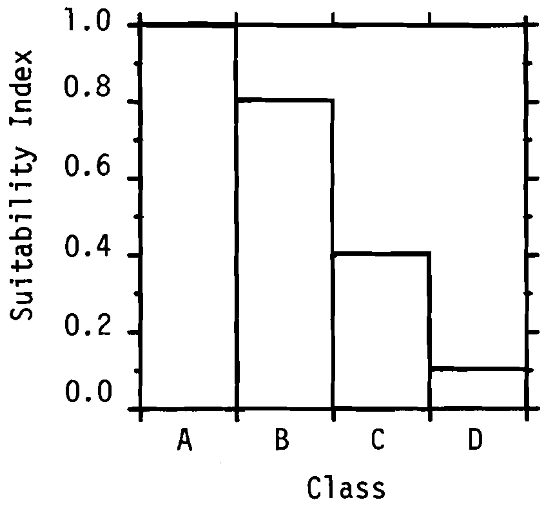


R (V$_7$) Maximum monthly average turbidity during summer.



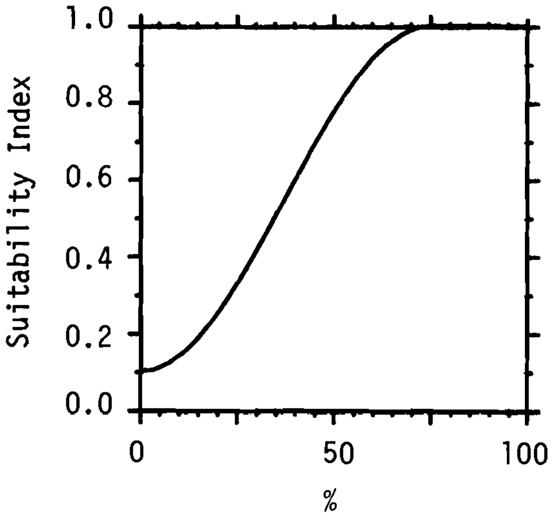
R (V$_8$) pH range during the year.

A) Stable in 6.0 to 9.0 range;
B) Never falls below 5.0 or goes above 9.5;
C) pH generally in 5.0 to 9.5 range, but occasionally < 5.0 or > 9.5;
D) pH frequently < 5 or > 9.5.



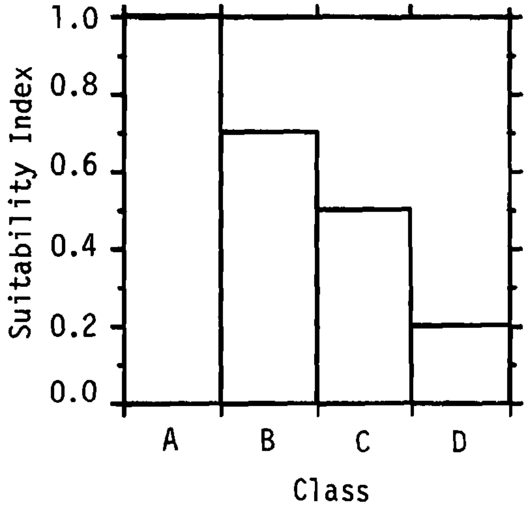
R (V$_9$) Vegetation index.

[2 (% shrubs) + 1.5 (% grasses) + (% trees) + 0 (% bare ground)].



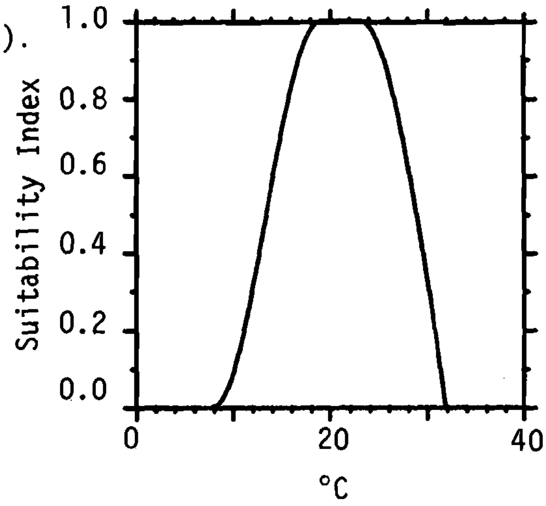
R (V$_{10}$) Food production potential in stream by substrate type present during average summer flow.

