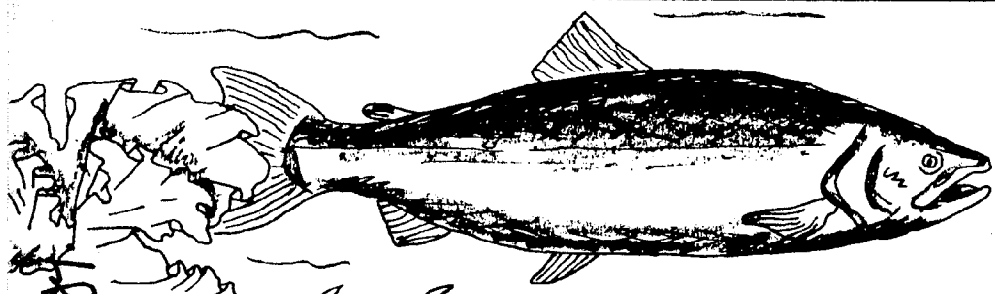
W.P.

10544

State of Washington
Department of Ecology
Coastal Zone Information Center

BASELINE STUDY PROGRAM



CRITICAL AREA STUDY
VOLUME 5
INVERTEBRATES

FINAL DRAFT REPORT

DECEMBER, 1976

CRITICAL AREA STUDY

VOLUME V

INVERTEBRATES

By

John S. Isakson

Mathematical Sciences Northwest, Inc.
P.O. Box 1887
Bellevue, Washington

INDEX TO INVERTEBRATE SPECIES

CODE NO.	COMMON NAME
I-1	Sea Cucumber
I-2	Green Sea Urchin
I-3	Red Sea Urchin
I-4	Purple Sea Urchin
I-5	Ocean Pink Shrimp
I-6	Northern Pink Shrimp
I-7	Sidestripe Shrimp
I-8	Spot Shrimp
I-9	Dock Shrimp
I-10	Humpy Shrimp
I-11	Coonstripe Shrimp
I-12	Brokenback Shrimp
I-13	Box Crab
I-14	Dungeness Crab
I-15	Red Rock Crab
I-16	Puget Sound King Crab
I-17	Kelp Crab
I-18	Pile Worm
I-19	Blue Mussel
I-20	California Mussel
I-21	Butter Clam
I-22	Common Cockle
I-23	Horse Clam
I-24	Gaper Clam
I-25	Soft Shell Clam
I-26	Japanese Little Neck
I-27	Piddock
I-28	Razor Clam
I-29	Native Little Neck

CODE NO.	COMMON NAME
I-30	Octopus (*hongkongensis*)
I-31	Octopus (*dofleini*)
I-32	Red Abalone
I-33	Northern Abalone
I-34	Geoduck
I-35	Pacific Pink Scallop
I-36	Sea Scallop
I-37	Rock Scallop
I-38	Hinds' Scallop
I-39	Pacific Coast Squid

INTERPRETATION OF INVERTEBRATE FACT SHEETS

Each fact sheet is headed with an accepted common and scientific name of each invertebrate species. In some cases the common names were selected to separate species often lumped together under one common name (i.e., "coonstripe" shrimp, "horse" clam, etc.). In these cases a second most common name was selected and used (i.e., "coonstripe" shrimp is commonly used for I-9, I-10, and I-11, which in this study are named: dock shrimp, humpy shrimp, and coonstripe shrimp, respectively).

These fact sheets and associated maps (if critical areas were determined for a species) are an initial evaluation of presently available information and by no means should be construed as a final statement on these invertebrate species. (See Introductory Volume).

Life History

An overview of the invertebrate species life history in Washington waters is provided, based primarily on a literature review - Beak Consultants, Inc., 1975, Oil Pollution and the Significant Biological Resources of Puget Sound, and newer reports such as Kozloff, E. N., 1976, Seashore Life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago.

The former literature review references are numbered in the text and are listed at the end of this volume by author and date. Volume II of the literature review contains the complete reference.

In addition, references were also selected with more recent information. In some cases this included older sources of information not located in the literature review. These sources have a letter reference in the text and are listed at the end of this volume.

Washington Distribution

The distribution of the invertebrate species is briefly described for the marine and estuarine waters of Washington State to provide the reader a general understanding of the species and numbers of animals in recorded locations. Seasonal use of areas is described when suitable information was located. This information will assist in determining when and where a given species would be most affected by man's activities.

Habitat Requirements

A brief description of the marine and estuarine habitats utilized by the species is provided. These were defined using Department of Ecology habitat types (rock, sand, mud, mixed: coarse, mixed: fine, eelgrass bed, kelp bed, saltmarsh, and open water) where possible. As the literature allowed, more specific details were added to better define the habitat used.

The invertebrate species habitat used is summarized in Table 1.

Critical Habitat Areas

The major thrust of this study was to locate and define any specific critical habitat areas that may exist in Washington marine and estuarine waters for each invertebrate species. As defined by DOE, critical habitats are:

1. The area supports population of a specie(s) that not only consistently reproduces itself but because of favorable environmental conditions (currents, water temperature, salinity, etc.) provides the major source of recruitment for adjacent areas or regions whose populations do not consistently reproduce themselves.

2. The area consists of a habitat type or types that provide either shelter, food; or other environmental necessities during a critical part of a species life history. For example: nesting sites or shelter from predators during early life history stages.

Unfortunately, our knowledge of these invertebrate species does not allow the use of the first definition; but critical habitat areas were defined for one species on the basis of the second definition.

Areas for species with critical locations were then named and underlined in the fact sheet text. Associated maps for the invertebrates illustrate these areas on overlays of USC and GS charts. On the map overlays, these areas are coded: I-14, (i.e., critical areas for invertebrate species, I-14, Dungeness Crab).

One very important point should be remembered by the user of this material. The critical habitat areas noted are by no means to be interpreted as the only critical invertebrate habitats in the marine environs of Washington. This is an initial listing based on a limited amount of data and the subjective judgment of some biologists who have studied these species and areas. As will be obvious to the reader, in many cases the areas are described in very general terms because of the lack of specific information on habitat types in an area and the usage of specific areas by the species involved.

Data Gaps

In this fact sheet section, data gaps for invertebrates were noted that were apparent from the compilation of information for each species. General comments follow on how these data gaps might be filled. In some cases, where invertebrates appeared to be incidental species in Washington waters, a comment is made questioning the validity of the species on an "important" invertebrate list for Washington State.

Invertebrate species data gaps are summarized in Table 2.

The major data gap noted for the invertebrates is the systematic and routine censusing of all Washington waters for these species. At present some species are surveyed in some areas of Washington. If practical, as many invertebrate species should be surveyed at one time as possible in any given area. Catch records of commercially important invertebrate species are compiled at present. Some of these records are of a proprietary nature. If possible with this constraint, a general description of quantities caught, areas and times of capture, would be useful to a future evaluation of invertebrate critical areas.

from federal as well as other state agencies. NMFS, BLM, USF&WS may also be compiling information at least on the open coast of Washington. These areas would then become the starting point for exploratory fishing on these species if such sampling is necessary beyond this catch record summary.

The early life history of many of these invertebrate species may be better known in unpublished Friday Harbor Laboratories information. Dr. R. L. Fernald, University of Washington (semi-retired), should be contacted when he is available as the embryological information is oriented around past courses at Friday Harbor.

References

The study relied principally on the literature review conducted for DOE. Numbered references in the fact sheet text are listed by author(s) and date at the end of the invertebrate volume and are coded with the same reference number as in Volume II of the DOE literature review.

Lettered references in the fact sheet text are for additional sources used to fill in literature review data gaps. These are listed at the end of the volume. This literature search was not exhaustive with the limited time and effort allotted for this study.

TABLE 1

HABITAT TYPES

INVERTEBRATES	Open Water	Rock	Sand	Mud	Mixed Coarse	Mixed Fine	Eel Grass	Kelp Bed	Salt Marsh
I-1 Sea Cucumber	x	x	x		x		x		
I-2 Green Sea Urchin	x	x	x	x	x	x	x		
I-3 Red Sea Urchin	x	x			x	x		x	
I-4 Purple Sea Urchin	x	x	x						
I-5 Ocean Pink Shrimp	x		x	x					
I-6 Northern Pink Shrimp	x			x					
I-7 Sidestripe Shrimp	x		x	x					
I-8 Spot Shrimp	x	x		x	x				
I-9 Dock Shrimp	x	x	x			x	x		
I-10 Humpy Shrimp	x	x	x		x	x			
I-11 Coonstripe Shrimp	x	x	x	x	x	x			
I-12 Brokenback Shrimp	x	x						x	
I-13 Box Crab	x	x	x						
I-14 Dungeness Crab	x		x	x		x			
I-15 Red Rock Crab	x	x	x	x	x	x	x		
I-16 Puget Sound King Crab	x	x			x				
I-17 Kelp Crab	x	x					x	x	
I-18 Pile Worm	x	x	x		x	x			
I-19 Blue Mussel	x	x	x		x	x			
I-20 California Mussel	x	x	x		x	x			
I-21 Butter Clam	x		x	x		x			
I-22 Common Cockle	x	x	x	x	x	x	x		

TABLE 1 (CONTINUED)

HABITAT TYPES

INVERTEBRATES	Open Water	Rock	Sand	Mud	Mixed Coarse	Mixed Fine	Eel Grass	Kelp Bed	Salt Marsh
I-23 Horse Clam	x		x		x	x	x		
I-24 Gaper Clam	x		x	x		x			
I-25 Soft Shell Clam	x		x	x	x	x			
I-26 Japanese Little Neck	x		x	x	x	x			
I-27 Piddock	x	x	x	x					
I-28 Razor Clam	x		x						
I-29 Native Little Neck	x		x	x	x	x			
I-30 Octopus (*honkongensis*)[1]	(See I-31 Octopus *dofleini*)								
I-31 Octopus (*dofleini*)	x	x							
I-32 Red Abalone	x	x			x	x			
I-33 Northern Abalone	x	x			x	x			
I-34 Geoduck	x		x		x	x			
I-35 Pacific Pink Scallop	x	x	x		x	x			
I-36 Sea Scallop	x		x			x			
I-37 Rock Scallop	x	x							
I-38 Hind's Scallop	x		x		x	x	x		
I-39 Pacific Coast Squid	x		x	x					

[1] This may be the species *O. Rubescens*.

TABLE 2

DATA GAPS

INVERTEBRATES	Critical Habitat Areas	Coast Catch Summary	Strait Catch Summary	General Census	Life History	Repro.	Feeding	Nursing	Migration	Lab. Studies	Detailed Data Search	Related Environ. Studies	No Research	Why On List
I-1 Sea Cucumber	-			x	x	x								
I-2 Green Sea Urchin	-			x	x					x				
I-3 Red Sea Urchin	-			x	x					x				
I-4 Purple Sea Urchin	-			x	x					x				
I-5 Ocean Pink Shrimp	-	x	x	x		x		x						
I-6 Northern Pink Shrimp	-	x	x	x		x		x						
I-7 Sidestripe Shrimp	-	x	x	x		x		x						
I-8 Spot Shrimp	-	x	x	x		x		x						
I-9 Dock Shrimp	-	x	x	x		x		x						
I-10 Humpy Shrimp	-	x	x	x	x	x	x	x						
I-11 Coonstripe Shrimp	-	x	x	x		x		x						
I-12 Brokenback Shrimp	-	x	x	x		x		x						
I-13 Box Crab	-	x	x	x	x					x	x			
I-14 Dungeness Crab	"2"			x	x	x								
I-15 Red Rock Crab	-			x	x	x				x				

TABLE 2 (CONTINUED)

DATA GAPS

	INVERTEBRATES	Critical Habitat Areas	Coast Catch Summary	Strait Catch Summary	General Census	Life History	Repro.	Feeding	Nursing	Migration	Lab. Studies	Detailed Data Search	Related Environ. Studies	No Research	Why On List
I-16	Puget Sound King Crab	-			x	x	x								
I-17	Kelp Crab	-			x	x					x				
I-18	Pile Worm	-				x	x								
I-19	Blue Mussel	-				x	x								
I-20	California Mussel	-			x	x									
I-21	Butter Clam	-			x	x									
I-22	Common Cockle	-			x	x									
I-23	Horse Clam	-			x	x									
I-24	Gaper Clam	-			x	x									
I-25	Soft Shell Clam	-			x	x					x				
I-26	Japanese Little Neck	-			x	x									
I-27	Piddock	-			x	x					x				
I-28	Razor Clam	-										x	x		
I-29	Native Little Neck	-			x	x									
I-30	Octopus (*honkongensis*)[1]	-			x	x	x	x		x					

[1]This may be the species *O. rubescens*.

TABLE 2 (CONTINUED)

DATA GAPS

	INVERTEBRATES	Critical Habitat Areas	Coast Catch Summary	Strait Catch Summary	General Census	Life History	Repro.	Feeding	Nursing	Migration	Lab. Studies	Detailed Data Search	Related Environ. Studies	No Research	Why On List
I-31	Octopus (*dofleini*)	-			x	x	x	x		x					
I-32	Red Abalone	-												x	x
I-33	Northern Abalone	-			x	x					x				
I-34	Geoduck	-	Enough information exists?												
I-35	Pacific Pink Scallop	-			x	x	x				x				
I-36	Sea Scallop	-			x	x	x				x				
I-37	Rock Scallop	-			x	x	x				x				
I-38	Hind's Scallop	-			x	x	x				x				
I-39	Pacific Coast Squid	-			x	x	x								

INVERTEBRATE VOLUME

NOTE TO THE USER

The user of these materials should have one additional source available:

Beak Consultants, Inc., 1975. Biological Oil Impact Literature Review - Volume II Bibliography. Prepared for Washington Department of Ecology.

An additional and useful source for most of the invertebrate species covered is:

Kozloff, E. N., 1976. Seashore Life of Puget Sound, the Strait of Georgia and the San Juan Archipelago. University of Washington Press. Seattle.

FACT SHEET

I-1 SEA CUCUMBER

Parastichopus californicus

LIFE HISTORY - This species is the largest of Washington's sea cucumbers (B) and abundant in Puget Sound from the shoreline to a depth of 44 fathoms (80 m) and to 50 to 100 fathoms in southern locations (California?) (J). *Parastichopus* reaches 18 inches in length or more (J). This sea cucumber is worm-shaped, typically five times as long as wide, and is a mottled reddish-brown color (J). Most of this species have separate sexes and possess a single gonad (704). Ova and sperm are discharged into the water. This species probably migrates into shallow water to spawn. Individuals with mature gonads have been collected in May-August (J). Time of spawning is around July-August (greater Puget Sound, 1004) and September (San Juan Islands, 268). The embryo produced is planktonic (1003, 1008). The planktonic stages have not been followed as they have for *P. japonicus*, whose development at 20 to 22 C was as follows: 10 hours - blastula; 24 hours - gastrula; 46 hours - auricularia, 10 to14 days - doliolaria; 11 to17 days - pentactula, and 15 to23 days - juvenile (J). The suitable temperature for *P. californicus* embryonic development is about 10 C while temperatures exceeding 14 C prove fatal (J), so the development of this species may be much slower than *P. japonicus*. The doliolaria, pentacula stage was found bottom-associated in North Sound in July-August (625). Juvenile *P. japonicus* settle as juveniles and are found intertidally and move to deeper water with growth (J).

The adult form often eviscerates itself in "stale" waters or as a defense mechanism (1008) or because of excess water pressure (C). The adult form contains a hydrovascular system which maintains the body shape and serves for locomotion via tube feet (1008).

Movements of sea cucumbers occur by manipulation of their tube feet (B). Adults can also "swim" by body flexing actions which seem to be an escape mechanism from starfish predation (J). Sea cucumbers move into shallow areas to spawn (1004) and move to deeper water with growth (J).

Feeding is accomplished by sweeping its tentacles (1008). These are specialized tube feet, like mops around the mouth (13). This species is a deposit feeder (551). Food of this species also includes plankton (protozoans, algae, diatoms).

More detailed biological information on sea cucumbers is located in the new WDF Study (J).

WASHINGTON DISTRIBUTION - This species of sea cucumber is reported from the Strait of Georgia to greater Puget Sound in the literature review (A). Outer coast sea cucumbers may be included in the "Pacific Northwest waters" area (A). Concentrations are not specifically reported in the literature review except to say that sea cucumbers are common and abundant in parts of the San Juan Archipelago (268), parts of South Sound (64) and parts of Whidbey Basin (208). They seem to be in scattered concentrations all over these inside waters with the possible exception of areas near large stream outflows where salinities

may be too low for this species. Most species are apparently not tolerant of low salinities.

This species was not reported in a recent study of San Juan Island and Shaw Island (F) nor in Grays Harbor (G) and Willapa Bay (H, I). This species is in abundance in the San Juans (Ron Westley, WDF, personal communication). Sea cucumbers would not be expected off the Columbia River mouth or in the lower river estuary. Coastal sea cucumbers of this species probably exist on the North Coast and in bays primarily with flatter bottoms in the Strait of Juan de Fuca. This species also exists on rocky bottomed areas.

HABITAT REQUIREMENTS - Sea cucumbers are bottom-associated in the open water habitat all of their lives except when the embryo is planktonic in the open water habitat. In California this species is primarily subtidal, but often comes to the intertidal (1008). The literature review (A) in the Northwest indicates they are low intertidal to subtidal. Bottom types associated with include solid rock, mixed: very coarse, mixed: medium, sand/eelgrass, silt, detritus, clay and sand (A). This species is common in eelgrass beds and found on pilings below the low tide line (1008). Temperatures of 14 C or higher are lethal for egg development, while the preferred temperature is about 10 C (1004). Sand would seem necessary in part of the habitat occupied because of the detritus feeding nature of this species.

CRITICAL HABITAT AREAS - No specific areas stand out in this review of the available information. Concentrations occur but no specific areas were noted as consistently having large numbers of sea cucumbers. Potential critical areas may be those shallow areas selected for spawning in July-September. These areas need to be generally surveyed to locate any that are consistently important areas for spawning.

DATA GAPS - More information appears needed for the early life history of sea cucumbers (locations of embryos) and age to bottom-dwelling stage by laboratory studies. Age of maturity and life span would also be important to determine. Marking may also be feasible to determine movements between or within areas.

More information is also needed from the Strait of Juan de Fuca, coast, and coastal bays, which would require specialized dredge-type trawls in these locations. Conceivably SCUBA methods could provide shallow water information on these sea cucumbers.

REFERENCES - A, B, C, F, G, H, I, J, 13, 64, 208, 268, 551, 625, 704, 1003, 1004, 1008.

FACT SHEET

I-2 GREEN SEA URCHIN

Strongylocentrotus droebachieusis

LIFE HISTORY - The green sea urchin is well adapted to cold temperatures and in the Eastern Pacific, ranges from Point Barrow to Washington State, being the dominant sea urchin in Puget Sound (K). The red (I-3) and the purple sea urchin (I-4), while ranging to Alaska, seem more adapted to more southerly waters. Except for its color, pointed spines, and usually smaller size, it resembles the purple sea urchin (I-4) (1008).

The green sea urchin has a life span of four years (493), although this is questionable. Sexes are separate (1008). Males are ripe nearly two months earlier than females, with spawning in winter or early spring (K). Reproducing adults have been seen in the San Juan Archipelago in April and May (121). Ova and sperm are discharged into the water (1008). The upper limit of normal larval development is 10 C, which may determine the southern range limit of the green sea urchin (K). Female urchins'(no species named) fecundity ranges from 100,000 to 2,000,000 eggs (K).

The free floating planktonic stage lasts for two to three months (493) when the organism has bilateral symetry rather than the adult's radial symetry (B). Studies to date indicate extremely low juvenile recruitment, which could mean the best habitats have not been studied, or that recruitment is sporadic and often not significant in many years (K).

The echinopluteus stage (embryo) are present in the San Juan Archipelago in June and August, bottom-associated in kelp in moderate to swift current areas (797). This may be the initiation of the settling period in this area.

Migrations are not expected to be extensive, except possibly by the planktonic larval stages. This species does move down with the fall of the tide (357). Large concentrations or "herds" have been seen and appear to be migratory groups (Ron Westley, WDF, personal communication).

The green sea urchin is omnivorous and feeds mainly on detritus (1008). Another source (925) indicates food availability determines whether a green sea urchin is a herbivore, detritus feeder, or carnivore. Numerous algal species, young barnacles, hydroids, copepods and detritus are reported foods (A). Washington sea urchin food is reported to consist largely of pieces of seaweed (B).

For more specific details of green sea urchin life history and biology, see WDF source (K).

WASHINGTON DISTRIBUTION - The green sea urchin is a bottom-associated species of the low intertidal to subtidal (A). Although living to 70 fathoms, this sea urchin is usually found in shallow waters (K). This species has a wide distribution in northern waters (B) and is indicated as common (1008) and dominant (K) in Puget Sound. The green sea urchin appears to favor more protected waters as compared to the purple sea urchin (I-4) which like surf-swept rocky shores (1008). Green sea urchin have a much wider range of habitat types than the red or purple sea urchin (Ron Westley, WDF, personal

communication) The green sea urchin appear to be crowding out the purple sea urchin (I-4) in the San Juan Islands (1008).

Adult green sea urchins in inside waters appear most abundant in the North Sound area, particularly in the San Juan Archipelago, Strait of Juan de Fuca, and in some parts of the Strait of Georgia (A). Sea urchins in general do not appear to tolerate low salinities, as noted at Kiket Island (Jon Houghton, Dames and Moore, personal communication). This pattern may also hold for much of the eastern part of North Sound and Puget Sound - at the vicinity of estuaries where larger streams enter salt water.

A few green sea urchins were reported in the San Juan Island survey - rare in the intertidal rock area (F). They were not reported in the Willapa Bay (H, I) and Grays Harbor studies (G). They would not be expected near the mouth of the Columbia River, nor in the estuary. They may be in reduced numbers on the north coast of Washington.

HABITAT REQUIREMENTS - Green sea urchins are very bottom-associated, except for the two to three month planktonic stage when they are pelagic in the open water habitat. Green sea urchin prefer rocky, gravelly, or shelly substrates. but may also be found on sandy, or rarely, muddy bottoms (K). Rock and kelp on rocks appears the most often bottom associated within the literature review (A). However, boulder; mixed very fine, sand, mixed: coarse, pebble-gravel, mixed: medium, shell fragments, clay, cobble, eelgrass, are other bottoms noted for the green sea urchin (A).

This seems to indicate a quite opportunistic nature to the sea urchin's use of habitats, possibly moving to food or staying in places where detritus

comes to the sea urchin. This species also seems able to survive on dock floats as well as pilings (B). Another determining factor to habitats used would be the presence or absence of a predator, like the sunflower star (*Pycnopodia helianthodes*) (29). Low salinities also influence the size, if not the numbers, of green sea urchins. Temperatures above 10 C cause abnormal development.

