TO: SECRETARY OF COMMERCE, UNITED STATES DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL MARINE FISHERIES SERVICE

From: Sam Wright (petitioner), 2103 Harrison NW, Ste. 2126, Olympia, WA. (Phone: (360) 943-4424)

Subject: Petition the Secretary of Commerce to list as threatened or endangered eighteen (18) "species/populations" or evolutionary significant units of "Puget Sound" marine fishes and to designate critical habitats. (Note: for the purposes of this petition, a species/population is defined as an important, existing (but severely depressed) native fish resource which is currently at-risk (threatened or endangered) and has no reasonable expectation of being able to recover over time by itself and/or from the surplus production of an adjacent or nearby population of the same species. Puget Sound is defined as all of the inland U. S. marine waters within the State of Washington that are east of the Bonilla-Tatoosh Line at Cape Flattery. As such, the definition includes the U. S. portion of the Strait of Juan de Fuca, U. S. parts of the San Juan Archipelago and Strait of Georgia, and all of Hood Canal. Puget Sound "proper" is defined as "To the east of Deception Pass, and to the south and east of Admiralty Head (and south of Point Wilson on the Quimper Peninsula)" (Dethier 1990, p. 10). This area has a unique set of geographic and oceanographic conditions which commonly limit gene flow between marine fish populations of the same species.

BASIS FOR THE PETITION

Petitioner files this petition under the Endangered Species Act (the "ESA"), 16 U. S. C. section 1531-1543 (1982) (ESA), its implementing regulations, 50 C. F. R. part 424, and the Administrative Procedure Act, 5 U. S. C. section 553 (c). The National Marine Fisheries Service ("NMFS") has jurisdiction over this petition under 16 U. S. C. section 1533 (a) and the August 26, 1974, Memorandum of Understanding Between the U. S. Fish and Wildlife Service and National Marine Fisheries Service Regarding Jurisdictional Responsibilities and Listing Procedures Under the Endangered Species Act of 1973.

The petitioner is a scientist and Certified Fisheries Professional (CFP, American Fisheries Society). The conservation, ecological, recreational, research and commercial interests of the citizens of the United States (including the petitioner) will be adversely affected if the requested petition is not granted.

Seventeen of the 18 species of concern were included in a July 1998 publication by the American Fisheries Society (Musick 1998). All of the entries were provided to the author by the petitioner, along with the supporting technical data needed to justify their inclusion. This draft AFS List of Marine Fish Stocks at Risk in North America (Musick 1998, p. 30) had the following entries for Puget Sound, including the primary cause for concern:

Pacific herring, *Clupea harengus pallasi* - other
Pacific cod, *Gadus macrocephalus* - slow growth/late maturity, other
walleye pollock, *Theragra chalcogramma* - other
Pacific hake, *Merluccius productus* - other
brown rockfish, *Sebastes auriculatus* - slow growth/late maturity
copper rockfish, *Sebastes caurinus* - slow growth/late maturity
greenstriped rockfish, *Sebastes elongatus* - slow growth/late maturity
widow rockfish, *Sebastes entomelas* - slow growth/late maturity
yellowtail rockfish, *Sebastes flavidus* - slow growth/late maturity
quillback rockfish, *Sebastes maliger* - slow growth/late maturity
black rockfish, *Sebastes melanops* - slow growth/late maturity
China rockfish, *Sebastes nebulosus* - slow growth/late maturity
tiger rockfish, *Sebastes nigrocinctus* - slow growth/late maturity
bocaccio, *Sebastes paucispinis* - slow growth/late maturity
canary rockfish, *Sebastes pinniger* - slow growth/late maturity
redstripe rockfish, *Sebastes proriger* - slow growth/late maturity
yelloweye rockfish, *Sebastes ruberrimus* - slow growth/late maturity

The 13 rockfish species listed above were designated as "important species of bottomfish in Puget Sound" by Palsson et al. (1997) and in an early 1998 draft of the Puget Sound Groundfish Management Plan. In the final version of this plan (Bargmann 1998a), the blue rockfish, *Sebastes mystinus*, was added to the list as "important".

In addition, alarming declines in populations of plant and animal species in the inland marine waters of British Columbia and Washington have prompted collaboration of scientists and managers from the two jurisdictions. The 1994 British Columbia/Washington Symposium on the Marine Environment identified species and species groups that had suffered significant anthropogenic stresses and were in need of special consideration for their protection (Wilson et al. 1994 cited in West 1997). The fish species identified were Pacific herring, Pacific cod, walleye pollock, Pacific hake, three species of demersal rockfish (brown, copper and quillback), and lingcod (*Ophiodon elongatus*).

