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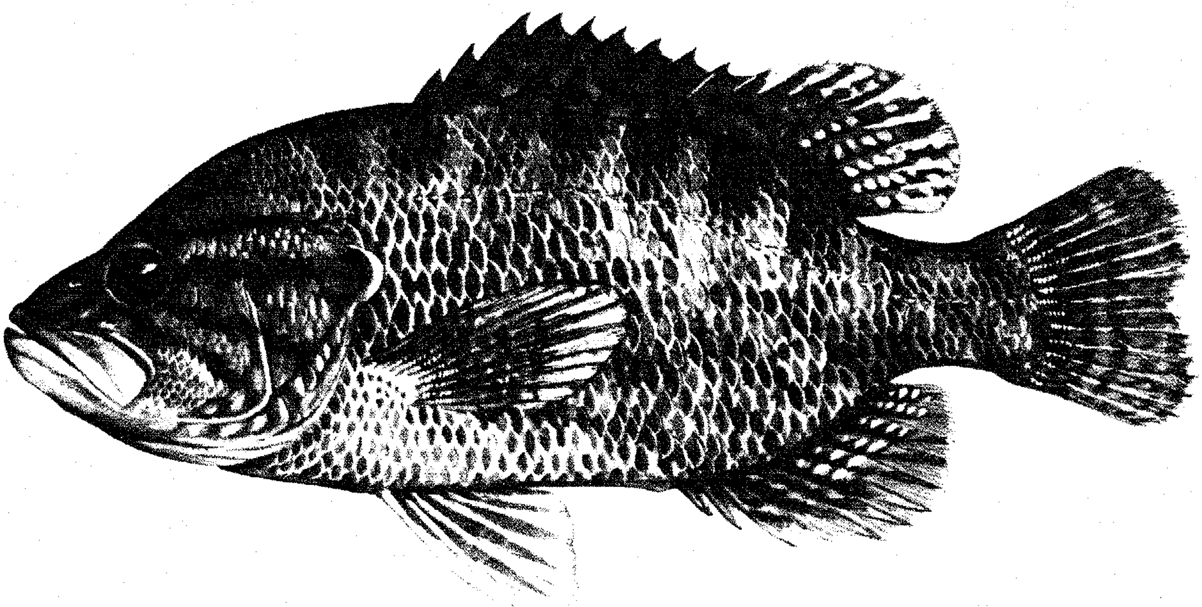
HABITAT SUITABILITY INDEX MODELS AND INSTREAM FLOW SUITABILITY CURVES: WARMOUTH



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HABITAT SUITABILITY INDEX MODELS AND INSTREAM FLOW SUITABILITY CURVES: WARMOUTH

by

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PREFACE

Information presented in this document is for use with Habitat Evaluation Procedures (HEP) and the Instream Flow Incremental Methodology (IFIM). The information should also be useful for impact assessment and for developing management recommendations and mitigation alternatives for the species using methodologies other than HEP or IFIM. The comparison and recommendations for use of HEP and IFIM presented by Armour et al. (1984)[1] should help potential users of these two methodologies determine the most efficient way to utilize the information in this publication.

The Suitability Index (SI) curves and graphs and Habitat Suitability Index (HSI) models presented herein are based primarily on a synthesis of information obtained from a review of the literature concerning habitat requirements of the species. The HSI models and SI curves are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Assumptions used to transform habitat use information into an index are noted, and guidelines for application of the curves and models are described. A discussion of the use of warmouth SI curves with IFIM is included.

The SI curves and HSI models presented herein are not standard components for either HEP or IFIM. They are starting points from which users should develop their own curves and models. Use of the information requires the setting of clear study objectives and is likely to require modification of the SI curves or graphs and HSI models to meet those objectives. Users of the SI graphs and/or HSI models with HEP should be familiar with standards for developing HSI models (U.S. Fish and Wildlife Service 1981)[1] and guidelines for simplifying HSI models (Terrell et al. 1982) and aquatic habitat variable measurement techniques (Hamilton and Bergersen 1984).[1] Users of the SI curves with IFIM should be familiar with the guide to stream habitat analysis (Bovee 1982)[1] and the User's Guide to the Physical Habitat Simulation System [PHABSIM (Milhous et al. 1984].[1]

The HSI models and SI curves presented herein are hypotheses of species-habitat relationships, not statements of proven cause and effect relationships. The curves and models are based on literature and professional judgment. They have not been applied in the field. For this reason, the U.S. Fish and Wildlife Service encourages model users to convey comments and suggestions that may help us increase the utility and effectiveness of this habitat-based approach to fisheries planning. Please send comments to:

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[1]Citation included in references.

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CONTENTS

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WARMOUTH (*Lepomis gulosus*)

HABITAT USE INFORMATION

General

The warmouth (*Lepomis gulosus*) occurs naturally throughout the central and southeastern United States. It is distributed throughout Kansas, Iowa, and Missouri, north to southern Wisconsin, lower Michigan, Lake Erie, and western Pennsylvania, and south to Florida and west through the Gulf States to the Rio Grande (Hubbs and Lagler 1947; Larimore 1957). It has been introduced into California (Hubble 1966; Moyle 1976), Arizona (Minckley 1973), and other western states (Smith 1896).

Warmouth are found almost invariably in slow-moving or still waters having a soft substrate and dense beds of submerged, floating, or emergent aquatic vegetation or other dense cover such as stumps, brush, or boulders (Larimore 1957; Cross 1967; Germann et al. 1975; Pflieger 1975; Guillory 1978; Trautman 1981). In Illinois, Ohio, and Missouri, warmouth habitat consists chiefly of weedy, sluggish streams, oxbows, and backwaters adjacent to large rivers and clear to moderately turbid, silt-bottomed ponds with dense cover along the shoreline (Larimore 1957; Pflieger 1975; Smith 1979; Trautman 1981). In California, where warmouth have been introduced, they are found in similar habitats where there is abundant vegetation and other cover in warm, turbid, muddy-bottomed sloughs and backwaters along the Sacramento, San Joaquin, and Colorado Rivers. In California, warmouth also occur in cool, fluctuating reservoirs where salmonids predominate (Moyle 1976). In the Southeast, the warmouth is also found in marshes and swamps such as the Everglades (Bangham 1939; Meehean 1942) and in the Okefenokee Swamp and Suwannee River, Georgia, where it is one of the primary sport fishes (Germann et al. 1975).