The information reviewed does not present a clear pattern of habitat usage by green sea urchins. They seem scattered, but abundant, in some locations in inside waters. They may be in some locations (protected areas) on the northern open coast and in the western Strait of Juan de Fuca.

CRITICAL HABITAT AREAS - The green sea urchin appears to use a wide variety of bottom types, although solid rock/kelp areas in the low intertidal to subtidal appear to be "preferred". No areas stand out from any others in the information reviewed. Possible large spawning areas exist that have not been located at this time. Shallow places of congregations for spawning (if they exist) could be critical areas for this species. Temperature seems to be critical to green sea urchin development with 10 C an upper limit for normal development. Warmer back-water bays that exceed this temperature in inside Washington probably have few, if any, green sea urchins.

DATA GAPS - The biggest data gap seems to be the distribution and abundance of this species in Washington State waters. The biology of other species, or this species from other areas, should be complemented with additional work in Washington State.

Dredging deeper areas and SCUBA observations in shallower waters, where visibility permits, should provide the distributional information if quarterly sampling is completed over inside Washington waters.

REFERENCES - A, D, F, G, H, I, K, 29, 121, 357, 493, 797, 925, 1008.

FACT SHEET

I-3 RED SEA URCHIN

Strongylocentrotus franciscanus

LIFE HISTORY - The red sea urchin is the largest species on our coasts, and the most important commercially, yet it has been little studied (K). Characteristically, this species inhabits the deeper pools and downward from low tide (1008). In 1976, the estimated catch will be about one million pounds (Ron Westley, WDF, personal communication).

No life span was described. Fecundity for sea urchins (no species given) is from 100,000 to 2,000,000 eggs (K). Sexes are separate, with ova and sperm discharged into the water, and planktonic larval stages before settling on the bottom as the juvenile (1008). Spawning is in March to April in Puget Sound (K).

Details described for green sea urchin (I-2) life history may apply to this species. See the pending WDF report (K) for more details on this and other sea urchin species.

Migrations would not be expected to be extensive, however, the planktonic larval stages may cover great distances. Movements tend to be short or random or long and preferentially directed towards new rocks (351).

The red sea urchin has marked food preferences with experimental results indicating the kelp *Macrocystis pyrifera* as the preferred food (K). Other preferred food in descending order included *Gigartina armata* and *Laminaria farlowii*, and other species (K). Other foods reported include other algae species and detritus (113, 351). Small barnacles are also eaten (B).

WASHINGTON DISTRIBUTION - The red sea urchin is a bottom-associated species, typically of the shallow depths (2.5 to 5.5 fathoms) though it may be found intertidally or to depths of 70 fathoms (K). The literature survey (A) presents a scattered distribution of "heavy" quantities of red sea urchins in inside waters and the Strait of Juan de Fuca. They are noted as "present" on the coast (1008).

In the recent San Juan Island-Shaw Island survey (F), the red sea urchin was found to be a dominant grazer in the subtidal rock (minus 5 m) level.

This species is not reported for Grays Harbor (G) and Willapa Bay (H, I) and probably only exists on the northern rocky coast of Washington, if at all.

HABITAT REQUIREMENTS - Red sea urchins are very bottom-associated except for the planktonic larval stage when they are pelagic in the open water habitat. The red sea urchin is usually found in rocky substrates in zones of brown sea weeds where currents are moderate to swift (K). This species tends to aggregate on rocks (351). Juveniles and adults are found quite close together and may be found in crevices and amongst kelp holdfasts in the high subtidal zone (K). This species inhabits relatively quiet shores as well as others with considerable wave action being common subtidally (B). This species is reported only abundant in high tidal velocity areas (541). A wide variety of bottoms associated with are indicated in the literature review (A) -- solid rock, mixed: fine, mixed: very coarse, mixed: coarse, and boulder.

The information reviewed presents no clear patterns of habitat usage by this species in Washington waters because of a limited amount of information and possibly an opportunistic nature to red sea urchins' use of habitats. The shallow subtidal in the brown algae zone appears to be the preferred habitat.

CRITICAL HABITAT AREAS - The general habitat requirements are vague and along with little distributional information, does not allow the delineation of critical areas at this time. Spawning areas (if large congregations of sea urchin exist) may be critical in some specific locations that have yet to be found. In general, however, the red sea urchin seems scattered over much of Washington's inside waters and outside (north coastal waters) and may not have critical areas as such.

DATA GAPS - See green sea urchin (I-2).

REFERENCES - A, B, F, G, H, I, K, 113, 351, 541, 1008.

FACT SHEET

I-4 PURPLE SEA URCHIN

Strongylocentrotus purpuratus

LIFE HISTORY - The purple sea urchin is the common intertidal sea urchin of the exposed and semiprotected rocky areas of our coast, being found on nearly every rocky outcrop and also located to depths up to 35 fathoms (K). In terms of abundance, this sea urchin is far less abundant than the red or green sea urchin (Ron Wesley, WDF, personal communication). The purple sea urchin is more gregarious than the green sea urchin (I-2) (357). The life history has not been well studied (K).

Life span is reported to be 20 to 30 years (798). This seems very long, compared to the green sea urchin's (I-2) reported life span of four years (493), which may be short. Gonad development is in the Summer and Fall with spawning in Winter (K). Sexes are separate with ova and sperm discharged into the water. Purple sea urchin larval recruitment does not occur in many years (reasons unknown) with no appreciable urchin settlement on the Washington coast between 1964 and 1969 (K). Life history of purple sea urchin may be similar to that described for green sea urchin (I-2). See the pending WDF report (K) for more details on this and other species.

Migrations of this species would not be expected to be extensive, however, the planktonic larval stages may cover great distances. Intertidal populations of purple sea urchin do not appear to be very mobile grazers (K).

The purple sea urchin exhibits marked food preferences in experiments with *Macrocystis pyrifera*, *Laminaria farlowii*, and *Gigartina armata*, the three top selected seaweeds (K). Other foods mentioned in the literature survey (A) are dissolved substances, zooplankton, micro organisms, plant/animal organic material (living or dead) and detritus.

WASHINGTON DISTRIBUTION - The purple sea urchin has the pattern of favoring shores with strong wave action, being common on the open coast, in only a few restricted populations in the San Juan Archipelago, and not in Puget Sound (B). This is different from the green (I-2) and red sea urchin (I-3). There is one report of a "rare" occurrence of the purple sea urchin in Hood Canal (Edwards Reef) (276). They are reported in Neah Bay and on the British Columbia side of the Strait of Juan de Fuca, and are probably also present, and are common, along the Washington shore of the Straits.

In the recent San Juan Island-Shaw Island survey (F), this species was not reported.

This species was not reported in Grays Harbor (G) and Willapa Bay (H, I). On the coast it would be expected where rocky headlands and rocky shores exist (generally Copalis area to Cape Flattery, but also at other rocky headlands to the south). No information was located for the Columbia River mouth, but they may exist there, although salinities may limit their size and numbers.

The purple sea urchin is known to occur in concentrations in scattered and isolated locations (Ron Westley, WDF, personal communication).

HABITAT REQUIREMENTS - Purple sea urchins are unique as compared to the other two species (I-2, I-3) with their occupation of high surf areas and their use of pits excavated in softer rock. There is controversy over the method of excavation, but the pit is probably the result of a combination of the abrasive action of the spines primarily (B) or a combination of spines and teeth (1008). The purple sea urchin thus creates a cavity or pit in which it is better protected from the high surf zone occupied. This sea urchin species mainly utilizes the low tide zone (C). The pit or crevice used is apparently retained by an individual as drift algae (and other detritus?) is apparently brought to the animal by surf and tide action, thus requiring little movement by the purple sea urchin.

The bottom associated with, as described in the literature review (A), is more specific than the other sea urchin species (I-2 and I-3), solid rock and boulders. Softer rock would apparently be preferred in high surf zone areas where pits might be "excavated". Hard clays might also be similarly utilized.

The subtidal existence of purple sea urchins (to 35 fathoms, K) was not described in the information reviewed and may well be more similar to green and red sea urchins (I-2 and I-3). The majority of purple sea urchins are apparently in the low intertidal zone, however.

Egg development in purple sea urchins may be normal at 13 C to 20 C, but can survive temporary cooling (5 C) overnight (K).

CRITICAL HABITAT AREAS - The purple sea urchin seems to have the greater potential for low intertidal critical areas, particularly if spawning also occurs there as compared to the other sea urchin species (I-2 and I-3). However, no information was located on the specific location of high density areas on the open coast (and possibly in the Strait of Juan de Fuca) nor were the "few restricted populations" (B) specifically located in the San Juan Archipelago.

The apparent high numbers on the open coast may mean the restricted populations in the San Juan Archipelago might not be critical in Washington waters.

On the basis of the information reviewed no critical areas were located. Areas may exist on the northern open coast, particularly during winter spawning that may be critical for this species, particularly if large concentrations exist in selected areas and are not evenly scattered throughout this coastal area.

DATA GAPS - The largest data gap seems to be the specific distribution of the purple sea urchin on the open coast from the low tidal zone to 35 fathoms in the subtidal. Intertidal surveys of the low intertidal zone should be completed along the coastal areas to quantify (possibly in meter squared quadrants) the density of purple sea urchins in these areas.

Dredging (where possible) and SCUBA diving could provide information on the distribution and abundance of purple sea urchins in the subtidal.

Life history information (gonad development, spawning time, etc.) should be collected in field surveys. Past laboratory studies have not proved valid when compared to field-sampled sea urchins (Ron Westley, WDF, personal communication). Also see green sea urchin (I-2).

REFERENCES - A, B, C, F, G, H, I, J, 276, 357, 493, 789, 1008.

FACT SHEET

I-5 OCEAN PINK SHRIMP[1]

Pandalus jordani

LIFE HISTORY - Ocean pink shrimp, like all Pandalid shrimp, exhibit protandric hermaphroditism (maturing first as a male and then becoming a female). Males mature by age 1.5 years and change to females by age 2.5 or 3.5 years (974). There are exceptions where the male stage is missed and the juvenile matures directly to a female stage ("primary" females) (141, D). This is apparently influenced by the environment or is density-dependent (D). In exceptional years as many as 40 percent of a year class matured at 1.5 years as females (974). Life span of ocean pink shrimp is two to four years. Fecundity ranges from 500 to 2,500 eggs/female (D). Annual variations in fecundity are seen within populations (297).

Ovarian development in mature females occurs in late Summer and breeding occurs in the Fall (974, 141). Fertilized eggs are brooded (and carried) by the female for three to nine months (141). Four to seven months is also reported (Ron Westley, WDF, personal communication). Ocean pink shrimp extrude eggs in October and November and carry the eggs to hatching in March and April (974). The larval stage is planktonic, lasting two to three months (141). During this period, the larvae is living off the bottom and unable to make headway against the currents (974). Within three months, they molt five or six times, gradually taking on the adult appearance (as a juvenile) and the habit of walking or at least resting on the bottom (974).

[1]Another common name is the smooth pink shrimp.

These juveniles generally mature first as males at 1.5 years to repeat the cycle.

Migrations are made by pandalid shrimp onshore, offshore, coastwise, and vertically in the water column (D). Off California this shrimp makes short spawning migrations during the Winter into deeper water and short Summer migrations (thought to be in search for food) (D). Other Pandalid shrimp exhibit movements of young juveniles to shallower waters (5 to 35 fathoms) for their first Summer (D) which may also occur in ocean pink shrimp. The deeper water spawning movement is to 160 fathoms (21).

Diel vertical migrations are made with the shrimp leaving the bottom during late afternoon or evening and returning to near or on the bottom about dawn. The time away from the bottom is directly related to the season's hours of darkness (D). Diel migrations are also thought a protection and dispersal mechanism (454).

Foods of shrimp are primarily euphausiids and copepods, which also make diel migrations (454). Other foods eaten while on the bottom are benthic organisms and detritus (454, 347, 141).

WASHINGTON DISTRIBUTION - Ocean pink shrimp are the important coastal commercial species (947). See the catch records that follow. In 1976, the coastal Washington pink shrimp catch is expected to be 8 to 10 million pounds (Ron Westley, WDF, personal communication). These adult shrimp are from areas 12 to 20 miles offshore from an area off the coast, ranging from off the south end of Willapa Bay to the south and off Cape Johnson to the north. No *P. jordani* have been seen in Grays Harbor (Herbert Tegelberg, WDF, personal communication) and the implication is that the whole coastal life cycle is completed offshore.

The Pounds of Commercial Shrimp Landed from Washington Areas, 1957-1975

Year	Bellingham Bay	Puget Sound					Hood Canal	Combined total	Washington coast
		San Juan	Skagit Bay	Saratoga Passage	Port Susan	Elliott Bay			
1957		8,268	3,440[1]			18,023	40,482	70,213	2,348,000
1958	8,054	7,174	1,202[1]	250	2,541	20,165	21,095	60,481	5,491,983
1959	242			7,308		4,671	43,169	55,390	2,477,496
1960	110			3,960	1,650	1,177	17,470	24,367	1,091,173
1961	4,403	1,258		2,484		409	18,046	26,600	1,720,623
1962	5,853			5,141	900	1,100	18,529	31,523	1,286,289
1963	4,788	987	2,870	3,611		5,989	27,210	45,455	857,882
1964	3,507	1,920	1,815	2,633	550	3,090	56,519	70,034	126,300
1965	3,237	1,925	3,965	155		1,117	53,651	64,050	23,468
1966	8,255					505	41,337	50,097	144,609
1967	9,071	1,035			670	1,061	17,939	29,776	970,750
1968	5,110		333[1]	5,515		188	13,934	25,080	962,017
1969	1,645	2,145		1,310	6,305	133	11,472	22,990	2,546,823
1970		1,835		4,835	5,378	276	20,750	12,324	2,052,698
1971	1,830	11,415				215	49,565	63,025	1,111,100
1972	360	22,390	240[1]	20	463		65,011	88,484	3,134,600
1973[2]		51,183	5	10		994[1]	91,410	144,093	5,270,065
1974[3]		15,661			200		90,185	115,162	9,262,345
1975[4]		24,146	1,364[1]	69	4,177		22,431	83,073	10,000,690

[1]Port Gardner [2]491 lbs.=173-Anacortes, 266-Carr Inlet, 52-Samish Bay

[3]9,116 lbs.=8,720-Carr Inlet, 240-Samish Bay, 156-Port Angeles

[4]30,886 lbs.=30,206-Carr Inlet, 327-Anacortes, 353-Port Angeles

The Pounds of Commercial Shrimp Landed from the Puget Sound District by Species, 1957-1975[1]

Year	Spot[2]	Pink[3]	Sidestripe[4]	Coonstripe[5]
1957	64,941	5,272		
1958	49,086	3,341	8,054	
1959	50,300	4,484	242	
1960	19,457	4,875	35	
1961	18,843	6,952	805	
1962	20,536	7,236	3,751	
1963	35,126	7,109	420	2,800
1964	62,850	5,089	510	1,585
1965	56,647	3,378	60	3,965
1966	41,975	4,726	3,396	
1967	19,580	8,195	2,001	
1968	17,319	346	7,415	
1969	20,035		2,955	
1970	33,074			
1971	53,780		9,245	
1972	65,108	522	21,575	1,279
1973	91,574	975	45,415	6,129
1974	91,619	1,422	13,911	8,210
1975	24,567	22,540	21,398	14,568

[1]Includes Hood Canal [4]Species I-7

[2]Species I-8 [5]Species I-11, I-10, and I-9

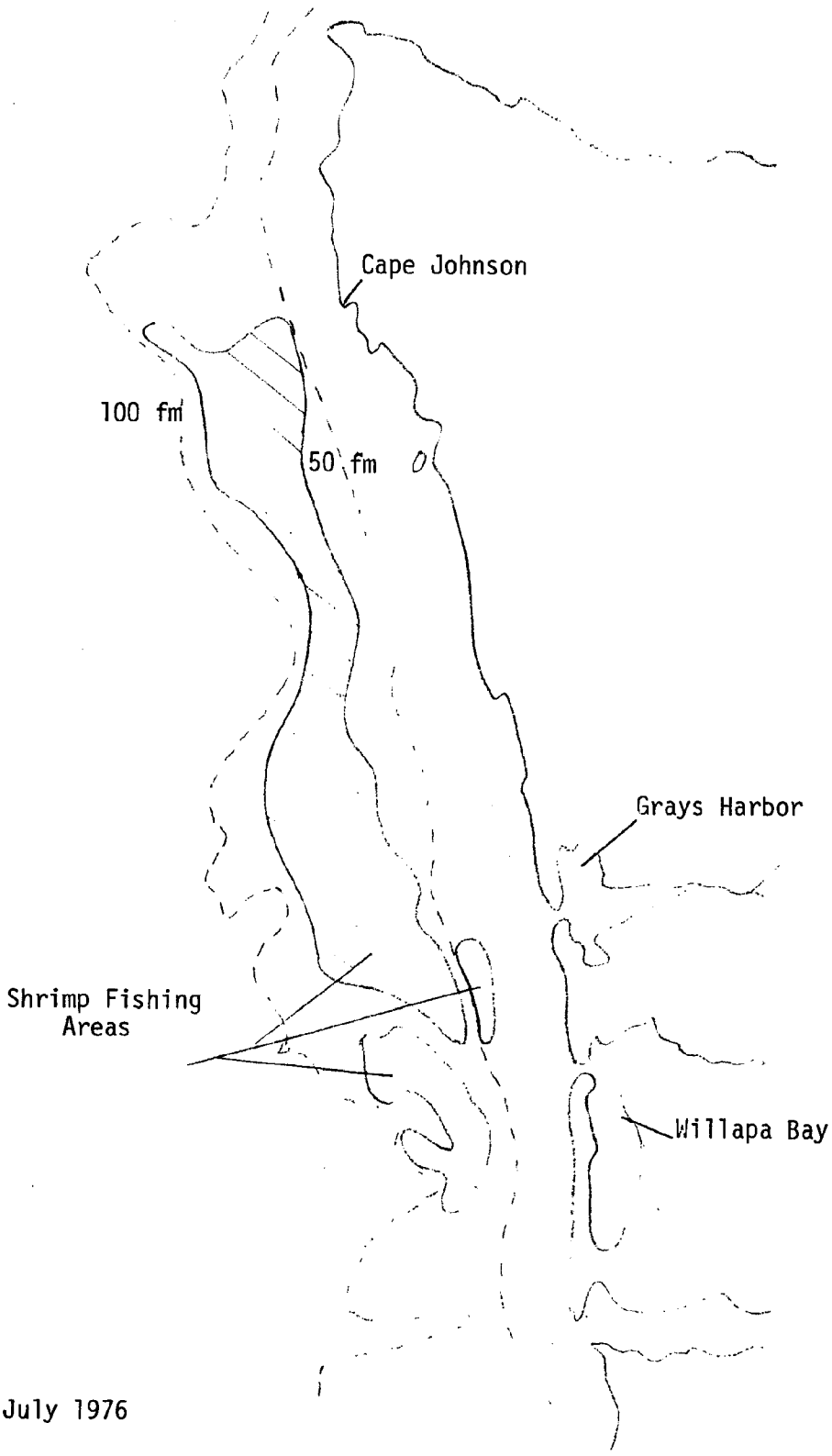
[3]Species I-5 and I-6 SOURCE: 974, WDF Statistical Data

The ocean pink shrimp is also in Puget Sound, being most abundant in South Sound from Vashon Island south and also around Possession Sound and Saratoga Passage (974).

This species was not reported in Grays Harbor (G) and Willapa Bay (H, I) and would not be expected in the lower Columbia River estuary. The following tables describe Washington catches of "pink" shrimp and nearly all the Washington coast catch is this species.

HABITAT REQUIREMENTS - The ocean pink shrimp utilizes the open water habitat type, although the species is bottom-associated as a juvenile and adult during "daylight" hours. The larval stage (two to three months) is planktonic and totally in the open water habitat.

The adults are found on green mud or green mud and sand bottoms from 25 to 200 fathoms, but the offshore commercial beds off Washington are 50 to 80 fathoms deep (974) and are beyond State waters (see map).



SOURCE: WDF, July 1976

Adults are present where the bottom type exists and are in concentrations, possibly when the organic content of the bottom is suited to the ocean pink shrimp (D). This organic content would presumably contain an abundance of detritus and benthic organisms suitable for feeding by this shrimp. Pandalid shrimp may also occupy harder or rockier bottoms not sampled by mud/sand bottom type trawls (D).

The temperature range for *P. jordani* is from 5.6 to 11.5 C and the salinity range is the highest of several Pandalid shrimp -- 28.7 to 34.6 ppt (D).

CRITICAL HABITAT AREAS - The general habitat description would indicate open water habitat over green mud bottoms of high organic content could be critical in March and April and for two to three months thereafter when the larvae are in this area (off the bottom to midwater) as this is thought the most critical life stage.

The annual variations in fecundity, age at maturity, and sex at first maturity, would indicate a great dependence on environmental parameters (food available, water temperature and salinity, etc.), to determine these characteristics in any shrimp year class.

Areas of concentration within the larger coastal fishing area and in inside waters were not well described and no critical areas stand out.

The coastal population, which is by far the greatest in numbers, may spend most or all of its life cycle beyond three miles and State waters.

No specific critical areas can be designated from the information reviewed.

DATA GAPS - The exploratory or commercial fishing data collected in the past in State waters should be summarized so that areas of historic concentration might be located from this sampling. From there, exploratory efforts should be initiated to check for present concentrations, particularly in the breeding (Fall) and in the hatching (March-April) periods. Areas given in South Puget Sound and in Possession Sound and Saratoga Passage whould be the initial focal points in Puget Sound. The coastal ocean pink shrimp are beyond State waters, but important to Washington fishermen, so there exists a question as to State research there. At the minimum, the State should continue to encourage federal research on these offshore areas. Trawling sampling should be completed in a standardized fashion to provide abundance information that can be compared between sampling areas with time.

REFERENCES - D, G, H, I, 21, 141, 277, 347, 454, 974.

FACT SHEET

I-6 NORTHERN PINK SHRIMP[1]

Pandalus borealis

LIFE HISTORY - The northern pink shrimp, as the name implies, is a more northern species compared to the ocean pink shrimp (I-5). The species prefers colder water and ranges as far south as the Columbia River (D), or Puget Sound (974).

This species is generally replaced by ocean pink shrimp (I-5) as the dominant ocean species south of Alaska (974).

The life history is basically like that of ocean pink shrimp (I-5). This species generally lives to four years (Washington), and six years (Alaska) (974).

Migrations are probably like those of ocean pink shrimp (I-5) except to deeper waters (490 fathoms) (141) or 350 fathoms (947). Migrations with age are documented (B).

Foods are like those of ocean pink shrimp (I-5).

