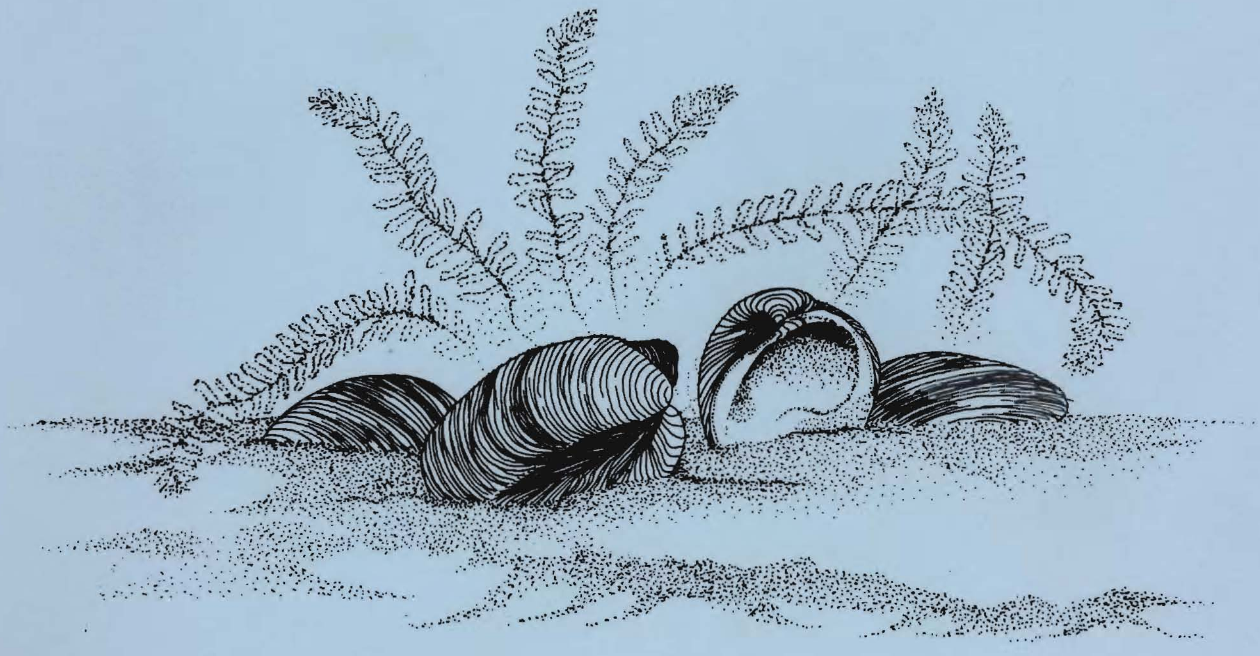
FWS/OBS-82/10.77
AUGUST 1984

HABITAT SUITABILITY INDEX MODELS: HARD CLAM



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.

MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. It is impossible, however, to develop a model that performs equally well in all situations. Each model is published individually to facilitate updating and reprinting as new information becomes available. Assistance from users and researchers is an important part of the model improvement process. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
1010 Gause Boulevard
Slidell, LA 70458

Thank you for your assistance.

Species______________ Geographic Location ____

Habitat or Cover Type(s)____

Type of Application: Impact Analysis_____ Management Action Analysis__________
Baseline______ Other____

Variables Measured or Evaluated____
____
____
____

Was the species information useful and accurate? Yes___ No___

If not, what corrections or improvements are needed?_________________________
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____
____

Were the variables and curves clearly defined and useful? Yes_____ No_____

If not, how were or could they be improved?________________________________
____
____
____

Were the techniques suggested for collection of field data:
Appropriate? Yes____ No____
Clearly defined? Yes____ No____
Easily applied? Yes____ No____

If not, what other data collection techniques are needed?____________________
____
____
____

Were the model equations logical? Yes____ No____
Appropriate? Yes____ No____

How were or could they be improved?____
____
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Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information)______________________________
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Additional references or information that should be included in the model:
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Model Evaluator or Reviewer_______________________ Date______________________

Agency____

Address____
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Telephone Number Comm:__________________ FTS_________________________

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August 1984

HABITAT SUITABILITY INDEX MODELS:
HARD CLAM

by

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PREFACE

The habitat suitability index (HSI) model in this report on the hard clam 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 (optimally suitable habitat). Assumptions involved in developing the HSI model and guidelines for model applications, including methods for measuring model variables, are described.

This model is a hypothesis of species-habitat relationships, not a statement of proven cause and effect. The model has not been field-tested. 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 and suggestions you may have on the HSI model to the following address.

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1010 Gause Boulevard
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CONTENTS

ACKNOWLEDGMENTS

Development of the habitat suitability index model for the hard clam was reviewed and constructively criticized by Dr. R. Winston Menzel, Oceanography Department, Florida State University, Tallahassee; and Dr. John J. Manzi, Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department, Charleston. Thorough evaluations of model structure and functional relationships were provided by personnel of the U.S. Fish and Wildlife Service's (FWS) National Coastal Ecosystems Team (NCET). Michael S. Brody served as project officer at NCET. Supportive narrative and model reviews also were provided by Regional personnel of the U.S. Fish and Wildlife Service and the Florida Department of Natural Resources. Funding for model development and publication was provided by the FWS. The cover illustration was prepared by David S. Maehr, Florida Game and Fresh Water Fish Commission.

HARD CLAM (Mercenaria campechiensis, Mercenaria mercenaria)

INTRODUCTION

Two species of hard clams occur along the Atlantic and Gulf of Mexico coasts of North America: the southern hard clam, Mercenaria campechiensis Gmelin 1791, and the northern hard clam, Mercenaria mercenaria Linne 1758 (Wells 1957b). The latter species, also commonly known as the quahog, was formerly named Venus mercenaria. The two species are closely related, produce viable hybrids (Menzel and Menzel 1965), and may be a single species.

Throughout their ranges, hard clams support extensive commercial and recreational fisheries (Ritchie 1977). Additionally, because adult clams are sedentary, they may serve as biological indicators of changing environmental conditions.

Distribution

Mercenaria mercenaria is found in intertidal and subtidal areas along the Atlantic and gulf coasts. Its range extends from the Gulf of St. Lawrence to Texas (Belding 1912; Johnson 1934; Abbott 1954, 1974), but it is most abundant from Massachusetts to Virginia (Stanley and DeWitt 1983). Mercenaria campechiensis ranges from New Jersey (Merrill and Ropes 1967) to St. Lucie Inlet, Florida (Godcharles and Jaap 1973) along the Atlantic coast, and from Florida to Texas in the Gulf of Mexico (Ladd 1951).

Life History Overview

Spawning. Hard clams spawn from spring to fall depending on latitude and temperature (Stanley and DeWitt 1983). In northwest Florida, the spawning period extends over at least 6 months and has a peak in the spring and a smaller peak in the fall (R. W. Menzel, Florida State University, Tallahassee; pers. comm.). In more northern latitudes, clams spawn from May to August (Stanley and DeWitt 1983). Not all clams in a given population spawn at the same time (Loosanoff 1937); rather, spawning is spread over a period of 8 to 10 weeks (Ansell 1967a). Water temperature is the determining factor in final maturation of the gametes. When stimulated by the appropriate temperature, males release semen containing pheromones. Water currents transport the pheromones to the females, which are in turn stimulated to release eggs (Nelson and Haskin 1949). Fertilization occurs in the water column. Carriker (1961) found that spawning occurred more frequently during neap than spring tides and suggested that the higher temperatures during neap tides triggered spawning. Bayne (1976) reported that M. mercenaria usually spawned at or just after low tide, which was coincident with maximum daily water temperature.

For *M. mercenaria* in Great South Bay, New York, Bricelj and Malouf (1980) noted a significant correlation between size (length) and egg production; 15% to 25% of the variation in fecundity was attributable to differences in clam size. The estimated maximum production for one female during a single spawning season was 16.8 million eggs. The sex ratio was about 1:1. There was no evidence of a decline in egg production with increasing age.

