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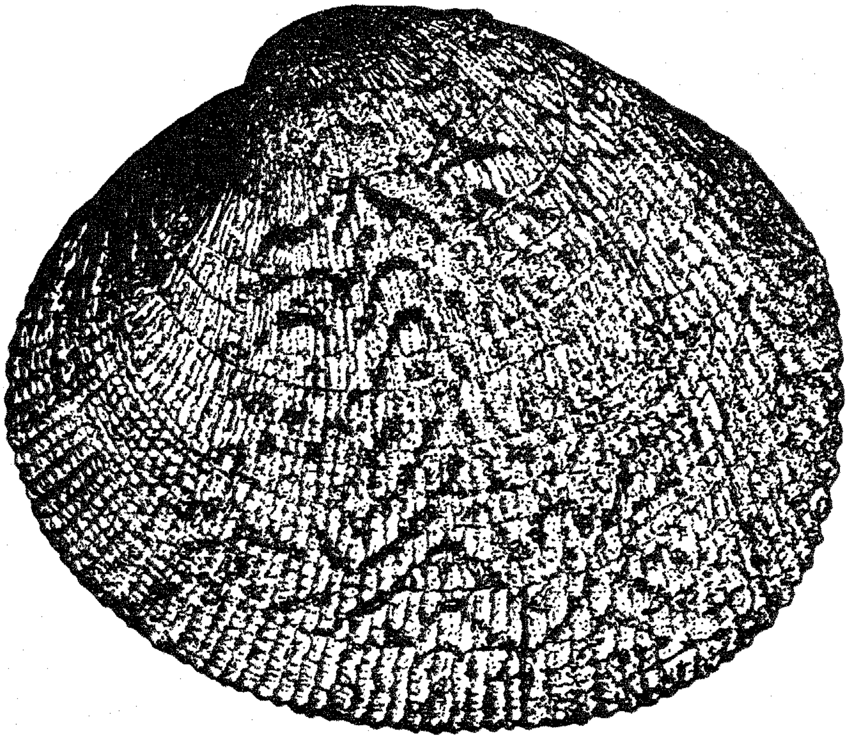
HABITAT SUITABILITY INDEX MODELS: LITTLENECK CLAM



sh and Wildlife Service

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September 1983

HABITAT SUITABILITY INDEX MODELS: LITTLENECK CLAM

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PREFACE

The habitat suitability index (HSI) model for the littleneck clam 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 (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 relationships, not a statement of proven cause and effect relationships. The relationships are the best that can be derived from the limited information available, and the model has not been field-tested. For this reason, the U.S. Fish and Wildlife Service encourages model users to convey comments, suggestions, and any new information that may help increase the utility and effectiveness of this approach to the littleneck clam. Please send any comments or suggestions you may have on the littleneck clam HSI model to:

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CONTENTS

ACKNOWLEDGMENTS

Development of the littleneck clam habitat suitability index model and narrative was monitored and reviewed by Wilbur Breese, Marine Science Center, Newport, Oregon; and Howard Horton, Oregon State University, Corvallis. 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. Model and supportive narrative reviews were also provided by Regional personnel of the U.S. Fish and Wildlife Service (FWS). Funding for model development and publication was provided by the FWS.

LITTLENECK CLAM (*Protothaca staminea*)

INTRODUCTION

The littleneck clam, a member of the family Veneridae, is a hardshell species found in estuaries, bays, sloughs, and open coastlines along the Pacific coast. This clam primarily inhabits the intertidal zone, but also occurs in subtidal areas (Hancock et al. 1979). It ranges from the Aleutian Islands to Socorro Island, Mexico (Fraser and Smith 1928; Fitch 1953). It is commercially important only in British Columbia and Washington, where it is a highly regarded table item (Goodwin 1971).

Life History Overview

Spawning in littleneck clams occurs from April to October and appears to be temperature related (Neave 1943; Quayle 1943). Spawners are either hermaphroditic or of separate sex (Rudy and Rudy 1979). Only a portion of the gametes ripen at one time, and clams may spawn several times during a season (Fitch 1953; Amos 1966).

Zygotes develop into free-swimming larvae (veligers), which disperse and colonize. This stage is the most critical to recruitment and year class success (Quayle and Bourne 1972). There is little information about the larval stage, which lasts about 3 weeks. Veligers settle onto a substrate and the spat stage begins.