WASHINGTON DISTRIBUTION - The northern pink shrimp is apparently not numerous (commercial quantities) on the open coast, although it is reported to range south to about the Columbia River by one source (D). The abundance of northern pink shrimp in Puget Sound is complexed by the commercial lumping of "pink" shrimp in catch records. Most of the "pink" shrimp from northern Puget Sound are northern pink shrimp, as this species

[1]Another common name is rough pink shrimp.

dominates there (974). The main area of U.S. concentrations of this species is in Alaska. Fishing concentrations on the outer coast are reported only as far south as British Columbia by one source (D).

In Puget Sound, the best fishing locations for this species is in Bellingham Bay, around the San Juan Islands, Port Susan, Possession Sound, Saratoga Passage (974). The northern pink shrimp also occupies the deeper waters of Hood Canal (974).

This species was not reported in intertidal San Juan Island studies (F) as would be expected. None were reported in Grays Harbor (G) and Willapa Bay (H, I). This species would not be expected near or in the lower Columbia River.

Catch records attached to the ocean pink shrimp fact sheet (I-5) describe "pink" shrimp catches for Puget Sound which includes this species.

HABITAT REQUIREMENTS - The northern pink shrimp apparently prefers colder waters and can utilize deeper waters than the ocean pink shrimp (I-5). The northern pink shrimp occupies the open water habitat, except as juveniles and adults during "daylight" hours when a mud bottom association exists. Only during the two to three-month larval life stage is this shrimp totally in the open water habitat.

Water depth of northern pink shrimp ranges from 30 to 350 fathoms (974) to 490 fathoms (141) for adults. Larvae are found in depth ranges of 5 to 35 fathoms (141).

Bottom type is mud and may be similar to that described for ocean pink shrimp (I-5).

Fishable concentrations of *P. borealis* have been found in the Bering Sea at temperatures of 0.5 C (D). This shrimp also has the lowest range of salinities of several pandalid shrimp -- 23.4 to 30.8 ppt (D).

CRITICAL HABITAT AREAS - Washington State is at the southern limit of this species (Puget Sound, 974; Columbia River, D). Even though a coastal limit is given, no commercial quantities are reported on the Washington coast. The areas with larger numbers of northern pink shrimp are reported for Puget Sound (Port Susan) and Hood Canal (Dabob Bay) in the Washington Distribution.

No details were located to determine the location of critical areas for this species. As for ocean pink shrimp (I-5), deep water areas of hatching larvae and the two to three-month larval stage are probably the most critical life stages.

DATA GAPS - See ocean pink shrimp (I-5). Sampling should focus in the areas of historic concentrations and expand to other areas with apparently suitable habitat requirements.

REFERENCES - D, F, G, H, I, 141, 974.

FACT SHEET

I-7 SIDESTRIPE SHRIMP

Pandalopsis dispar

LIFE HISTORY - The sidestripe shrimp is somewhat larger in size as compared to the two pink shrimp species (I-5, I-6). The life span is four years and fecundity averages 4,000 eggs/female (974) to over 4,000 eggs/female (D).

Life history is much like that of ocean pink shrimp (I-5) with breeding in the Fall, hatching of eggs in the Spring, with the pelagic larvae metamorphosis in July or August (141, 974). Males occur first at about 18 months and change to females in two plus years (974). The larvae of *P. dispar* seem to be more fully developed than is normal for other *Caridae* (328). The sidestripe shrimp is large, second only to the spot shrimp in size (974).

Migrations are assumed like those described for ocean pink shrimp (I-5) except to possibly go to deeper waters (350 fathoms) (974, 141). Migrations with age are documented (D).

Foods are as described for ocean pink shrimp -- euphausiids and copepods when in midwater areas and small crustaceans, detritus and worms when on the bottom. Larvae eat plankton (214).

WASHINGTON DISTRIBUTION - Commercial landings of sidestripe shrimp indicate a few scattered along the ocean coast (trawling) and similarly for Hood Canal (pot fishing) (974). San Juan Islands, Bellingham Bay and Saratoga Passage have produced good catches of this shrimp species (974). In the

literature survey (A), adult sidestripe shrimp are reported abundant in Harney Channel, Bellingham Bay, Alki and West Points, and Hood Canal, (Dabob Bay, Quilcene Bay, Dewatto area, Dosewallips River area, Duckabush River area, Hoodsport area).

No sidestripe shrimp were taken in the intertidal study around San Juan Island (F) as would be expected. This species was also not taken in coastal Washington Bays (G, H, I). This species would not be expected in or near the lower Columbia River.

Catch records for sidestripe shrimp are included in a table attached to the ocean pink shrimp fact sheet (I-5).

HABITAT REQUIREMENTS - The sidestripe shrimp, like the northern pink shrimp (I-6) apparently occurs in somewhat colder water than Washington has. Large commercial catches are north of British Columbia, ranking behind the northern pink shrimp (I-6) (D). The sidestripe shrimp's greatest concentrations (in Alaska) are deeper (at 60 to 120 fathoms) than the northern pink shrimp.

The sidestripe shrimp occupies the open water habitat, as juveniles and adults, except when bottom-associated during "daylight" hours. During the two to three-month larval stage, this shrimp is totally in the open water habitat.

The depth range of adult sidestripe shrimp is given as 25 to 350 fathoms (974, 141). Larvae were in shallower waters (5 to 35 fathoms) for other species, but have not been located for the sidestripe shrimp.

The bottom type is soft mud (974) or silt to clay (A) and may be similar to that described for ocean pink shrimp (I-5).

No temperature range was located for this shrimp species but the range

must be fairly wide for a species that ranges from the Pribiloff Islands to Manhattan Beach, Oregon (D).

A salinity range of 26.7 to 30.8 ppt was reported for sidestripe shrimp (D).

CRITICAL HABITAT AREAS - Washington State is near the southern limit - Manhattan Beach, Oregon - of sidestripe shrimp. Larger numbers of this species are apparently located north of British Columbia in Alaskan waters. The consistently producing areas in Washington appear to be in inside waters rather than on the coast. Bellingham Bay is reported to have the greatest sustained harvest of this species. Other inside water areas are noted in the Washington Distribution section, but no real specific and mappable critical areas exhibit themselves in the information reviewed.

No critical habitat areas are designated for the sidestripe shrimp.

DATA GAPS - See ocean pink shrimp (I-5) and northern pink shrimp (I-6). "Occasional" catch areas on the coast needto be documented. The focus of field studies should be based upon the location of historic catches after a review of past commercial and exploratory fishing efforts. Trawls and pots should be utilized as required by the area in past high catch areas and in other areas with apparently similar habitat.

REFERENCES - A, D, F, G, H, I, 141, 214, 328, 974.

FACT SHEET

I-8 SPOT SHRIMP

Pandalus platyceros

LIFE HISTORY - The spot shrimp is the largest shrimp in Washington (nine inches including the antennae, 974). The spot shrimp, unlike the previous shrimp species (I-5, I-6, I-7) has documented life history stages in water as shallow as two fathoms (974).

Life span is reported as about four years (333) to five years (974). Fecundity was not located. Life history is generally like previous pandalid shrimp (I-5, I-6, I-7) -- mature as males in two years (141), while the female change occurs in the third or fourth year (974). The spot shrimp breeds in the Fall (141). Normal spawning occurs as early as August with eggs carried for 5 to 5.5 months (974), eggs hatch in early Spring (974), and planktonic larvae are produced. The first two larval stages are found in deep water while the remaining larval and post larval stages in the first year are in shallow water (to two fathoms) (974). The spot shrimp migrates back to deeper waters at the end of the first year (333) and presumably remains in deeper waters for the remainder of the life cycle. Juveniles first mature at about two years to repeat the cycle. Environmental parameters can modify the life cycle of this spot shrimp (941).

Migrations are indicated in the larval and post larval stages with a movement from deeper waters (hatched larvae) to shallow waters (in two to three months?) and back to deeper waters (at the end of the first

year). Diel migrations occur with adult shrimp found at 28 to 40 fathoms during the daytime and at 10 to 27 fathoms at night in Dabob Bay (Hood Canal) (974, 941).

The diet is somewhat different from the "pink" shrimp (I-5, and I-6) and the sidestripe shrimp (I-7), as the spot shrimp also inhabits rocky areas and feeds there. Foods of first year spot shrimp includes amphipods and mysids, while second year shrimp eat epifauna of rocky shores and detritus in mud (332). Worms, detritus, copepods, and euphausiids are mentioned for this species, as for the preceding three species (141, 333).

WASHINGTON DISTRIBUTION - In inside waters, beds of spot shrimp are widely scattered in all areas but southern Puget Sound where few are caught (974). Best fishing areas in Hood Canal is around Hoodsport, Dewatto, Potlatch State Park, and Dabob Bay at depths of 16 to 66 fathoms (974). In Central and North Sound areas such as Elliott Bay, off Richmond Beach, Possession Sound, Saratoga Passage, off the west coast of Whidbey Island, Bellingham Bay and the west side of Lopez Island are good spot shrimp areas (974). In the literature review (A) areas with "abundant" spot shrimp include Bellingham Bay, Saratoga Passage to Oak Harbor, Similk Bay, Admiralty Inlet, Possession Sound, Elliott Bay, and several Hood Canal locations (Dabob Bay, Quilcene Bay, Dewatto River area, and Hoodsport area).

Spot shrimp make up virtually the entire Hood Canal commercial shrimp catch (364, 974). Major shrimp beds are noted in the south of Hood Canal from Sisters to Ayock Points and throughout Dabob and Quilcene Bays (364).

Spot shrimp are reported present on the open coast from LaPush and

northward at 50 to 140 fathoms (529) and near Protection Island in the Strait of Juan de Fuca (64, 359).

Spot shrimp were not taken in the San Juan Island survey (F). This species was also not reported in coastal bays (G, H, I) and would not be expected in the lower Columbia River or near the river's mouth.

A catch record table for spot shrimp is attached to the ocean pink shrimp fact sheet (I-5).

HABITAT REQUIREMENTS - As compared to the two "pink" shrimp (I-5 and I-6) and the sidestripe shrimp (I-7), the spot shrimp is apparently unique in using rocky and muddy areas. However, this may be due to sampling predominantly with mud and sand oriented trawls for the prior species.

The spot shrimp occupies the open water habitat, as juveniles and adults, except when bottom associated during "daylight" hours. During the two to three-month larval state, the spot shrimp is entirely in the open water habitat and is planktonic.

The spot shrimp occupies a wide range of depths, 2 to 260 fathoms (141, 974) with the shallowest depths occupied in the first eight to ten months of life and deeper depths used before and after that time. Juveniles are observed at 5 to 36 fathoms (141).

The bottom type ranges from rocky to muddy (974). The literature review mentions bottom-associations with very coarse, solid rock, clay, boulder, and mixed: medium types. In Puget Sound adult spot shrimp tend to be more numerous in the vicinity of a distinct bottom slope (a hole or drop-off, 974). In rocky areas, spot shrimp are observed in crevices on vertical rock walls (551).

The temperature range for spot shrimp was not located but must be quite wide for this species ranges from Unalaska Island to San Diego, California (D). The reported salinity ranges for spot shrimp is 26.4 to 30.8 ppt (D).

CRITICAL HABITAT AREAS - Spot shrimp seem to be adapted to a variety of bottom types when compared to the prior shrimp species (I-5, I-6, I-7). Exploratory fishing has apparently not found these prior species in habitats other than sand and mud. The spot shrimp appears to be scattered in all parts of Puget Sound except the southern part. Hood Canal seems to have the greatest numbers of this species in inside waters. In outside waters lesser numbers seem to be in the Strait of Juan de Fuca and on the coast from LaPush and northward.

The wide variety of bottom types associated with and the apparent scattered concentrations of this species do not seem to allow critical area determinations. Steep sloped or vertical areas appear important to this species. Data reviewed is too general to map specific critical areas. Critical areas may exist when larvae and post larvae would presumably be concentrated in shallow waters (to two fathoms) in bays like Dabob and Quilcene in Hood Canal.

No critical areas are designated for spot shrimp.

DATA GAPS - See ocean pink shrimp (I-5). Further sampling should first focus on areas of historic concentrations of spot shrimp as seen by summarizing past commercial and exploratory records. Sampling would only

be required to confirm spot shrimp concentrations are still there. Sampling should then proceed to areas with apparently suitable habitat types for spot shrimp that may not have been explored to date. Pot and trawl sampling methods should be used in a standardized fashion. SCUBA might be useful where visibility permits.

REFERENCES - A, D, F, G, H, I, 64, 141, 332, 333, 359, 364, 551, 941, 974.

FACT SHEET

I-9 DOCK SHRIMP

Pandalus danae

LIFE HISTORY - The dock shrimp is a shallower water species and breeds in other months not just in the fall, as compared to previous shrimp species (I-5 to I-8). "To some degree" breeding is throughout the year (332). The dock shrimp is also the only shrimp of commercial value to be found in the intertidal zone (C).

The general pattern of life history of other pandalid shrimp is followed. Males apparently mature at less than one year (974) -- 1.5 years (332) and change to the female stage at 1.5 years (974) -- 2.5 years (332). "Primary" females (mature first and only as females) are reported for dock shrimp (141, D). Dock shrimp probably do not survive into the fourth year (974). Breeding is not just confined to the Fall (332) so that hatching and larval stages may be scattered in the year. This species broods eggs three to nine months and a larval stage (planktonic) is for two to three months. Hatched dock shrimp, like sidestripe shrimp (I-7), are more fully developed than is normal for other Caridae (328). The larvae are in shallow waters (10 to 30 fathoms) near to where they hatch (974). They are in shallow water bays and inlets for the first year of life (332). The area used extends to the intertidal zone (C). The dock shrimp usually moves to deeper water before taken in commercial sizes (C). The males would usually mature at less than 1 to 1.5 years and repeat the cycle.

Migrations with age occur for this species as described above. The

first year is in shallower waters (10 to 30 fathoms) where the adult female carries the eggs to hatch. Juveniles enter the waters of the intertidal zone (C) and remain in shallow bays for the first year before migrating to deeper waters. The depth range for this species is shallower than previous shrimp species (I-5 to I-8) -- 10 to 100 fathoms (974) and shallower, to the intertidal zone (C).

Diel migrations (vertical) are also made, similar to other pandalid shrimp.

Foods of dock shrimp include amphipods, mysids, worms, detritus, copepods, and euphausiids (332, 141).

WASHINGTON DISTRIBUTION - The open coast and the Strait of Juan de Fuca have dock shrimp present (A). The best fishing areas in Washington are at the mouth of Budd Inlet in South Sound, around Port Orchard and Eagle Harbor in Central Sound, and in the Deception Pass area, Burrows Bay, and the San Juan Islands in northern Puget Sound (974). The Washington shrimp fishery began in Oro Bay, mostly on this species (D). The literature review (A) report dock shrimp abundant at Harney Channel, Lopez Sound, Deception Pass, Whidbey Basin, Skagit Island, Port Orchard, Eagle Harbor, Budd Inlet, Lookout Point (Howe Sound) and Squamish Estuary South (Howe Sound).

The San Juan Island survey (F) did not catch this species. This shrimp was not reported in Grays Harbor (G) nor specifically in Willapa Bay (H). Willapa Bay has free-swimming shrimp (not defined) which may include this species (but probably does not), as they would also probably be in Grays Harbor.

Dock shrimp are not expected in the lower Columbia River estuary or near the river's mouth.

Dock shrimp catches are included in Washington shrimp catch records (see tables with ocean pink shrimp, I-5) but unfortunately are lumped with other species (I-10 and I-11) as "coonstripe" shrimp.

HABITAT REQUIREMENTS - The dock shrimp is named because it is the one shrimp most likely to occur around floats (floating docks/pilings) (B). However, this species occurs in many other natural habitats. This species is wide-ranging -- Sitka, Alaska, to San Luis Obispo Bay, California (974).

The dock shrimp occupies the open water a planktonic larvae after hatching (two to three months). The post larvae, juvenile and adult, also move into the water column in diel migrations but are bottom-associated during "daylight" hours.

The depth range for this species is 10 to 100 fathoms (141, 974) with commercial densities usually below 35 fathoms (141). The dock shrimp juveniles (less than one year old) are seen intertidally before they move to deeper waters (C). At night, adults are seen near the surface. They are generally shallower living shrimp, as compared to the previous four species (I-6 to I-8).

The bottom type associated with is sand and gravel types (974). Clay is also mentioned in the literature review (A). One source (551) indicates dock shrimp have been observed in crevices on vertical rock walls. They also inhabit floating dock/piling areas. This species also prefers areas with strong tidal currents (974). Dock shrimp also appear (rarely and solitarily) in eelgrass bed areas, particularly at night (1008).

A maximum temperature for dock shrimp was 12.3 C (D). They must be able to live in colder waters near the northern end of their range. The salinity range for *P. danae* is 25.2 to 30.1 ppt (D).

CRITICAL HABITAT AREAS - Dock shrimp apparently exist in scattered concentrations in inside waters and are present in the Strait of Juan de Fuca and on open coast. The information reviewed is not specific enough to indicate where critical areas may be. Critical areas would probably exist for dock shrimp when young are in shallow water bays and inlets in their first year. This may be less critical than in spot shrimp (I-8) if dock shrimp are scattered through more of the year in these shallower waters because of breeding in most of the year.

No specific critical areas are designated for dock shrimp.

DATA GAPS - See spot shrimp (I-8) and ocean pink shrimp (I-5).

REFERENCES - A, B, C, D, F, G, H, 141, 328, 332, 551, 974, 1008.

FACT SHEET

I-10 HUMPY SHRIMP

Pandalus goniurus

LIFE HISTORY - The humpy shrimp (common name from source 974) is also called the "coonstripe" shrimp along with species *P. hypsinotus* (I-11) and *P. danae* (I-9). In this review *P. hypsinotus* (I-11) will be named "coonstripe" shrimp.

The life cycle of the humpy shrimp is still not well known (974). They appear to follow the pattern of most pandalids - breed in Fall, eggs carried in winter months, hatch in March and produce planktonic larvae for two to three months (141, 214, 974). They mature first as males by the first fall after hatching (less than one year) (another source: 1 year, 141), change to a female the following fall and die after eggs are hatched in the following spring (974).

Migrations are not described but are probably similar to the dock shrimp (I-9). Foods of larval humpy shrimp include plankton, while adults eat worms, copepods, euphausiids, detritus (141, 214).

WASHINGTON DISTRIBUTION - The southern limit of humpy shrimp is Puget Sound (D, 974). They are reported in the open coast, Strait of Juan de Fuca, and inside Washington waters. The humpy shrimp is reported present in the San Juan Islands where it is associated with the larger dock shrimp (I-9) (974). The literature review (A) lists the humpy shrimp as abundant at following locations: San Juan Archipelago (South Orcas

Island, West Sound, Foster Point, Blind Bay, Lopez Sound, Upright Head, North Pass, Elmo Bay, and East Sound entrance), North Puget Sound (Bellingham Bay, Chuckanut Bay, Pheasant Bay, Wild Cat Cove, Samish Bay, Vendovi Island, Similk Bay, Padilla Bay, Hale Passage, and Eliza Island) and Strait of Georgia (Howe Sound, British Columbia).

No humpy shrimp were taken in the San Juan Island survey (F), nor in Grays Harbor (G). The unspecified "free-swimming shrimp" of Willapa Bay (H) are not thought to be humpy shrimp because of the stated southern limit of this species' range - Puget Sound. For the same reason, they are not expected in the lower Columbia River area or near the river's mouth.

Humpy shrimp catch records are combined with the other "coonstripe" shrimp, *P. danae* (I-9) and *P. hypsinotus* in tables with the ocean pink shrimp (I-5) fact sheets. Humpy shrimp are not found in appreciable quantities off British Columbia or southward (D).

HABITAT REQUIREMENTS - Humpy shrimp utilize shallower waters over sand and gravel bottoms (974).

The humpy shrimp occupies the open water habitat totally as a planktonic larvae (two to three months) and as juveniles and adults except when bottom-associated during "daylight" hours.

The depth range for humpy shrimp is given as 3 to 100 fathoms (D, 974).

The literature review (A) lists bottom types other than sand and gravel that the humpy shrimp associates with. These are: silt, pebble-gravel, clay, solid rock, boulder and detritus (A).

The temperature range for humpy shrimp is not specified by the range of the species - Arctic Alaska to Puget Sound - would indicate the use of generally colder waters as compared to species that extend to Southern California. A salinity range was not reported.

CRITICAL HABITAT AREAS - The combination of little specific life history information and scattered "abundances" of humpy shrimp in inside waters does not allow the definition of critical areas.

If this species is like the shallow water dock shrimp (I-9) and spot shrimp (I-8), and utilizes shallow waters as a "nursery" area for larvae, post-larvae or juveniles, this would be expected to be the critical area for this species.

No specific critical areas are designated.

DATA GAPS - See spot shrimp (I-8) and ocean pink shrimp (I-5). In addition, more life history information is needed for this species which would require sampling for larvae, post-larvae, and juveniles in high spring concentration areas with plankton nets and small meshed mid-water and bottom trawls. Information could also be gained by laboratory observations, if possible.

REFERENCES - A, C, F, G, H, 141, 214, 974.

FACT SHEET

I-11 COONSTRIPE SHRIMP

Pandalus hypsinotus

LIFE HISTORY - The coonstripe shrimp is one of the larger shrimp in Washington whose importance in commercial landings is masked by the "lumping" of landings of this species with *P. goniurus* (I-10) and *P. danae* (I-9) under the name "coonstripe" (974). See note on common name of humpy shrimp (I-10).

The coonstripe follows the pandalid shrimp pattern - breed in the fall, females carry eggs over the winter, the eggs hatch in the spring. The juveniles usually mature first as males at 1.5 years (974, D) and then become females. There are two exceptions. They can mature as females in 1.5 years and skip the male stage (D, 974). They can start to mature as males but apparently do not mature, but change to the external female character in one year of age (974).

This species is a shallow water shrimp (3 to 70 fathoms) that may have a life cycle like the spot shrimp (see I-8).

Migrations are indicated and assumed similar to spot shrimp (I-8). A movement with age is indicated (juveniles 5 to 35 fathoms; adults 3 to 100 fathoms) (141).

Foods are the same as described for humpy shrimp (I-10).

WASHINGTON DISTRIBUTION - Coonstripe shrimp occur as scattered individuals, widely distributed in Puget Sound with some concentrations in Hood Canal, around Lopez Island, in Skagit Bay, and in Bellingham Bay (974). No areas of "abundant" quantities were reported for this species in the literature review (A). This review (A) also reports them present on the open coast including the Strait of Juan de Fuca. This conflicts partially with one source (D) which indicates the southern limit of this species is the Strait of Juan de Fuca. "Open coast" in the literature review (A) may refer to that of British Columbia where this species does occur. The documented southern limit is apparently Hood Canal or "Puget Sound" (974).

This coonstripe shrimp was not captured in the San Juan Island survey (F) as would be expected. This species was also not reported in coastal bays (G, H, I) and would not be expected in the lower Columbia River or river mouth with the stated southern range limit.