Egg. When first discharged by the female, the planktonic eggs of *M. mercenaria* appear grayish and granular (Carriker 1961). Kraeuter et al. (1982) found that survival was higher among large eggs (44 µm) than among small ones (25 µm). Eggs of hard clams differ from those of some other lamellibranchs in being surrounded by a thick gelatinous membrane (Loosanoff and Davis 1950). The fertilized egg reaches the two-celled stage in about 45 minutes and the four-celled stage in about 90 minutes. At 22°C (72°F), the trochophore stage is reached about 12 hours after fertilization (Loosanoff and Davis 1950).

Larva. The pear-shaped trochophores actively propel themselves through the water with a strongly ciliated velum (Loosanoff and Davis 1950). The trochophore begins to form a primitive mouth and develop a shell gland. It continues its planktonic existence after entering the shelled veliger stage, which consists of two forms: straight-hinged and umboned. In the straight-hinged phase a small thin shell secreted by the shell gland covers the entire animal. The highly developed velum enables the larva to become a proficient swimmer. The straight-hinged veliger phase lasts 1 to 3 days. The veliger then enters the umboned veliger phase, characterized by a gently sloping umbone projecting above the middle of the hinge line (Carriker 1961). After 6 to 20 days the veliger reaches the pediveliger stage, in which it has a foot and alternates between swimming in the water and crawling on the bottom. This stage terminates when the velum is lost. The pediveliger then enters the plantigrade benthic stages, and locomotion is limited to crawling on the bottom. Initially the larva becomes a byssal plantigrade and affixes itself to the substrate with a byssus. This is the setting or spatting stage. For a number of weeks, until the clam is about 9 mm (0.4 inches) long, the byssal plantigrade alternates between byssal attachment and crawling. The larva next enters the juvenile plantigrade stage, when the byssus gland is no longer functional and the byssus is lost; the clam then maintains its position beneath the sediment surface by means of its foot. The siphons are fully developed at this stage (Carriker 1961). The juveniles continue to grow and, as their siphons lengthen, they burrow deeper into the sediment and complete their development (Carriker 1956). The adult clam remains in much the same location for the rest of its life (Belding 1911). Chestnut (1952) reported that adult clams moved up to 15 cm (6 inches) laterally in 38 days, and Kerswill (1941) observed movements of up to 30 cm (12 inches) in 2 months.

Juvenile and adult. *M. mercenaria* secrete shell material daily and grow rapidly (Kennish and Loveland 1980). However, growth begins to slow at age 2 (Carriker 1961; Rhoads and Pannella 1970), when energy is diverted into reproductive processes (Kennish and Loveland 1980).

Recruitment throughout the range of the two species of *Mercenaria* is erratic and unpredictable (Hibbert 1976; Menzel 1976). It is probably determined by the amount of predation occurring after the juveniles settle (Menzel 1976). A major predator of small clams is the blue crab, *Callinectes sapidus* (Haven and Andrews 1957; Menzel and Sims 1962; Castagna 1970a,1970b; Castagna and Kraeuter 1977). Other major predators are whelks, *Busycon* spp.; moon snails, *Polinices duplicatus*; and stone crabs, *Menipe mercenaria* (Menzel et al. 1976).

SPECIFIC HABITAT REQUIREMENTS

Embryo, Larva, Juvenile

pH. Calabrese (1972) observed that the successful recruitment of *M. mercenaria* requires that the pH of estuarine waters not fall below 7.0; he found no significant decrease in the number of clam embryos developing normally within the pH range of 7.0-8.75, but that number was greatly reduced at pH 9.0. Survival of clam larvae was normal at pH 6.25-8.75, but the range for normal growth was 6.75-8.50. Although clam larvae can survive at pH 6.25, a pH of 7.0 is required for normal development of the embryo. Levels of pH below 7.0 limit recruitment of the species (Calabrese 1972).

Dissolved oxygen. Morrison (1971) found that growth of shelled veligers of *M. mercenaria* was normal when dissolved oxygen concentration was 4.2 mg/l or greater. Growth essentially ceased at concentrations of 2.4 mg/l and less. Larvae survived extended exposures (14 days) to 1 mg/l dissolved oxygen but grew little. Prolonged exposure to levels of less than 4.0 mg/l lengthened the clam's planktonic stage and decreased its probability of survival. Embryos developed normally at oxygen levels as low as 0.5 mg/l; however, 100% mortality occurred at 0.2 mg/l.

Salinity. Salinity appears to be most critical for *M. mercenaria* during the egg and larval stages (Stanley and DeWitt 1983). At Long Island Sound, New York, eggs developed into straight-hinged veligers only within the relatively narrow salinity range of 20.0 to 32.5 parts per thousand (ppt). The optimum for development of clam eggs was about 26.5 to 27.5 ppt (Davis 1958). Growth of larvae, once they attained the straight-hinged stage, was comparatively good at salinities as low as 20 ppt (Davis 1958), but Chanley (1958) found that growth of juvenile *M. mercenaria* was retarded at salinities of 22.5 ppt or lower. Castagna and Chanley (1973) found that metamorphosis of *M. mercenaria* from veliger to seed clam (byssal plantigrade stage) was inhibited below 17.5 to 20 ppt.

Temperature. Davis and Calabrese (1964) noted that laboratory-reared straight-hinged veligers of *M. mercenaria* were capable of ingestion, but not digestion, at 10°C (50°F), and consequently did not grow. Growth was positively related to temperature at 18.0° to 30.0°C (64° to 86°F). Growth of straight-hinged veligers of *M. mercenaria* was little affected by temperature differences within the range of 20° to 30°C (68° to 86°F). Although the optimum temperature for growth of *M. mercenaria* larvae was not well defined, growth was optimum at the following temperature/salinity combinations: 30°C (86°F)/22.5 ppt and higher, 27.5°C (81.5°F)/17.5 and 20.0 ppt, and 25°C (77°F)/15.0 ppt. The larvae appeared to be more sensitive to differences in salinity than to differences in temperature (Davis and Calabrese 1964). Kennedy et al. (1974) observed that temperature tolerance increased with age; cleavage stages were the most sensitive to high temperatures and straight-hinged larvae the least sensitive.

Substrate. The nature of the bottom substrate seems to be the main factor responsible for settling of larvae and for the qualitative composition of bottom communities (Thorson 1955). Keck et al. (1974) reported from laboratory studies that significantly higher ($P \leqslant 0.05$) numbers of *M. mercenaria* larvae set in sand than in mud; they suggested that the addition of organic material to the sediment may be responsible for reduced setting because of increased bacteria levels, reduced dissolved oxygen, and increased production of hydrogen sulfide. Carriker (1959) recommended that the substrate be firm and free of excessive organic mud for larval clam culture; muddy bottoms can be surfaced with shells, sand, or gravel.

Suspended solids. Suspended solids affect both the eggs and larvae of hard clams. Davis (1960) found that clam eggs did not develop normally at silt concentrations of 3.0 or 4.0 g/l. Growth of straight-hinged veligers was normal at a silt concentration of 0.75 g/l, retarded at 1.0 to 2.0 g/l, and negligible at 3.0 and 4.0 g/l.

Adult

pH. In mortality experiments with adult *M. mercenaria*, Calabrese (1972) observed that the pH of tidal estuarine waters should not fall below 7.0 even though larvae can survive at lower pH levels. The species could not reproduce successfully in waters where pH remained appreciably above 9.0 since at pH 9.50 to 9.75 there was virtually no development of embryos.

Dissolved oxygen. Fluctuations in dissolved oxygen do not affect hard clams as much as do fluctuations in temperature and salinity (Stanley and DeWitt 1983). The burrowing ability of *M. mercenaria* was neither severely nor permanently impaired by exposure to reduced oxygen levels (less than 1 mg/l seawater) for up to 3 weeks (Savage 1976). Pratt and Campbell (1956) found no correlation between growth rates and various concentrations of dissolved oxygen. All life stages tolerate nearly anoxic conditions for long periods, though they may cease growing (Stanley and DeWitt 1983). Greenfield and Crenshaw (1981) reported that *M. mercenaria* has evolved several metabolic responses to anoxia; the type of response depends on the length of exposure.