Within days the spat metamorphoses to a sessile and relatively immobile stage of life. Settling clams dig into the substrate and anchor themselves with a byssus during early stages of development (Fitch 1953). Because zygotes, veligers, and spat are susceptible to currents and predators, and because environmental factors influence reproductive output, clam populations characteristically have missing year classes and depend upon relatively few but successful year classes for persistence (Neave 1943, 1944, 1945; Paul and Feder 1973). Therefore, the regularity of reproduction in a population may be determined by its year-class structure.

Sexual maturity appears to be size, not age, dependent, and is attained when the littleneck clam reaches a width of 25-35 mm or 0.98-1.34 inches (Fraser and Smith 1928; Quayle 1943). Spawning may begin as early as the second year of life or as late as the eighth year, depending upon location and growth rate (Paul and Feder 1973).

Maximum life span is 7-10 years for southern stocks and up to 13 years for northern ones. Maximum recorded size is 72 mm (2.83 inches) in width (Fitch 1953; Paul et al. 1976; Rudy and Rudy 1979).

Littleneck clams grow continuously throughout life. Annual growth rate declines with age and varies considerably among different locations, depending on food availability and water temperature (Quayle and Bourne 1972). Water temperature is probably the most important factor affecting growth rates; slower growth occurs at higher latitudes (Paul and Feder 1973; Paul et al. 1976). Better growth occurs with higher temperatures and more stable temperature and salinity regimes (Houghton and Moore 1977).

Like other bivalves, the littleneck clam lays down annual growth rings on its shell's surface in winter (Fitch 1953; Gaumer and Halsted 1976). Analysis of growth rings reveals that growth is greatest during spring, summer, and early fall (Schmidt and Warme 1969). Thus, population-dynamics information (age and growth, year-class distributions, and survival rates) on this species is easily obtained. Additionally, sources of mortality can be determined from the shells because different predators open or fracture shells in characteristically different ways. Schmidt and Warme (1969) described a population census and aging study of this species than can be done quickly and effectively for management purposes.

SPECIFIC HABITAT REQUIREMENTS

Egg/Veliger

Although the embryonic and larval stages are perhaps the most sensitive to environmental variables--i.e., they have a narrow range of tolerances--there are little data except that minimum salinity for survival and growth of these stages is 20.0 parts per thousand (ppt) (Davis 1958). Larval transport mechanisms are also poorly understood.

Spat, Juvenile, and Adult

Successful spat settlement may be affected by temperature, adequate food supply, predation, and favorable settling conditions (Paul and Feder 1973). Data are only available for substrate composition, which influences the set and survival of spat, which in turn determine the distribution of juveniles and adults. Littleneck clams are most abundant in substrates containing mixtures of gravel (2.5-7.54 mm or 0.1-0.3 inches) and shell, and least abundant in substrates of fine sand or mud (Amos 1966; Goodwin 1973; Paul et al. 1976). The composition of optimal mixtures are unknown.

The littleneck burrows only to a depth from which the siphon can reach the surface; thus, large littleneck clams are found at greater depths within the substrate than small clams (Nickerson 1977). The vertical distribution is subject to some dispute. According to Amos (1966) and Paul and Feder (1973), it is limited to 8 cm (3.15 inches) below the substrate's surface, but Rudy and Rudy (1979) reported a depth of 15 cm (5.9 inches). Individuals less than 20 mm (0.78 inches) long burrow within 6 cm (2.4 inches) of the surface (Feder and Paul 1972; Peterson 1977). Vertical distribution does not depend on the composition of the substrate (Paul and Feder 1973). Movement within the substrate is limited, but adults can reburrow into the substrate after being removed (Schmidt and Warme 1969; Quayle and Bourne 1972).

Other habitat factors of importance are water current and tidal levels in the intertidal zone. The most productive beds are in areas where water currents exceed 51.44 cm/sec (1 kn) and are in the 77.1- to 154.3-cm/sec (1.5- to 3-kn) range (Goodwin 1973; Peterson 1977). Littleneck clams inhabit the intertidal zone between tidal levels of +1.0 and -0.75 m (+3.28 and -2.46 ft).

Intertidal clams experience limited periods of exposure to seawater. This limited exposure affects growth by limiting feeding time and exposing the clam to dessication and temperature fluctuation. Thus, clams grow better in areas near the mean low water mark than at higher intertidal locations (Paul et al. 1976; Houghton and Moore 1977). Thermal stress causes death at a few degrees below 0°C (32°F) and above 35°C (95°F) for intertidal bivalves (Gunther 1957); absolute temperature seems to have less effect than temperature variation. On three beaches in Galena Bay, Prince William Sound, Alaska, recruitment was greatest between the tidal heights of -0.43 and -0.64 m (-1.41 and -2.10 ft), and survival was greatest between +0.43 and -0.43 m (+1.41 and -1.41 ft). As growth is related to tidal level, best growth is achieved at lower levels (Nickerson 1977). Maximum densities have been recorded near the 0.0 tidal level (Amos 1966; Paul et al. 1976).