Age, Growth, and Food

Warmouth attain sexual maturity at ages I-II and at sizes > 8.75 cm (TL) in Illinois (Larimore 1957) and at ages II and III in the Okefenokee Swamp and Suwannee River, Georgia, respectively (Germann et al. 1975). Based on its diet and its habitat preferences, the warmouth is considered a food generalist and a habitat specialist (Larimore 1957; Guillory 1978; Savitz 1981). Warmouth fry and juveniles (< 8.75 cm) feed primarily on plankton and small insects, whereas crayfish and fish, in addition to insects, predominate in the diet of larger fish (Lewis and English 1949; Larimore 1957; Germann et al. 1975; Guillory 1978; Savitz 1981).

Reproduction

Nesting and spawning activity of warmouth commences in April or when temperatures exceed 21° C (Larimore 1957; Germann et al. 1975). Spawning generally peaks in late May to early June, but may extend through August if temperatures are favorable (Larimore 1957; Guillory 1978). Multiple spawning of individual fish has been reported in Texas where one pair of warmouth spawned three times in one season (Toole 1946).

Eggs are laid in nests built and guarded by males (Larimore 1957). Nests are built near cover in shallow, protected areas over a variety of substrates (Larimore 1957; Germann et al. 1975). Nests in Georgia swamps were found near stumps, root bases of trees along the shoreline, and in sluggish areas having water lilies and emergent vegetation (Germann et al. 1975).

Specific Habitat Requirements

Cover, velocity, and variables correlated with velocity (e.g., gradient and pool:riffle ratio) appear to be prime indicators of suitability of riverine habitats for warmouth. Warmouth are rarely found far from shallow areas near cover (Lewis and English 1949; Larimore 1957; Germann et al. 1975; Pflieger 1975; Savitz 1981), although larger fish can be found in deeper water that is less vegetated (Larimore 1957). In electrofishing surveys along the shoreline of Lake Conway, Florida, 4.7 warmouth/hr were collected in vegetated sections whereas only 0.2/hr were collected in nonvegetated zones (Guillory 1978). Pools, backwaters, swamps, marshes, and other areas of very slow current characterize suitable riverine habitat for warmouth. They are most abundant at near-zero gradients (Larimore 1957; Funk 1975; Pflieger 1975; Trautman 1981) and rare at gradients of 1.5 to 2.6 m/km and above (Larimore 1957). The maximum gradient where warmouth have been collected is 3.7 m/km (Flemer and Woolcott 1966).

The response of warmouth populations to impoundment has not been well-documented. Lewis and English (1949) reported that warmouth were abundant in an Iowa reservoir with an extensive shallow, weedy shoreline. Warmouth populations are likely to be adversely affected by channelization and other habitat alterations that increase water velocity, decrease percent pools, and/or decrease the amount of aquatic vegetation. In Illinois and Ohio, warmouth populations declined where habitat alterations increased turbidity and siltation resulting in the decline in aquatic vegetation (Smith 1979; Trautman 1981).

Warmouth are found in waters of varying turbidities. Some researchers report that warmouth are most abundant in clear, vegetated waters (e.g., Pflieger 1975; Trautman 1981), whereas others report that warmouth frequently comprise greater proportions of the total fish population in turbid waters than in clear (e.g., Forbes and Richardson 1920; Larimore 1957). Larimore (1957) suggests that abundance of warmouth in more turbid water may not indicate a preference but rather a greater tolerance to turbidity than other sunfishes. A common characteristic of warmouth habitat however, regardless of turbidity level, is the presence of aquatic vegetation. It seems likely that turbidity will have its greatest impact on habitat quality if it is high enough to reduce light penetration and thus inhibit growth of aquatic vegetation.

Warmouth are restricted primarily to freshwater (salinities < 1 parts per thousand) (Bailey et al. 1954; Kilby 1955), although a few have been found in salinities up to 4.1 ppt in tidal marshes of Florida and Louisiana (Carver 1967). The pH requirements of warmouth populations are unknown; however, they appear tolerant of relatively low levels since warmouth exist and grow well in several locations in Georgia where the pH is near 4.0 (Germann, pers. comm.). The upper pH tolerance level is probably near 9.5 based on the tolerances of largemouth (*Micropterus salmoides*) and smallmouth bass (*M. dolomieui*) (Calabrese 1969; Bulkley 1975), but warmouth may be tolerant of the short-term fluctuations in pH above 9.5 common to heavily-vegetated areas during the summer.

Adult. Adult warmouth are able to survive extremely low dissolved oxygen (DO) levels for short periods and are among the last species to die when subjected to low DO (Larimore 1957). Warmouth survived DO concentrations of 1.0 mg/l in the laboratory (Gould and Irwin 1965), 0.7 to 1.3 mg/l in a lake when allowed access to the surface (Baker 1941), and 0.3 mg/l for a short time in laboratory experiments (Larimore 1957). Based on experimental measurements of oxygen consumption rate experiments conducted by Larimore (1957), however, the critical DO level for long-term survival is 3.6 mg/l.

The temperature requirements of adult warmouth are not well-known. Warmouth have been found at temperatures as high as 33.9° C (Carver 1967). Presumably, temperatures that correspond to high growth, survival, and feeding of largemouth bass, i.e., 25 to 30° C, (Hart 1952; Strawn 1961; Coutant 1975; Brungs and Jones 1977) also are highly suitable for adult warmouth.