Salinity. The effects of salinity and temperature on clams are difficult to interpret because of the interaction between these two factors. Woodburn (1961, 1962) reported that near oceanic salinity (35 to 36 ppt) was best for *M. campechiensis* and recommended 20 ppt as a minimum level. The experimentally determined nonlethal minimum salinity for adult *M. mercenaria* was 12.5 ppt (Castagna and Chanley 1973). The range of salinities at a northwest Florida site supporting both species was 26 to 35 ppt (Menzel 1961). Menzel and Sims (1962) recommend a salinity in excess of 25 ppt for

M. mercenaria plantings in Florida. Adult hard clams are capable of withstanding low salinity by closing their shells. In South Carolina, M. mercenaria mortality was less than 5% during 2- and 3-week periods when salinity was less than 10 ppt (Burrell 1977). In the laboratory, Pearse (1936) found that adult M. mercenaria could survive for 114 hours in freshwater.

Temperature. The Joint Subcommittee on Aquaculture (1983) reported that hard clam gonadal development begins at 8° to 10°C (46° to 50°F), spawning occurs between 22° and 28°C (72° and 82°F), and that growth continues between 8° and 28°C (46° and 82°F). Kennish and Olsson (1975) reported 21° to 25°C (70° to 77°F) as the preferred or required temperature range for spawning of M. mercenaria in Barnegat Bay, New Jersey. Carriker (1961) reported spawning at temperatures of 22° to 30°C (72° to 86°F) in New Jersey, and Mitchell (1974) reported spawning at 18° to 20°C (64° to 68°F) in England. Menzel (1976) reported that spawning peaks in Florida when water temperatures approach 22° to 24°C (72° to 75°F). In northwest Florida, shell growth was greatest in spring and fall. Menzel (1961, 1962) demonstrated that growth of M. campechiensis was negligible during winter at temperatures approaching 10° to 12°C (50° to 54°F). M. campechiensis continued to grow until temperatures approached 35°C or 95°F (R. W. Menzel, Florida State University, Tallahassee; pers. comm.). Burrowing-rate response curves for M. mercenaria suggested a preferred range of 21° to 31°C (70° to 88°F) in Rhode Island (Savage 1976); growth was negligible at temperatures below 10°C or 50°F (Belding 1931; Pratt and Campbell 1956) and at temperatures above 27° to 28°C or 81° to 82°F (Menzel 1961, 1962). In his review paper, Ansell (1967b) concluded that 20°C (68°F) was the optimum temperature for growth of M. mercenaria and that the rate dropped off symmetrically at higher and lower temperatures, ceasing below 9°C (48°F) and above 31°C (88°F). In the laboratory, Storr et al. (1982) observed that maximum overall shell growth of M. mercenaria occurred at 12.8° to 15.6°C (55° to 60°F) and 23.9°C (75°F).

Substrate. Hard clams inhabit a variety of sediment types (Joint Subcommittee on Aquaculture 1983). Hibbert (1976) found that growth rates of M. mercenaria were similar on bottom substrates of 3% to 93% mud. Sims and Stokes (1967) could not establish a consistent correlation of sediment particle size with M. campechiensis population density for Tampa Bay, Florida; however, Pratt (1953) showed that the population density of M. mercenaria in Narragansett Bay, Rhode Island, was inversely correlated with the particle size of the major sediment constituent. Average concentrations of clams were greatest on predominantly muddy bottoms, less on sand bottoms, and least on rocky bottoms. Clams were most abundant in predominantly fine sediments, but in these sediments their abundance was generally a function of the coarseness of the minor constituents. Clams do not grow well in silty substrates. Pratt and Campbell (1956) found an inverse relationship between growth of M. mercenaria and the fineness of the sediment (expressed as percentage of silt and clay). The inferior growth was attributed to frequent gill clearing, which expended energy and interfered with feeding. Johnson (1977) also reported slower growth of M. mercenaria in finer sediment due to increased expulsion of pseudofeces.

Soft sediment was given as the principal factor limiting the abundance and diversity of benthic mollusks in bayfill canals in Tampa Bay, Florida (Sykes and Hall 1970). Sediment types can be roughly correlated with current velocities. A muddy bottom normally indicates calm water, whereas a coarse bottom generally indicates more turbulent water (Thorson 1955). Wells (1957a) found that the average density of *M. mercenaria* in Chincoteague Bay, Maryland, was highest where the water current was 30 to 50 cm/s. The Joint Subcommittee on Aquaculture (1983) reported that clams grow well where currents average 50 cm/s or less.

Suspended solids. Little information is available on the effects of suspended solids on adult clams. As clams filter feed, the uningestible materials are sorted, accumulated, and expelled as pseudofeces (Pratt and Campbell 1956). The rate of pseudofeces generation increases with turbidity (Pratt and Campbell 1956). Menzel (1961) suggested that high turbidity may have inhibited growth at one Florida site.

Food. Adult hard clams feed by filtering plankton and microorganisms (Chestnut 1951). They may depend on an abundant supply of plankton before and during spawning to provide sufficient energy to ripen the gonads (Ansell 1967a). In the laboratory, food concentrations of 300 mg carbon per liter of seawater were optimal for feeding of *M. mercenaria* (Tenore and Dunstan 1973). Robinson and Langton (1980) found that digestion was nearly continuous in a subtidal population of *M. mercenaria*, regardless of time of day or tidal stage.

Vegetation. Studies conducted in Florida's west coast estuaries have reported the association of *M. campechiensis* with stands of turtle grass, *Thalassia testudinum* (Schroeder 1924; Woodburn 1962; Sims and Stokes 1967; Taylor and Saloman 1968, 1970; Godcharles 1971). This association with rooted vegetation persists in inland waters but not offshore (Godcharles and Jaap 1973; Menzel 1976). In Bogue Sound, North Carolina, Peterson (1982) found a significantly higher ($P < 0.01$) average density of *M. mercenaria* in partly vegetated plots than in unvegetated plots and a significantly higher ($P < 0.01$) density in thickly vegetated than in partly vegetated plots. Although seagrasses may provide protection from predators and stabilize the sediment (Godcharles and Jaap 1973; Peterson 1982), they are apparently not essential for the well-being and survival of clams.

Water depth. Hard clams seem to prefer relatively shallow water, although they also are found in the open ocean. Along the South Carolina coast, Anderson et al. (1978) found that 50% of all the *M. mercenaria* and *M. campechiensis* were collected at a depth of about 2 m (7 ft), and less than 10% at depths greater than 5 m (16 ft). Cummins (1966) found commercial concentrations of *M. campechiensis* off the South Carolina coast at depths of 7.3 to 11 m (24 to 36 ft). Along the west coast of Florida the most productive beds were at 5.5 to 7.3 m (18 to 24 ft). *M. campechiensis* were generally most abundant at depths of 4.7 to 9.2 m (15.4 to 30.2 ft) in Tampa Bay, Florida (Godcharles and Japp 1973). Off Woods Hole, Massachusetts, Robinson and Langton (1980) collected *M. mercenaria* at 6 to 8.5 m (20 to 28 ft). In Maine, Gustafson (1955) noted that *M. mercenaria* lives between tide levels to depths of at least 15 m (49 ft).

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The model is applicable to intertidal and subtidal estuarine habitats as defined by Cowardin et al. (1979) along the Atlantic and gulf coasts and can be used for both *M. mercenaria* and *M. campechiensis*. It is not applicable in the open ocean. The effect of pollution has not been considered in model development; accordingly, the model is not applicable to heavily polluted waters.

Season. The model is structured to account for seasonal variations in habitat requirements of hard clams and, accordingly, to estimate the ability of an area to sustain a population year-round.

Minimum habitat area. Hard clams can grow in relatively high densities. The minimum area required for a self-sustaining population of hard clams is not known.

