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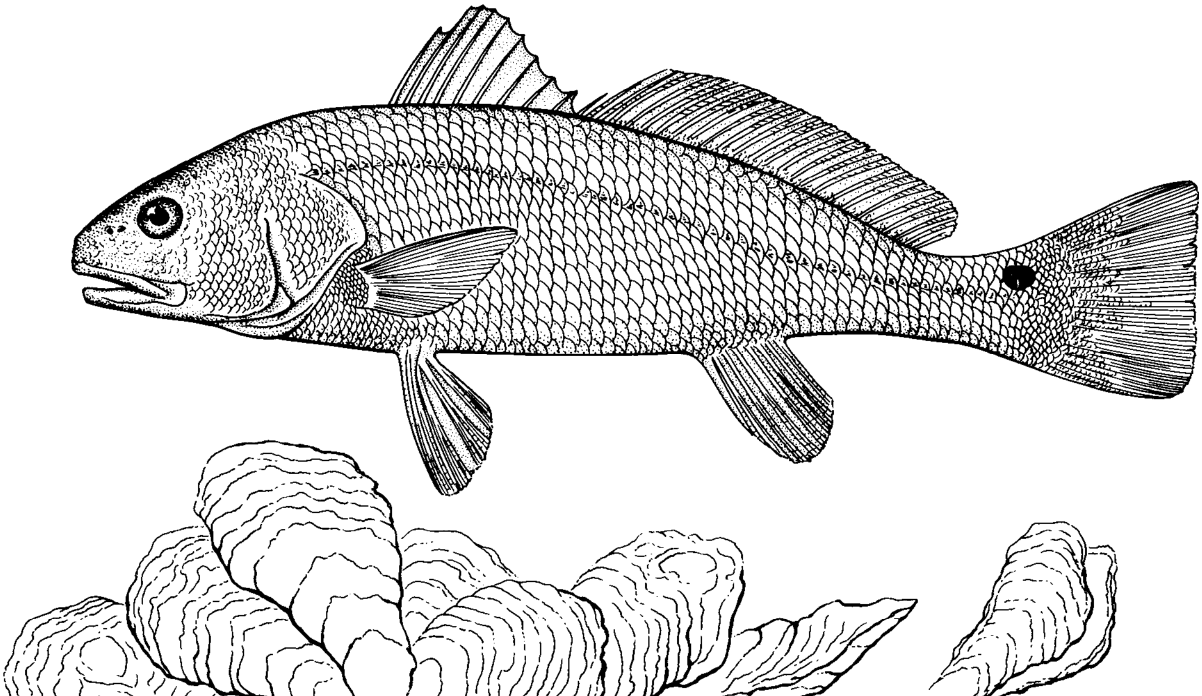
HABITAT SUITABILITY INDEX MODELS: LARVAL AND JUVENILE RED DRUM



and Wildlife Service

Department of the Interior

This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

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HABITAT SUITABILITY INDEX MODELS: LARVAL AND JUVENILE RED DRUM

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PREFACE

The habitat suitability index (HSI) model for larval and juvenile red drum is intended for use in the habitat evaluation procedures (HEP) developed by the U.S. Fish and Wildlife Service (1980) for 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 (optimal 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 relations, not a statement of proven cause and effect. The relations are the best that can be derived from the limited information available, and the model has not been field-tested. For these reasons, the U.S. Fish and Wildlife Service encourages users of the model to convey comments, suggestions, and new information that may help increase the utility and effectiveness of this approach to red drum habitat evaluation. Please send any comments or suggestions to:

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CONTENTS

ACKNOWLEDGMENTS

Development of the habitat suitability index model and narrative for larval and juvenile red drum was monitored and reviewed by Gary Matlock, Texas Parks and Wildlife Department, Austin; and J.Y. Christmas and Dr. Robin Overstreet, Gulf Coast Research Laboratory, Ocean Springs, Mississippi. Yodel structure and functional relations were evaluated by personnel of the U.S. Fish and Wildlife Service's (FWS) National Coastal Ecosystems Team. The Service's Regional personnel reviewed the model and report. The FWS funded model development and report publication. Patrick Lynch illustrated the cover.