Petitioner, as well as Washington Department of Fish and Wildlife (WDFW) professional staff members, have also nominated all of these same 18 species (except blue rockfish) as candidates for the Washington State list of endangered, threatened or sensitive species. In addition, WDFW has established a "Priority Habitats and Species List" which is intended to identify species and habitats of special concern in Washington (WDFW 1996). Priority species are those that require protective measures for their perpetuation due to population status, sensitivity to habitat alteration, and/or recreational, commercial or tribal importance. Ten species of groundfish were included on the Priority Habitats and Species List (WDFW 1996) and seven are addressed in this petition (Pacific herring, Pacific cod, walleye pollock, Pacific hake, copper rockfish, quillback rockfish, and yelloweye rockfish). In state regulations, certain areas have been declared "saltwater habitats of special concern", and these include herring spawning beds (WAC 220-110-250).

DEFINITION OF AT-RISK PUGET SOUND MARINE FISH STOCKS

In principle, "stock" is a biological term which refers to a population of fish which is reproductively isolated, or partially isolated, from other such populations of the same species. In terms of basic resource conservation or "viewing the resource as your client" (WDFW 1997), an "at-risk stock" should be defined as a population of an important, existing (but severely depressed) native fish resource which is currently at-risk (threatened or endangered) and has no reasonable expectation of being able to recover over time by itself and/or from the surplus production of an adjacent or nearby population of the same species. The "burden of proof" for this expectation must not fall on the resource.

The northern and southern regions of Puget Sound are geographically distinct and have characteristics that are unique to each. A narrow passage at Deception Pass and a sill in Admiralty Inlet separate the north and south "Puget Sound" areas from each other as different oceanographic water bodies. The north is more exposed to storms, receives more oceanic water, and contains abundant, often contiguous, rocky reef habitat. The southern area (or Puget Sound proper) is generally more protected, influenced more by freshwater, and contains much less, often isolated, rocky reef habitat. It has been designated as an Estuary of National Significance and ranks with Chesapeake Bay and Long Island Sound in regional importance.

Genetic differentiation might be expected among basins where gene flow is restricted within each basin due to sills forming barriers to movement, water masses and circulation entraining pelagic life history stages, and deep basins forming barriers to the dispersal of shallow water fishes. Within the south Puget Sound area, there are other basins and steep-walled fjords which could influence genetic differentiation and population structure. In north Puget Sound, three bodies of water include the Strait of Juan de Fuca, the Strait of Georgia, and the San Juan Archipelago. The latter may form a barrier to gene flow and may affect population genetics in north Puget Sound.

It is logical to expect to see greater population subdivision in Puget Sound because it is a large, highly subdivided estuarine system comprising a number of discrete basins separated from each other by sills and constricted entrances between peninsulas and islands. The complex physiographic and hydrographic features of Puget Sound suggest the potential for limited intraspecies mixing among basins. In genetic studies of three closely-related rockfish species, Seeb (1998) found abrupt changes in allele frequency over a relatively short geographic distance (approximately 70 km). It is significant that this change occurred between fish samples that were taken on opposite sides of the constrictions at Deception Pass and Admiralty Inlet.

For all of the populations discussed in this petition, the greatest danger with a small stock size occurs when predation, parasites and/or disease (i.e., any natural mortality cause) leads to a situation where the highest percent mortality occurs at low abundances of juveniles and/or adults. Peterman (1977) stated that populations with two or more "domains of stability" must be managed accordingly. In these cases, two or more different mortality processes combine in a series to create a stock-recruitment curve with more stable points than the single one exhibited by the standard Ricker model. In one case, an unfished population would be stable a point A, and could be continuously exploited without permanent harm as long as it never dropped down to point B. Below this point, the population would move toward extinction, even if harvesting was completely stopped. In a second case, a critical spawner abundance would also exist, but a population falling below point B would not go toward extinction but toward a lower stable equilibrium (point C), which would be very unproductive for harvesting. Elimination of all harvest would still not permit the population to return to the higher abundance near the upper stable point.

Even in the absence of the situation described above, ecologists often identify the concept of a "critical threshold" or a population level below which reproduction and survival are impaired, limiting the ability of a population to sustain itself. Unfortunately, all of these potential threats are commonly identified after-the-fact when populations have already collapsed and scientists can only debate the causative agents.