A) Rubble dominant in riffles with some gravel and/or boulders present; fines (silt, sand) not common; aquatic vegetation abundant (≥ 30%) in pool areas.
B) Rubble, gravel, boulders, and fines occur in nearly equal amounts in riffle areas; aquatic vegetation is 10-30% in pool areas.
C) Some rubble and gravel present, but fines or boulders are dominant; aquatic vegetation is scarce (< 10%) in pool areas.
D) Fines or bedrock are the dominant bottom material. Little or no rubble or aquatic vegetation present.

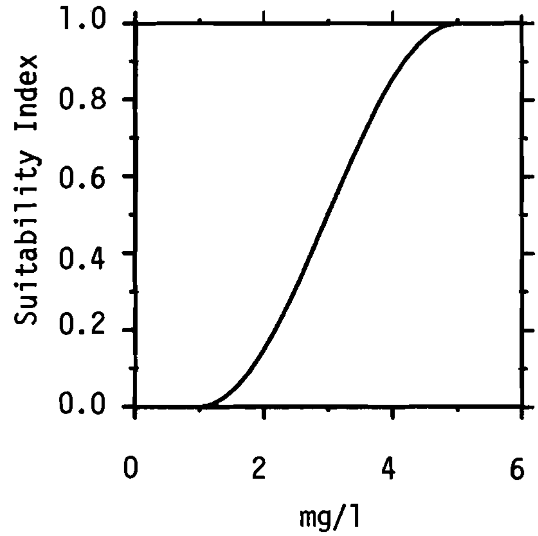


R (V$_{11}$) Average water temperatures during the summer (Adult, Juvenile, and Fry).

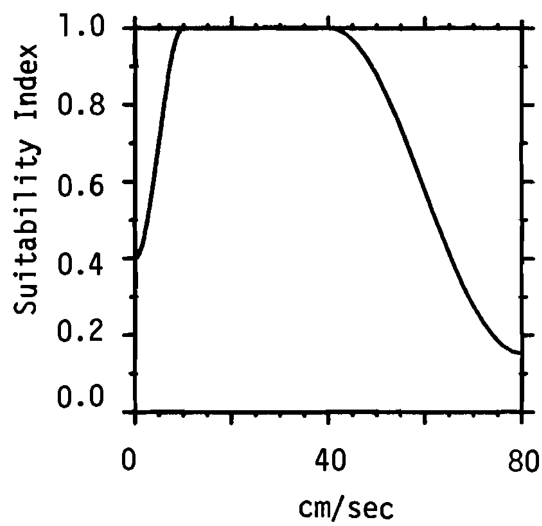
Note: If temperatures are ever ≥ 32° C, V_{11} = 0.0.



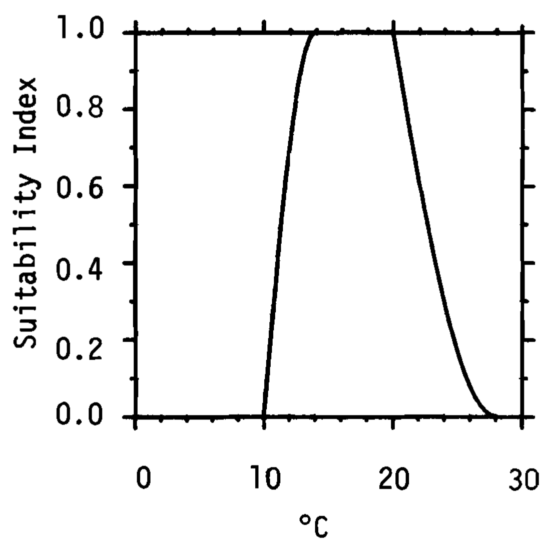
R (V$_{12}$) Minimum dissolved oxygen level during summer (Adult, Fry, and Juvenile).



