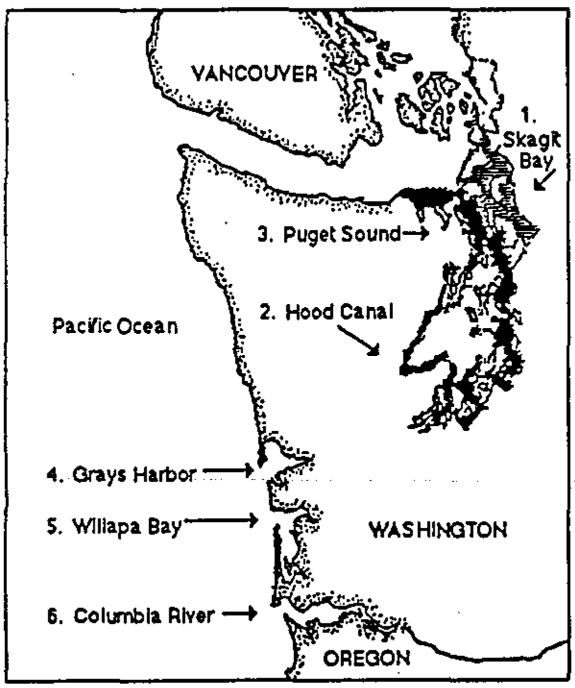
LIVING MARINE RESOURCES PROGRAM

NATIONAL ESTUARINE INVENTORY:

Estuarine Living Marine Resources Project Washington State Component

Mark E. Monaco and Robert L. Emmett

May 1988



National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Rockville, MD 20852

NOAA's National Estuarine Inventory

The *National Estuarine Inventory* (NEI) is a series of related activities of the Office of Oceanography and Marine Assessment (OMA), National Oceanic and Atmospheric Administration (NOAA) to develop a national estuarine data base and assessment capability. The NEI was initiated in June 1983 as part of NOAA's program of strategic assessments of the Nation's coastal and oceanic resources. No comprehensive inventory or data base of the Nation's estuaries could be found prior to the NEI in spite of the high value, intense use, frequent overuse, and thousands of scientific studies related to various aspects of estuaries. Without this fundamental set of information developed for the NEI, it is impossible to analyze or compare the estuaries that make up the Nation's estuarine resource base.

The cornerstone of the NEI is the *National Estuarine Inventory Data Atlas.* Volume 1, completed in November 1985, identifies 92 of the most important estuaries and subestuaries of the contiguous USA; presents information through maps and tables on physical and hydrologic characteristics of each estuary; and specifies a commonly derived spatial unit for all estuaries, the estuarine drainage area (EDA), for which data are compiled. These estuaries represent approximately 90 percent of the estuarine water surface area and 90 percent of the freshwater inflow to estuaries of the East Coast, West Coast, and Gulf of Mexico. Volume 2, Land Use, presents area estimates for seven categories and 24 subcategories of land use as well as 1970 and 1980 population estimates. Land use data are compiled for three spatial units: (1) the estuarine drainage area; (2) U.S. Geological Survey hydrologic cataloging units; and (3) counties that intersect EDAs. Population estimates are compiled for EDAs only. With these two volumes, the NEI represents the most consistent and complete set of data ever developed for the Nation's estuarine resource base.

The data base and assessment capability under development for the NEI are part of a dynamic and evolving process. Other estuaries and subestuaries have been added to the NEI from around the country. Refinements are being made to physical and hydrologic data estimated in Volume 1. Attributes such as volume and flushing rates have been added to the data base. Other NOAA projects whose data and information will be included in the NEI are: the distribution of estuarine-dependent living marine resources; characterization of estuarine shoreline modification, navigational channels, and dredged material disposal areas; the National Coastal Wetlands Data Base; the *National Shellfish Register* and related projects; the National Coastal Pollutant Discharge Inventory; and the Inventory of Outdoor Coastal Recreation Facilities.

Additional information on NOAA's *National Estuarine Inventory* is available from:

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INTRODUCTION

This report presents information compiled on the spatial and temporal distribution, relative abundance, and life history characteristics of 33 fish and invertebrate species found in six estuaries along the Washington coast. The presence or absence of each species' life history stage and the time period they utilize each estuary are identified. This is the first of a series of state and regional reports being developed from a nationwide project. When completed, the data base will contain information for approximately 120 estuarine species found in over 100 of the Nation's estuaries. The Estuarine Living Marine Resources (ELMR) project is a component of the National Ocean Service's (NOS) *Living Marine Resources Program*. The data are being organized within the framework developed by NOS's *National Estuarine Inventory* (NEI) (inside front cover). The NEI is a series of related activities to develop a national estuarine data base and assessment capability (Monaco et al. 1986). Currently, the inventory identifies 121 estuaries and embayments of the USA for which the ELMR data are being developed (Appendix I). The data are being stored and analyzed in NOAA's Living Marine Resources Computer Mapping and Analysis Systems.

The ELMR project has been underway for two years through a series of joint projects between NOAA's NOS and the National Marine Fisheries Service (NMFS). Currently, the NMFS Beaufort, NC; Galveston, TX; and the Hammond, OR laboratories are compiling the information for the southeast, Gulf of Mexico, and the West Coast regions, respectively. *The purpose of this report is to disseminate the results from the first completed component of the data base. The types of data being organized and the consistent framework developed to compile the information are illustrated.*

To date, information has been compiled and peer reviewed for 80 species found in 40 estuaries. Plans are to continue to conduct the study on a regional basis and to disseminate information through state and regional reports. Reports on the entire West Coast and the State of Florida's Gulf Coast are scheduled for completion in 1988. The nationwide data base and several analytic products are scheduled for completion within three years.

BACKGROUND

Estuaries are among our most productive natural systems (Mann 1982; Odum and Heald 1975). The physical, chemical, and biological composition of estuaries are critically important to sustaining many living resources (Healy 1982; Gunter 1967; Weinstein 1979). These important nursery areas provide food, refuge from predation, and various habitats for many aquatic species (Joseph 1973). Many of these organisms are important commercial and recreational fishes and invertebrates, such as salmonids, crabs, and shrimp. In spite of their well-documented importance to fish and invertebrate populations, very little comprehensive and consistent information exists on large numbers of species found in or among groups of estuaries. Much of the distributional and abundance information for these estuarine-dependent species primarily exists for the offshore life history stage, or the scale does not adequately address estuarine distributions (Darnell et al. 1983; SAB 1986).

Only a few sampling programs comprehensively collect organisms with the identical methods across groups of estuaries within a region. Thus, much of the data cannot be compared among estuaries due to the variability in sampling strategies. In addition, existing programs do not focus on the importance of groups of estuaries to the regional management of fishery resources. The comprehensive data that do exist are for a relatively few important commercial and recreational species.

Living Marine Resources Program. To address these problems, NOAA has developed a series of projects to make maximum use of existing data, information, and expertise to develop consistent and comprehensive information on the distribution, abundance, and biogeography of living marine resources. OAD's Living Marine Resources Program (inside back cover) is developing unique capabilities to address marine and estuarine resource use conflict issues. The data are organized into a consistent space, time, and function framework. Although the historical emphasis of the program has been offshore, the ELMR project will enable comprehensive analyses to be conducted, for the first time, from the head-of-tide to the edge of the continental shelf. Development of this capability is intended to complement the recent holistic ecosystem approach implemented by NMFS (1987) to understand and manage fish populations.

An extensive *peer review* process to review, supply, and revise species information is incorporated into all components of the *Living Marine Resources Program.* Literally hundreds of marine and estuarine scientists have been involved. Consulting with local and regional experts to obtain non-published data and gray literature available from their institutions and agencies is an essential part of the overall process. This peer review process provides an opportunity for knowledgeable individuals on specific species, estuaries, and regions to comment on and verify the data. This activity greatly improves the content, quality, and utility of the information developed.

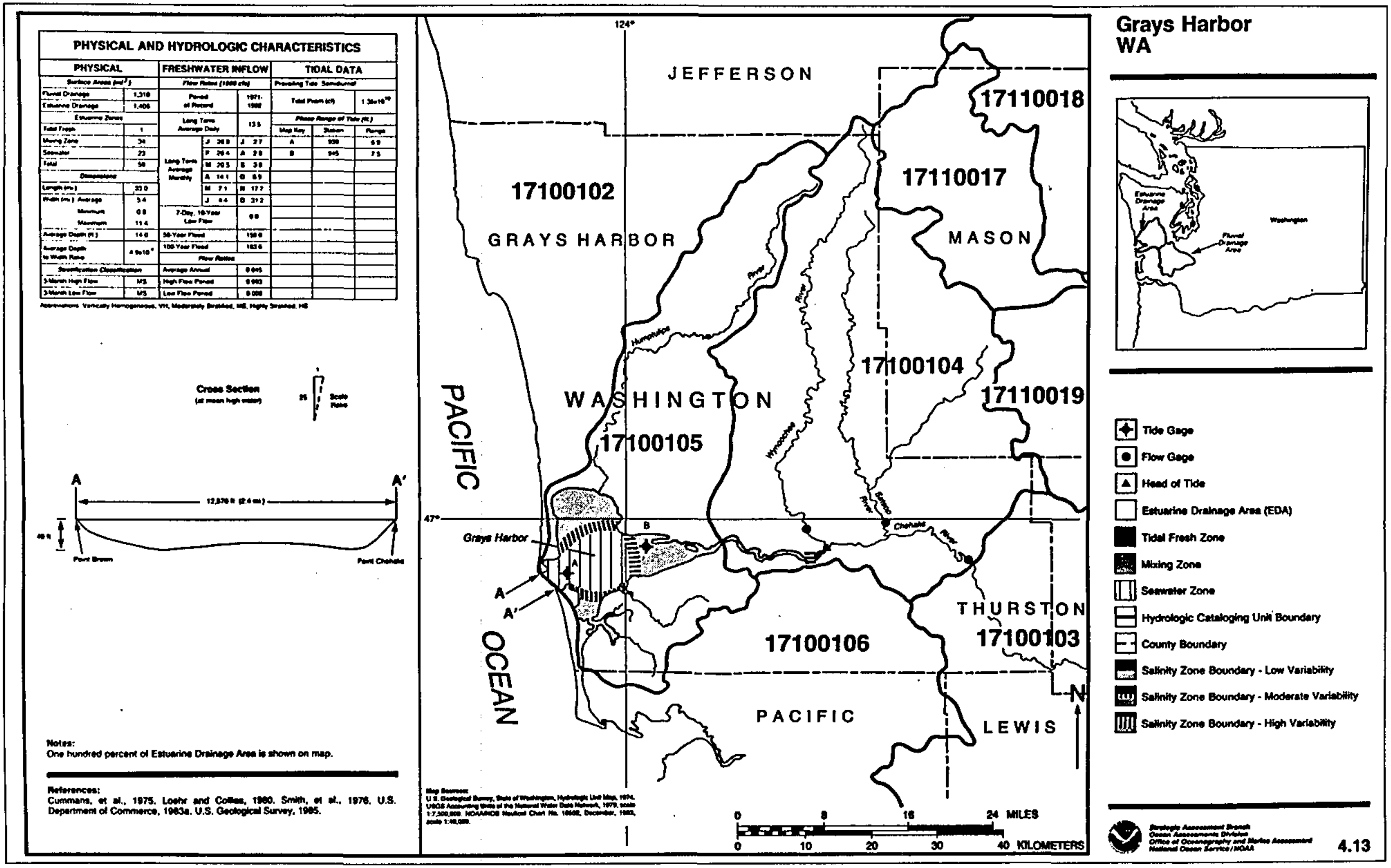
Since life stages of many species use both estuarine and marine environments, information on distribution, temporal utilization, and life history strategies needs to be combined to understand the relationships and linkages of estuaries to nearshore/offshore areas. However, little information currently exists to determine the importance of estuaries to nearshore/offshore living marine resources, except for the often quoted statistic that between 60-95 percent of commercially important species are estuarine dependent. To date, a national, comprehensive, and consistent information base does not exist on the time, space, and function of each life stage for many species found in estuarine and marine habitats. Consequently, a need exists to develop generalizations that might provide the basis for unifying the available fragments of information on marine and estuarine species and their associated habitats into a useful, comprehensive, and consistent framework. A major objective of this NOAA program is to explore the *biogeographic relationships* between species and habitats to develop an approach to link estuarine and marine living resources from a regional perspective. The ELMR project is a fundamental step toward the development of this capability.

National Estuarine Inventory. The ELMR project links the *Living Marine Resources Program* to the *National Estuarine Inventory.* The foundation of this effort is the *National Estuarine Inventory Data Atlas* and data base (SAB 1985). This volume presents information on important physical and hydrologic characteristics for 92 of the Nation's estuaries and coastal embayments. The maps and data tables developed for each estuary provide an overview of the characteristics of each estuary (Figure 1). For the ELMR project, the most important information in the atlas is the three salinity zones identified for each estuary. The tidal fresh (0.0 to 0.5 ppt), mixing (0.5 to 25.0 ppt), and seawater (25.0 and greater ppt) zones provide the spatial framework for consistently compiling and organizing information on the distribution of fishes and invertebrates in estuaries across spatial units that strongly affect species presence, absence, and distribution. Due to the diversity of projects within the NEI, other estuaries are being added to the inventory, including those of biological significance. Additional projects in the NEI include data sets being developed for each estuary on the amount and types of wetlands surrounding them, concentration and circulation characteristics of pollutant loadings, and quality of shellfish growing waters. Combining these projects with ELMR and other data sets permits unique national estuarine assessment capabilities, such as defining characteristics of important nursery areas and identifying relationships between productivity and species composition.

The Pilot Study. The first step in developing the ELMR project was to conduct a pilot study to assess data availability, to test data collection methods, and to assess the overall feasibility of the project (Monaco 1986). The pilot study provided guidance on the complexity and amount of data to compile and how best to structure the information. The pilot study was for 10 West Coast estuaries and 12 species. To maximize the effectiveness of consultations with estuarine and fisheries experts, the approach was to compile and review published information prior to "field" visits with individual experts.

Compiling consistent species data nationwide, for a region, or a state limits the amount of information and number of fishes and invertebrates possible to study. However, the results of

Figure 1. *Map Plate from the National Estuarine Inventory: Data Atlas, Volume 1, Physical and Hydrologic Characteristics*



the study indicated it was possible to develop a consistent regional data base on select species and estuaries, and that the information should be compiled by local experts. Thus, the cooperative studies between NOS and NMFS were initiated. Most importantly, due to the size and complexity of the project the pilot study indicated it would be time- and cost-prohibitive to map each species by life stage for each estuary, as is done for the offshore species in the *Living Marine Resources Program*. Therefore, the presence or absence of each species' life stage and monthly occurrence were recorded by estuary for the three habitat regimes (seawater, mixing zone, and tidal fresh zone) identified in Volume I of the NEI. Depending on the variability within an estuary (discussed below), the salinity zones shown on the NEI maps were found not to correspond necessarily to the actual habitat regime used by a species at any given time within an estuary. Nevertheless, the NEI and the three habitat regimes were found to be an appropriate framework for the study, provided the maps were used only as general guidance for developing the data. The pilot study also showed that a species' presence or absence recorded on a monthly basis captures the effects of temperature on species movements and development of life history stages. The methods developed during the pilot study have been refined and are now used by all investigators on the project.

WASHINGTON STUDY

Methods. Figure 2 summarizes the major steps taken to conduct the study. First, a species list was developed based on four general criteria. However, the underlying driving force for species selection was data availability. Many of the species selected are either commercially or recreationally important. But, when possible, species of ecological value or indicators of environmental stress were also chosen. The four criteria were:

(1) Commercial value: determined by reviewing catch and value statistics from NMFS and determining the relative commercial importance within an estuary and throughout the region.

(2) Recreational value: defined as a species that recreational fisherman specifically try to catch that may or may not be commercially important. Recreational species were determined by consulting regional fisheries experts and NMFS documents. In addition, for some estuaries, species of local recreational value that otherwise are unimportant were identified.

(3) Indicator species of environmental stress: identified from the literature, discussions with fisheries experts, and from monitoring programs such as OAD's National Status and Trends Program (OAD, 1984). These species are often mollusks or bottomfishes that consume benthic invertebrates. Their physiological disorders, morphological deformities, and bioaccumulation of contaminants, such as metals and PCBs, indicate episodes of pollution.

(4) Ecological value: based on several attributes, including trophic level, relative abundance, percentage of ecosystem biomass, and evidence of its importance as a key predator and/or prey species.

Table 1 lists the 33 species present in selected estuaries in the State of Washington. Approximately 50 species have been selected for the entire West Coast study (Appendix II).

The second step taken to conduct the Washington Study was to select estuaries to be studied. Of the 33 estuaries selected on the West Coast, six of these are located along the Washington coastline (Fig. 3):

1. Skagit Bay, (sub-estuary of Puget Sound)
2. Hood Canal, (sub-estuary of Puget Sound)
3. Puget Sound (delineated from north Admiralty Inlet to Olympia, WA),
4. Grays Harbor,
5. Willapa Bay, and the
6. Columbia River Estuary.

Figure 2. Steps to Conduct Study

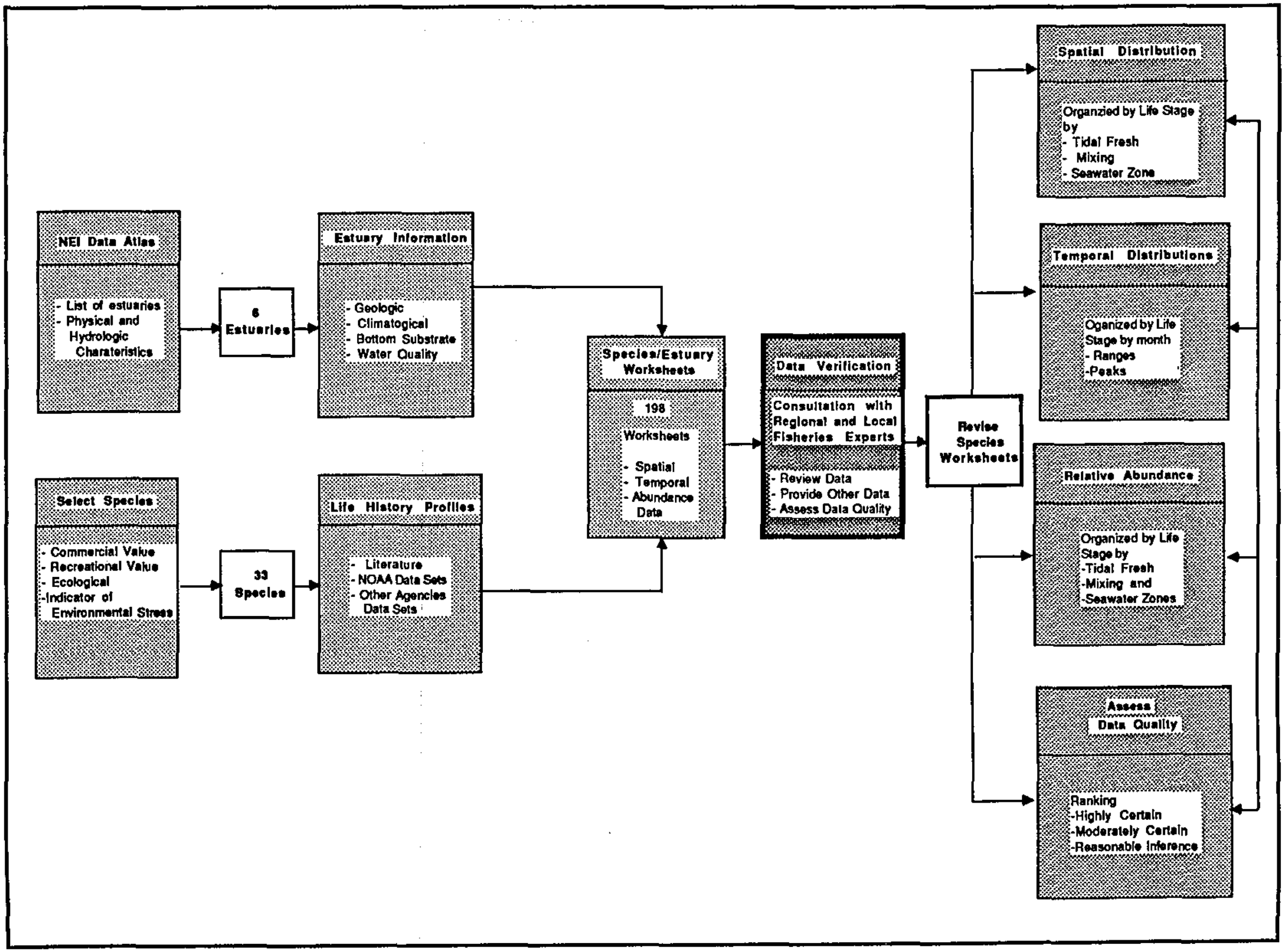
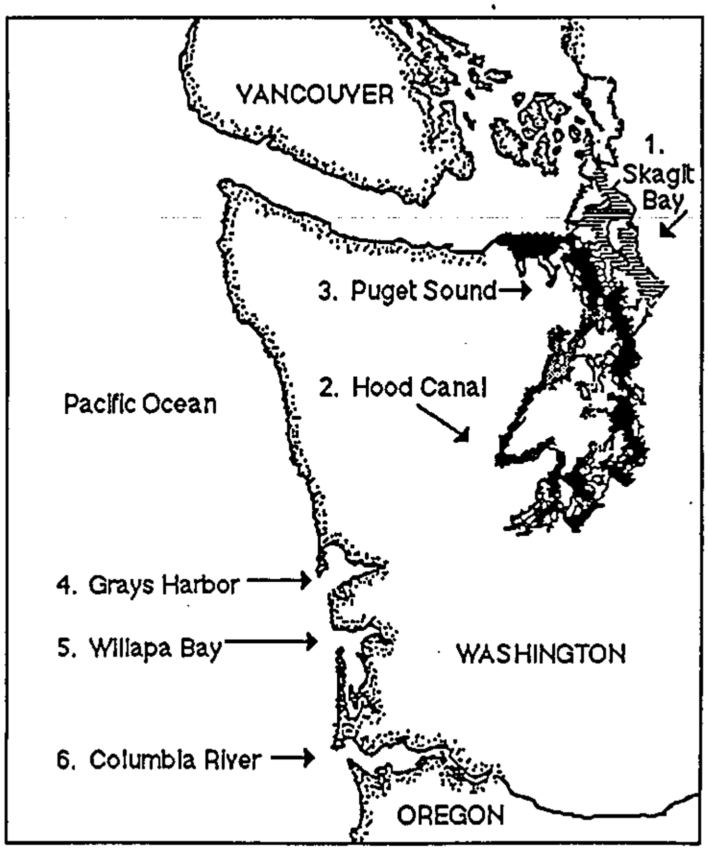


Table 1. Species of the ELMR Washington Study

Blue Mussel *Mytilus edulis*	**White Sturgeon** *Acipenser transmontanus*	**Surf Smelt** *Hypomesus pretiosus*
Pacific Oyster *Crassostrea gigas*	**American Shad** *Alosa sapidissima*	**Longfin Smelt** *Spirinchus thaleichthys*
Manila Clam *Venerupis japonica**	**Pacific Herring** *Clupea pallasi*	**Eulachon** *Thaleichthys pacificus*
Pacific Littleneck Clam *Protothaca staminea*	**Northern Anchovy** *Engraulis mordax*	**Pacific Tomcod** *Microgadus proximus*
Pacific Gaper *Tresus nuttalli*	**Pink Salmon** *Oncorhynchus gorbuscha*	**Threespine Stickleback** *Gasterosteus aculeatus*
Fat Gaper *Tresus capax*	**Chum Salmon** *Oncorhynchus keta*	**Shiner Perch** *Cymatogaster aggregata*
Geoduck *Panope generosa*	**Coho Salmon** *Oncorhynchus kisutch*	**Pacific Sand Lance** *Ammodytes hexapterus*
Eastern Softshell Clam *Mya arenaria*	**Sockeye Salmon** *Oncorhynchus nerka*	**Lingcod** *Ophiodon elongatus*
Bay Shrimp *Crangon franciscorum*	**Chinook Salmon** *Oncorhynchus tshawytscha*	**Pacific Staghorn Sculpin** *Leptocottus armatus*
Dungeness Crab *Cancer magister*	**Cutthroat Trout** *Salmo clarki*	**English Sole** *Parophrys vetulus*
Green Sturgeon *Acipenser medirostris*	**Steelhead** *Salmo gairdneri***	**Starry Flounder** *Platichthys stellatus*

* *Tapes philippinarum* ** *Paraslamo mykiss*

Figure 3. Washington Estuaries of the ELMR Project



Finally, additional information was collected on the six Washington estuaries to complement species data collection. Although critical for this study, Volume 1 (SAB 1985) of the NEI does not contain sufficient information on some physical parameters that affect species distributions. Additional information was compiled on geological history, bottom type, tidal and freshwater circulation, and water quality to assist in the development of each estuary's species composition and to understand the reported distribution of the organisms. These additional data helped filter out seasonal anomalies and reports of unusual species distributions. Therefore, the information shown represents the "normal" species' spatial and temporal distributions.

Two documents were developed to compile and present the information. First, a species profile was developed for each species to provide a life history overview. The profiles contain more information than is depicted in the data summaries of this report and were essential to understanding and interpreting the distribution of each species. Although many species profiles have been previously published by various state and Federal agencies, they lack the specifics on estuarine life history data deemed necessary for this study. Therefore, the profiles developed stressed estuarine ecology, a species' physiological tolerances, and life history information for estuarine dependent life stages. A representative species profile for Pacific herring is shown in Figure 4. It has been shortened to fit within the confines of the report, but the primary information is shown.

Second, a species worksheet was designed to enable quick compilation and simple graphic presentation of the data. Figure 5 shows the worksheet for Pacific herring. A draft worksheet was developed for each species and estuary before additional experts were consulted. The fundamental data collected on each species include: (1) the salinity zone it occupies--seawater, mixing, or tidal fresh; (2) monthly distribution throughout those zones; and (3) life history stage(s) in a particular zone and the relative abundance level. Two complete profiles and associated worksheets for chum salmon and Dungeness crab are shown in Appendix III.

Adults are defined as reproductively mature individuals, juveniles are immature but otherwise similar to adults, and spawning is defined as the release of eggs and sperm (fertilization). A few exceptions existed, such as the livebearers and mating in crabs. Three steps were taken to compile these data. First, the presence or absence of a species within an estuary was determined. Second, the species' monthly distribution was determined, and if possible, the peak occurrence of each life stage was noted. Finally, the relative abundance of a species in an estuary was determined using the following criteria:

- General distribution: the species is usually present in this area.
- Abundant: a moderate concentration of the species is present in this area.
- Highly abundant: a very high concentration of the species is present in this area.

For well-studied species, such as salmonids, quantitative data were used to estimate abundance levels. However, for many species within any given estuary the availability of reliable quantitative data were generally very limited. Regional and local experts were, therefore, consulted to estimate relative abundance based on the above criteria. Reference or guide species with abundance levels corresponding to the above criteria were developed for each estuary in cooperation with local biologists. Other species were then placed into the appropriate category relative to the guide species. Relative abundance levels could not be determined across a suite of estuaries. If a species or specific life stage was rare (< generally distributed), or not not known to be present, it was listed as "species not present" (SNP), or "life stage not present" (NP).

Consulting the Experts. Approximately 6 months were spent on data compilation and consultation with regional and local experts to develop, verify, and revise 198 draft species worksheets (Fig. 5). Initial interviews were arranged to explain the overall *Living Marine Resources Program* and to introduce the ELMR project. Each data sheet was carefully reviewed during these meetings, or subsequently by mailing the draft data sheets to reviewers. These important consultations complemented the NOAA and other published data sets aggregated by NOS/NMFS. For this report about 50 scientists and managers at 25 institutions or agencies were

Figure 4. Example of Species Profile

Common Name: Pacific herring
Scientific Name: *Clupea pallasi*

Other Common Names: California herring, Ches-Pechora herring, eastern herring, herring, Kara herring, Pacific Ocean herring, seld, white sea herring.

Classification:
Phylum:Chordata
Class: Osteichthyes
Order: Clupeiformes
Family: Clupeidae

Value and/or Selection Criteria:
Commercial: Pacific herring has a long history of exploitation by U.S. fishermen. From 1965 until the present, the fishery has concentrated on the gravid females for roe, which is primarily exported to Japan. Fishermen take advantage of the herrings' natural spawning cycle by harvesting herring in nearshore areas where and when they come to spawn. Recent U.S. harvests have been 116 million pounds annually—worth $47 million (Thompson 1986). A commercial bait fishery exists in Puget Sound (Trumble 1983) and in other West Coast estuaries.

Recreational: Fished primarily for bait for use in the salmon and other fisheries.

Indicator of Environmental Stress: Pacific herring larvae appear to have high mortality rates in oil-contaminated water (Nelson-Smith 1973).

Ecological: Pacific herring is seasonally one of the most abundant species in West Coast marine and estuarine neritic zones and is prey for many marine predators (salmon, seals, gulls, etc.).

Range:
Overall: Arctic-circumboreal. Ranges from Enseneda, Baja California, to St. Michael Island and to Cape Bathurst in the Beaufort Sea (Hart 1973). Also occurs in Arctic waters from Coronation Gulf, Canada, to the Chukchi Sea and the USSR Arctic.

Within the Study Area: Occurs in all West Coast estuaries north of San Diego, California and is increasingly abundant north of San Francisco Bay.

Life Mode:
Eggs are benthic and adhesive after fertilization. Larvae, juveniles, and adults are schooling pelagic neckton.

Habitat:
Type: Eggs are laid intertidally (3.7 meters above MLLW) and subtidally (to 20 meters), but normally occur in +1 to -2 meter depth. Larvae and juveniles are neritic, while adults are neritic-oceanic.