Puget Sound marine fish populations present a unique situation since they are probably younger in an evolutionary sense than those of the Pacific Coast. Much of Puget Sound and the Strait of Juan de Fuca (including the San Juan Islands) was covered with ice during the maximum extent of Wisconsin glaciation approximately 15,000 years ago (McPhail and Lindsey 1986 cited in Seeb 1998). Seeb (1998) believed that genetic bottlenecks and drift could have occurred during re-colonization of the Puget Sound fish populations. She found evidence of introgression between all three of the rockfish species involved in her study and suggested that Puget Sound may represent a rare case of active evolutionary processes in marine fish populations.

STATUS OF AT-RISK PUGET SOUND MARINE FISH RESOURCES

PUGET SOUND PACIFIC HERRING

Pacific herring (along with Pacific sandlance, *Ammodytes hexapterus*) are (and were historically) the most abundant forage fishes in Puget Sound, providing (as juveniles and adults) a source of food for many fish, bird, and marine mammal populations. They are a pelagic, schooling species that preys primarily on zooplankton. In Puget Sound, herring spawn from January to June, depositing adhesive eggs on blades of eelgrass (*Zostera marina*) and a variety of other marine vegetation. Eggs hatch in about two weeks, after which pelagic larvae are found in nearshore plankton. Larvae aggregate in protected bays, and after their first year they mix with adults in more pelagic habitats. 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 aggregate prior to spawning. The holding pattern usually begins 3 to 4 weeks prior to the first spawning event.

In Puget Sound, individual stocks are considered to be those fish which utilize specific spawning grounds, and eighteen (18) stocks have been identified (Bargmann 1998b). This conclusion was reached based on the combination of differences in spawning timing and growth rates by fish which utilized different spawning grounds (Trumble 1983). Thus, like salmon, herring generally return to their natal spawning grounds. However, straying rates between spawning grounds can be significant (up to 20%, Bargmann 1998b). Unlike salmon, herring do not all die following spawning, and individual fish can spawn annually for several years. West (1997) and Bargmann (1998b) reported that four herring stocks were in "depressed" or "critical" condition and that estimated annual natural (non-fishery) mortality of this species in Puget Sound has increased from about 30 to 40% (considered normal for healthy herring populations world-wide) before 1982 to 60-70% at the present time. As a consequence of this, the number of age classes comprising the bulk of the herring stocks in Puget Sound has decreased from five to two or three, with losses predominately from the oldest age classes. Clearly, the fish are now smaller and younger, on average, and carry fewer eggs per fish. The historic or evolutionary buffer against recruitment failure has been considerably diminished. Herring formerly lived to ages in excess of 10 years in Puget Sound. However, fish older than age 6 are now rare (Bargmann 1998b).

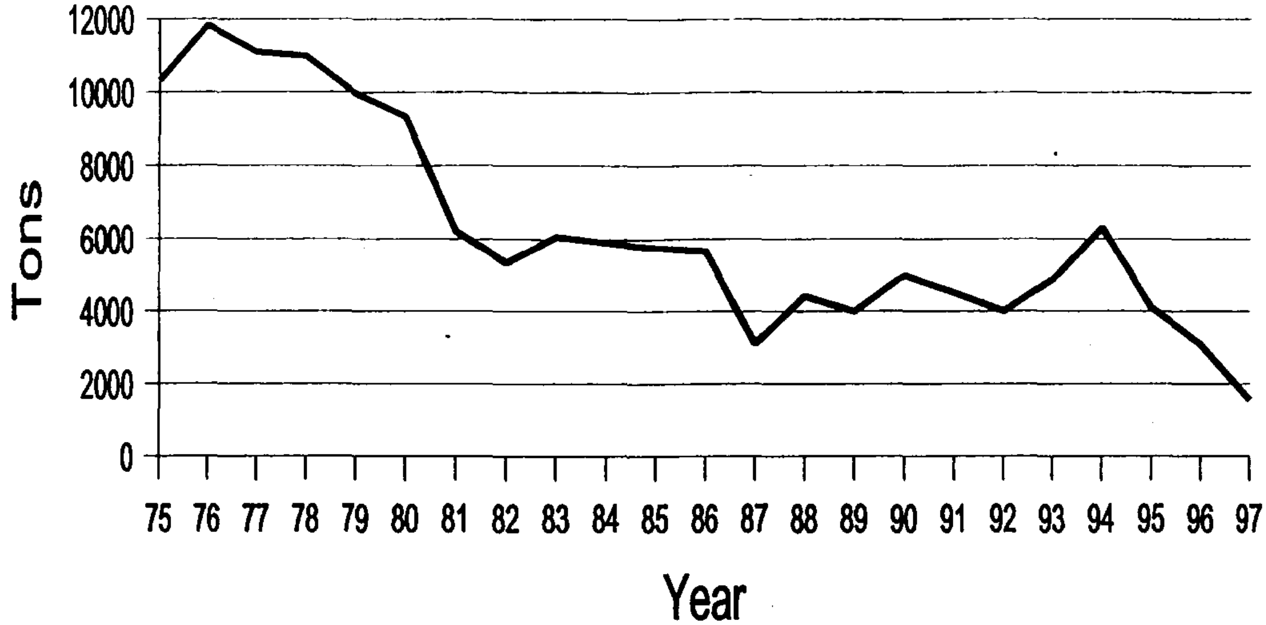
A further problem for the herring resource has been increased night-time sightings by herring-survey biologists of harbor seals near schools of herring and concurrent changes in the schooling behavior of herring, supporting the perception that predation by harbor seals has risen in recent years (Norm Lemberg WDFW, personal communication cited in West 1997).