HABITAT REQUIREMENTS - The coonstripe shrimp is a shallower water shrimp species, like the dock shrimp (I-9) and humpy shrimp (I-10). The coonstripe shrimp is a colder water shrimp, with a range from the Bering Sea to the Strait of Juan de Fuca (D) or Puget Sound (974), as compared to species ranging to Southern California.

The coonstripe shrimp occupies the open water habitat during the two to three month larval period while planktonic. As a post-larvae juvenile and adult this species presumably makes diel migrations into the water column but is bottom-associated during "daylight" hours.

The depth range of this species is given as 3 to 100 fathoms (D) and 3 to 70 fathoms (974) for adults and 5 to 35 fathoms for juveniles (141).

The bottom type associated with is mud and rocky bottom (974). The literature review (A) also mentions mixed: very coarse, mixed: fine, and clay bottoms.

A temperature range was not located for coonstripe shrimp but it would be on the cold side as compared to other species ranging as far south as California. A salinity range of 25.9 to 30.6 ppt was reported (D).

CRITICAL HABITAT AREAS - Coonstripe shrimp exist as scattered individuals widely distributed in Puget Sound with some distributions in Hood Canal, Lopez Island, Skagit Bay and Bellingham Bay (974).

No specific details were located to define specific critical areas for this species. No critical areas are designated for coonstripe shrimp.

DATA GAPS - See spot shrimp (I-8) and ocean pink shrimp (I-5).

REFERENCES - A, C, F, G, H, I, 141, 974.

FACT SHEET

I-12 BROKENBACK SHRIMP

Heptacarpus stimsoni

LIFE HISTORY - The brokenback shrimp is not covered by the literature review (A) nor the WDF shrimp study (974). Information in one source (B) is for this genus and is quite limited. *Heptacarpus* appears to be a shallow water shrimp species in the intertidal (tide pools, B) to the shallow subtidal (piling and floats, under "weed", B).

The brokenback shrimp actually exists as a *Heptacarpus spirontocaris* complex of species in Puget Sound and should be considered as such. (E. N. Kozloff, University of Washington, personal communication.)

No life history information was located. This species may follow the general pandalid pattern. *Heptacarpus* are largely carnivores (B).

WASHINGTON DISTRIBUTION - This genus is indicated to live in inside waters of Washington (B). No reports were located for the North Sound (F) or the open coast or coastal bays (G, H, I). They are indicated as common in tide pools (B).

HABITAT REQUIREMENTS - *Heptacarpus* are indicated as intertidal and possibly subtidal shallow water shrimp of inside Washington waters. These shrimp utilize algae and kelp as a hiding place (B) and are probably most common on rocky shores that support such vegetation. They are also described under vegetation on pilings and floats (B).

CRITICAL HABITAT AREAS - Too little information was located in this review to designate critical areas for this species of brokenback shrimp.

DATA GAPS - A more extensive data search would be necessary for this shrimp species. Field (intertidal) and laboratory studies should be completed on this species. This species should be considered as a complex of species which would seem to complicate life history and distributional studies. (See spot shrimp, I-8, and ocean pink shrimp, I-5).

REFERENCES - A, B, F, G, H, J, 974.

FACT SHEET

I-13 BOX CRAB

Lopholithodes foraminatus

LIFE HISTORY - The literature review (A) has one life history statement for box crab - "Puget Sound represents the northern limit of the range of distribution of box crab" - from a 1910 source (918).

The references reviewed did not provide additional information for this species.

WASHINGTON DISTRIBUTION - Adult box crab are indicated as "abundant" in the literature review (A) at "greater Puget Sound" at eight to nine fathoms. This species was indicated as present in the Strait of Juan de Fuca, San Juan Archipelago, and Strait of Georgia (Nanaimo) (A).

This species was not reported in the San Juan Island survey (F), nor in coastal Washington waters or coastal bays (G, H).

HABITAT REQUIREMENTS - The box crab occupies the open water habitat but is bottom-associated as a juvenile and adult. A pelagic larval stage probably exists in which the open water habitat is used without a bottom association.

The bottom associated with includes solid rock (476) in the San Juan Archipelago and Strait of Georgia to silt and sand (955) in the greater Puget Sound area.

The box crab appears to inhabit deeper waters than the Puget Sound king crab (Ron Westley, WDF, personal communication).

CRITICAL HABITAT AREAS - Too little life history and habitat information was located for box crabs to indicate any areas as critical.

DATA GAPS - A more detailed search of available information (California, Oregon) should be made for box crab. If data is scarce on life history, field and laboratory studies could provide further information on this species. SCUBA observations might be useful along with past divers' logs who have recognized this species.

Past commercial or sport catches of box crabs should be reviewed if they exist. Field studies could utilize pots in untrawlable areas and trawls on smooth bottomed areas.

REFERENCES - A, F, G, H, 476, 918, 955.

FACT SHEET

I-14 DUNGENESS CRAB

Cancer magister

LIFE HISTORY - The Dungeness crab is the most important commercial and recreational crab species in Washington State. A good deal of information has been gathered because of this importance.

The life span of Dungeness crabs is reported as a maximum of eight years and as not more than ten years, with an average longevity of eight years (D). Males mature at about three years and females mature at about two years of age (Queen Charlotte Islands) (D). Male crabs may actually breed at somewhat larger size (older) and females at smaller sizes (younger) (D). Dungeness crab mate in the Spring (776), May to June (Washington Coast) after the female moults, with the female carrying the eggs (October to June in British Columbia) and larvae emerging between December and April in Oregon waters (D). In Puget Sound eggs were observed on females in Similk Bay from December to April, in Hood Canal in February and March (A), and from October to March in Puget Sound commercial samples (Ron Westley, WDF, personal communication). Open coast egg carrying was from November through February (A). Fecundity was estimated at 1.5 million eggs/female (493).

The hatched larvae go through five zoeal stages and one megalops stage in the complete development of Dungeness crab (D). The larvae are first pelagic and then benthic (493). Laboratory studies indicate this larval period lasts about 100 days (D). The megalops stage is present from May to October (449). The larvae proceed to a juvenile stage and in about

two to three years to the adult stage to repeat the cycle.

Migrations are indicated by age and by season. Juvenile crabs move to deeper water with age from the shallow water (less than five fathoms) where post larval stages were most abundant (D). Adults migrate offshore (not over 50 fathoms, 493) in the winter months and return to the nearshore in early spring and summer (D). In Puget Sound, females (egg-bearing) move into shallow waters where larvae hatch. In Grays Harbor, larvae migrate into the upper Harbor and with age move westward to the lower Harbor and open ocean (218). There is also a movement with season - north to south in January to June (21) and presumably the reverse. Migrations were also observed counter-clockwise in Similk Bay with the current (208).

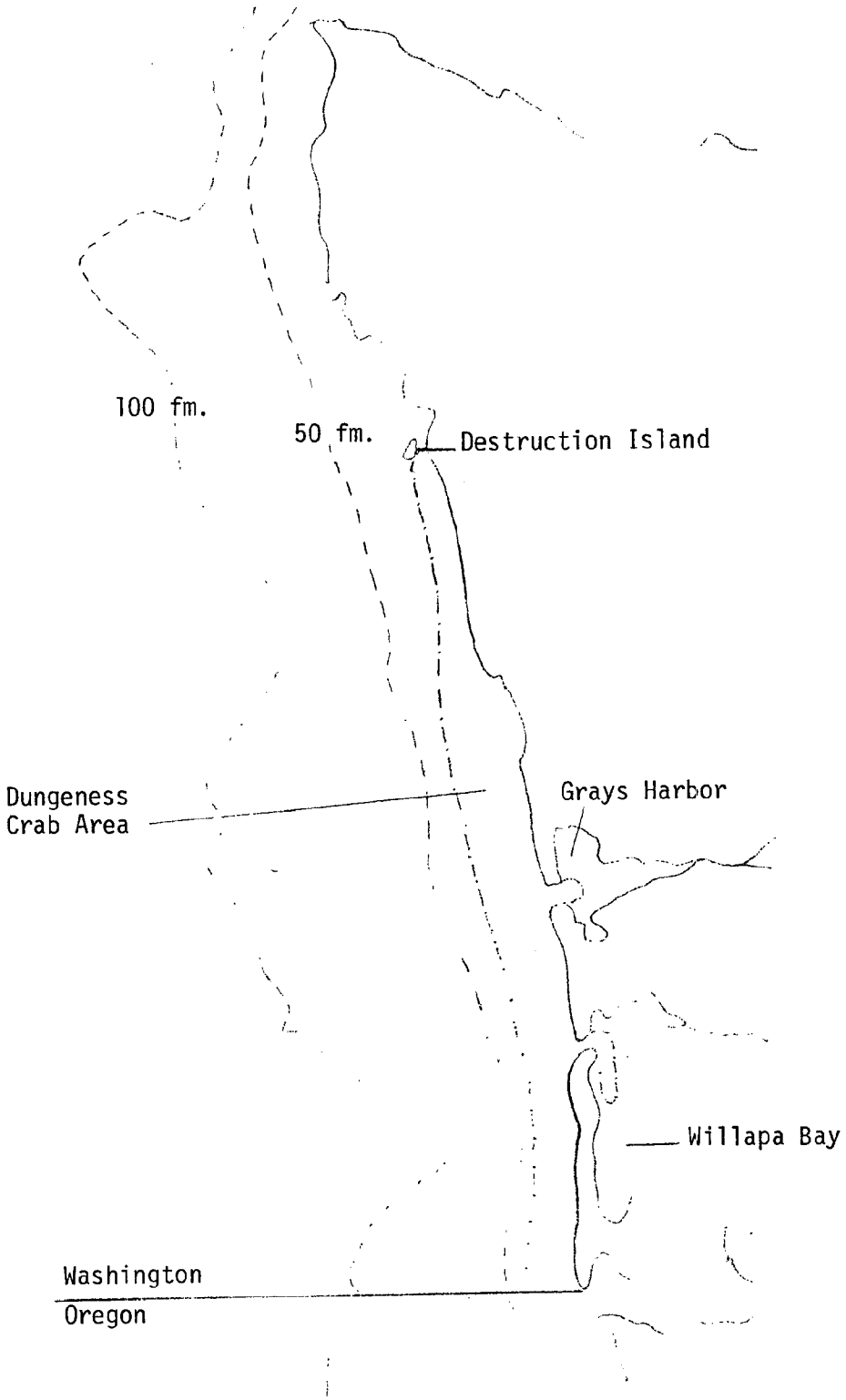
Feeding is mostly nocturnal (354) and reduced in the Winter (208). Food of zoea include phyto and zoo plankton; food of megalops include small crustaceans, crab eggs, and plankton; food of adults is quite dependent on the crabs' location and primarily includes shrimp, small crabs, barnacles, amphipods, pieces of clam, worms, and fish (21, D).

WASHINGTON DISTRIBUTION - Dungeness crab are widely distributed in inside and outside Washington waters over the sand and mud bottom type they prefer. This habitat use would seem to allow a greater number of crabs to exist in these types of areas rather than in the rocky-shored areas such as the San Juan Archipelago, Strait of Juan de Fuca and North Coast, although even these areas have some sand beaches and mud bays inhabitable by Dungeness crabs.

The Dungeness crab is a shallow water species (0 to 50 fathoms, 493) and apparently lives in these nearshore areas for most or all of its life.

In the North Sound beam trawl survey (L), Dungeness crab were least abundant in winter at all stations and less abundant at East Sound, as compared to Cherry Point and Guemes Channel. This crab appeared to be somewhat more abundant in shallower water (L). The beam trawl, however, is not a good method for sampling Dungeness crab. Dungeness crab was not taken in the intertidal San Juan Island study (F) as might be expected. At Kiket Island, Dungeness crab (2 to 4 cm, carapace width) were found in mud areas under rocks and cobble in the intertidal (205).

The most important commercial area for Dungeness crab is the coast of Washington area shown on the following map.



Source: WDF, 1976

This area includes Grays Harbor and Willapa Bay where Dungeness crab are also taken. These bays are probably nursery areas for young crabs which migrate to the ocean prior to sexual maturity (N, Herb Tegelberg, WDF, personal communication). Outside (open coast) waters may also support young crabs as do these coastal bays.

The recent Grays Harbor study (N) indicates a rather extensive population of sublegal-sized crabs throughout most of Grays Harbor. Crabs occurred upstream in the Chehalis River nearly to Cosmopolis (N). Dungeness crab are expected to be similarly numerous in Willapa Bay.

The generally fished Dungeness crab area (WDF, 1976, see map) goes to the Washington/Oregon border off the Columbia River mouth - or offshore the North Jetty area and possibly across the river mouth into Oregon.

HABITAT REQUIREMENTS - The Dungeness crab uses the open water habitat but is very bottom-associated all of its life except for the pelagic larval (zoea and early megalops stages) stages. After these stages the Dungeness crab is a bottom dweller on sand and mud bottoms. It is sometimes also found at low tide in sandy and muddy bays where there is a good growth of eel-grass (B). In laboratory studies, Dungeness crab chose fine sand over coarse sand and mud over fine sand (229).

Deeper waters are utilized in the Winter. Crabs in shallower waters in Winter exhibit an increased burrowing activity (208). Crab found in the intertidal area with tides out are also often buried in the sand or mud. Mud and sand bottomed areas are therefore very important to the Dungeness crab's life cycle.

No adult crab mortality was observed below 24 C with an optimum range for larvae at 10 to 13.9 C (D). The optimum salinity range of Dungeness crab larvae is 25 to 30 ppt (D), while sublegal crabs were taken in "good" catches in salinities as low as 9 to 10 ppt in Grays Harbor. These crabs therefore have a wide temperature and salinity range overall, but narrower optimum ranges in the larval period which appears to be the most sensitive life stage.

CRITICAL HABITAT AREAS - The movement of adults to shallow water in pring where larvae are hatched, or the movement of earlier life stages (possibly by currents) to shallow waters, would tend to concentrate these earlier, more sensitive life stages in waters "shallower than five fathoms",(D). All the areas that are used by Dungeness crab have not been surveyed and are not known. For inside waters, it appears that the larger the bay, the more important to Dungeness crab as a nursery area (David Mayer, TERA, personal communication).

The Grays Harbor study (N) indicated that the sublegal crabs there generally utilized the tide flats and sinks of the Harbor. The deeper channels are important during high runoff periods when salinities are generally reduced in the Harbor. In general, all the channels in the tide flats appear critical to sublegal crabs who are feeding on the flooded tide flats, and move to these channels for the low tide period (Herb Tegelberg, WDF, personal communication). These crabs are in these areas most all months of the year. Any channels lost to filling would possibly reduce the utility of adjacent tide flats as a feeding area for these sublegal crabs.

A similar use of channels is expected for Willapa Bay. These channel areas in Willapa Bay and Grays Harbor are labeled critical areas for Dungeness crab and are coded I-14.

In inside waters larger mud bays are probably similarly critical for Dungeness crab. However, no studies were located that point to any of these bays specifically being more important than others or relate them to the Grays Harbor area and the large adjacent coastal commercial fishery.

Another type of critical area for Dungeness crab is favored areas for mating which may exist (Ron Westley, WDF, personal communication).

DATA GAPS - Surveys as completed in Grays Harbor should be extended to Willapa Bay, lower Columbia River estuary, and large mud and sand bays of inside waters to determine the density and location of Dungeness crabs located there. Methods should follow those described in this survey (N). Only with this type of information collected with comparable gear, would one be able to relate all these areas and determine which areas are critical as determined by the numbers of crabs using each area.

Studies collecting these crabs by trawl or pot should also evaluate the timing of eggs being carried by females and the time of hatching in every area sampled. These possible favored mating areas should also be sought.

REFERENCES - A, B, D, F, L. N, 21, 208, 218, 229, 354, 449, 493, 776.

FACT SHEET

I-15 RED ROCK CRAB

Cancer productus

LIFE HISTORY - The red rock crab is less studied than the more commercially important Dungeness crab (I-14). The general life history probably follows that of Dungeness crab. Red rock crab are much more abundant intertidally than the Dungeness crab (B).

Males predominate in the intertidal zone from January to May; females from July to October, with copulation occurring in May and June (958). Eggs are extruded from November to January and hatch in March and April (958). If the Dungeness pattern is followed, about 100 days of larval stages follow before an adult-looking juvenile is produced. After about two to three years the mature adult would again mate to repeat the cycle.

The red rock crab is described as a mobile species (38), making on-shore-offshore migrations (493), presumably as described for the Dungeness crab (I-14).

Feeding is mostly nocturnal (354) and possibly reduced in winter as for Dungeness crab (I-14). Foods include dead sculpin, live barnacles, mussels, other *Cancer*, and detritus (354, 958).

WASHINGTON DISTRIBUTION - The red rock crab is common or abundant in many inside Washington water areas while being less abundant in the Strait of Juan de Fuca (A). The literature review (A) indicates no reports for the open coast. Few red rock crab were captured in the Grays Harbor study

(Herbert Tegelberg, WDF, personal communication). These crabs are modestly abundant on oyster beds in Grays Harbor and Willapa Bay (Ron Westley, WDF, personal communication). If the literature review is representative, the bulk of Washington's red rock crab are in inside waters and the Strait of Juan de Fuca.

The North Sound beam trawl survey (L) and the San Juan Island survey (F) did not report this species. As with Dungeness crab, this gear type is not suitable for red rock crab. Fair numbers of juvenile red rock crab were found in the mud (intertidal) at Kiket Island (205).

HABITAT REQUIREMENTS - Like the Dungeness crab (I-14), the red rock crab utilizes the open water habitat but is bottom-associated except for the planktonic part of the larval stage. The differences appear in the bottom types used and the greater use of intertidal areas by the red rock crab. The red rock crab occurs in sandy, muddy, and gravelly bays, especially where eelgrass beds occur and even in rocky situations (B). A similar variety of bottom associations are described in the literature review (A) - solid rock, eelgrass, mixed: medium, mixed: coarse, mixed: fine, mixed: very fine, cobble, pebble-gravel, silt, sand, boulder, shell fragments, and detritus bottoms.

The red rock crab may use deeper waters in winter like the Dungeness crab (I-14).

In general, the red rock crab utilizes the intertidal area and more bottom types than the Dungeness crab (I-14).

No physical parameters (temperature and salinity) were located for red rock crab. The intertidal areas used by this species at certain times of the year would have high temperature and salinity ranges which the red rock crab must be able to tolerate.

Red rock crab utilize a wide range of habitats (rock to mud) and have a wide depth distribution (intertidal to at least 50 fms) (Ron Westley, WDF, personal communication).

CRITICAL HABITAT AREAS - The critical life stages of red rock crab may be the early larval to juvenile stages when they are presumed in shallow water. Not enough life history and distribution information was located to say any shallow water bays and associated intertidal areas are more critical than others. No critical areas are designated for red rock crab.

DATA GAPS - Little life history and little quantitative and systematic data on the distribution of red rock crab was located. This species will present a sampling problem by the wide range of bottoms inhabited necessitating gear like pots over trawls (which can not sample rough bottom) and requiring sampling in many areas with all these bottom types.

Laboratory experiments would be useful to describe the larval stages and breeding behavior of this species. Experiments to determine bottom preferences (if they exist) would be of interest.

Any areas surveyed for red rock crab should also assess the egg-carrying stage and the approximate time of hatching for each surveyed area. Commercial and sport catches should be summarized by time and location of catch (if possible) to define areas to be exploratory fished for red rock crab.

REFERENCES - A, B, F, L, 38, 354, 493, 958.

FACT SHEET

I-16 PUGET SOUND KING CRAB

Lopholithodes mandtii

LIFE HISTORY - The Puget Sound king crab is a different species of the same genus to which the box crab (I-13) belongs. The literature review (A) contains one reference (126) for this species. This source (126) is used for most of the following life history discussion.

No life span was discussed, but it must be long as maturity is reached after a minimum of seven years. Mating occurs in May and eggs (up to 186,000) are carried by the female for one year - March to early May. Hatching occurs over about a two-week period. The larvae presumably pass through planktonic stages. There are four zoel and one megalops stage which at 10 C lasts about 33 and 26 days respectively.

Migrations of an offshore-onshore nature are noted. In early winter this species migrates from deep water (>16 fathoms) to shallow water (three to five fathoms). This movement is then reversed. The migration is related to their reproductive and molting cycle. The female leaves shallow water (May-June) after copulation. The males and juveniles are in shallower waters and molt in the summer, leaving for deeper waters by early fall.

Foods of larval stages probably include phyto and zoo plankton. Juveniles ate miscellaneous animal matter while adults ate asteroids (126).

WASHINGTON DISTRIBUTION - The Puget Sound king crab has not been systematically sampled, nor was it the subject of commercial fishing to depict areas of concentration. The literature review (A) has only three sources reporting this species - Tatoosh Island on the open coast (126), San Juan Archipelago and Strait of Georgia (476) and "greater" Puget Sound (955).

Solid rock is a substrate used (A), so this species is probably primarily in rocky inside areas, primarily in the San Juan Archipelago, the Strait of Juan de Fuca and in outside waters, the north open coast. Boulder and cobble areas used by this species (A) would allow even more areas to be potentially used in greater Puget Sound.

HABITAT REQUIREMENTS - Little information was located for this species. The Puget Sound king crab uses the open water habitat but is bottom-associated all of its life except for the one to two-months larval period that is planktonic. Apparently no excursions are made into the intertidal zone, but they do come into the shallow subtidal ($\sim$ 3 fathoms).

Bottoms associated with include solid rock, boulder and cobble bottoms (A). No temperature or salinity ranges were reported. Larval stages did develop at 10 C (in the laboratory?) (126).

CRITICAL HABITAT AREAS - The Puget Sound king crab is not well described in the available information, particularly as to distribution in Washington waters.

Potential critical areas would probably be in the shallow waters (three to five fathoms) that this species migrates to in early winter and where they would be in concentrations, as compared to being in deeper

waters (over 16 fathoms) where they are possibly scattered over wider areas.

More information would be needed to locate these specific shallow areas that are important to this species. No critical areas are designated for Puget Sound king crab.

DATA GAPS - The Puget Sound king crab needs a systematic survey of shallow water areas with rock, boulder, and cobble bottom near deeper waters that appear to be suitable for this species. Surveys should be early winter through early fall. Pots and SCUBA sampling might be useful in surveying this species. A detailed search of all catch records should be made to define existing areas that this species is known to occur in.

Specimens recovered should be assessed for the presence of eggs and the timing of hatching by area surveyed. This information would provide details on the mating behavior and egg carrying and hatching activities of this species.

REFERENCES - A, 126, 476, 955.

FACT SHEET

I-17 KELP CRAB

Pugettia gracilis

LIFE HISTORY - This kelp crab was not covered in the literature review (A). This species is one of two very common spider crabs in Washington waters - the other being a larger species, *P. producta* (B). Carapace length on *P. gracilis* rarely exceeds 3 cm, while on *P. producta* it can be up to almost 10 cm (B). The kelp crabs are decorator crabs, promoting the growth of sea weeds and other foreign organisms on their carapace.