Verification level. The model has not been field-tested. The acceptable model output is an index value between 0.0 and 1.0. Dr. R. Winston Menzel (Oceanography Department, Florida State University, Tallahassee) and Dr. John J. Manzi (Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department, Charleston) reviewed and evaluated the hard clam model. Although their comments have been incorporated, the author is responsible for the final version of this model.

Model Description

Overview. The structure of the hard clam HSI model is depicted graphically in Figure 1. The habitat suitability index model applies to the entire life cycle of hard clams. It uses two life requisites (water quality and substrate-suspended solids) to evaluate an area. It is based on six habitat variables: dissolved oxygen concentration (V_1), salinity (V_2), water temperature (V_3), percent silt-clay concentration in the substrate (V_4), water current (V_5), and suspended solids (V_6). A food component was not included because of insufficient information on food availability in estuaries. Vegetative cover was omitted because it is not an important habitat characteristic throughout the range of hard clams. This model does not apply to areas where clams are incapable of burrowing in the substrate.

Water quality component. Both adult and embryonic hard clams are capable of withstanding low dissolved oxygen concentrations. The dissolved oxygen requirements of the larval stage (V_1) are used to evaluate suitability. Dissolved oxygen is most important from April to September, the period when most spawning occurs. Prolonged exposure to less than 4.0 mg/l dissolved oxygen decreases the probability of survival of *M. mercenaria* larvae. The optimal dissolved oxygen concentration is 4.0 mg/l or higher.

Salinity (V_2) affects growth and survival of all life stages. The optimal salinity range for adult *M. campechiensis* is 24 to 35 ppt and 20 to 30 ppt for adult *M. mercenaria*. Growth of juvenile *M. mercenaria* is

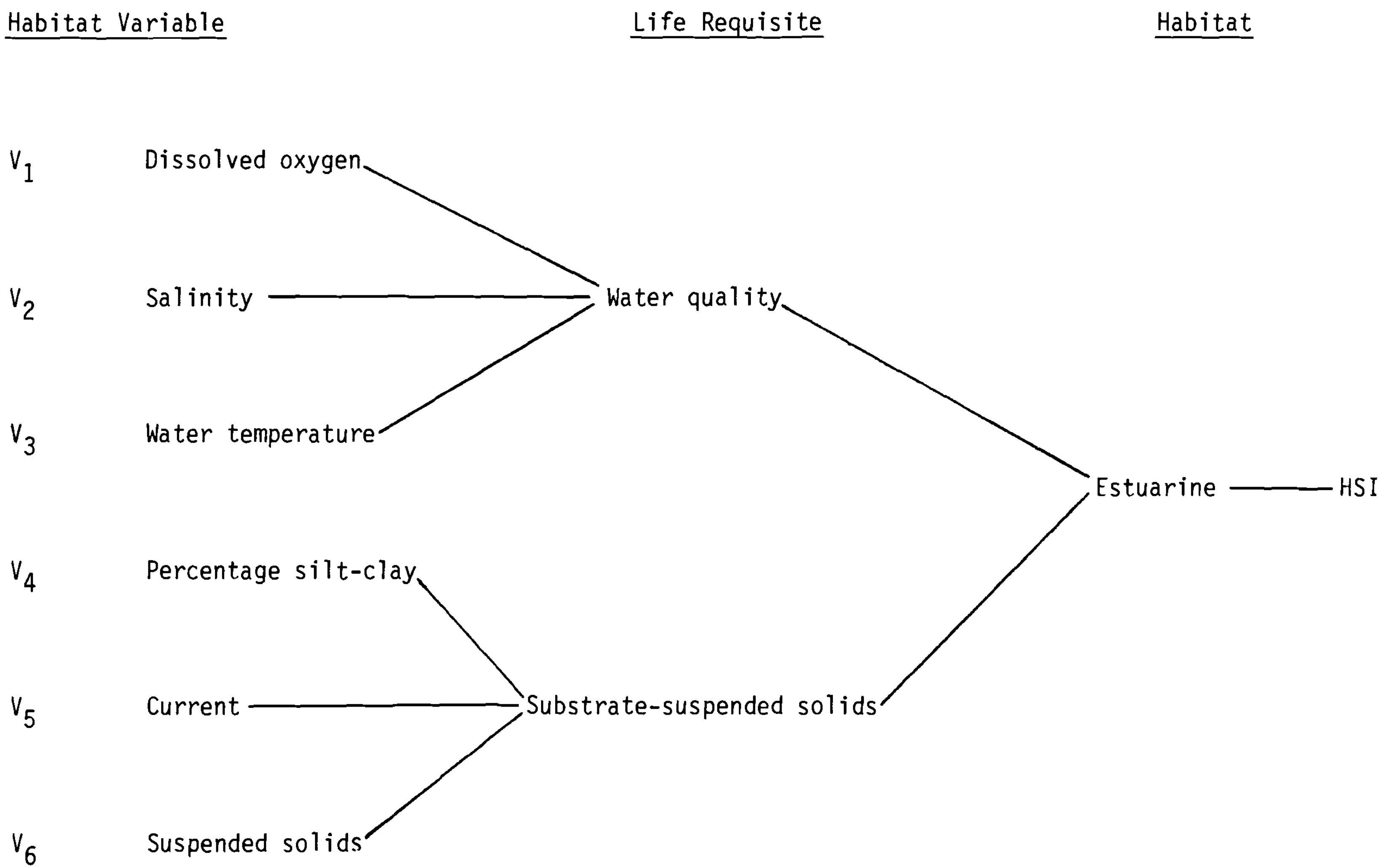


Figure 1. Relationship of habitat variables and life requisites to the HSI for hard clams.

retarded at salinities of 22.5 ppt and lower. The optimal salinity range for hard clams throughout their range is assumed to be 22 to 35 ppt.

Water temperature (V_3) requirements for all life stages are combined. Growth of adult M. mercenaria and M. campechiensis is negligible below 10°C (50°F), and straight-hinged veligers of M. mercenaria are unable to digest food at 10°C (50°F). Accordingly, temperatures of 10°C (50°F) or less are considered unsuitable. Growth is negligible above 28°C (82°F) for M. mercenaria and above 35°C (95°F) for M. campechiensis (Menzel 1961, 1962, pers. comm.). Temperatures of 35°C (95°F) and higher are considered unsuitable. The optimal temperature range for growth is assumed to be 20° to 31°C (68° to 88°F). Water temperature should be measured only during the growing season, where growing season is defined as the period of time when the mid-depth water temperature is greater than 10°C (50°F).

The pH requirements were not included because marine and estuarine waters normally have a high buffering capacity. An influx of pollutants, such as hydrogen sulfide, might alter the pH, but the present model is not designed to evaluate highly polluted areas. Water depth is not included since hard clams are distributed throughout estuaries at various depths.

Substrate-suspended solids component. Hard clams are found in almost any bottom type into which they can burrow. The percent silt and clay (V_4) in the substrate affects clam growth; as that percent increases, clams must more frequently clear their filtering apparatus, which expends energy and interferes with feeding.

Water currents (V_5) affect the type of sediment found in an area and the stability of the bottom; 30 to 50 cm/s is considered optimal.