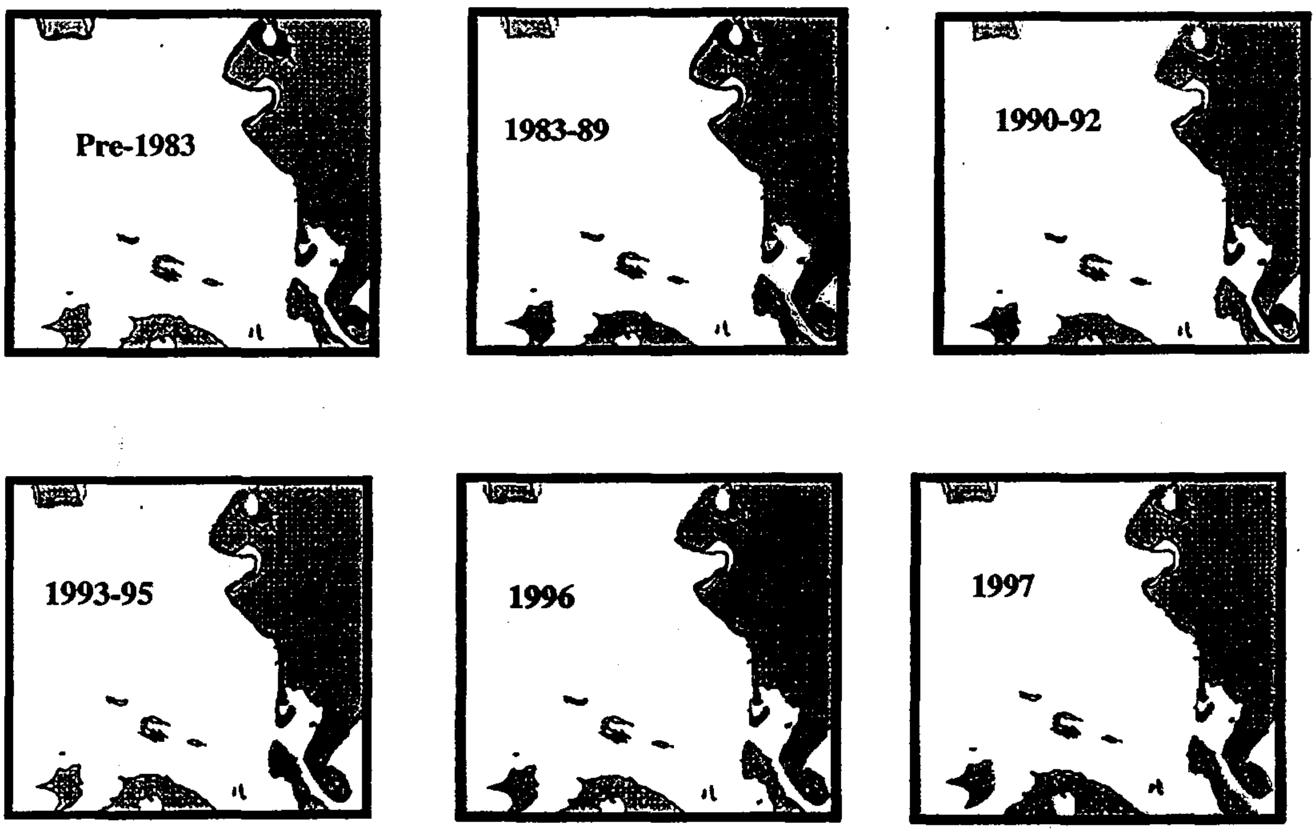
The Cherry Point herring stock is the largest in Puget Sound and is unique because of its exceptionally late spawning timing. The Cherry Point fish also exhibit relatively rapid growth rates after age one, therefore, it is believed that this may be a "migrant" stock, possibly summering off of the continental shelf. There have been directed adult fisheries on this stock in the past, primarily by purse seines and gill nets or for spawn-on-kelp. The run size in 1998 was assessed at 1322 tons, the lowest ever seen for this stock in 22 years of record (1977-1998). The amount in 1998 was 16% lower than the spawning run in 1997, which was the lowest amount ever seen until that year. Since 1985, this stock has been declining at an average rate of 6.5% per year. All of the fish that are currently too young to spawn (age 2 or less) came from small parental spawning populations. It will take an unusually high survival rate of the immature fish to even stabilize stock size in the next few years. In addition to the record low size of the spawning biomass, extent of the area actually used for spawning has been reduced to a small fraction of that used historically. The limited area still used is, unfortunately, centered in an area of existing and proposed industrial developments (see enclosed figures). WDFW records show the following spawning biomass estimates (in tons) as determined by spawn deposition surveys for the years 1977 through 1997: 11097, 10973, 9957, 9329, 6219, 5342, 8063, 5901, 5760, 5671, 3108, 4428, 4003, 4998, 4624, 4009, 4894, 6324, 4105, 3095, and 1530, respectively. Spawning biomass estimates made from acoustic/trawl surveys are also available for the same years as well as estimates of recruitment (also in tons).