No life history information was located. The species would presumably have a pelagic larval stage followed by the sluggish bottom-dwelling stage of juveniles and adults.

No migration or feeding information was located.

WASHINGTON DISTRIBUTION - This kelp crab is the most common of the kelp crabs in Washington. Areas of a wide variety of habitats such as mud/eelgrass, rocky/kelp bed, and pilings, support this species. Apparently they are potentially abundant in any of the two first natural habitats which are common throughout much of Washington.

No specific areas of abundance were located for Washington waters in North Sound studies (F, L) or in coastal bays (G, N, H).

HABITAT REQUIREMENTS - This species of kelp crab inhabits rocky/kelp bed areas and eelgrass beds and can utilize pilings and crevices (B, 1008). The

species uses the open water habitat with a strong bottom (or near bottom, while up on vegetation) association for the entire life except for a presumed planktonic larval stage.

CRITICAL HABITAT AREAS - The kelp crab, *P. gracilis*, is not well described in the life history area or in terms of abundance in various Washington water areas. The species seems well adapted to two extensive habitat types in Washington - rocky/kelp bed and eelgrass beds, and as such may be scattered all over Washington nearshore and intertidal areas and in no extensive concentrations anywhere.

No critical areas are designated for this kelp crab.

DATA GAPS - The life history and distribution of this species needs further review and study if no information exists.

Laboratory studies could be completed on this species to define early life history stages and breeding times of this crab.

Field studies - intertidal surveys - would provide distribution and abundance information: If this species moves off the intertidal to the nearshore subtidal, small pots or SCUBA might be useful survey methods.

REFERENCES - A, B, F, G, H, L, N, 1008.

FACT SHEET

I-18 PILE WORM

Nereis vexillosa

LIFE HISTORY - *N. vexillosa* is one of many nereid polychaetes in Washington waters. This species is the most nearly ubiquitous of our larger nereid polychaetes (B). The other common names are clam worm and sand worm (C).

A related species (*N. virens*) has a life span of four years and reaches sexual maturity at three years (493). Similar information and fecundity were not reported for *N. vexillosa*. Periodically during the summer the pile worm's appendages expand to paddle-like structures, allowing this bottom-dwelling worm to swim and then proceed to swarm near the surface (B). Reproducing adults were observed at Friday Harbor (June-August, 1008) and Kiket Island (March-July, 205). Tidal conditions influence timing of spawning (1008). Males spawn first followed by females, releading their sperm and ova directly into the water (1008). Eggs and sperm are spewed out through openings that develop in the body wall (B) and the worms die after spawning (1008). Predation by fish and birds is high during this swarming activity (1008). After fertilization in the sea, the zygote develops into a ciliated trochophore larva which later transforms into a young worm (E) which matures to repeat the cycle.

Migrations are not discussed, but some movement must exist in the summer spawning and the planktonic larval periods. These are not thought to to be extensive and for the most part may be the result of currents and not active directional movement by the pile worm.

Food of the pile worm includes algae (B). Small animals are also reported for *Nereis sp.* (E).

WASHINGTON DISTRIBUTION - The bulk of the literature review (A) distribution is not species specific to *N. vexillosa*. This species is labeled "nearly ubiquitous" (B) so it is presumed to be in all areas with suitable habitats (see next section).

The literature review (A) reports *Nereis sp.* and *N. vexillosa* (combined) in all areas of inside waters.

This species was not reported in the San Juan Island survey (F) where it might be expected. *N. vexillosa* is not reported for the "open coast" (A) nor in Grays Harbor (E) or Willapa Bay (H). This pile worm probably exists on the coast where rocky outcrops and mussel beds exist along the outer coast and particularly north of Point Grenville.

HABITAT REQUIREMENTS - The pile worm is unique as an adult that can live under the bottom surface, on the surface, and can swim while sexually mature and spawning.

The pile worm is often found in mussel beds, and is generally abundant under rocks and pieces of wood in quiet bays (B). It also burrows but is usually quite close to the surface (B). The mussel bed habitat of pile worms is a gritty mixture of sand and bits of shell with tightly packed mussels (B). Under rocks, on a sandy gravel beach, is another common habitat (C).

The literature review (A) reports *Nereis* from the high intertidal to the shallow subtidal. Nereid worms are said to live near the low tide

line (E). Bottoms associated with include solid rock, very coarse sand, mixed: very coarse, mixed: very fine, mixed: medium, shell fragments, fine sand, silt, cobble and boulder (A).

The pile worm utilizes the intertidal area with numerous bottom types and is bottom-associated in the open water habitat where subtidal. The pile worm is surface oriented in the open water habitat as a mature adult when spawning and as planktonic larval stages.

CRITICAL HABITAT AREAS - Critical areas for pile worms would be those summer surface water areas where they swarm in the spawning act. No data was located to indicate areas that are consistently used by great numbers of pile worms. As bottom-associated adults in the intertidal, they appear to be all over inside Washington waters in a wide variety of bottom types. No critical areas are designated for pile worms.

DATA GAPS - Summer surveys of spawning areas and density of spawners would possibly locate some critical surface water areas used by this species.

REFERENCES - A, B, C, E, F, H, 205, 493, 1008.

FACT SHEET

I-19 BLUE MUSSEL

Mytilus edulis

LIFE HISTORY - The blue or edible mussel is the most common of all local bivalves (C). The blue mussel is also called the bay mussel (A, B). The blue mussel is smaller (rarely exceeds 6 cm, B) and favors protected areas with lower salinity water as compared to the California mussel (I-20).

The life span is reported at eight years (205), or seven years with four years an average life span (493). Age of maturity was not located. Blue mussels may breed in the winter time (14). Ova and sperm are released into the water and planktonic larvae (veliger) are formed. Blue mussel spat (newly settled mussels following the planktonic stage) were observed in southern Strait of Georgia in July - August (625). Few details of blue mussel life history were located.

Any extensive movement of blue mussel is in the planktonic larval stages when currents presumably would be moving the early life stages.

Foods are not reported in the literature review (A). The blue mussel is a filter feeder (493), feeding on phytoplankton.

WASHINGTON DISTRIBUTION - The literature review reports blue mussel for all general Washington water areas except the open coast (A). The range of blue mussels on the West Coast of North America is from lower California

to Alaska (1008) so there may be scattered populations of blue mussel in more protected areas of the coast. Blue mussels are "not often observed on the exposed outer coast" (B). Blue mussels are reported in Grays Harbor (G) and in the tributary river estuaries of Willapa Bay (I). Puget Sound approaches the southern breeding limit of the blue mussel with greatest numbers of blue mussels in this area and north (14, 1008).

In general, blue mussel seem to be located over inside waters where habitat requirements are met (see next section) and in lower salinity areas on the coast (river estuaries) as in Willapa Bay and Grays Harbor. Blue mussels would presumably also be present in the lowest part of the Columbia River estuary.

HABITAT REQUIREMENTS - As distinguished from the similar but larger California mussel (I-20), the blue mussel is smaller and occupies more sheltered environments (199). Where the species are together, the blue mussel is smaller and higher in the intertidal zone. The blue mussel occupies the high, middle, and low intertidal area (A) and occurs in subtidal areas to 20 fathoms (1007). The blue mussel is characteristic in quiet waters and estuaries where the salinity is relatively low (B).

The other major habitat requirement is "any solid surface" (C). They are usually found on rocks, floats and pilings, and can even be on gravel if there is not too much wave action (C). The blue mussel forms its own habitat to a certain extent by forming in tight beds of small mussels.

The blue mussel utilizes the intertidal habitat that has solid, stable objects to attach to. These are usually in quiet waters with

lower salinities. Bottoms attached onto include pebble-gravel, sand, solid rock, boulder, cobble, mixed: medium, mixed: coarse, mixed: fine, mixed: very fine, mixed: very coarse, silt, shell fragments and fine sand (A).

The blue mussel dominates marine areas where shores are rocky, wave action is slight, circulation is slow and salinity is low (293). The blue mussel is also located among clumps of *Fucus* (551). This species is found throughout most of the intertidal zone (603). Blue mussels occupy only protected areas.

CRITICAL HABITAT AREAS - In inside Washington waters, the blue mussel is in many locations in great quantities and no areas stand out as critical. On the coast and in coastal bays, more isolated groups appear to exist but are not thought in critical areas. No critical areas are designated for this species.

DATA GAPS - If the information reviewed is representative, more details on the life history of blue mussel in Washington is needed to define critical time periods for this species (spawning and spat set periods) for different areas of Washington under different environmental conditions. A great amount of distributional information exists in the literature review (A). Any additional work should quantify abundance per unit area in methods as described by Houghton (205). Ongoing research at the University of Washington, under Dr. Ken Chew's supervision, will supply additional details on mussel species.

REFERENCES - A, B, C, G, I, 14, 199, 205, 293, 493, 551, 603, 625, 1007, 1008.

FACT SHEET

I-20 CALIFORNIA MUSSEL

Mytilus californianus

LIFE HISTORY - The California mussel is common on the open Coast of Washington, the Strait of Juan de Fuca, in scattered locations in the San Juan Archipelago, and in one reported location - Edwards Reef in Hood Canal (A). As compared to the blue mussel (I-19), the California mussel grows to a larger size and inhabits more exposed conditions (270) - open shores where wave action is strong, with free water circulation and high salinity (293).

No life span was located, but may be similar to the seven or eight years reported for blue mussel (I-19), or longer. This species exhibits a rapid growth rate and can spawn in its first year (120). Males mature faster than females (21). Females can produce up to 100,000 eggs/season (21). The major spawning season is from October to March (21), but the species may spawn all year round (14, 21). Eggs and sperm are released into the water where fertilization occurs and a planktonic veliger larvae develops. These develop into spat that settle and take on the bottom-attached adult life style. Spat are observed on the open coast, Strait of Juan de Fuca, and San Juan Archipelago in all months of the year (33). The mussel develops to maturity and repeats the cycle.

Extensive migrations are not possible for the adult mussel. The planktonic period could move the mussel larvae some distance with currents.

The California mussel is a cilliary filter feeder (120), feeding on both phytoplankton and zooplankton. Foods listed include suspended particulate matter (organic detritus and plankton) (21, 71, 353).

WASHINGTON DISTRIBUTION - The literature review reports California mussel for numerous places on the open coast and in the Strait of Juan de Fuca, in a few areas in the San Juan Archipelago, and in one reported area in Hood Canal - Edwards Reef (A). Presumably, the California mussel is scarce in other inside water areas. The range of the California mussel is from Alaska to Mexico (1008). The California mussel is in great numbers in dense beds where habitat requirements are met. (See next section.)

The California mussel's primary Washington habitat is the north coast of the state, (i.e., Point Grenville and North Coastal Islands, and the Western Strait of Juan de Fuca, where great amounts of rocky substrate and high surf exists. Rocky headlands and jetties to the south on the open coast also have this species. California mussel is reported in Grays Harbor (G), but not in Willapa Bay (I). The California mussel is probably scarce, but existing, in Willapa Bay. This species would also be expected around the mouth of the Columbia River, although low salinities may prevent extensive development by this species.

HABITAT REQUIREMENTS - The larger California mussel occupies more wave-swept open coast areas, as compared to the blue mussel (I-19). The California mussel ranges from the high, middle, and low intertidal zone to the shallow subtidal zone of the open water habitat (A). Its upper limit is set by desication and its lower limit is set by predators (*Pisaster sp.*, a starfish) (783) and possibly other predators.

The general habitat is one of rock substrate, more or less vertical, jagged and rough, exposed to constant circulation, with considerable wave action, and in more open waters, probably of high salinity (492). Another source (783) indicates they are rare on vertical zones or on overhangs, and prefer horizontal surfaces. They appear more numerous at locations exposed to surf (803). Salinities less than 29.6 ppt unfavorably affect the sex cells and larval growth of California mussel (626).

The general habitat must include a substrate to attach to. In the literature review (A), substrates include solid rock, mixed: Very coarse, pebble-gravel, sand, boulder and cobble. By far, solid rock is the most reported substrate (A).

Settling of California mussel spat is on vegetation - preferring the filamentous alga - *Endocladia sp.* (783).

The California mussel can dominate open rocky coast areas and form a habitat in itself - the dense beds of similar sized mussels. High salinity and strong wave action, with a lot of water circulation, are preferred habitat.

CRITICAL HABITAT AREAS - The main area of California mussel in Washington is the north open coast and the Western Strait of Juan de Fuca. No areas stand out from any others as critical, based upon the information reviewed. Scarce and a few scattered populations exist in inside waters (San Juan Archipelago, and one reported area in Hood Canal - Edwards Reef). None of these appear to be critical areas for California mussel. No critical areas are designated for this species.

DATA GAPS - More details on the open coast (including islands) distribution of California mussel should be gathered. More details of life history of this species from more areas in Washington should be gathered to better define critical life periods (spawning, spat fall, etc.). See blue mussel (I-19).

REFERENCES - A, G, I, 14, 21, 33, 71, 120, 270, 293, 353, 492, 626, 783, 803, 1008.

FACT SHEET

I-21 BUTTER CLAM

Saxidomus giganteus

LIFE HISTORY - The butter clam, or Washington clam, is extensively exploited commercially (B) as well as recreationally. The butter clam is one of the hard shell clams dug in greatest quantity in Puget Sound (C). These common names are also used for the larger clam, *S. nuttalli*, a more southern species (1008), not in Washington.

The butter clam has a life span of over 12 years at the +2 to -2 foot level (205). Maturity occurs at three (1008) to five years and the clams enter the fishery at five to seven years in British Columbia (488). Reproducing adults have been observed in the Strait of Juan de Fuca in April and May (488). In British Columbia spawning occurs throughout the year (488). Spawning occurs at about 20 C; sexes are separate (D). Eggs and sperm are discharged into the water where fertilization occurs. Larvae appear about 24 hours after fertilization (416). Larvae were free-swimming for 20 to 30 days and then set (413, 416). Spat were observed in June in the Bangor area of Hood Canal (780). Due to temperature, spawning and related spat fall is quite sporadic in British Columbia (D). In British Columbia larvae appeared as bivalved veligers in two weeks and settled on the gravel at less than 3/16 inch at the end of another four weeks (1008). These grow to maturity in three to five years to repeat the cycle.

Little adult vertical movement is reported (364), although at Kiket Island butter clams covered with two inches of gravel in May were found from four to eight inches deep in early November (205).

Butter clams are filter feeders. Phytoplankton was used as food in laboratory experiments with butter clams (413).

WASHINGTON DISTRIBUTION - The literature review (A) indicates there are butter clams in scattered abundance in North and South Sound and the Straits of Juan de Fuca and Georgia. The butter clam is indicated as the most abundant clam on suitable beaches in Puget Sound (1008). The butter clam was not reported in the San Juan Island survey (F), but are common in the San Juans (Ron Westley, WDF, personal communication). In Hood Canal, this clam was reported at over half of the stations surveyed (364).

The literature review (A) reports no butter clams from the open coast. One source (1008) indicates this clam rarely occurs on the open Washington coast or in inlets directly adjacent to oceanic waters (1008). In a Grays Harbor study the eastern limit for butter clams is about one to two miles into the mouth of the Harbor and into North Bay and South Bay along their western shores (M). In Willapa Bay the butter clams were located in the Stoney Point stations and were probably in other locations that were sampled only at mid to high tide levels (M). The only restriction on butter clams in Willapa Bay would be at low salinity areas near river mouths (M). This source (M) indicates that salinities (from large freshwater flow), temperatures and sulfite liquor levels present in Grays Harbor are dominant factors in bivalve distribution. The butter clam is not numerous in either Grays Harbor or Willapa Bay (M).

Some butter clams may be located in the Columbia River mouth vicinity, but no reports were located.

HABITAT REQUIREMENTS - The general habitat is gravelly beaches (B) but this species is also reported in mud or sandy mud of bays, lagoons, and estuaries (1005). The butter clam is located on the middle and low intertidal (A) - rarely above +3 or +4 feet, and subtidally to a depth of 30 feet (364) and 60 feet (1007). Another source (488) indicates the middle intertidal zone is the butter clam's upper limit in British Columbia. In Hood Canal, 75 percent of the butter clams sampled were within the -1 foot to +2 feet tidal elevations (364).

The butter clam utilizes pebble-gravel to fine sand and mud intertidal habitats (A) and presumably a similar mix of bottom associations exists for the open water habitat where the butter clam is subtidal.

The butter clam prefers mixtures of sand, shell, and gravel and its growth is stunted on exposed beaches (488). Small clams will reburrow when exposed to the surface (488).

(1005) with smaller clams closer to the surface (364) and larger clams possibly deeper in late fall, as compared to spring (205).

Laboratory experiments indicate the veliger stage of butter clams has optimum growth at 20 C and optimum survival at 15 C in a salinity range of 20 to 29 ppt (no difference in growth rates) (413). Temperatures of 25 C caused 50 percent mortality in 40 hours (501). Laboratory spawning occurred at 21 C (416). Another temperature range for British Columbia was 0 to 25 C with a salinity range of 20 to 35 ppt (488).

Tidal currents are quite important factors in distribution because of the clam's pelagic larvae (1008).

The butter clam is a dominant in the *Macoma* community. This community has a belt of eelgrass at its lower border and extends three feet or more below mean low tide (492). The deposition of materials by waves and currents is quite important to this community (492).

CRITICAL HABITAT AREAS - The butter clam is distributed where the gravelly beach to mud habitat exists under the lower salinity ranges this species prefers. The literature review (A) documents many records for the inside waters and Strait of Juan de Fuca of Washington. No areas stand out as critical areas among the many areas having an abundance of butter clams.

On the open coast no areas are reported as having this clam (A). In the coastal bays, the butter clam is limited (more so in Grays Harbor) to the westward or seaward and entrance portions of these bays. No critical areas are designated on the open coast or in these coastal bays.

DATA GAPS - A good deal of distribution information exists (A) but unfortunately is not presently in quantitative terms that can be cross-compared between areas. This type of density information (number/0.25m^2) would be necessary to detail which areas are the largest production areas of the many areas where the butter clam is located. Methodologies following those of Houghton (205) are recommended.

Studies over several years would also document annual variation and give some impressions of population trends within an area. Downward trends might be related to environmental changes. Further habitat requirements not presently understood for butter clams.

REFERENCES - A, B, C, D, F, M, 205, 364, 413, 416, 488, 492, 501, 780, 1005, 1007, 1008.

FACT SHEET

I-22 COMMON COCKLE

Clinocardium nuttallii

LIFE HISTORY - The common cockle is also called the basket or heart cockle (A). The common cockle's life span is reported as five years (205), and seven years (488). Common cockles have a reduced size and shorter life span in their southern beds (Washington), as compared to northern beds (Alaska) (1008). The common cockle's range is from lower California (Mexico) to Alaska (Bering Sea) (364). This species reaches its "maximum development" in British Columbia and Puget Sound (1008).

The common cockle is hermaphroditic, with sexual maturity reached in two years in British Columbia (488). Reproducing adults are reported from the Strait of Georgia, British Columbia, in May and June (488). Times may be different in Washington, as this cockle grew slower at Kiket Island than described by this source (488) for British Columbia (205). Eggs and sperm are released to the water where fertilization occurs (D), and larvae probably appear soon thereafter. Planktonic larvae exists (D) possibly for a month or so before the cockle settles as spat. Common cockle spat were observed in North Sound (Cherry Point area) in July and August (625). If assumed larval periods are correct, these spat dates would tend to agree with reproducing adults observed in May and June in British Columbia. After about two years the juvenile cockle would mature, to repeat the cycle.

The common cockle is a "powerful digger" (1008, 364). The common cockle does not dig deeply into the bottom because it lacks siphons (1008), or has very short siphons (364, B) and can not feed if deeper than one inch (C), to three inches (364). The species can migrate horizontally (488).

Foods are not reported for this felter feeder, but include phytoplankton and zooplankton, and possibly particulate detritus.

WASHINGTON DISTRIBUTION - The common cockle seems to be in all general Washington areas, except the open coast (A). The common cockle is very common in Southern Puget Sound (359). If the general habitat requirements are met (see next section), commom cockles are present in scattered areas of inside waters and coastal bays. In Hood Canal, common cockles were most abundant in the upper west and east sections, few in the lower west and Dabob Bay, and none in the eastern arm - probably related to substrate availability (364).

In the San Juan Island Study (F), the common cockle (with the bent-nosed clam) provided most of the biomass among bivalves at the minus one foot level in the mud habitat, and was less abundant at the same level in the protected gravel habitat.

In Grays Harbor, the common cockle is the most numerous hard shell clam species, and ranges in the outer harbor (Harbor mouth east to Johns River and Neds Rock) (532, M).

Commom cockles are present in Willapa Bay (425) and are intertidal and subtidal residents of the bay, occuring as deep as 15 feet below mean lower low water (I).

This species is apparently distributed through Willapa Bay except in the vicinity of low salinity areas at river mouths (M).

The common cockle is not numerous in either Grays Harbor or Willapa Bay (M).

Low salinities may limit common cockle numbers in the vicinity of the Columbia River mouth and lower estuary. No reports were located for cockles there.

HABITAT REQUIREMENTS - The common cockle seems to prefer those portions of quiet bays where the substrate consists of muddy, fine sands (B, 205, M, 488). Beds of eelgrass growing on mud often support large cockle populations (B). In Grays Harbor, the common cockle was found on coarse textured substrates with lower organic levels (532). the common cockle can also be plentiful in clean sand beaches (B). Substrates reported in the literature review (A) include mixed: medium, silt, sand, mixed: coarse, cobble, mixed: fine, shell fragments, solid rock, mixed: very fine, pebble-gravel, and clay. By far the greatest number of reports (A) are in the finer substrates.

The common cockle is located from the high intertidal (usually middle intertidal) to subtidal depths of 15 feet (I), 5 fathoms (1007), and 20 fathoms (758). Peak abundance was reported at the zero foot level, and probably deeper, at Kiket Island (205). Another source (622) reports a maximum abundance of common cockles at -11.5 to -8.2 feet. The majority (77 percent) of the common cockles collected in Hood Canal were from stations at -1 foot to -2 feet mean lower low water (364).

The common cockle's distribution in Grays Harbor is thought to be

limited by lower salinities in East Bay (532). A preference for higher salinities (greater than 15 ppt in winter, and greater than 25 ppt in summer) (G). Wide temperature ranges appear to be tolerated.

The common cockle generally utilizes higher salinity, of relatively flat intertidal areas (muddy sand substrate) and is bottom associated in the subtidal on similar bottom types. The common cockle is presumed to be entirely in the open water habitat for about a month, when free-swimming larvae exist. The abundant common cockles are located intertidally from -5 feet to -6 feet down.

CRITICAL HABITAT AREAS - The common cockle appears in scattered abundance, and distributed where suitable substrate and salinities exist. No critical areas are apparent for common cockle.

DATA GAPS - See butter clam (I-21).

REFERENCES - A, B, C, D, F, G, I, M, 205, 359, 364, 425, 488, 532, 622, 625, 758, 1007, 1008.