Embryo. Nests are constructed in shallow water (< 1 m depth); thus, rapidly falling water levels during the spring may adversely effect successful reproduction (Larimore 1957). Temperatures corresponding to a high level of spawning activity in warmouth (Larimore 1957) and which are optimum for incubation of largemouth bass embryos (21 to 27° C) (Coutant 1975) are assumed optimum for embryo survival and growth. Sudden drops in water temperature are reported to cause very significant embryo mortality resulting from fungal infection (Larimore 1957).

The dissolved oxygen (DO) requirements of warmouth embryos are unknown. DO requirements are assumed to be similar to those determined for largemouth and smallmouth bass; thus, DO levels of ≥ 6 mg/l are considered optimum for survival and growth, and DO levels ≤ 1.5 mg/l are considered lethal (Siefert et al. 1974; Eipper 1975).

Fry. Fry are found in shallow, dense cover of aquatic vegetation, roots, brush, and boulders (Larimore 1957). The survival of fry hatching late in the season (August) may be higher than that of earlier broods due to the availability of denser stands of aquatic vegetation as cover and less danger of sudden temperature drops which can result in embryo mortality (Larimore 1957). Other specific habitat requirements of warmouth fry are unknown.

Juveniles. Specific habitat requirements for juvenile warmouth (age I+ to sexual maturity) are not detailed in the literature. However, warmouth may mature at age I (Larimore 1957), thus requirements of juveniles are considered similar to those of adult warmouth.

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The models provided are assumed to be applicable to any water body within the native and introduced range of warmouth. The standard of comparison for each individual suitability index is the optimum value of the variable that occurs anywhere within this range.

Season. The models provide an index for a riverine or lacustrine habitat based on its ability to support all life stages of warmouth throughout the year.

Cover types. This model is applicable to riverine and lacustrine habitats, as described by Cowardin et al. (1979).

Verification level. These models have not been tested against habitats of known quality. As a first step in the model verification and validation process (Farmer et al. 1982), the models were reviewed by the biologists listed in the acknowledgements, who we considered to be familiar with warmouth habitat requirements. The reviewers neither endorsed or rejected the model. However, we did incorporate information on habitat requirements provided by the reviewers in the final model documentation.

Model Description

The Habitat Suitability Index (HSI) model is an attempt to condense available information on habitat requirements of warmouth into a set of habitat evaluation criteria that provide a measure of habitat quality for warmouth in riverine and lacustrine environments. The model is comprised of variables with a known impact on the growth, survival, distribution, or abundance of warmouth; these variables could, therefore, be expected to have an impact on the carrying capacity of a habitat. The model is structured to produce a relative index of the ability of a present or potential habitat to meet the food and cover, water quality, and reproductive requirements of warmouth. Variables that affect habitat quality for warmouth, but do not easily fit into one of these three major components, are combined under the heading of "Other" component. The relationship between habitat variables, model components, and the HSI is illustrated in Figure 1 and Figure 2.