Substrate:
Eggs occur on eelgrass, algae, tube worms, oysters, hydroids, driftwood, pilings, brush, rocks, and rocky-sandy bottoms (Garrison and Miller 1982).

Physical/Chemical Characteristics:
Eggs and larvae are tolerant of a wide range of salinities (12-26 ppt) (Alderdice and Velsen 1971). Optimum temperature and salinity conditions for egg and larvae survival appear to be 5.5 to 8.7 C and 13-19 ppt (Alderdice and Velsen 1971).

Figure 4. Example of Species Profile

Migrations and Movements:
Pacific herring do not make extensive coastal migrations (Morrow 1980). Adults move onshore and reside in "holding" areas before moving to spawning grounds. Most fish return to natal spawning grounds. Larvae are dispersed by currents. Juveniles usually stay in nearshore shallow waters until the fall when they disperse to deeper offshore waters.

Reproduction:
Mode: Sexual, separate sexes, oviparous, iteoparous.

Spawning: From November (southern areas) to August (northern populations). Pacific herring spawn in particular areas every year. These areas are usually protected open coast habitats or in bays and estuaries. Spawning occurs when tactile stimuli (storms, contact with bottom or other fish) causes some males to extrude milt that stimulates the entire school to spawn.

Fertilization: External, reaching maturity. Fecundity ranges from 4,000 to 134,000 eggs/female (Hart 1973).

Growth and Development:
Egg Size: 1.2-1.5 mm in diameter after fertilization (Hart 1973).

Embryonic Development: Hatching occurs in 11-12 days at 10.7 C, 14-15 days at 8.5 C, and 28-40 days at 4.4 C (Outram 1955).

Larval Size Range: 4-8 mm SL (X_- = 6 mm SL) to 35 mm (Fraser 1922, Stevenson 1966).

Juvenile Size Range: 3.5 to 13 cm SL, depending on the region.

Age and Size of Adults: 13-26 cm, depending on the region. Pacific herring mature at 2-3 years in California, 3-4 years in Washington, and can live up to 19 years and a maximum size of 50 cm (Morrow 1980).

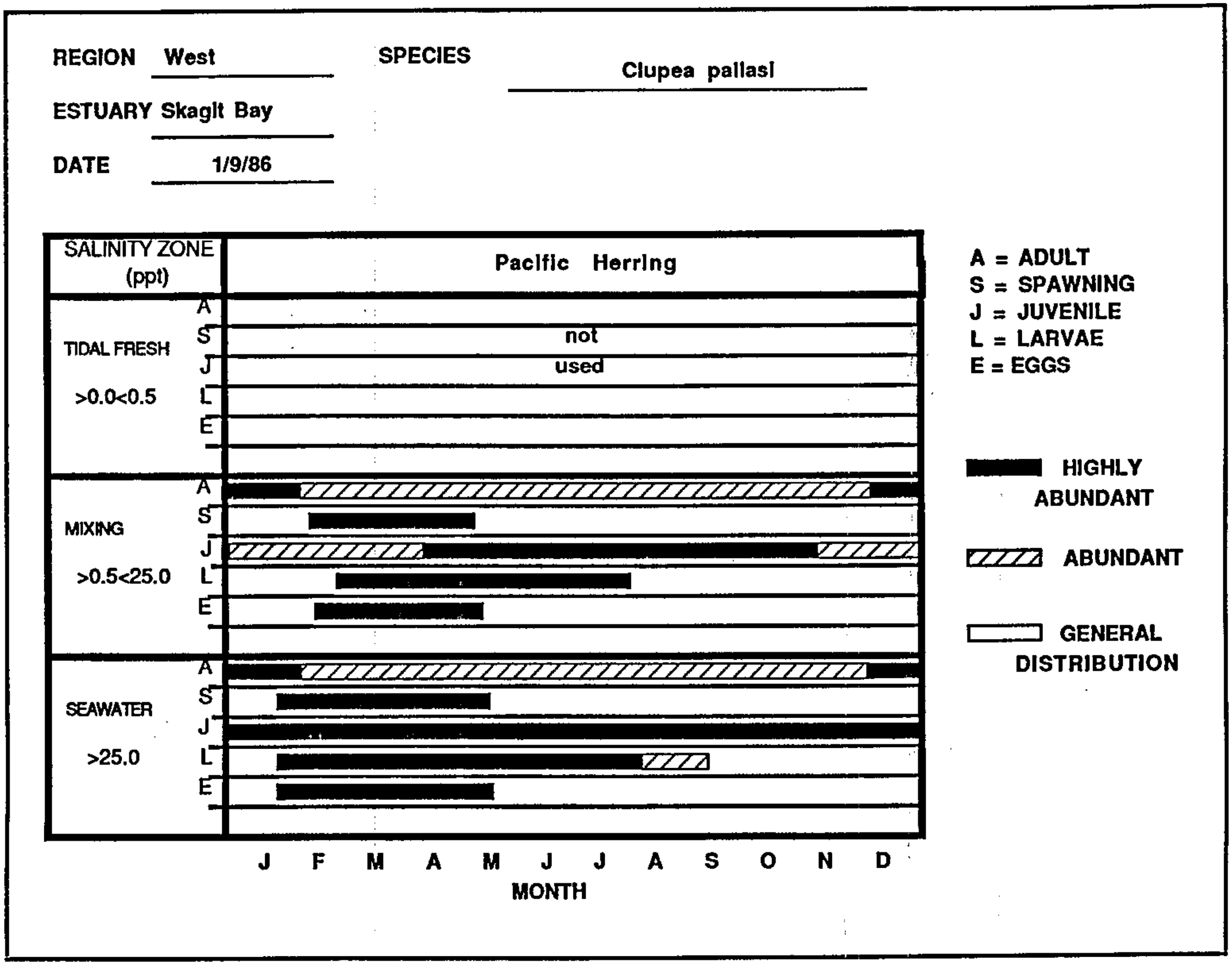
Food and Feeding:
Trophic Mode: Selective pelagic plankton feeder.

Food Items: Larvae consume diatoms, invertebrate eggs, crustacean larvae, and compepods. Juveniles eat primarily crustaceans—copepods, cladocerans, euphausiids, mycids, amphipods, and decapod larvae. Adults prey on copepods, euphausiids, amphipods, and fish larvae (Hart 1973, Simenstad et al. 1979, Miller et al. 1980, McCabe et al. 1983).

Biological Interactions:
Predation: Eggs are eaten by fish, ducks, and gulls; larvae are prey for ctenophores, jellyfish, amphipods, chaetognaths, clupeid fishes, and salmonids. Juveniles and adults are consumed by marine predators (Hart 1973 and Simenstad et al. 1979).

Factors Influencing Populations: No relation exists between the number of eggs spawned and the number of eventual recruits (PFMC 1981). Egg and larvae mortality is the suspected major components affecting population sizes. Tidal fluctuations, desiccation, freezing, low oxygen, wave action, and predation cause substantial mortality. Juveniles and adults are affected by competition, predation, disease, spawning stress, and fishing pressure. Human-induced alterations of water quality, spawning substrate and habitat, food supplies, and migration rates, also affect populations (Alaska Dept. of Fish and and Game 1985).

Figure 5. Example of Species Worksheet



consulted. The names and affiliations of these experts are listed in Appendix IV, as well as in Appendix V, that also lists the primary data sources for each species by estuary. Local experts were particularly helpful in providing estuary/species specific information on distribution and abundance. They also provided additional references and contacts and identified additional species to be included in the data base.

Data Summaries and Results. The information compiled for each species and estuary on the 198 worksheets has been synthesized into three data summaries. Examples of how the information is organized are shown in Figures 6, 7, 8. The entire set of data tables is located in the *Data Summary Tables* section. These summaries provide a graphic presentation of the distribution and abundance by life stage for selected species and estuaries. They are illustrative of how portions of the information will eventually be organized for the Nation's estuaries.

Table 2 summarizes the distribution and relative abundance by life stage for each species in each estuary by salinity zone (Fig. 6). The highest level of abundance at any point in the year in each estuary is depicted. Although this report is a small portion of the nationwide data base, Table 2 begins to show the significance of estuaries or at least their use by specific species and their life stages. In general, younger life stages occur at lower salinities, while adults are often found in the seawater zone.

Table 3 summarizes the temporal distribution of each species by month and life stage for each estuary; peak periods are also shown (Fig. 7). A peak period indicates that the individual species is most abundant during that period relative to itself. A species may be only generally distributed relative to other species, but may have a peak concentration at some point during the year.

HOW GOOD ARE THE DATA?

Criteria for Evaluation. An important aspect of any study, especially those based on literature reviews and consultations is to determine the quality of the data used. Depending on the questions to be addressed, data of varying quality may or may not be suitable to use. An effort was made to assess consistently the "overall" quality of the data developed so that the information can be used appropriately. Figure 8 illustrates how the reliability information is shown in Table 4 of the *Data Summary Tables* section.

Table 4 presents estimates of the reliability of the data by estuary, species, and life stage based on the following criteria:

- Highly certain - Considerable sampling data available. Distribution, behavior, and preferred habitats well-documented within an estuary.

- Moderately certain - Some sampling data available for an estuary. Distribution, preferred habitat, and behavior well documented in similar estuaries.

- Reasonable inference - Little or no sampling data available. Information on behavior and preferred habitats documented in similar estuaries.

The quality and quantity of information vary by species and by estuary. For example, a large amount of information is available on salmonids because they are highly valued both commercially and recreationally. For such species the data are often considered highly certain. Considerably more information was also usually available for fishes than for invertebrates. In general, data reliability is less for earlier life stages. The abundance and distribution data for larvae and eggs vary widely due to differing levels of research efforts to determine the presence and abundance of these life stages for specific species in individual estuaries. Whereas, adult and juvenile catch statistics are often available from various research and recreational catch studies.

Data reliability was also based on the number of studies conducted on a species within an estuary and whether they represented time-series data sets or were designed to identify and

Figure 6. Example of Distribution and Abundance Table

Species/ Life Stage		WASHINGTON ESTUARIES																	
		Skagit Bay			Hood Canal			Puget Sound			Grays Harbor			Willapa Bay			Columbia River		
		T	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*
American Shad	A	○	○	○							◉	◉	◉	◉	◉	◉	◉	◉	○
	S																○		
Alosa sapidissima	J	○	○	○							◉	◉	◉	◉	◉	◉	●	●	●
	L																		
	E																		
Pacific Herring	A		●	●		◉	◉		●	●						○		○	○
	S		●	●		●	●		●	●						○		○	
Clupea pallasi	J		●	●		●	●		●	●		◉	◉		◉	◉		●	●
	L		●	●		●	●		●	●		○	○		○	○		○	○
	E		●	●		●	●		●	●						○		○	
Northern Anchovy	A		○	○			○		○	○		◉	●		●	●		●	●
	S		○	○			○			○									
Engraulis mordax	J		○	○			○		○	○		◉	●		●	●		●	●
	L		○	○			○		○	○		○	○		○	○		○	○
	E		○	○			○		○	○		○	○		○	○		○	○
Pink Salmon	A	●	◉	◉	●	●	●	●	●	●									
	S																		
Oncorhynchus gorbuscha	J	●	●	●	◉	◉	◉	●	●	●									
	L				○			○											
	E																		
Chum Salmon	A	●	●	●	●	●	●	●	●	◉	●	◉	◉	●	●	●	○	○	○
	S																		
Oncorhynchus keta	J	●	●	●	●	●	●	●	●	◉	◉	◉	◉	●	●	◉	○	○	○
	L																		
	E																		
Coho Salmon	A	◉	◉	◉	◉	○	○	◉	○	○	◉	◉	◉	◉	◉	◉	◉	◉	◉
	S																		
Oncorhynchus kisutch	J	◉	○	○	◉	○	○	◉	○	○	◉	◉	◉	◉	◉	◉	◉	◉	◉
	L																		
	E																		

● Highly Abundant ◉ Abundant ○ Generally Distributed Blank — Not Present

T — Tidal Fresh *M* — Mixing Zone *S* — Seawater

A — Adult S — Spawning J — Juvenile L — Larva E — Egg M — Mating

Figure 7. Example of Temporal Distribution Table

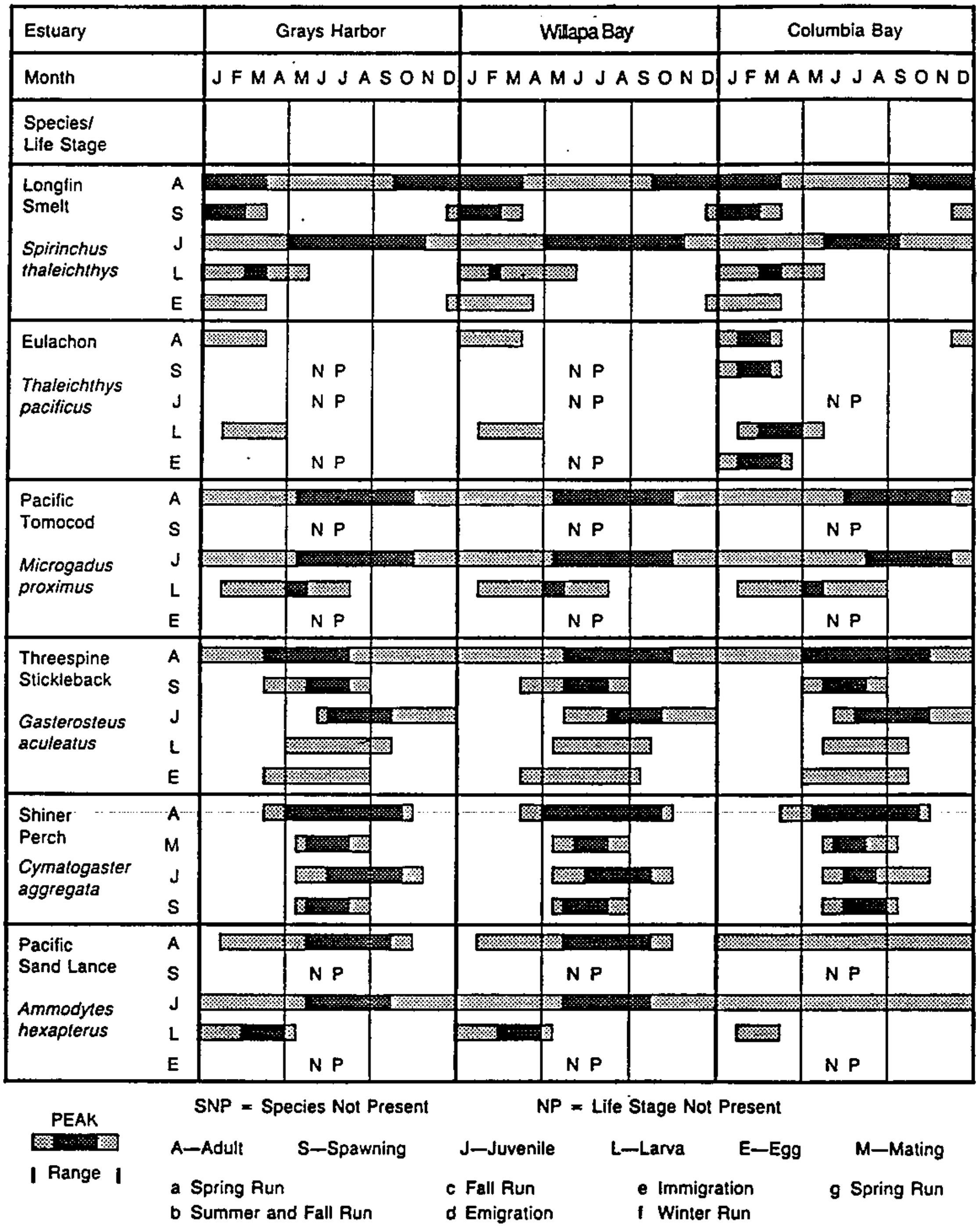


Figure 8. Example of Data Reliability Table

Species/ Life Stage		WASHINGTON ESTUARIES					
		Skagit Bay	Hood Canal	Puget Sound	Grays Harbor	Willapa Bay	Columbia River
American Shad	A	□	■	■	■	□	■
	S	■	■	■	■	■	▣
Alosa sapidissima	J	□	■	■	■	□	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
Pacific Herring	A	■	■	■	■	□	■
	S	■	■	■	■	□	■
Clupea pallasi	J	■	■	■	■	□	■
	L	■	■	■	▣	□	■
	E	■	■	■	■	□	▣
Northern Anchovy	A	■	■	■	■	□	■
	S	▣	▣	▣	■	■	■
Engraulis mordax	J	■	■	■	■	□	■
	L	▣	▣	▣	▣	□	■
	E	▣	▣	▣	▣	□	■
Pink Salmon	A	■	■	■	■	■	■
	S	■	■	■	■	■	■
Oncorhynchus gorbuscha	J	■	■	■	■	■	■
	L	■	▣	▣	■	■	■
	E	■	■	■	■	■	■
Chum Salmon	A	■	■	■	■	■	■
	S	■	■	■	■	■	■
Oncorhynchus keta	J	■	■	■	■	▣	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
Coho Salmon	A	■	■	■	■	■	■
	S	■	■	■	■	■	■
Oncorhynchus kisutch	J	■	▣	■	■	▣	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■

■ Highly Certain ▣ Moderately Certain □ Reasonable Inference

A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

quantify specific species' life stages. For example, the Columbia River Estuary Data Development Program (CREDDP) used different gear types to sample various habitats accurately and efficiently (Fox et al.1984). These data are more reliable than data for some of the smaller, less-studied estuaries where rigorous data sets have not been developed. In the case of limited studies, information was occasionally inferred. Because this report is part of the final West Coast data set, an opportunity exists to refine the data based on additional reviews prior to the entire West Coast report.

Given that the amount and quality of available information varies by species, by life stage, between estuaries, and even within an estuary, considerable scientific judgment is required to derive or infer spatial and temporal distributions from existing data and available literature. But even the most informed judgment is far from perfect due to complexity of estuarine systems. Consequently, information on the level of certainty associated with each data element must be presented when synthesizing multiple data sets (Table 4). In addition, Appendices IV and V provide a complete summary of the personal communications and primary references to enable individuals to track and obtain additional information efficiently.

Variability in Salinity Regimes. Salinity zone boundaries developed for each estuary in the NEI atlas (SAB 1985) are highly variable throughout the year. The atlas subdivides each estuary into three zones between the heads of tide and the seaward boundaries based on depth-averaged annual salinity concentrations (Fig.1). However, division of an estuary on the basis of salinity is highly variable due to the many interacting factors affecting salinity concentrations, such as variations in freshwater inflow, wind, and tides. To compile information on species distribution according to these zones, it is assumed that if a particular salinity zone increases or decreases, the distribution of a mobile species in that zone would correspond to that shift. For example, if increased freshwater inflow shifts the tidal fresh zone further down the estuary, the distribution of a species confined to that zone increases to include the new area. If a species exhibits a wide range in salinity tolerance, a shift may or may not occur. The final placement of species in a salinity zone was ultimately determined by where they have actually been observed or captured. For example, the seawater zone is not shown for the Columbia River when annual depth-averaged values are calculated; however, it does exist. At this time, some of the predominantly marine species use the high-salinity lower layer of the river. Therefore, species distributions for the marine zone were recorded on the worksheets.

Complex Life Histories. Due to the complex life histories of some species, brief descriptions are provided below to clarify spatial and temporal distributional data that cannot be adequately presented in simple data summaries.

Fishes - Aggregating species by salinity zone uses a fundamental habitat parameter, but a combination of habitat characteristics, such as bottom type and bathymetry, would more accurately indicate species spatial distributions. Temporal distributions could be refined if monthly isotherms existed for the Nation's estuaries. The temporal data are aggregated by month. Each month was divided into two time periods: (1) beginning to the middle of the month (days 1 through 15), and (2) from the middle to the end of the month (days 16 through 30). This captures many of the species movements triggered by temperature and photoperiod, such as migration into estuaries.

Salmonids - are present in estuaries as juveniles for brief time periods, and this residence time varies by species (Simenstad et al., 1982). Because estuaries function primarily as migratory corridors to and from spawning and rearing areas, only the adult and juvenile life stages are normally depicted. Spawning, eggs, and larvae usually occur in an estuary's freshwater tributaries.

Pink Salmon - Nearly all pink salmon mature in their second year of life, so odd- and even-year runs of adults occur. In Puget Sound, odd-year runs predominate. Pink salmon are not usually found in Grays Harbor, Willapa Bay, or the Columbia River.

Chum Salmon - Early-, middle-, and late-year runs of chum salmon occur in Puget Sound. The juvenile out migration in the Columbia River occurs during February through May.

Coho Salmon - Some long-term rearing of coho salmon occurs in Puget Sound (Simenstad et al. 1982).

Sockeye Salmon - Of the six Washington estuaries in this study, sockeye are only found in Puget Sound and the Columbia River. The Columbia River is the southernmost distribution of any sizable spawning runs. Eggs, alevins, fry, and parr live in fresh water while smolts and anadromous adults inhabit fresh to euhaline waters.

Chinook Salmon - The presence of fall, summer, and spring chinook runs (determined by when adults return to freshwater) varies throughout Washington estuaries. All three runs exist in the Columbia River while only a fall run occurs in Willapa Bay. Within the Columbia River, races are different "stocks" that separate as they reach their natal streams (Phinney 1986).

Cutthroat Trout (Searun variety) - The data for this species are organized by adult immigration into the estuaries and emmigration out. In many Washington estuaries where runs exist, two adult immigration peaks occur. An early run usually occurs in the fall with a peak in September, and the late run peaks in January. All fish immigrating may not be sexually mature.

Steelhead Trout - Summer and winter run adult steelhead occur in Washington estuaries with the winter run displaying two peaks. Peak outmigration of juveniles (smolts) occurs primarily in the spring. Kelt outmigrations (spawned out fish that migrate to sea) are not shown, but occur usually slightly before the smolt migration.

Longfin Smelt - In Puget Sound, this species is found only in the northern and Bellingham Bay areas. Spawning of longfin smelt occurs in a few northern Puget Sound rivers.

Shiner Perch - This species is ubiquitously distributed throughout the study area. This viviparous fish is abundant in Pacific Northwest estuaries. Large schools of adults are generally found in salinities of 9 ppt or greater (Moyle 1976), the mixing and seawater zones of this study. However, juveniles are found in tidal fresh waters. All juveniles are assumed to be mature by October when they move to deeper waters.

Pacific Staghorn Sculpin - Occurs in Puget Sound, but rarely found below 50 meters in depth. Spawning occurs at the mouths of estuaries or offshore. Although eggs are not reported in most estuaries they are probably present.

Starry Flounder - Spawning probably occurs off the mouths of Grays Harbor, Willapa Bay, and the Columbia River. Eggs may be present in the seawater zone, but have not been reported.

<u>Invertebrates</u> - Because nonmotile invertebrates, such as clams and oysters, are usually found in distinct pockets, the areal distribution of these organisms is overestimated, but the salinity zones of colonization are identified. Specific areas may contain acceptable salinity regimes, but suitable bottom habitat for colonization may not exist.

Blue Mussel - Juvenile settlement period is highly variable depending on water temperature.

Dungeness Crab - Juvenile Dungeness crab is the primary life stage to use estuaries since adults normally spawn at sea. However, in some estuaries all life stages are present.

Abundance Data. It was particularly difficult to obtain information on the relative abundance of species within an estuary and impossible to obtain relative abundance data across estuaries. Therefore, an attempt was made to determine only relative abundance compared to other species within an individual estuary. For well-studied species, such as salmonids in the Columbia River, quantitative data were used to estimate the level of abundance within that estuary. However, this information may be of limited use if quantitative data are not available for other species on which to base relative estimates. Consequently, after compiling as much quantitative data as possible, the final level of abundance assigned to a species was determined by asking regional and local experts for opinions based on their knowledge of specific species and estuaries. This complementary effort to the quantitative studies greatly increased the reliability of the abundance information. The fundamental point is:

Except for a relatively few important commercial or recreational species, little or no quantitative information is available to determine relative species abundance for a large number of organisms within and across estuaries. The data that are available are almost impossible to reconcile and combine because of the variability in sampling strategies and the inconsistencies of studies done across species and estuaries. Therefore, the information presented on abundance in the data summaries is the "best" that could be synthesized from multiple studies and expert reviews.

CONCLUDING COMMENTS

This study is the first completed component of an effort to develop a consistent and comprehensive data base on the life history, distribution, and relative abundance of selected fishes and invertebrates throughout estuaries of the USA. The information presented is a result of a program designed to "capture" the Nation's data, information, and expertise on species in estuaries. This work is the *first step* in developing an information base and operational capability to bridge the gap between site-specific estuarine problems and formulation of regional management strategies. Filling this gap is now more important than ever before, as it becomes clear that the cumulative effects of small changes in many places may have much greater systematic effects throughout the Nation's estuaries and coastal ocean. Compiling, transcribing, and unifying the myriad fragments of information is a difficult task, but necessary to manage effectively the Nation's estuarine resource base. Multi-state legislation has been implemented to control nonpoint nutrient runoff, and some states are limiting shoreline development (Chesapeake Bay Critical Area Commission, 1986). Although the knowledge available to preserve effectively these areas and their resources continues to be limited, the ELMR data base will enable identification of knowledge gaps; comparisons among species, groups of species, and specific life stages; as well as comparisons between times of year, within an estuary, or by geographic regions. Most important, will be its use in posing questions and developing and testing hypotheses when these data are combined with other NOAA data sets, including those on habitat, pollutant loadings, and estuarine processes.

Developing this information for the Nation is an enormous undertaking. This report alone required consultations with over 50 experts and use of over 300 references to develop the relatively simple data summaries for only six estuaries. Consequently, the ELMR project has emphasized developing primarily distributional information on individual species by estuary, paying particular attention to life stage, the time period a species uses an estuary, and its general habitat requirements. Although this type of information is not suitable for traditional fisheries management, such as stock assessment, knowing the detailed biogeography of many species across estuaries provides new opportunities to address a range of broader problems and provides a framework to identify resource use conflicts for further investigation.

Classifying and Comparing Estuaries. In spite of qualitative nature of the distributional data precluding exact comparisons of species abundances among estuaries, much can be done using information on presence or absence of life stages in a salinity zone. This information, combined with the identification of the time period each species uses the estuary, is the strength of the data base. Estuaries can be categorized in a preliminary way by their biological characteristics, and correlates of species distributions in and among estuaries may be identified. The relative importance of individual estuaries in a particular region can also be assessed for a specific group of species using some criterion of significance.

The species found in a given estuary are far more sensitive indicators of both mean and extreme conditions than any set of physical measurements. Estuaries can, therefore, be classified by the number of species present, whether they are primarily marine, estuarine, or freshwater. The species assemblage may correlate with a number of physical characteristics, such as bottom substrate, vegetation, and the areal and temporal characteristics of salinity zones. This can be done even with an incomplete species list, as long as the list's biases are accounted for. Even the low resolution of salinity zones in the present classification (now undergoing revision through the development of seasonal isohalines) can be refined by examining the species present in a given salinity zone. This can indicate whether the estuarine portion of the estuary is more marine than fresh. The information on species presence or absence, area, or other attributes can be used to see whether estuaries cluster or are spread out along a continuum.

When comparing estuaries, any shift in a species' position in a list ranked by degree of abundance warrants further analysis. A comparison among estuaries using various correlates of that species' distribution can identify those factors differing among estuaries that might account for the species' shift in relative abundance, thereby helping to define the major environmental variables controlling its distribution. In addition, ecological controls on a species can also be investigated. For example, a species may show differing salinity tolerances among estuaries, indicating that some other factor, such as presence of a competitor, predator, availability of specific food source, bottom type, or degree of pollution may be regulating its distribution.

Linkages to Large Marine Ecosystems. There are many species that use estuaries for specific parts of their life histories and spend the rest offshore as components of large marine ecosystems. Most fall into four general categories: 1) anadromous species using estuaries as migration corridors and, in some instances, nursery areas; 2) species that enter estuaries to use various habitats for spawning, such as specific salinity regimes; 3) other offshore species spawning near the mouths of estuaries so that tidal and wind-driven currents can carry eggs and larvae into the estuarine nursery areas; and 4) adults entering estuaries during certain times of year to feed on higher densities of prey. The importance of any estuary to primarily offshore species can be determined by the intensity of use of that estuary by those species, most of which fall into one or more of the four categories. Importance can be measured both by the number of offshore species present and by their actual abundances in the estuary and offshore. These data may provide clues for further investigation of the adverse effects on an offshore population due to environmental degradation of a given estuary. The objective of this effort is to provide some insight into the relationships of the physical, chemical, and biological characteristics that make up the habitat of living marine resources.

The presence or absence of members of a set of pre-selected species or species with specific life history strategies can be used to rank the estuaries' importance to these species on a regional basis. For example, if the species group is defined by anadromous species that are commercially important offshore, the strength of the offshore-estuarine linkage for each estuary can be established. This can be used to identify, on a regional basis, estuaries worthy of special attention or management. This kind of approach may facilitate the linking and importance of estuaries to geographically defined large marine ecosystems.

All of these analyses can be performed better and with more confidence in the results by the more complete any species list is for any estuary. Good quantitative data on actual abundances can also better define the strength of the offshore-estuarine linkages and refine the ranking of estuaries in terms of any measure of importance. For now, the current data sets developed or under development for the *Living Marine Resources Program* will enable regional level assessments with consistent species information for life stage and life history strategies from the head of tide in estuaries to the continental shelf. Futher, integrating the biological and physical data sets will enable NOAA to explore and define better the linkages and interchanges between estuarine and shelf habitats.

