Forage Fish Management Plan

A plan for managing the forage fish resources
and fisheries of Washington

by
Greg Bargmann

**Adopted by the
Washington Fish and Wildlife Commission
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Washington Department of Fish and Wildlife
600 Capitol Way N.
Olympia Washington 98501

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Executive Summary

This document contains a plan for the management of forage fish resources and fisheries in Washington state. The plan will be used to guide resource management decisions, establish priorities and develop fishing regulations.

Forage fish are small, schooling fish which serve as an important source of food for other fish species, birds and marine mammals. Examples of forage fish species are herring, smelt, anchovies and sardine. Both commercial and recreational fisheries exist for forage fish.

Forage fish populations tend to fluctuate greatly. These fluctuations are caused by natural factors, such as changes in environmental conditions and reproductive success, but can also be caused by fishing. Abundance levels of forage fish are marked by short periods of high abundance followed by lengthy periods of lessened abundance. No management strategy will produce stable populations of forage fish, however, proper management action can help maintain healthy populations.

Little is known of the biology or abundance of most stocks of forage fish: population levels, age composition and mortality rates are unknown. An exception is herring, a species for which we have more information. Basic stock identification is uncertain for several species.

Commercial landings of forage fish comprise approximately 3% of the commercial landings of all finfish caught in Washington. Most of the fishing harvest is taken by commercial activity: substantial commercial fisheries exist for herring, eulachon (Columbia River smelt) and surf smelt. There is growing interest in establishing a commercial fishery for a resurgent population of sardine along the Washington coast. Current levels of commercial harvest of forage fish are approximately 1.7 million pounds annually. Substantial recreational fisheries for some species of forage fish (surf smelt and eulachon) exist; however very limited information is available on the recreational fishery.

Conclusions

There are three important points to the development of this forage fish plan:

- Forage fish are subjected to fisheries, both commercial and recreational. These fisheries are often directed at spawning aggregations of fish.
- Forage fish are a key component of the marine ecosystem in Washington.
- Key management and biological information is usually lacking for most forage fish stocks.

The management plan accounts for these three factors by proposing an approach to management that:

- manages forage fish from an ecosystem based approach rather than a single species approach,
- utilizes a precautionary, conservative approach to fisheries management.

Ecosystem Management

Most management plans emphasis yield (or catch) as a major goal. This plan emphasizes the role of forage fish in the ecosystem and considers catch on a secondary basis. The availability of forage fish to provide a source of food for salmon, other fish, marine birds and marine mammals will be a primary consideration. To achieve this, potential catch will be foregone if needed.

Development of annual, or stock specific, harvest plans will consider the impact of harvest on the availability of forage fish.

Precautionary Approach

The precautionary approach utilizes caution when the agency is faced with a decision and a lack of information. The approach calls for reducing fishery or other activities if there is reason to believe that the activities will cause significant harm, even if such a link has not been established by clear scientific evidence.

Specific goals for the management of forage fish resources are outlined in this plan.

Treaty Indian tribes are not part of this policy and are not bound by it. Department staff will utilize the policy in development of joint management plans with the tribal governments.

If adopted, this plan will be used as a vehicle for forage fish management. It will be used to guide staff decisions regarding resource use, interagency meetings, joint meetings with tribes and to set research priorities.

The plan will also be used as a basis to develop detailed fishing regulations usage plans. The plan will be developed in the near future using the two major principles proposed here (ecosystem management and a precautionary approach). These usage plans will be developed by species and area and include additional opportunity for public and industry involvement.

FISH AND WILDLIFE COMMISSION
POLICY DECISION

POLICY TITLE: Forage Fish Management Policy, Goals and Plan **POLICY NUMBER:**

Cancels: N/A

Effective Date: January 24, 1998

Termination Date:

See Also: N/A

Approved by: ______________________
Fish and Wildlife Commission Chair

Policy

It shall be the policy of the department to maintain healthy populations of forage fish species and individual stocks of forage fish while assuring the integrity of the ecosystem and habitat upon which marine resources depend. If insufficient information exists or the condition of the resource is poor, a conservative approach to fisheries will be taken. Fishery management plans will consider the role of forage fish in the marine ecosystem and the need to supply sufficient quantities of forage fish for ecosystem needs. A precautionary approach to resource management shall be utilized. The department shall consider the best scientific information available.

Goals

Consistent with the general goals established by the Commission for the Department, the following specific goals will guide the management of the forage fish resources of Washington.

- Maintain healthy populations of forage fish in Washington.
- Fisheries shall be permitted, as appropriate, for sustainable resources.
- Washington based fishing industries (fishing, processing and marketing) shall receive consideration of an opportunity to utilize harvestable forage fish resources within state waters and the Exclusive Economic Zone.
- Management plans shall consider by-catch and wastage and provide for estimation of the magnitude of each and recommendations made for their reduction.
- Increase public confidence in forage fish management.
- All significant fisheries will have sufficient monitoring to estimate catch and evaluate resource condition and population trends.
- Stock status summary of principle species of forage fish shall be produced every two years.
- Document and protect spawning habitat of forage fish species.
- Implement the Wild Salmonid Policy as it relates to forage fish and their habitats.

Plan

Following the direction given in the forage fish policy and goals, the following plan of action will be implemented by the Department.

Habitat Surveys and Protection

Forage fish spawning habitat surveys are a high priority for forage fish management. Activities related to spawning ground documentation will include:

- conducting spawning habitat documentation surveys in areas likely to face human caused alterations,
- providing expert testimony in court cases or other legal activities, maintaining and updating databases, depending on funding,
- providing limited surveys in case of urgent need, upon request,
- completing a formal report which summarizes existing information and making it available to the public and interested officials.

Fishery Management

- Management of forage fish shall include provisions for rapid change in abundance.
- Forage fish shall be managed to avoid periods of low abundance.
- The achievement of maximum yield shall not be a goal of forage fish management.
- Consideration will be given to both recreational and commercial fishing interests when stock conditions permit fishing.
- The Department shall conduct a review and report on potential forage fish by-catch in each significant commercial fishery.

Stock Assessment

- Stock assessments shall be based on direct measurement of fish populations whenever possible.

The following plan of action shall be implemented for individual forage fish species:

Sardine

- The Department will participate in interstate planning and research efforts for coordinated management of the west coast sardine resource.
- The Department will investigate and, if feasible, allow a new commercial experimental fishery for sardine. This fishery would require coordinated management and include special monitoring/review for bycatch concerns. Any fishery is dependent on action by the Pacific Fishery Management Council.
- Annually review stock status, fishery results and fishery regulations.

Surf Smelt

- The Department will seek to increase its monitoring of fisheries and resources to:
  a. establish a biological database
  b. estimate growth and mortality rates.

- In the absence of better information, manage each individual spawning ground as a unique stock.
- Spawning habitat surveys shall emphasize potential surf smelt spawning grounds.
- The Department will seek to increase the mapping of surf smelt spawning habitat.
- Annually review stock status, fishery results and fishery regulations.

Anchovies

- The Department will participate in interstate planning and research efforts for coordinated management of the anchovy resource.
- Annually review stock status, fishery results and fishery regulations.
- No other agency action is planned for anchovies during the length of this plan.

Eulachon

- The Department will work with appropriate government agencies and the public, develop a harvest management plan for Columbia River smelt.
- The Department will pursue reduced harvest levels of Columbia River smelt until information is available for scientific management of the resource.
- The Department will seek to document eulachon spawning grounds.
- Annually review stock status, fishery results and fishery regulations.

Sand Lance

- The Department will end commercial fishing for sand lance in all state waters.
- Spawning habitat surveys shall emphasize potential sand lance spawning grounds.
- The Department will seek to increase the mapping of sand lance spawning habitat.
- Annually review stock status.

Herring

- Conduct surveys of known spawning grounds annually.
- Continue to gather biological data from selected spawning stocks.
- Annually review stock status, fishery results and fishery regulations.
- Institute no new commercial fisheries of herring in state waters. Continue the moratorium on commercial fisheries for herring in coastal waters.
- In the absence of information, treat each spawning ground as an individual stock
- Investigate, and report on sources of increased herring mortality.
- Participate in information exchange with herring researchers and managers from British Columbia and other areas.
- Institute a system of marine protected areas which include herring spawning grounds.
- Continue coordinated management with appropriate tribal governments.

Introduction

Forage fish in Washington consist of a variety of small schooling fish which are major food items for many species of fish, birds and marine mammals. In addition, several species of forage fish are subjected to commercial and recreational fisheries. Important species of forage fish in Washington (Table 1) include Pacific herring, northern anchovy, Pacific sand lance (also known as candlefish), surf smelt, and Pacific sardine (also called pilchard). Other species, such as capelin and night smelt, exist in Washington but little is known of their abundance or biology.

Table 1. Forage fish species in Washington State.

Common Name	Scientific Name
Northern anchovy	*Engraulis mordax*
Pacific sand lance (or candlefish)	*Ammodytes hexapterus*
Pacific herring	*Clupea pallasi*
Pacific sardine (or pilchard)	*Sardinops sagax*
Eulachon (or Columbia River smelt)	*Thaleichthys pacificus*
Longfin smelt	*Spirinchus thaleichthys*
Surf smelt	*Hypomesus pretiosus*
All other species of smelt	Osmeridae

Eulachon (also called Columbia River smelt) is an important species of forage fish. The fishery for this species occurs in the Columbia River and its tributaries, although periodic appearances occur in other coastal river systems. Management of the eulachon fishery and resource is shared with Oregon through the Columbia River Compact.

Herring has been the most actively managed forage fish species in Washington. This emphasis is due to the large fisheries for herring, the resultant economic value, and the importance of herring in the food chain.

By 1900, the destruction of herring and smelt spawning grounds was causing alarm and was blamed for greatly reducing the abundance of these species (Washington Department of Fisheries, 1901). In 1915 several herring preserves were closed to fishing during the spawning season.

The first published forage fish report was a comprehensive work on Puget Sound surf smelt by M. B. Schaefer in 1936. Chapman, Katz and Erickson followed with a wide-ranging study of Puget Sound herring stocks in 1941.

In the 1950s and 1960s, a low level of departmental effort was expended seasonally on herring management and biological studies, including occasional herring spawning ground surveys and the monitoring of an "all purpose" herring purse seine fishery in the San Juan Island region. Experimental herring tagging studies, herring brush weir management, and occasional surf smelt matters were also dealt with during this period. Commonly, departmental quarterly and annual reports included brief sections pertaining to on-going forage fish subjects.

In 1971, as an element of a Puget Sound salmon fishery enhancement initiative, the Puget Sound Baitfish Unit was initiated. This unit initially conducted spawning ground surveys for herring. Work was later expanded to other forage fish fishery management activities, including herring recruitment studies, and surf smelt spawning habitat surveys.

The existing forage fish plan (Trumble, 1983) was adopted by the former Department of Fisheries in 1983. Considerable changes have occurred since that time. These changes include changes in fishing technology, in markets and in important biological parameters of forage fish. The existing plan is in need of revision and approval by the Fish and Wildlife Commission. The purpose of the revised plan is to provide a framework of principles and criteria for the management of the forage fish resource in Washington. These principles will be used to develop detailed fishing regulations, to protect the natural production of these species and to guide department activities regarding forage fish.

Fisheries

Human use of forage fish began prior to written history. Certain types of forage fish, most notably herring, were important to native American groups in Washington (Stewart, 1977). Modern industrial fisheries for herring were among the first to develop in Washington (Hammond, 1886).

Commercial fisheries for forage fish have been characterized by change as markets, utilization, economics and fish abundance change. Herring, for example, are commercially caught for use as bait (including sport fishing bait, halibut bait and crab bait), for animal food (including food for zoo animals), for human consumption including use of herring eggs as human food. Each of these uses places various demands on the size and quantity of fish and on their reproductive output.

Both recreational and commercial fisheries exist for forage fish. These fisheries are seasonal, often occurring on spawning aggegregations. The recreational fisheries are very small in comparison to the commercial harvest. Because of the schooling nature of most forage fish species and their tendency to hold in predictable locations, forage fish are susceptible to net fisheries and can be easily over harvested. The commercial fisheries supply much of the information used in management for forage fish other than herring. Limited information is available on the recreational fisheries for any species of forage fish.

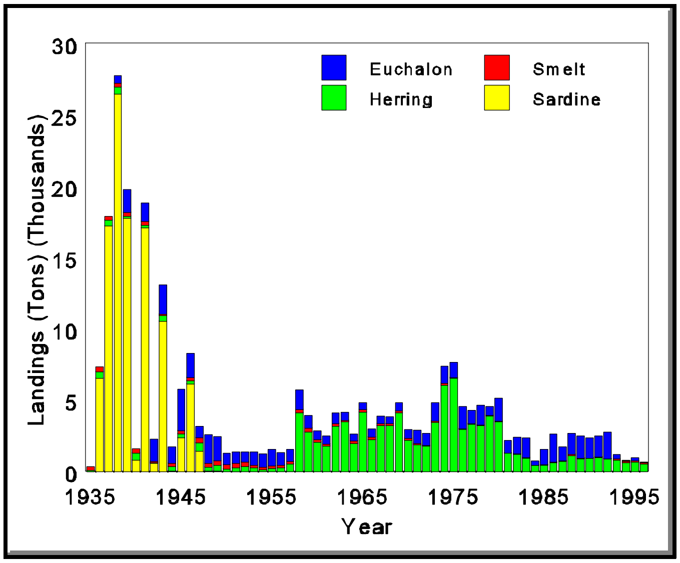

Figure 1. Annual commercial landings of forage fish.

In recent years, commercial harvests of forage fish have averaged about 1.7 million pounds (850 tons) annually (Appendix 1). This comprised about 3% of the weight of fin fish commercially caught in Washington state waters and adjoining coastal waters (Washington Department of Fish and Wildlife, unpublished data). Current commercial harvest are far below historical levels (Figure 1).

Allocation

Treaty Indian Fisheries

The federal court has ruled that tribes which signed treaties with the federal government in the 1850s have treaty fishing rights. Recently, the federal court ruled that these treaty fishing rights encompass the right to take every form of aquatic animal life, regardless of whether or not taken at treaty time. This federal court ruling is currently on appeal. Pending final resolution of this issue, the Department of Fish and Wildlife recognizes this federal court ruling as precedent on this issue.

To implement the federal treaty rights for the herring fisheries and to ensure conservation of herring, tribal and state governments have developed a process to allocate the herring fisheries resource. In the north Puget Sound area, the Department of Fish and Wildlife and the Lummi, Nooksack, Suquamish and Swinomish tribes adopted a formal herring allocation and management plan, which is updated with annual annexes. In the south Puget Sound area, no formal plan has been adopted, despite periodic meetings between state and tribal officials. Allocation questions in the south Puget Sound area are handled on an informal case-by-case basis. The treaty tribes' commercial harvest of herring in south Puget Sound is currently at a low level.

The treaty Indian tribes are not parties to this Forage Fish Management Plan. Tribes will not be bound by the provisions of the policy or the plan.

Allocation within the Non-Treaty Fisheries

No specific allocation exists between commercial and recreational forage fish fisheries. The vast majority (approximately 80%) of the forage fish harvest is taken by commercial fisheries. With the exception of surf smelt and eulachon, the recreational harvest of forage fish is too small to measure. The recreational harvest of surf smelt and eulachon is substantial, equal or greater than the commercial harvest, but no allocation between the two fishery types has been established.

Licensing

For all non-treaty fishing, a commercial fishing license is required to fish commercially for any species of forage fish in state waters. The authorized types of fishing gear are gill net, dip bag net, drag seine (i.e. beach seine), purse seine and lampara (a modified type of purse seine).

In 1973, the Washington legislature limited the number of commercial fishing licenses which could be issued to fish for herring in Washington waters. This legislation limited the number of herring licenses to 34 purse seine, 6 gill net, 42 lampara, 46 dip net, 10 beach seine and 1 trap. The legislation was revised in 1994 to require that each license be renewed annually. In addition, use of traps for herring was disallowed. Failure to renew a license meant that the license could not be renewed in the future. In 1997, the maximum number of herring licenses declined to 24 purse seine, 5 gill net, 26 lampara, 23 dip net and 6 drag seine. In addition, special herring spawn-on-kelp licenses are issued in certain years. The number of licenses issued depends on the abundance of herring. The number of licenses issued annually varies from 0 to 4. The department is authorized to issue a maximum of 5 spawn-on-kelp licenses annually.

The treaty Indian herring fleet is not restricted by the license limitation program nor is it under any growth restrictions.

There is no limitation on the issuance of licenses to fish commercially for species of forage fish other than herring. The number of commercial licenses issued annually has decreased in recent years (Table 2).

Table 2. Number of forage fish commercial licenses sold annually, 1994-96.

