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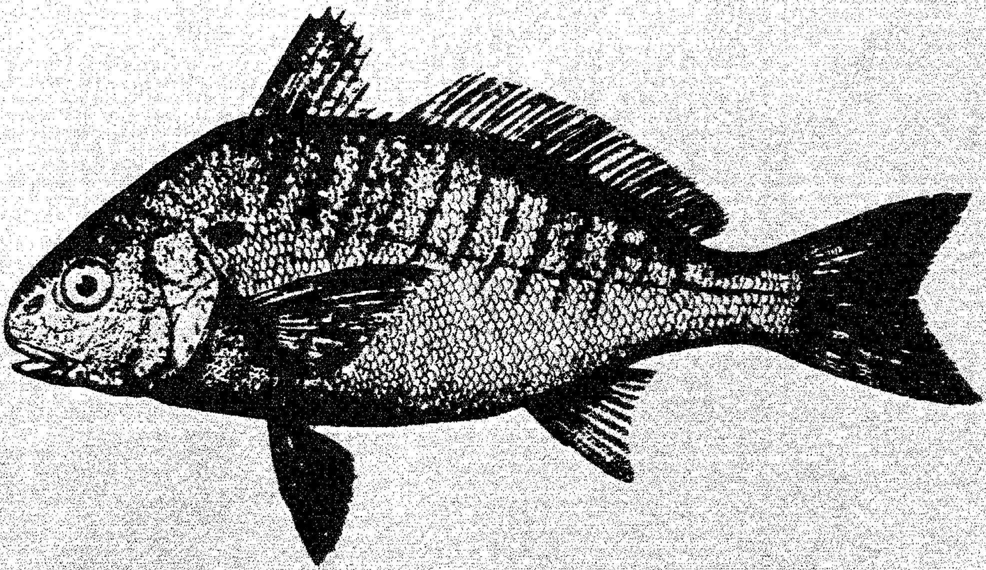
HABITAT SUITABILITY INDEX MODELS: JUVENILE SPOT



Fish and Wildlife Service

U.S. Department of the Interior

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July 1982

HABITAT SUITABILITY INDEX MODELS: JUVENILE SPOT

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PREFACE

The habitat use information and habitat suitability index (HSI) model for juvenile spot in this report is intended for use in impact assessment and habitat management. The model was developed from a review and synthesis of existing information and is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat). Assumptions used to transform habitat use information into the HSI model and guidelines for model application are described.

This model is a hypothesis of species-habitat relationships, not a statement of proven cause and effect relationships. The model has not been field-tested, but it has been applied to three sample data sets which are included. For this reason, the U.S. Fish and Wildlife Service encourages model users to convey comments and suggestions that may help increase the utility and effectiveness of this habitat-based approach to fish and wildlife management. Please send any comments or suggestions you may have on the spot HSI model to:

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CONTENTS

ACKNOWLEDGMENTS

Development of the habitat suitability index model and narrative for juvenile spot was monitored, expertly reviewed, and constructively criticized by Dr. Ronald G. Hodson, North Carolina State University, Raleigh, North Carolina, and Dr. Mark E. Chittenden, Texas A&M University, College Station, Texas. Thorough evaluations of model structure and functional relationships were provided by personnel of the U.S. Fish and Wildlife Service's National Coastal Ecosystems Team and Western Energy and Land Use Team and by Mr. John Lunz, Environmental Laboratory, U.S. Army Corps of Engineers, Vicksburg, Mississippi. Model and supportive narrative reviews were also provided by representatives of the National Marine Fisheries Service and by Regional personnel of the U.S. Fish and Wildlife Service. Finally, funding for model development and publication was provided by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

SPOT (*Leiostomus xanthurus*)

HABITAT USE INFORMATION

The spot, a demersal fish species, is a member of the drum family, Sciaenidae. Spot are abundant along the Gulf of Mexico and Atlantic coasts of the United States from Texas to New York, but they have been reported as far north as the Gulf of Maine (Bigelow and Schroeder 1953). In some areas, the spot supports sizable sport and commercial fisheries (Roithmayer 1965; Fore 1975). The spot is estuarine dependent. Adults spawn in nearshore marine waters, but juveniles spend much of their lives in estuaries.