Future Developments. Several projects have been initiated recently to refine and complement the ELMR data base and to enable analyses. The first is development of a "user friendly" microcomputer-based information system. This system will enable a relational data base to be developed that will considerably increase the range and complexity of the comparisons and relationships that can be examined. The types of anticipated analyses were discussed above.

Two experimental projects have also been initiated to enhance the spatial resolution and to define better species' habitats than the existing salinity zone framework. One is determining the distribution of bottom sediment type within estuaries. Several estuaries are being examined using data on NOAA nautical charts, estuary-specific sediment reports, and archived sediment data housed at the Smithsonian Institution. The other is improving the resolution of the existing salinity zones; tidal fresh, mixing, and seawater. Surface and bottom isohaline distribution at 5 ppt will be used to increase resolution. The plan is to develop isohalines for three-month high and three-month low salinity regimes representative of long-term, "average" seasonal patterns, as well as the sensitivity of each salinity regime to temporal fluctuations.

DATA SUMMARY TABLES

Table 2. Distribution and Relative Abundance

Table 3. Temporal Distribution

Table 4. Data Reliability

Table 2. Distribution and Relative Abundance

Species/ Life Stage		WASHINGTON ESTUARIES: Skagit Bay			Hood Canal			Puget Sound			Grays Harbor			Willapa Bay			Columbia River		
		T	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*
Blue Mussel	A		◉	●		◉	◉		●	●		○	○		○	○			○
	S		◉	●		◉	◉		●	●		○	○		○	○			○
Mytilus edulis	J		◉	●		◉	◉		●	●		○	○		○	○			○
	L		○	○		○	○		◉	◉		○	○		○	○			○
	E		○	○		○	○		◉	◉		○	○		○	○			○
Pacific Oyster	A			○		●	●		●	●		●	●		●	●			
	S					●	●			●					●				
Crassostrea gigas	J			○		●	●		●	●		●	●		●	●			
	L					○	●			○					●	○			
	E					○	●			○					●				
Manila Clam	A		○	○		◉	○		●	○		◉	○		●	○			
	S		○	○		◉	○		●	○		◉	○		●	○			
Venerupis japonica	J		○	○		◉	○		●	○		◉	○		●	○			
	L		○	○		○	○		○	○		○	○		○	○			
	E		○	○		○	○		○	○		○	○		○	○			
Pacific Littleneck Clam	A		●	●		●	●		●	●		○	○		○	○			
	S		●	●		●	●		●	●		○	○		○	○			
Protothaca staminea	J		●	●		●	●		●	●		○	○		○	○			
	L		○	○		◉	○		○	○		○	○		○	○			
	E		○	○		◉	○		○	○		○	○		○	○			
Pacific Gaper	A		○	○		◉	◉		◉	◉									
	S			○		◉	◉		◉	◉									
Tresus nuttalli	J		○	○		◉	◉		◉	◉									
	L		○	○		○	○		○	○									
	E			○		○	○		○	○									
Fat Gaper	A		○	◉		○	◉		○	◉			○			○			
Tresus capax	S			◉			◉			◉			○			○			
	J		○	◉		○	◉		○	◉			○			○			
	L		○	○		○	○		○	○			○			○			
	E			○			○			○			○			○			

● Highly Abundant ◉ Abundant ○ Generally Distributed Blank — Not Present

T — Tidal Fresh *M* — Mixing Zone *S* — Seawater

A — Adult S — Spawning J — Juvenile L—Larva E — Egg M — Mating

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Species/ Life Stage		WASHINGTON ESTUARIES																	
		Skagit Bay			Hood Canal			Puget Sound			Grays Harbor			Willapa Bay			Columbia River		
		T	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*
Geoducks	A			○		◉	◉		◉	◉									
	S			○			◉			◉									
Panope generosa	J			○		◉	◉		◉	◉									
	L			○		○	◉		○	◉									
	E			○			◉			◉									
Eastern Softshell Clam	A		●	○		○	○		◉	○		○	○		◉	○		○	
	S		●	○		○	○		◉	○		○	○		◉	○		○	
Mya arenaria	J		●	○		○	○		◉	○		○	○		○	○		○	
	L		○	○		○	○		○	○		○	○		○	○		○	
	E		○	○		○	○		○	○		○	○		○	○		○	
Bay Shrimp	A		◉	◉		○	○		◉	◉		◉	◉		◉	◉		◉	◉
	S		◉	◉		○	○		◉	◉		◉	◉		◉	◉		◉	◉
Crangon franciscorum	J	○	●	◉		○	○		◉	◉	○	●	◉	○	●	◉	○	●	◉
	L		◉	◉		○	○		◉	◉		◉	◉		◉	◉		◉	◉
	E		◉	◉		○	○		◉	◉		◉	◉		◉	◉		◉	◉
Dungeness Crab	A		◉	◉		○	○		◉	◉		○	○		○	○		○	○
	M			○			○			○									
Cancer magister	J		●	●		●	●		●	●		●	●		●	●		●	●
	L		○	○		○	○		○	○		○	○		○	○		○	○
	E			○			○			○									
Green Sturgeon	A											◉	◉		◉	◉		◉	◉
	S																		
Acipenser medirostris	J																		
	L																		
	E																		
White Sturgeon	A										○	○	○	○	○	○	○	○	○
	S																		
Acipenser transmontanus	J										◉	◉	◉	◉	◉	◉	◉	◉	
	L																		
	E																		

● Highly Abundant ◉ Abundant ○ Generally Distributed Blank — Not Present

T — Tidal Fresh *M* — Mixing Zone *S* — Seawater

A — Adult S — Spawning J — Juvenile L — Larva E — Egg M — Mating

Table 2. Distribution and Relative Abundance

Species/ Life Stage		WASHINGTON ESTUARIES																	
		Skagit Bay			Hood Canal			Puget Sound			Grays Harbor			Willapa Bay			Columbia River		
		T	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*
American Shad	A	○	○	○							◉	◉	◉	◉	◉	◉	◉	◉	○
	S																○		
Alosa sapidissima	J	○	○	○							◉	◉	◉	◉	◉	◉	●	●	●
	L																		
	E																		
Pacific Herring	A		●	●		◉	◉		●	●						○		○	○
	S		●	●		●	●		●	●						○		○	
Clupea pallasi	J		●	●		●	●		●	●		◉	◉		◉	◉		●	●
	L		●	●		●	●		●	●		○	○		○	○		○	○
	E		●	●		●	●		●	●						○		○	
Northern Anchovy	A		○	○			○		○	○		◉	●		●	●		●	●
	S		○	○			○			○									
Engraulis mordax	J		○	○			○		○	○		◉	●		●	●		●	●
	L		○	○			○		○	○		○	○		○	○		○	○
	E		○	○			○		○	○		○	○		○	○		○	○
Pink Salmon	A	●	◉	◉	●	●	●	●	●	●									
	S																		
Oncorhynchus gorbuscha	J	●	●	●	◉	◉	◉	●	●	●									
	L				○			○											
	E																		
Chum Salmon	A	●	●	●	●	●	●	●	●	◉	●	◉	◉	●	●	●	○	○	○
	S																		
Oncorhynchus keta	J	●	●	●	●	●	●	●	●	◉	◉	◉	◉	●	●	◉	○	○	○
	L																		
	E																		
Coho Salmon	A	◉	◉	◉	◉	○	○	◉	○	○	◉	◉	◉	◉	◉	◉	◉	◉	◉
	S																		
Oncorhynchus kisutch	J	◉	○	○	◉	○	○	◉	○	○	◉	◉	◉	◉	◉	◉	◉	◉	◉
	L																		
	E																		

● Highly Abundant ◉ Abundant ○ Generally Distributed Blank — Not Present

T — Tidal Fresh *M* — Mixing Zone *S* — Seawater

A — Adult S — Spawning J — Juvenile L — Larva E — Egg M — Mating

Table 2. Distribution and Relative Abundance

Species/ Life Stage		WASHINGTON ESTUARIES																	
		Skagit Bay			Hood Canal			Puget Sound			Grays Harbor			Willapa Bay			Columbia River		
		T	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*
Sockeye Salmon	A							◉	◉	○							○	○	○
	S																		
Oncorhynchus nerka	J							◉	◉	○							○	○	○
	L																		
	E																		
Chinook Salmon	A	●	◉	◉	◉	◉	◉	◉	◉	○	◉	◉	◉	◉	◉	◉	◉	◉	◉
	S																		
Oncorhynchus tshawytscha	J	◉	◉	○	◉	○	○	◉	◉	○	●	●	●	◉	◉	◉	●	●	●
	L																		
	E																		
Cutthroat Trout	A	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	S																		
Salmo clarki	J	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	L																		
	E																		
Steelhead	A	○	○	○	○	○	○	○	○	○	◉	○	○	◉	○	○	◉	◉	◉
	S																		
Salmo gairdneri	J	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	◉	◉	◉
	L																		
	E																		
Surf Smelt	A		◉	◉		◉	◉		◉	◉		○	○		○	○		○	○
	S		●	●		●			●	●									
Hypomesus pretiosus	J		◉	◉		◉	◉		◉	◉		○	○		○	○		◉	◉
	L		●	●		●			◉	◉		○	○		○	○		○	○
	E		●	●		●			●	●									
Longfin Smelt	A		○	○					◉	◉		○	○		○	○		◉	○
	S	◉						◉			◉			◉			◉		
Spirinchus thaleichthys	J		◉	◉					○	○		◉	○		◉	○		●	○
	L	○	◉	◉					◉	◉	○	●	◉	○	●	◉	○	●	◉
	E							◉			◉			◉			◉		

● Highly Abundant ◉ Abundant ○ Generally Distributed Blank — Not Present

T — Tidal Fresh *M* — Mixing Zone *S* — Seawater

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Table 2. Distribution and Relative Abundance

Species/ Life Stage		WASHINGTON ESTUARIES: Skagit Bay			Hood Canal			Puget Sound			Grays Harbor			Willapa Bay			Columbia River		
		T	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*
Eulachon	A										○	○	○	○	○	○	◉	◉	◉
Thaleichthys	S																◉		
pacificus	J																		
	L										○	○	○	○	○	○	◉	◉	◉
	E																◉		
Pacific Tomocod	A		◉	◉		○	○		○	○		○	○		○	○		○	○
	S			○			○			○									
Microgadus	J		●	●		○	○		◉	◉		●	◉		●	◉		●	◉
proximus	L		○	○		○	○		○	○		○	○		○	○		○	○
	E			○			○			○									
Threespine Stickleback	A	●	●	○	○	○	○	○	○	○	◉	◉	○	◉	◉	○	◉	◉	
	S	◉	○		○	○		○	○		◉	○		◉	○		◉	○	
Gasterosteus	J	●	●	○	◉	○	○	◉	◉	○	●	◉	○	●	◉	○	●	◉	
aculeatus	L	○	○		○	○		○	○		○	○		○	○		○	○	
	E	○	○		○	○		○	○		○	○		○	○		○	○	
Shiner Perch	A		●	●		●	●		●	●		◉	○		◉	○		◉	○
	M		◉	○		◉	○		◉	○		◉			◉			◉	
Cymatogaster	J	○	●	◉	○	●	◉	○	●	◉	○	●	○	○	●	○	○	●	○
aggregata	S		◉			◉			◉			◉			◉			◉	
Pacific San Lance	A		○	○		○	○		○	○			○			○		○	○
	S		●	●		●	●		●	●									
Ammodytes	J		●	●		●	●		●	●		○	◉		○	◉		○	○
hexapterus	L		●	●		●	●		●	●		○	○		○	○		○	○
	E		◉	◉		◉	◉		◉	◉									
Lingcod	A			○			○			○									
	S			○			○			○									
Ophiodon	J		○	○		○	○		○	○		○	○		○	○			
elongatus	L		○	○		○	○		○	○		○	○		○	○			
	E			○			○			○									

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Species/ Life Stage		WASHINGTON ESTUARIES																	
		Skagit Bay			Hood Canal			Puget Sound			Grays Harbor			Willapa Bay			Columbia River		
		T	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*	*T*	*M*	*S*
Pacific Staghorn Sculpin	A		◉	◉		◉	◉		◉	◉		◉	◉		◉	◉	○	◉	○
	S			○			○			○			○			○			○
Leptocottus armatus	J	○	◉	◉	○	◉	◉	○	◉	◉	○	◉	◉	○	◉	◉	○	◉	◉
	L		○	○		○	○		○	○			○			○		○	○
	E			○			○			○			○			○			○
English Sole	A			○			○			○									
	S			○			○			○									
Parophrys vetulus	J		◉	◉		◉	◉		◉	◉		◉	◉		◉	◉		◉	○
	L		○	○		◉	◉		◉	◉		○	○		○	○		○	○
	E			○			○			○									
Starry Flounder	A		○	◉		○	◉		○	◉		○	○		○	○		○	○
	S			○			○			○									
Platichthys stellatus	J	◉	◉	◉	◉	◉	◉	◉	○	○	◉	◉	◉	◉	◉	◉	◉	◉	○
	L		○	◉		○	○		○	○		○	○		○	○		○	
	E			○			○			○									

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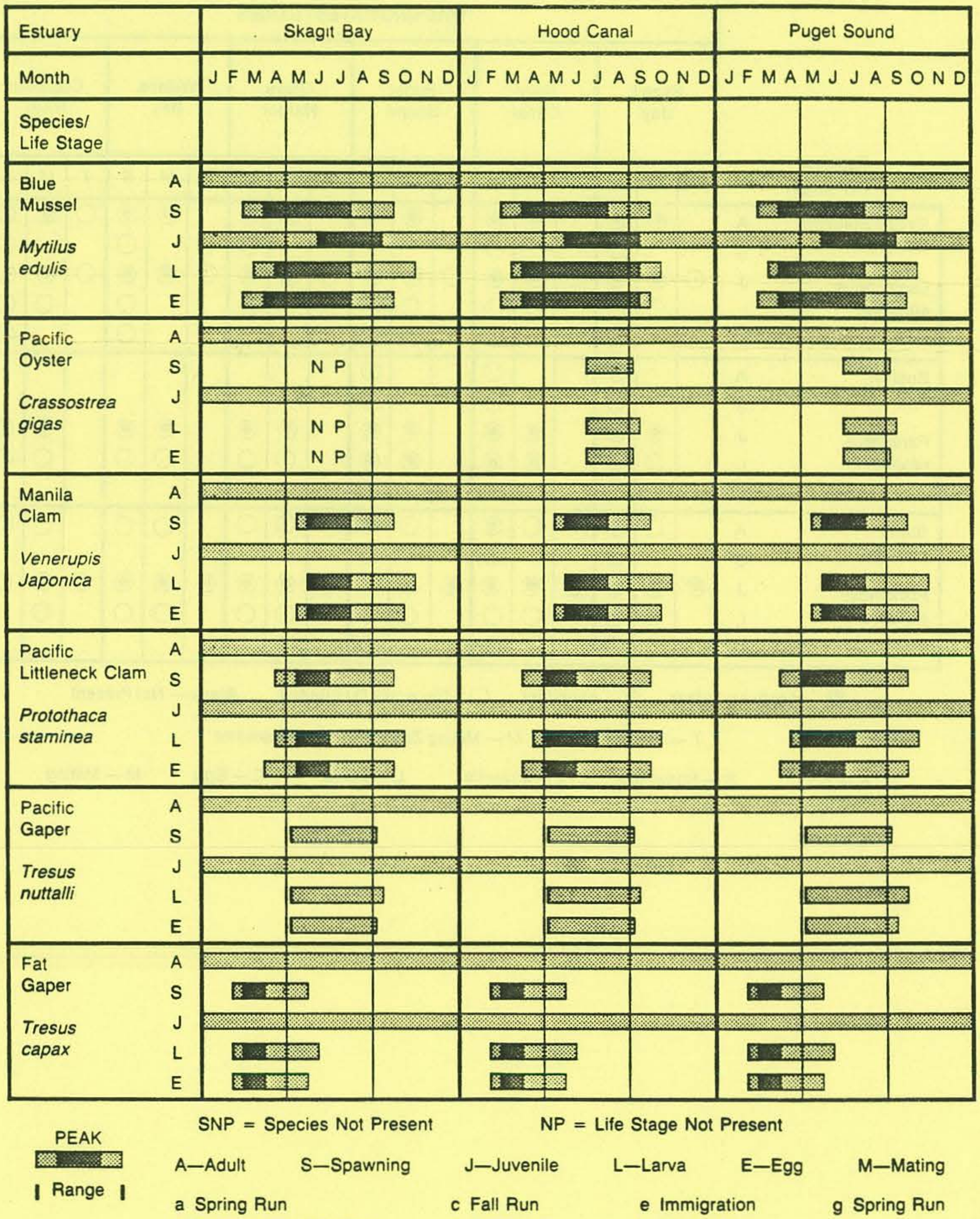
T — Tidal Fresh *M* — Mixing Zone *S* — Seawater

A — Adult S — Spawning J — Juvenile L — Larva E — Egg M — Mating

Table 3. Temporal Distribution

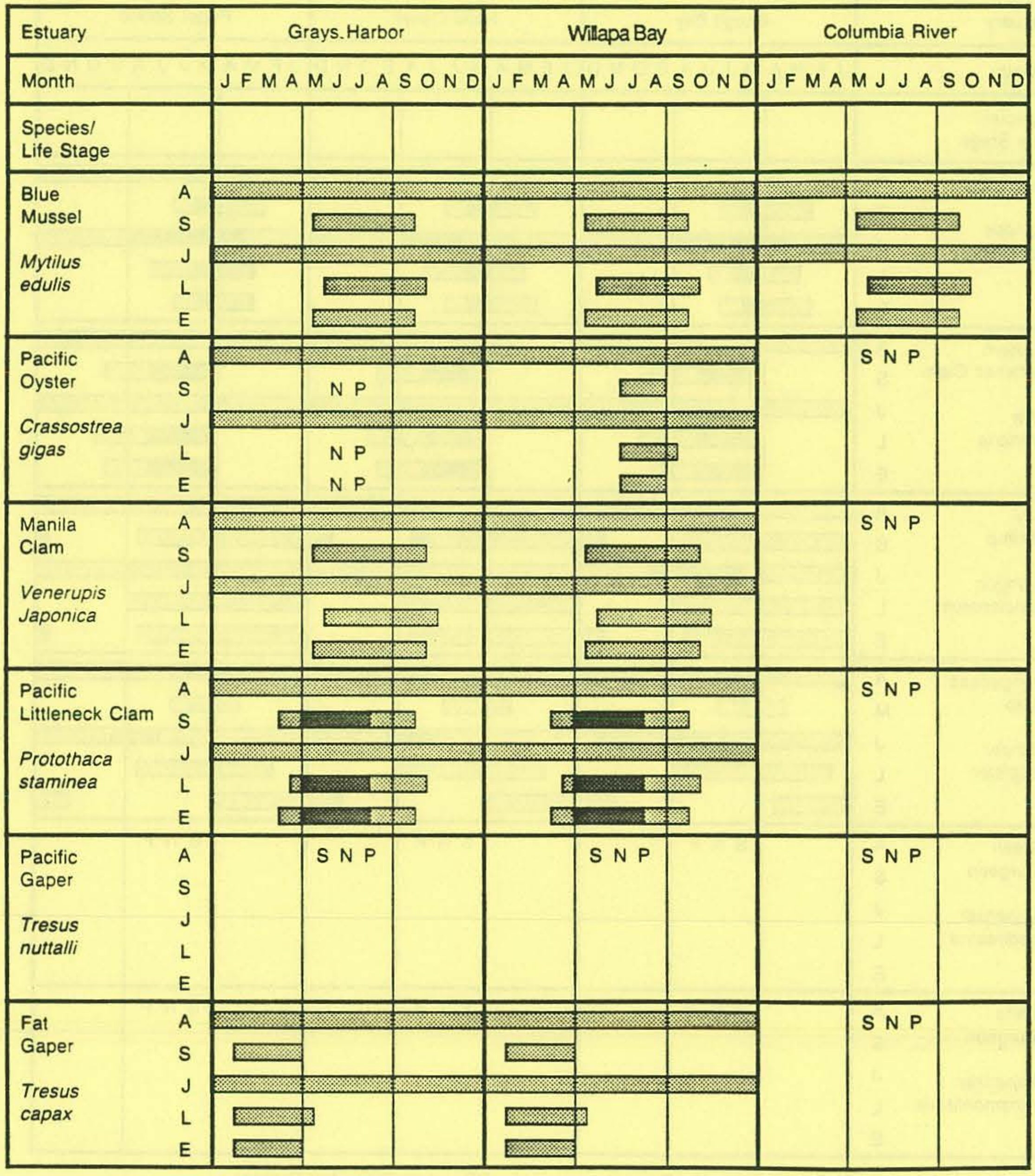


SNP = Species Not Present NP = Life Stage Not Present

A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

a Spring Run c Fall Run e Immigration g Spring Run
b Summer and Fall Run d Emigration f Winter Run

Table 3. Temporal Distribution



PEAK

Range

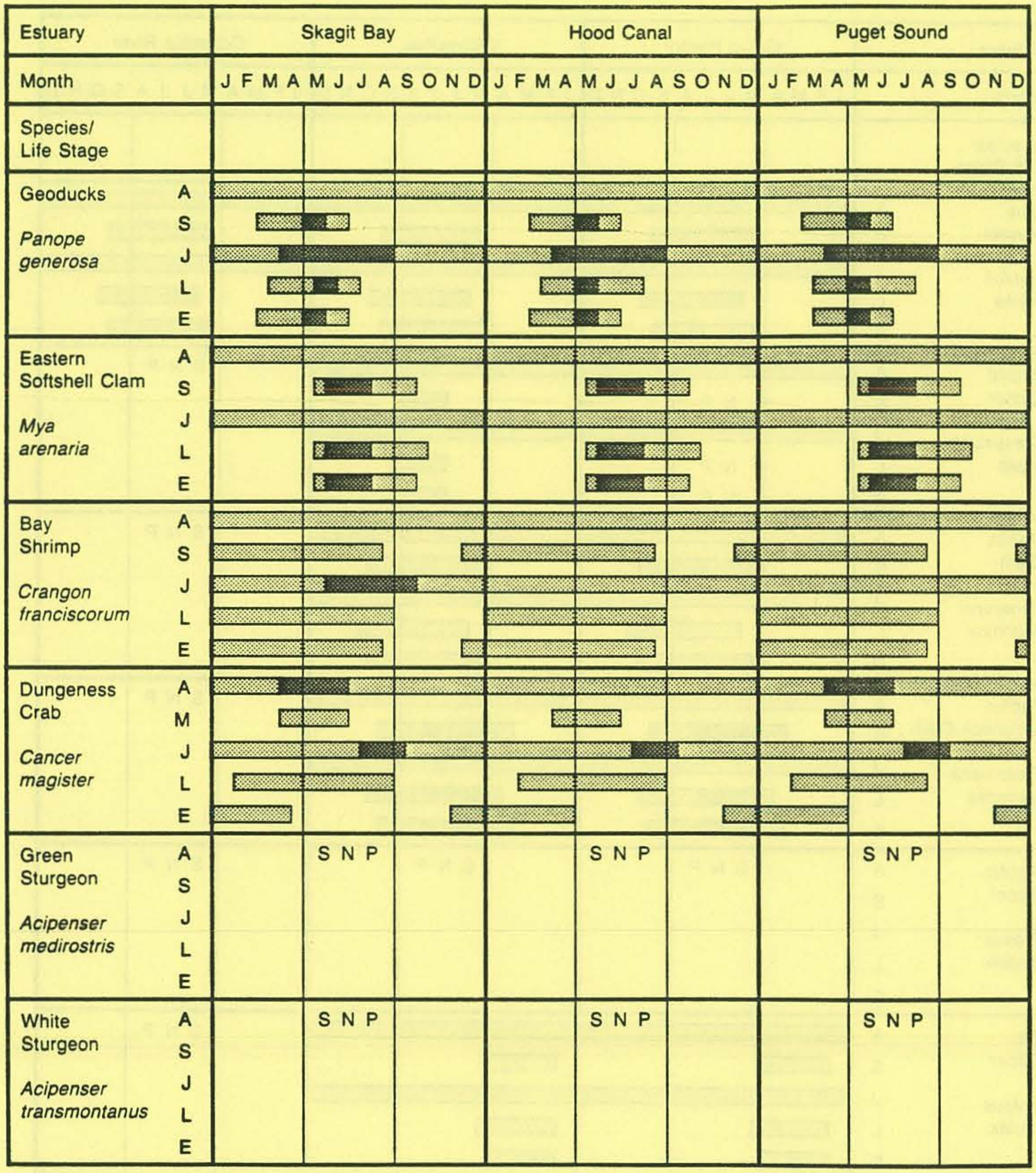
SNP = Species Not Present NP = Life Stage Not Present

A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

a Spring Run c Fall Run e Immigration g Spring Run

b Summer and Fall Run d Emigration f Winter Run

Table 3. Temporal Distribution



PEAK

| Range |

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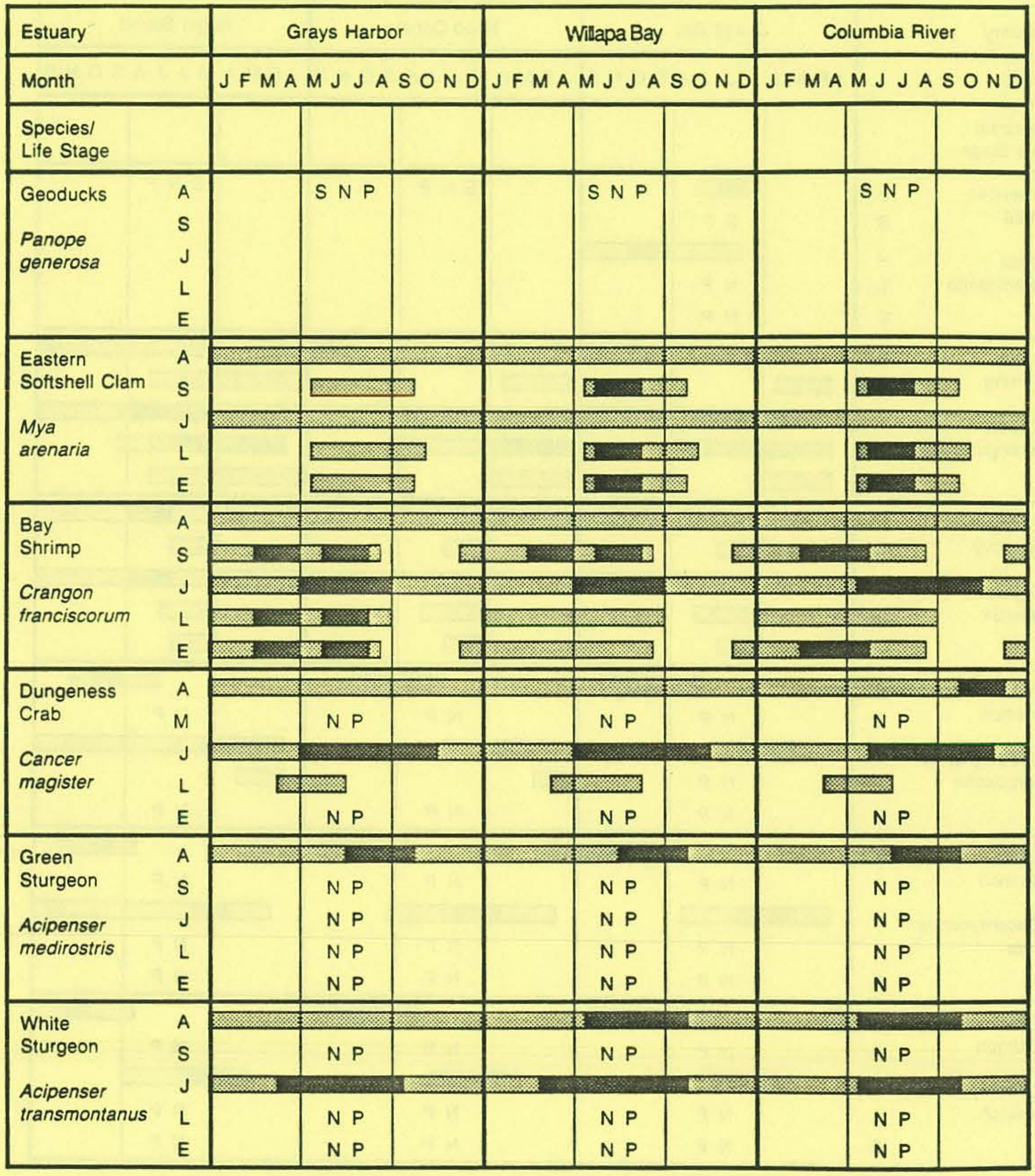