LICENSE TYPE	1994	1995	1996
Herring dip bag*	28	26	23
Herring drag seine*	6	6	6
Herring gillnet*	5	5	5
Herring lampara*	30	26	26
Herring purse seine*	28	25	24
Smelt gillnet	0	0	0
Smelt dip bag	1	2	3
Baitfish lampara	3	3	1
Baitfish purse seine	5	4	3
Foodfish drag seine	19	20	15
TOTAL	125	117	106

* limited entry license

Other than for smelt and eulachon (which require no license) a personal use food fish license is required to fish for forage fish for personal use. The authorized types of gear to be used for personal use are baitfish jig, dipnet and rake. The use of castnets or gillnets for personal use fishing is prohibited in Washington.

Legislative Authority

Relevant Legislation

The department adopts regulations for the management of the forage fish resources under authority granted to it by the legislature. These authorities are detailed in the Revised Code of Washington (RCW). Detailed rules are adopted by the Department in the Washington Administrative Code (WAC).

The overall mandate of the department is specified in RCW 75.08.012:

> "The department shall preserve, protect, perpetuate and manage the food fish and shellfish in state waters and offshore waters.
>
> The department shall conserve the food fish and shellfish resources in a manner that does not impair the resource. In a manner consistent with this goal, the department shall seek to maintain the economic well-being and stability of the fishing industry in the state. The department shall promote orderly fisheries and shall enhance and improve recreational and commercial fishing in the state."

RCW 75.30 states... "The legislature further finds that the stocks of herring within the waters of this state are limited in extent and are in need of strict preservation."

The legislature has concluded that herring are an important resource. RCW 75.30.260 states that... "the legislature finds that wise management of the herring resource is of paramount importance to the people of the state. The legislature finds that herring are an important part of the food chain for a number of the state's living marine resources."

Priority Species And Habitats

The Department of Fish and Wildlife has established the "Priority Habitats and Species List" which is intended to identify species and habitats of special concern in Washington (Washington Department of Fish and Wildlife, 1996) . Five species of forage fish and their spawning habitat are included on this list as priority species and habitats: Pacific herring, eulachon, longfin smelt, surf smelt and Pacific sand lance.

In addition, certain areas have been declared "saltwater habitats of special concern" (WAC 220-110-250). These areas include surf smelt spawning beds, sand lance spawning beds and herring spawning beds. As a habitat of special concern, disturbance of the spawning beds by construction projects may be prohibited or conditioned during certain times of the year (WAC 220-110-271).

Wild Salmonid Policy

On December 5, 1997, the Fish and Wildlife Commission adopted the "Wild Salmonid Policy." The goal of this policy is to protect, restore and enhance wild salmonids and their ecosystems in Washington (Washington Department of Fish and Wildlife, 1997). One section of this policy directly affects forage fish management; the marine area policy. The marine area policy is as follows:

- Provide nearshore marine, estuarine, and tidally influenced marine ecosystems that contain productive, balanced, integrated communities of organisms having species composition, abundance, diversity, structure, and organization comparable to that of natural ecosystems of the region.

- Ensure that functions and values of the following habitat types are maintained or increased: eelgrass habitats, herring spawning habitats, intertidal forage fish spawning habitats...

To implement this policy, the Commission determined that the following actions are required:

- Ensure no net loss of eelgrass habitat, herring spawning areas or function, intertidal forage fish spawning habitat area or function.

- Develop reserves for herring spawning habitat.

Forage Value

Forage fish are an important portion of the food chain in the marine environment. They are a major portion of the diet of other fishes, seabirds and marine mammals.

Fish

Many species of fish feed on forage fish. Major predators of herring include Pacific cod (42% of diet), whiting (32%), lingcod (71%), halibut (53%), coho (58%) and chinook salmon (58%), (Environment Canada 1994). Sand lance and anchovies (Beacham, 1986) are also important sources of food for fish. In the past, when sardine were abundant, they formed an important source of food for chinook and coho salmon (Chapman, 1936) In the Columbia River, juvenile sturgeon feed heavily on eulachon during the spring (McCabe et al., 1993).

A premise of salmon management and enhancement efforts is that the limitation to salmon production occurs in freshwater areas. The ocean environment is assumed to be non-limiting as historical salmon abundances were higher than salmon abundance at the present time (Brodeur et al., 1992). However, recent studies have indicated that early ocean feeding of salmon may be important, even critical to growth and survival of salmonids (Brodeur and Pearcy, 1990).

Dietary information on salmon in the marine waters is incomplete and may vary from year to year (Brodeur and Pearcy, 1990). However, the available information indicates that chinook and coho salmon feed heavily on fishes, while fishes are a minor portion of the diet of juvenile sockeye, pink and chum salmon (Healey, 1980).

Juvenile chinook salmon feed heavily on fish. The most important species of fish are anchovies, sand lance and juvenile rockfish. In the Strait of Georgia (the east side of Vancouver Island) fish comprised up to 65% of the diet of chinook; this is dominated by herring (Healey, 1980). Chinook begin to feed heavily on herring as soon as they enter the marine environment and continue feeding on forage fish until the salmon return to freshwater.

A study of adult chinook salmon in 1989 revealed they were feeding primarily on sand lance and herring. In another study the diet of adult chinook was dominated by herring and to a lesser extent, smelt (Gearin et al., 1994).

Juvenile coho salmon consume a wide variety of prey items. Fishes made up 72% of the diet of adult coho salmon; the fish prey was dominated by anchovies, sand lance, and juvenile rock fish. In the Strait of Georgia, fish are an unimportant part of coho salmon diet until summer when herring and sand lance made up 29-35% of the diet of coho salmon.

In British Columbia, a positive correlation was found between chinook and coho abundance and food supply; when food was abundant so were salmon with the converse also occurring, coho and chinook salmon appear to congregate in areas of best feeding opportunity (Healey 1980).

Chinook salmon on the west side of Vancouver Island are larger than the same-aged chinook on the east side of the island. The difference in growth rates has been attributed to a lack of food on the east side; primarily forage fish (Prakash, 1962).

In the Great Lakes a large scale stocking program of salmonid species (chinook salmon, coho salmon and lake trout) has a major impact on the forage fish base and may destablize the predator-prey system (Stewart et al., 1981).

Seabirds

Many species of seabirds depend heavily on forage fish for food. Large-scale reproductive failures of fish-eating marine birds have been associated with the collapse of their prey resource (Springer et al., 1984). Juvenile herring are probably the most important prey of seabirds (Hay et al., 1989). Sand lance are also important; and are the dominant food item for nesting auklets (Bertron and Kaiser, 1993). The availability of anchovies directly affects the breeding success of pelicans, terns gulls and auks (Pacific Fishery Management Council, 1996). Seabirds are sensitive to changes in their food supply (Furness and Camphuysen, 1997).

Historically, sardine were probably important as forage for seabirds; however, in recent years the population of sardine has been too low to provide an important food source. The decline of sardine in California earlier this century shifted the breeding distributions of pelicans in California. Recent sardine population increases in California have been followed by increased breeding success and abundance of brown pelicans (Pacific Fishery Management Council, 1996).

Marine Mammals

Marine mammals prey heavily on forage fish; 32% of the diet of harbor seals in British Columbia is comprised of herring (Environment Canada, 1994). In Washington and British Columbia forage fish are an important component of the diet of the following marine mammals: harbor seals, California sea lions, Stellar sea lions, harbor porpoises, Dall's porpoises, and Minke whales (Calambokidis and Baird, 1994).

The prey item most frequently taken by harbor seals in the Columbia River is eulachon and the highest counts of seals coincide with the winter spawning run of eulachon. In Puget Sound, herring is an important component of harbor seals diet, while along the coast anchovies and smelt are more important (National Marine Fisheries Service, 1997).

Harbor porpoises caught in the Strait of Juan de Fuca feed heavily on herring and smelt. Smelt and herring comprised 64% to 89% of the fish remains seen in the stomachs of harbor porpoises. Adult porpoises feed primarily on herring and subadults feed on both smelt and herring (Gearin et al., 1994).

Ecosystem Management

Food Webs

Because of the importance of forage fish species to many other species, changes in abundance of forage fish can have impacts on other species, including fish, mammals and birds. The base of fish prey supporting the piscivores (i.e. consumers of fish) in Puget Sound consists primarily of herring, sand lance, smelt, juvenile hake and juvenile pollock (West, 1997). A simplified food web (Figure 2) shows that a few species support most of the piscivores in Puget Sound.

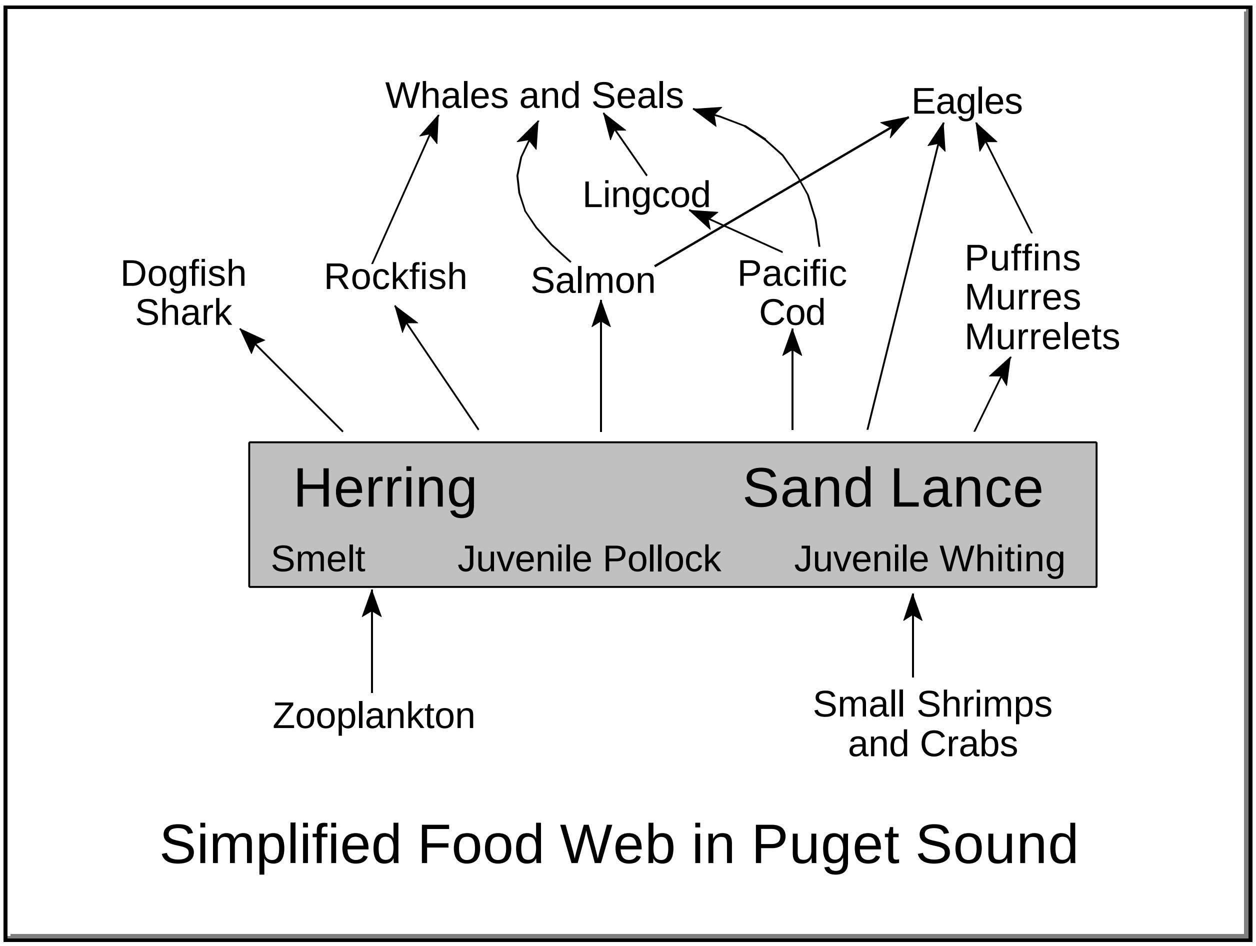

Figure 2 Simplified food web of piscivorous species in Puget Sound (adapted from West, 1997).

Many marine ecosystems share an important aspect in the structure of their biological communities. These ecosystems contain a large number of species, such as plankton, at low trophic levels. They also contain a substantial number of species such as large fish, seabirds and mammals at a high trophic levels. However, in many of these ecosystems, there is a crucial intermediate trophic level which is occupied by small pelagic fishes of which there is only a few number of abundant species (Bakun, 1996). This community structure, featuring many species at the bottom of the food web, many at the top, but only a few dominant species at mid-level has been called "wasp-waist ecosystems" (Rice, 1995). Forage fish characterize the species at the wasp-waist.

Modeling studies have shown that the variability in these ecosystems is dominated by variations in the mid-level populations (Rice, 1995). Typically, these populations of small pelagic fish vary greatly in size and these variations have major impact on the higher trophic levels (which depend on the wasp-waist populations for food) and on the lower trophic levels which are fed upon by the variable wasp-waist populations. The major control of these ecosystems is not bottom up or top down, but rather "both up and down from the middle " (Bakun, 1996). Forage fish often constitute the wasp-waist populations and potentially exert direct control on the trophic dynamics of entire ecosystems.

An example of this type of control is the herring-cod-marine mammal-seabird food web in the Barents Sea, near Norway (Hamre, 1994). In this ecosystem, herring (and capelin, a similar species) are the main plankton feeders and cod is the dominant predator with seabirds and mammals being secondary predators. Since the 1970's the herring stock has been greatly over fished, leading to severely reduced abundance of herring. In the 1980's recruitment of cod was successful and three strong years classes were produced. The herring stock was not large enough to provide sufficient food to the increased cod population. The rapidly growing cod stock grazed down the other prey species as well and soon starved cod, seabirds and seals appeared washed up along the coast line. The capelin fishery also collapsed and the cod fisheries were struck by the most serious crisis in their history.

In Europe, the abundance of sand lance has been linked to the breeding success of several species of seabirds; declines in abundance of sand lance resulted in declining reproductive success of seabirds (Monaghan, 1992).

One example of this occurred in the North Sea of the Atlantic Ocean where fishing for mackerel and cod led to an increase in their prey (sand lance) and a subsequent increase in seabird populations. Later, after a sand lance fishery started and that resource was heavily fished, the seabird populations declined (Furness and Ainley, 1984).

Stock Identification

A stock of fish is the smallest group of fish which can be treated identically for fishery management and conservation purposes. The correct identification of stocks is one of the most important facets of resource management. A group of fish can be treated as a single stock if both differences within the group and interchanges with other groups can be ignored (Gulland, 1983). Incorrectly identifying several small stocks as a single large stock could result in local depletion and extinction of smaller local groups of fish. Incorrectly identifying a large stock as several small stocks could result in curtailment of fisheries without benefit to the resource.

The stocks of forage fish widely vary. One extreme is sardine. There is one stock of sardine along the Pacific coast from southern California to Vancouver Island. The fish move up and down the coast seasonally. Harvests in one area need to be compared to the total coastwide harvest to evaluate the total impact on the stock. For example, large harvests of sardine in California may have significant impact on future abundance of sardine along our coast. The other extreme is represented by Pacific herring, which in Washington are considered to consist of isolated spawning stocks which return to the same area to spawn each year. Within Puget Sound, some herring stocks can be healthy, but adjacent stocks depressed (Washington Department of Fish and Wildlife, 1995). Fishing needs to be adjusted for each stock condition. In fisheries which harvest mixed stocks, the stock in worst condition will drive the fishery management needs.

Stock Stability

Four patterns of stock stability in fishes have been identified (Caddy and Gulland, 1983):

- Steady state stocks
  Catches in these fisheries remain at about the same level each year, with variations of less than 20-30% each year.

- Cyclical stocks
  Stock abundance show cycles; a pattern of high or low catches repeated at regular intervals.

- Irregular stocks
  Stocks that show irregular periods of high abundance without consistency in alteration between abundance and scarcity.

- Spasmodic stocks
  Stocks that show periods of high abundance alternating with collapse or rarity of the resource, with long periods of time before recovery in abundance.

In general, forage fish exhibit patterns of irregular or spasmodic stock stability (Cady and Gulland, 1983). This pattern of abundance has profound impact on fishery and resource management. Important points to consider when managing forage fish resources and fisheries are:

- The abundance of forage fish may vary greatly from year to year, even in the absence of fishing (Soutar and Isaacs, 1974).

- Recruitment (the strength of a year class) is highly variable.

- There is a tendency for fisheries to develop rapidly when abundance is high. Policy makers and the public may consider the periods of high abundance as “normal” and base plans for investments and resource utilization on these years.

- Regular stock assessment techniques do not perform well and may produce results with much uncertainty. Application of the results of these techniques by managers may actually exaggerate natural fluctuations (Caddy and Gulland, 1983).