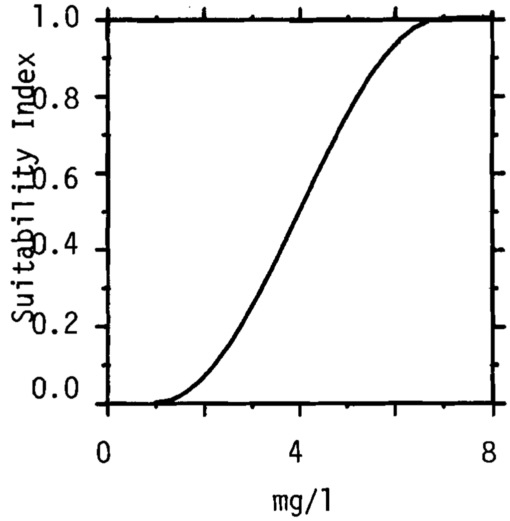
R (V$_{13}$) Average current velocity (at 0.6 depth) during average summer flow (Adult and Juvenile).



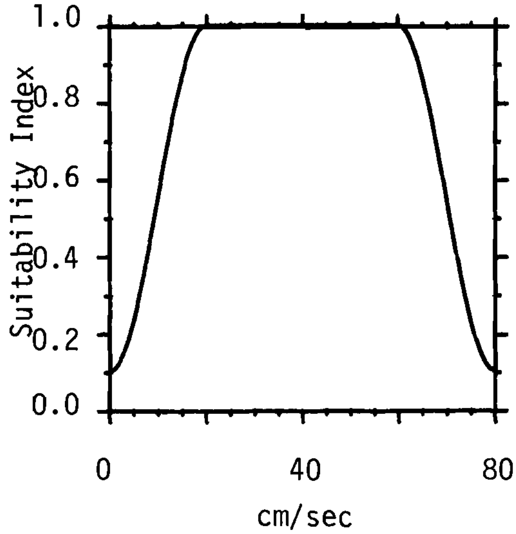
R (V$_{14}$) Average water temperature during spring (Embryo).



R (V15) Minimum dissolved oxygen levels during spring (Embryo).



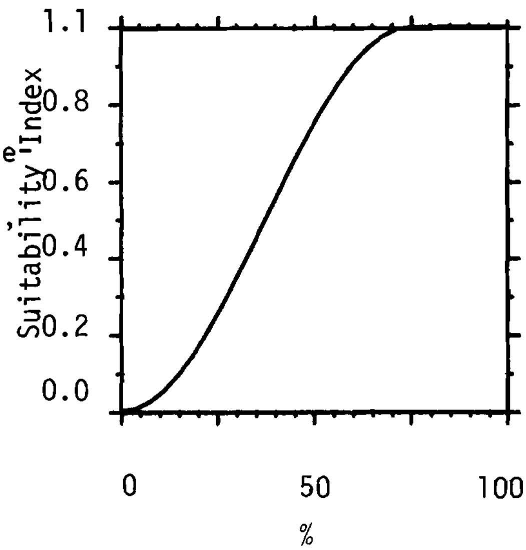
R (V16) Average current velocity (at 0.6 depth) in riffle/run areas during April-June (Embryo).