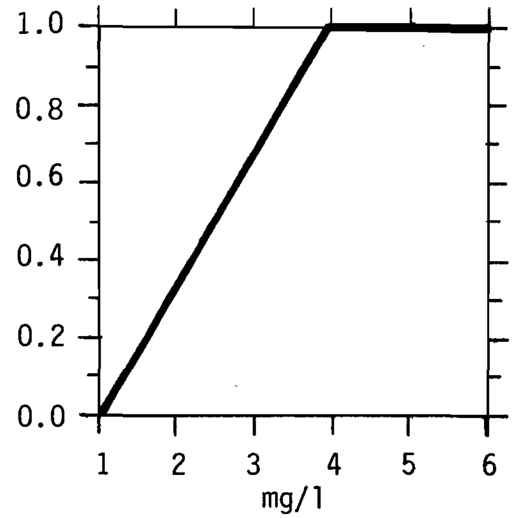
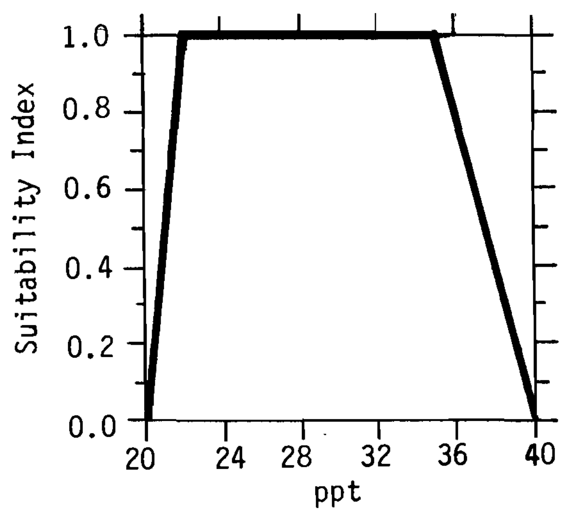
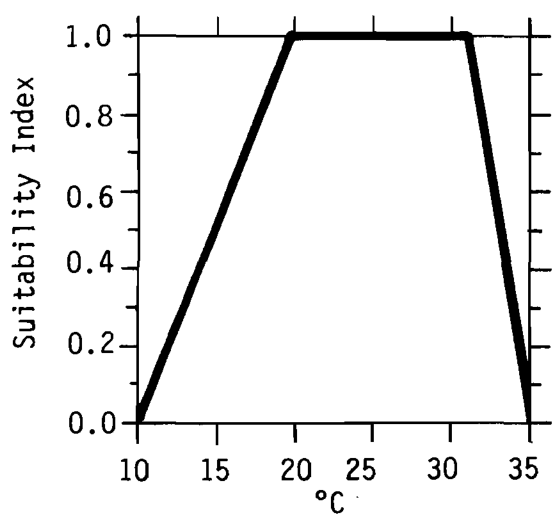
Suspended solids (V_6) affect larval clam development. Growth of larvae is normal at silt concentrations as high as 0.75 g/l, but growth decreases at higher levels and ceases at 3.0 to 4.0 g/l. Turbidity should be measured during the spawning season from April to September.

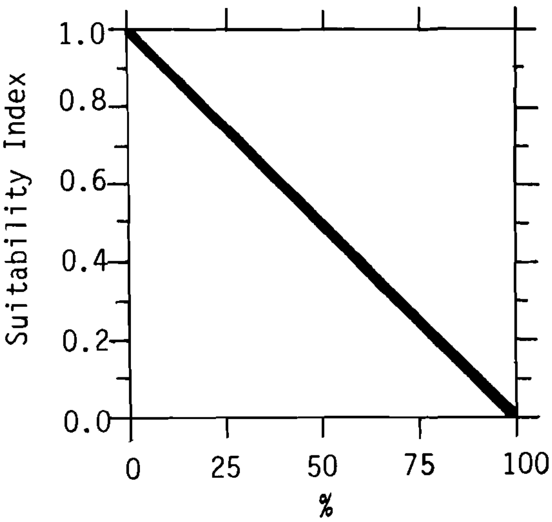
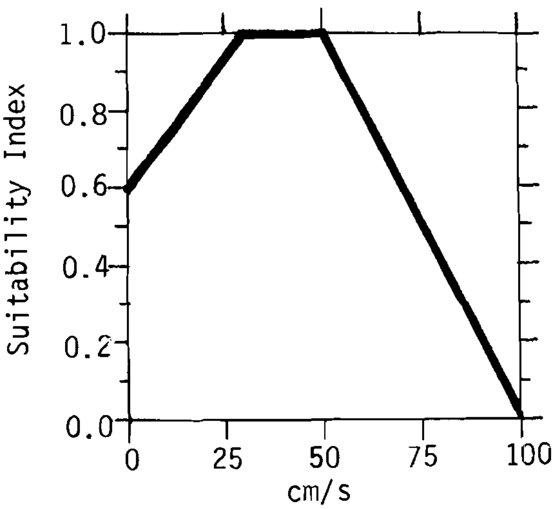
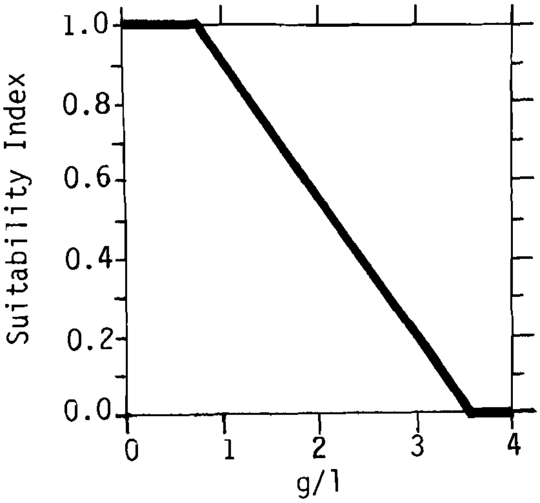
Suitability Index (SI) Graphs for Model Variables

Graphic representations of the relationship between the habitat variables and hard clam habitat quality are given here. Optimum suitability is indicated by an SI value of 1.0 and unsuitability by a value of 0.0. The SI graphs are based on the assumption that the suitability of a particular habitat variable can be represented by a two-dimensional response surface and is independent of other variables that contribute to habitat suitability. Data sources and assumptions associated with SI graphs are listed in Table 1.

Table 1. Variable sources and assumptions for hard clam suitability indices.

	Variable and source	Assumption
V_1	Morrison 1971	Optimal dissolved oxygen concentration for larval *M. mercenaria* growth and survival is 4.0 mg/l or higher.
V_2	Chanley 1958 Davis 1958 Woodburn 1961, 1962 Taylor and Saloman 1970 Castagna and Chanley 1973 R. W. Menzel, pers. comm.	The optimal salinity range for growth and survival of adult *M. campechiensis* is 24 to 35 ppt while optimal range for adult *M. mercenaria* is 20 to 30 ppt. The optimal salinity range for hard clams throughout their range is assumed to be 22 to 35 ppt.
V_3	Menzel 1961, 1962 Davis and Calabrese 1964 Savage 1976	Growth of *M. mercenaria* and *M. campechiensis* adults is negligible below 10°C (50°F), and *M. mercenaria* veligers cannot digest food at 10°C. Growth is negligible above 28°C (82°F) for *M. mercenaria* and above 35°C (95°F) for *M. campechiensis*. Optimal range for growth is assumed to be 20° to 31°C (70° to 88°F).
V_4	Pratt and Campbell 1956 Johnson 1977	Clams must be capable of burrowing in substrate. As percentage of silt-clay content increases, growth decreases.
V_5	Wells 1957a Joint Subcommittee on Aquaculture 1983	Densities of clams are highest where current velocities are 30 to 50 cm/s.
V_6	Davis 1960	Larval clam growth is optimal at silt concentrations of 0.75 g/l or less.

Variable	Description	Suitability Graph
V_1	Mean mid-depth dissolved oxygen concentration April to September.	
V_2	Mean annual mid-depth salinity.	
V_3	Mean mid-depth water temperature during growing season.	

Variable	Description	Suitability Graph
V_4	Percentage silt-clay in substrate sample.	
V_5	Mean annual surface water current velocity.	
V_6	Mean total suspended solids April to September.	

Component Index (CI) Equation and HSI Determination

Development of an HSI for hard clams requires that the SI values for the habitat variables be combined into component indices (CI) for water quality and for substrate-suspended solids. Percentage of silt-clay (SI_{V_4}) is squared because it is considered the most important habitat variable. The suggested equation follows.