Littleneck clams are suspension feeders and may spend as much as 95% of the time feeding, ventilating an excess of 1 liter/hr (0.26 gal/hr) of water (Boyle 1981). Phytoplankton forms a major portion of the adult's diet. Zooplankton, veliger larvae of mollusks, detritus, and bacteria are also ingested (Marriage 1958). The nutritional benefit of each dietary component is unknown.

Special Considerations

Chemical toxicants, predators, and catastrophic events also influence the abundance of littleneck clams in some habitats. Discussion of each follows.

Chemical toxicants. Antifouling paint used on boat hulls contains copper. Extremely low concentrations of it are lethal to the littleneck clam (Graham 1972; Roesijadi 1980). Concentration levels of 7 and 18 µg/l slightly reduced survival; levels of 39 and 82 µg/l were acutely toxic (Roesijadi 1980).

Cadmium is a potential contaminant to littleneck clams at levels above 1 mg/l (Graham 1972; Cardwell et al. 1979; Hardy et al. 1981). Sediments remove dissolved cadmium from the water column.

Chlorine is used as a biocide in powerplants and as a disinfectant in domestic waste treatment systems. Chlorine may adversely impact marine organisms and should be considered stressful to littleneck clams (Roesijadi 1980).

Compounds produced by ozonation of seawater, especially bromate, are toxic to littleneck clams (Crecelius 1979). Although concentrations of bromate near powerplants were below levels considered toxic to littleneck clams, the bromate can remain at those levels in coastal water for months and may reduce habitat suitability (Crecelius 1979).

Concentrations of methoxychlor at 17 mg/l and of dodecyl sulfate (DDS) at 0.3 mg/l are toxic to littleneck clams. Either toxicant at those levels will render a habitat unsuitable for the clams (Cardwell et al. 1979).

A significant portion of petroleum compounds that enter the marine environment becomes associated with bottom sediments. Compounds of high molecular weight are relatively persistent in clam tissue. Littleneck clams bury to a shallower depth in oiled substrates and are more vulnerable to predation (Roesijadi et al. 1978). Habitats polluted with pertoleum compounds are considered unsuitable for littleneck clams.

Wood fiber and bark from pulp mills and logging operations are heavy enough to sink and form an impenetrable layer on the bottom, creating anaerobic conditions and smothering clams (Quayle and Bourne 1972). Furthermore, the living material in logged subsoil may rot and form toxic gases.

Predators. Common predators on juvenile and adult littleneck clams include snails, crabs, sea stars, flounders, ducks, gulls, and octopi. Heavy predation may cause significant mortality and render some habitats less suitable (Bourne 1968; Gorsz and Yocum 1972; Quayle and Bourne 1972; Hemingway 1978; Pearson et al. 1979; Hartwick et al. 1981). The amount of predation and the species involved can be partially evaluated through examination of clams.

Catastrophic events. Gale inshore winds, sharp drops in air temperatures, and sharp reductions in salinities may strand or stress littleneck clams and reduce habitat suitability (Gibson 1963; Crisp 1964; Eggleston and Hickman 1972). These events can displace or kill littleneck clams.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. The model is designed to apply to littleneck clams throughout their range along the Pacific coast.

Habitat types. The littleneck clam inhabits bays, sloughs, estuaries, and open coastlines. This model can be applied to the following wetland classified according to Cowardin et al. (1979):

Marine, Intertidal, Rocky Shore, Rubble
Marine, Intertidal, Unconsolidated Shore, Cobble-Gravel
Marine, Intertidal, Unconsolidated Shore, Sand
Estuarine, Intertidal, Rocky Shore, Rubble
Estuarine, Intertidal, Unconsolidated Shore, Cobble-Gravel
Estuarine, Intertidal, Unconsolidated Shore, Sand

Season. The model is designed for year-round use.

Verification level. This model has not been field-tested. Wilbur Breese Marine Science Center, Newport, Oregon; and Howard Horton, Oregon State University, Corvallis, have reviewed the model.

Model Description

This model is designed for the juvenile and adult life stages of the littleneck clam. Only physical parameters are used. Habitat variables are based upon two life requisites: cover and food. Figure 1 illustrates the relationships of habitat variables to life requisites, life stages, habitats, and HSI value.