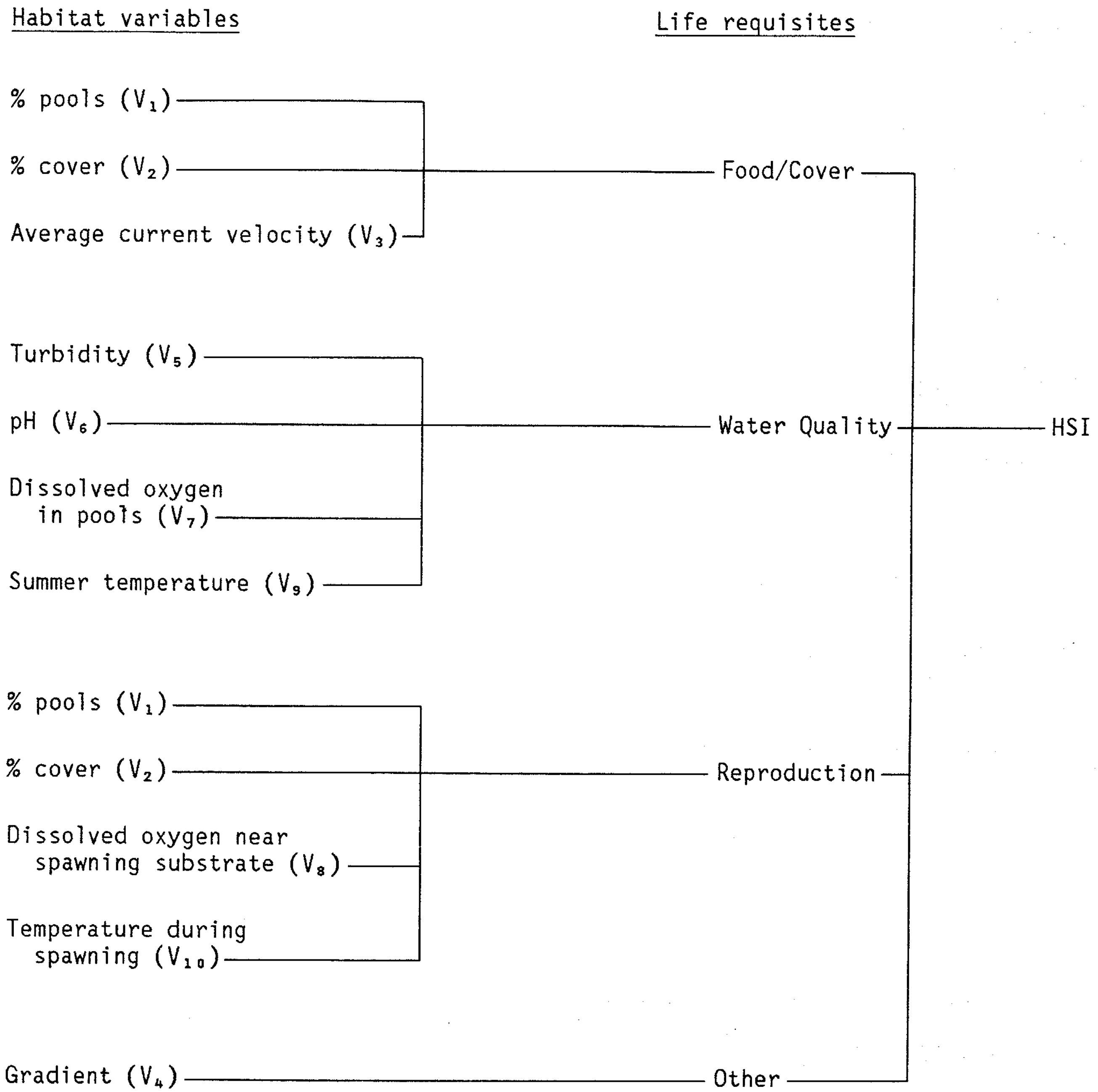


Figure 1. Diagram illustrating habitat variables in the riverine HSI model and the aggregation of the corresponding suitability indices (SI's) into an HSI.

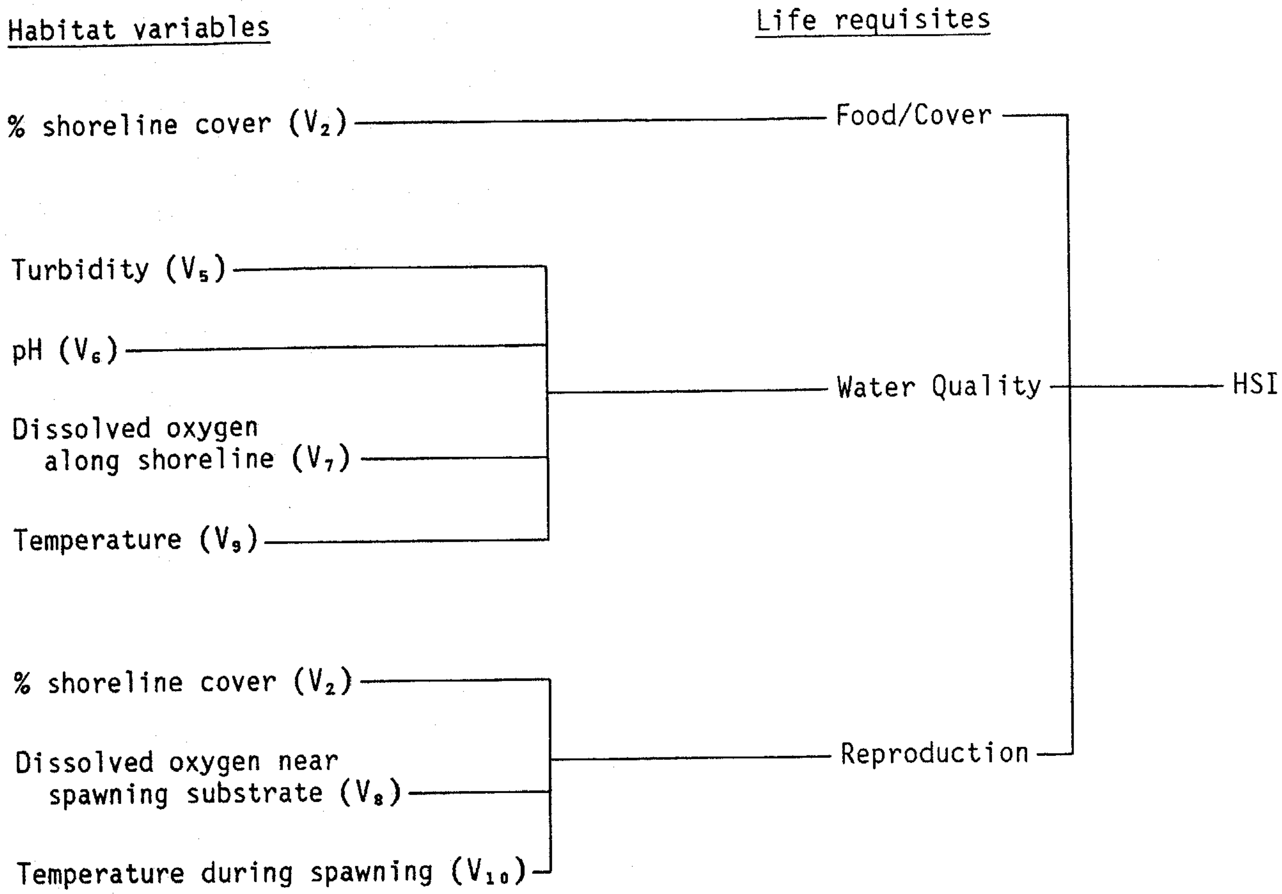


Figure 2. Diagram illustrating habitat variables in the lacustrine HSI model and the aggregation of the corresponding suitability indices (SI's) into an HSI.

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

Model Description - Riverine

Food/cover component. Percent pools (V_1) was included in this component because warmouth densities have been shown to vary with the amount of pool habitat available. Percent cover (V_2) was included in this component because: (1) cover provides habitat for the food items eaten by warmouth (i.e., insects and small fish); (2) warmouth forage primarily in or near cover (Savitz 1981); and (3) abundance and distribution of warmouth is closely associated with dense vegetation and other forms of structural cover. Average current velocity (V_3) was also included because warmouth distribution is limited by high velocities.

Of these three variables, percent cover (V_2) is probably the most important determinant of habitat suitability for warmouth. Observations of warmouth habitat usage throughout its native and introduced range reveal that dense cover is a prime component of warmouth habitat.