RED DRUM (*Sciaenops ocellatus*)

INTRODUCTION

Distribution

The red drum is an estuarine-dependent species found along the Atlantic coast and in the Gulf of Mexico (Hildebrand and Schroeder 1928). Other common names for this species include redfish and channel bass. Abundance decreases with increase in latitude along the east coast, and the species is rare north of New Jersey. There have been limited successful freshwater introductions (Simmons and Breuer 1962). Relative abundance, as indicated by commercial landings, is greater in the Gulf of Mexico than along the Atlantic coast (Yokel 1966).

Red drum support an important sport and commercial fishery along the gulf coast and, to a lesser extent, along the south Atlantic coast (Matlock 1980). The estimated catch by sport fisherman in 1979 was 236,000 kg (520,000 lb) along the south Atlantic coast and 1,633,000 kg (3,593,000 lb) in the Gulf of Mexico (U.S. Department of Commerce 1981).

Life History Overview

Spawning of red drum generally begins in early fall and lasts into early winter, the time depending on location. Along the middle and south Atlantic, spawning begins in mid-August and extends to late September (Mansueti 1960). In the Gulf of Mexico, red drum spawn from the end of September through mid-November but primarily in October (Pearson 1929). Along the gulf coast, spawning takes place in nearshore waters adjacent to channels and passes (Pearson 1929). There is no specific information on the location of spawning on the Atlantic coast, although collections of larvae indicate that spawning is in habitats similar to those on the gulf coast (Mansueti 1960).

Females produce 0.5 to 3.5 million eggs, depending on size and age (Pearson 1929). Eggs are buoyant, clear, and spherical; mean diameter is 0.93 mm (range 0.86-0.98 mm) (Holt et al. 1981b).

The period from hatching to arrival in a shallow estuarine area is critical for red drum. The mechanism of transport and larval activity appears to differ between populations of the drowned river valley estuaries on the Atlantic coast and those of the barrier beach estuaries in the Gulf of Mexico. Mansueti (1960) postulated that eggs and larvae are transported by deep subsurface currents of high-density water into the Chesapeake Bay. Along the gulf coast, tidal currents transport the newly hatched larvae into bays

(Pearson 1929). Larvae sometimes swim actively during transport along the gulf coast, whereas they are passive during transport in the Chesapeake Bay (Yokel 1966). Environmental conditions adversely affecting transport can have a significant impact on an estuarine-dependent species (Nelson et al. 1977).

Larvae transform to the juvenile stage at about 40 mm (1.5 inches) total length (Tt) (Simmons and Breuer 1962). Growth is rapid during the first 2 years; the fish reach 21.5 cm (8.5 inches) TL in 6 months, 34 cm (13.5 inches) in 1 year, and 53-60 cm (21-23.6 inches) in 2 years (Pearson 1929). Growth rate varies greatly, depending on year and location. Average monthly growth rates were 18.8 mm (0.8 inches) in Louisiana (Bass and Avault 1975), and 28.0 mm (1 inch) in Texas (Simmons and Breuer 1962) . Red drum reached 9.5 kg (21 lb) in 6 years when isolated in a saltwater impoundment (Theiling and Loyacano 1976). Recruitment to the fishery begins after the first year at a total length of about 30 cm or 12 inches (Yokel 1966).

Female red drum mature at 4 or 5 years of age and males at 3 (Pearson 1929). Length at maturity ranges between 35 and 75 cm (13.75 and 29.5 inches) TL and varies with location; males mature at a smaller size than females (Perret et al. 1980). The maximum length of adult red drum probably does not exceed 160 cm (63 inches) TL (Welsh and Breder 1924). Adult red drum are most frequently found in nearshore marine waters, where they travel in large schools. Fish occasionally move far offshore, but there is no specific information available on timing, duration, or extent of these movements. Some adults move into bays in spring, but after their first spawning, red drum spend less time in the estuary (Yokel 1966). During spring and summer, small adults that have entered estuaries and large juveniles are found along the marsh perimeter in water less than 2 m (6.5 ft) deep (Benson 1982). In Texas and Florida, tagged fish showed little interbay or bay-to-gulf movement, suggesting that localized populations inhabit each bay (Simmons and Breuer 1962). In contrast, a tagging study in Mississippi indicated that large adults migrated extensively (Overstreet 1983). Along the Atlantic coast, Welsh and Breder (1924) described a northward migration of fish from southern waters to the coast of New Jersey.