FACT SHEET

I-23 HORSE CLAM

Tresus nuttallii

LIFE HISTORY - Other common names of the horse clam include gaper, big neck, and great Washington clam (A). The common name, gaper clam, is applied to *T. capax* (I-24) and will be used for that species. *T. capax* is distinguished from *T. nuttallii* by having a rounder shell outline and leathery skin on the siphon and edges of the shell are more tan, rather than the dark brown or black as in *T. nuttallii*. The general users lump *T. nuttallii* and *T. capax* (I-24) as the horse or gaper clam.

Life history information was not reported in great detail. Life span and age at maturity were not located. Spawning occurs in the summer (780). The spawning months in the Strait of Georgia, British Columbia, were July to August (488). Presumably eggs and sperm are released into the water where fertilization is followed by one or more months of a pelagic larval stage. A timing of spat settlement was not located. The clams would mature and repeat the cycle.

Vertical movement is thought to be slow, although the species can be found at depths of three feet. This species burrows poorly (488).

Foods are not reported. Diatoms are reported as the food of *T. capax* (959).

WASHINGTON DISTRIBUTION - Washington is the northern limit of this species' range and the horse clam is subject to freezing mortalities (916). *T. nuttallii* is more susceptible to freezing than *T. capax* (962). The literature review (A) reports the horse clam (*Tresus sp.*, primarily) for all general inside water areas including the Straits of Georgia and Juan de Fuca. No open coast or coast bay reports were in this literature review (A). Horse clams were not reported in the San Juan Island survey (F), or Kiket Island (205). The horse clam was taken in Grays Harbor - Oyhut Channel (M) and was not taken in another study (G). The gaper clam is reported for Willapa Bay, while the horse clam is not reported there (H). *T. nuttallii* is reported in Willapa Bay-Stoney Point by one source (M).

No reports were located about horse clams in the lower Columbia River mouth.

HABITAT REQUIREMENTS - The horse clam prefers clean sand substrate (488). The horse clam is at the northern limit of its range in Washington (916). This large hardshell clam has an extremely long siphon (1005) and lives at depths of 16 to 26 inches below the surface (780, 488).

In general, this species occupies fine sand or firm sandy muds in bays, sloughs, and estuaries (1005). This species prefers quiet bays, but may be found on the outer coast (1008). This source does not specify if this includes Washington. Bottoms used, as described in the literature review (A), include fine, very fine sand, mixed: fine, eelgrass, mixed: coarse, shell fragments and cobble. The bulk of the reports are sand, and mixed: fine type of bottoms (A). In Hood Canal, *Tresus sp.* prefers a sand-gravel-eelgrass substrate with 70 percent of those taken between -2 feet and +1 foot mean lower low water (364).

The horse clam is located in the high, middle and low intertidal zone (A). Most reports seem to be in the middle and low intertidal zones (A).

Laboratory experiments indicated temperatures of 25 C caused 50 percent mortalities to test animals in 50 hours (501).

The horse clam occupies the intertidal and subtidal (mud to sand bottoms) and occupies the open water habitat when the planktonic larval stage exists.

CRITICAL HABITAT AREAS - The horse clam appears distributed in areas where freezing is not a problem. Scattered abundances exist all over inside waters and not on the coast but in coastal bays. No areas stand out from any others, so no critical areas are designated for horse clam. The species apparently never congregates densely in any given areas, as compared to smaller hard shelled clams.

DATA GAPS - See butter clam (I-21).

REFERENCES - A, F, G, H, M, 205, 364, 488, 501, 780, 916, 959, 962, 1005, 1008.

FACT SHEET

I-24 GAPER CLAM

Tresus capax

LIFE HISTORY - Other common names of the gaper clam are horse clam, big neck, and great Washington clam. The general user lumps this species with *T. nuttallii*(I-23) as the horse clam. Different physical characteristics exist and are noted on the horse clam (I-23) fact sheet.

The gaper clam is one of the largest clams found in Washington State's marine waters (776). The gaper clam is a more northern form, as compared to the horse clam (I-23), which is more characteristic of more southern latitudes (364).

The life span of gaper clam is 15 years (415) and possibly longer. Sexual maturity is reached in about three years (70 mm) in southern British Columbia. In southern British Columbia, gonads begin rapid development in September-October, are ripe by December-January, with spawning by February and through May (415). Winter spawning is also reported in Hood Canal (780). Spawning begins at the time of the seasonal minimum temperatures and lasts from six to eight weeks (415). Eggs and sperm are released to the water where fertilization occurs. The planktonic larval stage follows and lasts for variable times dependent on water temperature (laboratory studies 5 C - 34 days to metamorphosis, versus 10 and 15 C with metamorphosis in two days, 414). With winter spawning, the lower temperature would seem more representative of Washington waters, so the larval stage possibly lasts for 20 to 30 days. The clam settles with metamorphosis and matures in about three years to repeat the cycle.

Vertical movement of the gaper clam is presumed slow. It reburrows poorly (488).

Food of the filter-feeding clam is reported to be diatoms (959).

WASHINGTON DISTRIBUTION - The gaper clam is indicated on the open British Columbia coast and inside waters of Washington including the Strait of Juan de Fuca (A). Unfortunately, most of the literature review distribution is for *Tresus sp.* which may be the gaper clam (*T. capax*). Many *Tresus sp.* reports are made from Hood Canal (A). The gaper clam is the dominant *Tresus* clam in Puget Sound.

The San Juan Island survey (F) did not report this species. No reports were located for the open coast of Washington, however, they are reported in Grays Harbor in one study (G), while only *T. nuttallii* was reported by another study (M). These clams in Grays Harbor were limited to the west shores of North and South Bays and the vicinity of the Harbor mouth (M).

In Willapa Bay gaper clams were present within the tidal zone (H). Only *T. nuttallii* was reported in Willapa Bay in another study (M). They were also reported numerous subtidally in channels extending to 15 to 20 feet below mean lower low water (I).

No reports were located for the Columbia River estuary and mouth.

HABITAT REQUIREMENTS - The gaper clam generally lives on tide flats of quiet bays where the substrate is essentially mud with gravel and bits of shell worked into it, and is sometimes found in rather stiff clay (B). The gaper clam prefers beaches with a higher gravel than sand content (415) or

with sand, gravel and shell fragment mixtures (488). One source (962) indicates the gaper clam prefers more compact sediment than the horse clam, but the above sources indicate otherwise. In Hood Canal, *Tresus sp.* prefers a sand-gravel-eelgrass substrate (364).

The gaper clam utilizes the high, middle and low intertidal areas, as well as the shallow subtidal (A). Most reports in the literature review (A) are for clams in the middle and low intertidal and subtidal areas. Subtidal reports are to 15 feet below mean lower low water in Willapa Bay (I). On Kiket Island, gaper clams were taken occasionally on the north side at the zero foot level (205). Possibly more gaper clams existed in lower zones (205). In Hood Canal, 70 percent of the *Tresus sp.* were at stations between -2 feet and +1 foot mean lower low water (364).

The gaper clam is reported below the surface to depths of 10 to 18 inches (780), to 18 inches (415), from 18 to 36 inches (1008), and 36 inches and more (1005). Depth located is probably substrate dependent and possibly seasonally dependent.

The gaper clam generally utilizes gravel to sand type (mixed: fine) beaches in the middle to low intertidal and into the shallow subtidal. The gaper clam is an open water inhabitant during the pelagic free-swimming larval period.

Laboratory studies on the trochophore (larval) stage of gaper clams indicated excellent survival in 5, 10, and 15 C, but slow growth at 5 C (414, 424). Mortality was 100 percent at 20 C (414, 424). Optimum growth and survival of the larvae was seen at salinities of 21 to 28 ppt (424).

CRITICAL HABITAT AREAS - The gaper clam is apparently the dominant *Tresus* clam in Puget Sound and from the literature review (A) appears in the Strait of Juan de Fuca, in all general inside Washington water areas, and in coastal bays. Hood Canal has numerous gaper clam reports (A). No specific areas stand out from any others as being critical. No areas are mapped for gaper clams on the basis of the information reviewed.

DATA GAPS - See butter clam (I-21).

REFERENCES - A, B, F, G, H, I, M, 205, 364, 414, 415, 424, 488, 776, 780, 959, 962, 1005, 1008.

FACT SHEET

I-25 SOFT SHELL CLAM

Mya arenaria

LIFE HISTORY - The soft shell or mud clam was introduced from the Atlantic (1005, B, 1008) in the 1800's and is an euryhaline species capable of living in brackish waters and at freezing temperatures (364). Willapa Bay was the first Washington area this species appeared in (1008). This clam species is small, length is less than five inches (1008). This clam is not widely sought in Puget Sound. Fossil evidence indicates this species may be native to this coast (364).

The life span of the soft shell clam is variously reported, seven years (493), and eight or nine years (205). Sexes are separate (728) and eggs and sperm are released to the water where fertilization occurs. Spawning occurs in "bursts" (728). Fecundity of the East Coast (Massachusetts) is eported as about three million eggs/female/year (728). Spawning occurs in June and July (784) and in all months in upper Grays Harbor (218). The larvae are pelagic for two weeks then settle as spat (728). A great deal of mortality occurs at this larval stage from tidal flushing and other causes (728) with about one percent surviving to maturity. The juveniles mature at about two years and are sexually viable for about five years, and the cycle is repeated.

Vertical movement is apparently not great in this clam. Power of digging is somewhat reduced with age and the clam can not maintain itself in some shifting substrates (1008). These clams can be exposed to the air by wave action.

"No information stored" is the food report in the literature review (A) for this filter-feeding clam. Phytoplankton and suspended organic materials are possible foods of this clam.

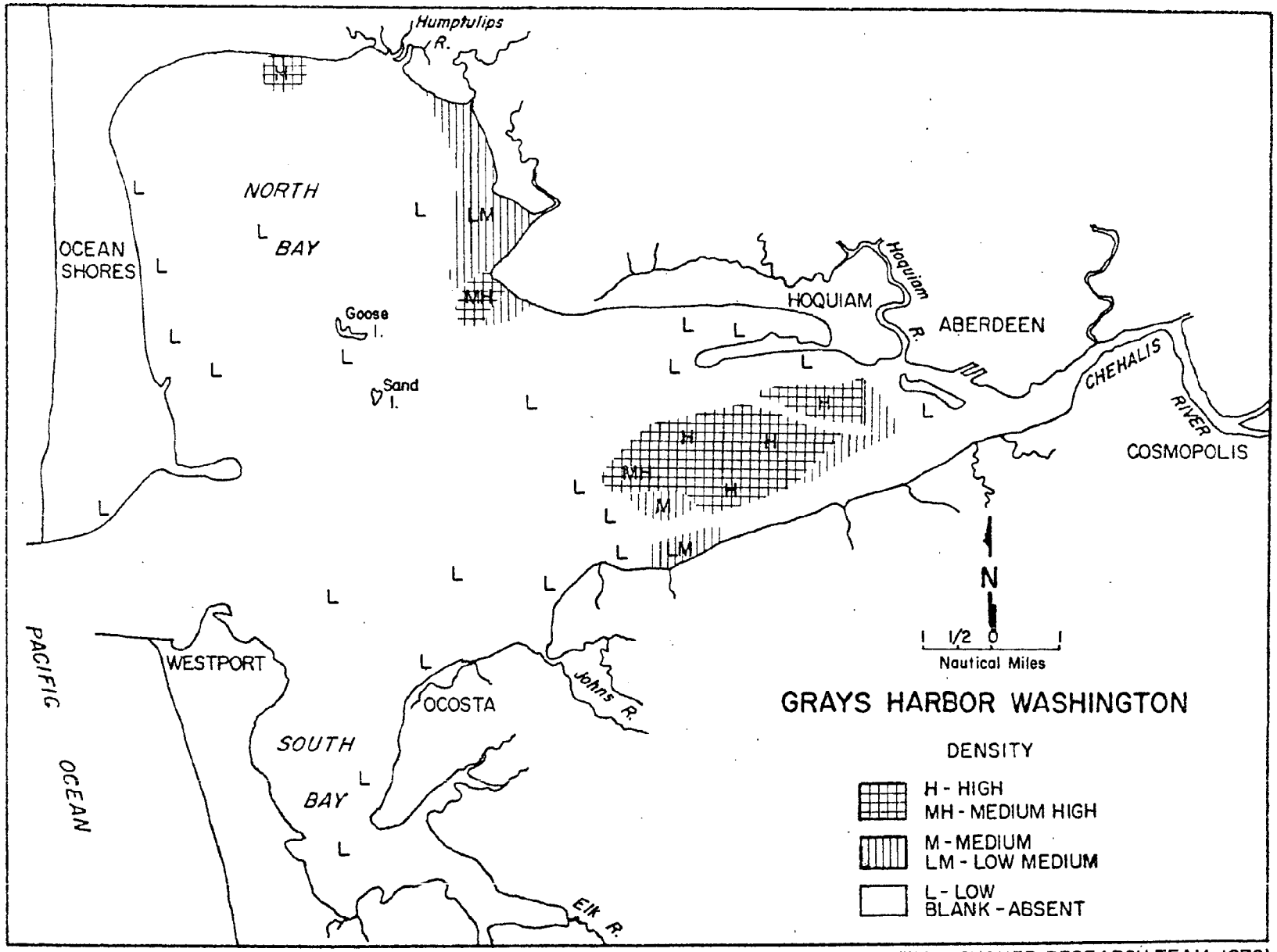
WASHINGTON DISTRIBUTION - The literature review (A) and life history indicates this species is located in Washington estuaries where low salinities exist that this species can tolerate. In Hood Canal, this species was taken at half the stations surveyed (364). Skagit Flats have an abundance of this species (784). The literature review (A) indicates this species is scattered throughout inside Washington waters including the Strait of Juan de Fuca and in coastal byas (Willapa and Grays Harbor).

In the San Juan Island survey (F), the soft shell clam was taken mostly in the mud habitat and primarily at lower levels as compared to the highest level sampled (+5.5 feet). On Kiket Island, the highest occurrence of this clam was at +8 feet, higher than any other major subsurface bivalve (205). Commercial concentrations occur in Skagit Bay, Port Susan, and Grays Harbor (Ron Westley, WDF, personal communication).

In Grays Harbor, the highest concentrations were in the mid-Harbor Flats with lesser concentrations around the rest of the bay except for the areas near the Harbor mouth (see map). Similarly in Willapa Bay, this species is in the Bay, except near the Bay's mouth (G, M). This species is the most abundant large clam in Grays Harbor (218).

The soft shell clam occurs throughout the Bay tidelands and is most frequently on muddy or sandy bottom in the upper tidal areas and in brackish water areas of tributary streams (I).

This species is probably also in some abundance in the lower Columbia



(ADAPTED FROM CHOKER RESEARCH TEAM, 1972)

RELATIVE DENSITIES OF MYA ARENARIA IN GRAYS HARBOR

SOURCE: G

River estuary and near the mouth where muddy or sandy muddy areas exist.

HABITAT REQUIREMENTS - The soft shell clam is very euryhaline, often found in brackish water and can withstand freezing temperatures (364). Additional tolerance is shown in anerobic conditions which this species can tolerate for long periods of time (780), for eight days (1008).

This species is typically found in mixtures of sand and mud or mud and gravel where the salinity is reduced by the influx of fresh water from stream or from seepage (B). The softshell clam is also reported in heavy black mud in back waters of bays, lagoons, and sloughs in fresh water/sea water mixing areas (1005). A looser substrate appears more favorable for growth as growth was double that of clams in a compact mud-gravel-shell mixture (525). Bottom types in the literature review (A) include silt, mixed: medium, mixed: fine, pebble-gravel, sand, shell fragments, mixed: coarse, fine sand and very fine sand. The majority of the reports are the finer substrate (A).

The soft shell clam is usually about eight inches (B) or ten or more inches below the surface (1005).

This species is primarily intertidal in Puget Sound but is also located subtidally (407). In Hood Canal, 75 percent of these clams taken were between +2 and +5 feet mean lower low water (364).

Salinity ranges where soft shell clams are found at Skagit Bay was 2.54 to 24.53 ppt (784) and at Dabob Bay was 8 to 28 ppt (364). Temperatures at Skagit Bay where soft shell clams were located were from 4.8 to 15.7 C. For a variety of Whidbey basin areas, temperatures ranged from about 8.5 to 11.5 C (407). This species can withstand freezing temperatures (364).

In Willapa Bay and Grays Harbor, three factors must limit the soft shell clams' distribution (M):

1. Fresh water limits the eastern distribution; high salinities limit the distribution near the Bay mouths.

2. Substrates with small grain size (< .16 mm) and high moistures.

3. Packed sand substrates with low moistures and low organic content.

CRITICAL HABITAT AREAS - Critical habitat areas would seem to be the low salinity estuaries where this species thrives (i.e., Grays Harbor, Skagit Bay). However, this species seems common to abundant in many estuaries and no single or group of estuaries stand out as critical areas. No areas are designated for soft shelled clam.

DATA GAPS - More information should be gathered on the Washington life history (particularly early life history) both in laboratory studies and field studies in May-September when spawning occurs and following spawning (two weeks) when spat are located. These studies should cover representative areas of inside waters and coastal bays to provide timing information on these sensitive life stages.

For additional details on distribution studies, see butter clam (I-21).

REFERENCES - A, B, F, G, I, M, 205, 218, 364, 407, 493, 525, 728, 780, 784, 1005, 1008.

FACT SHEET

I-26 JAPANESE LITTLE NECK

Venerupis japonica

LIFE HISTORY - The Japanese little neck is also called the little neck, or Manila clam. It is to be distinguished from the native little neck, *Protothaca staminea*, (I-29). This species was introduced into the Northwest (205) about 1930 (C), and Vancouver Island is the northern limit of this species on this coast (364). Introduction from Japan was with seed oysters (B).

The life span reported in Japan was eight years (R). The Japanese little neck enters the fishery in three to four years (488, 422). The life span may be similar to native little neck - ten years (488) or twelve years (205). Spawning occurs throughout the summer (488) when temperatures approach 70 °F (94). Spawning peaks for females in June and July, and in June and August, and September for males (94). Eggs and sperm are released to the water where fertilization occurs. The resulting larval (veliger) stage lasts about three to four weeks, with settling reported all year long (421), but more specifically, beginning at the end of May with a main spatfall in June through October (422). The juveniles would mature (age not located) and repeat the life cycle.

Little vertical movement is seen in Japanese little neck clams - to depths of two to three inches (364). Sometimes this clam is on the surface

under oysters (94). There is "no information stored" in the literature review of foods of this filter-feeding clam species. Phytoplankton, and suspended organic material (detritus) may be foods of this clam.

WASHINGTON DISTRIBUTION - The Japanese little neck clam is reported from all inside areas and coastal Washington bays (Grays Harbor), but does not occur on the open coast (A). Both Straits of Juan de Fuca and Georgia have this species present, and abundant (A). The majority of the literature review (A) is for reports from Hood Canal.

The Japanese little neck clam was reported in the San Juan Islands survey (as *Tapes japonica*) in the "protected gravel" habitat at the plus two foot level (F). This species is indicated as one of the less numerous of five large bivalues that are the dominant group at this level (F). The native little neck (I-29) was the most abundant bivalve in biomass (F).

The Japanese little neck was also reported in Grays Harbor as *Tapes japonica* (G), and *Tapes semidecussata* in Oyhut area (M). The Japanese little neck (as *Tapes*) has a distribution in Grays Harbor much like butter clam (I-21), and gaper clam (I-24) -- not far into the Harbor proper -- and only along the west shores of North and South Bay (M, G).

Japanese little neck clams (reported as Manila clam) are present in the intertidal zone of Willapa Bay (H) and throughout the Bay (reported as *T. semidecussata*) (M).

No reports were located for the lower Columbia River estuary and mouth where this clam may occur.

HABITAT REQUIREMENTS - The Japanese little neck prefers mud and gravel beaches in the intertidal (high, middle and low areas, A) zone (488). Some subtidal reports were made on similar bottom types (A). Subtidal clams are probably in shallow water areas near the intertidal zone. Intertidally, the Japanese little neck usually lives under oysters (94), at least in oyster areas. This clam is labeled a typical gravel beach inhabitant, along with butter clams (I-21) and native little neck (I-29) (C). The Japanese little neck can be differentiated from these other clam species (locally from six to twelve inches deep at the zero tide level or below) because this introduced species is very close to the surface and from the plus two or three foot up to plus six or seven foot tide level (C). In Hood Canal 94 percent of this species taken came from the zero foot to plus five feet tidal level (364). Bottom associations in the literature review (A) for the clam include pebble-gravel, sand, mixed: very fine, mixed: medium silt, shell fragments, mixed: very coarse, and cobble. The clam may be found with the native little neck (I-29), but generally the Japanese little neck tends to reside at slightly higher tide levels (B). At Kiket Island, the Japanese little neck was distributed similar to the soft shell clam (I-25) (205).

A gravel substrate is indicated as prefered over mud in Willapa Bay, as studies indicate this clam and the native little neck (I-29) could be increased tremendously with the addition of a thin layer of gravel (H). The Japanese little neck is a shallow and presumably poor burrower, and would benefit from this type of substrate change.

The Japanese little neck clam is susceptible to freezing mortalities because of the shallow depths (zero to two inches, (94); two to three inches,

(364). This species lives below the surface. One apparent winter mortality of 93 percent was reported in Hood Canal (422).

This clam is also limited in colonization of some areas (i.e., Grays Harbor), by low winter salinities (532), although other factors, pollution and freezing temperatures, could also be involved. Laboratory studies of the veliger stage indicate optimum growth and survival at 20 to 28 ppt, while limits to survival and growth were seen at lower (12 ppt) and higher (32 ppt) salinities (424). A temperature of 21 C was used in these studies (424). Quite warm temperatures are tolerable, if 70 F ques spawning by this clam species (94).

CRITICAL HABITAT AREAS - The Japanese little neck clam seems abundant where mud and gravel (or mixed) beaches exist in moderate to high salinity ranges. No areas stand out from others to indicate any that are critical. No areas are designated for this clam species.

DATA GAPS - See butter clams (I-21).

REFERENCES - A, B, C, F, G, H, M, 94, 205, 364, 421, 422, 424, 488, 532.

FACT SHEET

I-27 PIDDOCK

Zirfaea pilsbryi

LIFE HISTORY - Little life history or distribution information was located in the literature review. The piddock is known as a clay-boring clam (C). The life span of this clam is seven to eight years (1008). On reaching maturity this clam presumably releases eggs and sperm into the water where fertilization occurs and a brief pelagic larval stage follows. These set (as spat), mature and repeat the cycle.

Although vertical movement is deep (10 to 14 inches, 1005), the piddock is a slow burrower.

Foods of this filter feeding clam has "no information stored" in the literature review (A). Foods could include phytoplankton, zooplankton and possibly suspended organic material.