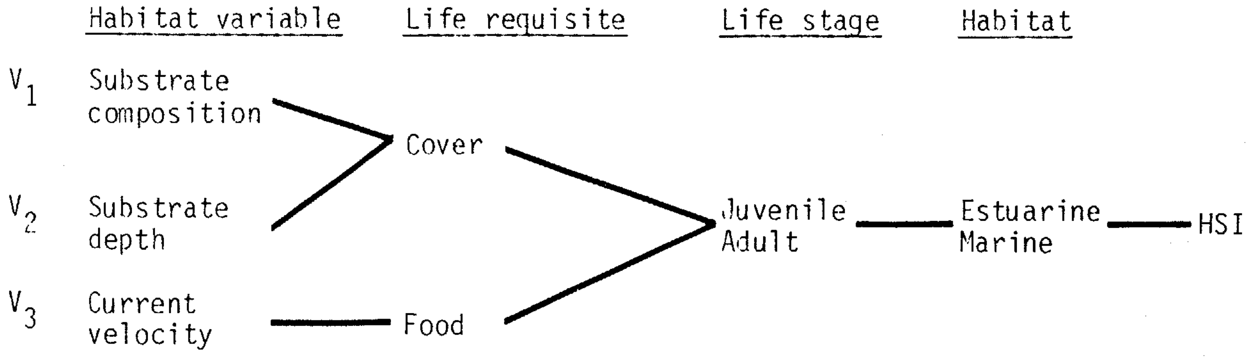


Figure 1. Relationships of habitat variables to life requisites, life stages, habitats, and habitat suitability index (HSI) for littleneck clams in intertidal marine and estuarine habitats.

Cover. Substrate composition (V_1) and substrate depth (V_2) are cover life requisites. Coarse sand, gravel, or loose rocks are preferred over fine sand; pure muck is less suitable. Littleneck clams burrow to about 8 cm (3.15 inches), and substrate depths exceeding 3 cm (1.2 inches) are assumed optimal.

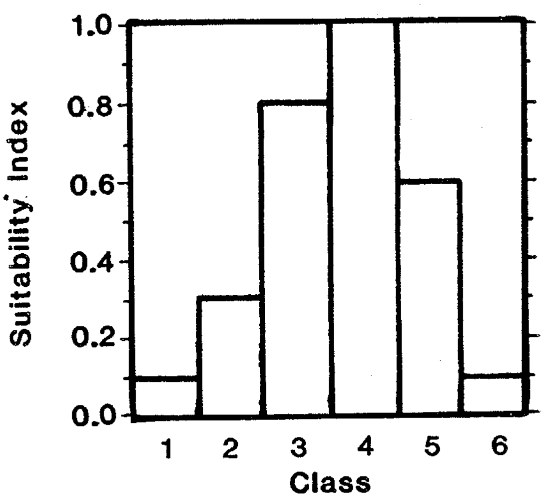
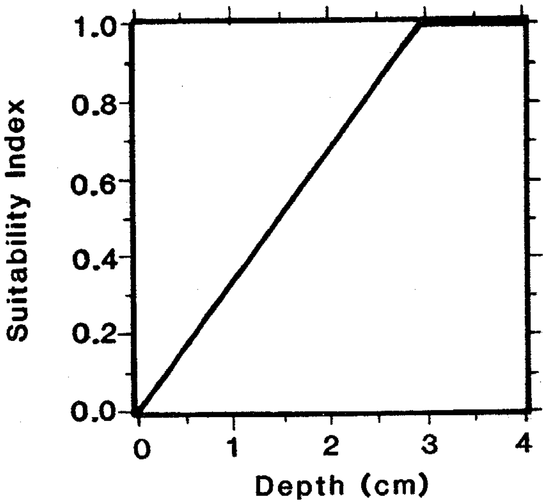
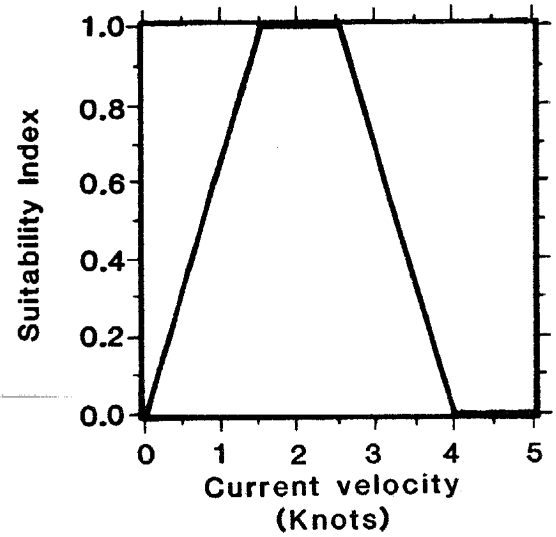
Food. Current velocity (V_3) is the principal habitat variable for the food life requisite. Littleneck clams feed by straining food from the water, and optimal clam habitats exist where current velocities range from 77.16-128.6 cm/sec (1.5-2.5 kn).