SPECIFIC HABITAT REQUIREMENTS

Adult/Spawning

Adults are euryhaline, but Simmons and Breuer (1962) found them to be most abundant at salinities of 30-55 parts per thousand (ppt). They reported that the species had been successfully transplanted into freshwater. Adults are also eurythermal, having been observed in water from 2“ to 33" C (35.6' to 91.5' F) (Simmons and Breuer 1962). Drastic environmental changes, particularly a rapid reduction in water temperature, can cause mortalities (Gunter 1941; Gunter and Hildebrand 1951). The rate of temperature change is more important than the lowest temperature reached.

In laboratory studies, temperature appeared to be critical to spawning success. Holt et al. (1981a) found that red drum spawned at temperatures of

22°-30° C (71.5°-86° F); optimal temperatures were 22°-25° C (71.5°-77° F). They postulated that an early reduction in nearshore water temperature could adversely affect year-class strength.

Egg

Salinity is an important factor in hatching success. Red drum eggs float at salinities greater than 25 ppt and sink at lower salinities (Holt et al. 1981a). Sinking could lead to clumping, respiratory stress, and increased mortality. A reduction in nearshore salinity immediately after spawning could severely reduce hatching success. The temperature and salinity for hatching were optimal at 25" C (77" F) and 30 ppt, and poorest at 30" C (86° F) and 15 ppt (Holt et al. 1981a). Eggs hatch 28-29 h after fertilization at 23°-24° C (73°-75° F) (Holt et al. 1981b).

Larva

Red drum larvae occupy either vegetated or unvegetated bottoms in estuaries. In Texas, larvae rest among submerged aquatic vegetation in shallow areas with muddy bottoms until they begin swimming actively (Miles 1950). Vegetation provides protection from predation and tidal displacement (Miles 1950; Holt et al. 1983). Red drum larvae are associated with shoalgrass (Halodule wrightii) and widgeongrass (Ruppia maritima) in Texas and South Carolina (Miles 1951; Holt et al. 1983). Louisiana has many shallow, quiet bays (<3 m [9.8 ft] deep) with little or no submerged vegetation that serve as nurseries for larval and juvenile red drum (Bass and Avault 1975; Dr. William Herke, Louisiana State University, Baton Rouge, unpublished data from Sabine National Wildlife Refuge). These areas are typically fringed with marsh, have little current, have soft or hard bottom, are turbid, and are connected with estuaries.

Both temperature and salinity are important during the first 24 h after hatching; Holt et al. 1981a reported that the optimum conditions for 24-h survival were 25" C (77" F) and 30 ppt. Salinity did not affect growth and, though important in hatching and 24-h survival, was not a factor in survival at 2 weeks. Temperature becomes a more important factor as larvae develop. Holt et al. (1981a) found that temperatures below 25° C (77" F) resulted in reduced larval survival at 2 weeks. Temperature had a pronounced effect on larval growth rate; growth was much faster at 25" or 30" C (77" or 86" F) than at lower temperatures. At water temperatures below 20" C (68" F), Holt et al. (1981a) suggested, red drum may be unable to make the transition to active feeding--a critical period in fish development (May 1974; Vladimirov 1974). (Larval red drum feed on copepods and copepod naaplii [Boothby and Avault 19711).

Juvenile

For the first year, juveniles live in protected water with little wave action; in Texas they avoid current and prefer grassy clumps or muddy bottoms (Simmons and Breuer 1962). In Louisiana estuaries, where submerged vegetation is uncommon, the fish use shallow, unvegetated, quiet bays (Bass and Avault

1975). At the end of the first year, they move into deeper bays or marine littoral areas during cold weather (Pearson 1929); in spring, they move back into the estuary. While in the estuary, older juveniles are found along or in marshes at depths less than 2 m (6.5 ft). Progressively more time is spent in marine areas as red drum mature (Yokel 1966).