Water quality component. Turbidity (V_5) was included because abundance and growth of warmouth have been related to turbidity level. Dissolved oxygen (V_7), pH (V_6), and temperature (V_9) were included because these water quality parameters affect abundance, growth, and survival of warmouth or related species. These three variables are considered overriding determinants of overall habitat suitability if they approach levels that are lethal or result in greatly reduced growth or survival. Toxic substances are not included in this model, but should be considered when evaluating water quality for warmouth.

Reproduction component. Percent pools (V_1) and percent cover in pools (V_2) were included in this component because warmouth spawn in calm water near cover. Dissolved oxygen (V_8) and temperature (V_{10}) were included because these water quality parameters affect survival and growth in embryos of species related to warmouth and were assumed to have a similar impact on warmouth.

Other component. Gradient (V_4) was included in this component because abundance of warmouth varies with this habitat parameter.

HSI determination. We believe that we have defined individual SI's below 1.0 to represent suboptimum conditions, regardless of the value of other habitat variables. Therefore, we assumed that the most limiting factor (i.e., the lowest SI score) defines carrying capacity for warmouth in streams; thus, the HSI equals the minimum value of any of the suitability indices V_1 to V_{10}.

Model Description - Lacustrine

Food/cover component. Percent cover within the littoral zone (V_2) is included because warmouth generally occur only in near-shore areas. Again, it seems that more available cover indicates a more suitable habitat for forage items utilized by warmouth.

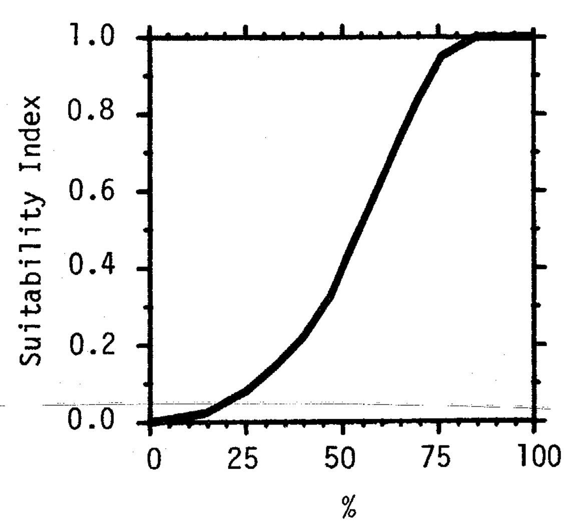
Water quality component. Same as for the riverine model description.

Reproduction component. Percent cover in the littoral zone (V_2) was included in this component as a measure of the quality of spawning habitat available to warmouth. Substrate type does not appear as important as availability of cover when choosing a nest site, so it was not included as a variable in this model. Dissolved oxygen (V_8) and temperature (V_{10}) are included because these water quality parameters affect survival and growth in embryos of species related to warmouth.

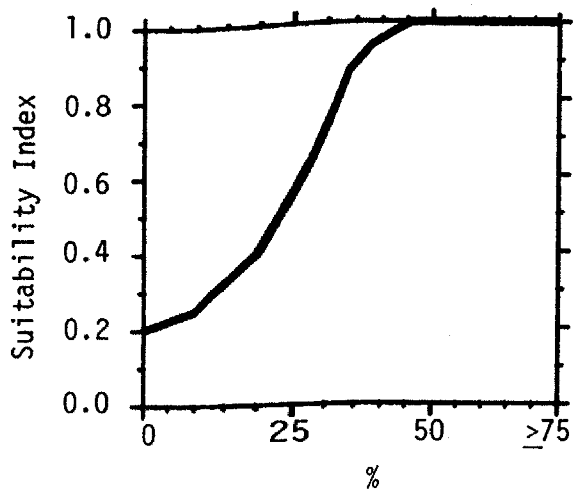
HSI determination. We assumed the most limiting factor (i.e., the lowest SI score) defines carrying capacity for warmouth in lacustrine environments; thus, the HSI equals the minimum value for suitability indices V_2, and V_5 through V_{10}.

Suitability Index (SI) Graphs for Model Variables

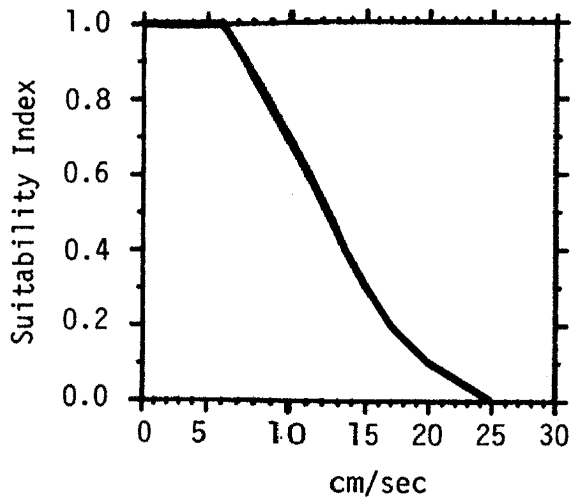
Table 1 lists the rationale and assumptions used in constructing each SI graph. Graphs were constructed by converting available information on the habitat requirements of warmouth into an index of suitability from 0.0 (unsuitable) to 1.0 (optimum). Descriptors for each habitat variable were chosen to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

Habitat	Variable		Suitability graph
R	V_1	Percent pools during average summer flow.	