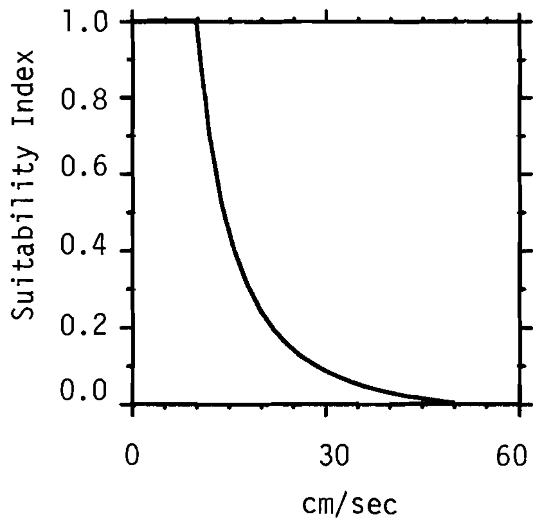
R (V17) Percent substrate type in riffle/run areas during spawning (Embryo).

Substrate index =
2(% gravel) + (% cobble boulders) + 0 [% fines (sand, silt), detritus, or bedrock].

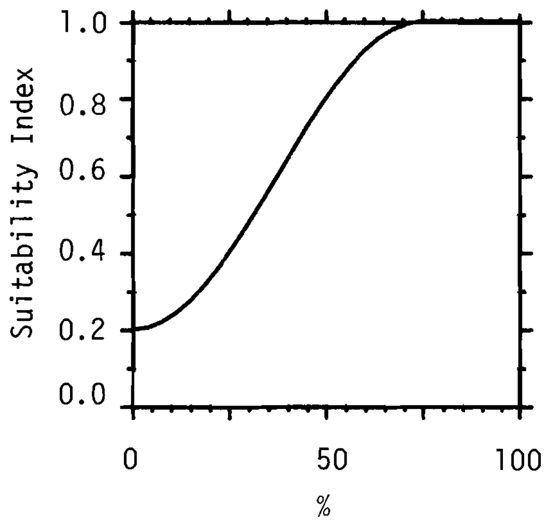
Spawning substrate is unsuitable if it is highly embedded or compacted or if the substrate is anoxic (i.e., H_2S present).



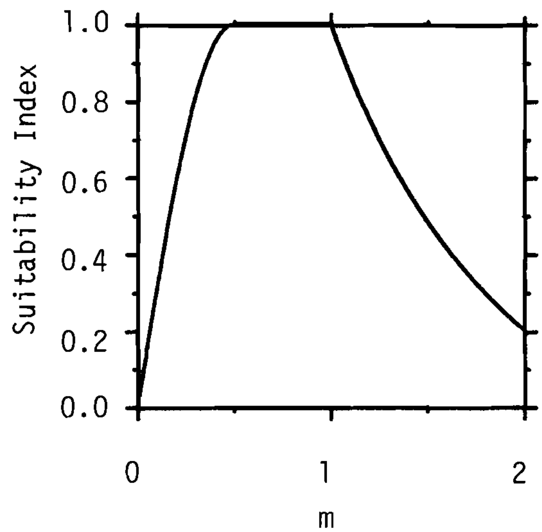
R (V18) Velocity along edges of stream during average summer flow (Fry).



R (V19) Average percent of stream shaded between 1000 and 1500 hours during midsummer.



R (V20) Average of maximum stream depths during average summer flow.



Riverine Model

This model utilizes the life requisite approach and consists of five components: Food, Cover, Water Quality, Reproduction, and Other.

Food (C_F)

$$C_F = \frac{V_9 + V_{10}}{2}$$

Cover (C_C)

$$C_C = (V_1 \times V_2 \times V_3 \times V_4 \times V_{13} \times V_{18})^{1/6}$$

Water Quality (C_{WQ})

$$C_{WQ} = (V_7 \times V_8 \times V_{11} \times V_{12} \times V_{19})^{1/5}$$

If V_8, V_{11}, or V_{12} is ≤ 0.4, then C_{WQ} equals the lowest of the following: V_8, V_{11}, V_{12}, or the above equation.

Reproduction (C_R)

$$C_R = (V_{14} \times V_{15} \times V_{16} \times V_{17}^2)^{1/5}$$

If V_{14} or V_{15} is ≤ 0.4, then C_R equals the lowest of the following: V_{14}, V_{15}, or the above equation.