Young red drum are both euryhaline and eurythermal. They have been found at salinities of 0 to 50 ppt and water temperatures of 13" to 28" C (55.4" to 82.4' F) (Perret et al. 1980). Red drum can acclimate to freshwater in 3 h (Lasswell 1977). Rapid declines in water temperature can cause mortality (Gunter 1941).

Juvenile red drum between 40 and 50 mm TL (1.5 and '2 inches) feed on mysid shrimp and amphipods; thereafter penaeid shrimp, blue crabs (Callinectes sapidus), and fish are the major foods (Bass and Avault 1975). Adult red drum are usually indiscriminate predators, feeding on shrimp, crabs, and fish (Boothby and Avault 1971; Overstreet and Heard 1978).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability and Verification Level

This habitat suitability index model is designed for use throughout the red drum's range. It is applicable in the estuarine subtidal habitat classes of Cowardin et al. (1979). The model does not address marine habitat use. It can be applied to assess habitat suitability for the larval or juvenile life stage or both. Because adults are highly mobile and tolerate a wide range of environmental conditions, no model was developed for this life stage. Since habitat variables have been derived from research on Gulf of Mexico populations of red drum, the model should be applied only with caution in Atlantic coast habitats. Although general relations would be the same, some modification of habitat variables may be necessary. The model is intended for year-round use, but some habitat variables apply only to the season when specific life stages are present.

The HSI models produce an index from 0 to 1.0, which is assumed to be related to the ability of specific habitats to support a population of red drum. An index value of 1.0 represents optimal habitat and decreasing values represent less suitable habitat. The models were reviewed by Gary Matlock, Texas Parks and Wildlife Department, Austin, and by J. Y. Christmas and Dr. Robin Overstreet, Gulf Coast Research Laboratory, Ocean Springs, Mississippi. Although their suggestions were incorporated when feasible, the author is responsible for the final versions of the models. The models have not been field tested.

Model Description

Two models were developed for larval and juvenile red drum; one is designed for use in estuaries with naturally vegetated substrates and the other for use in estuaries that cannot support bottom vegetation because of natural factors such as high turbidity. Water quality, food, and cover life requisites are included in the models. The habitat variables, either individually or in combination, define the life requisite. The relations among life requisites, habitat variables, and the HSI are shown in Figure 1.

Water quality. Water quality affects habitat suitability in both models and i-defined by water temperature and salinity during the larval development period. It is assumed that a mean temperature below 15" C (59" F) is unsuitable for larval red drum and that 25°-30° C (77°-86° F) is optimal (V_1). Mean salinity levels below 10 ppt are unsuitable, and optimal salinity conditions are assumed to be 25-30 ppt (V_2). Although V_1 and V_2 are important only to larvae (since the juveniles tolerate a wide temperature and salinity range), larval and juvenile life stages are combined to calculate the estuarine HSI.

Food and cover. In both models, it is assumed that food availability is a function of estuarine productivity and that the amount of intertidal wetlands is related to productivity, Although the optimum ratios of wetland to open water are unknown, it is assumed that red drum food abundance increases as the percentage of open water edge fringed with intertidal wetlands increases (V_3). Intertidal wetland is defined for these models as an estuarine area vegetated with persistent emergent species such as Spartina spp. and Juncus spp. Estuaries in the eastern gulf, along the middle and south Texas coast, and on the Atlantic coast have suitable water clarity and substrate for the growth of submerged vegetation. In these estuaries, water depth is of little importance in providing cover. The percentage of substrate that supports growth of submerged vegetation (V_4) is assumed to interact with V_3 to determine suitability of the food and cover component. Because open water over nonvegetated substrate is important for feeding, habitat suitability is assumed to decrease as cover of submerged vegetation exceeds 75%.