Suitability Index (SI) Graphs for Habitat Variables

The relationships between habitat variables and habitat quality for the littleneck clam in estuarine (E) and marine (M) habitats are presented in this section. The suitability index (SI) values can be read directly from the graphs. Table 1 presents data sources and assumptions used to document the SI graphs.

Table 1. Data sources and assumptions for littleneck clam habitat suitability indices.

Variable	Source	Assumption
V_1	Fraser and Smith 1928 Fitch 1953 Amos 1966 Goodwin 1973 Paul and Feder 1973 Lukas and Gaumer 1974 Paul et al. 1976 Peterson 1977 Hancock et al. 1979	Substrates composed of a mixture of coarse sand and gravel are optimal. Coarse sand with fine sand and small amounts of mud are suitable. Pure mud or fine sand are not suitable.
V_2	Quayle 1940 Fitch 1953 Amos 1966 Feder and Paul 1972 Quayle and Bourne 1972 Goodwin 1973 Paul and Feder 1973 Peterson 1977 Rudy and Rudy 1979	Littleneck clams are most commonly found in substrates less than 8 cm (3.1 inches) deep, but may be present to 15 cm (5.9 inches). Small individuals burrow to lesser depths than large ones.
V_3	Fraser and Smith 1928 Goodwin 1971, 1973 Paul and Feder 1973 Peterson 1977	Exposed habitats containing considerable tidal currents (77.16-128.6 cm/sec or 1.5-2.5 kn) are optimal for adult littleneck clams. Areas protected from currents or with strong currents are less suitable.

Habitat	Variable	Suitability Graph
E, M	V_1 Substrate composition class. 1) Mud (<0.25 mm). 2) Fine sand (0.25-1.0 mm). 3) Coarse sand (1.1-2.5 mm). 4) Gravel, shell (2.6-7.5 mm). 5) Rock (7.6-30 mm). 6) Boulders (>30 mm).	
E, M	V_2 Substrate depth.	
E, M	V_3 Current velocity.	

Life Requisite and Habitat Suitability Index Equations

To obtain an HSI for littleneck clams, the habitat variables must be combined into life requisite component indicies (CI). Suggested equations follow:

Component	Equation
Cover (CI_C)	SI_{V_1} or SI_{V_2}, whichever is lower.
Food (CI_F)	SI_{V_3}

HSI = CI_C or CI_F, whichever is lower.

Field Use of Model

Each section of coastline being evaluated will contain habitats of different suitability because of tidal influences. High and low tide boundaries should be marked off from +1.0 to -0.75 m (+3.28 to -2.46 ft) in the intertidal zone. We suggest that the variables be measured along two transects that run 90° to each other and that bisect the study area (or portion of the area, depending upon the needs and demands of the investigation), as diagrammed in Figure 2. This method will give a systematic series of points that will account for systematic changes in quality of the study area. More transects increase the precision of the estimate. Sampling intervals will be determined by constraints of time, money, and the desired level of accuracy. Suggested methods for measuring V_1, V_2, and V_3 are listed in Table 2.