Age, Growth, and Food

Spot usually do not live longer than 2 years of age (Joseph 1972), but a few live as long as 4 years (Welsh and Breder 1923; Sundararaj 1960). Growth is most rapid in their first year of life (Sundararaj 1960). Average total length is 110 mm by the end of their first year and ranges from 234 to 290 mm at the end of 4 years (Welsh and Breder 1923; Sundararaj 1960; Parker 1971).

Juvenile spot take bites from the bottom to obtain food (Roelofs 1954). They feed almost exclusively on benthic invertebrates; only a few eat fish. The volume of the stomach contents from 50 juvenile spot from 21 to 35 mm long was 72% ostracods and 8% copepods (Welsh and Breder 1923). Benthic copepods are an important food. Copepods were dominant in juvenile spot stomachs examined by Hildebrand and Cable (1930), Roelofs (1954), Van Engel and Joseph (1968), Stickney et al. (1975), Sheridan (1979), and Hodson et al. (1981a). Harpacticoids were the dominant copepods (Stickney et al. 1975; Sheridan 1979; Hodson et al. 1981a). Polychaetes also were important food for spot (Chao 1976; Sheridan 1979).

Migrating postlarvae spot apparently feed on microzooplankton. In one study, copepods made up 99% of the volume and weight of the stomach contents of postlarval spot (Kjelson et al. 1975).

Reproduction

Spot spawn in marine waters in winter (Hildebrand and Schroeder 1927; Hildebrand and Cable 1930; Gunter 1945; Dawson 1958). Eggs and sperm are released into the water column where the density of individuals in the spawning population may influence the percentage of eggs that are fertilized. Time required for embryo development depends on water temperature. Some adults may live to spawn twice, but the small number older than 2 years of age indicates high mortality following first spawning (Joseph 1972).

Specific Habitat Requirements

Adult. Adult spot are abundant in nearshore marine waters. They apparently do not re-enter estuaries after they have emigrated as juveniles.

Embryo. Eggs and embryos inhabit the water column of the Continental Shelf in winter.

Postlarva. Yolk sac absorption in newly hatched spot requires about 5 days at 20°C (68°F) under laboratory conditions (Powell and Gordy 1980). Thereafter, the postlarval fish have sufficiently developed mouth parts to begin feeding. Postlarval spot migrate from the marine environment into estuaries in winter and spring as water temperature and length of day increase.

Juvenile. Postlarval spot develop into juveniles in the estuary. Juvenile spot may concentrate in waters dominated by salt marshes or in river channels near the saltwater-freshwater boundary (Weinstein et at. 1980). They tend to seek waters along the marsh fringe and in tidal creeks (Weinstein 1979). Spot are common near grass beds (Orth and Heck 1980) and over muddy bottoms (Reid 1955; Parker 1971). No correlation was found between the abundance of spot and organic and sand bottom sediments (Weinstein 1979). Juveniles have been collected in waters with salinities ranging from 0 to 60 parts per thousand (ppt) (Hedgpeth 1967; Tagatz 1968; Music 1974) and over a wide temperature range (Gunter 1945; Tagatz 1968).

Juvenile spot can tolerate temperatures from 1.2° to 35.5°C (34.2° to 95.9°F) according to Parker (1971), but he concluded that they prefer a range of 6° to 20°C (42.8° to 68.0°F). The lower lethal temperature is between 4° and 5°C (39.2° to 41.0°F) according to Dawson (1958). The upper incipient lethal temperature for postlarval and juvenile spot is 35.2°C (95.4°F) according to Hodson et al. (1981b).

Juvenile spot may inhabit waters with dissolved oxygen concentrations as low as 1.3 to 5.4 mg/l (Ogren and Brusher 1977), but most prefer concentrations exceeding 5.0 mg/l. They are usually more abundant in waters 4 m (13.1 ft) deep than in waters 8 m (26.2 ft) deep in estuaries (Stickney and Miller 1974).