Component	Equation
Water quality (WQ)	$(SI_{V_1} \times SI_{V_2} \times SI_{V_3})^{1/3}$
Substrate-suspended solids (SS)	$(SI_{V_4}^{2} \times SI_{V_5} \times SI_{V_6})^{1/4}$

$$HSI = (WQ \times SS)^{1/2}$$

Sample data sets representing a range of hypothetical habitat values for hard clams are presented (Table 2). The HSI values generated are believed to reflect the relative potential of the habitats to support hard clams.

Interpreting Model Outputs

The hard clam HSI determined by use of these models does not necessarily represent the population of hard clams in an area. Habitats with an HSI of 0 may contain some hard clams and habitats with a high HSI may contain only a few. The proper interpretation of the HSI is one of comparison. On average, habitats with high HSI's would be able to support higher populations of hard clams than habitats with low HSI's. A close correlation between population size and HSI is unlikely.

Table 2. Calculations of suitability indices (SI), component indices (CI), and habitat suitability indices (HSI) for three hypothetical data sets on the basis of 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 (mg/l)	6	1.0	3	0.67	4	1.0
V_2 (ppt)	20	0.0	26	1.0	35	1.0
V_3 (°C)	25	1.0	15	0.5	20	1.0
V_4 (%)	50	0.5	0	1.0	75	0.25
V_5 (cm/s)	0	0.6	25	0.93	50	1.0
V_6 (g/l)	1	0.9	2	0.54	0.5	1.0
WQ	0.0		0.69		1.0	
SS	0.6		0.84		0.5	
HSI	0.0		0.76		0.7	

Field Use of Model

This model is designed for use in intertidal and subtidal estuarine areas and not for open ocean areas. It is set up to evaluate habitat suitability for both _M. mercenaria_ and _M. campechiensis_. Inasmuch as information on habitat variables was not always available for both species, information pertaining to _M. mercenaria_ was applied to _M. campechiensis_ and vice versa. Information was merged into a range of values when information on both species was available. This adjustment may have caused the optimal ranges of some variables to be wider than if each species was treated individually. Since the two species interbreed and produce viable offspring, this use of the habitat information seems to be justified.

The reliability of the calculated HSI values can be only as good as the data used for their calculation. Estimates of variables cannot replace field measurements of variables. The HSI values are most useful when the habitat variables are measured in the specific evaluation area. Existing water quality information for the area should be used if it is available and accurate. Adult clams are capable of withstanding suboptimal conditions by simply closing their shells. Accordingly, temporary fluctuations in water quality characteristics may not influence habitat suitability. Since spawning occurs over an extended period and involves massive numbers of eggs, temporary fluctuations in water quality may kill only a portion of the yearly production of embryos and larvae. Accordingly, it is best to use long-term data whenever possible to evaluate the suitability of an area for hard clams. In the northern areas of the hard clam distribution, water temperatures may remain below the optimal range of 20° to 31°C (68° to 88°F) throughout the year. If hard clams are known to inhabit these areas, the temperature suitability curve may require adjustment.

Suggested methods for measuring model variables in areas where data are not available are described in Table 3. A valid sampling scheme must be developed before field sampling is done. It is insufficient to take only a few samples. Local fluctuations in water quality affect only portions of a hard clam population and do not determine the overall suitability of an area. If subjective estimates must be used, they should be made by experienced professionals familiar with the evaluation area and be accompanied by full documentation of the basis on which they were made. If further information is required on hard clams, see the detailed annotated bibliography published by McHugh et al. (1982).

Table 3. Suggested methods for measurement of variables used in hard clam HSI model. For all variables, use existing data if possible.

Variable	Method
V_1	Mid-depth dissolved oxygen can be measured by using Winkler titration or an oxygen meter (American Public Health Association 1976). Measure from April through September.
V_2	Mid-depth salinity can be measured by titration, refractometer, or salinity meter.
V_3	Mid-depth temperature can be measured by thermometer or temperature probe (American Public Health Association 1976).
V_4	Percentage of silt-clay can be determined by washing a known weight of sediment through a 63-µm (Tyler series No. 250) sieve. Silt and clay pass through the sieve.
V_5	Surface water current velocity can be measured with a flowmeter.
V_6	Turbidity can be measured by direct measurement of suspended solids (American Public Health Association 1976). Measure from April to September.

LITERATURE CITED

Abbott, R. T. 1954. American seashells. Van Nostrand Co., Inc. New York. 541 pp.

Abbott, R. T. 1974. American seashells, 2nd ed. Van Nostrand Reinhold Co. Inc., New York. 663 pp.

American Public Health Association. 1976. Standard methods for the examination of water, sewage, and wastewater, 14th ed. Am. Public Health Assoc., Am. Waterworks Assoc., and Am. Public Health Assoc., Washington, D.C. 1193 pp.

Anderson, W. D., W. J. Keith, F. H. Mills, M. E. Bailey, and J. L. Steinmeyer. 1978. A survey of South Carolina's hard clam resources. S.C. Wildl. Mar. Resour. Dep., Mar. Resour. Cent., Tech. Rep. 32. 17 pp.

Ansell, A. D. 1967a. Egg production of *Mercenaria mercenaria*. Limnol. Oceanogr. 12:172-176.

Ansell, A. D. 1967b. The rate of growth of the hard clam *Mercenaria mercenaria* (L) throughout the geographical range. J. Cons. *Perm. Int. Explor. Mer* 31:364-409.

Bayne, B. L. 1976. Aspects of reproduction in bivalve molluscs. Pages 432-448 *in* Martin Wiley, ed. Estuarine processes. Vol. I. Uses, stresses, and adaptation to the estuary. Academic Press, New York.

Belding, D. L. 1911. The life history and growth of the quahaug (*Venus mercenaria*). Rep. Mass. Comm. Fish Game 1910:18-128.

Belding, D. L. 1912. A report upon the quahaug and oyster fisheries of Massachusetts, including the life history, growth and cultivation of the quahaug (*Venus mercenaria*), and observations on the set of the oyster spat in *Wellfleet Bay*. Boston, Wright and Potter Printing Co., Mass. 134 pp.

Belding, D. L. 1931. The quahaug fishery of Massachusetts. Mass. Dep. Conserv., Div. Fish Game, Mar. Fish. Serv. 2. 41 pp.

Bricelj, V. M., and R. E. Malouf. 1980. Aspects of reproduction of hard clams (*Mercenaria mercenaria*) in Great South Bay, New York. Proc. Natl. *Shellfish. Assoc. 70:216-229*.

Burrell, V. G., Jr. 1977. Mortalities of oysters and hard clams associated with heavy runoff in the Santee River system, South Carolina in the spring of 1975. Proc. Natl. Shellfish. Assoc. 67:35-43.

Calabrese, A. 1972. How some pollutants affect embryos and larvae of American oyster and hard-shell clam. U.S. Natl. Mar. Fish. Serv. Mar. Fish. Rev. 34(11-12):66-77.

Carriker, M. R. 1956. Biology and propagation of young hard clams, Mercenaria mercenaria. J. Elisha Mitchell Sci. Soc. 72:57-60.

Carriker, M. R. 1959. The role of physical and biological factors in the culture of Crassostrea and Mercenaria in a salt-water pond. Ecol. Monogr. 29:219-266.

Carriker, M. R. 1961. Interrelation of functional morphology, behavior, and autecology in early stages of the bivalve Mercenaria mercenaria. J. Elisha Mitchell Sci. Soc. 77:168-241.

Castagna, M. 1970a. Field experiments testing the use of aggregate covers to protect juvenile clams. Proc. Natl. Shellfish. Assoc. 60:1. (Abstr.)

Castagna, M. A. 1970b. Hard clam culture method developed at VIMS. Aggregates on bottom protect seed clams from predators. Mar. Resour. Advis. Ser. 4. 3 pp.

Castagna, M., and P. Chanley. 1973. Salinity tolerance of some marine bivalves from inshore and estuarine environments in Virginia waters on the western mid-Atlantic coast. Malacologia 12:47-96.

Castagna, M., and J. N. Kraeuter. 1977. Mercenaria culture using stone aggregate for predator protection. Proc. Natl. Shellfish. Assoc. 67:1-6.