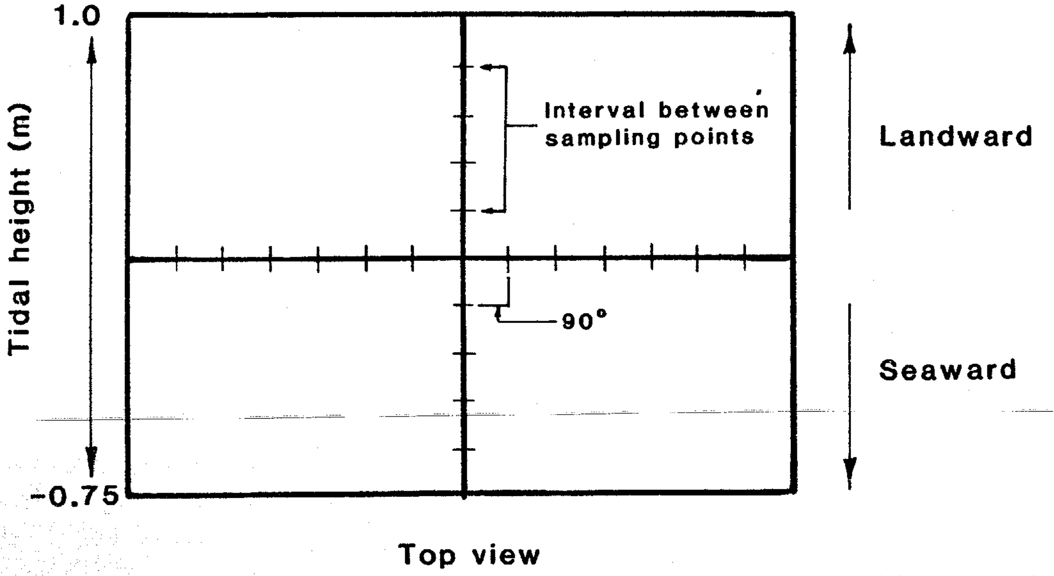


Figure 2. Diagram of transects suggested for measuring habitat variables.

Table 2. Suggested techniques for measuring variables in intertidal estuarine and marine habitats for the littleneck clam model.

	Habitat variable	Technique
V_1	Substrate composition	Substrate cores can be taken with commercially available coring devices used by sportsmen to capture clams. Coffee cans are adequate. Do not sample deeper than 20 cm. Use the following series for substrate composition: mud (<0.25 mm), fine sand (0.25-1.0 mm), coarse sand (1.1-2.5 mm), gravel (2.6-7.5 mm), rock (7.6-30 mm), and boulders (>30 mm). Calculate a suitability index (SI) for each 5-cm interval and use the mean for the substrate type for the station.
V_2	Substrate depth	Determine depth by using commercially available coring devices.
V_3	Current velocity	If available, use commercial current meter as directed. Otherwise, time movement of a neutrally buoyant object (an orange is close) between two points.

For each variable, calculate an average SI over all sample points in the study area. The average SI for the variable is used to determine the HSI. Table 3 lists a sample data set to illustrate the derivation of HSI for the littleneck clam. It is a composite taken from different studies. No one study used all the variables presented in this profile.

Interpreting Model Outputs

The HSI model estimates conditions necessary for the maintenance and persistence of a species. Data for the model can be gathered quickly for ecological assessment. Therefore, time-consuming and costly measuring of population responses and densities can be eliminated if the following assumptions can be made: (1) An HSI value that does not change over the duration of several generations (i.e., environmental conditions are constant) may be a good correlate of population density. (2) Ecological factors are important in the distribution and abundance of a species, and interactions among species should be (theoretically) stable in a locale if the environment is uniform through time; therefore, densities of various species within the community should be constant.

These assumptions can be verified by examining records of human activity, weather (long-term), and predator species introductions. For example, heavy fishing or harvesting--not HSI variables--may be responsible for low population levels and harvest data should be reviewed. Also, the potential presence of chemical toxicants (discussed under Special Considerations) should be investigated; data on copper, cadmium, methoxychlor, and DDS are in Table 4. A population may be recovering from a catastrophic weather event long past the time of measurement; the HSI will not correspond well to population density because of a time lag in population response. Potential predation (see Special Considerations section) should also be examined. Ultimately, the best model will mimic population responses to environmental changes, but it is impossible to model dynamics with the present data base. Model verification should be a by-product when suitability indices for substrate (V_1 and V_2) are determined.

Increased precision allowing for regional differences can be attained by taking measurements at different types of sites or at the same site under different ecological conditions.

Table 3. Calculation of habitat suitability index (HSI) for the littleneck clam based on substrate composition (V_1), substrate depth (V_2), and current velocity (V_3).

Transect No.	Sample No.	Variable	Raw score	SI
1	1	V_1	Mud (<0.25 mm)	0.1
	1	V_2	5 cm	1.0
	1	V_3	0.05 kn	0.03
	2	V_1	Fine sand (0.35 mm)	0.3
	2	V_2	40 cm	1.0
	2	V_3	0.5 kn	0.3
	3	V_1	Coarse sand (1.4 mm)	0.8
	3	V_2	55 cm	1.0
	3	V_3	1 kn	0.66
2	1	V_1	Fine sand (0.96 mm)	0.3
	1	V_2	63 cm	1.0
	1	V_3	1.7 kn	1.0
	2	V_1	Fine sand (0.45 mm)	0.3
	2	V_2	60 cm	1.0
	2	V_3	1.5 kn	1.0
	3	V_1	Fine sand (0.50 mm)	0.3
	3	V_2	63 cm	1.0
	3	V_3	1.6 kn	1.0

Variable	Average SI (6 samples)
V_1	0.35
V_2	1.00
V_3	0.67

Component	Value
Cover (CI_C)	0.35
Food (CI_F)	0.67

HSI = 0.35

Table 4. Concentrations of chemical toxicants that are stressful or lethal to littleneck clams.