WASHINGTON DISTRIBUTION - There are few (eight) reports of piddock distribution in Washington waters. Few clams are reported for South Sound (64). This clam is "present" in the Strait of Georgia and "Pacific Northwest waters" (A).

This species was not reported in the San Juan Island survey (F), in Grays Harbor (G) and Willapa Bay (H, I).

No reports were located for the lower Columbia River estuary or river mouth.

HABITAT REQUIREMENTS - The primary habitat is intertidal, although the piddock is found subtidally to 10 fathoms (758). The intertidal substrate includes heavy mud, clay, and soft rock of bays, lagoons and estuaries (1005, 981). This species bores into limestone (1007). Clay and solid rock are the substrates mentioned in the literature review (A).

The piddock bores to depths of 10 to 14 inches in these substrates (1005).

No salinity or temperature tolerance information was located.

CRITICAL HABITAT AREAS - Too little life history and general distribution information exists to define any areas as critical. No areas are designated.

DATA GAPS - The piddock is not well studied in Washington if the information reviewed is representative. Studies must be completed to evaluate their life history - quarterly sampling in hard mud to soft rock substrate to determine time of spawning and possibly spat fall. Laboratory studies could complement these field studies.

For further studies to define piddock distribution see butter clam (I-21).

REFERENCES - A, C, F, G, H, I, 64, 758, 981, 1005, 1007, 1008.

FACT SHEET

I-28 RAZOR CLAM

Siliqua patula

LIFE HISTORY - The razor clam is one of the best known and most utilized bivalves in Washington state. This importance is reflected in the amount of information available about this species.

Life span in Washington is 9 years and in Alaska is up to 19 years (D). Sexes are separate (D). Fecundity is reported as 6 - 10 million eggs/female (21). Maturity is reached in the second year (21,927) or two or more years (D). Spawning occurs when temperatures reach 13C (D). This is April and May in Washington (21), spring and early summer (106). Successful breeding is infrequent in central B.C., at intervals up to 10 years (488). Eggs and sperm are discharged through the excurrent siphon (D). Fertilization is in the water and eggs hatch into larvae (D). The free swimming larval stage (veliger) last 8 weeks (927) or 5 to 16 weeks (D). After this stage the young clams develop a shell and settle onto the bottom where they set (as spat) in the top layer of sand, mortalities are high at this stage due to rain, crowding and predation (21). The clams grow slowly through fall and winter but accelerate during the spring with warming water and an increased food supply (D). At two years of age, the razor clam matures to repeat the cycle.

Vertical migration of the razor clam is fast when disturbed and to a considerable depth (1005) - 18 inches (C). The razor clam is normally found in the upper 10 inches of sand (488).

Foods of the filter feeding razor clam are beach diatoms. The principal species in October to April is Chaetoceros armatus (610, 21).

WASHINGTON DISTRIBUTION - The commonly understood habitat of razor clams - ocean beach with strong surf - would place all razor clams on the open coast of Washington which is the major area utilized by this species. There are however records for inside waters (Strait of Georgia, B.C., 488; Skagit Bay - Silqua sp. or related species, 64),and coastal bays (Grays Harbor, G; Willapa Bay, H)

The principal Washington razor clam area is geographically separated into four ocean beaches - Long Beach, Twin Harbors Beach, Copalis Beach and Mocrocks Beach (610).

In Willapa Bay the area of razor clam abundance is on the detached spit area at the Bay's mouth with higher densities on the Bay side of this tidal delta (H).

HABITAT REQUIREMENTS - The razor clam prefers ocean beaches with strong surf (21). Other parameters involved in optimum production include sand coarseness, food production and sand deposition/erosion rates (Herb Tegelberg, WDF, personal communication). Salinity is apparently less of a factor for adults, although rainfall on freshly set spat can cause mortalities.

The habitat requirements are not fully understood but apparently they change in a given location and cause changes in razor clam production. Mocrocks Beach - extending from Copalis River to Moclips River - has become an important producer in the past decade (as of 1968) (610). In earlier years the southern Washington beaches were the biggest producers of razor clams

(Herb Tegelberg, WDF, personal communication). No consistent areas stand out for razor clams. Highest counts of spat have occurred from Conner Creek to Moclips Beach in recent years (Herb Tegelberg, WDF, personal communication).

The location on the beach is from the mid intertidal to the subtidal (about 5 fm) with another not fully described species (*S. medina*) from about 5 fms to 50-60 fms, (Herb Tegelberg, WDF, personal communication). The razor clam (*S. patula*) is in greatest numbers in the intertidal in the beach area exposed by about minus 1 foot and lower tides (B) - or the low intertidal. Subtidal (to 5 fm) clams make an unknown recruitment contribution to the intertidal clam population.

Vertically the razor clam is usually in the upper 10 inches of sand when undisturbed and can be washed out of the sand by heavy surf (488, 1005). When disturbed the razor clam can go substantially deeper (1005) to about 18 inches (C).

The only temperature variable mentioned as impostant is the 13 C temperature that cues spawning (21). Salinity ranges that occured at North Head (south end of Long Beach) where razor clams exist ranged from slightly less than 22 ppt to over 31 ppt (0).

The razor clam is bottom associated all of its life, except for the planktonic egg and larval stages that can last 5 to 16 weeks (D). This stage and the early spat fall period are probably the critical life stages for this species. Cold spring and summer years when waters would not reach 13 C could prevent or reduce successful spawning by razor clams.

CRITICAL HABITAT AREAS - Of the open coast of Washington producing areas, no area has consistently over the years been the major producer of razor clams.

For this reason, no critical areas are noted for this species. The only notation possible would be all of their principal habitat areas Long Beach, Twin Harbors Beach, Copalis Beach, and Mocrocks Beach.

DATA GAPS - Additional work should be completed to attempt a better definition of the environmental parameters that are known (sand coarseness, food production, sand deposition and erosion rates) and possibly unknown parameters that determine more optimum production of razor clams. WDF indexing programs for management presently gather the production data to measure against changing environmntal conditions.

REFERENCES - B, C, D, G, H, O, 21, 64, 106, 488, 610, 927, 1005.

FACT SHEET

I-29 NATIVE LITTLE NECK

Protothaca staminea

LIFE HISTORY - The native little neck is also commonly called the rock little neck, rock cockle, and rock venus (A). In the native little neck's range -- Aleutian Islands to Baja, the largest populations occur in Puget Sound (364).

The life span of this clam is 10 years (488), 12 years (205). About half the clams reach sexual maturity in three years (776). Hermaphroditism is common (776). Spawning is variously reported in winter (776), sporadic throughout the summer -- May and June in Strait of Georgia, British Columbia (488). Eggs and sperm are released to the water where fertilization occurs (776). The fertilized eggs develop into pelagic larvae (veliger) which lasts for three weeks (488). A few spat were observed north of Cherry Point in July and August (625). After about three years, the juvenile native little neck would mature to repeat the cycle.

Vertical movement in this species is not great. This clam is a poor digger and is not present in shifting substrates (624). Depths from the surface to three and six inches are reported (488, 776).

Foods of adult native little neck is plankton (not specific) (761, 776).

WASHINGTON DISTRIBUTION - The native little neck reaches its largest populations in Puget Sound (364) which is reflected in the numerous literature review reports (A). The only Washington area not having this species is the open coast (A). Coastal bays (Grays Harbor and Willapa Bay) have this species (M), apparently in less abundance than the inside waters.

In the San Juan Island survey (F), the native little neck was found to be the most abundant bivalve (in biomass) in the plus two-foot level in the protected gravel community. This species was by far the most abundant and widely distributed pelecypod at Kiket Island (205). The native little neck is first in abundance in protected situations, at least in the lower reaches of the intertidal (B). In Hood Canal, this clam was one of the most common species found -- present at 64 percent of the stations sampled (364).

In Grays Harbor this species is on the 1974-1975 species list, but not discussed in detail, apparently not in great abundance in the Harbor (G). This bivalve was located in Oyhut Channel (M). In Willapa Bay the native little neck, like the Japanese little neck (I-26) is present (M) and could be increased in abundance with a thin layer of gravel on existing mud flats (H).

No reports were located for the lower Columbia River estuary and mouth where this species may occur.

HABITAT REQUIREMENTS - The native little neck is often found with butter clams (I-21) (364) at the zero tide level or below. At Kiket Island native little neck were in peak abundance at plus two feet (205). The introduced Japanese little neck (I-26) is usually higher on the gravel beach -- plus two or three feet, to the plus six or seven feet tide level (C) or the middle intertidal (205).

Native little neck clams in Hood Canal prefer a slightly firmer substrate, generally higher in the intertidal zone, as compared to butter clams (364). In Hood Canal, 90 percent of this species taken was from -1 foot to +3 feet mean lower low water (364).

The typical location is in protected areas (B). The preferred substrate at Kiket Island was silty mixed gravel, coarse sand and shell, frequently with considerable cobble present (205). All substrates except solid rock are noted for native little neck in the literature review (A). By far, the gravelly beach is the typical substrate of the native little neck (A).

Subtidal distribution of the native little neck is to seven or eight fathoms (488), but generally less, two to five fathoms (624).

Depths located in the substrate, usually about three inches below the surface (776), less than eight inches (364).

Laboratory studies on the veliger (larval) stage indicates an optimum temperature is 10 to 15 C -- a narrow range of tolerance (424). The same studies (424) report an optimum salinity range of 27 to 32 ppt -- a narrow range of tolerance.

CRITICAL HABITAT AREAS - The native little neck in inside waters of Washington seems abundant in many locations with no specific areas standing out from the rest. This species is absent on the open coast and apparently in lower numbers (as compared to some inside areas) in Grays Harbor and Willapa Bay. No areas are designated critical for the native little neck clam.

DATA GAPS - See butter clam (I-21).

REFERENCES - A, B, C, F, G, H, M, 205, 364, 424, 488, 624, 625, 761, 776.

FACT SHEET

I-30 OCTOPUS

Octopus hongkongensis[1]

LIFE HISTORY - The literature review (A) does not make a solid distinction between this species and *O. dofleini* (I-31) in most distribution and life history information. The most recent report on Washington octopus (P) indicates that the species *honkongensis* is a species that matures at a smaller size but apparently is not known to inhabit Washington waters. The two species known in Washington waters are *O. dofleini* (I-31) and the smaller *O. rubescens* (P). Kotzloff (B) indicates that *O. dofleini* (I-31) and another species, "evidently still not named" that is taken occasionally in the intertidal as well as subtidal are the Washington octopus species.

The actual specific name of the second species (to *O. dofleini*) is somewhat academic because the information base in the literature review (A) is not specific for *O. hongkongensis*. This species should probably be referred to as *O. rubescens* after one source (P).

See *O. dofleini* (I-31) for details that may apply to this second "smaller species of octopus" in Washington waters.

REFERENCES - A, B, P.

---

[1]The octopus referred to by this name may be the species *O. rubescens*.

FACT SHEET

I-31 OCTOPUS

Octopus dofleini[1]

LIFE HISTORY - This species of octopus is the large octopus that is much sought after by sport divers and commercial fisheries, and reaches a weight of about 100 pounds (B). The second species of octopus, *O. rubescens* (P) is smaller and is apparently little understood in Washington waters (see I-30). The literature review (A) has octopus information, but little is species specific. The majority of the information that follows (except as otherwise noted) is from a single WDF source (P) which should be consulted by readers seeking more information than the overview presented here. Most of the *O. dofleini* information is for this species in Japan, not in Washington.

The life span of this octopus is imperfectly known - three to five years (140). The female dies in captivity after spawning and brooding the eggs, possibly until they hatch. Age of maturity is expected to start at about one and one-half to two years. Fecundity is 30,000 to 100,000 eggs, but apparently only about two-thirds of these are laid. Breeding occurs long before the female is fully mature. Peak breeding in Japan is from October through December, and breeding individuals are seen in April. Reproducing adults were present in the San Juan Archipelago in April and May (455). The viable sperm is held by the female and fertilization occurs

[1] A more specific scientific name is *O. d. var. martini.*

internally when the eggs are laid. The eggs are oval shaped with a filament end, and are laid in string-like bunches attached to the bottom. The female ceases hunting and basically starves to death brooding the eggs - moving water over them and protecting them. Apparently the females die before the eggs finally hatch. Incubation times were not reported and probably are a function of water temperature.

The larvae hatching from the egg are about 7 mm long by 3 mm wide and are heavier than water, having to expel water to keep from sinking (in the laboratory). Planktonic larvae were taken as long as 14 mm. The age and size at settling to the bottom is not know. April is the apparent peak month of hatching off the Queen Charlotte Islands. The larvae are vertically distributed offshore, with most near the surface and fewest at about 500 fms, with most above 55 fms (140).

The early benthic stage is not understood, and not until the octopus are 1 Kg (2.2 lbs.) or greater are they recovered in the Japanese fishery. These immatures would live to about one and one-half to two years of age, and begin to mature and repeat the cycle. Growth is rapid in this species.

Migrations of immatures are known in Japan with the population in deep water from February through April and from August through October, and in shallow water from May through July and November through January. Movements with season are reported in Puget Sound with South Sound octopus in the winter in shallow waters (less than 50 feet) and in the springtime they move to 100 feet or greater water. Octopus are mostly active at night (B) and are nocturnal feeders (1003).

Octopus feed largely on crabs (B, C), fish and clams (C). They apparently will eat just about any animal they can catch. Shrimp, sea cucumber, sea squirt, starfish, squid, and other octopus are other foods mentioned in the WDF report (P).

WASHINGTON DISTRIBUTION - The literature review (A) has only one report specific for *O. dofleini* - that is for the presence in the San Juan Archipelago (455). The remaining reports are probably also for this species and include all inside areas and the open coast.

Grays Harbor (G) and Willapa Bay (H) reports do not mention octopus. These areas may lack the rough rocky substrate and kelp beds useful for hiding in daylight hours.

The open coast had the greatest pounds of octopus landed, followed by the Strait of Juan de Fuca (A). Presumably all or most of these landings are made up of this species.

HABITAT REQUIREMENTS - The octopus has a requirement for a hiding area in a sheltered place during daylight hours (C). They are usually not seen by people on beaches (C) apparently being bottom oriented as adults in rocky rough shore areas that provide caves, crevices, and other hiding areas. One reference is made to a solid rock substrate in the literature review (A).

This octopus is reported from the high, middle, and low intertidal, as well as subtidal (A), but they primarily frequent the subtidal and pools in the lowest point of the intertidal (B). Seasonal movements to shallower waters (less than 50 feet) in the winter as compared to waters 100 feet or more deep in the springtime and into the summer.

One salinity range of 27.6 to 31.2 ppt was reported where octopus were present in Port Angeles Harbor (811).

CRITICAL HABITAT AREAS - Too little life history information for Washington and species specific distributional information exists to determine critical areas. From commercial landings, the open coast (and offshore waters?) is the greatest commercial octopus producing area, followed by the Strait of Juan de Fuca. No specific areas stand out from the rest to label any areas as critical for this octopus species.

DATA GAPS - If the information reviewed is representative for Washington, little is known about this species, its habitats, and its distribution in inside waters and the open coast. Trapping and scuba surveys in rough rocky kelp areas would need to be initiated in many areas to locate the species, follow their food habitats, and by tagging, follow their movements and growth, and observe their reproductive behavior. The Strait of Juan de Fuca and north coast of Washington would seem the logical places to begin, then moving to other inside rocky areas in the San Juan Archipelago, Whidbey Basin, Central and South Sound. Studies should focus in April-May, initially define the reproductive activities of this species.

REFERENCES - A, B, C, G, H, P, 140, 455, 811, 1003.

FACT SHEET

I-32 RED ABALONE

Haliotis rufescens

LIFE HISTORY - The red abalone was introduced from California in 1958 - 300 animals to the Strait of Juan de Fuca (474). No Washington life history was located for this species. See Northern abalone (I-33).

Movement as an adult is not expected to be extensive. Travel by planktonic stages could occur and be extensive, depending on currents and time in the planktonic stage.

The red abalone is an important herbivore that eats algae - *Macrocystis pyrifera* (sprophylli and holdfast) and *Nereocystis luetkeana* (38, 71, 474). In California, this abalone competes with sea urchins for food (474).

WASHINGTON DISTRIBUTION - The red abalone is reported from the Strait of Juan de Fuca, San Juan Archipelago, and Whidbey Basin (A). Only the Strait of Juan de Fuca has commercial landing for general abalone - not necessarily the red abalone (348). The other areas have red abalone as "present, few, and scattered" (A). The red abalone appears to be a struggling, introduced species that has not been very successful in Washington waters.

HABITAT REQUIREMENTS - The red abalone is a bottom associated invertebrate as a juvenile and adult, being located on solid rock and pebble-gravel bottoms (A).

This species is usually found from the high intertidal to the deeper subtidal (90 fms) with maximum abundance at 3 to 6 fms in the shallow subtidal in California (474).

The red abalone is usually found under active surf, with the young hiding under rocks or in cracks and crevices in the rocks (California) (474).

CRITICAL HABITAT AREAS - The red abalone seems to be in low numbers and scattered in Washington waters, after being introduced in 1958. This species does not seem to find much of Washington inhabitable, and appears to be a struggling introduction. With limited species specific information on life history and Washington distribution, no critical areas were located for this species. A species like this may have no real critical habitat areas in Washington.

DATA GAPS - The numbers of red abalone in Washington waters appears to be small, so research, specifically on this species, does not appear justified. A larger question exists as to whether this is a "significant" Washington invertebrate.

REFERENCES - A, 38, 71, 348, 474.

FACT SHEET

I-33 NORTHERN ABALONE

Haliotis kamtschatkana

LIFE HISTORY - The northern abalone is a native species in Washington waters. Little life history information was located. Another common name is the pinto abalone (474).

The northern abalone is a slow growing species, taking six years to reach 63 mm across the short diameter of the shell - legal size (554). No life span was located for Washington. Sexual differentiation occurs at 25 mm and sexual maturity occurs at three years of age (554). If like other marine gastropods, a large number of eggs are produced that develop into a veliger (free-swimming) larval form before metamorphosing to the adult form (E). In about three years, the juveniles would mature to repeat the cycle.

Movements of adults are thought to be very limited. Larval stages that are planktonic may move extensive distances, depending on currents and the time spent in the larvial stage.

This species is a herbivoic eating brown algae and "small surface algae" (474, 283, 1007).

WASHINGTON DISTRIBUTION - The northern abalone is limited in its local distribution to the Straits of Juan de Fuca and Georgia, San Juan Archipelago, Hood Canal, and Whidbey Basin (A). The northern open coast of

Washington probably also has this species, because it is on the west coast of Vancouver Island and ranges south to California (762, 312). The quantities landed commercially is sporadic, but greater for the total Strait of Juan de Fuca area (Straits, San Juan Archipelago, North Sound, and Hood Canal) (348).

HABITAT REQUIREMENTS - The northern abalone is sometimes found intertidally, but it becomes more abundant in the subtidal (B). The preferred habitat is from extreme low tide to subtidal kelp bed areas (100 feet in rocky areas, 483, 1007). This species prefers areas of swift current and constant temperatures (283, 483) and is usually found where there are boulders separated by clean gravel (483). The adult form is bottom associated, primarily in the subtidal on bottoms of solid rock, shell fragments, mixed: coarse and pebble-gravel(A).

The larval stage is free swimming and occupies to pelagic open water habitat.

"Constant temperatures" (283) could be inferred to be colder waters of constant temperatures.

CRITICAL HABITAT AREAS - Subtidal rocky bottom areas with kelp beds (and other macro algae) are the primary habitat. The main area for the northern abalone is not accurately specified by the literature reviews (A) general comments. Until specific areas are surveyed, no critical areas can be designated for northern abalone.

DATA GAPS - The Washington biology and distribution needs to be studied before much can be said about northern abalone. Quarterly surveys in any known areas of abundance would indicate spawning periods and related behavior. Laboratory studies at field temperature/salinity levels would compliment these field studies.

Distributional information could be assessed by scuba divers using large quadrat or transect line systems of census that would be quantitative, duplicatable, and accurate between different survey areas. With distributional information and more Washington life history critical areas may become apparent.

REFERENCES - A, B, E, 283, 321, 348, 474, 483, 554, 762, 1007.

FACT SHEET

I-34 GEODUCK

Panopea generosa

LIFE HISTORY - The common name of this species is also spelled gweduc. The geoduck is the largest clam in Washington waters, exceeding the horse clam (I-23) and gaper clam (I-24). Reputable reports exist of geoducks as large as eleven pounds (C), twelve pounds (780) and twenty pounds (B). A commonly attained weight is six pounds with a nine inch shell length (780).

Life span is long, at least to ten years, (410) and probably longer. Sexes are separate (418). First spawning for males is at three years, for females at four years (99). Females develop sexually through the late fall and winter to spawn in spring and early summer (418). Males are found in many stages of sexual development at any time of the year (418). In the laboratory, spawning can be induced at 12 to 14 C (531), at 9 to 12 C (780). Eggs and sperm are released to the water where fertilization occurs. Eggs are seen in April to June in Pacific Northwest waters (104). Eggs develop into a pelagic veliger (larval) stage which lasts about one month (99). Veliger have been observed in Hood Canal from March through August. The veliger larval metamorphoses to the bottom-associated spat and have been observed in all months in Hood Canal (99). In three to four years the juvenile matures to repeat the cycle.

Migrations are implied with young in shallower water and at shallower substrate depths than larger clams (780). The method of movement is not described, but it is presumed to be a slow process. The geoduck also moves to some extent during the month-long planktonic larval atage.

Foods of this filter feeding clam are *Phaeodactylum tricornutium* and *Monocrisis lutheri* (larvae) (104).

WASHINGTON DISTRIBUTION - Washington is near the center of the geoduck's range and this species is very abundant in Puget Sound (364). The literature review (A) reports the geoduckin all inside water areas in Washington with no reports for the open coast and coastal bays. The reports indicate geoducks are scarce for North Sound (A), and in only one area in the San Juan Archipelago - Leo Reef (A). The Strait of Juan de Fuca, Whidbey Basin, Admiralty Inlet, Puget Sound Basin, South Puget Sound, and Hood Canal all have numerous geoduck reports, with the last three areas having the majority of these reports. Extensive subtidal beds are reported in Hood Canal (364).

The geoduck does not apparently exist on the open coast (salinities too high, no suitable substrate), or in coastal bays - Grays Harbor (G) and Willapa Bay (H). No reports were located for the Columbia River estuary or mouth.

HABITAT REQUIREMENTS - The geoduck is primarly a subtidal species (364) being scarce in the intertidal area (B). Commercial geoduck harvesting is in the shallow subtidal (4 to 8 fms) (780). The geoduckis found on sand or sand-gravel beaches with horse and gaper clams (I-23, I-24), but deeper in a suitable beach - three feet versus two feet for *Tresus* (C). The geoducklives in sandy mud of bays, sloughs, and estuaries (1005). This species perfers sand and

mud substrates (780). The literature review (A) reports the following bottom types: sand, pebble-gravel, boulder, mixed: fine, shell fragments, mixed: medium, silt, and mixed: coarse.