Along the Louisiana coast, estuaries have little submerged vegetation. for estuaries with naturally unvegetated bottoms, the food and cover life requisites for red drum are considered separately (Figure 1). Food quality is assumed to be determined by the percentage of open water edge fringed with wetlands (V_3) alone. Substrate composition and mean depth define cover suitability. In the model, substrate (V_5) is classified as five types: mud, fine sand, coarse sand, rock, and shell. Over this range of substrates, mud represents the optimal and shell the least suitable habitat. Mean depth (V_6) of 1.5-2.5 m (4.9-8.2 ft) at low tide is considered optimum.

Suitability Index (SI) Graphs for Habitat Variables

Graphic representations of the relation between habitat variables and habitat suitability are shown in the following section. All variables are associated with estuarine (E) habitat. The data sources and assumptions associated with documentation of suitability index graphs are shown in Table 1.

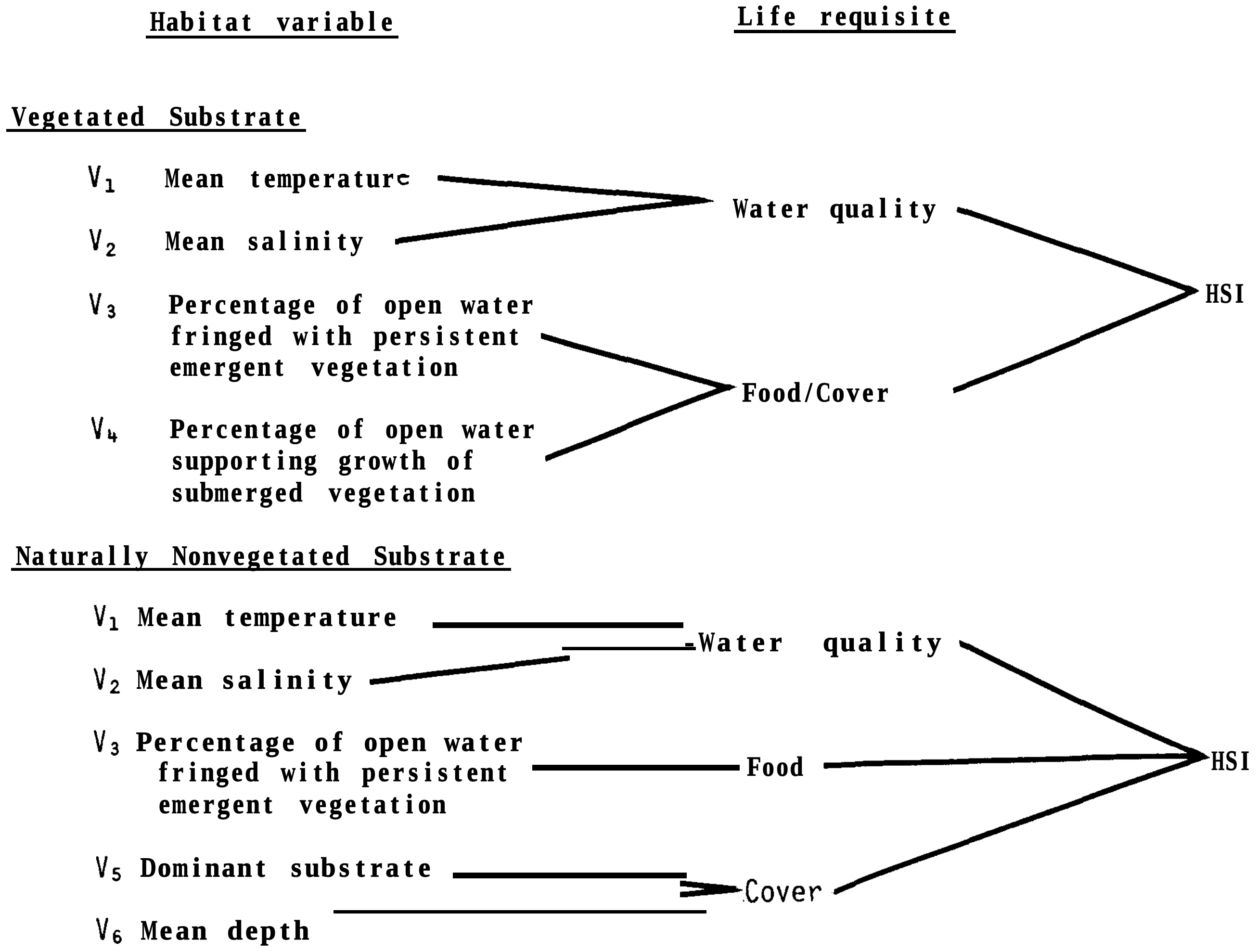
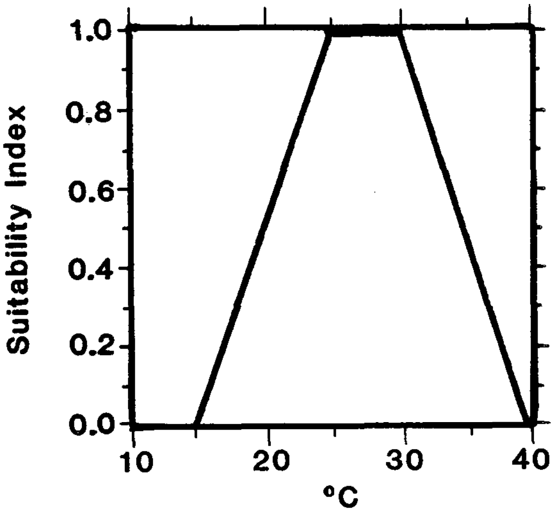
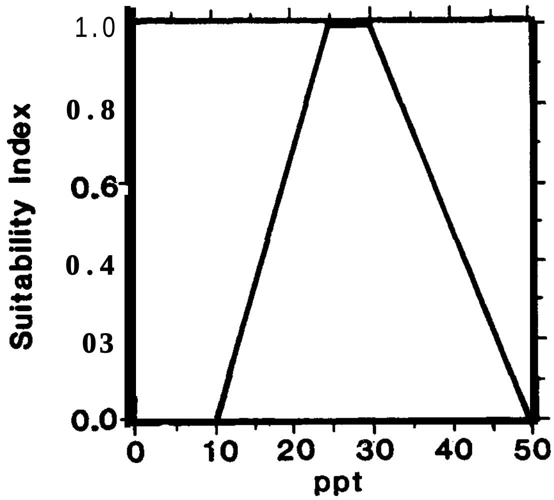
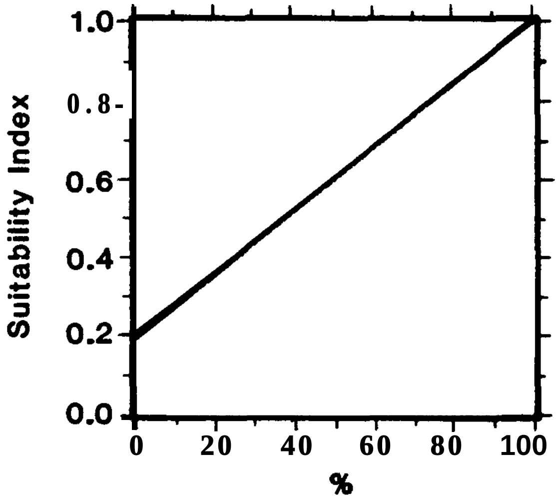
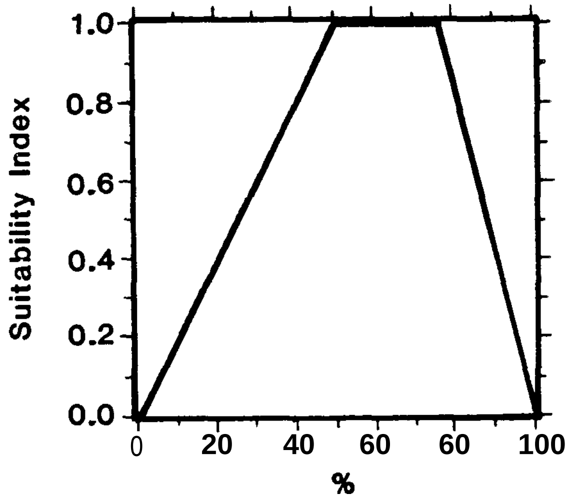


Figure 1. The relations of habitat variables and life requisites to the habitat suitability index for larval and juvenile red drum in estuarine habitat with vegetated and naturally nonvegetated substrate.