Instability of Forage Fish Resources

An important characteristic that forage fish population have in common is a tendancy for rapid change (Lluch-Belda et al. 1989). Population size may greatly change over a short period of time. Forage fish abundance varied considerably even before modern fisheries began; much of this variation is due to changes in environmental condition. Fishing may have increased the natural variability due to decreased stock sizes and loss of older fish (Pacific Fishery Management Council, 1996).

A second characteristic that will impact some forage fish species is the geographical expansion and contraction in range associated with changes in forage fish populations. The range expands when abundance increases and contracts during low abundance. (Pacific Fishery Management Council, 1996).

It is important to recognize that instability in population size is an important characteristic of forage fish stocks. No management plan will produce stable populations for individual species (Pacific Fishery Management Council, 1996).

Forage fish species also interact with each other in complex ways. Changes in abundance of one forage fish may lead to changes in abundance in other species. For example, it has been long known that sardine and anchovies have a negative correlation in abundance: when one species is abundant, the other is less so (Gulland, 1983). An increase in sardine in coastal areas may also negatively impact herring which spawn in Puget Sound. Some of these herring stocks summer in the coastal area (Trumble, 1983) and there may be a direct competition for food between these two species. An analysis of sardine and herring catches in British Columbia between 1917 and 1947 indicates a biological interaction between these two species on the summer feeding grounds. High abundance of sardine appear to adversely affect survival of herring (Ware and McFarlane, 1989). In the Atlantic Ocean, a number of forage fish species, such as sand lance, increased in abundance when the herring resource was over-fished, and this increase may have prevented recovery of the herring stock (Monaghan, 1992).

These interactions add to the complexities of forage fish management. If a forage fish stock is reduced in abundance and fishing subsequently curtailed, stock recovery may be delayed by the forage fish interactions. In many cases, forage fish stocks do not recover for decades, or longer, following the cessation of fishing (Beaverton, 1990).

Expectation of forage fish resources should include considerable year-to-year variation in abundance. Abundance of individual species may decline to low levels for an extended periods of time, and periods of low abundance will probably occur more frequently and last longer under intense exploitation (Pacific Fishery Management Plan, 1996). Once a forage fish stock reaches a low level of abundance, recovery may require a protracted period of time, even if fisheries are curtailed or stopped.

Fishery Management Principles

Our current understanding of forage fish fisheries management indicates that two principles are important for protecting the resource and establishing harvest quotas (Schweigert 1994; Zheng et al. 1993). These two principles are a fixed harvest rate and a threshold policy.

The fixed harvest rate limits the harvest to a set percentage of the abundance (i.e., a fraction of the estimated abundance). Thus, the amount of allowable harvest each year changes in accordance with the abundance of fish; when abundance is high, the allowable harvest is high, when abundance is low, the harvest is low. This principle allows a large portion of each year class to remain unharvested to buffer population declines (Trumble and Humphries, 1985).

The threshold policy is a strategy whereby harvesting ceases when a population drops below a threshold level. This approach provides maximum protection to the stocks during periods of low abundance (Zheng et al., 1993).

The use of a threshold value and precentage to establish an allowable amount of harvest is shown in the following formula (Pacific Fishery Management Council, 1996):

HARVEST = (BIOMASS - THRESHOLD) * PERCENTAGE

Commercial Fishing Effort

The widely varying abundance of forage fish stocks results in situations where fishing fleets and associated industries (processors and wholesalers) make large capital investments during times of high abundance. These assets become idle or underutilized during periods of lesser abundance. A suggested management approach to this problem is to limit permanent access to the resource to a small number of participants (Cady and Gulland, 1983).

Recreational Fishing Effort

Unlike commercial fishing, recreational fishing for forage fish is much more responsive to changes in stock abundance and fishing opportunity. Recreational fishers have other recreational opportunities when fishing for forage fish is curtailed. Conversely, when fishing opportunities are expanded, recreational fishers can rapidly acquire the necessary equipment. Management of recreational fishing effort and catch can usually be achieved through changes in the daily bag limit and changes in the number of days open for fishing (either a shorter fishing season or days within a week when fishing is not allowed).

Resource Monitoring

Throughout the world in recent years, there have been numerous declines in fisheries for forage fish. Due to the extent and speed at which they occurred, the declines can only be called stock collapses (Beverton, 1990). Through the example of these collapses, it is apparent that traditional stock management techniques do not work well with forage fish. Use of traditional methods will mask stock declines; only when the stock is near collapse will signs of stress appear.

The reason for the failure of traditional stock assessment techniques is that the "catchability" of forage fish increases as the stock declines. Catchability is a measure of the probability of a fish being caught by a given amount of fishing effort (i.e., fishing mortality divided by fishing effort). For most species of fish, catchability remains constant over various stock sizes. However, due to the schooling nature of forage fish and their vulnerability to modern acoustics and fishing gear, catch rates remain constant, even when the stock is rapidly falling in size (Beverton, 1990). Thus declines in stock size will not be apparent to managers or to the fishing industry, based on catch per unit effort statistics.

Management of forage fish stocks require direct measurement of stock size. This can be accomplished by surveying fish abundance during the spawning season, or by conducting scientifically designed acoustic surveys of schools of forage fish (Trumble et al., 1982). Failure to monitor stock directly will result in the inability to determine changes, even severe declines, in forage fish abundance.

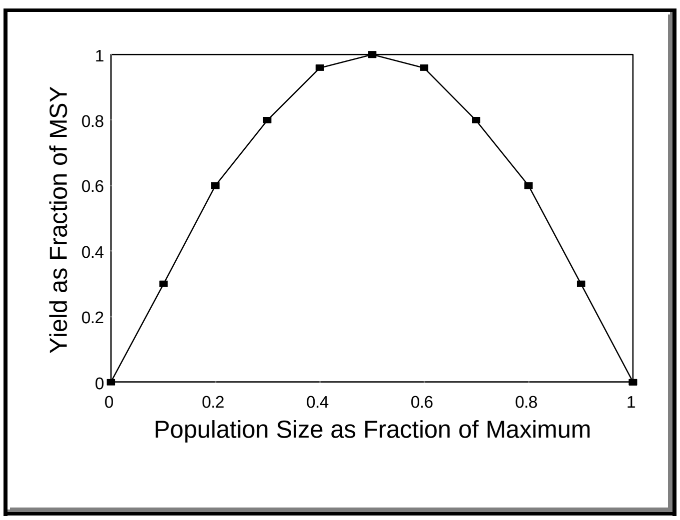

Figure 3. Generalized yield curve.

Effect of Fishing on Forage Fish Populations

A yield curve is a graphic method is illustrate the relationship between catch and population size on a long term basis. Every fishery resource has a yield curve similar to the one shown in Figure 3 although the dynamics at low stock size may be uncertain. For fish populations, there tends to be an upper population level which population does not exceed, because of some natural limitation. This is called the maximum population size and generally reflects average conditions for an unfished resource. As fishing begins on the resource, the population size will decline. At a constant level of fishing the population is expected to stabilize at a lower level. The absolute equiliburim (stabilized) abundance will vary dependent on environmental and fishing conditions. Some amount of fishing will produce the greatest catch (or yield) over the long term; this level of yield is called the maximum sustainable yield (MSY). (This is the largest average catch taken over a long period of time. The annual harvest will vary around the average).

Most fishery plans have a goal of achieving maximum sustainable yield or some derivation of it (often called optimal yield). Optimal yield is usually a fraction of maximum yield; the reductions in yield are made considering economic, social and biological factors. (MacCall, 1977). In Washington for example, the maximum sustainable yield of herring has been calculated to be 28% of the population annually, the annual maximum allowable harvest rate was set at 20% to account for other factors (Trumble, 1983).

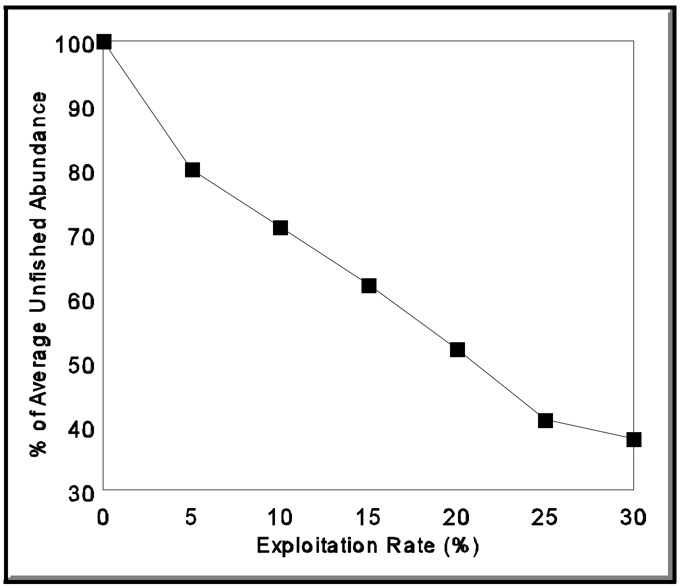

Figure 4. Effect of fishing on herring abundance.

A harvest rate of 20% will result in an average decrease in the population much greater than 20%. Using herring as an example, a 20% harvest rate applied over a long time will result in a population size approximately one half of the unfished populations size (Figure 4).

This relationship is true for most species of fish; a harvest rate at or near the maximum yield level will reduce the population to 35% to 50% of its unfished level. Although the details of the biology of many species of forage fish in Washington are lacking, a similar relationship can be expected between fishing and resultant population size; that is full exploitation will reduce the abundance level to one half or less of its unfished level.

Species Profiles

This section contains a summary of important biological and fishery information for the most common and economically important species of forage fish in Washington. The basic biology and harvest information is summarized as is information on the stock structure and risk of habitat alteration.

Pacific Herring

Herring is the most widely known and best studied species of forage fish in Washington. The reasons for this are that there are extensive commercial fisheries for herring, the importance of herring as bait for salmon fishing and the widespread abundance of herring in all marine waters of Washington. Herring are abundant throughout the northeast Pacific Ocean. Extensive research has been conducted on herring in Alaska and British Columbia and much of this research is applicable to herring in Washington waters (Hay and McCarter, 1995).

Biology

Herring spawn at 19 well defined locations in Washington: 1 coastal location and 18 locations east of Cape Flattery (Appendix 1 - Figure 1). The grounds utilized are very specific as is the time of spawning. The peak of spawning rarely varies more than 7 days from year-to-year (Table 3).

Herring spawn by depositing eggs on vegetation or other shallow water substrate. Spawning occurs in the shallow sub-tidal zone. Most egg deposition occurs from 0 to -10 feet in tidal elevation. The eggs incubate from 10 to 14 days before hatching (the incubation length varies with water temperature). Following hatching, the larvae drift in the ocean currents. It is important that the food supply for these larvae is sufficient to meet their needs. If the larvae drift to an unproductive area, year class strength is likely to be low (Sinclair and Tremblay, 1984).

Following metamorphosis, Puget Sound stocks of young herring spend their first year in Puget Sound. Some stocks of herring spend their entire lives within Puget Sound ("resident stocks") while other stocks ("migratory stocks") summer in the coastal areas of Washington and southern British Columbia (Trumble, 1983).

Following the attainment of sexual maturity at age two to four, the herring migrate back to the spawning grounds. Typically, each stock has a pre-spawner holding area where ripening adult herring mill prior to spawning. The holding patterns usually begins 3 to 4 weeks prior to the first spawning event (Trumble et al. 1982).

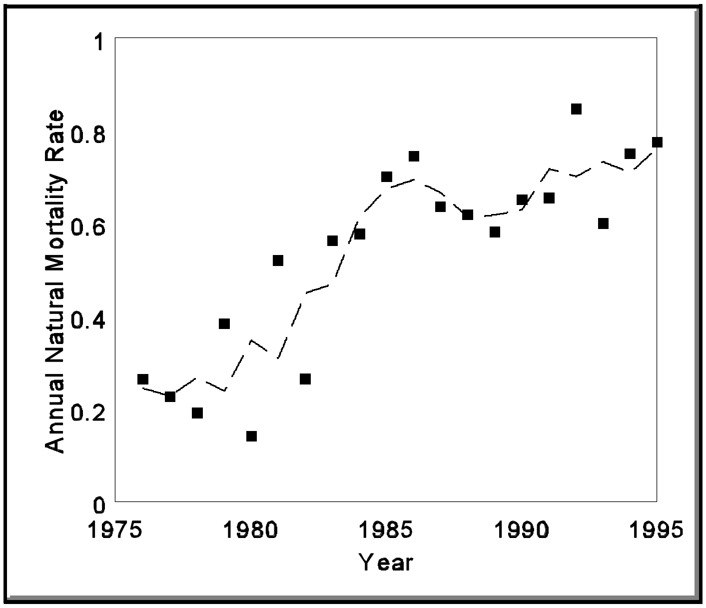

Figure 5. Annual natural (all causes other than fishing) mortality rate of Pacific herring in Puget Sound. The rectangles represent individual annual values and the line, smoothed values.

Like salmon, herring generally return to their natal spawning area. However, straying rates between spawning grounds can be high, approximately 20%. Unlike salmon, herring do not all die following spawning, and individual fish can spawn annually for several years.

Herring formerly lived to ages in excess of 10 years in Puget Sound. However, the mortality rate of adult fish has been increasing in recent years. Fish older than age 6 are now rare (Figure 5).

The relationship between spawning stock size and reproductive success in herring has been the subject of considerable research. Until recently, it appeared that there was little relationship between the numbers of spawners and the size of these resultant year class. Many other factors, such as water temperature, and river discharge can affect spawning success (Beamish, 1995). However, more recent studies indicate that there is a relationship (Zheng, 1996); reproductive success appears to be greatest at intermediate spawning stock sizes (Stocker et al., 1985).

Stock Structure

In Washington individual stocks are considered to be those fish which utilize specific spawning grounds. This conclusion is reached due to differences in spawning timing and growth by fish which utilize different spawning grounds (Trumble 1983). This is in marked contrast to British Columbia where multiple spawning areas are considered by fishery managers to be one stock. These two management conclusions have vastly different consequences. In Washington, we attempt to maintain viable populations utilizing each ground each year; in British Columbia loss of herring utilizing a specific ground is not a concern, the management goal is to maintain the overall abundance.

Stock Status

Of the 19 stocks of herring, 8 are in healthy condition, 1 in moderately heathy condition, 3 depressed, 1 critical and 6 in unknown stock condition (Table 3).

Table 3. Major herring spawning grounds in Washington.

	Spawning Ground	Months of Peak Spawning	1977-1996 Average Run Size (tons of herring)	Current Stock Status
1	Squaxin Pass	Jan-April	439	moderately healthy
2	Quartermaster Harbor	Jan-April	1,224	healthy
3	Port Orchard/Port Madison	Jan-April	1,281	depressed
4	South Hood Canal	Jan-March	272	unknown
5	Quilcene Bay	Jan-April	251	healthy
6	Port Gamble	Jan-April	2,214	healthy
7	Kilisut Harbor	Feb-March	405	unknown
8	Port Susan	Jan-April	823	depressed
9	Holmes Harbor	Feb-April	373	unknown
10	Skagit Bay	Feb-April	867	healthy
11	Fidalgo Bay	Jan-April	775	healthy
12	Samish-Portage Bay	Feb-April	283	healthy
13	Interior San Juan Islands	Jan-April	254	unknown
14	NW San Juan Island	Jan-April	200	unknown
15	Semiahmoo Bay	Feb-April	1,461	healthy
16	Cherry Point	March-June	6,095	depressed
17	Discovery Bay	Feb-April	1,468	critical
18	Dungeness Bay	Jan-March	188	healthy
19	Willapa Bay	Feb	UNKNOWN	unknown

Source: Washington Department of fish and Wildlife (draft report) 1996 Forage Fish Stock Status Report. MRD-SSR 96-01.

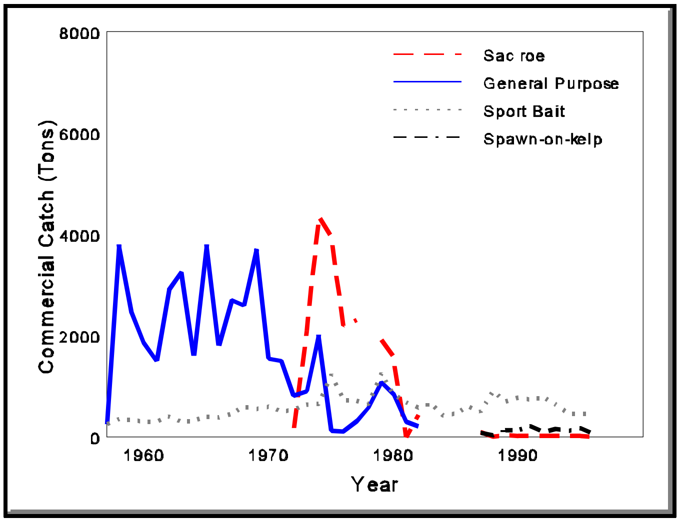

Figure 6. Annual landings of herring 1960-96.