Toxicant	Reference	Concentration
Copper	Graham 1972 Roesijadi 1980	Extremely stressful 39 and 82 µg/l
Cadmium	Graham 1972 Cardwell et al. 1979 Hardy et al. 1981	Potential contaminant above 1 mg/l
Methoxychlor	Cardwell et al. 1979	Toxic at 17 mg/l
DDS	Cardwell et al. 1979	Toxic at 0.3 mg/l

REFERENCES

Amos, M.H. 1966. Commercial clams of the North American Pacific coast. U.S. Fish Wildl. Serv. Circ. 237:18.

Bourne, N. 1968. Clam research in British Columbia. Proc. Natl. Shellfish. Assoc. 59:10.

Boyle, P.R. 1981. Molluscs and man. Edward Arnold Publishers, London. 60 pp.

Cardwell, R.D., C.E. Woelke, M.I. Can, and E.W. Sanborn. 1979. Toxic substance and water quality effects on larval marine organisms. Wash. Dep. Fish. Tech. Rep. 45:1-71.

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.

Crecelius, E.A. 1979. Measurements of oxidants in ozonized seawater and some biological reactions. J. Fish. Res. Board Can. 36:1006-1008.

Crisp, D.J. 1964. The effects of severe winter of 1962-63 on marine life in Britain. J. Anim. Ecol. 33:165-210.

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

Eggleston, D., and R.W. Hickman. 1972. Mass stranding of molluscs at Te Waewe Bay, Southland, New Zealand. N. Z. J. Mar. Freshw. Res. 6(3):379-382.

Feder, H.M., and A.J. Paul. 1972. The littleneck clam, Protothaca staminea (Conrad), a potential fishery resource in Prince William Sound, Alaska. Proc. Alaskan Sci. Conf. 23:46.

Fitch, J.E. 1953. Common marine bivalves of California. Calif. Dep. Fish Game Fish Bull. 90. 102 pp.

Fraser, C.M., and G.M. Smith. 1928. Notes on the ecology of the littleneck clam, Paphia staminea Conrad. Trans. R. Soc. Can. (Sec. 5) 22:249-270.

Gaumer, T.F., and B.G. Halsted. 1976. Methods of supplementing clam and abalone production. Annu. Rep. Oreg. Dep. Fish Wildl. 65 pp.

Gibson, F.A. 1963. Mortality in marine animals during storms. Irish Nat. J. 14:118-119.

Goodwin, C.L. 1971. Distribution of subtidal hardshell clams in Puget Sound, Washington. Proc. Natl. Shellfish. Assoc. 62:4-5.

Goodwin, C.L. 1973. Distribution and abundance of subtidal hardshell clams in Puget Sound, Washington, Wash. Dep. Fish. Tech. Rep. 14. 81 pp.

Gotshall, D.W. 1977. Stomach contents of northern California Dungeness crabs, *Cancer magister*. Calif. Fish Game 63:43-51.

Graham, D.L. 1972. Trace metals in intertidal mollusks of California. Veliger 14(4):365-372.

Grosz, T., and C.F. Yocum. 1972. Food habits of the white-winged scoter in northwestern California. J. Wildl. Manage. 36:1279-1282.

Gunther, G. 1957. Temperature. Pages 139-384 *in* I.W. Hedgepeth, ed. Treatise on marine ecology and paleoecology, Vol. 1: Ecology. Geol. Soc. Am. Mem. 67(1).

Hancock, D.R., T.F. Gaumer, G.B. Willeke, G.P. Robert, and J. Flynn. 1979. Subtidal clam populations: distribution, abundance, ecology. Oregon State University Sea Grant, Corvallis. 243 pp.

Hardy, J.T., R.L. Schmidt, and C.W. Apts. 1981. Marine sediment and interstitial water: effects on bioavailability of cadmium to gills of the clam *Protothaca staminea*. Bull. Environ. Contam. Toxicol. 27:798-805.

Hartwick, B., L. Tulloch, and S. MacDonald. 1981. Feeding and growth of *Octopus dofleini* (Wulker). Veliger 24:129-138.