Habitat	Variable		Suitability Graph
E	V_1	Mean water temperature during period of larval development.	
	V_2	Mean salinity during period of larval development.	
	V_3	Percentage of open water edge fringed with persistent emergent vegetation.	

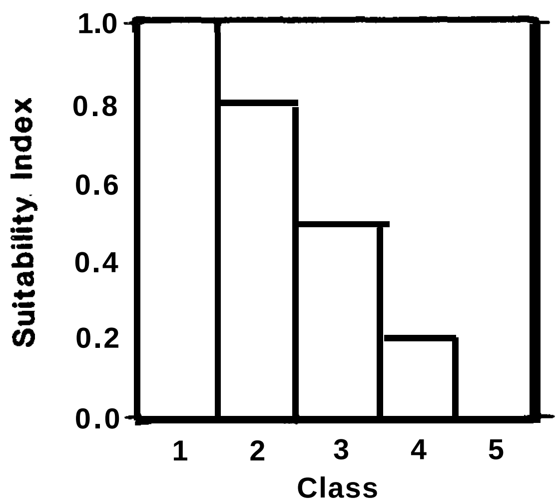
Habitat **Variable** **Suitability Graph**

E V_4 Percentage of area covered by submerged vegetation.



V_5 Substrate composition.

(1) Mud
(2) Fine sand
(3) Coarse sand
(4) Rock
(5) Shell



V_6 Mean depth of estuarine open water area at low tide.

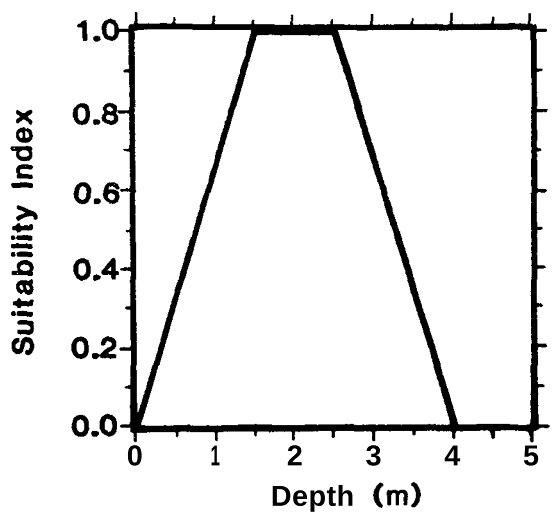


Table 1. Data sources and assumptions for red drum suitability indexes.

	Variable and source	Assumptions
V_1	Holt et al. 1981a Holt et al. 1981b	Temperature associated with highest survival is optimum.
V_2	Holt et al. 1981a Holt et al. 1981b	Salinity associated with highest survival rate is optimum.
V_3	Yokel 1966 Turner 1977 Bahr et al. 1982	Intertidal wetlands are related to productivity and loss of wetlands results in a reduction in carrying capacity.
V_4	Pearson 1929 Miles 1950 Simmons and Breuer 1962 Weinstein 1979 Holt et al. 1983	Submerged vegetation provides cover, but some unvegetated bottom is necessary for feeding by larval and juvenile red drum.
V_5	Miles 1950 Simmons and Breuer 1962 Holt et al. 1983	Red drum larvae and juveniles prefer mud substrate over sand and rock; shell is unsuitable.
V_6	Bass and Avault 1975 Dr. William Herke, Louisiana State Univ. (unpublished data)	Larvae and juveniles prefer water depths of 1.5-2.5 m in naturally unvegetated bottoms.

Component Index and Habitat Suitability Index Equations

The following equations are suggested for combining habitat variables to obtain component index and HSI values for larval and juvenile red drum.

Estuaries with submerged vegetation.

Component	Equation
Water Quality (WQ)	$(SI_{V_1}^{2} \times SI_{V_2})^{1/3}$
Food/Cover (FC)	$(SI_{V_3} \times SI_{V_4})^{1/2}$

HSI = WQ or FC, whichever is lower

Estuaries with little or no submerged vegetation.