Fisheries

Human use of herring has occurred for centuries as herring was, and continues to be, an important resource for native American groups. Modern use of herring began in the 1860's when it was not uncommon for a group of fishers to take 200 to 300 barrels of herring a night (Hammond, 1886). Modern fishery management for herring began in 1915; a detailed history of management is given in Trumble (1983). Several fisheries for herring operate in Puget Sound. Under existing regulations, no commercial harvest of herring in coastal waters is allowed. Existing or recent fisheries are commercial sport bait, general purpose, sac-roe, spawn-on-kelp and recreational (Figure 6).

Commercial Sport Bait Fishery

One of the longest existing commercial fisheries for herring provides bait for recreational fishing. This fishery captures herring (mainly juvenile) for use as fishing bait. The fishery occurs mainly in the spring, summer and early fall when sport fishing is at its peak. The catch in this fishery is largely driven by consumer demand; in recent years salmon fishing has been restricted in Washington, resulting in lowered catch of herring in this fishery. The catches peaked in the mid-1970's at approximately 1,000 tons annually. Subsequently, catches have averaged 547 tons annually. Most of the catch comes from southern Puget Sound and is comprised of “medium” sized herring (i.e. 1 year old fish) (Table 4).

Table 4. Annual landings of herring in the sport bait fishery 1992-96 (tons of herring).

Area	Size Category	1992	1993	1994	1995	1996	Average
Hood Canal - Admiralty Inlet	Small	2	1	0	T		1
	Medium	30	90	0	T		24
	Large	T	73	0	T		15
	Total	32	164	0			40
Central Puget Sound	Small	9	4	10	13	15	10
	Medium	249	97	99	94	157	139
	Large	38	66	48	72	40	53
	Total	296	167	157	179	212	202
South Puget Sound	Small	15	5	16	13	8	11
	Medium	334	173	216	162	130	203
	Large	39	127	69	106	108	90
	Total	388	305	301	281	246	304
Other Areas	Small	7					1
	Medium						
	Large						
	Total	7					1
All Areas	Small	26	10	26	26	23	23
	Medium	613	360	315	256	287	366
	Large	77	266	117	178	148	158
	Total	716	636	458	460	458	547

T = Less than .5 tons

General Purpose Fishery

The herring caught in this fishery were used for many purposes, including production of fish meal and oil, food for zoo animals and bait. The fishery began in 1956 and continued until 1983 when it was closed. This fishery occurred in the winter in Bellingham Bay and the San Juan Islands and most likely consisted of herring from several stocks (Buchanan, 1985).

Landings in this fishery peaked at about 3,600 tons annually in 1970 then rapidly declined until the fishery closed. The fishery was closed due to concerns about the quantity of small fish in the catch, and the origin of the herring caught in this fishery (Buchanan, 1985).

Sac-roe Fishery

This fishery began in 1973 when large amounts of spawning herring were detected in the vicinity of Cherry Point, near Bellingham (Trumble, 1983). This fishery harvests spawning adult herring for their eggs. The sac roe fishery captures and kills the herring with gillnets or seines. The egg sacs are removed from the females and sold. The fishery targeted on the spring spawning fish in the vicinity of Cherry Point. Landings in this fishery grew rapidly and peaked in 1974 at over 4,000 tons. Subsequently, the landings dropped as the herring stock size dropped rapidly. The fishery was closed in 1980 in response to plummeting stock size. A low level treaty fishery for sac-roe on this stock continues to occur. No non-treaty sac-roe fishing has been allowed for several years.

The fishery was controversial with many members of the public concerned about the impact of the fishery on the abundance of herring. An analysis of the fishery (Trumble, 1979) indicated that the abundance of herring in other areas of the Sound was unlikely to be affected by this fishery.

Spawn-on-kelp Fishery

This fishery operates on the same stock of fish as the sac-roe fishery. The spawn-on-kelp fishery was instituted as a low impact, value added alternative to the sac-roe fishery. In a spawn-on-kelp fishery the fish are captured in a seine and placed alive in a pen in which kelp has been suspended. The herring are allowed to deposit their eggs on the kelp. Once spawning has been completed, the herring are released and allowed to swim away. The egg-laden kelp is then harvested, processed and sold. In a well-run spawn-on-kelp fishery the mortality of fish involved is 10% or less. (Washington Department of Fisheries, 1990). An alternate method of spawn-on-kelp fishery does not involve handling the herring at all. This method involves spreading a line with kelp attached in the herring spawning area and allowing the fish to deposit their eggs on it. In this fishery the mortality of adult herring is zero. The product of both types of spawn-on-kelp fishery is quite valuable with values of up to $30 per pound.

The spawn-on-kelp fishery began in 1990 and continued annually on a very limited basis until 1996. In 1997, no fishery was allowed due to the low abundance of spawning herring. Management of this fishery has been conservative with captures of approximately 6% of the herring run size annually, compared to 20% annual harvests in British Columbia. Non-treaty spawn-on-kelp fisheries have been limited to the Cherry Point stock of herring. Treaty spawn-on-kelp fisheries have operated on that stock and in Port Gamble and Port Madison.

Sport Fishing

The recreational harvest of herring is very low; too low to estimate precisely. Most of the herring caught by sport fishers is used for bait and is often not brought ashore. The sport harvest of herring is not considered a significant source of mortality and has not been included in harvest management plans.

In summary, the fisheries for herring have undergone great changes in the past 40 years. The landings peaked between 1955 and 1975 and subsequently have dropped to low levels. The changes in landings reflect the dynamic nature of both the herring resource and the various herring fisheries.

Habitat Protection

Maintenance of herring spawning habitat is of prime importance to the preservation of herring resource. The herring spawn in intertidal or shallow sub-tidal areas of Puget Sound. These areas are under pressure for alternation as the human population of Puget Sound grows and the demand for residential and industrial use of shoreline increases. The spawning ground utilized for herring are quite specific and there is no known method to successfully replace or mitigate for lost spawning grounds.

Management Needs

Maintaining viable spawning grounds is the largest challenge to herring management in Washington. Spawning grounds can be lost or damaged through construction activities, loss of vegetation or oiling.

The increase in non-fishing mortality rate is alarming and needs further investigations. This increase in mortality threatens the continued abundance of herring much more than existing harvests.

Eulachon

Biology

The eulachon is seasonally one of the most common species of fish in the Columbia River and some of its tributaries. The adult fish spend most of their lives in the Pacific Ocean and may range from Oregon to Vancouver Island. High levels of by-catch of eulachon in the shrimp fishery have been reported in certain areas of the ocean ranging from northern Oregon to the southern end of British Columbia.

The adults returns to the river to spawn in the winter usually starting in December and continuing until spring.

The fish spawn by depositing their eggs which adhere to the bottom substrate. Certain sites are utilized for spawning each year. Other sites are used sporadically, occasionally being heavily utilized then not utilized for several years. The timing and locations of spawning appears to be highly influenced by river conditions such as water temperature, current and turbidity.

There is a high level of mortality of adult eulachon following spawning. However, it is unknown if all of the adults always die after spawning, as is the case with salmon.

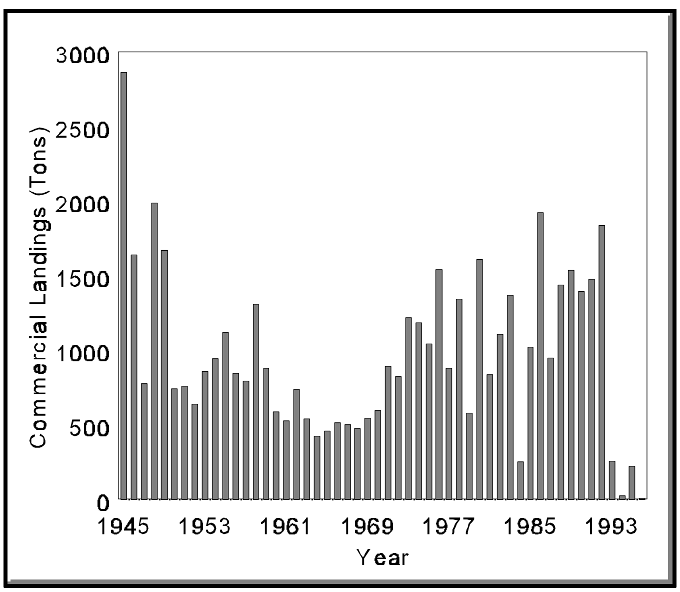

Figure 7. Annual commercial landings of Eulachon (includes fish caught in the Columbia River and landed in Oregon).

The larvae incubate in the gravel until hatching they then rapidly drift downstream and enter the ocean where little is known of their life history. Eulachon larvae have been detected in the lower river as late as June.

Fisheries

The species has been the subject of commercial and recreational fisheries for many years. Commercial catches have exceeded 5 million pounds in some years but have greatly declined in recent years (Figure 7). The commercial catch is taken with gill nets, dip nets and trawls.

A popular recreational fishery for eulachon also occurs during the spawning season. This fishery utilizes long handled dip nets from the shore or boats. Most of the fishing in Washington occurs in the lower Cowlitz or in the Columbia downstream from the Cowlitz. Little is known of the magnitude of the recreational fishery; observations indicate that the annual harvest may be approximately the same amount as the commercial fishery (W. Dammers, WDFW, personal communication).

Stock Assessment

No quantitative stock assessment is conducted. Commercial landings are monitored by tallying the annual catch. There is no annual estimate of the total stock size. Therefore no estimate of the harvest rate is made.

Stock Structure

There is generally considered to be one stock in the Columbia River, its tributaries and adjacent river systems.

Habitat

The portion of the river utilized for spawning is subject to frequent dredging to maintain shipping lanes. The impact of this dredging on the spawning grounds, on the incubating eggs or on the larvae is unknown.

The spawning habitat is poorly known. Despite the frequent changes in spawning location, there may be certain characteristics of sediment, stream depth and current that are needed for successful spawning.

Management Needs

This species is in urgent need of a management plan to control harvest. An additional urgent need is the development of a method to determine the abundance of each year’s run size so that harvest may be appropriately scaled to the anticipated run size.

It is important to note that the nearest major stock of eculachon, in the Fraser River of southern British Columbia, is also undergoing a similar decline in abundance (Doug Hay, Department of Ocean and Fisheries, personal communication). This may indicate a regional wide environmental change which is affecting eculachon populations.

Northern Anchovy

The northern anchovy is an abundant fish along the Pacific coast from Baja California to British Columbia. Anchovies are typically found in schools near the surface. They are subject to a large fishery off of California and Mexico (Richardson, 1981) but in Washington anchovies are caught only in a small fishery for bait. Most of the anchovies occur along the coast although at times they can be common in Puget Sound.

Biology

There are three sub-populations of anchovy along the Pacific coast. Those found north of Cape Mendocino, California are considered the northern stock (Richardson, 1981). Little is known of the northern stock. The spawning season lasts from mid-June to mid-August. Spawning locations are not well identified. Anchovy eggs have been reported in Puget Sound and off the mouth of the Columbia River. Larvae and juveniles have been reported from the same areas (Richardson, 1981). The major spawning area for the northern stock appears to be the Columbia River and, possibly, the Fraser River (Pike, 1951).

The abundance of anchovies in Washington is unknown. Anchovies were reported as abundant in Puget Sound in the 1890's (Jordan and Starks, 1895). The most recent study of anchovy northern abundance estimated the population at between 100,000 and 1,000,000 metric tons (Richardson, 1981). There are no more recent quantitative estimates of the population size available, however there are some indications that the population may have declined since the 1980's (Dr. Richard Parrish, National Marine Fisheries Service, personal communication).

The bulk of the anchovy population is well offshore. During the summer months, anchovies may be found in Gray's Harbor, Willapa Bay or the Columbia River mouth. The abundance of anchovies in these inshore areas varies from year to year but this variation appears to be due to changes in behavior, not changes in abundance. It is in these locations that most of the harvest occurs (Table 5), which has resulted in some public concern. The fish in these inshore areas are considered to be part of the larger population and the department has not acted to reduce the harvest.

Table 5. Annual landings of anchovies in Washington.

Year	Grays Harbor	Columbia River Estuary	Willapa Bay	Pacific Ocean
		(Tons of Anchovies)		
1980				
1981	1			
1982		6		
1983		3		
1984		11		
1985	1	12		
1986	0	1		23
1987	23	1		48
1988	17			27
1989	28			40
1990	28			27
1991	56			4
1992	5			41
1993	20		27	22
1994	17		33	26
1995	13		13	118
1996	66		18	11

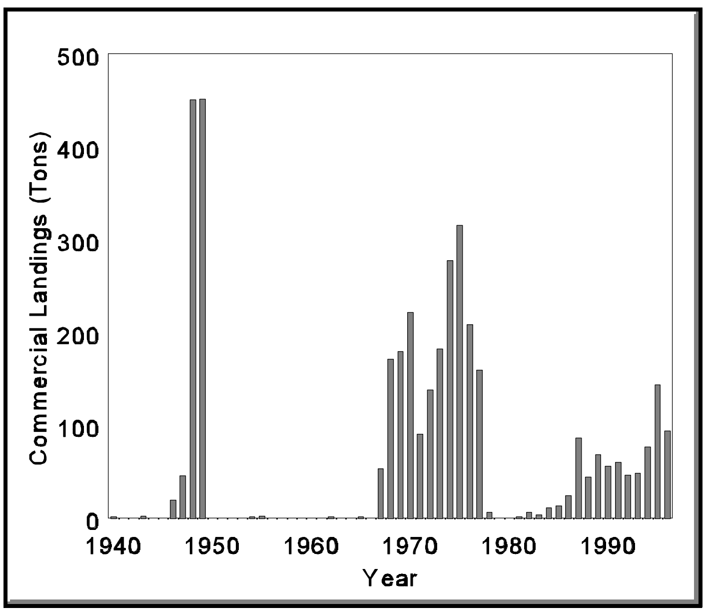

Figure 8. Annual commercial landings of anchovies.

Fishery

Commercial anchovy landings in recent years have been between 40 and 140 tons without a trend long-term in landings although the landings have been increasing since the early 1980's (Figure 8). The recreational fishery for anchovies is insignificant.

Landings are determined more by market demand than by abundance of anchovies.

Most of the harvest occurs in the summer and early fall. The anchovies caught are used to supply bait to sport and commercial fisheries. The fishery is not actively managed other than to minimize bycatch of other species, specifically juvenile salmon during the fishing operations.

Stock status - no current information exists on the abundance of anchovies. The current harvest of anchovies is not thought to be having a measurable impact on the population.

Habitat

There are no known major habitat concerns with anchovies. The fish are pelagic spawners and do not depend on any specific shoreline for successful spawning.

Pacific Sand Lance[1]

The Pacific sand lance, is found from southern California around the north Pacific Ocean to the Sea of Japan, and across Arctic Canada (Hart 1973). It is a common fish of nearshore marine waters throughout Washington state. It is generally acknowledged to be of great ecological importance in local marine food webs.

Biology

Very little is known about the life history or biology of sand lance populations in Washington State. Typically, sand lances are poorly represented in the catches most standard types of net-fishing gear, due to their body shape and behavior. No known sampling program by any local resource agency or research institution has yielded a comprehensive data set for an adult sand lance population in the Puget Sound basin.

Field (1988) has drawn together much of what was known of the biology of the sand lance populations of the Northeast Pacific Ocean. This information may be applicable to Washington State stocks of sand lance, as is the data summarized in Garrison and Miller (1982) The knowledge of the sand lance species complex of the North Atlantic Ocean is much more extensive, however it is uncertain how much of that information is applicable locally (Reay, 1970).

The actual spawning habitat of the Pacific sand lance was virtually unknown prior to the discovery of their spawn deposits in the upper intertidal zone of Port Gamble Bay in 1989. With the development of new sampling techniques, systematic surveys have documented sand lance spawning habitat on 129 lineal statute miles of Puget Sound shoreline (Pentilla 1995a, 1995b, 1997). The sand lance spawning habitat survey was estimated to be about 75% complete for the Puget Sound basin prior to being reduced by budget reductions in 1997. Sand lance spawning populations on Washington's outer coast and coastal estuaries have not been surveyed, although the occurrence of yolk sac sand lance larvae in those areas in the winter months indicates their presence.

Puget Sound sand lance populations appear to be obligate upper intertidal spawners, depositing their eggs in sand-gravel substrates between the mean high tide line and about +5 feet in tidal elevation. Individual broods of eggs incubate in the beach substrate for about one month, after which time the larvae are a common component of the nearshore plankton in many parts of Puget Sound. Several spawnings may occur at any given spawning site during the November-February spawning season. Spawning sites appear to be used year-after-year (Appendix Figure 2). Incubating sand lance eggs

[1] Based on material provided by Dan Pentilla, Washington Department of Fish and Wildlife.

occur in the same substrate with the eggs of surf smelt spawning populations, both species using the same stretches of beach for spawning at the same times of year.