Other (C_{OT})

$$C_{OT} = \frac{V_5 + V_6 + V_{20}}{3}$$

HSI determination

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

If C_C, C_{WQ}, or C_R is ≤ 0.4, then the HSI equals the lowest of the following: 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 used in calculating HSI's from the above model are given in Table 2. The data sets are not actual field measurements, but the different variable values used in calculating the HSI's are thought to represent realistic conditions that could occur in creek chub riverine habitats. The HSI's calculated from the data seem to reflect what carrying capacity trends would be in riverine habitats with the listed characteristics. Thus, the model meets the acceptance goal of producing an index between 0 and 1 which is thought to have a positive relationship to carrying capacity of a habitat for creek chubs.

Table 1. Data sources and assumptions for creek chub suitability indices.

Variable	and source	Assumption
V_1	Trautman 1957 Minckley 1963 Moshenko and Gee 1973	Streams with approximately equal amounts of pools and riffles will provide optimum conditions for meeting the needs of creek chubs for cover, spawning habitat, and food (aquatic insects).
V_2	Moshenko and Gee 1973 Copes 1978	Large and deep pools are most suitable as cover for creek chubs; shallow and or small pools are suboptimum.
V_3	Trautman 1957 Copes 1978	The high abundance of creek chubs in areas with instream cover indicates that optimum conditions will occur in areas with high amounts of instream cover.
V_4	Trautman 1957 Paloumpis 1958 Copes 1978	Optimum conditions for winter cover are large, deep pools with abundant instream cover or free access to larger streams within 5 km.
V_5	Trautman 1957 Moshenko and Gee 1973 Hocutt and Stauffer 1975	Streams with gradients corresponding to those with high abundance of creek chubs are optimum.
V_6	Starrett 1950 Dinsmore 1962 Hocutt and Stauffer 1975	Streams with widths corresponding to those with high abundance of creek chubs are optimum.
V_7	Minckley 1963 Barber and Minckley 1971 Branson and Batch 1972 Scott and Crossman 1973 Pflieger 1975	Turbidity levels associated with high abundance of creek chubs are optimum.
V_8	McKee and Wolf 1963 Minckley 1963 Smith 1964	The pH range that is associated with high abundance of creek chubs and that is most suitable for survival and growth of freshwater fishes is optimum.

Table 1. (continued)

Variable and source		Assumption
V_9	Moshenko and Gee 1973 Cummins 1974	The amount and type of streambank vegetation associated with high allochthonous input (terrestrial insects) of food for creek chubs is optimum. In terms of production of terrestrial insects, shrubs > grasses-forbs > trees > bare ground.
V_{10}	Hynes 1970	The amount and type of substrate or the amount of aquatic vegetation associated with high production of aquatic insects (used as food by creek chubs) is optimum.
V_{11}	Brett 1944 Hart 1947 Starrett 1950 Miller 1964 Moshenko and Gee 1973	Temperature levels associated with highest growth are optimum. Levels associated with reduced survival and growth are suboptimum.
V_{12}	Davis 1975	Levels associated with high survival and growth of freshwater fish in general are considered optimum for creek chubs. Levels where survival is poor are unsuitable.
V_{13}	Minckley 1963 Moshenko and Gee 1973	Velocities where creek chub adults and juveniles are most abundant are optimum. Velocities where creek chub adults and juveniles are less abundant are suboptimum.
V_{14}	Clark 1943 Moshenko and Gee 1973 Copes 1978	Temperature levels associated with high survival and production are optimum.
V_{15}	Davis 1975	Levels associated with high survival of embryos of coolwater fishes are considered to be optimum for creek chubs.
V_{16}	Moshenko and Gee 1973	Velocities where survival and production of creek chub embryos are highest are optimum.