The geoduck is located in the substrate at depths related to the clam's size (larger clams are deeper in substrate) (410). They are normally two to three feet (104) to four feet or more (104), to five feet (C).

The geoduck is located from the low intertidal to the deeper subtidal (30 fms) (99). In Hood Canal, geoducks were found at +1 or 2 feet mean lower low water, although they are essentially subtidal (364). In this area they are also reported in sand-eelgrass and sand-gravel-eelgrass at depth of -2 to -3 feet (364).

Water temperatures of 20 C are lethal (780), while 9 to 12 C (780), 12 to 14 C (531) induce spawning. Eggs were located in waters 8.5 to 16 C (104). Optimum temperatures for the veliger larvae was 6 to 16 C (531). Spat were located in Hood Canal at temperatures ranging from 0 to 25 C (99).

The geoduck is an estuarine species and cannot tolerate salinities over 25 ppt (531). The eggs of geoducks were held in the laboratory at 27.5 to 32.5 ppt (104). The optimum salinity for the veliger larvae was 27.5 to 32.5 ppt (531). Spat were located in Hood Canal in the salinity range of 5 to 30 ppt (99).

CRITICAL HABITAT AREAS - The geoduck is located in high numbers in numerous areas in inside waters of Washington (A). No areas stand out from the others in these inside waters. No critical ares are designated for geoduck.

DATA GAP - The geoduck is numerous in inside water in many locations. A good deal of information seems to exist on the distribution of the geoduck.

REFERENCES - A, B, C, G, H, 99, 104, 364, 410, 418, 531, 780, 1005.

FACT SHEET

I-35 PACIFIC PINK SCALLOP

Chlamys hastata hericia

LIFE HISTORY - Little information was located for the Pacific pink scallop. All of the literature review (A) information is for adults. This species of scallop may have a life history similar to the sea scallop (I-36).

Movement occurs in short bursts in the adults, as an escape mechanism from certain predators - like sea stars (B). Movement is accomplished by clapping its valves together repeatedly (B) and forcing water out through the mantle (1008).

Foods of this filter-feeder were not reported (A).

WASHINGTON DISTRIBUTION - Few reports exist in the literature review (A) for the Pacific pink scallop. One source (B) indicates they are rather frequently seen in intertidal areas and floats in Puget Sound and the San Juan Archipelago, relative to other species of scallops. This species is reported "abundant" in only one general area - channels in the San Juan Archipelago (A). Lesser quantities are reported in the Strait of Juan de Fuca, North Sound, Whidbey Basin, Puget Sound Basin, and South Sound (A).

No reports were located for the open coast where they might be expected.

HABITAT REQUIREMENTS - The Pacific pink scallop is located from the low intertidal to depths of 100 fms (1007). The bottom preferred is in deeper waters in which gravel and shells predominate (B). The literature review (A) reports

bottom-associations with mixed: very coarse, solid rock, sand, sand: very fine, and shell fragments type substrates. Substrates used may change with age. Adults are free-swimming, while juveniles are often found attached (1007).

This scallop would presumably be in the open water habitat totally during a planktonic larval stage, but the bulk of its life is spent in a close association with the bottom.

Adults (*Chlamys* sp.) were located in waters 8.5 and 12 C (407).

CRITICAL HABITAT AREAS - Too little life history and distributional information exists for the Pacific pink scallop. No critical areas were located.

DATA GAPS - The life history and distribution needs more study in Washington waters if the information reviewed is representative. Quarterly trawling of known scallop areas would provide information on age of maturity, spawning season, and growth rates in Washington waters. Laboratory studies at field temperatures and salinities would complement these field observations. Low intertidal area surveys and scuba observations would also provide distributional information.

Surveys should also be completed in unsurveyed areas of suitable bottom types. Before this can be completed previous catch time and locations should be summarized to define areas to begin distributionsal surveys.

REFERENCES - A, B, 407, 1007, 1008.

FACT SHEET

I-36 SEA SCALLOP

Pecten caurinus

LIFE HISTORY - Other common names for this species include weather vane scallop and giant Pacific scallop (A). This is the large scallop in this area - up to 15 cm in diameter (B). No life history information was in the literature review (A).

Life span was not located. Scallops get at least 18 years old in Alaska (D). Sexes are separate (D). Spawning in Alaska was in June and July, and one annual spawning is thought to occur (D). Temperature is thought to trigger spawning (D). If age and annual shell rings correspond, most scallops (Alaska) sexually mature at age three and all are mature at age four (D). More southerly waters (Washington) may have sea scallops maturing at an earlier age. The size of sexually mature sea scallops in Alaska was 100 mm (shell height) (D). Presumably, eggs and sperm are released to the water where fertilization occurs and a planktonic larvae exists for a short period of time before metamorphosis to spat, which settle to begin the bottom-associated adult existence. If like the Pacific pink scallop (I-35) the juvenile is attached, while the adult is free-swimming.

Movements are expected similar to the Pacific pink scallop (I-35).

No foods were reported for this filter-feeding bivalve (A).

WASHINGTON DISTRIBUTION - Few reports exist for this species in Washington waters (A). No "abundant" reports are in the review (A). Reports of presence exist for the open coast (Breakers, Washington), Strait of Juan de Fuca, Skagit Island (scarce), Port Townsend, and Greater Puget Sound.

Sea scallops are probably scattered in the deeper inside and outside waters (10 to 90 fms).

HABITAT REQUIREMENTS - The sea scallop is a subtidal species never found intertidally (B). They are located in deep water beds (32 to 48 fms) off Northern California (1005). Bottom types associated with include mixed: fine, clay, silt, and sand (A).

In Alaska, sea scallops are most abundant between 30 and 70 fms (D). This species is reported from 3 to 90 fms (1007, 758). These deep water areas would imply requirements for stable and colder water temperatures and stable and higher salinities.

CRITICAL HABITAT AREAS - The sea scallop has insufficient life history and distributional information to name any areas critical in Washington waters. This species appears scattered in inside and outside waters where water depths and suitable substrate conditions exist. No critical areas are designated for this species.

DATA GAPS - See Pacific pink scallop (I-35). Trawling on suitable bottom in 10 to 90 fms would be the way to initiate surveys once historical catch records are summarized for this species.

REFERENCES - A, B, D, 758, 1005, 1007.

FACT SHEET

I-37 ROCK SCALLOP

Hinnites giganteus

LIFE HISTORY - Another common name for this species is the purple hinged scallop (A). This scallop is unique from the other scallops by being firmly attached to rocks by its right valve (B). All of the literature review (A) for this species is the adult distribution. See sea scallop (I-36) for a general scallop life history.

Unlike the other scallops, the rock scallop juvenile is "free-swimming" while the adult is attached. Some movement occurs in the juvenile phase but it is not extensive. The planktonic larval stage would also allow for some rock scallop movement.

Food of this filter-feeding bivalve was not located (A).

WASHINGTON DISTRIBUTION - Limited information exists on this species' distribution in Washington (A). The literature review (A) reports this species in "heavy" quantities in the San Juan Archipelago and in moderate abundance in Hood Canal. The open coast, Strait of Juan de Fuca (not abundant intertidally),Strait of Georgia, and the greater Puget Sound, have the rock scallop as present (A). Few or scattered is reported for North Puget Sound and Whidbey Basin. Open coast rock scallops would primarily be in the north (rocky) coastal area where an intertidal and shallow subtidal rock substrate exists.

HABITAT REQUIREMENTS - The bottom association habitat for all rock scallop reports is solid rock (A). The rock scallop is found from the intertidal to depths of 16 fathoms (1007), 20 fathoms (758), and 25 fathoms (955). Middle and low intertidal areas are reported for this species (A).

The juvenile is free-swimming but bottom associated and the adult is attached to rocks or other stationary objects after it reaches a shell size of a little over one inch in length (1007, 1005). Presumably, a short free-swimming plankton stage exists for this scallop as for other bivalves.

No temperature/salinity tolerance information was located. As compared to the sea scallop (I-36), one would assume that the rock scallop is more tolerant of higher, less stable temperatures and lower, less stable salinities.

CRITICAL HABITAT AREAS - Too little Washington life history and distributional information exists for the rock scallop to define critical areas. No such areas are designated.

DATA GAPS - See Pacific pink scallop (I-35). Intertidal surveys should also be completed.

REFERENCES - A, B, 758, 955, 1005, 1007

FACT SHEET

I-38 HINDS' SCALLOP

Chlamys rubida

LIFE HISTORY - The Hinds' scallop also has no life history information in the literature review (A). See sea scallop (I-36) for general life history details which may apply to this species.

Movement is probably as described for Pacific pink scallop (I-35) and sea scallop (I-36).

Foods of this filter feeder are not reported in the literature review (A). Presumably suspended organic material (plankton and possibly detritus) are utilized as food.

WASHINGTON DISTRIBUTION - Little information exists in the literature review (A) for the Hinds' scallop. Nearly all the references are for *Chlamys sp.* The Hinds' scallop is listed as common in "Pacific Northwest waters" (312) and present in "greater" Puget Sound (955, 1008). If like the generalization for *Chlamys* - primarily animals of deeper waters (B), this species should also be in North Sound, Strait of Juan de Fuca and the north open coast.

HABITAT REQUIREMENTS - *Chlamys* are primarily animals of deeper waters and tend to concentrate on gravel and shell substrates (B). Substrates for *Chlamys sp.* include fine sand, very fine sand, shell fragments and mixed very coarse (A). This species also occurs in eelgrass beds (1008).

The Hinds' scallop is not located in the intertidal. This species occupies the subtidal from 10 to 60 fathoms (758), 5 to 50 fathoms (1007).

This scallop is bottom-associated in the open water habitat all of its life except when "swimming" from predators (1008) and when a presumed larval stage is pelagic for a short period of time.

Temperatures at *Chlamys sp.* locations of 8.5 C and 12 C are reported (407).

CRITICAL HABITAT AREAS - Too little Washington life history and distribution information exists to define any areas as critical. No such areas are designated for Hinds' scallop.

DATA GAPS - See Pacific pink scallop (I-35).

REFERENCES - A, B, 312, 407, 758, 955, 1007, 1008.

FACT SHEET

I-39 PACIFIC COAST SQUID

Loligo opalescens

LIFE HISTORY - The Pacific Coast squid is a warmer water species whose northern limit is southern British Columbia (259). Life span is three years (259, 552). Sexes are separate. Spawning occurs in shallower waters of sheltered bays that have sloping sand and mud bottoms (259). Mating occurs at night in late summer when large schools form near the bottom (552) at depths of 1.5 to 22 fathoms (259). Spawning occurs only once in its life span indicating maturity is generally at three years. The females are internally fertilized and eggs are layed in capsules (300 eggs/each) that are attached to the bottom (552). As many as 20 capsules may be attached per night (552).

Eggs were present on the open coast in July and August (259). There is no larval stage (E). The eggs hatch in 19 to 25 days (259) as miniature adults able to swim and feed at once (E). In about three years the squid matures to repeat the cycle. The greatest numbers caught are two-year olds (Al Lasater, WDF, personal communication).

Movements are not well understood. There are seasonal migrations (359) like the movement to shallower waters to mate and spawn in the summer.

Foods of this squid species is given as 75 percent other squid and 25 percent crustaceans, while at other times the diet can be 75 percent

fish and 25 percent crustaceans (552). Euphausiids, mysids, polychaetes are other foods (259, 379).

WASHINGTON DISTRIBUTION - The Pacific Coast squid is reported in all inside and outside water areas of Washington (A). This species is the "dominant inshore squid" on the open coast (259). This species is listed as "abundant" in Whidbey Basin, Saratoga Passage, Holmes Harbor, Southern Puget Sound (South Tacoma Narrows, Carr Inlet, Case Inlet, Budd Inlet, Oakland Bay, and Dalco Passage) (A).

Reports from the open coast do not name Willapa Harbor and Grays Harbor (H, G, A) but they would be expected to come into the bays in the summer months to mate and spawn. No reports were located for this squid species near the Columbia River mouth.

HABITAT REQUIREMENTS - The Pacific Ocean squid is a pelagic/bottom-oriented species (A). This species occupies the open water habitat nearly all its life except for the 19 to 25 days when they are in egg capsules attached to the bottom. Bottom types are sloping sand and mud areas in shallow sheltered bays (259) in the summer months.

Temperature appears to be a limiting factor on this squid species (northern limit is southern British Columbia). There are indications that while squid are always present in Washington waters, they are less noticed in average summer temperature years when they are in low numbers, but when two or three years (last occurrence: 1957-1959) of a warmer summer occur, the squid species populations expand to very noticeable numbers (Al Lasater, WDF, personal communication).

The salinity range tolerated by the squid must be fairly great if oceanic (high) salinities are occupied as well as shallow summer bay areas.

CRITICAL HABITAT AREAS - Critical habitat areas would seem to be the sheltered shallow bays utilized for mating and egg capsule laying. Unfortunately, the data reviewed is not specific as to actual locations and densities of adults or possibly the egg capsules themselves. This movement to shallower waters would greatly concentrate these squid and this would appear a critical stage in their life cycle requiring concern and protection if necessary. The sporadic nature of abundant squid in Washington waters may be a function of summer water temperatures and not a controllable parameter by man. No critical areas are designated for Pacific Ocean squid.

DATA GAPS - The large data gap is in the specific location of these mating and egg capsule laying squid. Summer surveys of shallow and sloping sand and mud bottom bays in warmer water years would provide this information. SCUBA observation may be feasible. Trawling with shallow water otter or beam trawls would also capture this species. Shallow water purse seining might be a quantitative method of squid assessment over selected bottom areas.

Sampled squid should be measured, sexed and state of maturity assessed to better understand the relationship of area and water temperature to the biology of this squid species.

REFERENCES - A, E, G, H, 259, 359, 379, 552.

INVERTEBRATE REFERENCES

A. Beak Consultants, Inc., 1975, Biological Oil Impact Literature Review, Volumes I (191 00) and II (464 pp), nine computer printout appendices (3,018 pp). Prepared for Washington Department of Ecology, October.

B. Kozloff, E. N., 1976. Seashore Life of Puget Sound, Strait of Georgia and the San Juan Archipelago. University of Washington Press. Third Printing, 282 pp.

C. Smith, L., 1962. Common Seashore Life of the Pacific Northwest. Naturegraph Company, 66 pp.

D. Rosenberg, D. H., 1972. A Review of the Oceanography and Renewable Resources of the Northern Gulf of Alaska. University of Alaska. IMS Report R72-23, 690 pp.

E. Storer, T. I., and R. L. Usinger, 1957. General Zoology. McGraw-Hill, 664 pp.

F. Nyblade, C. F., 1975. Baseline Study-Final Report - Contract 75-014. For Washington Department of Ecology. University of Washington, Friday Harbor Laboratories. 260 pp.

G. Smith, J. L., R. Albright, and A. D. Rammer, 1976. The Effect of Intertidal Dredged Material Disposal on Benthic Invertebrates in Grays Harbor, Washington In: Appendix E of Maintenance and Dredging and the Environment of Grays Harbor, Washington. Prepared for the Army Corps of Engineers by DOE and contractors.(Preliminary Draft.)

H. U.S. Fish and Wildlife Service, 1970. Fish and Wildlife of Willapa Bay, Washington. Portland, Oregon. 33 pp.

I. U.S. Army Corps of Engineers. FEIS Willapa River and Harbor Navigation Project - Washington. January, 1976.

J. Mottet, M. G.,1976. The Fishery Biology and Market Preparation of Sea Cucumbers. Draft Technical Report for Washington Department of Fisheries. 65 pp.

K. Mottet, M. G., 1976. The Fishery Biology of Sea Urchins in the Family *Strongylocentrotidae*. Technical Report No. 19 for Washington of Fisheries. 94 pp.

L. English, T. S., 1976. Baseline Study - Final Report - Contract 75-008 to Washington Department of Ecology. University of Washington, Department of Oceanography. 408 pp.

M. Smith, S. and R. B. Herrmann, 1972. Clam Distribution and Abundances in Willapa Bay and Grays Harbor as Related to Environmental Conditions. Summary Report. Weyerhaeuser Company, Longview. 53 pp.

N. Tegelberg, H. and R. Arthur, 1976. Distribution of Dungeness Crabs (*Cancer magister*) in Grays Harbor and Some Effects of Channel Maintenance Dredging. In: Appendix N of Maintenance Dredging and the Environment of Grays Harbor, Washington. Prepared for the Army Corps of Engineers by DOE and Contractors. (Preliminary Draft)

O. Isakson, J. S., 1969. Total Phosphorus, and Phosphorus -32 in Seawater, Invertebrates and Algae from North Head, Washington, 1965-1966. MS Thesis, University of Washington. 63 pp.

P. Mottet, M. G., 1975. The Fishery Biology of *Octopus dofleini* (Wülker). Washington Department of Fisheries, Technical Report 16. 39 pp.

Q. Kozloff, E. N., 1974. Keys to the Marine Invertebrates of Puget Sound, the San Juan Archipelago, and Adjacent Regions. University of Washington Press, Seattle, 226 pp.

R. Cahn, A. R., 1951. Clam Culture in Japan. Natural Resources Section of General Headquarters, Supreme Commander for the Allied Forces. Report No. 146. September.

A new report was received as this study was being completed. Although not used in the study, the author felt this source should be referenced for the user's benefit:

Armstrong, John W., Craig P. Staude, Ronald M. Thom and Kenneth K. Chew, 1976.

(Habitats and Relative Abundances of the Intertidal Macrofauna at Five Puget Sound Beaches in the Seattle, Washington, Area)

Interim Report to METRO under Contract #63-1535 from the University of Washington, College of Fisheries.

INVERTEBRATE LITERATURE REVIEW REFERENCES

(See Biological Oil Impact Literature Review, Vol. II)

Source No.	Author(s) Date
13	Fauchald, K., 1971
14	Straugh, D., 1971
21	McCauley, James E. and Danil R. Hancock, 1971
29	Paine, Robert T. and Robert L. Vadas, 1969
33	Dayton, Paul Kuykendall III, 1970
38	North, W. J., M. Newschul, Jr. and K. A. Clendenning, 1964
64	Puget Sound Task Force of the Pacific Northwest River Basins Commission, Fish and Wildlife Technical Committee, 1970
71	Phillips, Ronald D., 1974
94	Holland, David A., 1972
99	Anderson, Aven M., 1971
104	Goodwin, C. Lynn , 1973
106	Tegelberg, H., 1964
113	Shimek, Roy, 1971
120	Woodin, Sally and Bill Nilsom, 1970
121	McPherson, B. J., 1970
126	Nyblade, Carl, 1974
140	Green, Madelon, G., 1973
141	Fox, William W., 1972
199	Dow, David, 1967
205	Houghton, Jonathan P., 1973
208	Mayer, David L., 1973.

Source No.	Author(s) Date
214	Berkeley, A. A., 1929
218	Deschamps, G. and S. G. Wright, 1971
229	Resech, Robert, 1965
259	Trumble, Robert J., 1973
268	Birkeland, C, et. al., 1968
270	Dayton, Paul Kuykendall III, 1970
276	Lambert, Gretchen, 1967
283	Nash, Ed, 1971
293	Towler, E. D., 1930
297	Robinson, J. G., 1971
312	Abbot, R. Tucker, 1954
328	Berkeley, Alfreda A., 1930
332	Butler, T. H., 1964
333	Butler, T. H., 1970
347	Dahlstrom, W. A., 1970
348	Department of Fisheries of Canada
351	Jackson, George A., 1970
353	Kubly, Dennis, 1971
354	Palmisano, John F., 1970
357	Stains, Howard J., 1953
359	University of Washington, 1972
364	Yoshinaka, Marvin S. and Nancy J. Ellifrit, 1974
379	Fields, W. Gordon, 1965
407	Lie, Ulf, 1968
410	Anderson, A. M., 1971

Source No.	Author(s) Date
413	Bourne, Neil, 1970
414	Bourne, Neil and D. W. Smith, 1971
415	Bourne, Neil and D. W. Smith, 1971
416	Breese, W. P. and F. D. Phibbs, 1969
418	Goodwin, C. Lynn, 1969
421	Nosho, T. Y. and K. K. Chew, 1970
422	Nosho, T. Y. and K. K. Chew, 1971
424	Phibbs, F. D., 1970
425	Sayce, C. F. and D. F. Tufts, 1969
449	Mackay, Donald C. G., 1942
454	Pearcy, William G., 1970
455	Pickford, Grace E., 1964
474	Cox, Keith W., 1962
476	Fraser, C. McLean, 1932
483	Livingston, Robert J., 1952
488	Quayle, D. B. and N. Bourne, 1972
492	Shelford, V. E. and E. D. Towler, 1925
493	Moore, Stephen F., Gary R. Chirlin, Charles J. Puccia, and Bradley P. Schrader, 1974
501	Desvoigne, David M., 1970
525	Swan, Emery F., 1952
531	Goodwin, C. Lynn, 1972
532	Herrmann, R. B., 1972
541	Bernard, R. R. and D. C. Miller, 1973
551	McDaniel, Neil G., 1973

Source No.	Author(s) Date
552	MacFarlane, S. A. and M. Yamamoto, 1974
554	Quayle, D. B., 1971
603	Goodman, Dan, 1971
610	Tegelberg, H. C. and C. D. Magoon, 1968
622	Schneider, David E. and Maurice A. Dobe, 1972
624	Goodwin, C. Lynn, 1973
625	Dube, Maurice A., 1970
626	Widdowson, T. B., 1965
704	Barnes, Robert D., 1963
728	Ayers, J. C., 1956
758	Bernard, F., 1967
761	Frizzell, Donald L., 1931
762	Griffith, Lela M., 1967
776	Battelle Pacific Northwest Laboratories, 1973
780	Navy Environmental Protection Base, 1973
783	Paine, Robert T., 1974
784	Porter, Russell G., 1974
797	Andrews, Harry, 1925
798	Castenhaltz, R. W., 1967
803	Rigg, G. B. and R. C. Miller, 1949
811	Stein, J. E., J. E. Denison and G. W. Isaac, 1963
916	Pearce, Jack B., 1965. Box Crab
918	Rathbun, M. J., et. al., 1910
925	Weese, A. O. 1928

Source No.	Author(s) Date
927	Weymouth, F. W., et. al., 1925
941	Chew, Kenneth K., David Holland, John W. Wells, Daniel H. McKenzie and Colin K. Harris, 1974
955	Flora, G. J. and E. Fairbanks, 1966
958	Knudsen, Jens, 1964
959	Pearce, Jack B., 1966
962	Swan, E. F. and J. H. Finucane, 1952
974	Magoon, Charles D., 1974
981	Quale, D. B., 1955
1003	Barnes, Robert D., 1963
1004	Courtney, W. D., 1927
1005	Fitch, John E., 1953
1007	Rice, Tom, 1971
1008	Ricketts, Edward F. and Jack Calvin, 1962.