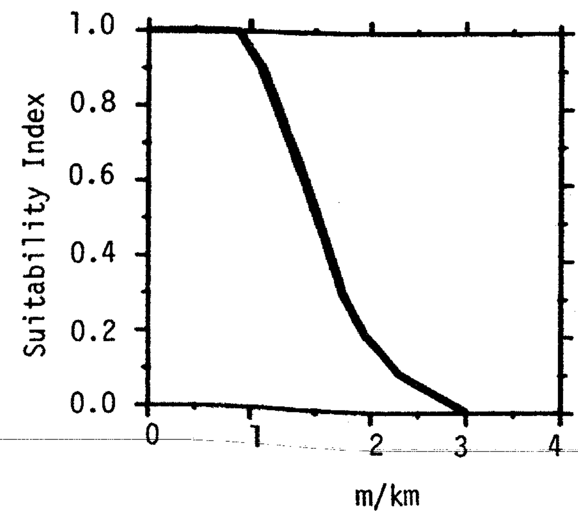
R,L V_2 Percent cover (e.g., aquatic vegetation, logs, rocks, roots, and brush) in pools (R) or along the shoreline (L) during the summer.



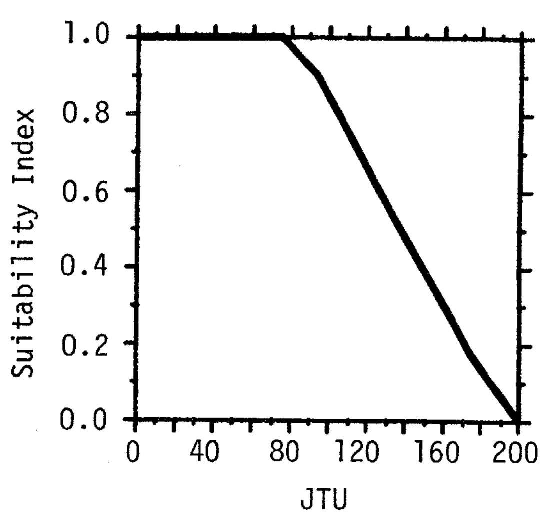
R V_3 Average current velocity at 0.6 times depth during average summer flow.



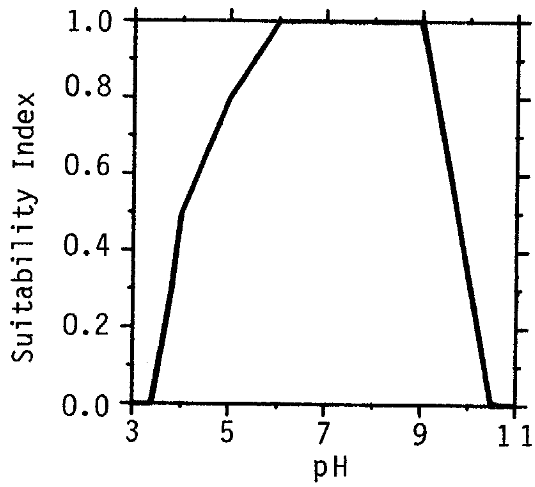
R V_4 Stream gradient within the sampling reach.



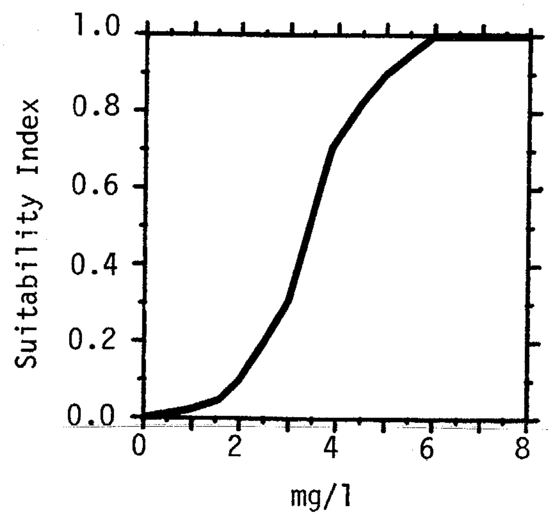
R,L V_5 Maximum monthly average turbidity during summer.



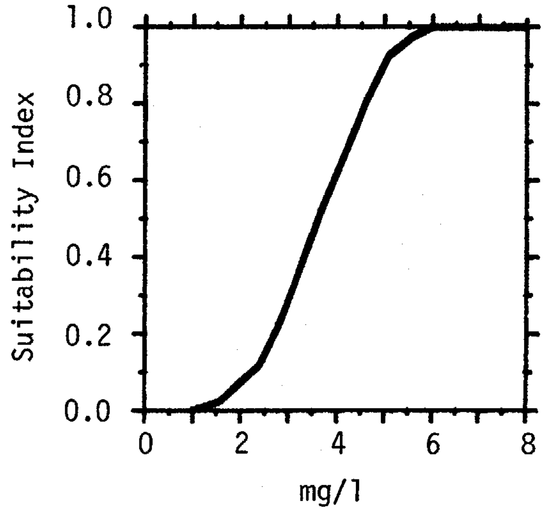
R,L V_6 Minimum or maximum pH during the year. (Use value which has the lowest SI).



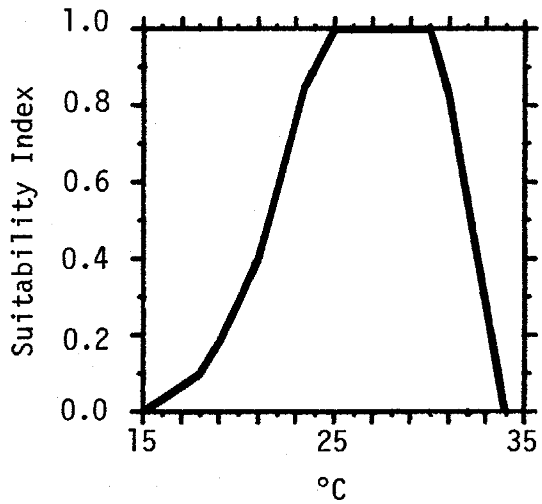
R,L V_7 Average daily minimum dissolved oxygen level in pools (R) or along the shoreline (L) during summer (adult, juvenile, and fry).