The Discovery Bay herring stock is the major Strait of Juan de Fuca population in U. S. waters and 22 years of quantitative population assessments have been made. Historically, it was believed to be one of the largest stocks in Washington, but is currently at a critically low level of abundance. The reasons for this are unknown. There are no known fishery interceptions, and the spawning ground is among the most pristine in Washington. The run size in 1998 was zero - surveyers were unable to detect a single herring egg in Discovery Bay. This stock has been declining at a rate of 7.8% annually since 1985. However, the 1996 spawning stock was relatively abundant and the progeny should be fully recruited as adults this year. The fish that spawned in 1996 represent the last reasonable hope for stock rebuilding. WDFW records show the following estimates of spawning biomass (in tons) as determined from spawn deposition surveys for the years 1978 and 1980 through 1997: 1305, 3220, 3070, 2356, 2578, 3144, 1447, 1566, 1593, 853, 1225, 855, 925, 727, 737, 375, 261, 747, and 199, respectively.

Cherry Point Herring Stock

Spawning Biomass and Distribution



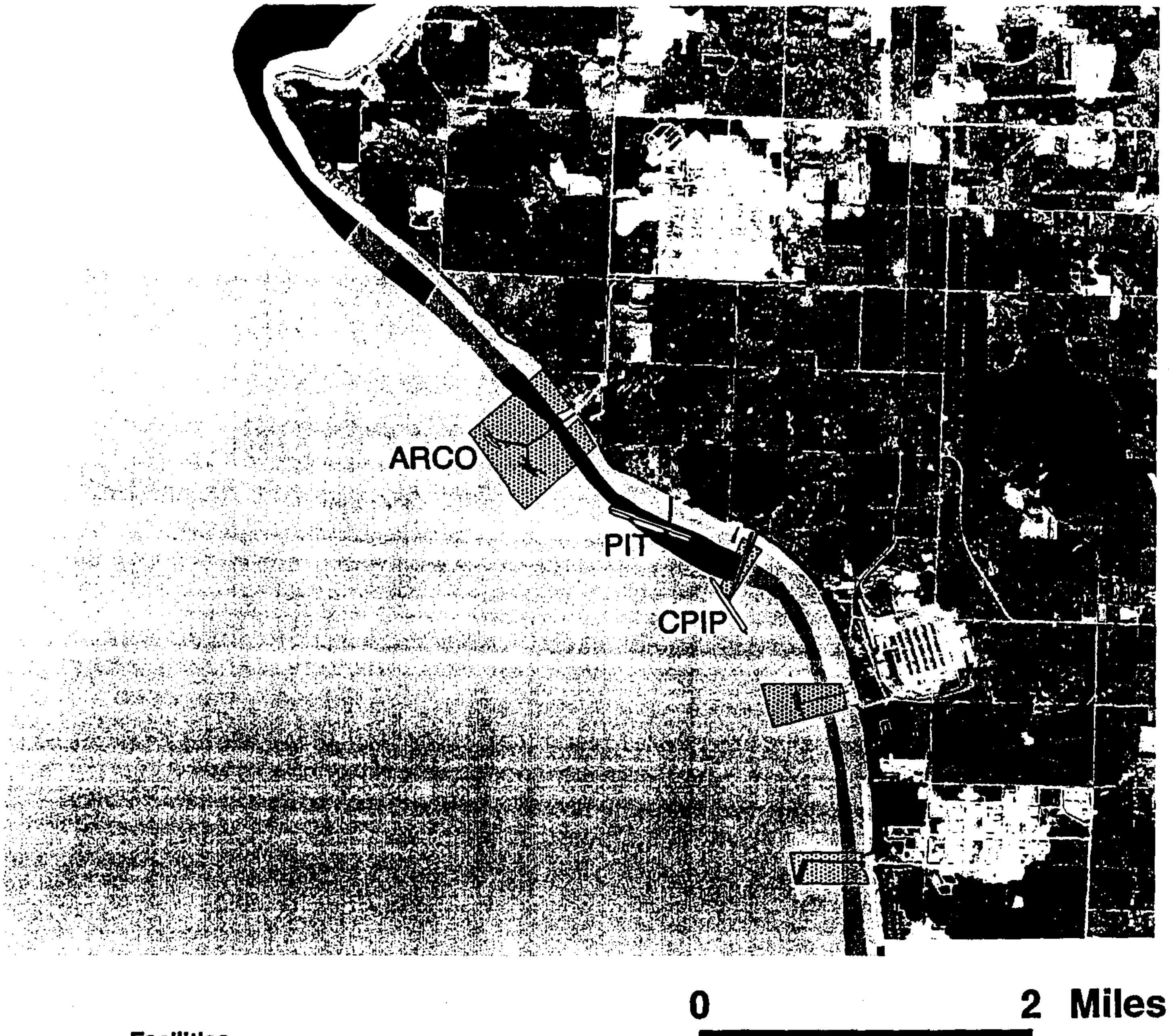


Spawning Habitat Used

Spawning Habitat Not Used

Source: DNR Aquatic Resources Div. interpretation of WDFW Cherry Point herring stock assessment data and trends (Mark O'Toole pers comm 1997). Prepared 11/97.

Existing and Proposed Facilities Around Cherry Point



Facilities
- Existing Structures
- Proposed Structures
- Chicago Bridge and Iron Lease
- ARCO Lease
- INTALCO Lease
- Bellingham Sand & Gravel Lease
- TOSCO Lease

Herring Spawn Habitat
- 1997 Habitat Used
- Historic Habitat

Ownership of Land
- Private
- Public
- Tribal Reservation

Produced by DNR Aquatic Resources using DNR ownership information and analysis of WDFW herring stock assessment information (Mark O'Toole, personal communication, 1997). 11/20/97

The two additional at-risk herring spawning stocks identified by West (1997) utilize spawning grounds in the Port Susan and Port Orchard/Port Madison areas, respectively. Spawning biomass estimates for the two stocks were presented graphically by West (1997) and show the same type of distinct downward trends exhibited by the Cherry Point and Discovery Bay herring stocks. Of the fourteen remaining Puget Sound herring stocks, 9 are currently classified as "healthy" or "moderately healthy" and the status of 5 is "unknown" (Bargmann 1998b). However, it is difficult to call any Puget Sound herring stock healthy in view of the alarming increase in annual natural mortality rates and concurrent decline in number of age classes available to carry the resource forward on a sustainable basis. (Note: the only additional Pacific herring stock in the entire state is found in Willapa Bay on the Washington coast - status "unknown").