Fishery

Presently, no directed commercial fishery effort occurs on sand lance in Washington. Small, sporadic recreational catches commonly occur in the summer and fall months when salmon anglers dip-net sand lances for fresh bait from "balls," tight schools of fish driven to the surface by the actions of diving seabirds.

Spawning sand lances would seem to be vulnerable to potential harvest during their spawning activity along many shorelines. However, this fishery has not been developed.

Stock Assessment

Sand lances are not amenable to assessment techniques presently used. Judging from the reported biology of the species, the widespread nature of their spawning grounds, spawn densities on the spawning beaches, and numbers of spawnings per spawning season, it is possible that there are thousands of tons of sand lances residing in the Puget Sound basin on a year-round basis.

Habitat Protection

The Pacific sand lance's habit of depositing and incubating its eggs in the upper intertidal zone makes it vulnerable to nearshore habitat alterations of the type commonly being undertaken along the local shorelines. Sand lance spawning habitats can be damaged or destroyed by physical burial under bulkhead-fill structures intruding into the intertidal zone from adjacent uplands, by alteration of the normal supply and movement of beach sediments, and by oiling. Healthy sand lance spawning habitats can only be maintained by the preservation of erosional sediment inputs, commonly in direct opposition to local trends in increased shoreline armoring to prevent erosion on developing shorelines (Thom et al., 1994).

Present regulatory policy emphasizes the protection of all natural sand lance spawning habitats. There is no known mitigation methodology to replace destroyed sand lance spawning habitat by artificial means in perpetuity.

Management Needs

Basic biological information needs to be collected for spawning populations.

The inventory of sand lance spawning habitats in Washington needs to be completed, so that all sites can be afforded regulatory habitat protection, and none inadvertently destroyed for lack of knowledge of the presence of the resource.

Surf Smelt[2]

The surf smelt occurs from southern California to central Alaska. Surf smelt have an entirely marine/estuarine life history, in contrast to the related eulachon and longfin smelt, which are anadromous. Surf smelt are very widespread in Washington, occurring in the outer coastal estuaries, the shores of the Olympic peninsula, and the greater Puget Sound basin from Olympia to the US-Canada border.

Biology

Surf smelt are common, year-round residents in many nearshore areas. They appear to be relatively short-lived fish, with the bulk of their spawning populations comprised of 1-2 year old fish (Penttila, 1978). Spawning occurs at high tides on mixed sand-gravel substrates in the upper intertidal zone. Although spawning stocks are presumed to have equal male:female sex ratio, spawning schools are commonly dominated numerically by males, several of which attend each ripe female during the spawning act. There is no suggestion of mass-mortalities of post-spawning surf smelt. Older specimens, interpreted as 3-4 year olds from scale patterns, are almost invariably females.

Surf smelt eggs are briefly adhesive during fertilization, and adhere tightly to the beach surface substrate. Subsequent wave action disperses the eggs into the top several inches of beach material, where they generally incubate for 2-5 weeks, depending on the seasonal ambient temperature. Spawning may occur at intervals of a few days at any particular spawning site, and thus surf smelt spawn deposits commonly contain several ages of eggs.

Surf smelt are somewhat unusual in having a very extended spawning season in the Puget Sound basin. Some areas receive several months of spawning activity centered in either the summer months or a fall-winter period. In recent years, systematic habitat surveys have documented year-round surf smelt spawning activity in a number of areas. These surveys have also expanded the extent of the documented surf smelt spawning to about 195 lineal statute miles of shoreline in the state. About 25% of the shoreline in Puget Sound basin remained to be adequately surveyed by mid-1997, when budget reductions resulted in diminished survey coverage.

The life history other than spawning of the surf smelt is not known. There is no evidence of widespread migrations to and from the outer coast. The relationship between spawning stocks and spawning grounds is also not known. There is some suggestion of genetic separation between widely-spaced smelt spawning stocks in the few thousand years that stocks have recolonized the Puget Sound basin since the last glaciation (Kilambi 1965), but there appears to be great potential for interchange between

[2] Based on material submitted by Dan Pentilla, Washington Department of Fish and Wildlife.

adjacent spawning areas at the larval-juvenile stage. Stocks of mixed juvenile and recovering-spent surf smelt occur in the general vicinity of known spawning grounds between local spawning seasons, suggesting some long-term residency.

Surf smelt compared with herring stocks appear to have significantly different behavior in Puget Sound waters. They appear to rarely, if ever form open-water pelagic schools. They are almost always very poorly represented in mid-water research catches, even in areas of Puget Sound where surf smelt spawning is known to have been underway over a broad area for a long period of time. This suggests a tendency to inhabit shallower nearshore zones and/or to remain close to the bottom at all times.

Fisheries

Commercial fisheries occur on surf smelt populations at many sites throughout the state (Table 6). Drag seine is the most common gear used, catching fish as they approach the spawning beaches. Commonly, only a small proportion of any given surf smelt spawning population is exposed to fishing pressure, due to annual fishery closures and lack of public access to the majority of spawning grounds in Puget Sound.

Table 6. Commercial landings in tons of surf smelt in Washington 1980-96.

Year	North Puget Sound	Strait of Juan de Fuca	Central Puget Sound	Hood Canal	South Puget Sound	Coast	Total of all Areas
1980	2	2	15	4	2	6	31
1981	3	1	21	5	2	32	64
1982	2	1	13	0	0	12	29
1983	6	1	5	1	5	14	32
1984	7	2	18	2	2	16	47
1985	1	0	14	8	1	22	46
1986	0	1	25	2	5	35	68
1987	1	1	26	1	1	35	65
1988	10	0	27	1	8	38	84
1989	0	0	1	1	0	37	39
1990	0	0	2	2	5	22	31
1991	0	0	3	6	1	24	34
1992	6	0	4	2	10	15	37
1993	6	0	7	18	1	51	83
1994	44	0	6	22	31	20	123
1995	0	0	37	12	9	20	78
1996	0	0	64	7	6	8	85

Recreational fisheries for surf smelt occur at many traditional sites throughout the marine areas of Washington state. These sport fisheries are of two types: jig fisheries generally catching non-spawning smelt (Hoffmann and Palsson, 1990) and dipnetting for spawning fish on the actual spawning beaches. Adequate fishery statistics are generally lacking for these fisheries, in spite of their local importance. The sport catch tonnage may exceed that of the commercial catch for this species.

In the present day, surf smelt fisheries in Washington state are curtailed by increasing privatization of shorelines, lack of public knowledge of the resource, saturation of commercial markets with a labor-intensive product, and market competition with other smelt species (eulachon). Unlike other local forage fish species, so far as is known, all surf smelt catches are for human consumption.

Given the recent increases in our knowledge of the true nature of the state's surf smelt spawning areas and seasons, and the elements curtailing the fishery, there is little concern over the overall status of most local surf smelt stocks.

Habitat Management

The surf smelt's habit of depositing and incubating its eggs in upper intertidal sand-gravel beaches has made it quite vulnerable to the negative impacts of human shoreline development and manipulation. Prior to 1972, there was no regulation of surf smelt spawning beaches in the face of widespread shoreline armoring practices, and many miles of such habitat were damaged or destroyed in the Puget Sound basin.

Currently, all documented surf smelt spawning sites in Washington are under WAC protection (Appendix Figure 3). It is presumed that additional surf smelt spawning habitats lie within those sectors of the state's shoreline that have not yet been adequately surveyed. Until properly documented these sites will be endangered by inadvertent destruction caused by lack of knowledge of the presence of the resource.

Surf smelt spawning habitats can be damaged or destroyed by physical burial by armoring bulkhead/fill structures intruding into the intertidal zone from adjacent uplands, alteration or disruption of the natural erosion and longshore transport of beach substrate (the "longshore drift"), or by oiling. Surf smelt spawning habitat protection efforts may often run counter to human efforts to stabilize the naturally-dynamic beach zone and stop erosion (Thom et al. 1994).

Current habitat protection efforts focus on the preservation of all naturally-occurring surf smelt spawning sites. There is no mitigation methodology known to suitably replace surf smelt spawning habitat.

Management Needs

Basic biological information needs to be gathered from a variety of surf smelt spawning stocks, both by way of recreational fishery monitoring and fishery-independent net sampling.

The systematic inventory of all existing surf smelt spawning areas needs to be completed, so that all such areas have regulatory habitat protection.

Sardine

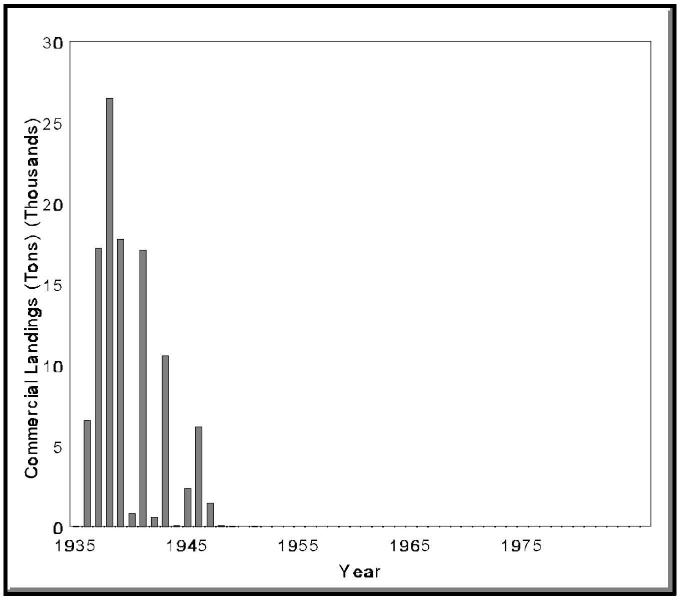

Figure 9. Annual landings of sardine in Washington.

Sardine were formerly extremely abundant along the Washington coast. The population, and commercial fishery, crashed during the 1930's (Figure 9). Subsequently, the sardine population has remained low. In 1997, for the first time in fifty years, the sardine population is Washington is substantial. Predictions are that the population in Washington will grow rapidly and may be fully recovered by the end of the century. This will likely result in demand for a commercial fishery in Washington waters which would have a potential for bycatch of salmon and perhaps other species. In addition, the increased sardine population may have substantial negative impacts on other pelagic fish species such as anchovies and herring.

Biology

The center of sardine abundance is in southern California and Mexico. However, the range extends northward through Washington and British Columbia. In recent years the population has grown rapidly and expanded to the north; increasing approximately 30% annually. This increase is likely to continue as recruitment has been strong. Based on past experience, these young fish will appear in Washington waters as they grow older. Computer modeling of the population suggests that the population will continue to increase until early in the next century (Barnes et al., 1996).

The reason for the collapse has been the subject of intense debate but it is clear that the collapse occurred during a time of very heavy fishing pressure and several successive years of low reproductive success.

The Pacific Salmon Commission and the Canadian Fish and Oceans reports catching over 1,000 sardine in a test fishery for sockeye salmon on the Canadian side of the Strait of Juan de Fuca during June of 1997. A mid-water trawl fishery conducted in Washington and British Columbia during late June and early July encountered substantial numbers of sardine from the mouth of the Columbia river to the northern end of Vancouver Island. (Dr. Richard Beamish, Department of Fish and Oceans Canada, personal communication). Sardine are now abundant all along the Washington Coast during warm water months.

Fishery

The fishery ended with the Pacific coast collapse of the resource, effectively ending the fishery and the presence of this species in Washington. No fishing for sardine has occurred for fifty years in Washington.

The collapse of the Pacific coast sardine resource is one of the most spectacular fishery collapses known (Gulland, 1983). At its peak, the fishery was harvesting 800,000 tons of sardine annually; this amount dwindled to nearly zero in a few years.

No fisheries for sardine are now occurring in Washington. Regulations prohibit commercial fishing for sardine in coastal waters, except by special permit issued by the director (WAC 220-44-020). In Puget Sound (i.e. marine waters east of Cape Flattery) landings of sardine are legal and a purse seine season is open (WAC 220-49-020), although there is no participation in the fishery.

The market for sardine is changing dramatically. In 1991, in California, 75 percent of the landed sardine were sold to processors and canned as pet food. In 1996, over 95 percent of the sardine landed in southern California were for human consumption. Another change is the demand for sardine exports. Between 1991-1994, an average of 1,300 tons of sardine were exported from California annually. In 1996, this amount was 14,000 tons. Demand from Japan for sardine is likely to increase as their sardine resource has recently collapsed (Barnes et al., 1996).

Interest in fishing for sardine is growing. Sardine are now the second largest component of the commercial fishery in California (data from the California Department of Fish and Game). In California, the landings have outpaced the growth of the stock (Barnes et al., 1996). The California Fish and Game Department is concerned about the growth of the fishery and is recommending a limited entry plan be implemented for sardine in California (request made at the June 1997 meeting of the Pacific Fishery Management Council). At the June, 1997 meeting of the Pacific Fishery Management Council, the Council received information that fish processing businesses are currently developing feasibility studies for sardine processing plants in Oregon and Washington. The Council voted to develop a pelagic fishery management plan which would include sardine. It is unclear if sardine fishing in Washington would be covered by the plan. The plan is scheduled for adoption in the fall of 1998.

Stock Structure

There is one stock of sardine from Canada to Central California. Sardine appear in our waters when the water temperature is warm and when sardine are abundant.

Habitat Issues

Sardine are pelagic fish and there for no pressing habitat issues. It is not known if spawning is now occurring in our waters.

Fishery Management Issues

If a fishery is to be allowed in Washington waters, two important issues must be considered. First, the management of sardine and, equally important, the potential bycatch in the sardine fishery.

The historical management of sardine has shown that interstate management is essential for success. The fish freely move among the three costal states and a fishery in any area will effect future abundance in the other states. Development of quotas and harvest plan by each state independent of harvests in the other state will likely result in over harvest of the resource and risk a repeat of the resource collapse. The Pacific Fishery Management Council's coastal plan for the management of pelagic fish will address these issues.

Any potential fishery for sardine would likely utilize lampara and purse seines nets. The bycatch of salmon in such a fishery is unknown, as is the mortality of any salmon caught in a sardine fishery. Other bycatch concerns would include seabirds, marine mammals and other predatory fish. Such a fishery could have substantial negative impacts on recovery efforts for listed species coastwide, if the bycatch is substantial. In any event, the authorization of a seine fishery in coastal waters will likely entail substantial review for ESA purposes.

Longfin Smelt[3]

The longfin smelt is locally common in a few estuarine areas of Washington state. Anadromous spawning populations may occur throughout western Washington, but the species is generally poorly known and little studied. The species is reported to occur from San Francisco Bay, California to Prince William Sound, Alaska (Hart 1973).

Biology

Little is known of the biology of anadromous stocks of longfin smelt in the Pacific Northwest, although land-locked populations in Lake Washington have received some study (Dryfoos 1965, Moulton, 1974). Available information on Washington longfin smelt is summarized in Gardner (1981).

The longfin smelt spawning season in the lower reaches of the Nooksack River is thought to only occur from November until as late as April.

In Lake Washington, longfin smelt live for two years. The major spawning area is the Cedar River and the peak spawning occurring between mid-February and mid-March. There is considerable differences in growth rates in different years (Moulton, 1974). There is also a consistent pattern of alternating strong and weak year classes (Chigbu and Sibley, 1994).

Habitat

The actual spawning sites of the Nooksack River longfin smelt have not been identified. If the preferred spawning substrate resembles the sand-gravel used by the surf smelt or eulachon, the available spawning habitat may be quite limited in extent. The Nooksack River, for example, is laden with glacial silt, and the vast majority of the river bottom in its lower reaches may be fine-grained silt. The preservation of existing gravel bars in the tidewater stretch of the Nooksack River may be essential to the preservation of this fish stock.

Fishery

Sport and tribal commercial fisheries have been reported to occur on the Nooksack longfin smelt stock in the area of the town of Marietta in November-December. The sport fisheries are reportedly undertaken with long-handled dipnets from the banks of the river, the commercial fishery with drag seines. These fisheries are presently unmonitored by state and tribal management entities, and no catch

3 The section is based on material prepared by Dan Pentilla, Washington Department of Fish and Wildlife.

data are available. There are unverified reports of a recreational fishery for longfin smelt in Lake Washington.

Management Needs

- Basic biological information needs to be collected from both freshwater and adjacent saltwater life history stages for a number of years.
- An inventory of longfin smelt spawning habitat sites and substrate characteristics on known spawning streams is needed.

Availability of Management Information

Table 7 summarizes the availability of basic fishery and biological information needed to manage stocks of forage fish in Washington. As highlighted in this table, basic management information is lacking for most forage fish, even species with active fisheries. This lack of information precludes, for most stocks, the ability to scientifically manage the resource or the fishery.