SNP = Species Not Present   NP = Life Stage Not Present

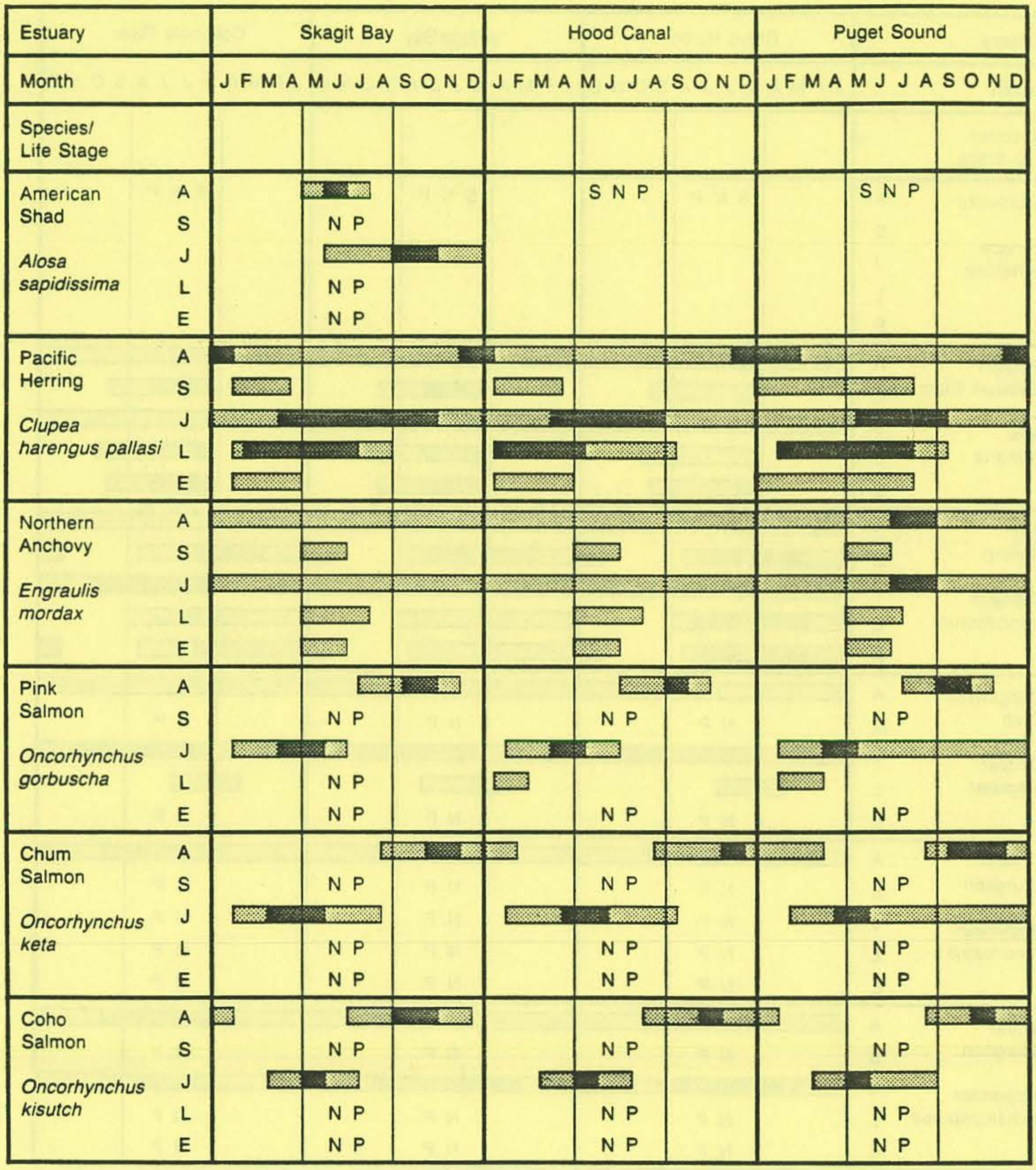
PEAK

| Range |

A—Adult   S—Spawning   J—Juvenile   L—Larva   E—Egg   M—Mating

a Spring Run
b Summer and Fall Run
c Fall Run
d Emigration
e Immigration
f Winter Run
g Spring Run

Table 3. Temporal Distribution



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PEAK

Range

A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

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e Immigration
f Winter Run
g Spring Run

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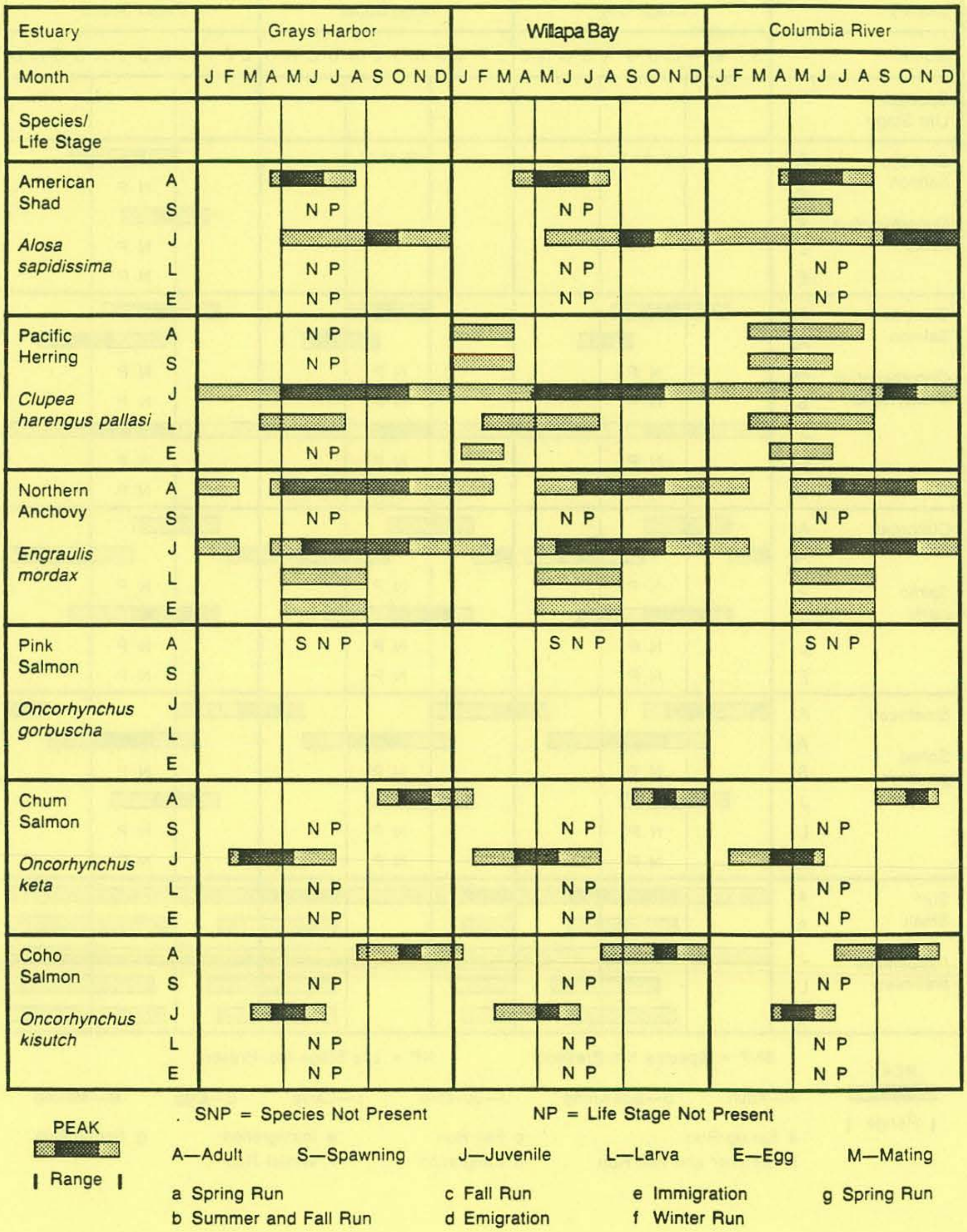
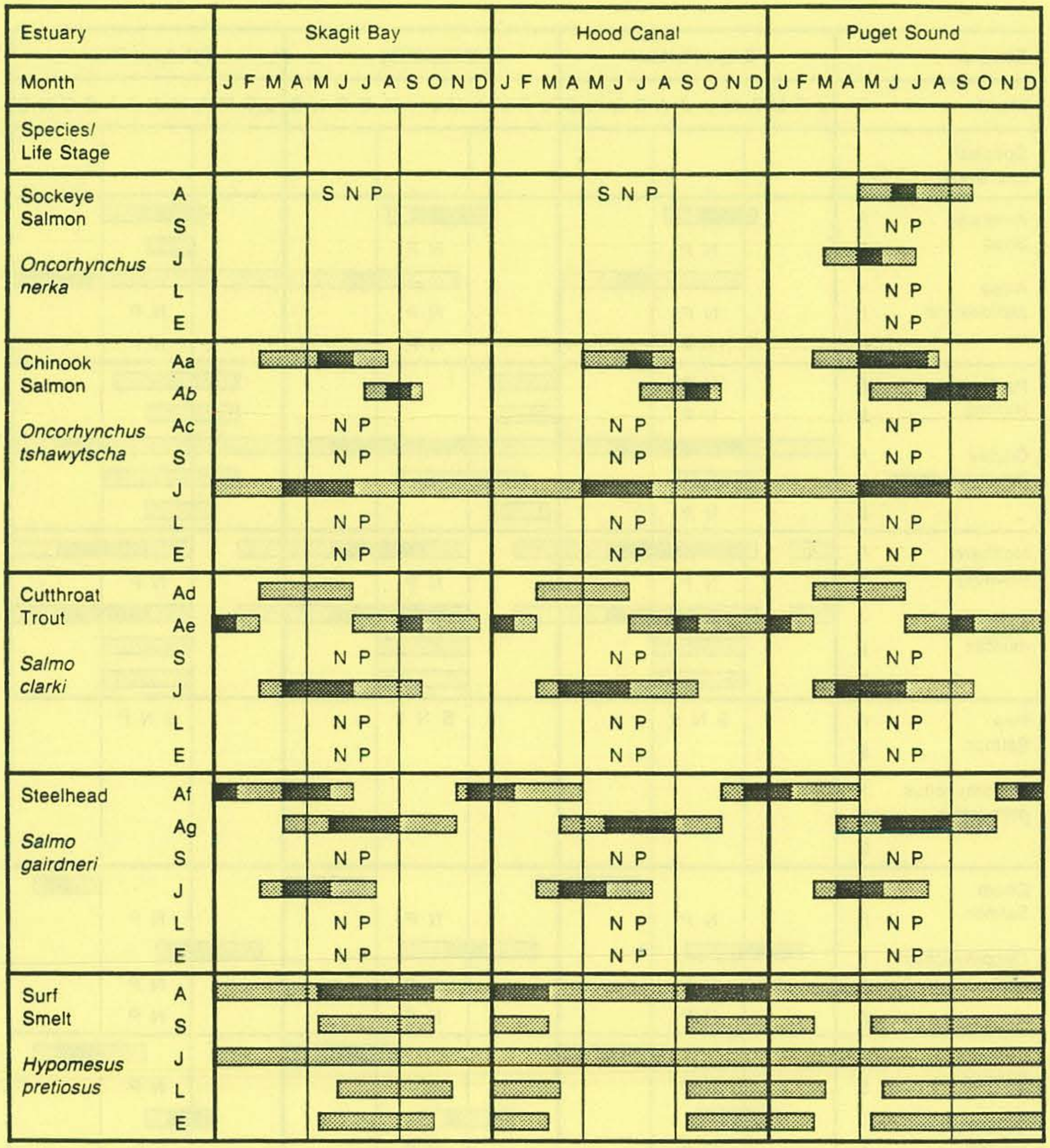


Table 3. Temporal Distribution



PEAK

| Range |

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A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

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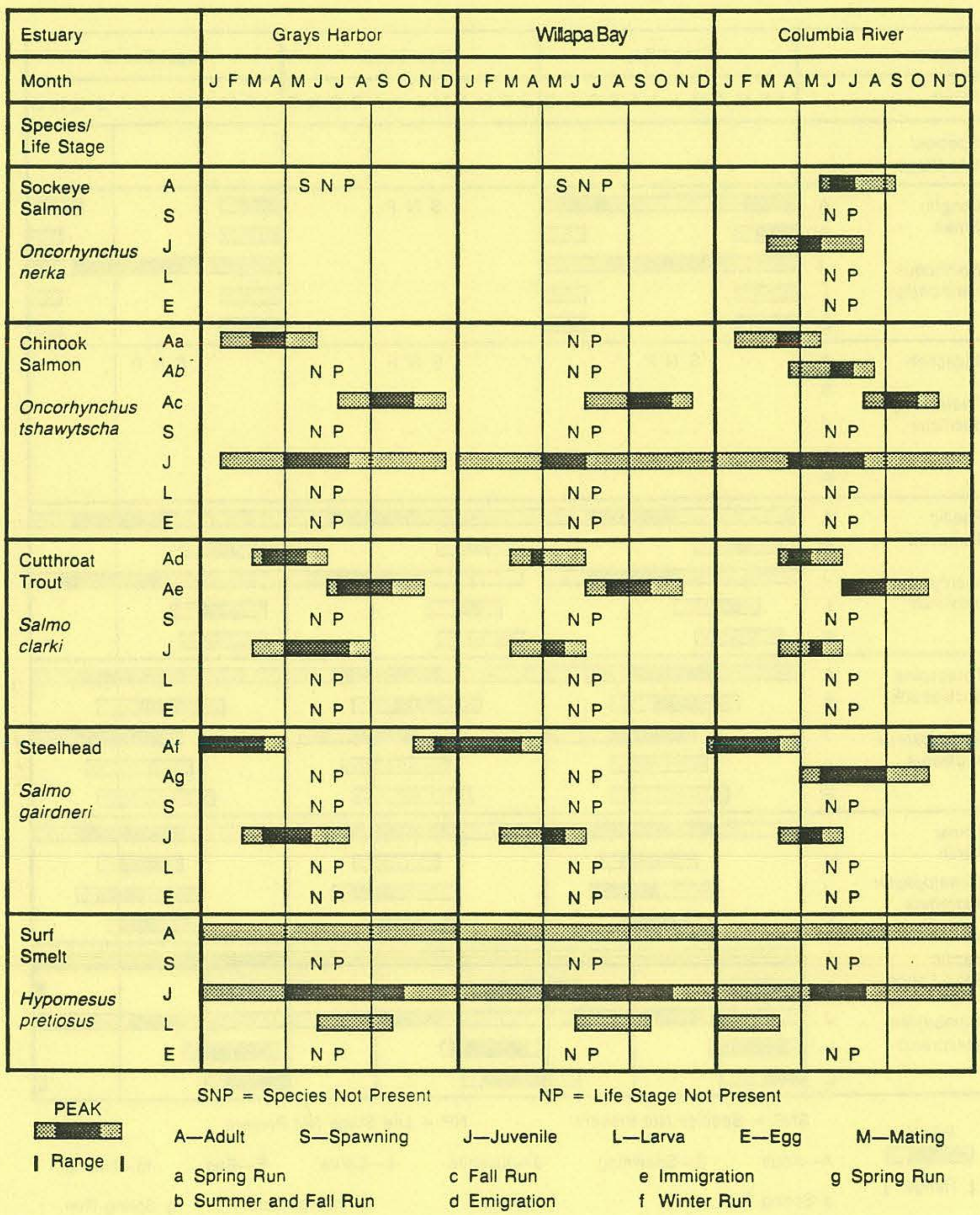
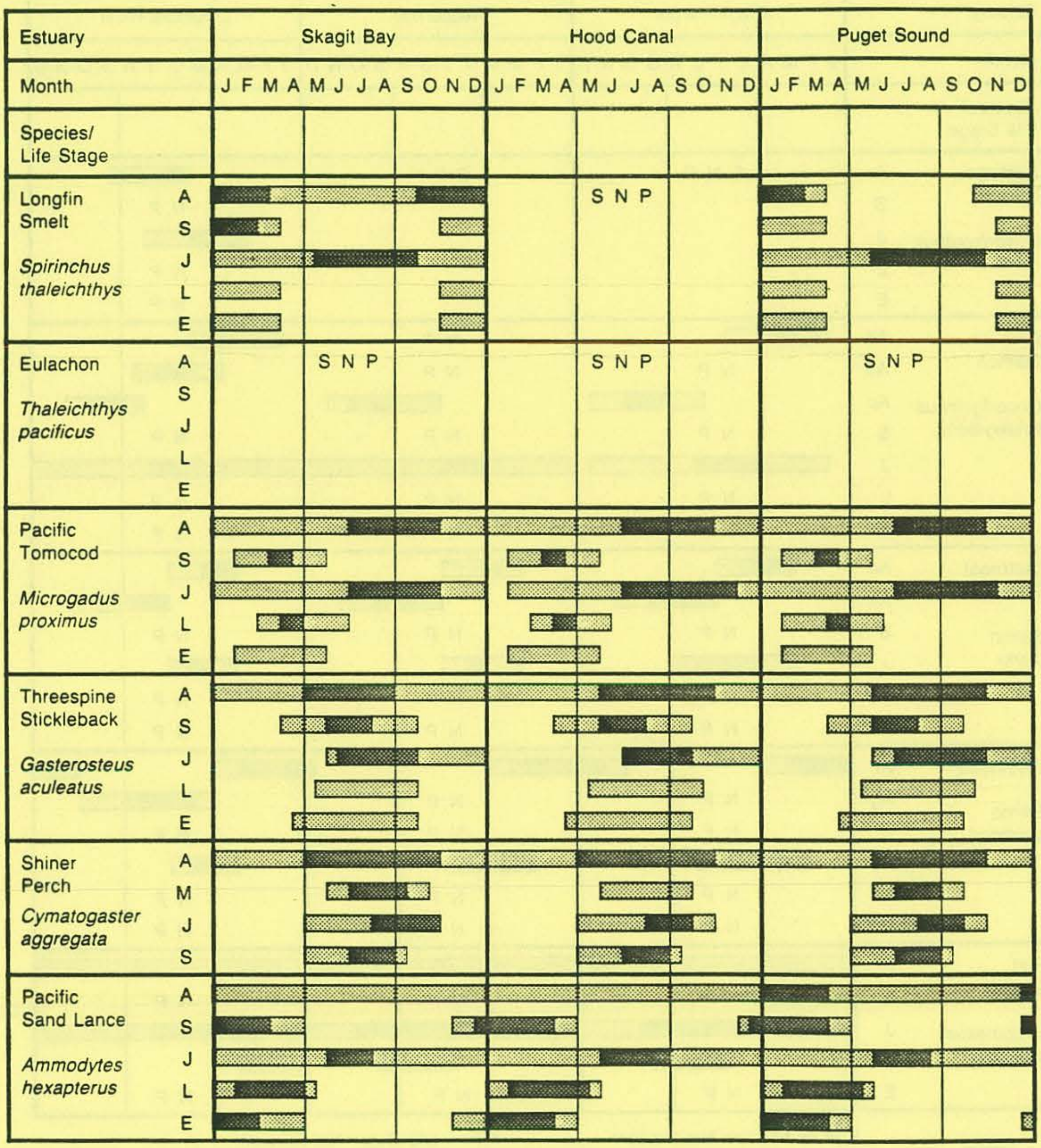


Table 3. Temporal Distribution



PEAK

| Range |

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A—Adult   S—Spawning   J—Juvenile   L—Larva   E—Egg   M—Mating

a Spring Run   c Fall Run   e Immigration   g Spring Run

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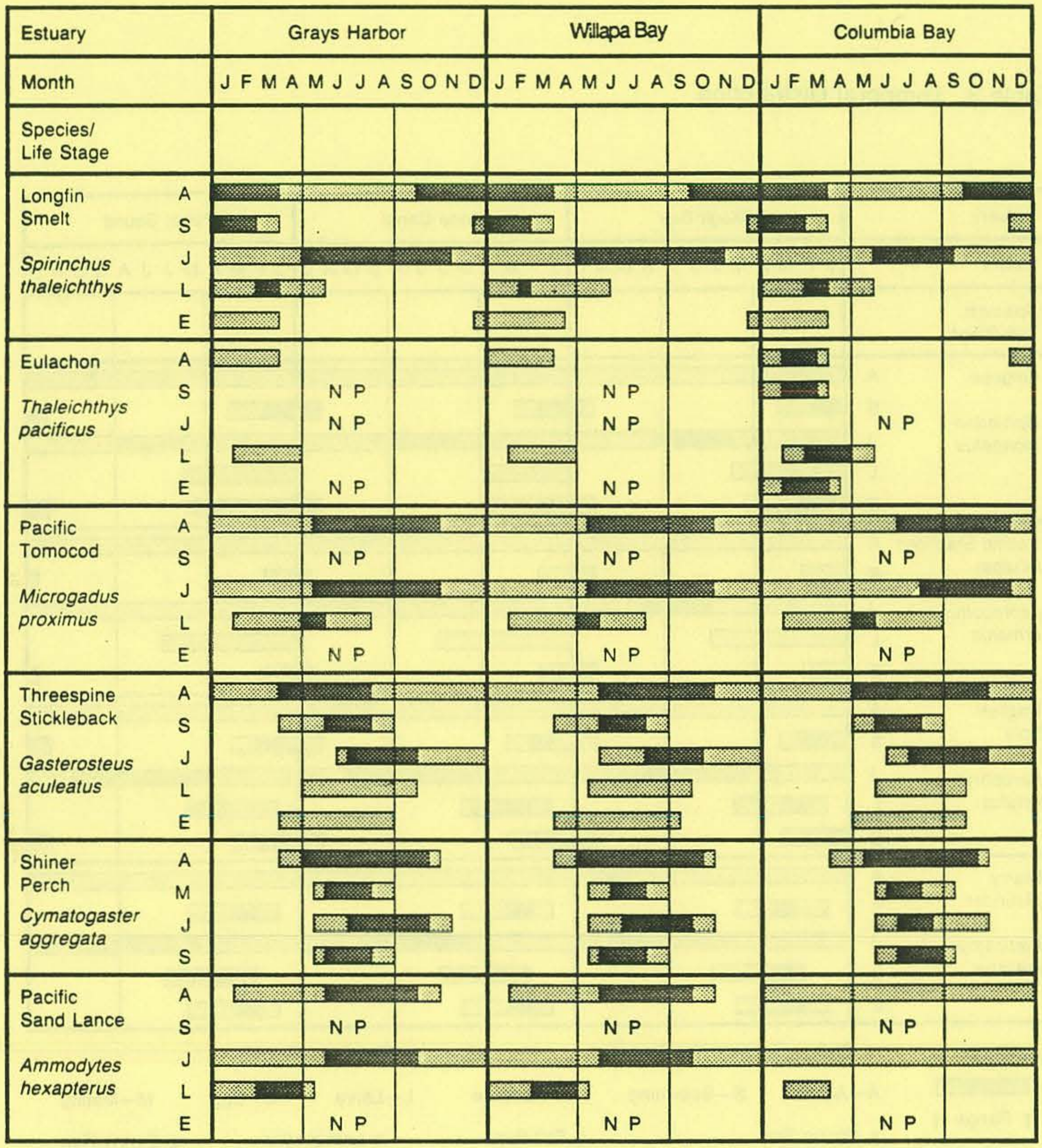

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PEAK

Range

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a Spring Run
b Summer and Fall Run
c Fall Run
d Emigration
e Immigration
f Winter Run
g Spring Run

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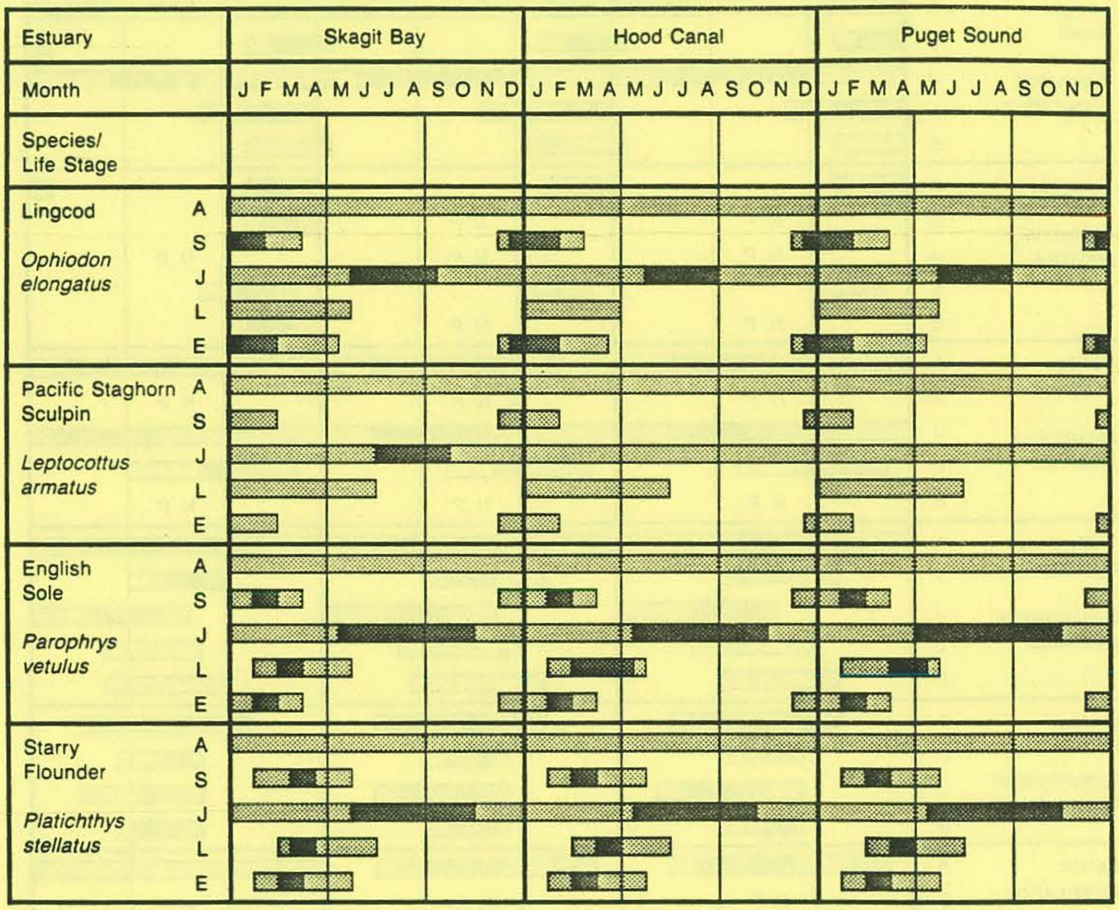

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PEAK

| Range |

A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

a Spring Run
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e Immigration
f Winter Run
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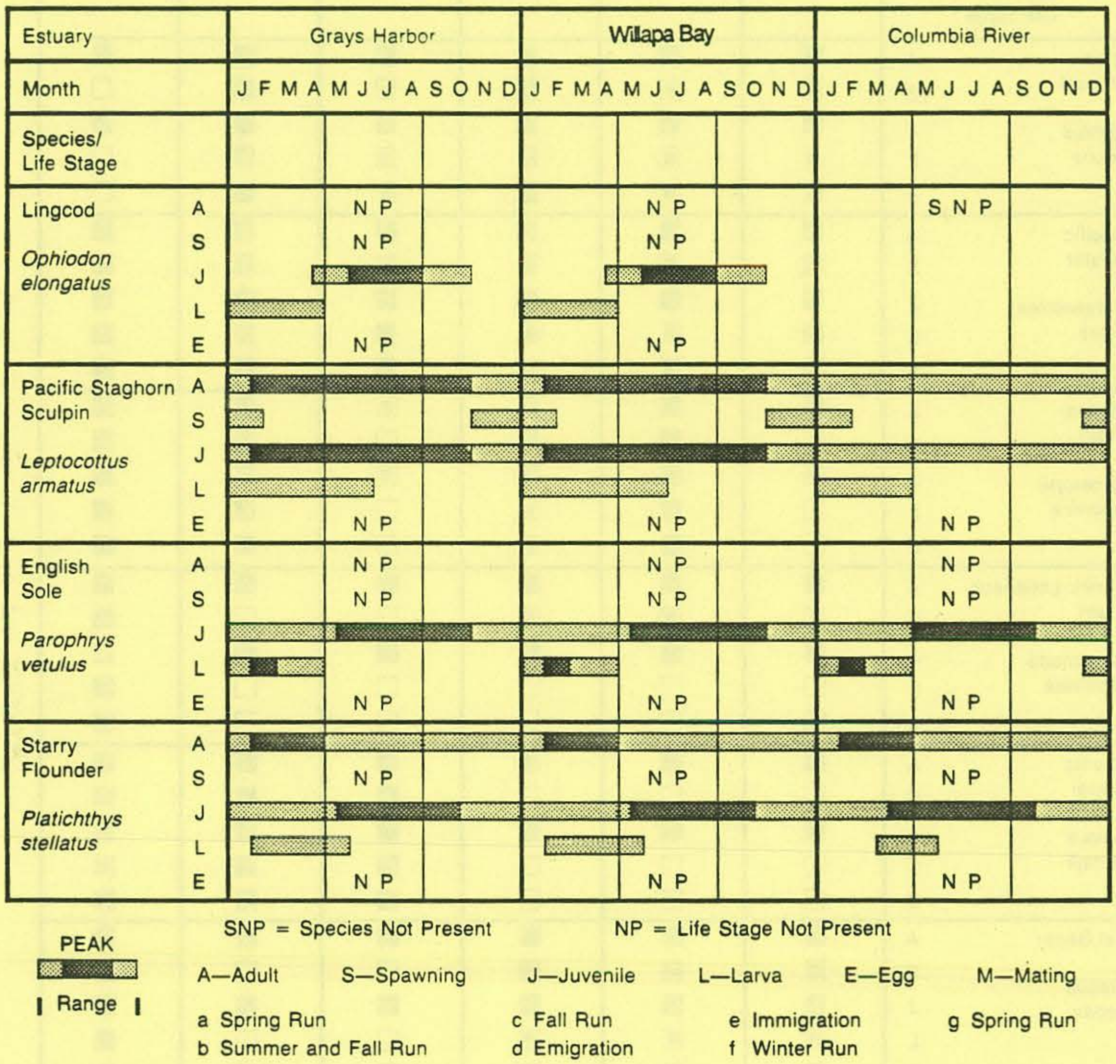