Chanley, P. E. 1958. Survival of some juvenile bivalves in water of low salinity. Proc. Natl. Shellfish. Assoc. 48:52-65.

Chestnut, A. F. 1951. The oyster and other mollusks in North Carolina. Pages 141-90 in H. F. Taylor, ed. Survey of marine fisheries of North Carolina. University of North Carolina Press, Chapel Hill.

Chestnut, A. F. 1952. Growth rates and movements of hard clams Venus mercenaria. Proc. Gulf Caribb. Fish. Inst. 4:49-59.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. Biol. Serv. Program FWS/OBS-79/31. 103 pp.

Cummins, R., Jr. 1966. Hard-clam explorations off Southeastern United States. U.S. Bur. Commer. Fish. Commer. Fish. Rev. 28(12):33-42.

Davis, H. C. 1958. Survival and growth of clam and oyster larvae at different salinities. Biol. Bull. (Woods Hole) 114:296-307.

Davis, H. C. 1960. Effects of turbidity-producing materials in sea water on eggs and larvae of the clam (Venus (Mercenaria) mercenaria). Biol. Bull. (Woods Hole) 118:48-54.

Davis, H. C., and A. Calabrese. 1964. Combined effects of temperature and salinity on development of eggs and growth of larvae of M. mercenaria and C. virginica. U.S. Fish Wildl. Serv. Fish. Bull. 63:643-655.

Godcharles, M. F. 1971. A study of the effects of a commercial hydraulic clam dredge on benthic communities in estuarine areas. Fla. Dep. Nat. Resour. Mar. Res. Lab. Tech. Ser. No. 64. 51 pp.

Godcharles, M. F., and W. C. Jaap. 1973. Exploratory clam survey of Florida nearshore and estuarine waters with commercial hydraulic dredging gear. Fla. Dep. Nat. Resour. Mar. Res. Lab. Prof. Pap. Ser. 21. 77 pp.

Greenfield, E., and M. A. Crenshaw. 1981. Variations in the rate of anaerobic succinate accumulation within the central and marginal regions of an euryoxic bivalve mantle. Mar. Ecol. 2:353-362.

Gustafson, A. H. 1955. Growth studies in the quahog Venus mercenaria. Proc. Natl. Shellfish. Assoc. 45:140-150.

Haven, D., and J. D. Andrews. 1957. Survival and growth of Venus mercenaria, Venus campechiensis, and their hybrids in suspended trays and on natural bottoms. Proc. Natl. Shellfish. Assoc. 47:43-49.

Hibbert, C. J. 1976. Biomass and production of a bivalve community on an intertidal mud-flat. J. Exp. Mar. Biol. Ecol. 25:249-261.

Johnson, C. W. 1934. List of marine mollusca of the Atlantic coast from Labrador to Texas. Proc. Boston Soc. Nat. Hist. 40:1-204.

Johnson, J. K. 1977. A study of the shell length of Mercenaria mercenaria in relationship to bottom sediments of Little Bay, New Jersey. Bull. N. J. Acad. Sci. 22(2):52. (Abstr.)

Joint Subcommittee on Aquaculture. 1983. National Aquaculture Development Plan. Vol. 2. Washington, D.C. 196 pp.

Keck, R., D. Maurer, and R. Malouf. 1974. Factors influencing the setting behavior of larval hard clams, Mercenaria mercenaria. Proc. Natl. Shellfish. Assoc. 64:59-67.

Kennedy, V. S., W. H. Roosenburg, M. Castagna, and J. A. Mihursky. 1974. Mercenaria mercenaria (Mollusca: Bivalvia): temperature-time relationships for survival of embryos and larvae. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 72:1160-1166.

Kennish, M. J., and R. E. Loveland. 1980. Growth models of the northern quahog, *Mercenaria mercenaria* (Linne). Proc. Natl. Shellfish. Assoc. 70:230-239.

Kennish, M. J., and R. K. Olsson. 1975. Effects of thermal discharges on the microstructural growth of *Mercenaria mercenaria*. Environ. Geol. 1:41-64.

Kerswill, C. J. 1941. Some environmental factors limiting growth and distribution of the quahog *Venus mercenaria* L. Ph.D. Thesis. University of Toronto, Canada. 104 pp.

Kraeuter, J. N., M. Castagna, and R. Van Dessel. 1982. Egg size and larval survival of *Mercenaria mercenaria* (L.) and *Argopecten irradians* (LAMARCK). J. Exp. Mar. Biol. Ecol. 56:3-8.

Ladd, H. S. 1951. Brackish-water and marine assemblages of the Texas coast, with special reference to mollusks. Publ. Inst. Mar. Sci. Univ. Tex. 2(1):125-164.

Loosanoff, V. L. 1937. Spawning of *Venus mercenaria* (L.). Ecology 18:506-515.

Loosanoff, V. L., and H. C. Davis. 1950. Conditioning *V. mercenaria* for spawning in winter and breeding its larvae in the laboratory. Biol. Bull. (Woods Hole) 98:60-65.

McHugh, J. L., M. W. Summer, P. J. Flagg, D. W. Lipton, and W. J. Behrens. 1982. Annotated bibliography of the hard clam (*Mercenaria mercenaria*). NOAA Tech. Rep. U.S. Natl. Mar. Fish. Serv. SSRF-756. 845 pp.

Menzel, R. W. 1961. Seasonal growth of the northern quahog, *Mercenaria mercenaria* and the southern quahog, *M. campechiensis*, in Alligator Harbor, Florida. Proc. Natl. Shellfish. Assoc. 52:37-46.

Menzel, R. W. 1962. Seasonal growth of northern and southern quahogs, *Mercenaria mercenaria* and *M. campechiensis*, and their hybrids in Florida. Proc. Natl. Shellfish. Assoc. 53:111-119.

Menzel, R. W. 1976. Comprehensive report on the quahog clam (*Mercenaria* spp.) industry in Florida. School of Marine Science, University of Delaware, Newark. Ms. 20 pp.

Menzel, R. W., and M. Y. Menzel. 1965. Chromosomes of two species of quahogs and their hybrids. Biol. Bull. (Woods Hole) 129:181-188.

Menzel, R. W., and H. W. Sims. 1962. Experimental farming of hard clams, *Mercenaria mercenaria*, in Florida. Proc. Natl. Shellfish. Assoc. 53:103-109.

Menzel, R. W., E. W. Cake, M. L. Haines, R. E. Martin, and L. A. Olsen. 1976. Clam mariculture in northwest Florida: field study on predation. Proc. Natl. Shellfish. Assoc. 65:59-62.

Merrill, A. S., and J. W. Ropes. 1967. Distribution of southern quahogs off the middle Atlantic coast. U.S. Bur. Commer. Fish. Commer. Fish. Rev. 29(4):62-64.

Mitchell, R. 1974. Aspects of the ecology of the lamellibranch _Mercenaria mercenaria_ (L.) in British water. Hydrobiol. Bull. 8:124-138.

Morrison, G. 1971. Dissolved oxygen requirements for embryonic and larval development of the hard-shelled clam, _Mercenaria mercenaria_. J. Fish. Res. Board Can. 28:379-381.

Nelson, T. C., and H. H. Haskin. 1949. On the spawning behaviour of oysters and of _Venus mercenaria_ with especial reference to the effects of spermatic hormones. Anat. Rec. 105:484-485.

Pearse, A. S. 1936. Estuarine animals at Beaufort, North Carolina. J. Elisha Mitchell Sci. Soc. 52:174-222.

Peterson, C. H. 1982. Clam predation by whelks (_Busycon_ spp.): experimental tests of the importance of prey size, prey density, and seagrass cover. Mar. Biol. 66:159-170.

Pratt, D. M. 1953. Abundance and growth of _Venus mercenaria_ and _Callocardia morrhuana_ in relationship to the character of bottom sediments. J. Mar. Res. 12:60-74.

Pratt, D. M., and D. A. Campbell. 1956. Environmental factors affecting growth in _Venus mercenaria_. Limnol. Oceanogr. 1:2-17.