As a result of this lack of basic information in Washington, forage fish are not managed with catch quotas (an exception being some herring fisheries). Rather fisheries are managed through closed season and areas and limitation on the fishery gear (i.e. net length and mesh size). Recreational fisheries are managed by daily closures and bag limits.

This lack of information makes it very difficult to determine changes in stock size. Only extreme changes in stock size are likely to be detected. Any detection in change of abundance will likely be quantitative, rather than quantitative. The lack of critical information and the biology of forage fish species indicates the need for a conservative management approach.

Table 7. Summary of information available for the management of forage fish.

Species	Basic Stock Management Unit	Availability of Basic Fishery Information	Availability of Basic Biological Information	Ability to Monitor Current Stock Condition	Risk of Habitat Loss	Active Fisheries in Washington		
						Commercial	Recreational	Treaty Indian
Herring	Individual spawning grounds	Good	Good for P.S. - None for coastal stocks	Good for P.S. - Poor for the coast	High	Yes	No	Yes
Surf smelt	Individual spawning grounds	Fair for commercial fisheries - poor for recreational fisheries	No current information. Some historical information exists	None	High	Yes	Yes	Yes
Eulachon	Columbia River and tributaries	Commercial landing data only	None	Poor	Unknown	Yes	Yes	No
Sand Lance	Individual spawning grounds	No fishery	None	None	High	No	No	No
Anchovy	N. California to Canada	Commercial landing data only	None	Poor	Low	Yes	No	No
Sardine	Pacific Coast: Mexico to Canada	No fishery	None in WA. Good in Cal.	Good through efforts of Cal. Fish and Game	Low	No	No	No
Longfin smelt	Unknown	None	None	None	High	No	Sporadic	Sporadic

General Approach to Setting Harvest Regulations

Forage fish are an important part of the marine ecosystem of Puget Sound and Washington coastal waters. Forage fish provide an important link in the food web and are critical food sources for many other animals. In addition, forage fish are subjected to both recreational and commercial fisheries.

Despite their importance and active utilization, little information is available for most forage fish species. Abundance, changes in abundance, basic biological facts and spawning locations are poorly known.

There are three important points to the development of this forage fish plan:

- Forage fish are subjected to fisheries, both commercial and recreational. These fisheries are often directed at spawning aggregations of fish.
- Forage fish are a key component of the marine ecosystem in Washington.
- Key management and biological information is usually lacking for most forage fish stocks.

The management plan accounts for these three factors by proposing an approach to harvest regulations that:

- manages forage from an ecosystem based approach rather than a single species approach
- utilizes a precautionary, conservative approach.

Ecosystem Management

Most management plans emphasis yield, or catch as a major goal. This plan emphasis the role of forage fish in the ecosystem and considers catch on a secondary basis. The availability of forage fish to provide a source of food for salmon, other fish, marine birds and marine mammals will be a primary consideration. To achieve this, potential catch will be foregone if needed.

Development of annual, or stock specific, harvest plans will consider the impact of harvest on the availability.

Precautionary Approach

The precautionary approach utilizes caution when faced with a decision and a lack of information. The approach calls for reducing fishing, or other activities, if there is reason to believe that the activities will cause significant harm, even if such a link has not been established by clear scientific evidence.

Because of their ecosystem importance and lack of information, a cautious approach is advisable for management of these resources. A good example of a cautious approach to fisheries management is the "precautionary principle" as developed by the Food and Agricultural Organization of the United Nations precautionary principles (FAO, 1996). The precautionary principle states:

> "Management according to the precautionary approach exercises prudent foresight to avoid unacceptable or undesirable situations, taking into account that changes in fisheries systems are slowly reversible, difficult to control, not well understood and subject to change in the environment and human values" (quoted in Francis and Shotton, 1997).

For forage fish in Washington , the precautionary principle can be as follows (adapted from Garcia, 1994):

> To protect forage fish and their habitats from possibly damaging effects of fishing, habitat alteration or environment degradation, a precautionary approach is necessary. The approach may require action to control human activities even before a casual link has been established by clear scientific evidence.
>
> The department accepts the principle of safeguarding forage fish resources by reducing dangerous fishing practices, by use of best scientific information and other measures. This applies especially when there is reason to assume that damage to the forage fish resources are likely to be caused by human activities even when there is no scientific evidence to prove a casual link between human activities and effects on forage fish.

Adoption of the precautionary principle would alter the burden of proof used in fishery management. Traditionally, when scientific work is used to regulate the development and management of new fisheries, managers and scientists must demonstrate that harm is or will be done to the resource before the activities can be restricted (Garcia, 1994). Modern fisheries management has seen many more failures then successes (Francis and Shotton, 1997). Part of the reason for the numerous failures may be due to the requirement of "proof" prior to an agency taking management actions.

Adoption of the precautionary principle would fundamentally shift the burden of proof to showing that a proposed activity would not harm forage fish prior to the authorization of the activity.

Adoption of the precautionary principle would also mean caution in the absence of information. When data are sparse, management will be conservative. This means a lack of information will restrict fisheries. It will also serve as an incentive for research and data collection as industry will benefit directly from such activities.

The goals of ecosystem management and precautionary approach can be achieved using a combination of threshold and harvest percentage.

To achieve these goals a high threshold would be set and combined with a low harvest percentage. The threshold level probably would be most important (Pacific Fishery Management Council, 1996).

By setting a high threshold level, fishing would cease when the forage fish stock is still relative abundant. This action would preserve more fish for spawning and stock rebuilding. In addition it would avoid fishing during times of low forage fish abundance when food for other animals is most likely to be scarce.

The development of numerical threshold and harvest percentage needs to be done on a stock-by-stock, area-by-area basis.

This strategy would minimize risk to forage fish resources, protect critical habitat, allow recreational and commercial fisheries to operate under appropriate circumstances and provide the beginning of ecosystem based management of forage fish.

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Appendix 1

Appendix Table 1. Historical landings of forage fish in Washington (tons).

Year	Herring	Surf Smelt	Anchovy	Sand lance	Sardine	Eulachon[1]
1935	69	227			12	
1936	454	309			6,557	
1937	438	212	T	5	17,214	
1938	508	221		3	26,488	521
1939	142	282	4	8	17,764	1,548
1940	462	269	T	6	824	
1941	174	269		2	17,100	1,266
1942	36	100			584	1,541
1943	394	110	2		10,541	1,989
1944	303	235			42	1,134
1945	269	231		T	2,363	2,860
1946	227	232	19	1	6,145	1,638
1947	597	336	45	1	1,425	773
1948	242	277	450	T	54	1,987
1949	420	326	451	1	28	1,667
1950	194	313		2		741
1951	273	298		2	1	759
1952	359	334		1		638
1953	283	186		T		856
1954	133	162	1	2		942
1955	230	190	2	3		1,119
1956	266	202		5		842
1957	549	178		2		790
1958	4,152	219		2		1,308
1959	2,768	268		T		878
1960	2,052	172		T		586
1961	1,801	129		2		526

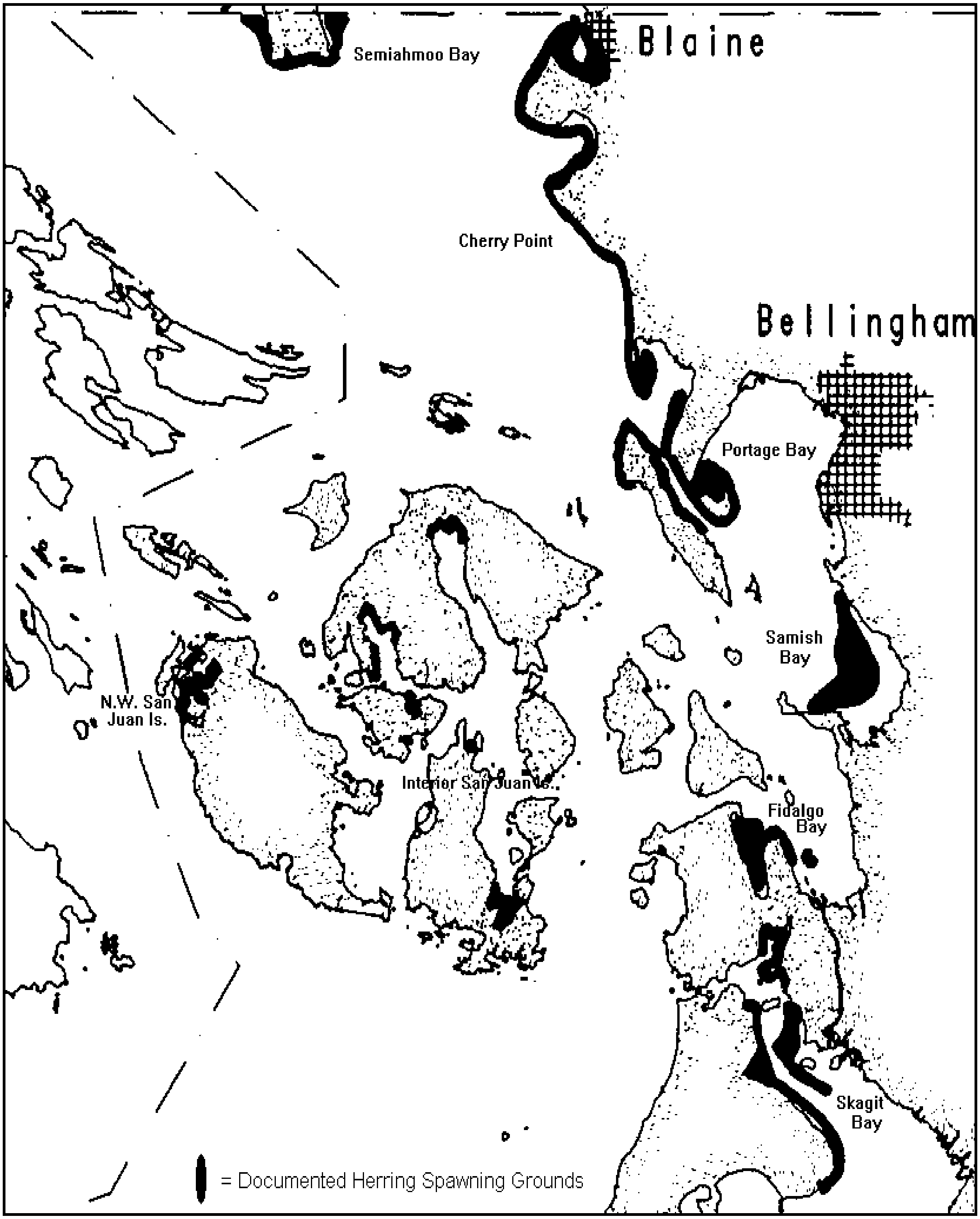
Year	Herring	Surf Smelt	Anchovy	Sand lance	Sardine	Eulachon[1]
1962	3,184	175	T	2		737
1963	3,486	113		1		539
1964	1,980	188		1		421
1965	4,173	159	1	1		456
1966	2,257	174		T		514
1967	3,224	132	53	1		501
1968	3,224	124	171	T		474
1969	4,148	94	179	T		542
1970	2,209	110	221	T		592
1971	1,893	71	90	1		889
1972	1,771	49	138			822
1973	3,450	114	182	T		1,217
1974	6,070	112	277			1,181
1975	7,171	40	315			1,039
1976	3,045	43	208			1,538
1977	3,115	56	159			877
1978	3,030	39	6			1,340
1979	3,592	47		T		579
1980	3,513	31		T		1,606
1981	1,531	64	1	T		836
1982	1,314	29	6			1,105
1983	872	32	8			1,365
1984	576	47	11			249
1985	466	46	13	1		1,019
1986	602	68	23			1,920
1987	628	65	84			948
1988	1,027	84	44			1,434
1989	961	39	68			1,534

Year	Herring	Surf Smelt	Anchovy	Sand lance	Sardine	Eulachon[1]
1990	1,076	31	56			1,392
1991	1,003	34	60	T		1,475
1992	968	37	47			1,837
1993	938	83	48	T		257
1994	799	123	76			22
1995	793	78	143			220
1996	593	85	94	T		5

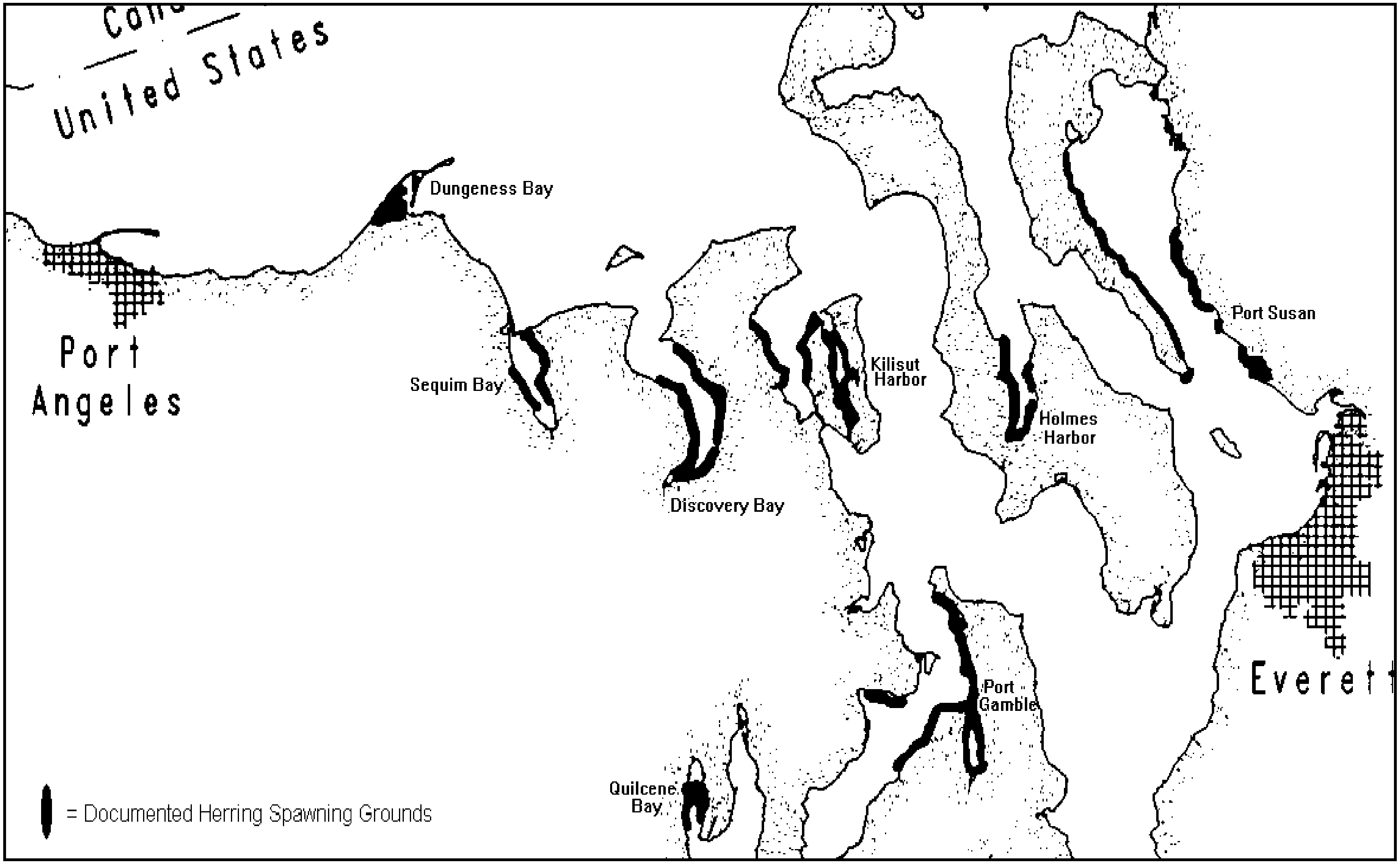
Commercial landings only; recreational catch excluded.
T - represents annual landings of less than 1,000 pounds.

[1] - Eulachon landings include all eulachon caught from the Columbia River system.