Component	Equation
Water Quality (WQ)	$(SI_{V_1}^{\ 2} \times SI_{V_2})^{1/3}$
Food (F)	SI_{V_3}
Cover (C)	$(SI_{V_5} \times SI_{V_6})^{1/2}$

HSI = WQ, F, or C, whichever is lowest

Hypothetical data sets (Tables 2 and 3) were used to calculate component and HSI values for larval and juvenile red drum. The resulting HSI values are believed to reflect the relative potential of these habitats to support red drum.

Table 2. Calculations of water quality (WQ) and food and cover (FC) component indices and the habitat suitability index (HSI) for three sample data sets for larval and juvenile red drum from an estuary with submerged vegetation.

Model component	Data set 1		Data set 2		Data set 3	
	Data	SI	Data	SI	Data	SI
V_1	16" C	0.1	25" c	1.0	22" c	0.7
V_2	26 ppt	1.0	30 ppt	1.0	35 ppt	0.75
V_3	10%	0.28	90%	0.92	50%	0.6
V_4	15%	0.3	50%	1.0	80%	0.8
V_5						
V_6						
WQ	0.22		1.0		0.72	
FC	0.29		0.96		0.69	
HSI	0.22		0.96		0.69	

Table 3. Calculations of water quality (WQ), food (F), and cover (C) component indices and the habitat suitability index (HSI) for three sample data sets for larval and juvenile red drum from an estuary with little or no submerged vegetation. Numbers in parentheses indicate substrate composition class.

Model component	Data set 1		Data set 2		Data set 3	
	Data	SI	Data	SI	Data	SI
V_1	16" C	0.1	25" C	1.0	22" c	0.7
V_2	26 ppt	1.0	30 ppt	1.0	35 ppt	0.75
V_3	10%	0.28	90%	0.92	50%	0.6
V_4						
V_5	(4)	0.2	(1)	1.0	(3)	0.5
V_6	0.3 m	0.2	1.5 m	1.0	2.5 m	1.0
WQ	0.22		1.0		0.72	
F	0.28		0.92		0.6	
C	0.2		1.0		0.71	
HSI	0.2		0.92		0.6	

Field Use of Models

Information required for use of this model may be available from published reports. Table 4 lists techniques suggested for obtaining information necessary to use suitability graphs.

It may be prudent to alter the HSI model structure for some field applications. As noted previously, the water quality component is assumed to affect the larval life stage alone. Because red drum can disperse to new habitat after metamorphosis to the juvenile stage, water quality should not influence habitat suitability in areas believed to be used by post-larval stages only. In such areas, the water quality component is dropped from the HSI equations presented above.

Table 4. Suggested methods for field measurement of variables in the red drum HSI model.

Variable	Method
V_1 Mean temperature	Existing data or field sampling with a thermometer,
V_2 Mean salinity	Existing data or field sampling with a refractometer or salinity meter.
V_3 Percentage of open water fringed with persistent emergent vegetation	Calculate by using aerial photographs, existing maps, or LANDSAT imagery (Short 1982).
V_4 Percentage of submerged vegetation	Calculate by using same methods suggested for V_3.
V_5 Dominant substrate	A core sampler or several types of dredges can be used (Edmondson and Winberg 1971).
V_6 Depth	Charts, depth finder, or sounding.

Interpreting Model Outputs

The red drum HSI represents the potential of a habitat to support fish of this species. Because actual abundance may be determined by many nonhabitat factors excluded from this model, there may be no correlation between model output and red drun population numbers. The sound use of the HSI consists of comparison of habitat potential of a single area at different points in time or of different areas at a single point in time.

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16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a habitat model for larval and juvenile red drum. The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat) for estuarine areas along the Gulf of Mexico and Atlantic coasts. Habitat suitability indices are designed for use with habitat evaluation procedures developed by the U.S. Fish and Wildlife Service. Guidelines for model application and techniques for estimating model variables are provided.

17. Document Analysis a. Descriptors

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Sciaenops ocellatus

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