Many marine ecosystems share an important aspect in the structure of their biological communities. They contain a large number of species, typically plankton, at low trophic levels. They also contain a substantial number of species such as large fish, seabirds and mammals at high trophic levels. However, in many of these ecosystems, there is a crucial intermediate trophic level which is occupied by only a few species of small pelagic fishes (Bakun 1996 cited in Bargmann 1998b). This community structure, with many species at the bottom of the food web as well as at the top, but with only a few species at mid-level, has been called a "wasp-waist ecosystem" (Rice 1995 cited in Bargmann 1998b). Pacific herring in Puget Sound can be considered a dominant species at the wasp-waist. A recurring theme in Bakun (1996 cited in Bargmann 1998b) is the decadal-scale shifts in abundance that may occur in wasp-waist species; often, but not always, due to replacement by other forage fishes. Puget Sound herring appear to be one of the exceptions to this generalization.

PUGET SOUND PACIFIC COD

Palsson (1990) distinguished three stocks of Pacific cod in Puget Sound based upon fishery patterns, location of spawning grounds, parasitic markers, and tagging studies. These included a northern stock found in the Gulf-Bellingham area and in southern British Columbia, a western stock found in eastern Strait of Juan de Fuca and in Port Townsend Bay, and a southern stock found south of Admiralty Inlet and including fish spawning in Hood Canal, Agate Passage, and Dalco Passage near Tacoma. The tagging data were the primary determinant of this stock structure. Fish were typically tagged on the spawning grounds. In most cases, tags were recovered during the same spawning season on the same spawning grounds, indicating a high fishing mortality rate. However, for the tagged fish escaping the fishery, the majority remained within the respective stock area. Some fish (generally less than 10%) moved out of their stock area but were usually caught in the adjacent stock area. At least two of the three Puget Sound Pacific cod stocks are currently at-risk.