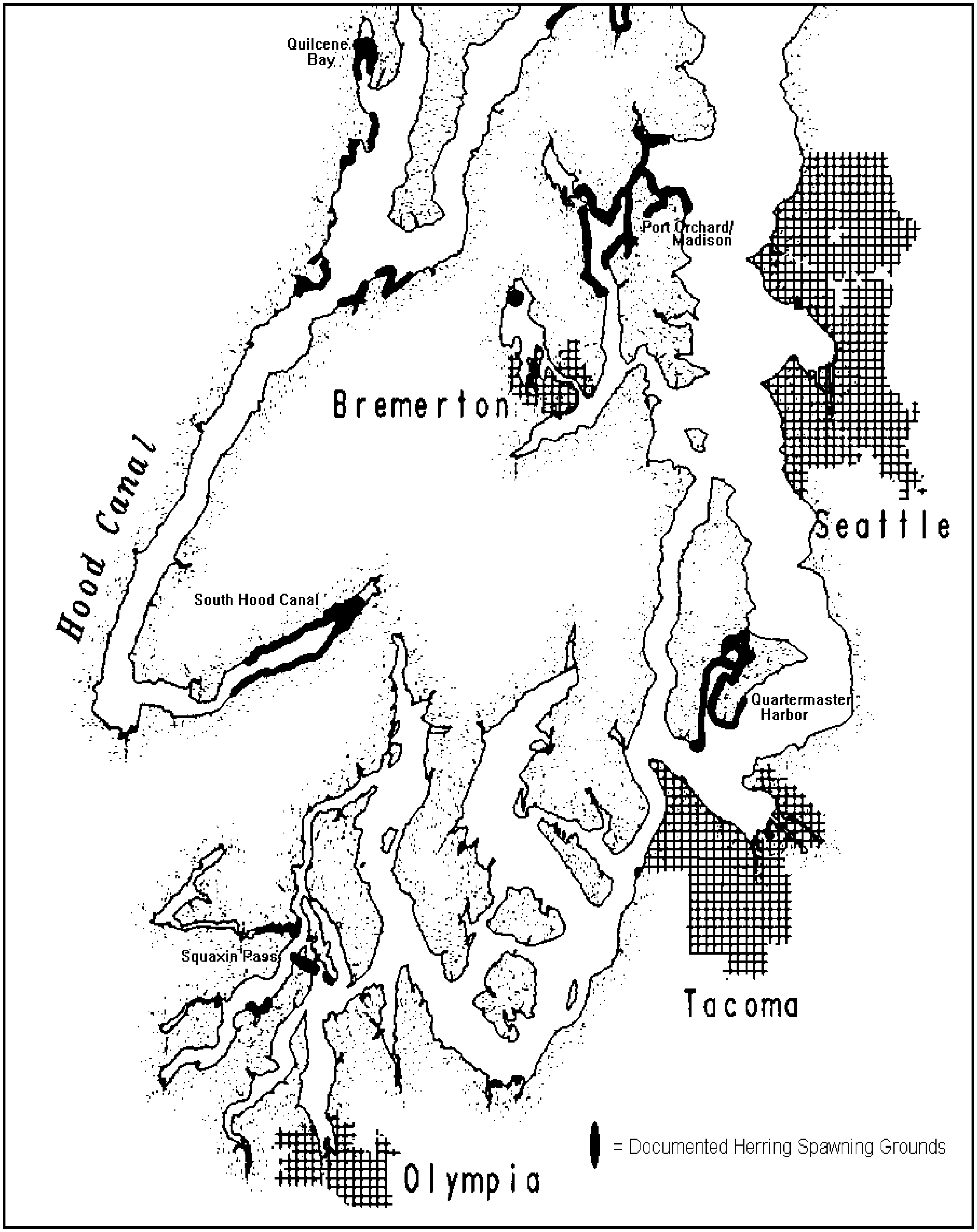
Appendix Figures



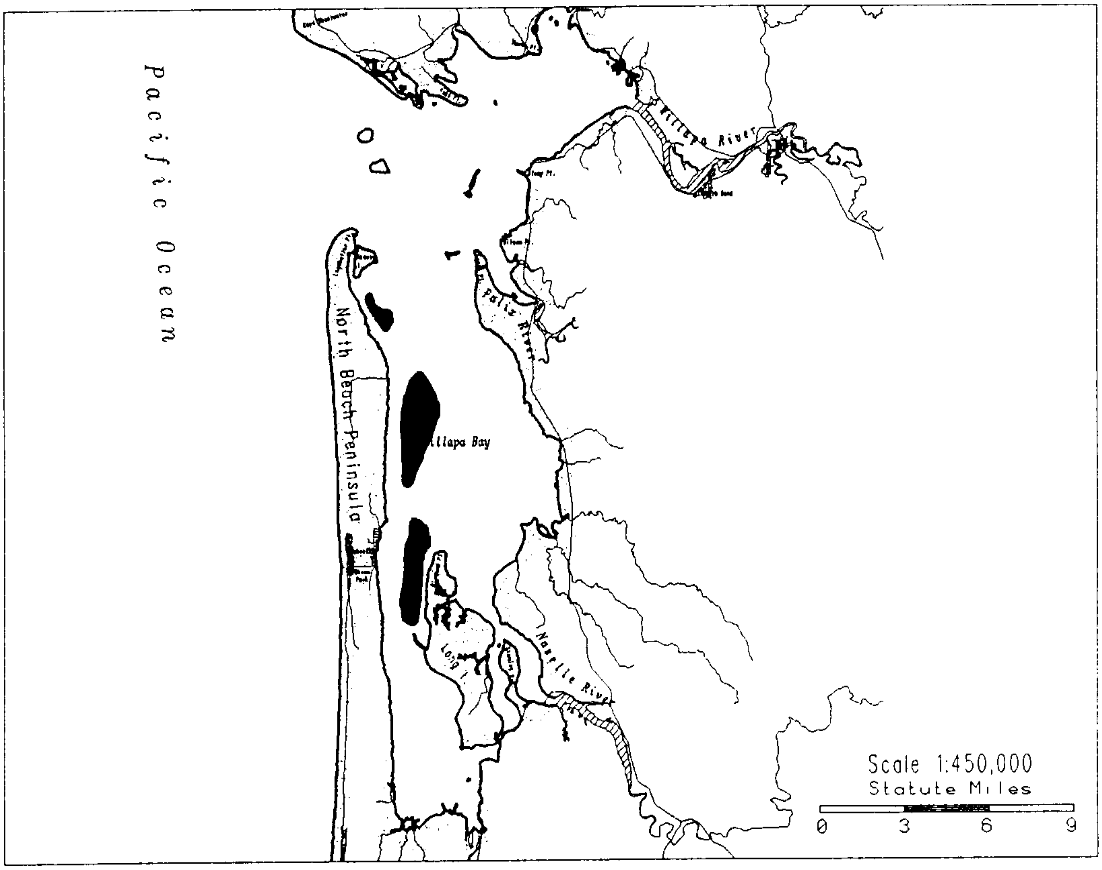
Appendix Figure 1. Documented herring spawning grounds in northern Puget Sound.



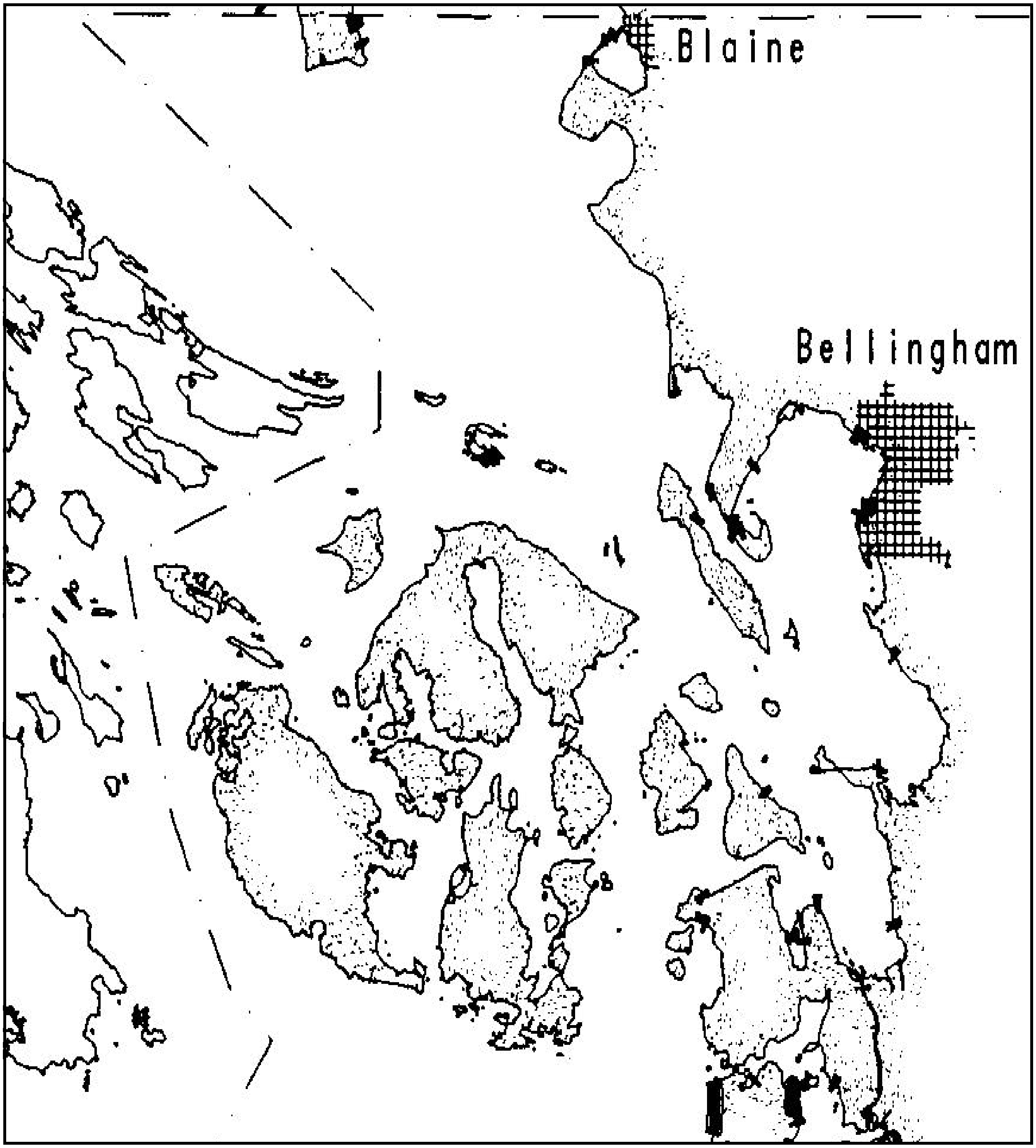
Appendix Figure 2. Documented herring spawning grounds in central Puget Sound and Strait of Juan de Fuca.



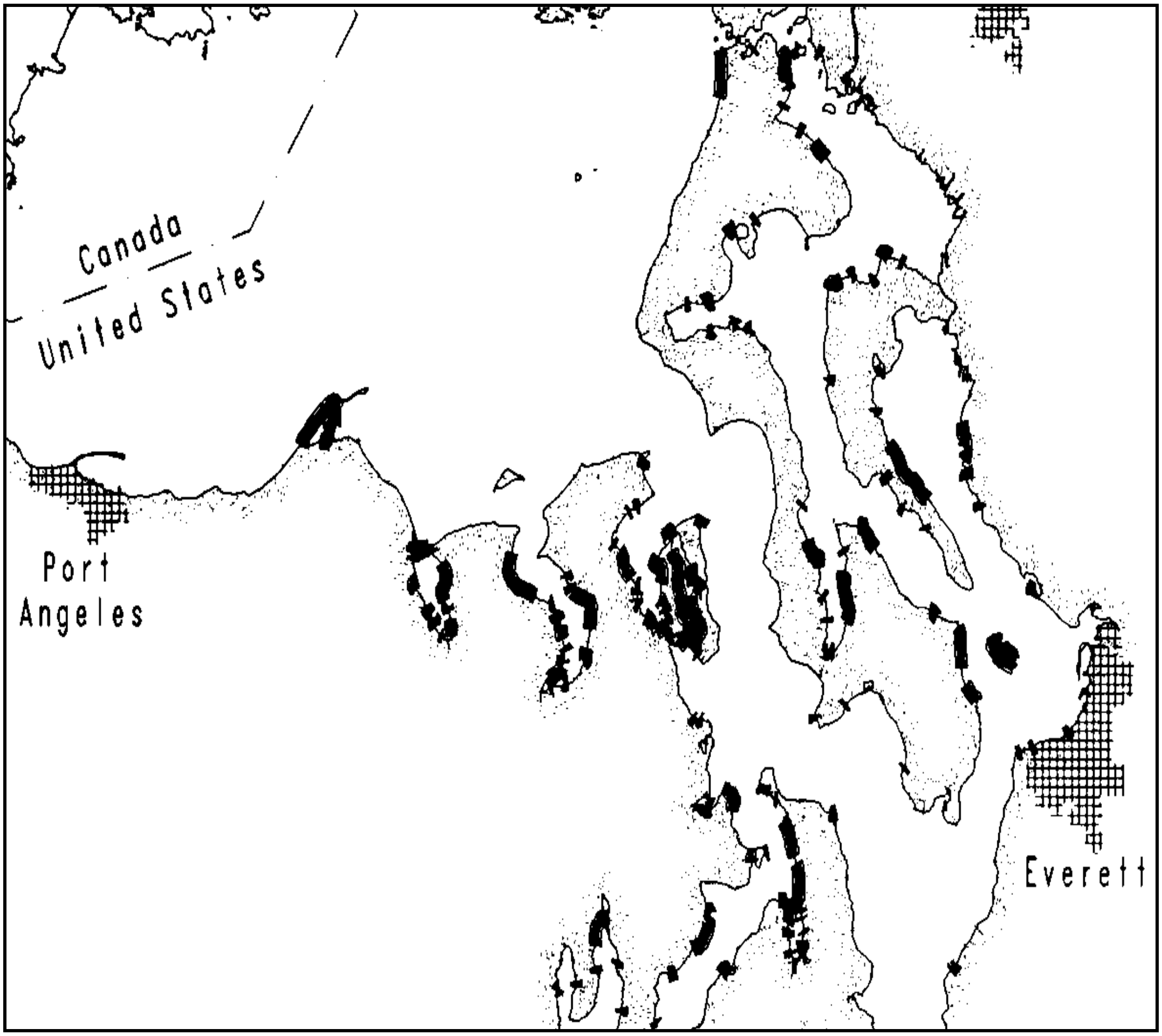
Appendix Figure 3. Documented herring spawning grounds in southern Puget Sound.



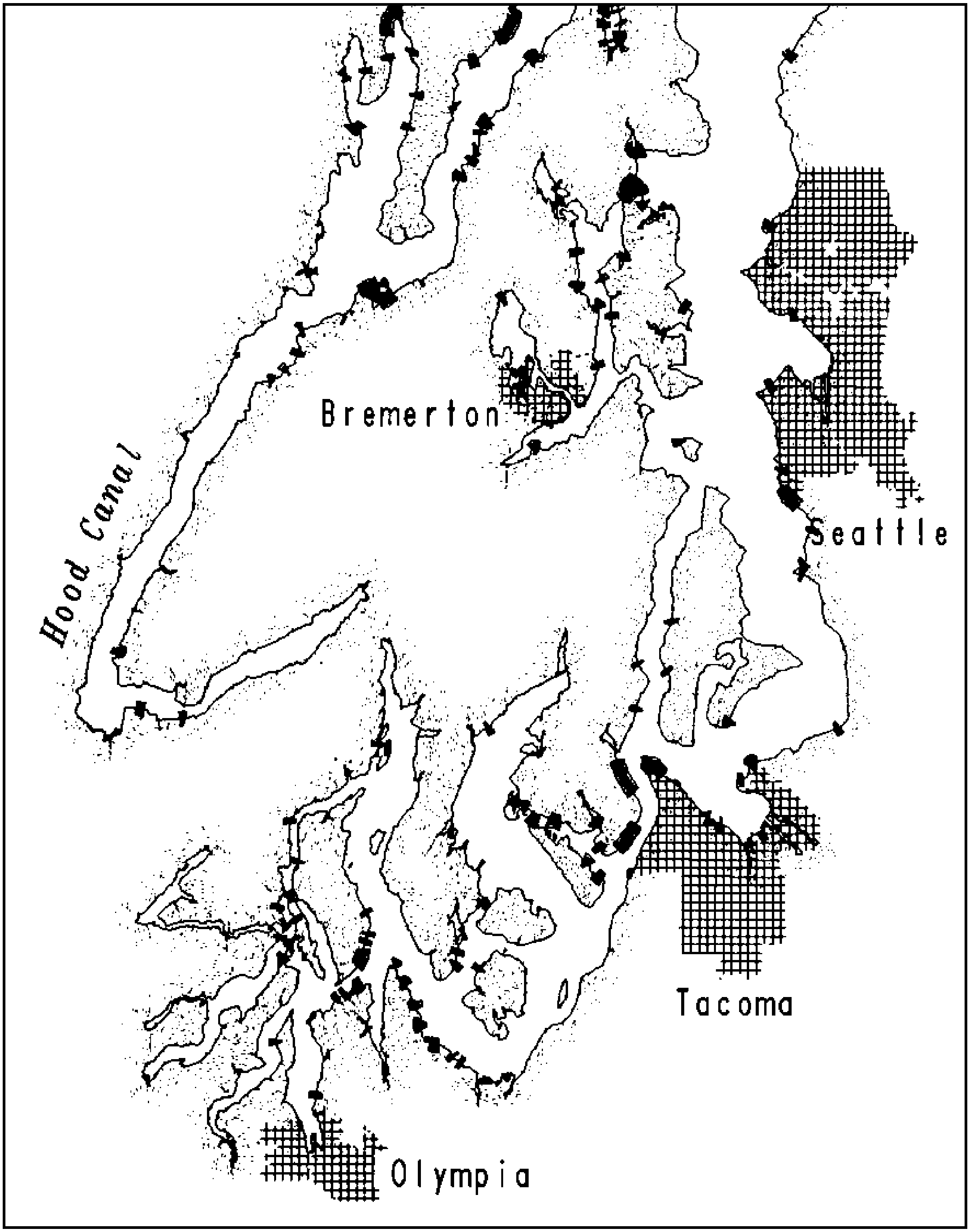
Appendix Figure 4. Documented herring spawning grounds on coast of Washington (Willapa Bay).