Hemingway, G.T. 1973. Feeding in the marine snail *Acanthina spirata*. Am. Zool. 13:1335.

Hemingway, G.T. 1978. Evidence for a paralytic venom in the intertidal snail, *Acanthina spirata* (Neogastropoda: Thaisidae). Comp. Biochem. Physiol. 60C:79-81.

Houghton, J.P., and D.E. Moore. 1977. Age and growth of *Protothaca staminea* and *Saxidomus giganteus* at Kicket Island, Washington. Proc. Natl. Shellfish. Assoc. 67:119.

Lukas, G., and T.F. Gaumer. 1974. Clam-abalone stock supplementation feasibility study. Annu. Rep. Fish Comm. Oreg. 19 pp.

Marriage, L.D. 1958. The bay clams of Oregon. Fish Comm. Oreg. Educ. Bull. No. 2. 47 pp.

Neave, F. 1943. Biological investigations of commercial shellfish. Br. Columbia Fish. Dep. Rep. 70-74.

Neave, F. 1944. Biological investigations of commercial shellfish. Br. Columbia Fish. Dep. Rep. 75-79.

Neave, F. 1945. Biological investigations of commerical shellfish. Br. Columbia Fish. Dep. Rep. 64-67.

Nickerson, R.B. 1977. A study of the littleneck clam (*Protothaca staminea* Conrad) and the butter clam (*Saxidomus giganteus* Deshayes) in a habitat permitting coexistence. Prince William Sound, Alaska. Proc. Natl. Shellfish. Assoc. 67:85-102.

Paul, A.J., and H.M. Feder. 1973. Growth, recruitment and distribution of the littleneck clam, *Protothaca staminea*, in Galena Bay, Prince William Sound, Alaska. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 71:665-667.

Paul, A.J., J.M. Paul, and H.M. Feder. 1976. Recruitment and growth in the bivalve *Protothaca staminea* in Olsen Bay, Prince William Sound, ten years after the 1964 earthquake. Veliger 18(4):385-392.

Pearson, W.H., P.C. Sugarman, and D.L. Woodruff. 1979. Thresholds for detection and feeding behavior in the Dungeness crab, *Cancer magister* (Dana). J. Exp. Mar. Biol. Ecol. 39:65-78.

Pearson, W.H., D.L. Woodruff, P.C. Sugarman, and B.L. Olla. 1981. Effects of oiled sediment on predation on the littleneck clam, *Protothaca staminea*, by the Dungeness crab, *Cancer magister*. Estuarine Coastal Shelf Sci. 13:445-454.

Peterson, C.H. 1977. Competitive organization of the soft bottom macrobenthic communities of southern California lagoons. Mar. Biol. (Berl.) 43(4):343-360.

Quayle, D.B. 1940. A preliminary report on the British Columbia clam investigation. Br. Columbia Fish. Dep. Pacific Biol. Stn., Nanaimo K67-K71.

Quayle, D.B. 1943. Sex, gonad development and seasonal gonad changes in *Paphia staminea* Conrad. J. Fish. Res. Board Can. 6:140-151.

Quayle, D.B., and N. Bourne. 1972. The clam fisheries of British Columbia. Fish. Res. Board Can. Bull. 179:1-70.

Roesijadi, G. 1980. Influence of copper on the clam *Protothaca staminea*: effects on gills and occurrence of copper binding proteins. Biol. Bull. (Woods Hole) 158:233-247.

Roesijadi, G., J.W. Anderson, and J.W. Blaylock. 1978. Uptake of hydrocarbons from marine sediments contaminated with Prudhoe Bay crude oil: influence of feeding type of test species and availability of polycyclic aromatic hydrocarbons. J. Fish. Res. Board Can. 35:608-614.

Rudy, P., and L.H. Rudy. 1979. Oregon estuarine invertebrates: an illustrated guide to the common and important invertebrate animals. U.S. Fish Wildl. Serv. Biol. Serv. Program. FWS/OBS-79/111:166-168.

Schmidt, R.R., and J.E. Warme. 1969. Population characteristics of *Protothaca staminea* from Mugu Lagoon, California. Veliger 12(2):193-199.

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A review and synthesis of existing information were used to develop a habitat model for littleneck clam (Protothaca staminea). The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat) for estuarine and marine areas of the Pacific coast. Habitat suitability indices are designed for use with habitat evaluation procedures previously developed by the U.S. Fish and Wildlife Service. Guidelines for model applications and techniques for estimating model variables are described.

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