No information was reported on spot migration from one estuary to another following their entrance into coastal waters as postlarvae. The juveniles move into the marine habitat in fall.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model is designed to apply to juvenile spot in estuaries. The model applies to spot throughout most of its normal range, here defined as coastal waters from Galveston east in the Gulf of Mexico and the Atlantic coast north to Long Island Sound.

Season. The model deals with the estuarine phase of the spot life cycle. This phase begins with immigration of postlarvae into estuaries in winter and ends with emigration of pre-spawning adults in fall. Although spot enter estuaries as pelagic postlarvae, this phase lasts only for a short time and is not included in the model.

Cover types. The model can be applied to any estuary within the range of the species. Although some information is available to support the concept that spot prefer vegetative cover and low salinity gradients, the fish are adapted to, and live in virtually all portions of estuaries. As depth increases, the suitability of the environment appears to decrease. Most concentrate in water a few centimeters to 8 m deep.

Minimum habitat area. Minimum habitat is defined as the minimum area of contiguous suitable habitat required for a species to live and reproduce. No attempt has been made to establish a minimum habitat size for spot because they must migrate to and from spawning grounds.

Verification level. This model has not been verified in the field, but is based upon information documented in the literature. Adjustments to the model may be required after adequate field tests have been completed.

Dr. Ronald G. Hodson, North Carolina State University, Raleigh, North Carolina, and Dr. Mark E. Chittenden, Texas A&M University, College Station, Texas, monitored and evaluated development of the model.

Model Description - Estuarine

Food and water quality are the only life requisites considered in this model for spot. When specific information was unavailable, professional extrapolation of existing data was used. The relationships among habitat variables, life requisites, life stages, and HSI are in Figure 1.

Although much is known about the effects of toxins on spot survival, toxicity has not been incorporated into the model. When pollution is suspected or apparent, the concentration of pollutants in the estuary should be compared with concentrations tolerated by spot. When tolerances are unknown, further study will be required before habitat suitability can be fully determined.

Food component. Because spot commonly live over muddy bottoms (Parker 1971) in or near aquatic vegetation, sediment type is assumed to provide an index of food availability. Since Weinstein (1979) was unable to correlate spot abundance with percentage of organic matter in the sediments, the HSI model for spot includes only mean sediment grain size as an index of food availability. Sediment type rather than benthos abundance has been selected for ease and rapidity of assessment. Studies throughout spot habitat indicate that food organisms of the proper sizes usually are available.

Water quality variables. Water quality variables used for the HSI model are temperature, salinity, dissolved oxygen, and depth. The first three variables affect growth and survival, whereas depth is more a factor of abundance.

Basic Assumption

Juvenile spot optimal habitat is river-marsh estuary where the unidirectional flow of the river changes to a slowly mixing circulation. Waters are