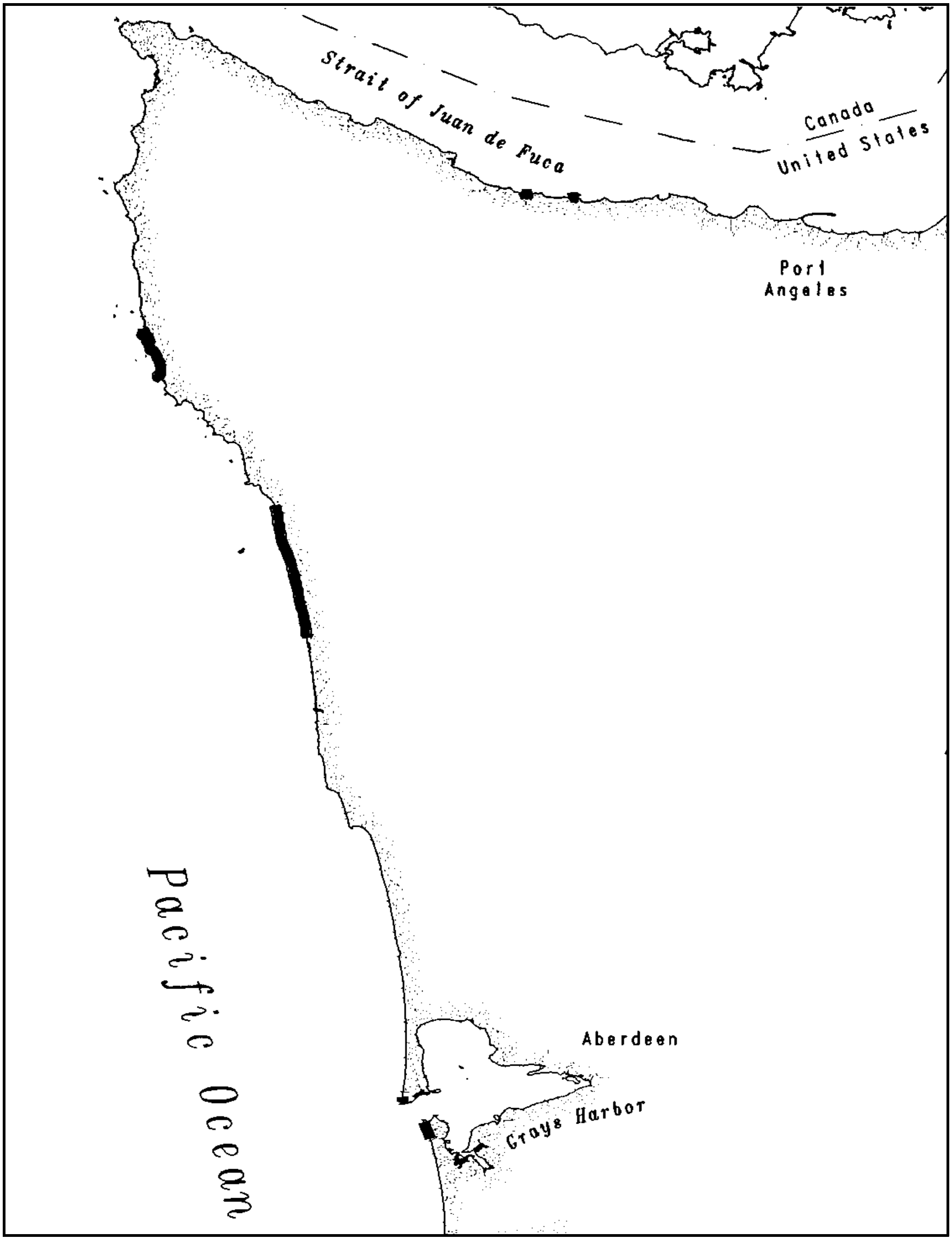
Appendix Figure 5. Documented sand lance spawning grounds in northern Puget Sound.



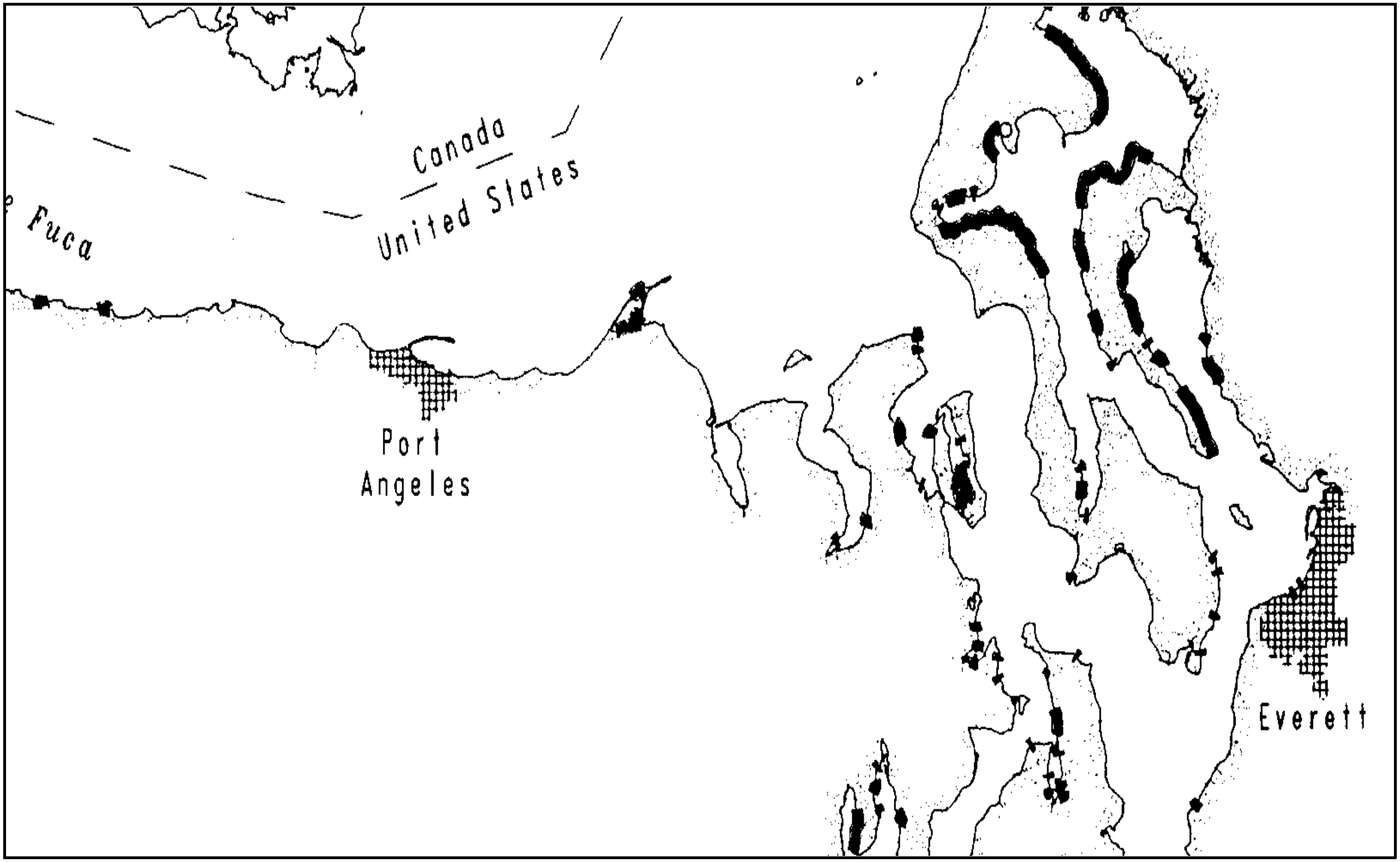
Appendix Figure 6. Documented sand lance spawning grounds in central Puget Sound and Strait of Juan de Fuca.



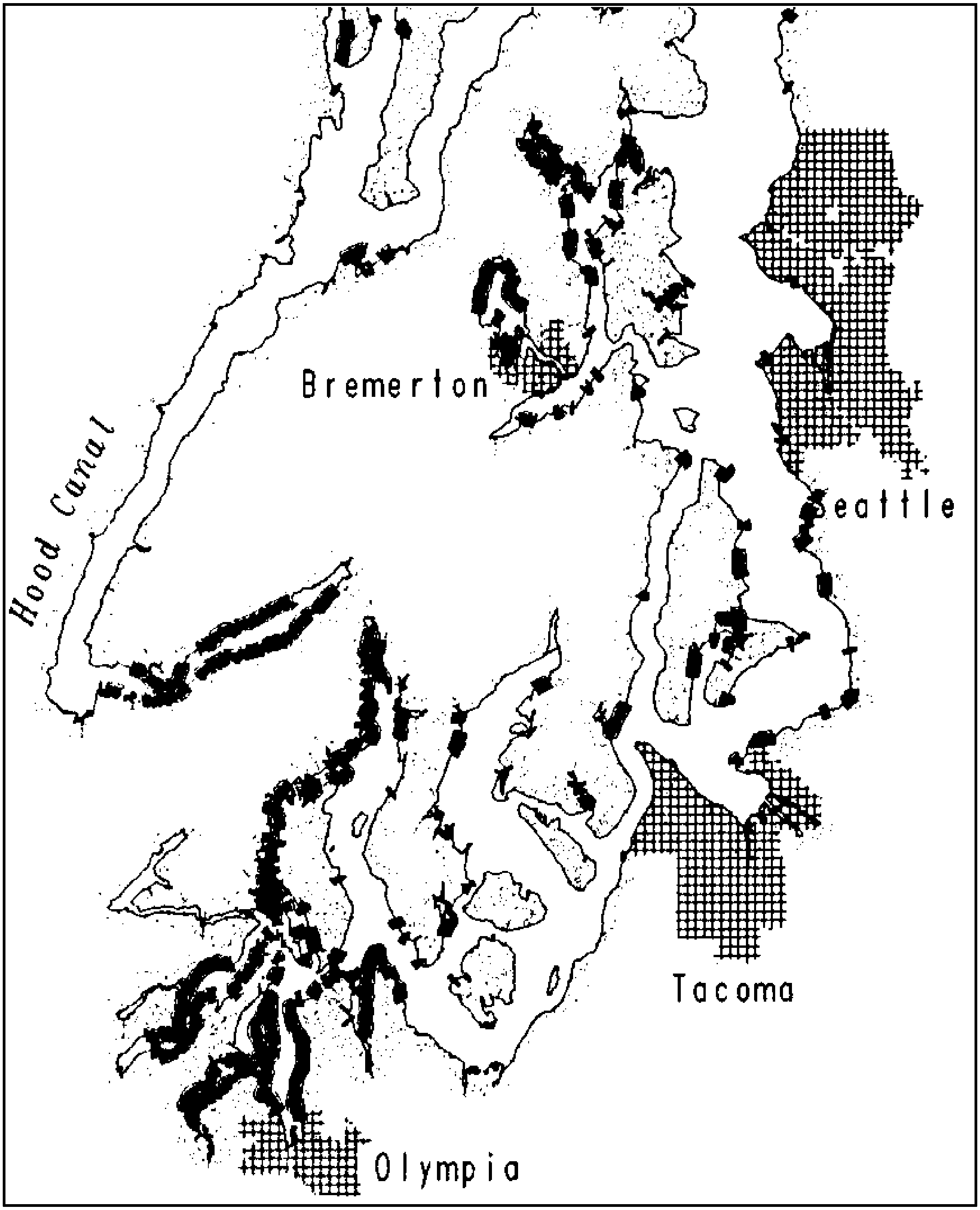
Appendix Figure 7. Documented sand lance spawning grounds in southern Puget Sound.



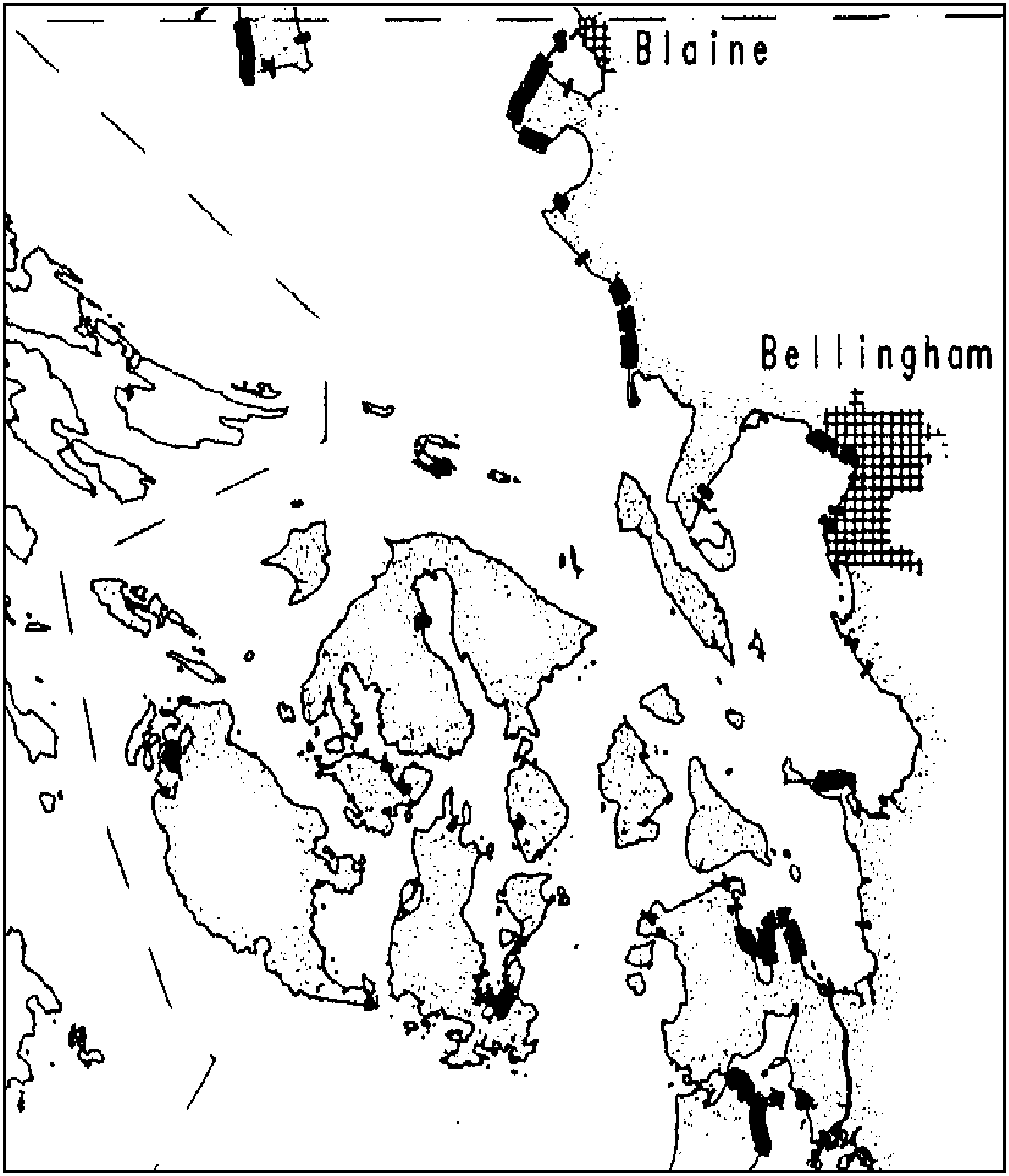
Appendix Figure 8. Documented surf smelt spawning ground of the Washington coast.



Appendix Figure 9. Documented surf smelt spawning grounds in central Puget Sound and Strait of Juan de Fuca.



Appendix Figure 10. Documented surf smelt spawning grounds in southern Puget Sound.



Appendix Figure 11. Documented surf smelt spawning grounds in northern Puget Sound.