R,L V_8 Average daily minimum dissolved oxygen level at the surface of the spawning substrate in pools (R) or along the shoreline (L) during spawning (embryo).



R,L V_9 Mean weekly water temperature in pools (R) or along the shoreline (L) during summer (adult, juvenile, and fry).



R,L V_{10} Mean weekly water temperature in pools (R) or along the shoreline (L) during spawning (embryo).

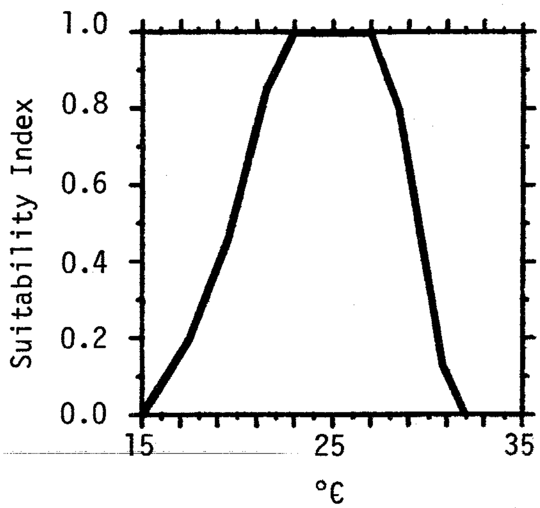


Table 1. Sources of information and assumptions used in construction of the suitability index graphs. "Excellent" habitat for warmouth refers to an SI of 0.8 to 1.0, "good" an SI of 0.5 to 0.7, "fair" 0.2 to 0.4, and "poor" habitat 0.0 to 0.1.

Variable	Assumptions and sources
V_1	High percent pools (≥ 75%) is considered excellent inasmuch as warmouth occur almost exclusively in marshes, swamps, backwaters, sloughs, and sluggish streams (Kilby 1955; Larimore 1957; Germann et al. 1975; Moyle 1976; Trautman 1980). Habitat suitability for warmouth was assumed to decline with decrease in pool area because warmouth are rare in fast-moving creeks and moderate-to-high gradient streams (Larimore 1957; Trautman 1981).
V_2	High percent cover is considered excellent because: (1) warmouth are almost invariably found in close association with dense cover (Lewis and English 1949; Larimore 1957; Germann et al. 1975; Guillory 1978; Smith 1979; Trautman 1981; Savitch 1981); (2) warmouth exhibit a preference for nest construction near cover (Larimore 1957; Germann et al. 1975); and (3) warmouth abundance declined in areas where a decline in aquatic vegetation was due to increased turbidity and siltation (Smith 1979; Trautman 1981). The selection of ≥ 40% cover as excellent is our best estimate based on available information. Very low percent cover (< 5%) is assigned an SI of 0.2 because we assumed that a stream, pond, or reservoir may still be able to support warmouth, although at a much reduced level (e.g., Guillory 1978).
V_3	Current velocities corresponding to highest abundance of warmouth (≤ 10 cm/sec) (Bailey et al. 1954; Finnell et al. 1956; Jones 1970, 1973; Pflieger 1975) are excellent. Warmouth are rare at higher velocities (Bailey et al. 1954; Finnell et al. 1956; Jones 1970, 1973; Trautman 1981), thus suitability at these velocities declines.
V_4	Gradients where warmouth abundance is highest (near or at zero) are excellent (Finnell et al. 1956; Larimore 1957; Funk 1975; Trautman 1981). Gradients where warmouth occur in low numbers are fair (1.51 to 2.65 m/km) (Larimore 1957), and where absent (> 4 m/km) (Larimore 1957; Funk 1975), are poor.

Table 1. (continued).

Variable	Assumptions and sources
V_5	Clear-to-moderate turbidity levels are assumed excellent because warmouth grow best in clear water (Jenkins et al. 1955) and are often most abundant in the turbid waters characteristic of lowland lakes, backwaters, and sluggish streams (Larimore 1957; Moyle 1976; Smith 1979; Trautman 1981) or the tannin-stained waters of swamps and marshes (Germann et al. 1975). We assumed that habitat suitability for warmouth would decline at turbidities exceeding 100 JTU because: (1) Jenkins et al. (1955) found that growth was slowest in highly turbid Oklahoma ponds; (2) warmouth abundance in Illinois (Smith 1979) and Ohio (Trautman 1981) declined in areas subject to high turbidity and siltation; and (3) high turbidities would reduce the growth of aquatic vegetation favored as habitat by warmouths.
V_6	pH levels corresponding to good growth and abundance of warmouth in Georgia (4.0 to 6.5) are considered good-excellent. Levels that were lethal to largemouth bass in laboratory experiments are considered poor (≥ 10.3) (Calabrese 1969). We could not find any data specifically describing negative impacts to warmouth of pH values lower than 4.0. We arbitrarily selected a pH of 3.4 as poor suitability.
V_7	Dissolved oxygen (DO) concentrations below the critical level for long-term survival and growth (3.6 mg/l at 20° C) (Larimore 1957) are fair to poor. Concentrations corresponding to highest growth for centrarchids in general (> 6.0 mg/l) (Stewart et al. 1967) are deemed excellent for warmouth.
V_8	DO levels corresponding to low survival of largemouth and smallmouth bass embryos (< 2.0 mg/l) (Siefert et al. 1974; Eipper 1975) are poor for warmouth embryos. DO levels corresponding to highest survival and growth of smallmouth bass embryos (≥ 6.0 mg/l) (Siefert et al. 1974) are excellent.
V_9	Because warmouth frequent warm, slack water habitats favored by largemouth bass, its temperature requirements are assumed similar. Thus, temperatures corresponding to high growth, survival, and feeding in largemouth bass (~ 25 to 30° C) are excellent and those corresponding to high mortality and/or greatly reduced feeding in largemouth bass (< 15° C and > 32° C) (Hart 1952; Strawn 1961; Coutant 1975; Brungs and Jones 1977) are poor for warmouth.