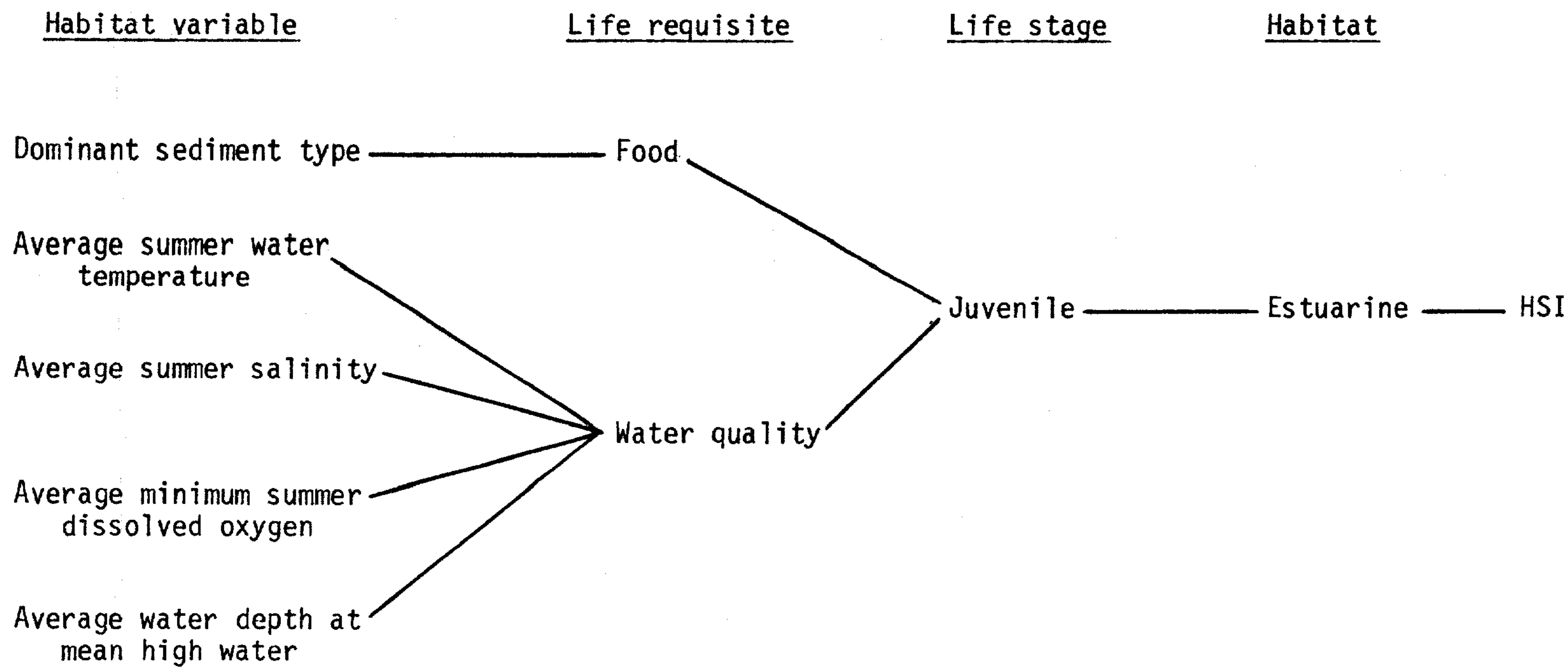
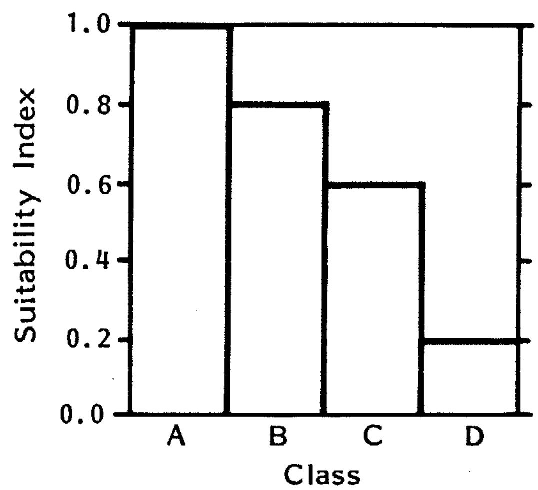
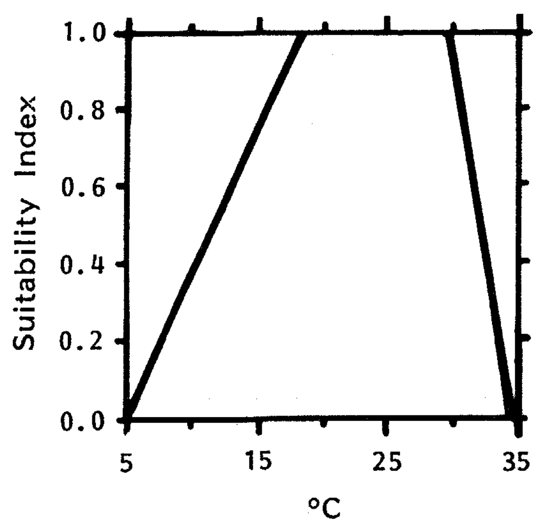


Figure 1. The relationship of habitat variables, life requisites, life stages, habitat type, and the habitat suitability index (HSI) for juvenile spot.

turbid and contain large amounts of silt coming in from the river. Bottoms are dominated by grass and filter-feeding clams, e.g., *Rangia cuneata*, in the south temperate zone and *Mya arenaria* in the northern temperate zone, with some overlap in the intermediate zones. During strong fluctuations in river flow, sudden changes in turbidity, salinity, and water temperature are common.