The overall Pacific cod resource is widely distributed in relatively shallow marine waters (50-200 m) along the shoreline of the northern arc of the Pacific Ocean, from Japan to western North America. Cape Flattery at the entrance to Juan de Fuca Strait and the inland waters of Washington are considered the southern limit of fishery-exploitable populations of this large demersal carnivore (exceeding 140 cm in its northern range, but less than 100 cm in Puget Sound).

Palsson et al. (1997) reported that the Puget Sound Pacific cod stocks have some of the highest growth and egg production rates of any cod stocks on the Pacific Coast. Palsson (1990) stated that a former commercial cod fishery targeted spawning cod that used the waters of Killisut Harbor and Port Townsend Bay during the winter. The fishery built-up in the late 1970's and early 1980's, the cod stock and fishery declined in the mid-1980's, and the fishery was closed in 1987. This cod stock has not recovered. Cod were seldom harvested by trawl fisheries which continued in Admiralty Inlet until 1994 nor did experimental trawling find cod in Port Townsend Bay in 1988.

The next cod stock to collapse was the southerly population. This stock supplied the fish once harvested in a popular wintertime recreational fishery on spawning cod in Agate Passage. It was not uncommon to see several hundred boats floating above the spawning area with many fishers catching their limit of 15 fish. WDFW developed a special survey to monitor this fishery in the mid-1980's but was only successful in documenting rapidly diminishing catches. By 1988, few fish were being harvested and a complete closure of the area during every winter began in 1991. Daily bag limits for the remaining open season were decreased from 15 to two fish in 1991 and then to zero prior to the 1997 fishery. Palsson et al. (1997) stated that the recreational fishery catch rate is the primary stock indicator for south Puget Sound cod. It has continuously declined since 1977. WDFW also began special surveys of the Agate Passage cod using scientific echosounding equipment. Biologists found some acoustic aggregations during 1987 and 1988, but recent surveys during the traditional spawning period failed to reveal any similar acoustic targets. These results clearly identify a stock at a critical or near extinct level.

Recreational catch rates (fish per angler trip) provided by Palsson et al. (1997) and WDFW records for the years 1977 through 1996 were as follows: 0.78, 1.02, 0.42, 0.65, 0.57, 0.59, 0.34, 0.56, 0.28, 0.42, 0.30, 0.16, 0.08, 0.01, 0.02, 0.05, 0.00, 0.01, 0.0, and 0.0, respectively. The stock decline was further confirmed by the following commercial trawl catch rates (pounds per hour) for 1970 through 1993: 37.3, 66.9, 107.3, 84.5, 121.8, 136.3, 124.6, 95.3, 63.6, 27.7, 25.4, 60.6, 29.0, 21.7, 32.9, 21.2, 20.2, 27.2, 39.2, 17.7, 9.1, 21.4, 14.9, and 6.6, respectively (the fishery was closed in 1994). A third source of evidence comes from trawl surveys conducted in 1987, 1989, and 1991. The estimated abundance (N x 1000) was 1606, 208, and 47, respectively. The estimated biomass (mt) was 1280, 152, and 44, respectively.

SOUTH PUGET SOUND (PUGET SOUND PROPER) WALLEYE POLLOCK

The walleye pollock is a carnivorous, midwater schooling codfish and is considered a northern, colder-water species, occurring along the shoreline of the northern arc of the Pacific Ocean from Japan to western North America. Like Pacific cod, Puget Sound represents the southern extent of fishery-exploitable populations. Walleye pollock grow at different rates between north and south Puget Sound and demonstrate spatial separation during spawning periods, indicating that they are discrete stocks (WDFW unpublished data cited in Palsson et al. 1997). The at-risk stock occurs in the latter area.