Table 4. Data Reliability

Species/ Life Stage		WASHINGTON ESTUARIES					
		Skagit Bay	Hood Canal	Puget Sound	Grays Harbor	Willapa Bay	Columbia River
Blue Mussel *Mytilus edulis*	A	■	■	■	■	■	■
	S	▣	▣	■	▣	■	□
	J	■	■	■	■	■	■
	L	▣	▣	■	▣	■	□
	E	▣	▣	■	▣	■	□
Pacific Oyster *Crassostrea gigas*	A	■	■	■	■	■	■
	S	■	▣	▣	■	■	■
	J	■	■	■	■	■	■
	L	■	▣	▣	■	■	■
	E	■	▣	▣	■	■	■
Manila Clam *Venerupis japonica*	A	■	■	■	▣	■	■
	S	□	■	■	□	■	■
	J	■	■	■	▣	■	■
	L	□	■	▣	□	■	■
	E	□	■	▣	□	■	■
Pacific Littleneck Clam *Protothaca staminea*	A	■	■	■	■	■	■
	S	▣	▣	▣	□	□	■
	J	■	■	■	■	■	■
	L	□	□	□	□	□	■
	E	□	□	□	□	□	■
Pacific Gaper *Tresus nuttalli*	A	■	■	■	■	■	■
	S	□	□	□	■	■	■
	J	■	■	■	■	■	■
	L	□	□	□	■	■	■
	E	□	□	□	■	■	■
Fat Gaper *Tresus capax*	A	■	■	■	■	■	■
	S	■	■	■	□	□	■
	J	■	■	■	■	■	■
	L	▣	▣	▣	□	□	■
	E	▣	▣	▣	□	□	■

■ Highly Certain ▣ Moderately Certain □ Reasonable Inference

A — Adult S — Spawning J — Juvenile L — Larva E — Egg M — Mating

Table 4. Data Reliability

Species/ Life Stage		WASHINGTON ESTUARIES Skagit Bay	Hood Canal	Puget Sound	Grays Harbor	Willapa Bay	Columbia River
Geoducks	A	■	■	■	■	■	■
	S	□	■	■	■	■	■
Panope generosa	J	■	■	■	■	■	■
	L	□	■	■	■	■	■
	E	□	■	■	■	■	■
Eastern Softshell Clam	A	■	■	■	■	■	■
	S	■	□	▣	□	□	□
Mya arenaria	J	■	■	■	■	■	■
	L	■	□	▣	□	▣	□
	E	■	□	▣	□	□	□
Bay Shrimp	A	■	□	■	■	□	■
	S	□	□	□	□	□	■
Crangon franciscorum	J	▣	□	▣	■	□	■
	L	□	□	□	□	□	□
	E	□	□	□	□	□	■
Dungeness Crab	A	■	▣	■	■	▣	■
	M	■	□	■	■	■	■
Cancer magister	J	■	□	■	■	■	■
	L	▣	□	▣	□	□	■
	E	■	□	▣	■	■	■
Green Sturgeon	A	■	■	■	▣	▣	■
	S	■	■	■	■	■	■
Acipenser medirostris	J	■	■	■	■	■	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
White Sturgeon	A	■	■	■	■	▣	■
	S	■	■	■	■	■	■
Acipenser transmontanus	J	■	■	■	▣	□	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■

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A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

Table 4. Data Reliability

Species/ Life Stage		WASHINGTON ESTUARIES					
		Skagit Bay	Hood Canal	Puget Sound	Grays Harbor	Willapa Bay	Columbia River
American Shad	A	□	■	■	■	□	■
	S	■	■	■	■	■	▣
Alosa sapidissima	J	□	■	■	■	□	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
Pacific Herring	A	■	■	■	■	□	■
	S	■	■	■	■	□	■
Clupea pallasi	J	■	■	■	■	□	■
	L	■	■	■	▣	□	■
	E	■	■	■	■	□	▣
Northern Anchovy	A	■	■	■	■	□	■
	S	▣	▣	▣	■	■	■
Engraulis mordax	J	■	■	■	■	□	■
	L	▣	▣	▣	▣	□	■
	E	▣	▣	▣	▣	□	■
Pink Salmon	A	■	■	■	■	■	■
	S	■	■	■	■	■	■
Oncorhynchus gorbuscha	J	■	■	■	■	■	■
	L	■	▣	▣	■	■	■
	E	■	■	■	■	■	■
Chum Salmon	A	■	■	■	■	■	■
	S	■	■	■	■	■	■
Oncorhynchus keta	J	■	■	■	■	▣	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
Coho Salmon	A	■	■	■	■	■	■
	S	■	■	■	■	■	■
Oncorhynchus kisutch	J	■	▣	■	■	▣	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■

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A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

Table 4. Data Reliability

Species/ Life Stage		WASHINGTON ESTUARIES Skagit Bay	Hood Canal	Puget Sound	Grays Harbor	Willapa Bay	Columbia River
Sockeye Salmon *Oncorhynchus nerka*	A	■	■	■	■	■	■
	S	■	■	■	■	■	■
	J	■	■	■	■	■	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
Chinook Salmon *Oncorhynchus tshawytscha*	A	■	■	■	■	■	■
	S	■	■	■	■	■	■
	J	■	▣	■	■	▣	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
Cutthroat Trout *Salmo clarki*	A	▣	■	■	▣	▣	■
	S	■	■	■	■	■	■
	J	▣	▣	▣	▣	▣	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
Steelhead *Salmo gairdneri*	A	■	■	■	■	▣	■
	S	■	■	■	■	■	■
	J	■	▣	▣	■	□	■
	L	■	■	■	■	■	■
	E	■	■	■	■	■	■
Surf Smelt *Hypomesus pretiosus*	A	▣	■	■	■	□	■
	S	■	■	■	■	□	■
	J	■	▣	■	■	□	■
	L	■	■	■	■	□	■
	E	■	■	■	■	□	■
Longfin Smelt *Spirinchus thaleichthys*	A	■	■	▣	▣	□	■
	S	□	■	▣	■	□	▣
	J	■	■	▣	▣	□	■
	L	□	■	▣	□	□	■
	E	■	■	▣	□	□	▣

■ Highly Certain ▣ Moderately Certain □ Reasonable Inference

A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

Table 4. Data Reliability

Species/ Life Stage		WASHINGTON ESTUARIES					
		Skagit Bay	Hood Canal	Puget Sound	Grays Harbor	Willapa Bay	Columbia River
Eulachon	A	■	■	■	□	□	■
	S	■	■	■	■	■	■
Thaleichthys pacificus	J	■	■	■	■	■	■
	L	■	■	■	□	□	■
	E	■	■	■	■	■	■
Pacific Tomocod	A	■	▣	▣	■	□	■
	S	□	□	▣	▣	□	■
Microgadus proximus	J	▣	▣	▣	■	□	■
	L	■	□	□	□	□	■
	E	□	□	□	▣	□	■
Threespine Stickleback	A	■	■	■	▣	□	■
	S	▣	□	□	□	□	■
Gasterosteus aculeatus	J	□	□	■	▣	□	■
	L	□	□	□	□	□	□
	E	□	□	□	□	□	□
Shiner Perch	A	■	■	■	■	□	■
	M	□	□	▣	□	□	□
Cymatogaster aggregata	J	▣	□	▣	▣	□	■
	S	■	■	▣	■	□	■
Pacific Sand Lance	A	■	▣	■	■	□	■
	S	□	□	▣	■	■	■
Ammodytes hexapterus	J	▣	▣	■	■	□	■
	L	■	□	▣	▣	□	■
	E	▣	□	▣	■	■	■
Lingcod	A	▣	■	■	■	■	■
	S	□	■	■	■	■	■
Ophiodon elongatus	J	▣	■	■	■	□	■
	L	□	□	□	□	□	■
	E	▣	■	■	■	■	■

■ Highly Certain ▣ Moderately Certain □ Reasonable Inference

A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

Table 4. Data Reliability

Species/ Life Stage		WASHINGTON ESTUARIES					
		Skagit Bay	Hood Canal	Puget Sound	Grays Harbor	Willapa Bay	Columbia River
Pacific Staghorn Sculpin	A	■	▣	■	■	□	■
	S	▣	□	□	□	□	■
Leptocottus armatus	J	■	□	■	■	□	■
	L	■	□	□	□	□	■
	E	▣	□	□	□	□	□
English Sole	A	■	■	■	■	■	■
	S	▣	□	▣	■	■	■
Parophrys vetulus	J	■	▣	▣	■	□	■
	L	■	□	▣	▣	□	■
	E	▣	□	□	■	■	■
Starry Flounder	A	■	■	■	■	□	■
	S	■	□	□	■	■	■
Platichthys stellatus	J	■	□	▣	■	□	■
	L	■	□	▣	□	□	■
	E	▣	□	□	□	□	□

■ Highly Certain ▣ Moderately Certain □ Reasonable Inference

A—Adult S—Spawning J—Juvenile L—Larva E—Egg M—Mating

APPENDICIES

Appendix I. Estuaries and Embayments of the National Estuarine Inventory

Appendix II. Complete West Coast Species List

Appendix III. Selected Species Profiles and Worksheets

Appendix IV. Personal Communications

Appendix V. Primary References and Personal Communications

Appendix I. Estuaries and Embayments of the NEI

Northeast Region

Passamaquoddy Bay
Englishman Bay
Narraguagus Bay
Blue Hill Bay
Penobscot Bay
Muscongus Bay
Sheepscot Bay
Casco Bay
Saco Bay
Great Bay
Merrimack River
Massachusetts Bay
  Boston Bay*
Cape Cod Bay
Buzzards Bay
Narragansett Bay
Gardiners Bay
Long Island Sound
  Connecticut River*
Great South Bay
Hudson River/Raritan Bay
Barnegat Bay
Delaware Bay
Delaware Inland Bays
Chincoteague Bay
Chesapeake Bay
  Potomac River*
  Rapppahannock River*
  York River*
  James River*

Southeast Region

Albemarle Sound
Pamlico Sound
  Pamlico and Pungo Rivers*
  Neuse River*
Bogue Sound
New River
Cape Fear River
Winyah Bay
North & South Santee Rivers
Charleston Harbor
St. Helena Sound
Broad River
Savannah River
Ossabaw Sound
St. Catherines/Sapelo Sound
Altamaha River
St. Andrew/St. Simons Sound
St. Johns River
Indian River
Biscayne Bay
Florida Bay**

Gulf Region

Ten Thousand Islands
Charlotte Harbor
  Caloosahatchee River*
Sarasota Bay
Tampa Bay
Suwanee River
Apalachee Bay
Apalachicola Bay
St. Andrew Bay
Choctawhatchee Bay
Pensacola Bay
Peridido Bay
Mobile Bay
Mississippi Sound
  Lake Borgne*
  Lake Pontchartrain*
Breton/Chandeleur Sounds
Mississippi River
Barataria Bay
Calcasieu Lake
Sabine Lake
Terrebonne/Timbalier Bays
Atchafalaya/Vermilion Bays
Galveston Bay
Brazos River
Matagorda Bay
San Antonio Bay
Aransas Bay
Corpus Christi Bay
Laguna Madre
  Baffin Bay*

West Region

Tijuana Estuary
San Diego Bay
Mission Bay**
Newport Bay**
San Pedro Bay
  Alamitos Bay**
  Anaheim Bay**
Santa Monica Bay
Monterey Bay
  Elkhorn Slough**
San Francisco Bay
  South San Francisco Bay**
  Central San Francisco/
  San Pablo/Suisun Bays**
Tomales Bay**
Eel River
Humboldt Bay
Klamath River
Rogue River
Coos Bay
Winchester Bay
Siuslaw River
Alsea Bay
Yaquina Bay
Siletz Bay
Netarts Bay
Tillamook Bay
Nehalem River
Columbia River
Willapa Bay
Grays Harbor
Puget Sound
  Hood Canal*
  Skagit Bay*

* = Subsystem

** = Only Living Marine Resource Data Compiled for these systems

Appendix II. Complete West Coast Species List

Blue Mussel *Mytilus edulis*	**Lepard Shark** *Triakis semifasciata*	**Chinook Salmon** *Oncorhynchus tshawytscha*	**Barred Sand Bass** *Paralabrax nebulifer*
Pacific Oyster *Crassostrea gigas*	**Green Sturgeon** *Acipenser medirostris*	**Cutthroat Trout** *Salmo clarki*	**White Seabass** *Atractoscion noblis*
Manila Clam *Venerupis japonica**	**White Sturgeon** *Acipenser transmontanus*	**Steelhead** *Salmo gairdneri***	**White Croaker** *Genyonemus lineatus*
Pacific Littleneck Clam *Protothaca staminea*	**American Shad** *Alosa sapidissima*	**Surf Smelt** *Hypomesus pretiosus*	**Shiner Perch** *Cymatogaster aggregata*
Pacific Gaper *Tresus nuttalli*	**Pacific Herring** *Clupea pallasi*	**Longfin Smelt** *Spirinchus thaleichthys*	**Arrow Goby** *Clevelandia ios*
Fat Gaper *Tresus capax*	**Northern Anchovy** *Engraulis mordax*	**Eulachon** *Thaleichthys pacificus*	**Pacific Sand Lance** *Ammodytes hexapterus*
California Jackknife Clam *Tagelus californianus*	**Deepbody Anchovy** *Anchoa compressa*	**Pacific Tomocod** *Microgadus proximus*	**Lingcod** *Ophiodon elongatus*
Geoduck *Panope generosa*	**Slough Anchovy** *Anchoa delicatissima*	**Topsmelt** *Atherinops affinis*	**Pacific Staghorn Sculpin** *Leptocottus armatus*
Eastern Softshell Clam *Mya arenaria*	**Pink Salmon** *Oncorhynchus gorbuscha*	**Jacksmelt** *Atherinopsis californiensis*	**California Halibut** *Paralichthys californicus*
Bay Shrimp *Crangon franciscorum*	**Chum Salmon** *Oncorhynchus keta*	**Threespine Stickleback** *Gasterosteus aculeatus*	**Diamond Turbot** *Hypsopsetta guttulata*
Dungeness Crab *Cancer magister*	**Coho Salmon** *Oncorhynchus kisutch*	**Striped Bass** *Morone saxatilis*	**English Sole** *Parophrys vetulus*
	Sockeye Salmon *Oncorhynchus nerka*	**Kelp Bass** *Paralabrax clathratus*	**Starry Flounder** *Platichthys stellatus*

* = *Tapes philippinarum*

Minor modifications of this list will occur as the study continues

** = *Parasalmo mykiss*

Common Name: Chum salmon

Scientific Name: Onchorynchus keta (Walbaum)

Other Common Names: Dog salmon, calico salmon, chub, fall salmon, (Shiino 1976).

Classification

Phylum:	Chordata
Class:	Osteichthyes
Order:	Salmoniformes
Family:	Salmonidae (Robins et al. 1980)

Value

Commercial: The most important salmon to Japanese commercial fisherman (Forrester 1981), but third in importance to U.S. fisherman (Thompson 1986). From 1980-84, close to 94 million pounds were landed by U.S. fisherman with the 1985 catch worth over $36 million. Commercially fished in North American waters from Oregon to Alaska. However, most (75percent) are landed in Alaskan waters, with only Puget Sound, Washington, producing any sizable landings outside Alaska (Forrester 1981). Chum salmon are captured primarily by fixed or drift gillnets and purse seines. Generally caught during June-September in Alaska and September-December in Washington (Forrester 1981).

Recreational: Not a target sport fish in marine waters (Scott and Crossman 1973), but sometimes fished in rivers that have good runs. The marine sport catch is low and is grouped with sockeye salmon (also not often taken) in the reported marine sport catches (PMFC 1985, 1986). This species does not strike lures or baits as well as other salmon (coho and chinook) and its flesh does not have the oil content of other salmon species.

Indicator of Environmental Stress: The freshwater, estuarine, early marine life stages appear to be critical for this species (Shepard 1981).

Ecological: The second most abundant salmonid in the north Pacific region (Forrester 1981). Chum salmon have the widest distribution of any Pacific salmon (Bakkala 1970).

Range

Overall: In North America, they inhabit coastal streams from the Sacramento River, California, occasionally as far south as the San Lorenzo River (Moyle 1976), northward to the Arctic shore of Alaska (Atkinson et al. 1967; Aro and Shepard 1967; Hallock and Fry 1967) and as far east as the Mackenzie River, Canada. In Asia they are found south to Tone River of Chiba Prefecture on the Pacific side of Honshu, in Nagasaki Prefecture of Kyushu in the Sea of Japan, and in the Nakdong River of the Republic of Korea (Sano 1967; Bakkala 1970). In Asia, most spawning occurs in the lower 100 km of coastal streams, however chum salmon spawn 2,500 km from the sea in both the Amur River of the U.S.S.R. and the Yukon River of Alaska and Canada (Sano 1966; Bakkala 1970). Their oceanic distribution ranges from the Bering Sea to about 40 N Lat. in the western Pacific Ocean and approximately 44 N Lat. in the eastern Pacific Ocean (Neave et al. 1976; Fredin et al. 1977).

Within Study Area: Primarily found in Oregon and Washington north of the Rogue River, Oregon (Atkinson et al. 1967; Ratti 1979), with the southern most run found in the Sacramento River, California (Hallock and Fry 1967). In the ocean they can be found as far south as San Diego, California (Eschmeyer et al. 1983).

Life Mode

Anadromous species. Eggs and alevins (yolk-sac larvae) are benthic and infaunal; fry and adults are benthopelagic; ocean dwelling juveniles are epipelagic (Sano 1966; Bakkala 1970; Fredin et al. 1977).

Habitat

Type: Eggs and alevins occur in rivers and streams, from intertidal areas to 2,500 km upriver in large river systems (Bakkala 1970), but they are normally found in riverine areas less than 200 km from the sea (Sano 1966). Fry are found in rivers, estuaries, and marine waters, but prefer shallow waters (nearshore and intertidal areas <1.0 meters) during their initial outmigration (Bakkala 1970; Healey 1980) before moving out to sea. Once at sea, juveniles are primarily epipelagic (0-60 meters) (Manzer 1964), but may be found to depths of 95 m (LeBrasseur and Barner 1964). Adults occur in neritic, estuarine, and riverine waters (Bakkala 1970; Fredin et al. 1977).

Substrate
Eggs and alevins are found primarily in medium-sized gravel (about 2-4 cm in diameter) (Bakkala 1970; Alaska Dept. of Fish and Game 1985), and are buried down to 40 cm (Moyle 1976). Recommended spawning gravels range from 1.3-10.2 cm (Reiser and Bjornn 1979). Burner (1951) found Columbia River redds were composed of 81percent medium and small gravel (< 15 cm diameter), 13 percent large gravel (> 15 cm), and 6 percent mud-silt-sand. Fry initially occur in shallow areas of varying substrate.

Physical/Chemical Characteristics
Recommended spawning temperatures range from 7.2-12.8 C, with incubation temperatures 4.4-13.3 C (Bell 1984). Eggs can survive lower temperatures provided initial development has progressed to a stage that is cold-water tolerant (Reiser and Bjornn 1979). Optimum outmigration temperatures for fry are 6.7-13.3 C (Bell 1984). Ocean dwelling juveniles occur in waters of 1.0-15.0 C, but prefer 2.0-11.0 C. Adults migrate upstream in temperatures of just above freezing to 21.1 C, but optimum temperatures are 8.3-15.6 C. Upper lethal temperature is 25.6 C, lower lethal is 0.0 C (Bell 1984). Adults migrate upstream in velocities up to 2.44 m/sec and successfully spawn in velocities of 46-101 cm/sec (Reiser and Bjornn 1979). Dissolved oxygen (DO) levels below saturation can adversely affect swimming performance of adults; DO values above 80 percent saturation, with temporary levels no lower than 5.0 mg/l, are recommended for spawning (Reiser and Bjornn 1979). Eggs and alevins are primarily freshwater, but can tolerate euhaline conditions for short periods (McNeil 1966). Fry show a preference for salt water and cannot live for extended periods in fresh water (Baggerman 1960). A limited residence in mesohaline (10-15 ppt) estuarine environment may be needed for complete adaptation to seawater (Iwata and Komatsu 1984).

Other
Buttoned-up alevins show abnormal behavior at pH 6.0 (Rombough 1983). Incubation temperatures affect alevins length at hatching (Beacham and Murray 1987).

Migrations and Movements
An anadromous species that is highly migratory. Chum salmon migrate seaward immediately after emerging from the spawning gravel, although some may reside in freshwater for several months (Simenstad et al. 1982). They migrate primarily at night in small rivers and sometimes during daylight in larger rivers (Bakkala 1970). Chums are typically 30-55 cm in length when they enter estuaries from March to mid-May, however some may be larger, depending on the duration of the migration (Moyle 1976). Once chum salmon enter estuaries, their migration typically slows and many will rear for up to several months in the estuary (Healey 1982; Levy and Northcote 1982; Simenstad et al. 1982). Salinity increases schooling behavior (Shelboun 1966). Chums occur in Washington estuaries from January to July, with peak abundance occurring from late March to mid-May. Most chum salmon are gone from Oregon estuaries by mid-May (Myers 1980). Chums will move in and out of tidal creeks, sloughs, marsh habitats, and intertidal areas as the tide fluctuates (Mason 1974; Healey 1982). Besides this daily tidal movement, there is a general movement seaward as they grow (Healey 1982). Individual chums may spend 4-32 days in estuaries with residency varying seasonally. In some stocks, early migrants may reside longer than later migrants, while in other stocks the opposite is true (Healey 1979; Simenstad et al. 1982; Kaeriyama 1986). Most chums move offshore in April-June when they average 80-100 mm in fork length (Healey 1982). Some chums do not appear to migrate out of Puget Sound (Hartt and Dell 1986). Once in the ocean, migrating chum salmon head north but stay along the continental shelf until fall when they disperse out into the Gulf of Alaska (Hartt and Dell 1986) where they mix with other salmon species and other age groups of chums. Immature fish move about 28 km/day, while maturing fish average 35 km/day (Neave et al. 1976). Immature chum salmon are temperature sensitive and move south in the North Pacific in winter and north in summer (Neave

et al. 1976). They spend from 0.5 to 6 years at sea (generally 3-5 years) before returning to their natal stream where they occur from June-September in most of Alaska (McPhail and Lindsey 1970), and from October-January in Oregon and Washington (Bell 1984).

Reproduction
Mode: Sexual, separate sexes, oviparous (Bakkala 1970).

Spawning: Two spawning populations exist—a northern stock that spawns from June-September, and a southern stock that spawns during August-January (Sano 1966; Bakkala 1970). Washington, Oregon, and California stocks are all-late run stocks. Chum salmon are sexually dimorphic when mature—males having a hooked snout, a slight hump, and more fanglike teeth than females (Bakkala 1970). As with other salmonids, the female chum builds the nest by turning on her side and excavating the nest by fanning the streambed with her caudal fin (Bakkala 1970). During spawning, the male and female will settle into the nest, their mouths agape. Eggs and milt are released while the fish quiver (Scott and Crossman 1973). After laying the eggs the female will cover the eggs by digging upstream. The process continues until the female is spent. Males may spawn with more than one female and both are aggressive on the spawning grounds. An average redd is 2.8 m2 (Reiser and Bjornn 1979). The female will guard the redd as long as she is able but all chums die after spawning. Chum salmon may spend less than a week in fresh water because they may be sexually mature when they reach fresh water (Scott and Crossman 1973).

Reproductive Capacity: Large females may lay over 4,000 eggs, but on average 2,400-3,000 eggs are laid (Scott and Crossman 1973). Late-run southern stocks are more fecund than early run stocks (Sano 1966; Bakkala 1970). This may be a function of size differences in the stocks.

Growth and Development
Egg size: Eggs are reported to be 7.0-8.7 mm (Bell 1984) and 6.0-9.5 mm (Bakkala 1970) in diameter after fertilization.

Embryonic Development: Indirect and external. Eggs take from 0.5-4.5 months to hatch (depending on temperature), with hatching usually occurring from December-February (McPhail and Lindsey 1970; Scott and Crossman 1973). Alevins take 30-50 days to absorb their yolk-sac; the exact length of time depending on temperatures (Wydoski and Whitney 1979).

Larval Size Range: Alevins are 20.0-24.0 mm long at hatching (Bakkala 1970; Kaeriyama 1986; Beacham and Murray 1987) and grow to 30.0-35.0 mm before leaving the gravel (Moyle 1976; Wydoski and Whitney 1979).

Juvenile Size Range: Fresh water fry are 30.0-35.0 mm to 70.0 mm, depending on the distance between the estuary and spawning grounds (Scott and Crossman 1973). Growth in the ocean is rapid; by the end of their first year at sea they will average over 30.0 cm in length and after five years, 50.0 cm (Fredin et al. 1977).

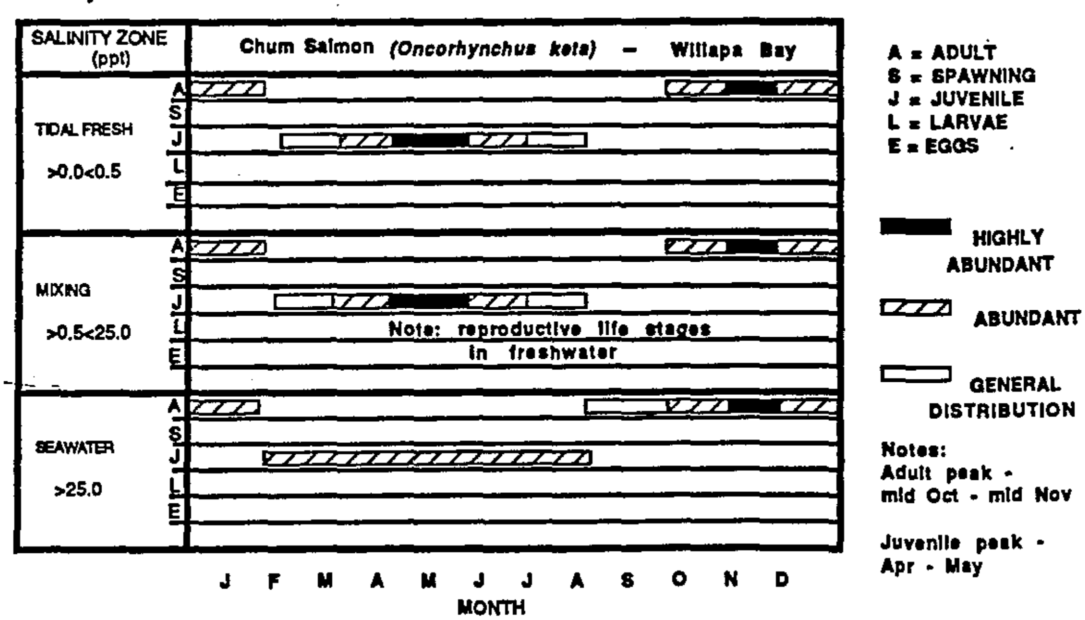
Age and Size of Adults: Adults return to spawn at ages 2 to 7 (primarily 3-5) (Scott and Crossman 1973). Bell (1984) reported that chum salmon average 63.5 cm in length and 4.0 kg at maturity but Squire and Smith (1977) reported they can grow up to 107 cm in length and their average weight is 4.5-5.3 kg at maturity. This parameter varies widely, depending on stock and run.

Food and Feeding
Trophic Mode: Carnivore.

Food Items: Alevins live primarily off their yolk-sac. Fry may not feed in fresh water if their migration to estuarine waters is quick, however, if freshwater residency is lengthy, fry will feed on aquatic and terrestrial insects and small crustaceans. Chironomid larvae appear to be particularly important (Sano 1966; Bakkala 1970; Scott and Crossman 1973). Feeding in nearshore marine areas and estuaries by fry and fingerlings appears to be an important component of chum salmon life history (Healey 1980; Simenstad 1983). Initially chums feed in shallow waters and concentrate on epibenthic prey, such as harpacticoid copepods and gammarid amphipods, but they may also eat terrestrial insects and other small crustacea (Healey 1979; Simenstad and Salo 1982; Kaeriyama 1986). Young chums are size-selective feeders (Feller and Kaczynski 1975). Food limitation in shallow waters may induce movement to deeper waters (Healey 1980; Simenstad and Salo 1982) where their diet shifts to include more pelagic prey, such as calanoid copepods, hyperiid amphipods, crustacean larvae, and larvaceans (Fresh et al. 1981; Simenstad and Salo 1982; Kaeriyama 1986). In the ocean, they feed on euphausiids, hyperiid amphipods, squids, pteropods, crab larvae, and fishes (Allen and Aron 1958; Andrievskaya 1957; LeBrasseur 1966; Peterson et al. 1982; Pearcy et al. 1984).

Biological Interactions
Predation: In freshwater and estuarine environments the primary predators are probably other salmonids. Chum fry are reportedly eaten by juvenile coho, sockeye, and chinook salmon; cutthroat and rainbow trout; Dolly Varden; sculpins; Pacific cod; and birds and ducks (kingfishers, merganser, and others) (Bakkala 1970; Scott and Crossman 1973; Bax et al. 1980; Fresh 1984). Predation is variable, depending on such factors as predator and prey size, the amount of yolk on the fry, abundance of fry, and composition of other prey (Hunter 1959; Fresh and Schroder 1987). At sea, they are preyed on by lamprey, sharks, and probably other large predatory fishes. Adult chum salmon are eaten by marine mammals (killer whales, harbor seals ect.) (Fiscus 1980), land mammals (bears), and large predatory birds (osprey and eagles) (Scott and Crossman 1973).