Table 1. (concluded).

Variable	Assumptions and sources
V_{10}	Temperatures corresponding to high spawning activity in warmouth (21 to 27° C) (Larimore 1957) are excellent, as are optimum temperatures for incubation of largemouth bass embryos (Coutant 1977). Temperatures outside this range are considered less suitable and temperatures < 15° C are rated poor.

Interpreting Model Outputs

The riverine and lacustrine models described previously are generalized descriptors of habitat requirements of warmouth and are not expected to discriminate among different habitats with a high degree of resolution. Each model variable is considered to have some effect on either individual warmouth or warmouth populations in general, as depicted by the suitability index graphs. A major potential weakness of the models is that, while model variables may be necessary to determine suitability of a habitat for warmouth, they may not be sufficient. A relationship between HSI's generated by these models and measurable indices of population abundance (e.g., standing crop) should not be assumed, unless it has been demonstrated by testing in habitats similar to where the model will be applied.

Model outputs should be interpreted as indicators (or predictors) of excellent (0.8 to 1.0), good (0.5 to 0.7), fair (0.2 to 0.4), or poor (0.0 to 0.1) habitat for warmouth. The output of the models provided should be most useful in comparing different habitats. If two study areas have different HSI's, the one with the higher HSI is expected to have the potential to support a larger warmouth population. The models also provide the basic framework for incorporating new model hypotheses or other site-specific factors that affect habitat suitability for warmouth.

Results from testing other HSI models strongly suggest that if a study requires a prediction of population abundance, use of the HSI models presented herein may not be appropriate. The model should first be evaluated with actual field measurements to better define which variables are important predictors of population abundance in the proposed area of model application or under present or post-project conditions. Users conducting impact assessments requiring major model improvements and testing may want to concentrate on building a falsifiable model. The model should use a clearly documented chain of logic to predict a measurable (and thus falsifiable) response (e.g., survival rate) that is acceptable for judging a selected impact.

ADDITIONAL HABITAT MODELS

Descriptive Models

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

Riverine Model

Optimum riverine habitat for warmouth is characterized by the following conditions, provided water quality is not limiting: (1) warm summer temperatures (25 to 30° C); (2) ≥ 70% pool area; and (3) high amounts of aquatic vegetation or other cover present.

$$HSI = \frac{\text{number of above conditions present}}{3}$$

Lacustrine Model

Optimum lacustrine habitat for warmouth is characterized by the following conditions, provided water quality is not limiting: (1) warm summer temperatures (25 to 30° C); (2) extensive shallow littoral area; and (3) high amounts of aquatic vegetation or other cover present along the shoreline.

$$HSI = \frac{\text{number of above criteria present}}{3}$$

Reservoir Regression Model

Aggus and Morais (1979) developed regression equations to predict standing crop of sunfish in reservoirs from easily obtainable preconstruction data. They discuss procedures for converting measured or predicted standing crop values to HSI values for sunfish.

SUITABILITY INDEX GRAPHS FOR THE INSTREAM FLOW INCREMENTAL METHODOLOGY (IFIM)

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

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

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

Availability of Graphs for Use in IFIM

All the SI curves available for the IFIM analysis of warmouth riverine physical microhabitat (Table 2) can be found in the HSI model section of this report (sources and assumptions in Table 1). All of the available SI curves are derived from general statements in the literature and the professional judgement of the authors. The curves describe the general habitat suitability of a variable throughout the entire range of a species may not accurately describe small changes of a variable within a specific stream.

Warmouth generally spawn sometime between May and August, depending on locale (Carlander 1977). The SI curves for spawning habitat should be used for the defined spawning period within the selected study area. Egg incubation generally requires 1 to 2 days (Ibid) and, therefore, egg incubations curves should be used for the defined spawning period. Fry are defined as individuals less than 2.5 cm in length, and fry curves should be used for the period from the beginning to 1 month after the end of spawning. Juveniles are defined to range in length from 2.5 to 7.5 cm; and sexually mature adults are generally greater than 7.5 cm in length. Juvenile and adult habitat is required year-round.

The SI curves for percent cover and velocity suitability (V_2, V_3) are meant to be used for all life stages of warmouth. SI curves for temperature suitability are represented by V_9 and V_{10}. Curve coordinates can be taken from the curves for entry into FISHFIL. Any curves which are thought not to represent circumstances found at a given site may be modified for IFIM applications. No curves are available for depth or substrate suitability for any of the life stages, and will have to be generated by the investigator before a complete IFIM analysis can be undertaken.

Table 2. Availability of SI curves for the IFIM analyses of warmouth habitat.

	Velocity[a]	Depth	Substrate	Temperature[a]	Cover[a]
Spawning	Use SI curve for V_3.	No curve available.	No curve available.	Use SI curve for V_{10}.	Use SI curve for V_2.
Egg incubation	Use SI curve for V_3.	No curve available.	No curve available.	Use SI curve for V_{10}.	Use SI curve for V_2.
Fry	Use SI curve for V_3.	No curve available.	No curve available.	Use SI curve for V_9.	Use SI curve for V_2.
Juvenile	Use SI curve for V_3.	No curve available.	No curve available.	Use SI curve for V_9.	Use SI curve for V_2.
Adult	Use SI curve for V_3.	No curve available.	No curve available.	Use SI curve for V_9.	Use SI curve for V_2.

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

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The Suitability Index (SI) curves and graphs and Habitat Suitability Index (HSI) models presented in this report are based on a synthesis of information obtained from a review of the literature on habitat requirements of the warmouth (Lepomis gulosus). The HSI models and SI curves are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Assumptions used to transform habitat use information into an index are noted, and guidelines for application of the curves and models are described.

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