Suitability Index (SI) Graphs for Habitat Variables

Graphic representations of the relationships between estuarine habitat (E) variables and habitat suitability for spot are in this section. The data sources and assumptions associated with documentation of the SI graphs are shown in Table 1. Equations for relating the variables and deriving HSI follow.

Habitat	Variable		Suitability Graph
E	V_1	Dominant sediment type. A) Mud B) Fine sand C) Coarse sand D) Shell or pebble	
E	V_2	Average summer water temperature.	

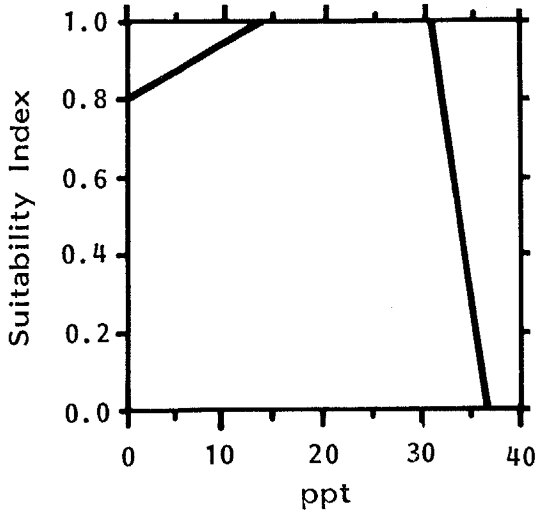
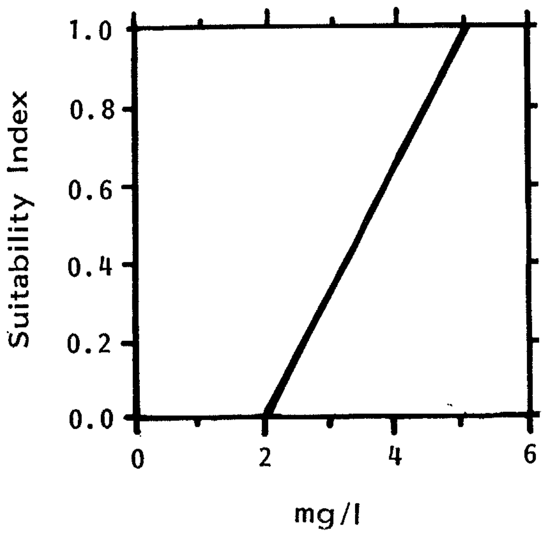
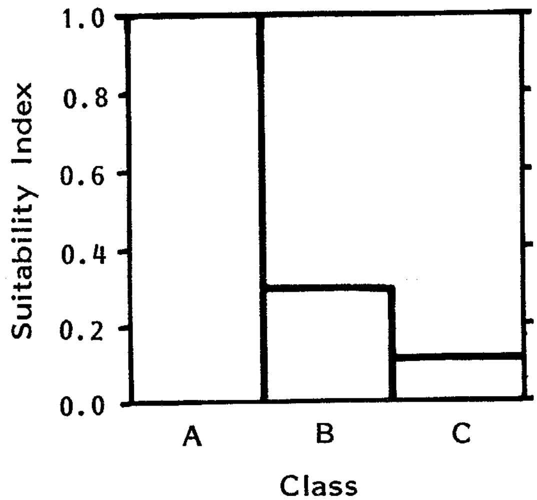
Habitat	Variable		Suitability Graph
E	V_3	Average summer salinity.	
E	V_4	Average minimum summer dissolved oxygen concentration.	
E	V_5	Average water depth at mean high water. A) 0 to 3 m B) >3 to 6 m C) >6 m	

Table 1. Data sources and assumptions for juvenile spot suitability indices.