Factors Influencing Populations: To augment natural production, chum salmon are produced by hatcheries in Oregon, Washington, Alaska, Canada, U.S.S.R., and Japan (Atkinson et al. 1967, Sano 1967). Over 23.7 million were released from hatcheries along the Pacific coast in 1976 (Wahle and Smith 1979). However, in 1983, over 83 million chum fry were released in Washington State alone (Hill 1984). Most natural mortality occurs in freshwater during the embryonic stage as a result of poor environmental conditions, such as siltation, low dissolved oxygen, spawning gravel disruptions, and freezing (McNeil 1966; Wydoski and Whitney 1979). Beacham and Starr (1982) concluded that freshwater survival in the Fraser River, Canada, was mostly a function of interactions among temperature, rainfall, and egg abundance. Human alterations of freshwater habitat caused by improper logging practices, hydroelectric and irrigation developments, channelization, chemical and pollutant introductions, and other factors, can lower salmon production (Bottom et al. 1985). Besides their freshwater life history portion, chums appear to have a critical early marine residence period that can affect the eventual number of returning adults (Bakkala 1970; Bax 1983). For example, Bax (1983) showed that chum salmon in Puget Sound can have high early marine mortality. Parker (1971) suggested that chum salmon fry must "outgrow" their marine predators. There also appear to be adverse interactions between pink salmon and chum salmon, with fewer chums returning on pink years than non-pink years (Ames 1983; Fresh 1984). Beacham and Starr (1982) suggested that competition between chum and pink salmon in the Fraser River estuary or Strait of Georgia reduces eventual adult chum salmon abundance. Andrievskaya (1970) found that in years of low pink salmon abundance, chum and pink salmon in the ocean would eat similar prey, but in years of high pink abundance, chum salmon would consume different prey. Fishing pressure also affects abundance. The Japanese have high seas salmon fishing fleets (restricted to west of 175 W. Long.), and unrestricted squid gillnet fishery that take an unknown number of incidental U.S. chum salmon.



Appendix III. Species Profile and Worksheet

Common Name: Dungeness crab

Scientific Name: Cancer magister (Dana)

Other Common Names: Pacific edible crab, edible crab, market crab, commercial crab (Hart 1982; Pauley et al. 1986)

Classification (Garth and Abbott 1980)

Phylum:	Arthropoda
Class:	Crustacea
Order:	Decapoda
Suborder:	Raptantia
Section:	Brachyura
Family:	Cancridae

Value

Commercial: An important commercial shellfish that is taken from Alaska to California. In 1985, more than 28 million pounds, worth over $39 million, was landed (Thompson 1986). The abundance of this species cycles widely, but long-term average landings are 37.6 million pounds (PMFC 1986). Fished primarily by baited crab pots in nearshore marine waters normally <65 fathoms deep (usually shallower) (Dahlstrom and Wild 1983; Barry 1985). The commercial season occurs primarily when males are hard shelled; the season opens December 1 off northern California, Oregon, and Washington where only males larger than 259 mm (carapace width) can be legally taken (Barry 1985; Demory 1985; Warner 1985). The season opens July 1 off southeast Alaska; May 1 off Yakutat and Kodiak, Alaska; and April 1 off Prince William Sound where only males > 165 mm can be legally taken (Eaton 1985, Kimker 1985, Koeneman 1985). Open season may last nine months, but most are captured within the first two months of opening. Dungeness crab are sold cooked whole, or shelled and frozen, or vacuum-packed in cans.

Recreational: Limited data are available on numbers of Dungeness crabs captured by sport fishermen. Crabs are primarily caught in bays and estuaries; they are captured intertidally by hand or subtidally by baited crab pots, ring nets, dip nets, and hook and line (Pauley et al. 1986). Sport legal crabs must be male and > 146 mm in Oregon, and >152 mm in Washington. In California, where both males and females can be taken and must be > 165 mm (Dahlstrom and Wild 1983).

Indicator of Environmental Stress: See Factors Influencing Populations.

Ecological: An important predator (on crangon shrimp and bivales) and prey (includes all age classes) in nearshore and estuarine habitats. Estuaries are important in early life stages (Tasto 1983; Armstrong and Gunderson 1985; Emmett and Durkin 1985).

Range

Overall: Found in West Coast coastal waters intertidally down to 420 meters, but not abundant below 90 m. It occurs from the Pribilof Islands (southeastern Bering Sea) in the north, to Santa Barbara, California, in the south (Schmitt 1921; MacKay 1942; Pauley et al. 1985), but not to Baja California as reported (Garth and Abbott 1980).

Within Study Area: They occur in coastal waters and probably all the bays and estuaries north of Morro Bay-Avila, California (Soule and Tasto 1983), into Puget Sound, Washington. Major commercial landings are north of and include Fort Bragg, California (Garth and Abbott 1980).

Life Mode

Eggs adhere to pleopods of the epibenthic living adult female. Larvae (zoea) are planktonic. Megalopae are primarily planktonic, but when close to molting to a benthic dwelling juvenile, they become benthic oriented (Reilly 1983a). Megalopae can actively swim, sometimes forming "swarms" near the surface (Lough 1976; Hatfield 1983). Megalopae are often found on the hydrozoan Velella velella (Wickham 1979; Stevens and Armstrong 1985). Juveniles and adults are epibenthic.

Habitat

Type: Eggs occur on pleopods of female crabs in euhaline (30-40 ppt) waters. Females with eggs can be found intertidally and out to deeper nearshore waters (MacKay 1942). Larvae initially occur in nearshore euhaline waters (5-16 km from shore) (Lough 1976; Orcutt 1977; Reilly 1983a), with offshore movement and distribution influenced by depth, latitude, temperature, salinity, and currents (Reilly 1983a 1985). Larvae are found near the surface at night and 15-25 meters deep during daylight (Reilly 1983a, 1985). Megalopae are in the upper 15 meters both day and night (Reilly 1983a, 1985), but they also have diel migrations (Booth et al. 1985) and are found primarily in shallow water nearshore areas (Lough 1976; Hatfield 1983; Reilly 1983a). Juveniles occur primarily in shallow coastal waters and estuaries (Butler 1956; Orcutt et al 1975; Stevens and Armstrong 1984, 1985). Adults are found primarily intertidally to 90 meters in marine (euhaline) waters, but sizable numbers occur in the lower reaches of estuaries.

Substrate

Dungeness crabs are found over variable substrates; juveniles are often found intertidally in estuarine areas of soft substrate containing eel grass, oyster shells, and other bivalve shells (Armstrong and Gunderson 1985). Adults can be found on mud, rock, and gravel bottoms but prefer sand (Frey 1971; Karpov 1983; Rudy and Rudy 1983).

Physical/Chemical Characteristics

Salinity tolerances vary with life stages (Pauley et al. 1985), but small juveniles do not appear to be more tolerant than adults (Stevens and Armstrong 1985). Larvae are highly sensitive to salinity variations and are found primarily in euhaline waters (Buchanan and Milleman 1969; Lough 1976; Reilly 1983a). Eggs hatch at a wide range of salinities, but survival is best in euhaline waters (Pauley et al. 1985). With regard to larval survival, significant interaction exists between salinity and temperature. At lower temperatures (< 10 C), eggs take longer to hatch and have lower hatching mortality (Mayer 1973; Wild 1983). Larval survival is best when temperatures are 10.0-14.0 C and salinities are 25-30 ppt (Reed 1969; Pauley et al. 1985). Juvenile and adult crabs in estuaries are exposed to rapid changing salinities that they respond to by pulsing and closure (Surgarman et al. 1983) and movement (Stevens et al. 1984). Mating takes place at temperatures of 8.0-17.0 C (Pauley et al 1985). Upper lethal temperature appears to be 20.0-25.0 C or lower, depending on other environmental factors (Wild 1983; Pauley et al. 1985).

Other

The effects of urban pollution—chlorine residuals, heavy metals, chlorinated pesticides, PCB's, and hydrocarbons—on Dungeness crabs is not clear, but sublethal effects are indicated for some pollutants at concentrations presently occurring in San Francisco Bay (Guard et al. 1983; Haugen 1983a, 1983b; Horne et al. 1983; Cheney and Mumford 1986). Crabs are intolerant of low dissolved oxygen (optimal is > 5 ppm). Ammonia is toxic at low concentrations (Cheney and Mumford 1986). The insecticide Sevin (carbaryl) is sometimes used to control ghost shrimp in Pacific oyster beds but is also very toxic to Dungeness crabs (Buchanan et al. 1985). Zoea of *C. magister* are the most sensitive life stages to insecticides and fungicides (Buchanan et al. 1970; Armstrong et al. 1976; Caldwell et al. 1978).

Migrations and Movements

Larvae initially appear in nearshore waters 5-16 km from shore in late January in Oregon and in December in California before spreading offshore. Megalopae appear in early March-mid April in California and in April off Oregon and Washington (Lough 1976; Reilly 1983a; Pauley et al. 1985). Both larvae and megalopae undergo vertical migrations (Reilly 1983a; Booth et al. 1985). Tidal currents and self-propulsion bring megalopae within 1 km of shore and into estuaries in Oregon (Lough 1976). Megalopae may also "ride" Velella velella inshore (Wickham 1979). Early juveniles settle out in shallow water estuarine areas or adjacent marine waters and many move into estuaries (Tasto 1983; Stevens and Armstrong 1985). Juveniles also settle on tidal flats at high tide (Stevens and Armstrong 1984; Armstrong and Gunderson 1985). Adult crabs move out of estuaries to mate and reproduce, but there are always some adults in estuaries. Tagging studies have shown adult crabs can move widely but most crabs show limited random movements

(Waldron 1958; Diamond and Hankin 1985). However, there is some evidence that male crabs move northward and into shallow waters during winter and southward and into deeper waters during summer (Gotshall 1978).

Reproduction

Mode: Sexual, separate sexes, oviparous, iteroparous.

Mating: Occurs from April-September in British Columbia (MacKay 1942; Butler 1956); primarily March-April, but sometimes to June in Washington (Cleaver 1949; Pauley et al. 1985); and March to July in California (Pauley et al. 1985). Mating takes place in non-estuarine locations, with males finding females possibly with the aid of pheromones (Knudsen 1964; Pauley et al. 1985). Mating occurs when the female is soft-shelled; the female may be held by the male in a premating embrace for up to seven days before she molts (Snow and Neilsen 1966). After she molts, the male inserts his gonopods into the spermathecae of the female and deposits spermatophores. The male may remain with the female for two days, ensuring protection of the female (Snow and Neilsen 1966). The spermatophores remain viable in the female for many months and fertilize the eggs when they are extruded (MacKay 1942; Wild 1983). Males can mate with more than one female.

Reproductive Capacity: Eggs are extruded in late fall and winter; September-February in British Columbia (MacKay 1942; Butler 1956), October-December in Washington (Cleaver 1949), October-March in Oregon (Waldron 1958), and September-November in California (Orcutt et al. 1976; Wild 1983). A female can carry up to 2.5 million eggs (Wickham 1980), but the actual number that hatches is much less (Wild 1980, 1983). A female may have 3-4 broods in a lifetime (MacKay 1942). Females have to be buried in sand for eggs to adhere properly to pleopods (Wild 1983). Eggs form an orange "sponge" that gets darker as the eggs mature.

Growth and Development

Egg size: 0.4-0.6 mm (smaller at higher temperatures) (Wild 1983).

Embryonic Development: Indirect and external. Egg incubations take 64-128 days, depending on temperature (Cleaver 1949; Orcutt 1978; Wild 1983). Upon hatching, crabs emerge as prezoeae and molt to zoeae within one hour (Buchanan and Milleman 1969). The larvae molt through five zoeal stages before molting into megalopae (Poole 1966; Lough 1976). The megalopa is the final planktonic stage that eventually molts to become the initial juvenile instar (Reilly 1983a, 1985).

Larval Size Range: 2.5-11.0 mm (Poole 1966).

Juvenile Size Range: As small as 5.0 mm to about 100 mm wide (larger for the males) (Cleaver 1949; Waldron 1958; Butler 1960, 1961; Poole 1967). Crabs may molt 11-12 times before reaching sexual maturity (Butler 1961).

Age and Size of Adults: Dungeness crabs mature after approximately 2 yrs when they are 116 mm (males) or 100 mm (females) wide (Butler 1960, 1961). They can live up to 8-10 years and 218 mm (males), and 160 mm (females) wide (MacKay 1942; Butler 1961).

Food and Feeding

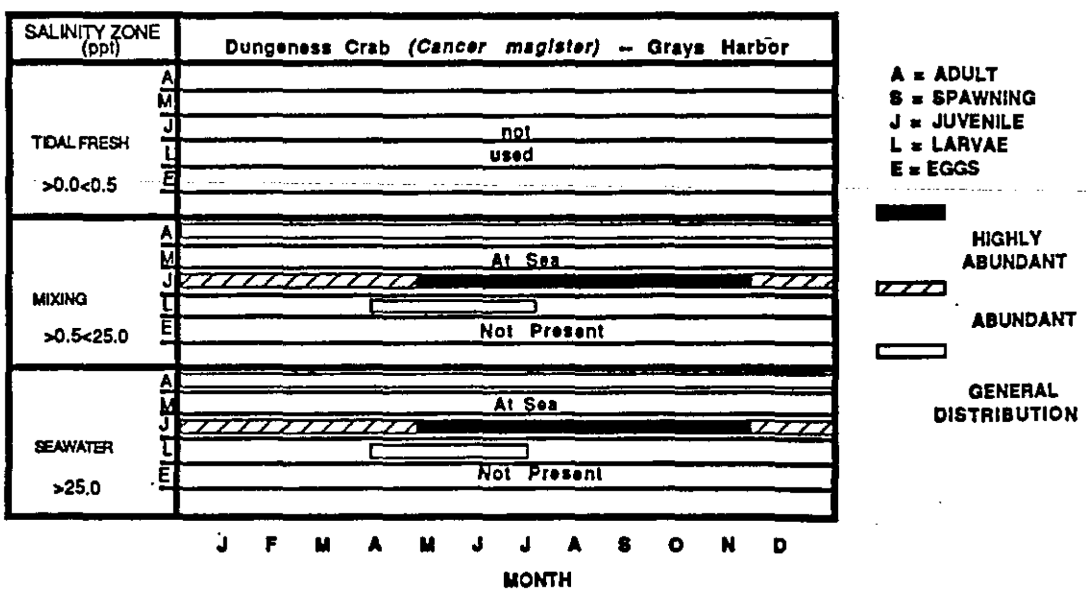
Trophic Mode: Carnivores.

Food Items: Larvae and megalopae eat phytoplankton and zooplankton, but primarily zooplankton (Lough 1976; Ebert et al. 1983). Juvenile crabs eat fish, mollusks, and crustaceans (Butler 1954; Gotshall 1977; Stevens et al. 1982). Shrimp (*Crangon spp.*) appear to be a preferred prey for juveniles that are 61-100 mm wide in Grays Harbor, Washington (Stevens et al. 1982). Cannibalism often occurs between larger juveniles preying on smaller crabs (MacKay 1942; Butler 1954; Gotshall 1977; Stevens et al. 1982). Adults also eat mollusks, fish, and crustaceans, and are nonspecific feeders that alter their food habits as prey resources fluctuate in abundance (Gotshall 1977). In general, crabs eat bivalves their first year, *Crangon spp.* their second year, and fish their third year (Stevens et al. 1982). Diel movements to intertidal habitats may be a result of food availability (Stevens et al. 1984).

Biological Interactions

Predation: Dungeness crab eggs are consumed by the nemertean, *Carcinonemertes errans*, that can cause large losses in egg production (Wickham 1979). Larvae are eaten by planktonic feeding fishes, such as herring, pilchard, and others (Garth and Abbott 1980; Pauley et al. 1986). Megalopae are eaten by rockfish, coho and chinook salmon, and probably other fishes (Prince and Gotshall 1976). Juveniles are eaten by a large number of fishes: starry flounder, English sole, rock sole, lingcod, cabezon, wolf-eels, rockfish, sturgeon, sharks, skates, Pacific halibut, and others (Waldron 1958; Orcutt 1977; Reilly 1983b). Other important predators include octopus and sea otters (Kimker 1985b). Adults are consumed by man, harbor seals, and gulls.

Factors Influencing Populations: Upwelling (Peterson 1973) and cannibalism (Botsford and Wickham 1978) have been proposed as causes for the cyclic nature of crab abundances. The success of a year class is determined by larval survival to metamorphosis, and thus, factors influencing egg, larvae, and megalopae survival are very important (Peterson 1973; Lough 1976, Pauley et al. 1986). Factors affecting larval survival include predation, high and low water temperatures, currents, and food availability (Lough 1976). Other causes of mortality that may influence population abundance include egg predation by *Carcinonemertes errans* (Wickham 1979), megalopae predation by salmon (Reilly 1983b), and diseases (Stevens and Armstrong 1981). Commercial trawling kills approximately 0.53 crabs/trawling hr (all males) in California (Reilly 1983c). Finally, estuaries play an important role in Dungeness crab abundance; estimates of juvenile crab populations in Willapa Bay and Grays Harbor, Washington, showed that these two systems contribute substantially to crab catches (Stevens and Armstrong 1984, 1985). Estuaries are important nursery habitats for 0+ and 1+ age crabs; dredging and habitat modifications in estuaries should take into consideration crab populations (Armstrong and Gunderson 1985; Emmett and Durkin 1985; Pauley et al. 1985).



Appendix IV. Personal Communications

Letter Code
Corresponds
to App. V.

A.	Armstrong, D.	University of Washington, Seattle.
B.	Brix, R.	Washington Department of Fisheries, Montesano.
C.	Culver, B.	Washington Department of Fisheries, Montesano.
D.	Dinnell, P.	University of Washington, Seattle.
E.	Emmett, R.	National Marine Fisheries Service, Hammond, OR.
F.	Fresh, K.	Washington Department of Fisheries, Olympia.
G.	Freymond, W.	Washington Department of Game, Olympia.
H.	Galbreath, L.	National Marine Fisheries Service, N Bonneville, Washington.
I.	Galbreath, J.	Oregon Department of Fisheries, Clackamas.
J.	Goodwin, L.	Washington Department of Fisheries, Brennon.
K.	Hueckel, G.	Washington Department of Fisheries, Olympia.
L.	Hurlburt E.	Washington Department of Fisheries, Olympia.
M.	Johnston, J. M.	Washington Department of Game, Bellingham.
N.	King, S.	Oregon Department Fish and Wildlife, Clackamas.
O.	Kreitman, G.	Washington Department of Fisheries, Olympia.
P.	Lock, J.	Washington Department of Game, Kalama.
Q.	McCabe, G., Jr.	National Marine Fisheries Service, Hammond, OR.
R.	McConnell, R.	National Marine Fisheries Service, Hammond, OR.
S.	Orrell, R.	Washington Department of Fisheries, Mount Vernon.
T.	Penttila, D.	Washington Department of Fisheries, Seattle.
U.	Scholls, A.	Washington Department of Fisheries, Brennon.
V.	Simenstad, C. A.	University of Washington, Seattle.
W.	Tufts, D.	Washington Department of Fisheries, Ocean Park, WA.
X.	Walters, G.	National Marine Fisheries Service, Seattle, WA.

Appendix V. Primary References and Communications

Species/Estuary	SKAGIT BAY	HOOD CANAL	PUGET SOUND
Blue Mussel	41, 116, 153, 226, 227, U, J	153, 226, 227, 275, U, J,	41, 119, 153, 226, 227, U, J
Pacific Oyster	41, 153, U, J,	41, 153, 176, 195, U, J	41, 153, 195, U, J, L
Manila Clam	41, 44, 116, U, J	41, 44, 92, 164, 275, U, J	44, 164, 206, U, J
Pacific Littleneck Clam	41, 116, 217, U, J	4, 41, 217, 275, U, J	41, U, J
Pacific Gaper	41, 196, U, J	41, 196, U, J	41, 196, U, J
Fat Gaper	29, 153, 196, U, J	29, 153,196, U, J	29, 153, 196, U, J
Geoduck	6, 89, 90, U, J	6, 89, 90, U, J	6, 89, 90, U, J
Eastern Softshell Clam	91, 153, 166, 191, U, J	191, 275, U, J	153, 166, 191, U, J, D
Bay Shrimp	130, 141	275	41, 130, D
Dungeness Crab	58, 142, D	275, D	59, D
Green Sturgeon	151	151	151
White Sturgeon	151	151	151
American Shad	85, 151	151	151
Pacific Herring	24, 88, 153, 252, T, F	87, 88, 153, 252, 275, T	77, 79, 87, 88, 153, 252, T, F
Northern Anchovy	24, 85, 151, T, F	151, V, T, F	24, 151, T, F
Pink Salmon	163, 224, 241, V, F, S	163, 210, 273, 275, V, F	163, 224, 273, V, F
Chum Salmon	48, 163, 242, F, V, S	163, 210, 224, 273, 275, F, V	70, 79, 163, 224, 273, F, V
Coho Salmon	163, 241, 262, 273, F, S	210, 273, 275, F, V	77, 79, 163, 224, 273, F
Sockeye Salmon	273	273	163, 273, F, V
Chinook Salmon	48, 240, 273, S, F, V	163, 224, 273, 275, F, V	79, 163, 224, 242, 273, F, V
Cutthroat Trout	120, M	120, 275, M	120, M
Steelhead	83, 151, 178, 180, G, F, V	83, 151, 216, 275, G, F, V	83, 151, 180, G, F, V
Surf Smelt	153, 184, 241, 252, T	153, 184, 252, T	153, 184, 252, T
Longfin Smelt	24, 241, T, F, V	T	24, 61, 151, 152, T, V
Eulachon	151, T	151, T	151, 274
Pacific Tomcod	24, 241, 260, 264	151, 182, 260, 264	54, 60, 79, 151, 260, 264, X
Threespine Stickleback	54, 151, 241, 253, 256, S	54, 151, 256, 275	54, 77, 150, 151, 256, 274, V, F
Shiner Perch	49, 85, 151, 240, S	54, 85, 151, 275	54, 60, 79, 85, 150, 151, 264, 269
Pacific Sand Lance	24, 151, T, F	275, T, F	24, 77, 79, 151, 251, 259, T, F
Lingcod	17, 34, 131, 151, K	17, 34, 131, V, K	17, 34, 131, V, K
Pacific Staghorn Sculpin	24, 49, 240, V, F	24, 264, 275, V, F	24, 60, 79, V, F
English Sole	24, 240, 242	24, 85, 183	24, 79, 85, 151, 183, 255, 259
Starry Flounder	24, 49, 249, S	24, 183, 259, 264, 275	24, 79, 258, 259, 264, V, F

Numbers Correspond to References Listed in the Literature Cited Section

Letters Correspond to Individuals Listed in Appendix IV - Personal Communications

Appendix V. Primary References and Communications

Species/Estuary	GRAYS HARBOR	WILLAPA BAY	COLUMBIA RIVER
Blue Mussel	W	W	E
Pacific Oyster	153, 263, W	72, 153, 263, W	E
Manila Clam	41, 44, 229, W	44, 229, W	E
Pacific Littleneck Clam	41, 229, W	229, W	E
Pacific Gaper	W	W	E
Fat Gaper	36, 101, 229, W	36, 101, 229, W	E
Geoduck	W	W	E
Eastern Softshell Clam	56, 191, 229, W	72, 191, W	191, E
Bay Shrimp	114, 130, A	114, 130, A	63, 130, 272
Dungeness Crab	10, 236, A	10, A	145, Q
Green Sturgeon	56, B, O	56, B, O	171, Q, O, N
White Sturgeon	56, O	56, 243, O	243, Q, O, N
American Shad	56, 223, V, B	56, 223, V	27, 46, 68, 100, 171, 247
Pacific Herring	154, 223, V, F	153, 154, 223, V, F	27, 46, 74, 143, 154, Q
Northern Anchovy	154, 223, V	122, 154, V	27, 46, 74, 98, 122, 154, Q
Pink Salmon	188, F	188	H, I
Chum Salmon	56, 188, 193, 228, B, V, F	188, 254, 263, B	27, 42, 52, Q
Coho Salmon	56, 188, 223, 228, B, F, V	188, 254, 263, F, B	27, 46, 52, 62, 143, Q
Sockeye Salmon	188	188	27, 46, 52, 68
Chinook Salmon	56, 188, 223, 224, 228, B, F, V	188, 263, F, B	27, 46, 52, 84, 143, 146, Q, H, I
Cutthroat Trout	56	72, 254	46, 135, P
Steelhead	56, 223, F, V	111, 254, F	27, 46, 52, 171, H, I, Q
Surf Smelt	56, 223, T, V	56, 223, V	27, 46, 154, Q
Longfin Smelt	61, 113, 154, 211, 223, 228, F, V	72, 113, 154, 223	27, 46, 98, 154, Q
Eulachon	56, B	B	68, 154, R
Pacific Tomocod	56, 113, 154, 204, 228, B	56, 113, 154, 204, 228	27, 46, 154, 204, Q
Threespine Stickleback	56, 228, 256	56, 228, 256	27, 46, 144, 256, Q
Shiner Perch	56, 211, 228, 269, B	56, 211, 228, 269	27, 46, 269, Q
Pacific Sand Lance	154, 223, V	154, 223, V	27, 46, 154, Q
Lingcod	10, 47, 53, 154	10, 47, 53, 154	46, E
Pacific Staghorn Sculpin	10, 56, 154, 228, V, B	10, 56, 154, 228, V	27, 46, 121, 154, Q
English Sole	147, 154, 207	147, 154, 207	27, 46, 154, Q
Starry Flounder	10, 56, 154, 228, B, C	10, 56, 154, 228	27, 46, 122, 154, Q

Numbers Correspond to References Listed in the Literature Cited Section

Letters Correspond to Individuals Listed in Appendix IV - Personal Communications

Literature Cited

1. Alaska Dept. of Fish and Game. 1985. Alaska habitat management guide. Southcentral region, Vol. 1: Life histories and habitat requirements of fish and wildlife. Alaska Dept. of Fish Game. Juneau, AK 429 pp.

2. Alderdice, D.F. and F.P.J. Velsen. 1971. Some effects of salinity and temperature on early development of Pacific herring *(Clupea pallasi)*. J. Fish. Res. Board Can. 28(10):1545-1562.

3. Allen, G.H. and W. Aron. 1958. Food of salmonid fishes of the western north Pacific Ocean. In: Special Scientific Report Fish. U.S. Fish and Wildlife Service. p. 237.

4. Allen, M.J., R.J. Wolotira, Jr., T.M. Sample, S.F. Noel, and C.R. Iten. In press. Pacific littleneck clam, *protothaca staminea*. In: Life history descriptions and brief harvest summaries for several shellfish species of the Northeast Pacific Ocean and Bering Sea. NWAFC Tech. Mem., NMFS/NOAA, Seattle, WA.

5. Ames, J. 1983. Salmon stock interactions in Puget Sound: A preliminary look. Southeast Alaska coho salmon research and management review and planning workshop. In: M.A. Miller (ed.) May 18-19, 1982. Alaska Dept. of Fish and Game Rpt. Juneau, AK. pp. 84-95.

6. Andersen, A. M., Jr. 1971. Spawning, growth, and spatial distribution of the geoduck clam, *Panope generosa* Gould, in Hood Canal, Washington. Ph.D. diss., University of Washington, Seattle, WA.

7. Andrievskaya, L.D. 1957. Pitanie Tikhookeanskikh lososei v severo-zapadnoi chasti Tikhogo okeana [The food of Pacific salmon in the northwestern Pacific Ocean]. In: Materialy po biologii morskogo perioda zhizni dal'nevostochnykh losoei, Vses. Nauch.-issled. Inst. Morsk. Ryb. Koz. Okeanogr. Moscow. [Fish. Res. Board Can., Trans. Ser., No. 182. 1958.]

8. Andrievskaya, L.D. 1970. Pitanie molodi tikhokeanskikh losoei v Okhotskom more. [Feeding of Pacific salmon juveniles in the Sea of Okhotsk]. In: Izvestiya Tikhookeanskogo Nauchno-Issledovatel'skogo Institute rybnogo Knozyaistva i Okeanografii (TINRO). [Proceedings of the Pacific Scientific Research Institute of Marine Fisheries and Oceanography] 78:105-115. [Fish. Res. Board Can., Trans. Ser. No. 2441. 1973.]

9. Armstrong, D.A., D.V. Buchanan, and R.S. Caldwell. 1976. A mycosis caused by Lagenidium sp. in laboratory-reared larvae of the Dungeness crab, *Cancer magister*, and possible chemical treatments. Journal of Invertebrate Pathology 28:329-336.

10. Armstrong, D. A., G. G. Stevens, and J. C. Hoeman. 1982. Distribution and abundance of Dungeness crab and *Cragnon* shrimp, and dredging-related mortality of invertebrates and fish in Grays Harbor, Washington. Technical Report to Washington Department of Fisheries and U.S. Army Corps of Engineers. School of Fisheries, University of Washington, Seattle, WA.

11. Armstrong, D.A., and D.R. Gunderson. 1985. The role of estuaries in Dungeness crab early life history: A case study in Grays Harbor, Washington. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. of Alaska, Alaska Sea Grant Rpt. No. 85-3, Fairbanks, AK. pp. 145-170.

12. Armstrong, D.A., J.L. Armstrong, and D. R. Gunderson. 1986. Juvenile Dungeness crab population dynamics in Grays Harbor and Willapa Bay and along the adjacent coast, spring and summer, 1985. Final Report to Evans-Hamilton, Inc., and U.S. Army Corps of Engineers, Seattle, WA.

13. Aro, K.V. and M.P. Shepard. 1967. Salmon of the North Pacific Ocean—Part IV. Spawning populations of North Pacific salmon. 5. Pacific salmon in Canada. Int. No. Pac. Fish. Comm. Bull. 23:225-327.

14. Atkinson, C.E., J.H. Rose, and T.O. Duncan. 1967. Salmon on the North Pacific Ocean - Part IV. Spawning populations of North Pacific salmon. 5. Pacific salmon in Canada. Int. No. Pac. Fish. Comm. Bull. 23: 225-327.

15. Baggerman, B. 1960. Salinity preference, thyroid activity and seaward migration of four species of Pacific salmon *(Oncorhynchus)*. J. Fish. Res. Board Can. 17(3):295-322.

16. Bakkala, R.G. 1970. Synopsis of biological data on the chum salmon, Oncorhynchus keta (Walbaum) 1972. FAO Species Synopsis No. 41. 89 p.