Table 1. (concluded)

Variable and source		Assumption
V_{17}	Washburn 1945 Trautman 1957 Miller 1964 Copes 1978	The amount and type of substrate associated with high survival and production of creek chub embryos is optimum. Substrate types associated with lower survival rates of embryos are suboptimum.
V_{18}	Same as V_{13}	Velocities where fry are most abundant are optimum.
V_{19}	Karr and Schlosser 1978	The amount of stream shaded from the sun controls the magnitude of daily and seasonal temperature extremes of small streams. Hence, high percentages of stream shading must be present for optimum temperature conditions for creek chubs to occur. Low percentages of stream shade often result in high summer temperatures and widely-fluctuating daily temperatures and are thus considered suboptimum.
V_{20}	Minckley 1963 Miller 1964 Barber and Minckley 1971 Hocutt and Stauffer 1975 Powles et al. 1977	Streams with depths corresponding to those with high abundance of creek chubs are optimum.

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	60	1.0	75	0.5	90	0.1
Pool class	V_2	A	1.0	B	0.6	C	0.3
% cover	V_3	30	0.9	15	0.5	75	1.0
Winter cover	V_4	-	0.76	-	0.53	-	0.5
Gradient (m/km)	V_5	14.5	0.9	16.5	0.6	2	0.3
Width (m)	V_6	3	1.0	10	0.5	1.5	0.9
Turbidity (JTU)	V_7	25	1.0	90	0.5	105	0.3
pH	V_8	7.5	1.0	5.5	0.8	9.5	0.8
Streambank vegetation index	V_9	75	1.0	30	0.4	10	0.1
Substrate (for food prod.)	V_{10}	A	1.0	C	0.5	D	0.2
Temperature (°C) - A, J, F	V_{11}	19	1.0	25	0.5	25	0.5
D.O.(mg/l) - A,J,F	V_{12}	6	1.0	4	0.9	3	0.5
Velocity (cm/sec) - A,J	V_{13}	20	1.0	10	1.0	2	0.5
Temperature (°C) - E	V_{14}	15	1.0	20	1.0	23	0.5
D.O. (mg/l) - E	V_{15}	6	0.9	5	0.75	4	0.5
Velocity (cm/sec) - E	V_{16}	30	1.0	17	0.8	5	0.2
Substrate index - spawning	V_{17}	55	0.8	45	0.6	35	0.4
Velocity (cm/sec) - F	V_{18}	5	1.0	2	1.0	< 1	1.0

Table 2. (concluded)

Variable		Data set 1 Data	SI	Data set 2 Data	SI	Data set 3 Data	SI
% shade	V_{19}	80	1.0	45	0.7	15	0.3
Stream depth (m)	V_{20}	1.5	1.0	2.0	0.2	1.8	0.3
Component SI							
C_F =			1.00		0.45		0.15
C_C =			0.94		0.66		0.44
C_{WQ} =			1.00		0.66		0.45
C_R =			0.90		0.74		0.38
C_{OT} =			0.97		0.43		0.50
HSI =			0.96		0.57		0.38[1]

[1]Note: HSI equals C_R, since $C_R \leq 0.4$.

Lacustrine Model

Specific lacustrine suitability indices for creek chub were not developed due to a lack of information on habitat requirements and limited use of lacustrine habitats by creek chubs. Small populations might occur if suitable spawning habitat near shoreline is present, i.e., gravel substrates with some current (Scott and Crossman 1973).

Interpreting Model Outputs

The HSI for creek chubs as determined by one of the above models may not necessarily represent the exact population level of creek chubs in the study area. This may be due to the fact that these models rely on habitat-based factors, and other factors may be operating that more significantly affect the population level of creek chubs present in an area. If the HSI's calculated from the models are a good representation of creek chub habitat quality, then in riverine environments where creek chub population levels are due primarily to habitat-based factors, the HSI should be positively correlated to the long-term average population levels. However, this has not been tested. The proper interpretation of the HSI is one of comparison. If two study areas have different HSI's, the one with the higher HSI should have the potential to support more creek chubs than the one with the lower HSI, given that the model assumptions have not been violated.