Rhoads, D. C., and G. Pannella. 1970. The use of molluscan shell growth patterns in ecology and paleoecology. Lethaia 3:143-161.

Ritchie, T. P. 1977. A comprehensive review of the commercial clam industries in the United States. U.S. Natl. Mar. Fish. Serv., Del. Sea Grant Prog., Coll. Mar. Stud., Univ. Del., Newark and Lewes. DEL-SG-26-76. 106 pp.

Robinson, W. E., and R. W. Langton. 1980. Digestion in a subtidal population of _Mercenaria mercenaria_ (Bivalvia). Mar. Biol. 58:173-179.

Savage, N. B. 1976. Burrowing activity in _Mercenaria mercenaria_ (L.) and _Spisula solidissima_ (Dillwyn) as a function of temperature and dissolved oxygen. Mar. Behav. Physiol. 3:221-234.

Schroeder, W. C. 1924. Fisheries of Key West and the clam industry of southern Florida. Rep. U.S. Comm. Fish. for 1923, Append. 12, Doc. 962. 74 pp.

Sims, H. W., Jr., and R. J. Stokes. 1967. A survey of the hard shell clam (Mercenaria campechiensis) (Gmelin) population in Tampa Bay, Florida. Fla. State Board Conserv. Mar. Lab. Spec. Sci. Rep. No. 17. 8 pp.

Stanley, J. G., and R. DeWitt. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic) -- hard clam. U.S. Fish Wildl. Serv. FWS/OBS-82/11.18. U.S. Army Corps of Engineers, TR EL-82-4. 19 pp.

Storr, J. F., A. L. Costa, and D. A. Prawel. 1982. Effects of temperature on calcium deposition in the hard-shell clam, Mercenaria mercenaria. J. Therm. Biol. 7:57-61.

Sykes, J. E., and J. R. Hall. 1970. Comparative distribution of mollusks in dredged and undredged portions of an estuary, with a systematic list of species. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 68:299-306.

Taylor, J. L., and C. H. Saloman. 1968. Benthic project. Pages 3-5 in J. E. Sykes, ed. Report of the Bureau of Commercial Fisheries Biological Laboratory, St. Petersburg Beach, Florida, fiscal year 1967. U.S. Fish Wildl. Serv. Circ. 290.

Taylor, J. L., and C. H. Saloman. 1970. Benthic project. Pages 3-10 in J. E. Sykes, ed. Report of the Bureau of Commercial Fisheries Biological Laboratory, St. Petersburg Beach, Florida, fiscal year 1969. U.S. Fish Wildl. Serv. Circ. 342.

Tenore, K. R., and W. M. Dunstan. 1973. Comparison of feeding and biodeposition of three bivalves at different food levels. Mar. Biol. 21:190-195.

Thorson, G. 1955. Modern aspects of marine level-bottom animal communities. J. Mar. Res. 14:387-397.

U. S. Fish and Wildlife Service. 1980. Habitat evaluation procedures (HEP). ESM 102. Wshington, D.C. n.p.

Wells, H. W. 1957a. Abundance of the hard clam Mercenaria mercenaria in relationship to environmental factors. Ecology 38:123-128.

Wells, H. W. 1957b. Status of the name Venus. Ecology 38:160-161.

Woodburn, K. D. 1961. Survival and growth of laboratory-reared northern clams (Mercenaria mercenaria) and hybrids (M. mercenaria x M. campechiensis) in Florida waters. Proc. Natl. Shellfish. Assoc. 52:31-36.

Woodburn, K. D. 1962. Clams and oysters in Charlotte County and vicinity. Fla. State Board Conserv. Mar. Lab., Mimeo Rep. No. 62-12. 29 pp.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a model suitable for evaluating estuarine habitat for hard clams (Mercenaria mercenaria and Mercenaria campechiensis). The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat) for the Atlantic and Gulf coasts of the United States. Habitat suitability indices are designed for use with the Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Mathematical models
Estuaries
Mollusca
Habitat

b. Identifiers/Open-Ended Terms

Bivalves
Habitat Suitability Index
Hard clam
Mercenaria mercenaria
Mercenaria campechiensis
Venus mercenaria
Quahog

c. COSATI Field/Group

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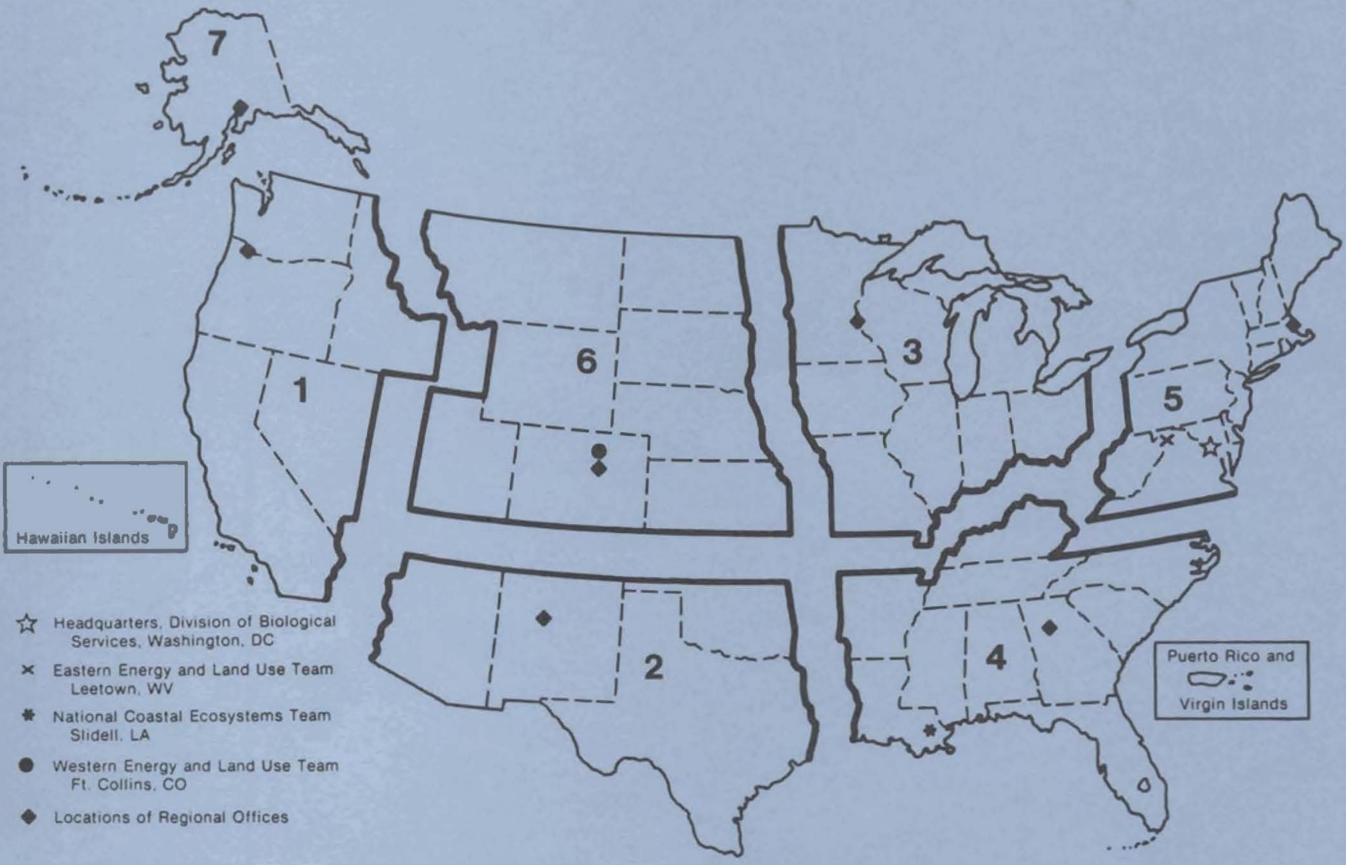

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