17. Bargmann, G. G. 1982. The biology and fisheries for lingcod *(Ophiodon elongatus)* in Puget Sound. Tech. Rep. No. 66. Department of Fisheries, Olympia, WA.

18. Barry, S. 1985. Overview of the Washington coastal Dungeness crab fishery. Proceedings of the symposium on Dungeness crab biology and management. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. of Alaska, Alaska Sea Grant Rpt. No. 85-3, Fairbanks, AK. pp. 33-36.

19. Bax, N.J. 1983. Early marine mortality of marked juvenile chum salmon *(Oncorhynchus keta)* released into Hood Canal, Puget Sound, Washington, in 1980. Can. J. Fish. Aquat. Sci. 40:426-435.

20. Bax, N.J., E.O. Salo, B.P. Snyder, C.A. Simenstad, and W.J. Kinney. 1980. Salmon outmigration studies in Hood Canal: A summary-1977. In: W.J. McNeil and D.C. Himsworth (eds.). Salmonid ecosystems of the North Pacific. Oregon State Univ. Press, Corvallis, OR. pp. 171-201.

21. Beacham T.D. and P. Starr. 1982. Population biology of chum salmon, *(Oncorhynchus keta)* from the Fraser River, British Columbia. U.S. Fish. Bull. 80(4):813-825.

22. Beacham, T.D. and C.B. Murray. 1987. Adaptive variation in body size, age, morphology, egg size, and developmental biology of chum salmon *(Oncorhynchus keta)* in British Columbia. Can. J. Fish. Aquat. Sci. 44(2):244-261.

23. Bell, M.C. 1984. Fisheries handbook of engineering requirements and biological criteria. Fish Pass. Dev. Eval. Prog., U.S. Army Corps of Eng., No. Pac. Div., Contract No. DACW57-79-M-1594 and No. DACW57-80-M-0567. Portland, OR. 290 pp.

24. Blackburn, J.E. 1973. Pelagic eggs and larval fish of Skagit Bay. In: Q.J. Stober, and E.O. Salo, (eds). Ecological studies of the proposed Kiket Island nuclear power site.Contract FRI-UW-7304. Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

25. Booth, J., A. Phillips and G.S. Jamieson. 1985. Fine scale spatial distribution of *Cancer magister* megalopae and its relevance to sampling methodology. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. Alaska, Alaska Sea Grant Rpt. No. 85-3. Fairbanks, AK. pp. 273-286.

26. Botsford, L.W. and D.E. Wickham. 1978. Behavior of age-specific, density-dependent models and the northern California Dungeness crab *(Cancer magister)* fishery. J. Fish. Res. Board. Can. 35(6):833-843.

27. Bottom, D.L., K.K. Jones, and M.J. Herring. 1984. Fishes of the Columbia River estuary. Columbia River Data Development Program, Columbia River Estuary Study Taskforce, Astoria, OR. 113 pp. plus appendices.

28. Bottom, D.L., P.J. Howell, and J.D. Rodgers. 1985. The effects of stream alterations on salmon and trout habitat in Oregon. Oregon Dept. Fish Wildl., Portland, OR. 70 pp.

29. Bourne, N. and D.W. Smith. 1972. Breeding and growth of the horse clam, *Tresus capax* (Gould), in southern British Columbia. Proceedings of the National Shellfish Association. 62:38-48.

30. Bowman T.E. and L.G. Abele. 1982. Classification of the recent crustacea. In: The Biology of Crustacea. Vol. 1. Systematics the fossil record and biogeography. Ed. Abele. Academic Press, N.Y. pp. 1-27.

31. Buchanan, D.W. and R.E. Milleman. 1969. The prezoeal stage of the Dungeness crab, *Cancer magister* Dana. Biol. Bull. 137(2):250-255.

32. Buchanan, D.W., R.E. Millemann, and N.E. Stewart. 1970. Effects of the insecticide SEVIN on various stages of Dungeness crab, *Cancer magister*. J. Fish. Res. Board Can. 27:93-104.

33. Buchanan, D.V., D.L. Bottom, and D.A. Armstrong. 1985. The controversial use of the insecticide SEVIN in Pacific Northwest estuaries: Its effects on Dungeness crab, Pacific oyster, and other species. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. of Alaska, Alaska Sea Grant Rpt. No. 85-3, Fairbanks, AK. pp. 401-417.

34. Buckley, R., G. Hueckel, B. Benson, S. Quinnell, and M. Canfield. 1984. Enhancement research on lingcod *(Ophiodon elongatus)* in Puget Sound. Progress Report Number 216, Washington Department of Fisheries, Olympia, WA.

35. Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. Fish. Bull. U.S. 61(52):97-110.

36. Burt, W. V. and W. B. McAlister. 1959. Recent studies in the hydrography of Oregon estuaries. Fish Commission of Oregon, Research Briefs. 7(1):14-27.

37. Butler, T.H. 1956. The distribution and abundance of early larval stages of the British Columbia commercial crab. Prog. Rep. J. Fish. Res. Board Can. 107:22-23.

38. Butler, T.H. 1960. Maturity and breeding of the Pacific edible crab, *Cancer magister* Dana. J. Fish. Res. Board Can. 17(5):641-646.

39. Butler, T.H. 1961. Growth and age determination of the Pacific edible crab, *Cancer magister* Dana. J. Fish. Res. Board Can. 18(5):873-889.

40. Caldwell, R.S., D.V. Buchanan, D.A. Armstrong, M.H. Mallon, and R.E. Millemann. 1978. Toxicity of the herbicides DEF. Propanil and Trifluralin to the Dungeness crab, *Cancer magister*. Archives of Environmental Contamination and Toxicology 8:383-396.

41. Cheney, D.P. and T.F. Mumford, Jr. 1986. Shellfish and seaweed harvests of Puget Sound. Washington Sea Grant, University of Washington, Seattle, WA. 164 pp.

42. Cheney, E.D. and L.E. Perry. 1976. Columbia Basin salmon and steelhead analysis. Summary Report. Pacific Northwest Regional Commission.

43. Chesapeake Bay Critical Area Commission. 1986. Subtitle 18. Chesapeake Bay Critical Area Protection Program (NRA 8-1801-1816) with amendments. Dec. 1986. Annapolis, MD. 16 pp.

44. Chew, K.K. In press. Manila clam biology and fishery development in western North America. In: Clam mariculture in North America.

45. Cleaver, F.C. 1949. Preliminary results of the coastal crab *(Cancer magister)* investigation. Biol. Rep. 49A:74-82. Wash. State Dept. Fish., Olympia, WA.

46. Coastal Zone and Estuarine Studies Division. 1981. Columbia River estuary data development program report, salmonid and non-salmonid fish. Northwest Alaska Fisheries Center, NMFS/NOAA. Hammond, OR.

47. Coley, T.C., G.T. McCabe, R. L. Emmett, and R.J. McConnell. 1986. Juvenile lingcod outer harbor field survey, Grays Harbor navigation improvement project. NWAFC Processed Report, Coastal Zone Estuarine Studies Division, Northwest and Alaska Fisheries Center. NMFS/NOAA, 2725 Montlake Blvd., E., Seattle, WA 98112.

48. Congleton, J.L., S.K. Davis, and S.R. Foley. 1981. Distribution, abundance, and outmigration timing of chum and chinook salmon fry in the Skagit salt marsh. In: E.L. Brannon and E.O. Salo, (eds.). Salmon and trout migratory behavior symposium. Fisheries Research Institute, College of Fisheries, University of Washington, Seattle, WA. pp. 153-163.

49. Conley, R.L. 1977. Distribution, relative abundance, and feeding habits of marine and juvenile anadromous fishes of Everett Bay, Washington. M.S. thesis, University of Washington. Seattle, WA.

50. Dahlstrom, W.A. and P.W. Wild. 1983. A history of Dungeness crab fisheries in California. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish Game Fish. Bull. 69(172):7-24.

51. Darnell, R.M., Defenbaugh, R.E., and D. Moore. 1983. Northwestern Gulf shelf bio-atlas. Open File Report No. 82-04. Minerals Management Service, Gulf of Mexico OCS Regional Office. Metainie, LA. 438 pp.

52. Dawley, E.M., R.D. Ledgerwood, and A.L. Jensen. 1985. Beach-purse seine sampling of juvenile salmonids in the Columbia River estuary and ocean plume, 1977-1983. Volume 1. Procedures, sampling effort, and catch data. NWAFC Processed Report. Coastal Zone and Estuarine Studies Division, Northwest Alaska Fisheries Center, NMFS/NOAA, 2725 Montlake Blvd., E., Seattle, WA 98112.

53. Day, M.E., C.A. Coumes, P.L. Striplin, and D.Grosse. 1986. Review and annotated bibliography of juvenile lingcod and flatfish populations inhabiting Grays Harbor with reference to potential adverse impacts caused by dredging. Final Report to U.S. Army Corps of Engineers by Evans-Hamilton, Inc., and Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

54. DeLacy, A.C., B.S. Miller, S.F. Borton. 1972. Checklist of Puget Sound Fishes. Washington Sea Grant, Division of Marine Resources, University of Washington. Seattle, WA.

55. Demory, D. 1985. An overview of Oregon Dungeness crab fishery with management concepts for the future. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. of Alaska, Alaska Sea Grant Rpt. No. 85-3, Fairbanks, AK. pp. 27-32.

56. Deschamps, G., S.G. Wright, and R.E. Watson. 1971. Fish migration and distribution in the lower Chehalis River and upper Grays Harbor. In: Grays Harbor cooperative water quality study, 1964-1966. Technical Report 7, Washington Department Fisheries, Olympia, WA. pp. 1-55.

57. Diamond, N. and D.G. Hankin. 1985. Movements of adult female Dungeness crabs *(Cancer magister)* in northern California based on tag recoveries. Can. J. Fish. Aquat. Sci. 42(5):919-926.

58. Dinnel, P.A., D. Armstrong, B. Miller, and R. Donnelly. 1986. U.S. Navy homeport disposal site investigations summer cruise report. Fisheries Research Institute, School of Fisheries, University of Washington. Seattle, WA.

59. Dinnell, P.A., R.O. McMillan, D.A. Armstrong, T.C. Wainwright, A.J. Whiley, R. Burge, and R. Baumgarner. 1987. Padilla Bay Dungeness crab, *Cancer magister*, habitat study. Fisheries Research Institute, School of Fisheries, University of Washington. Seattle, WA.

60. Donnelly, R., B. Miller, R. Lauth, and J. Shriner. 1984. Fish ecology. Section 7, Volume VI. In: Q.J. Stober and K.K. Chew (principal investigators). Renton sewage treatment plant project: Seahurst baseline study. Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

61. Dryfoos, R.L. 1965. The ecology and life history of the longfin smelt in Lake Washington. Ph.D. diss. University of Washington. Seattle, WA.

62. Durkin, J.T. 1982. Migration characteristics of coho salmon *(Oncorhynchus kisutch)* smelts in the Columbia River and its estuary. In: V. S. Kennedy, (ed). Estuarine comparisons. Academic Press, New York, NY. pp. 365-376.

63. Durkin, J.T. and S.J. Lipovsky. 1977. Aquatic disposal field investigations Columbia River disposal site, Oregon. Appendix E: Demersal fish and decapod shellfish studies. Technical Report D-77-30, U.S. Army Corps of Engineers, Waterways Experiment Station. Vicksburg, MS.

64. Eaton, M.F. 1985. Kodiak Island commercial Dungeness, *Cancer magister,* fishery. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. of Alaska, Alaska Sea Grant Rpt. No. 85-3. Fairbanks, AK. pp. 97-116.

65. Ebert, E.E., A.W. Hazeltine, J.L. Houk, and R.O. Kelly. 1983. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish & Game. Fish. Bull. 69(172):259-309.

66. Emmett, R.L. and J. T. Durkin. 1985. The Columbia River estuary: An important nursery for Dungeness crabs, *Cancer magister.* Mar. Fish. Rev. 47(3):21-25.

67. Emmett, R.L., D.R. Miller, and T.H. Blahm. 1986. Food of juvenile chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*, salmon off the northern Oregon and southern Washington coasts, May-September 1980. California Dept. Fish and Game Fish. Bull. 72(1):38-46.

68. Environmental Protection Agency. 1971. Columbia River thermal effects study. Volume 1: Biological effects studies. U.S. Environmental Protection Agency, U.S. Atomic Energy Commission, and National Marine Fisheries Service.

69. Eschmeyer, W.N., W.S. Herald, and H. Hammann. 1983. A field guide to Pacific Coast fishes of North America. Boston: Houghton Mifflin Co. 336 pp.

70. Feller, R.J. and V.W. Kaczynski. 1975. Size selective predation by juvenile chum salmon *(Oncorhynchus keta)* on epibenthic prey in Puget Sound. J. Fish. Res. Board Can. Bull. 32:1419-1429.

71. Fiscus, C.H. 1980. Marine mammal-salmonid interactions: A review. In: W.J. McNeil and D.C. Himsworth (eds.). Salmonid ecosystems of the North Pacific. Oregon State Univ. Press, Corvallis, OR. pp. 121-131.

72. Fish and Wildlife Service. 1970. Fish and Wildlife of Willapa Bay, Washington. U.S. Department of Interior. Portland, OR.

73. Forrester, C.R. 1981. Statistical yearbook 1978. Intern. No. Pacific Fish. Comm. Vancouver, Canada. 123 pp.

74. Fox, D.S., S. Bell, W. Nehlson, and J. Damron. 1984. The Columbia River estuary: Atlas of physical and biological characteristics. Columbia River Estuary Data Development Program, Columbia River Estuary Study Taskforce. Astoria, OR.

75. Fraser, C.M. 1922. The Pacific herring. Biol. Board Can., Contrib. Can. Biol. Fish. 192(6):102-111.

76. Fredin, R.A., R.L. Major, R.G. Bakkala, G.K. Tanonaka. 1977. Pacific salmon and the high seas salmon fisheries of Japan. NWAFC Processed Report. 324 pp. Northwest and Alaska Fisheries Center, NMFS/NOAA, 2725 Montlake Blvd., E., Seattle, WA 98112.

77. Fresh, K.L. 1979. Distribution and abundance of fishes occurring in the nearshore surface water of northern Puget Sound, Washington. M.S. thesis, University of Washington. Seattle, WA.

78. Fresh K.L. 1984. Evaluation of potential species interaction effects in the planning and selection of salmonid enhancement projects. Report prepared by the Species Interaction Work Group of the Enhancement Planning Team. Northwest and Alaska Fisheries Center, NMFS/NOAA. Seattle, WA. 80 pp.

79. Fresh, K.L., D. Rabin, C. Simenstad, E.O. Salo, K. Garrison, and C. Matheson. 1979. Fish ecology studies in the Nisqually reach area of southern Puget Sound, Washington. Final Report to Weyerhaeuser Company, contract FRI-UW-7904. Fisheries Research Institute, College of Fisheries, University of Washington, Seattle.

80. Fresh, K.L., R.D. Cardwell, and R.R. Koons. 1981. Food habits of Pacific salmon their potential competitors and predators in the marine waters of Washington, August 1978 to September 1979. Wash. Dept. Fish., Prog. Rept. No. 145. 58 pp.

81. Fresh, K.L., and S.L. Schroder. 1987. Influence of the abundance, size, and yolk reserves of juvenile chum salmon *(Oncorhynchus keta)* on predation by freshwater fishes in a small coastal stream. Can. J. Fish. Aquat. Sci. 44(22):236-243.

82. Frey, H.W. 1971. California's living marine resources and their utilization. Calif. Dept. Fish & Game. Sacramento, California. 148 pp.

83. Freymond, W. and S. Foley. 1985. Wild steelhead: Spawning escapements for Boldt case area rivers. Washington Department of Fisheries. Seattle, WA. pp. 86-12.

84. Galbreath, J. L. 1966. Timing of tributary races of chinook salmon through the lower Columbia River based on analysis of tag recoveries. Fish Commission of Oregon, Research Briefs 12(1):58-80.

85. Garrison, K. J. and B. S. Miller. 1982. Review of the early life history of Puget Sound fishes. Contract FRI-UW-8216. Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA. 729 pp.

86. Garth, J.S. and D.P. Abbott. 1980. Brachyura: The true crabs. In: R.H. Morris, D.P. Abbott, and E.C. Haderlie (eds.). Intertidal invertebrates of California. Stanford Univ. Press. Stanford, CA. pp. 594-630.

87. Gonyea, G.P. 1985. Abundance of Pacific herring in central and southern Puget Sound. Technical Report 87, Washington Department of Fisheries. Olympia, WA.

88. Gonyea, G., S. Burton, and D. Penttila. 1982. Summary of 1982 herring recruitment studies in Puget Sound. Progress Report 179, Washington Department of Fisheries. Olympia, WA.

89. Goodwin, L. 1973. Subtidal geoducks of Puget Sound. Technical Report 13, Washington Department of Fisheries. Olympia, WA.

90. Goodwin, L. 1979. Puget Sound subtidal geoduck and hardshell clam survey data, March 1978 to April 1979. Progress Report 95, Washington Department of Fisheries. Olympia, WA.

91. Goodwin, L. and C. Jones. 1976. Standing crop estimates of soft-shell clams in Skagit and Port Susan Bays. Washington Department of Fisheries. Olympia, WA.

92. Goodwin, L. and S. Warren. 1978. Puget Sound subtidal hardshell clam survey data. Progress Report 44, Washington Department of Fisheries. Olympia, WA.

93. Gotshall, D.W. 1977. Stomach contents of northern California Dungeness crabs *(Cancer magister)*. Calif. Dept. Fish & Game Fish. Bull. 63(1):43-51.

94. Gotshall, D.W. 1978. Northern California Dungeness crab, *Cancer magister*, movements as shown by tagging. Calif. Dept. Fish & Game Fish. Bull. 64(4):234-254.

95. Guard, H.E., L.H. DiSalvo, J. Ng, and P.W. Wild. 1983. Hydrocarbons in Dungeness crabs, *Cancer magister*, and estuarine sediments. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept Fish & Game. Fish. Bull. 69(172):243-257.

96. Gunter, G. 1967. Some relationships of estuaries to the fisheries of the Gulf of Mexico. In: G.H. Lauff (ed.). Estuaries. American Association for the Advancement of Science. Publication No. 83. Washington, DC. 757 pp.

97. Haedrick, R.L. and C.A.S. Hall. 1976. Fishes and estuaries. Oceanus 19(5): 55-63.

98. Haertel, L. and C. Osterberg. 1967. Ecology of zooplankton, benthos, and fishes in the Columbia River estuary. Ecology. 50:962-978.

99. Hallock, R.J. and D.H. Fry, Jr. 1967. Five species of salmon, *Oncorhynchus*, in the Sacramento River, California. Calif. Dept. Fish & Game Fish. Bull. 53(24):5-22.

100. Hammann, M.G. 1981. Utilization of the Columbia River estuary by American shad, *Alosa sapidissima* (Wilson). M.S. thesis, Oregon State University. Corvallis, OR. 48 pp.

101. Hancock, D.R., T.F. Gaumer, G.B. Willeke, G.P. Robart and J. Flynn. 1979. Subtidal clam populations: Distribution, abundance, and ecology. Publication ORESU-T-79-002. Oregon State University Sea Grant College Program. Corvallis, OR.

102. Hart, J.L. 1973. Pacific fishes and Canada. J. Fish Res. Board Can. Bull. 24(53):5-22.

103. Hart, J.F.L. 1982. Crabs and their relatives of British Columbia. British Columbia Provincial Museum Handbook No. 40. British Columbia Provincial Museum, Victoria, Canada. 266 pp.

104. Hartt, A.C. and M.B. Dell. 1986. Early oceanic migrations and growth of juvenile pacific salmon and steelhead trout. Bull. 46 Int. North Pacific Fisheries Commission. 105 pp.

105. Hatfield, S.E. 1983. Intermolt staging and distribution of Dungeness crab, *Cancer magister*, megalopae. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish & Game. Fish. Bull. 69(172):85-96.

106. Haugen, C.W. 1983a. Field and laboratory studies of toxic trace elements in Dungeness crabs. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish & Game. Fish Bull. 69(172):227-238.

107. Haugen, C.W. 1983b. Chlorinated hydrocarbon pesticides and polychlorinated biphenyls in dungeness crabs. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish & Game. Fish Bull. 69(172):239-241.

108. Healey, M.C. 1979. Detritus and juvenile salmon production in the Nanaimo estuary: Volume 1. Production and feeding rates of juvenile chum salmon *(Oncorhynchus keta)*. J. Fish. Res. Board Can. Bull. 36(5):488-496.

109. Healey, M.C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. In: W.J. McNeil and D.C. Himsworth (eds.). Salmonid ecosystems of the North Pacific. Oregon State Univ. Press. Corvallis, OR. pp. 203-229.

110. Healey, M.C. 1982. Juvenile pacific salmon in estuaries: The life support system. In: V.S. Kennedy (ed.). Estuarine Comparisons. New York: Academic Press. pp. 315-342.

111. Hedgepeth, J.W and S. Obrebski. 1981. Willapa Bay: A historical perspective and a rationale for research. Contract FWS/OBS-81/03. Office of Biological Services, U.S. Fish and Wildlife Service, Washington, D.C.

112. Hill, P.M. 1984. A detailed listing of the liberations of salmon into the open waters of the state of Washington during 1983. Wash. Dept. Fish., Prog. Rpt. No. 210. 369 pp.

113. Hoeman, J.C. 1982. Distribution and abundance of benthic fish in Grays Harbor. In: D.A. Armstrong, B.G. Stevens, and J.C. Hoeman, (eds.). Distribution and abundance of Dungeness crab and *Crangon* shrimp and dredging related mortality on invertebrates and fish in Grays Harbor, Washington. Seattle District, U.S. Army Corps of Engineers. Seattle, WA. pp. 154-177.

114. Hoeman, J.C., and D.A. Armstrong. 1982. Distribution and abundance of three species of crangonid shrimp in Grays Harbor. In: D. A. Armstrong, B. G. Stevens, and J. C. Hoeman, (eds.). Distribution and abundance of Dungeness crab and *Crangon* shrimp and dredging related mortality on invertebrates and fish in Grays Harbor, Washington. Seattle District, U.S. Army Corps of Engineers. Seattle, WA. pp. 225-267.

115. Horne, A.J., M. Bennett, R. Valentine, R.E. Selleck, P.P. Russell, and P. W. Wild. 1983. The effects of chlorination of wastewater on juvenile Dungeness crabs in San Francisco Bay waters. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish & Game. Fish. Bull. 69(172):215-225.

116. Houghton, J.P. 1973. Intertidal ecology. In: Q.J. Stober and E.O. Salo (eds.). Ecological studies of the proposed Kiket Island nuclear power site. Contract FRI-UW-7304. Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

117. Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. J. Fish. Res. Board Can. Bull. 16(6):835-886.

118. Iwata, M. and S. Komatsu. 1984. Importance of estuarine residence for adaptation of chum salmon *(Oncorhynchus keta)* fry to seawater. Can. J. Fish. Aquat. Sci. 41:747-749.

119. Johnson, K.W. 1979. The relationship between *Mytilus edulis* larvae in the plankton and settlement for Holmes Harbor, Washington. M.S. thesis, University of Washington. Seattle, WA.

120. Johnston, J.M. 1981. Life histories of anadromous cutthroat with emphasis on migratory behavior. In: E.L. Brannon and E.O. Salo (eds.) Salmon and trout migratory behavior symposium. University of Washington. Seattle, WA. pp. 123-127.

121. Jones, A.C. 1959. The biology of the euryhaline fish, *Leptocottus armatus armatus* Girard. University of California Publications in Zoology 67(4):321-368.

122. Jones, K.K. and D.L. Bottom. 1984. Zooplankton and larval fishes of the Columbia River estuary. Columbia River Data Development Program, Columbia River Estuary Study Taskforce, Astoria, OR.

123. Joseph, E.B. 1973. Analysis of a nursery ground. In: A.L. Pachecc (ed.). Proceedings of a Workshop on Egg, Larval, and Juvenile Stages of Fish in Atlantic Coast Estuaries.

124. Kaeriyama, M. 1986. Ecological study of early life of the chum salmon, *(Oncorhynchus keta)* (Walbaum). Sci. Rpt. of the Hokkaido Salmon Hatchery. 40:31:92.

125. Karpov, K.A. 1983. Effect of substrate type on survival and growth in high density communal cultures of juvenile Dungeness crabs, *Cancer magister*. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif Dept. Fish & Game. Fish Bull. 69(172):311-318.

126. Kimker, A. 1985a. Overview of the Prince William Sound management area Dungeness crab fishery. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. of Alaska, Alaska Sea Grant Rpt. No. 85-3. Fairbanks, AK. pp. 77-83.

127. Kimker, A. 1985b. A recent history of the Orca Inlet, Prince William Sound Dungeness crab fishery with specific reference to sea otter predation. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. Alaska, Alaska Sea Grant Rpt. No. 85-3. Fairbanks, AK. pp. 231-241.

128. Knudsen, J.W. 1964. Observations of the reproductive cycles and ecology of the common Brachyura and crablike Anomura of Puget Sound, Washington. Pac. Sci. 18(1):3-33.

129. Koeneman, T.M. 1985. A brief review of the commercial fisheries for *Cancer magister* in southeast Alaska and Yakutat waters, with emphasis on recent seasons. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. Alaska, Alaska Sea Grant Rpt. No. 85-3. Fairbanks, AK. pp. 61-76.

130. Krygier, E.E. and H.F. Horton. 1975. Distribution, reproduction, and growth of *Crangon nigricauda* and *Crangon franciscorum* in Yaquina Bay, Oregon. Northwest Science 49(4):216-240.

131. LaRiviere, M.G., D.D. Jessup, and S.B. Mathews. 1981. Lingcod, *Ophiodon elongatus*, spawning and nesting in San Juan Channel, Washington. California Fish and Game Fish. Bull. 67(4):231-239.

132. LeBrasseur, R.J. 1966. Stomach contents of salmon and steelhead trout in the northeastern Pacific Ocean. J. Fish. Res. Board Can. Bull. 23(1):85-100.

133. LeBrasseur, R.J. and L.W. Barner. 1964. Midwater trawl salmon catches in northern Hecata Strait, November 1963. J. Fish. Res. Board Can. Bull. MS Rep. 176. 13 pp.

134. Levy, D.A., and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Can. J. Fish. Aquat. Sci. 39:270-276.

135. Lock, J.J. 1982. Juvenile and adult steelhead and sea-run cutthroat trout within the Columbia River estuary, 1980. Washington Department of Game. Olympia, WA.

136. Lough, R.G. 1976. Larval dynamics of the Dungeness crab, *Cancer magister*, off the central Oregon coast, 1970-71. Fish. Bull. (U.S.) 74(2):353-375.

137. MacKay, D.C.G. 1942. The Pacific edible crab, *Cancer magister*. J. Fish Res. Board Can. Bull. No. 62. 32 pp.

138. Mann, K.H. 1982. Ecology of coastal waters. University of California Press, Los Angeles, CA. 322 pp.

139. Manzer, J.I. 1964. Preliminary observations on the vertical distribution of Pacific salmon *(genus Oncorhynchus)* in the Gulf of Alaska. J. Fish. Res. Board Can. Bull. 21(5):891-903.

140. Mason, J.L. 1974. Behavior ecology of chum salmon fry *(Oncorhynchus keta)* in a small estuary. J. Fish Res. Board Can. Bull. 31:83-92.

141. Mayer, D.L. 1973a. Subtidal ecology. In: Q.J. Stober and E.O. Salo (eds.). Ecological studies of the proposed Kiket Island nuclear power site. Contract FRI-UW-7304. Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA. pp. 259-370.

142. Mayer, D.L. 1973b. The ecology and thermal sensitivity of the Dungeness crab, *Cancer magister*, and related species of its benthic community in Similk Bay, Washington. Ph.D. diss. University of Washington, Seattle, WA. 188 pp.

143. McCabe, G.T., Jr., W.D. Muir, R.L. Emmett, and J.T. Durkin. 1983. Interrelationships between juvenile salmonids and nonsalmonid fish in the Columbia River estuary. Fish. Bull. (U.S.) 81(4):815-826.

144. McCabe, G.T., Jr., R.L. Emmett, T.C. Coley, W.D. Muir, and R.J. McConnell. 1984. Fish sampling in Cathlamet Bay, Oregon—1984. Final Report to U.S. Army Corps of Engineers, National Marine Fisheries Service. Hammond, OR.

145. McCabe, G.T., Jr., R.L. Emmett, T.C. Coley, and R.J. McConnell. 1986a. Distribution, abundance, and size-class structure of Dungeness crabs in the Columbia River estuary. NWAFC Processed Report. Coastal Zone and Estuaries Studies Division. Northwest and Alaska Fisheries Center, NMFS/NOAA, 2725 Montlake Blvd., E., Seattle, WA 98112.

146. McCabe, G.T., Jr., R.L. Emmett, W.D. Muir, and T.H. Blahm. 1986b. Utilization of the Columbia River estuary by subyearling chinook salmon. Northwest Science 60(2):113-124.

147. McDowell, K.M. and C.A. Simenstad. 1981. Distribution and abundance of English sole. In: C.A. Simenstad and D.M. Eggers (preparers). Juvenile salmonid and baitfish distribution, abundance, and prey resources in selected areas of Grays Harbor, Washington. Final Report to Seattle District, U.S. Army Corps of Engineers. Contract #DACW67-80-C-0102. Seattle, WA.

148. McNeil, W.J. 1966. Effect of the spawning bed environment on reproduction of pink and chum salmon. Fish. Bull. U.S. 65(2):495-523.