ADDITIONAL HABITAT MODELS

Model 1

Optimum riverine habitat for creek chubs is characterized by the following conditions, assuming water quality is adequate: small (≤ 7 m wide); cool (summer temperatures 19-23° C); at least 40% gravel substrate; approximately 50% pools:50% riffles-runs; abundant (≥ 40%) instream cover.

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

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

Literature describing the habitat preferences of the creek chub (Semotilus atromaculatus) is reviewed, and the relationships of habitat variables and life requisites in the creek chub are illustrated.

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 (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.

17. Document Analysis a. Descriptors

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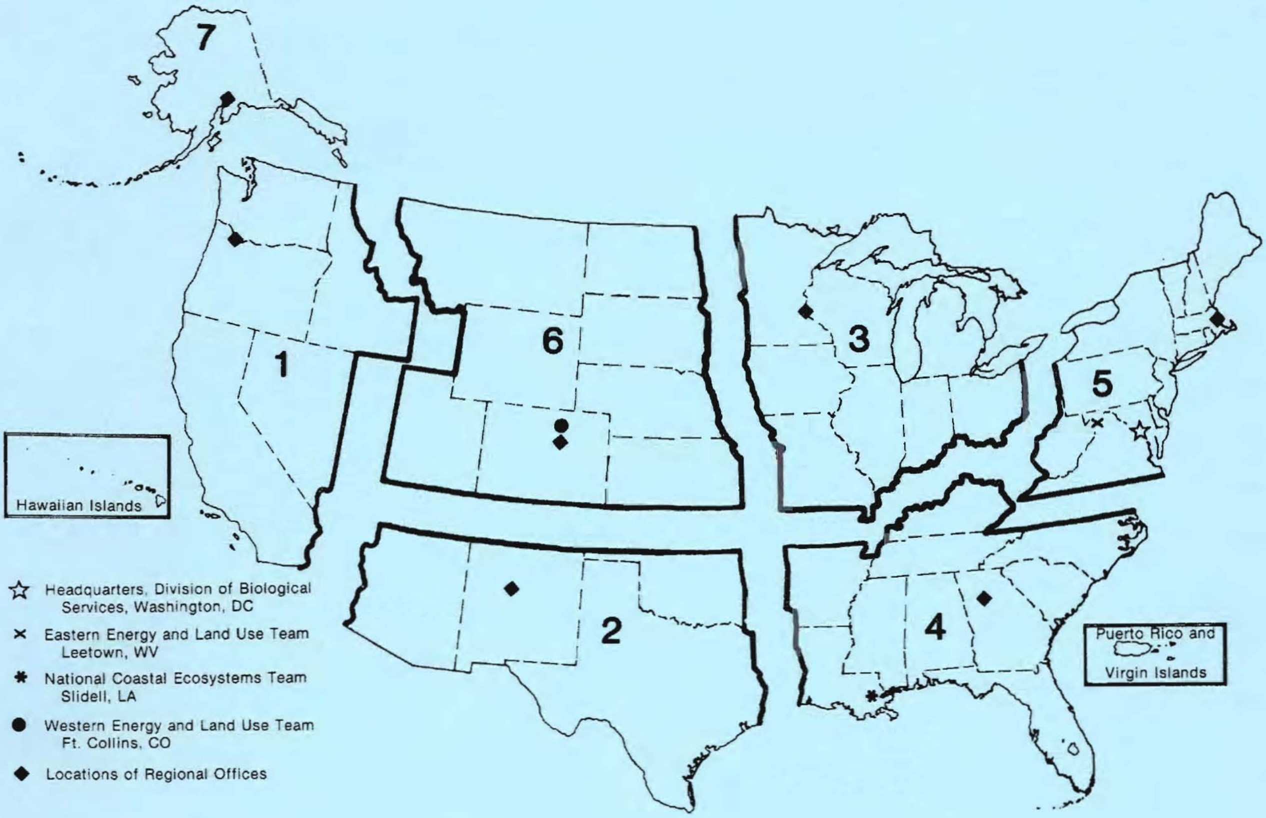

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