Variable and source		Assumption
V_1	Parker 1971 Weinstein 1979	Habitats where food availability is high are optimum. Sediment type is an index of food availability.
V_2	Gunter 1945 Dawson 1958 Tagatz 1968 Parker 1971 Music 1974 Ogren and Brusher 1977	Water temperatures where spot are abundant are optimal and temperatures adequate for survival are suitable. Only extremes near 5° or 34°C are likely to be unsuitable.
V_3	Hedgpeth 1967 Tagatz 1968 Music 1974	Salinities where spot are commonly found are suitable.
V_4	Ogren and Brusher 1977 Burton et al. 1980	Sustained high concentrations of dissolved oxygen (DO) exceeding 5 mg/l are optimal for spot. Concentrations from 2 to 5 mg/l are suitable and concentrations near or less than 1.3 mg/l may be lethal. Where data are not available, another gage may be used. Waters where fish kills rarely if ever occur because of a lack of sufficient oxygen are optimal (SI=1.0); waters where fish kills are observed nearly every year are suitable (SI=0.6); waters where fish kills are relatively common every year are unsuitable (SI=0.2).
V_5	Stickney and Miller 1974 Weinstein 1979	Water depths where spot are most commonly found are suitable. These include the intertidal zone, an optimal habitat.

Equations. The SI values for the habitat variables are combined through the use of equations so that life requisite scores for spot can be obtained. The suggested equations for obtaining food and water quality values for spot are as follows:

Life requisite	Equation
Food (F)	V_1
Water quality (WQ)	V_2, V_3, V_4, or V_5, whichever is lowest.

HSI determination. The equation for determining HSI is based on the limiting factor concept which would indicate that HSI is equal to the lowest life requisite level. Sample data sets from which habitat suitability index values have been generated with the model equations are given in Table 2. The equation for spot is as follows:

HSI = F or WQ, whichever is lowest.

Table 2. Calculations of food (F) and water quality (WQ) suitability indexes (SI) and the habitat suitability index (HSI) for three sample data sets, using the spot habitat variables (V) and model equations.

Model component	Data set 1		Data set 2		Data set 3	
	Data	SI	Data	SI	Data	SI
V_1	A	1.0	A	1.0	B	0.8
V_2	22	1.0	25	1.0	30	0.9
V_3	13	1.0	18	1.0	20	1.0
V_4	4	0.65	5	1.0	6	1.0
V_5	A	1.0	B	0.3	A	1.0
F		1.0		1.0		0.8
WQ		0.65		0.3		1.0
HSI		0.65		0.3		0.8

Field Use of the Model

The simplicity of the HSI model for spot eliminates the need for extensive field sampling. One-time measurements of variables are not recommended because model reliability will depend, in part, upon having sufficient data. This is particularly apparent for water quality variables (V_2 to V_5) that are based on mean values.

The variables used in this model can be easily measured. Sediment type can be determined by visual examination of a sediment grab sample or by more elaborate means, e.g., complete grain size analysis. Temperature, salinity, and dissolved oxygen measurements should be taken near the bottom of the water column because spot are most common there. Temperature can be measured with a thermometer or thermistor. Salinity is most simply and quickly measured with a refractometer, although conductivity meters, hydrometers, and titration may give more precise readings. Dissolved oxygen can be measured by Winkler titration or with an oxygen meter. The latter often incorporates a thermistor, so temperature and dissolved oxygen can be obtained with the same instrument.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop an estuarine habitat model for juvenile spot (Leiostomus xanthurus). The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat) for estuarine areas of the continental United States. Habitat suitability indices are designed for use with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service. Guidelines for juvenile spot model applications and techniques for estimating model variables are described.

17. Document Analysis a. Descriptors

Habitability
Fishes
Estuaries

b. Identifiers/Open-Ended Terms

Habitat
Habitat Suitability Index
Spot
Leiostomus xanthurus

c. COSATI Field/Group

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