149. McPhail, J.D. and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish. Res. Board Can. Bull. 27(173). 381 pp.

150. Miller, B.S., C.A. Simenstad, L.L. Moulton, K.L. Fresh, F.C. Funk, W.A. Karp, and S.F. Borton. 1977. Puget Sound baseline program nearshore fish survey. Final Report to Washington Department of Ecology, Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

151. Miller, B.S., and S.F. Borton. 1980. Geographical distribution of Puget Sound fishes: Maps and data source sheets. 3 Volumes. Washington Sea Grant Program and Washington State Department of Ecology. Seattle, WA.

152. Miller, B.S., C.A. Simenstad, J.N. Cross, K.L. Fresh, and S.N. Steinfort. 1980. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan de Fuca including food habits of the common nearshore fish: Final report of three years sampling, 1976-1979. U.S. Department of Commerce, U.S. Environmental Protection Agency. 211 pp.

153. Mills, M.L. and F. Solomon. In press. Salmon, marine fish and shellfish resources and associated fisheries in Washington's coastal and inland marine waters. Technical Report 79. Washington Department Fisheries. Olympia, WA.

154. Misitano, D.A. 1977. Species composition and relative abundance of larval and post-larval fishes in the Columbia River estuary, 1973. Fish. Bull. (U.S.) 75:218-222.

155. Monaco, M.E. 1986. National estuarine inventory: Living marine resources component, preliminary West Coast study. Ocean Assessments Division, NOS/NOAA. Rockville, MD. 33 pp.

156. Monaco, M.E., J.P. Tolson, M.L. Donovan, and C.J. Klein. 1986. Strategic assessments of the nation's estuaries: Activities of NOAA's Ocean Assessments Division. Renewable Resources Journal 4(1):18-22.

157. Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publications. Anchorage, AK, 248p.

158. Moyle, P.B. 1976. Inland fishes of California. University California Press. Berkeley, CA. 405 pp.

159. Myers, K.W.W. 1980. An investigation of the utilization of four study areas in Yaquina Bay, Oregon, by hatchery and wild juvenile salmonids. M.S. thesis, Oregon State University. Corvallis, OR. 234 pp.

160. National Marine Fisheries Service. 1987. NOAA/NMFS program development plan for ecosystems monitoring and fisheries management. Washington, D.C. 26 pp. plus appendix.

161. Neave, F., T. Yonemori, and R.G. Bakkala. 1976. Distribution and origin of chum salmon in offshore waters of the North Pacific Ocean. Int. Nat. Pac. Fish. Comm. Bull. 35. 79 pp.

162. Nelson-Smith, A. 1973. Oil pollution and marine ecology. New York: Plenum. 260 pp.

163. Northwest Indian Fisheries Commission and Washington Department of Fisheries. 1986. Puget Sound salmon management periods and their derivations. Northwest Indian Fisheries Commission and Washington Department of Fisheries, Olympia, WA.

164. Nosho, T.Y. and K.K. Chew. 1972. The setting and growth of the Manila clam, *Venerupis japonica* (Deshayes) in Hood Canal, Washington. Proceedings of the National Shellfish Association 62:50-58.

165. Ocean Assessments Division, NOS/NOAA. 1984. The national status and trends program for marine environmental quality: Program description (memo). Rockville, MD. 28 pp.

166. Oceanographic Institute of Washington. 1981. Clam and mussel harvesting industries in Washington state. Oceanographic Institute of Washington. Seattle, WA.

167. Odum, W.E. and E.J. Heald. 1975. The detritus-based food web of an estuarine mangrove community. In: L.E. Cronim (ed.). Estuarine Research. Academic Press. New York, N.Y. pp. 265-286.

168. Orcutt, H.G. 1977. Dungeness crab research program. Calif. Dept. Fish & Game Mar. Res. Rpt. No. 75-16. 23 pp.

169. Orcutt, H.G. 1978. Dungeness crab research program. Calif. Dept. Fish & Game Mar. Res. Rpt. No. 77-21. 55 pp.

170. Orcutt, H.G., R.N. Tastao, P.W. Wild, C.W. Haugen, and P.C. Collier. 1975. Dungeness crab research program. Calif. Dept. Fish & Game Mar. Res. Rpt. No. 75-16. 23 pp.

171. Oregon Department Fish and Wildlife and Washington Department of Fisheries. 1987. Status report: Columbia River fish runs and fisheries, 1960-1986.

172. Outram, D.N. 1955. The development of the Pacific herring egg and its use in estimating age of spawn. J. Fish. Res. Board Can. Bull. Pac. Biol. Sta. Circ. 40, 9 pp.

173. Pacific Fishery Management Council. 1981. Pacific herring fishery management plan. Pac. Fish. Mgmt. Council. Portland, OR. 127 pp.

174. Pacific Marine Fisheries Commission. 1985. 37th annual report of the Pacific Marine Fisheries Commission for the year 1984. Pac. Mar. Fish. Comm. Portland, OR. 35 pp.

175. Pacific Marine Fisheries Commission. 1986. 38th annual report of the Pacific Marine Fisheries Commission for the year 1984. Pac. Mar. Fish. Comm. Portland, OR. 35 pp.

176. Packer, J.F. 1980. Prediction of Pacific oyster spatfall intensity in Dabob Bay. Progress Report 126, Washington Department of Fisheries. Olympia, WA.

177. Parker, R.R. 1971. Size selective predation among juvenile salmonid fishes in a British Columbia inlet. J. Fish. Res. Board Can. Bull. 28(10):1503-1510.

178. Pauley, G.B., B.M. Bortz, and M.F. Shepard. 1986a. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)-steelhead trout. Report to U.S. Army Corps of Engineers, contract TR EL-82-4. U.S. Fish and Wildlife Service, Biol. Rpt. 82(11.62). Washington, D.C.

179. Pauley, G.B., D.A. Armstrong, and T.W. Heun. 1986b. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)- Dungeness crab. Report to U.S. Army Corps of Engineers, contract TR EL-82-4. U.S. Fish and Wildlife Service, Biol. Rpt. 82(11.63). Washington, D.C. 20 pp.

180. Pautzke, C.F. and R.C. Meigs. 1941. Studies on the life history of the Puget Sound steelhead trout *(Salmo gairdnerii)*. Transactions of the American Fisheries Society 70:209-220.

181. Pearcy, W., T. Nishiyama, T. Fujii, and K. Masuda. 1984. Deil variations in the feeding habitats of Pacific salmon caught in gill nets during a 24-hour period in the Gulf of Alaska. Fish. Bull. (U.S.) 82(2):391-399.

182. Pedersen, M.G., M.L. Mills, M. Gosho. 1978. Bottomfish studies in Hood Canal, Washington. Progress Report Number 54, Washington Department of Fisheries, Olympia, WA.

183. Pedersen, M.G. and G. DiDonato. 1982. Groundfish management plan for Washington's inside waters. Progress Report 170. Washington Department of Fisheries, Olympia, WA.

184. Penttila, D. 1978. Studies of the surf smelt *(Hypomesus pretiosus)* in Puget Sound. Technical Report 42, Washington Department of Fisheries. Olympia, WA.

185. Peterson, W.T. 1973. Upwelling indices and annual catches of Dungeness crab, *Cancer magister*, along the West Coast of the United States. Fish. Bull. (U.S.) 22(3):902-910.

186. Peterson, W.T., R.D. Brodeur, W.G. Pearcy. 1982. Food habits of juvenile salmon in the Oregon coastal zone, June 1979. Fish. Bull. (U.S.) 80(4):841-851.

187. Phinney, L.A. 1986. Chinook salmon of the Columbia River Basin. In: A.S. Eno, R.L. DiSilvestro, and W.J. Chandler (eds.). Audubon Wildlife report 1986. The National Audubon Society, NY. pp. 715-741.

188. Phinney, L.A., P. Bucknell, and R. Williams. 1975. A catalog of Washington streams and salmon utilization. Volume 2. Coastal region. Washington Department of Fisheries, Olympia, WA.

189. Poole, R.L. 1966. A description of the laboratory-reared zoeae of *Cancer magister* Dana, and megalopae taken under natural conditions (*Decapoda, Brachura*). Crustaceana 11(1):83-97.

190. Poole, R.L. 1967. Preliminary results of the age and growth study of the market crab, *Cancer magister*, in California: the age and growth of *Cancer magister* in Bodega Bay. Proceedings of the symposium on crustacea. Mar. Biol. Assoc. India, Ernakulam, Part II. pp. 553-567.

191. Porter, R.G. 1974. Reproductive cycle of the softshell clam, *Mya arenaria*, at Skagit Bay, Washington. Fish. Bull. (U.S.)72(3):648-656.

192. Prince, E.D.,and D.W. Gotshall. 1976. Food of the copper rockfish, *Sebastes caurinus* Richardson, associated with an articifial reef in south Humboldt Bay, California. Calif. Dept. Fish and Game Fish. Bull. 62(4):274-285.

193. Prinslow, J.E., K.M. McDowell, and C.A. Simenstad. 1981. Distribution and abundance of juvenile salmonids. In: C.A. Simenstad and D.M. Eggers (preparers). Juvenile salmonid and baitfish distribution, abundance and prey resources in selected areas of Grays Harbor, Washington. Final Report to U.S. Army Corps of Engineers. Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

194. Pritchard, D.H. I967. What is an estuary? Physical viewpoint. In: G.H. Lauff (ed). Estuaries. American Association for the Advancement of Science. Publication 83. Washington, D.C.

195. Quayle, D.B. 1969. Pacific oyster culture in British Columbia. J. Fish. Res. Board Can. Bull. 26(169).

196. Quayle, D.B. and N. Bourne. 1972. The clam fisheries of British Columbia. J. Fish. Res. Board Can. Bull. 29(179).

197. Ratti, F. 1979. Natural resources of Rogue estuary. Oregon Dept. Fish Wildl., Portland, OR. 33 pp.

198. Reed, P.H. 1969. Culture methods and effect of temperature and salinity on survival and growth of Dungeness crab *(Cancer magister)* larvae in the laboratory. J. Fish. Res. Board Can. Bull. 26(2):389-397.

199. Reilly, P.N. 1983a. Dynamics of the Dungeness crab, *Cancer magister*, larvae off central and northern California. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish and Game. Fish. Bull. 69(172):57-84.

200. Reilly, P.N. 1983b. Predation on Dungeness crabs, *Cancer magister*, in central California. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish & Game. Fish Bull. 69:(172).

201. Reilly, P.N. 1983c. Effects of commercial trawling on Dungeness crab survival. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of Dungeness crab, *Cancer magister,* with emphasis on the central California fishery resource. Calif. Dept. Fish and Game. Fish. Bull. 69(172):165-169.

202. Reilly, P.N. 1985. Dynamics of the Dungeness crab, *Cancer magister*, larvae off central and northern California. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. Alaska, Alaska Sea Grant Rpt. No. 85-3, Fairbanks, AK. pp. 245-272.

203. Reiser, D.W. and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. In: W.R. Meehan (ed.). Influence of forest and rangeland management on anadromous fish habitat in the western United States and Canada. Pac. Northwest For. Range Exp. Sta., U.S. Forest Service, Portland, OR. 54 pp.

204. Richardson, S. L.,and W. G. Pearcy. 1977. Coastal and oceanic fish larvae in an area of upwelling off Yaquina Bay, Oregon. Fish. Bull. (U.S.) 75(1):125-145.

205. Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. Am. Fish. Soc., Spec. Pub. 12. 174 pp.

206. Robinson, A.M. and W.P. Breese. 1984. Gonadal development and hatchery rearing techniques for the Manila clam *Tapes philippinarum* (Adams and Reeve). Journal of Shellfish Research 4(2):161-163.

207. Rogers, D. 1985. Population dynamics of juvenile flatfish in Grays Harbor estuary and adjacent nearshore area. M.S. thesis, University of Washington. Seattle, WA.

208. Rombough, P.J. 1983. Effects of low pH on eyed embryos and alevins of Pacific salmon. Can. J. Fish. Aquat. Sci. 40(10):1575-1582.

209. Rudy, P., Jr. and L.H. Rudy. 1983. Oregon estuarine invertebrates—an illustrated guide to the common and important invertebrate animals. U.S. Fish Wildl. Serv. Contract FWS/OBS-83/16. Oregon Institute of Marine Biology, University of Oregon. Charleston, OR. 225 pp.

210. Salo, E.O., N.J. Bax, T.E. Prinslow, C.J. Whitmus, B.P. Snyder, C.A. Simenstad. 1980. The effects of construction of naval facilities on the outmigration of juvenile salmonids from Hood Canal, Washington. Final Report to U.S. Navy, contract FRI-UW-8006. Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

211. Samuelson, C.E., D.C. Fagergren, and E.G. Hoffman. 1977. Grays Harbor division support: Final Report—estuarine assessment programs, 1975-1977. ITT Rayonier Inc. Shelton, WA.

212. Sano, S. 1966. Salmon of the North Pacific Ocean—Part III. A review of the life history of North Pacific salmon. 3. Chum Salmon in the Far East. Int. No. Pac. Fish. Comm. Bull. 18:41-57.

213. Sano, S. 1967. Salmon of the North Pacific Ocean—Spawning populations of North Pacific salmon. 3. Chum salmon in the Far East. Int. No. Pac. Fish. Comm. Bull. 23:23-41.

214. Schmitt, W.L. 1921. The marine decapod crustacea of California. Univ. Calif. Publ. Zool. No. 23. 470 pp.

215. Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. J. Fish. Res. Board Can., Bull. 30(184). 966 pp.

216. Seiler, D., S. Neuhauser, and M. Ackley. 1981. Upstream/downstream salmonid trapping project, 1977-1980. Progress Report 144, Washington Department of Fisheries. Olympia, WA.

217. Shaw, W.N. 1986. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)-common littleneck clam. U.S. Fish and Wildlife Service Biological Report 82(11.46). U.S. Army Corps of Engineers, contract TR EL-82-4.

218. Shelboun, J.E. 1966. Influence of temperature, salinity, and photoperiod on the aggregations of chum salmon fry. J. Fish Res. Board Can. Bull. 23:293-304.

219. Shepard, M.F. 1981. Status and review of the knowledge pertaining to the estuarine habitat requirements and life history of chum and chinook salmon juveniles in Puget Sound. Final Report to Wash. Coop. Fish. Res. Unit, College of Fish., University of Washington. Seattle, WA. 113 pp.

220. Shiniino, S. 1976. List of common names of fishes of the world, those prevailing among English-speaking nations. Science Rept. Shima Marineland No. 4., Kashikojima, Shima, Mie, Japan. 262 pp.

221. Simenstad, C.A. 1983. The ecology of estuarine channels of the Pacific Northwest coast: A community profile. Contract FWS/OBS-83/05. U.S. Fish Wildlife Service. Washington, DC. 181 pp.

222. Simenstad, C.A., B.S. Miller, C.F. Nyblad, K. Thornburgh, and L.J. Bledsoe. 1979. Food web relationships of northern Puget Sound and the Strait of Juan De Fuca. U.S. Interagency (NOAA/EPA) Energy/Environ. Res. Dev. Prog. Rep., contract EPA-600/7-79-259. Washington, D.C., 335 pp.

223. Simenstad, C.A. and D.M. Eggers. 1981. Juvenile salmonid and baitfish distribution abundance, and prey resources in selected areas of Grays Harbor, Washington. Final Report to Seattle District, U.S. Army Corps of Engineers, Fisheries Research Institute, College of Fisheries. Seattle, WA.

224. Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: An unappreciated function. In: V.S. Kennedy (ed.). Estuarine Comparisons. New York: Academic Press, Inc.

225. Simenstad, C.A. and E.O. Salo. 1982. Foraging success as a determinant of estuarine and nearshore carrying capacity of juvenile chum salmon *(Oncorhynchus keta)* in Hood Canal, Washington. In: B.R. Melteff and R.A. Neve (eds.). Proceedings of the North Pacific aquaculture symposium. Alaska Sea Grant Prog., Univ. Alaska. Fairbanks, AK. pp. 21-37.

226. Skidmore, D.A. 1983. Settlement, growth, and survival of *Mytilus edulis,* L. in Puget Sound and assessment of *Mytilus californianus* for aquaculture. M.S. thesis, University of Washington. Seattle, WA.

227. Skidmore, D.A. and K.K. Chew. 1985. Mussel aquaculture in Puget Sound. Washington Sea Grant Program, University of Washington. Seattle, WA.

228. Smith, J.L., O. Bengstrom, and J. Brown. 1976. Impact of dredging on the fishes in Grays Harbor. Appendix G. In: Maintenance dredging and the environment of Grays Harbor, Washington. U.S. Army Corps of Engineers. Seattle, WA.

229. Smith, S., and R.B. Herrmann. 1972. Clam distributions and abundances in Willapa Bay and Grays Harbor as related to environmental conditions. Summary Report, Weyerhaeuser Company. Longview, WA.

230. Snow, C.D. and J.R. Neilsen. 1966. Premating and mating behavior of the Dungeness crab *(Cancer magister* Dana). J. Fish. Res. Board Can. Bull. 23(9):1319-1323.

231. Soule, M. and R.N. Tasto. 1983. Stock identification studies on the Dungeness crab, *Cancer magister.* In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish and Game. Fish Bull. 69(172).

232. Spratt, J.D., 1981. Status of the Pacific herring, *Clupea Harengus* pallasii, resource in California l972 to l980. Calif. Dept. Fish and Game Fish Bull. 67(171). 107 pp.

233. Squire, J.L. and S.E. Smith. 1977. Anglers' guide to the United States Pacific Coast: Marine fish, fishing grounds, and facilities. NMFS/NOAA. Seattle, WA. 139 pp.

234. Stevens, B.G. and D.A. Armstrong. 1981. Mass mortality of female Dugeness crab, *Cancer magister*, on the southern Washington coast. Fish. Bull. (U.S.)79(2):349-352.

235. Stevens, B.G., D.A. Armstrong, and R. Cusimano. 1982. Feeding habits of the dungeness crab *Cancer magister* as determined by the index of relative importance. Mar. Biol. Berl. 72(1):135-145.

236. Stevens, B.G. and D.A. Armstrong. 1984. Distribution, abundance, and growth of juvenile Dungeness crabs, *Cancer magister*, in Grays Harbor estuary, Washington. Fish. Bull. (U.S.) 82(3):469-483.

237. Stevens, B.G., D.A. Armstrong, and J.C. Hoeman. 1984. Diel activity of an estuarine population of Dungeness crabs, *Cancer magister*, in relation to feeding and environmental factors. J. Crustacean Biol. 4(3):390-403.

238. Stevens, B.G. and D.A. Armstrong. 1985. Ecology, growth, and population dynamics of juvenile Dungeness crab *Cancer magister* Dana, in Grays Harbor, Washington 1980-1981. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield fisheries Symposia Series, Univ. of Alaska, Alaska Sea Grant Rpt. No. 85-3, Fairbanks, AK. pp. 119-134.

239. Stevenson, J.C. 1962. Distribution and survival of herring larvae *(Clupea pallasi Valenciennes)* in British Columbia waters. J. Fish. Res. Board Can. Bull. 19(5):735-810.

240. Stober, Q.J., D.T. Griggs, and D.L. Mayer. 1973a. Species diversity of the marine fish community in north Skagit Bay. In: Q.J. Stober, and E.O. Salo, (eds.). Ecological studies of the proposed Kiket Island nuclear power site. College of Fisheries, Fisheries Research Institute. Seattle, WA.

241. Stober, Q.J., S.J. Walden, and D.T. Griggs. 1973b. Juvenile salmonid migration through north Skagit Bay. In: Q.J. Stober, and E.O. Salo (eds.). Ecological studies of the proposed Kiket Island nuclear power site. College of Fisheries, Fisheries Research Institute. Seattle, WA.

242. Stober, Q.J. and K.B. Pierson. 1984. A review of the water quality and marine resources of Elliott Bay, Seattle, Washington. Final Report. Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

243. Stockley, C. 1981. Columbia River sturgeon. Progress Report 150, Washington Department Fisheries, Olympia, WA.

244. Strategic Assessment Branch. 1986. Gulf of Mexico coastal and ocean zones strategic assessment data atlas. Ocean Assessments Division, NOS/NOAA. Rockville, MD. 190 pp.

245. Strategic Assessment Branch. 1985. National estuarine inventory data atlas: Physical and hydrologic characteristics (mimeo). Ocean Assessments Division, NOS/NOAA. Rockville, MD. 103 pp.

246. Sugarman, P.C., W.H. Pearson, and D.L. Woodruff. 1983. Salinity detection and associated behavior in the Dungeness crab, *Cancer magister.* Estuaries 6(4):380-386.

247. Talbot, G.B. (n.d). Passage of shad at the Bonneville fishways. U.S. Fish and Wildlife Service, Special Scientific Report: Fisheries Number 94.

248. Tasto, R.N. 1983. Juvenile Dungeness crab, *Cancer magister,* studies in the San Francisco Bay area. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish and Game Fish. Bull. 69(172).

249. Taylor, F.H.C. 1964. Life history and present status of British Columbia herring stocks.

250. Thompson, B.G. 1986. Fisheries of the United States, 1985. Current Fishery Statistics No. 8368. Nat. Fish. Stat. Prog. (F/S21), NMFS/NOAA. Washington, D.C. 222 pp.

251. Trumble, R.J. 1973. Under utilized fishery resources of the Northeast Pacific. In: N.M. Ehrhardt and C.T. Bledsoe (eds.). Marine fisheries of the Northeastern Pacific: A synopsis. Norfish Paper Number 14, Washington Sea Grant, University of Washington. Seattle, WA.

252. Trumble, R.J. 1983. Management plan for baitfish species in Washington state. Progress Report 195, Washington Department of Fisheries, Olympia WA. 106 pp.

253. Tyler, R.W. 1964. Distribution and migration of young salmon in Bellingham, Washington. Circular Number 212, Fisheries Research Institute, College of Fisheries, University of Washington. Seattle, WA.

254. Army Corps of Engineers. 1976. Environmental evaluation of the Willapa River and harbor navigation project, Pacific County, Washington. U.S. Army Corps of Engineers, Seattle, WA.

255. Van Cleve, R. and S.Z. El-Sayed. 1969. Age, growth, and productivity of an English sole population in Puget Sound, Washington. Pacific Marine Fisheries Commission, Bulletin 7:51-72.

256. Vrat, V. 1949. Reproduction, behavior, and development of eggs of the three-spined stickleback *(Gasterosteus aculeatus)* of California. Copeia 1949(4):252-260.

257. Wahle, R.J. and R.Z. Smith. 1979. A historical and descriptive account of Pacific Coast anadromous salmonid rearing facilities and summary of their releases by region, 1960-76. NOAA Tech. Rpt. NMFS SSRF-736. 35 pp.

258. Waldron, K.D. 1958. The fishery and biology of the Dungeness crab *(Cancer magister* Dana) in Oregon waters. Oreg. Fish Comm., Contrib. No. 24:1-43.

259. Waldron, K.D. 1972. Fish larvae collected from the Northeastern Pacific Ocean and Puget Sound during April-May 1967. Tech. Report, NMFS/NOAA, Special Scientific Report Number 663.

260. Walters, G. 1984. Ecological aspects of larval and juvenile Pacific cod *(Gadus macrocephalus)*, walleye pollock *(Theragra chalcogramma)*, and Pacific tomcod *(Microgadus proximus)* in Port Townsend, Washington. M.S. thesis, University of Washington. Seattle, WA.

261. Warner, R.W. 1985. Overview of the California Dungeness crab, *Cancer magister*, fisheries. In: B.R. Melteff (coord.). Proceedings of the symposium on Dungeness crab biology and management. Lowell Wakefield Fisheries Symposia Series, Univ. of Alaska, Alaska Sea Grant Rpt. No. 85-3, Fairbanks, AK. pp. 11-26.

262. Washington Department of Fisheries. 1977. Status of Puget Sound coho salmon and recommendations for management. Progress Report 24, Washington Department of Fisheries. Olympia, WA.

263. Washington Department of Fisheries and Washington Department of Ecology. 1985. Use of the insecticide SEVIN to control ghost and mud shrimp in oyster beds of Willapa Bay and Grays Harbor. Final Environmental Impact Statement. Washington Department of Fisheries and Washington Department of Ecology. Olympia, WA.

264. Washington, P.M. 1977. Recreationally important marine fishes of Puget sound, Washington. NWAFC Processed Report, Northwest and Alaska Fisheries Center, NMFS/NOAA, 2725 Montlake Blvd., E., Seattle, WA 98112.

265. Weinstein, M.P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish. Cape Fear River, North Carolina. Fish. Bull. (US) 77:339-357.

266. Whitney R.R. 1979. Inland fishes of Washington. University of Washington Press, Seattle, WA.

267. Wickham, D.E. 1979. The relationship between megalopae of the Dungeness crab, *Cancer magister*, and the hydroid, *Velella velella*, and its influence on abundance estimates of *C. magister* megalopae. Calif. Dept. Fish and Game Fish. Bull. 65(3):184-186.

268. Wickham, D.E. 1980. Aspects of the life history of *Carcinonemertes errans (Nemertea: Carcinonemertidae)*, an egg predator of the crab *Cancer magister*. Woods Hole, MA: Biol. Bull. 159:247-257.

269. Wiebe, J. 1968. The reproductive cycle of the viviparous sea perch, *Cymatogaster aggregata* Gibbons. Can J. Zoology 46:1221-1234.

270. Wild, P.W. 1980. Effects of seawater temperature on spawning, egg development, hatching success, and population fluctuations of the Dungeness crab, *Cancer magister*. Calif Coop. Oceanic Fish. Invest., Rpt. 21:115-120.

271. Wild, P.W. 1983. The influence of seawater temperature on spawning, egg development, and hatching success of the Dungeness crab, *Cancer magister*. In: P.W. Wild and R.N. Tasto (eds.). Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish and Game Fish. Bull. 69(172).

272. Williams, G.T. 1983. Distribution and relative abundance of major ebibenthic crustacea in the Columbia River estuary. M.S. thesis, University of Washington. Seattle, WA.

273. Williams, R.W., R.M. Laramie, J.J. Ames. 1975. A catalog of Washington streams and salmon utilization. Volume 1. Puget Sound region. Washington Department of Fisheries. Olympia, WA.

274. Wydoski, R.S. and Whitney, R.R. 1979. Inland fishes of Washington, University of Washington Press. Seattle, WA. 220 pp.

275. Yoshinaka, M.S. and N.J. Ellifrit. 1974. Hood Canal—priorities for tomorrow: An initial report on fish and wildlife, developmental aspects and planning considerations for Hood Canal, Washington. U.S. Fish and Wildlife Service. Portland, OR.

The Living Marine Resources Assessment Program

The Living Marine Resources Program (LMR) is a component of the Ocean Assessments Division's Strategic Assessment Branch. Focusing on the Nation's coastal and estuarine waters, including the Nation's Exclusive Economic Zone (EEZ), this program assembles the best available information on all spatial and temporal aspects of the distribution and life histories of species considered important ecologically, economically, or legally. These species include: *marine, estuarine; and anadromous fishes; seabirds, shorebirds, and ocean-associated waterfowl; marine mammals, sea turtles, and crocodilians ; and invertebrates, primarily mollusks and crustaceans.* Also considered are other biological aspects of the environment, such as biogeography and patterns of primary productivity, zooplankton biomass, and benthic biomass. Information is gathered from published and unpublished sources in cooperation with NOAA scientists, primarily of the National Marine Fisheries Service, and other experts. Once assembled, these data are synthesized and presented in a series of data atlases and technical reports and entered into a unique Living Marine Resources Computer Mapping and Analysis System. Although the historical emphasis of the program has been offshore, an estuarine component has been added to complement the existing program and NOAA's National Estuarine Inventory.

Data Atlases. A major product of the Strategic Assessment Branch is a series of four regional strategic assessment data atlases that presents maps on the important features and activities in the Nation's coastal areas. Each of these atlases contains sections on important biological features and maps portraying spatial and temporal attributes of important living marine resources. Due to the large areas covered, emphasis has been on selected species, with a supplementary description. The attributes portrayed on the living marine resources maps include: adult, juvenile, and larval distributions, using as many as three levels of relative abundance; areas of importance for reproductive activities such as mating, nesting, or spawning; and migratory pathways and corridors. Where appropriate, these mapped areas have been defined by time period to show the dynamics of species movements. These attributes are portrayed in a consistent geography-based framework. All maps and materials are thoroughly reviewed by outside experts to ensure their accuracy. To date, the atlases have portrayed information on nearly 420 species.

Computer Mapping and Analysis System. To facilitate comparisons and analyses (difficult, if not impossible, to do by using maps alone), the mapped information is digitized and entered into a computer mapping and analysis system. This microcomputer-based system allows rapid spatial and temporal comparisons and statistical analyses of any user-specified combination of species and their attributes. It can be used to portray spatial and temporal distributions, providing a suite of analytical tools that allows examination of the data base across space, time, and function. It is intended for as-needed use by resource managers and scientists concerned with region-wide issues.

Technical Reports. The program produces a series of technical reports on its activities and manuals on the uses of the computer mapping analysis system. An example of the first is the series of reports presenting information, the distribution and abundance by life-stage and time period, of fishes and invertebrates by estuary. These reports will eventually cover the distribution of approximately 120 species in over 100 estuaries. User manuals for the computer system are in preparation. Reports on specific applications of the computer system for regional analyses are also available.

Future Activities. A major program emphasis in FY 1989 will be to begin an extensive revision of the original East Coast Data Atlas (1979), involving a considerable expansion of the LMR section. Computer mapping analytical capabilities will be expanded to incorporate a wider variety of data sets and will include increasingly sophisticated statistical analyses of spatial and temporal data sets, both biological and physical. An overall future goal is to combine the offshore and estuarine components into a single system to examine the importance of ocean-estuary linkages.

Additional information on NOAA's Computer Mapping and Analysis System for Living Marine Resources is available from:

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