Palsson et al. (1997) reported that walleye pollock in south Puget Sound are on the extreme southern end of their Pacific Coast distribution but that a unique recreational fishery near Tacoma once made pollock the most common bottomfish harvested in Puget Sound recreational fisheries. Anglers harvested the great majority of their pollock in south Puget Sound and catches exceeded 400,000 pounds per year from 1977 to 1986. After 1986, catches diminished and the fishery collapsed after 1988. The primary stock indicator used by WDFW is the recreational catch rate and Palsson et al. (1997) and WDFW records report the following values (in fish per angler trip) for the years 1977 through 1996: 0.71, 1.31, 1.37, 0.97, 0.88, 0.85, 0.59, 0.99, 0.52, 0.49, 0.26, 0.25, 0.02, 0.1 and 0.0 for 1991-1996, respectively (the zero fish bag limit took effect in 1997). The trawl catch rates (pounds per hour) show the following values for the years 1970 through 1993: 0.9, 1.0, 0.8, 6.0, 3.3, 4.7, 4.3, 3.6, 2.5, 9.1, 8.0, 2.7, 2.1, 1.2, 0.4, 0.1, 2.1, 1.1, 0.9, 0.2, and 0.0 for 1990-1993, respectively (the commercial trawl fishery has been closed since 1994). Trawl survey were conducted in 1987, 1989, and 1991. The abundance estimates (N x 1000) were 3537, 172, and 99, respectively, while the estimated biomass (mt) was 452, 50, and 17, respectively. Palsson et al. (1997) state that another secondary indicator, the population of pollock estimated from cohort analysis, details the decline of the population in the early 1980's. The cohort analysis also showed that the resource was being over-utilized in the 1980's. In any case, the available data conclusively demonstrate that the population is at a critical, possibly extinct status.

SOUTH PUGET SOUND (PUGET SOUND PROPER) PACIFIC HAKE

In common with walleye pollock, the Pacific hake is a carnivorous, midwater, schooling codfish. However, Pacific hake is considered to be a southern or warm-water species, with abundant populations occurring off the coasts of California and Baja. These populations undergo feeding migrations northward in the summer to as far as Washington and British Columbia, returning to spawn in southerly waters in the winter. A smaller, genetically distinct, resident population occurs in south Puget Sound which migrates seasonally between Port Susan and Saratoga Passage. Utter and Hodgins (1971 cited in Palsson et al. 1997) demonstrated that Puget Sound Pacific hake were genetically distinct from coastal populations and Goni (1988 cited in Palsson et al. 1997) used growth information to separate Pacific hake from north and south Puget Sound. The growth differences plus the distinctive spawning areas indicate that there are separate stocks of Pacific hake in north and south Puget Sound. It is this latter population whose numbers have experienced a severe decline in recent years and is now at-risk. (Note: Jagielo et al. (1996) found lingcod from Puget Sound differed genetically from other coastal samples, including those from Alaska and California.)

Palsson et al. (1997) reported that most south Puget Sound Pacific hake spawn in Port Susan where a commercial midwater trawl fishery once harvested up to 15 million pounds of spawning hake per year. The catch declined rapidly after a 1983 peak and, by 1991, low abundance resulted in a closure of the directed fishery. The primary stock indicator is a fishery-independent acoustic and midwater trawl survey conducted during the winter in Port Susan. Spawning hake in Port Susan once had an estimated adult biomass of over 40 million pounds, but this biomass steadily declined between 1982 and 1993 when barely one million pounds were estimated. The survey biomass estimates provided by Palsson et al. (1997) and WDFW records were as follows (in millions of pounds) for the years 1983 through 1998: 45.1, 27.1, 16.0, 16.0, 11.9, 12.8, 12.1, 13.5, 11.7, 8.9, 1.1, 1.3, 0.9, 7.3, 2.4, and 1.1, respectively. The stock status is at a critical level. The midwater trawl catch rate, a secondary stock indicator, mirrored the survey population trend. For the years 1970 through 1991, the midwater trawl catch rates (in 1000's of pounds per hour) were as follows: 6.0, 3.3, 3.0, 3.5, 6.5, 7.8, 17.0, 10.6, 18.0, 22.6, 21.8, 12.1, 9.6, 6.4, 4.7, 5.4, 3.3, 7.2, 9.3, 2.4, 0.3, and 10.0, respectively (there has not been a fishery since 1991). The fishery definitely over-utilized the stock in the 1980's when the annual exploitation rate reached as high as 40% of the adult population. In addition to the overall biomass decline, average fish has become noticeably smaller (and younger) and many would not now be usable for commercial purposes. High predation by marine mammals is probably preventing recovery of the population.

Schmitt et al. (1995) believed that marine mammal predation was an important factor affecting the numbers of some marine fish species in Puget Sound. They estimated that harbor seals and sea lions consume 3488 to 4645 mt of food annually. Although these marine mammals also prey on other species such as squid and salmon, marine fish species constitute the majority of their diets. As a result, predation may be two or three times the total of marine fish taken by the combination of sport and commercial fisheries in Puget Sound. Schmitt et al. (1995) estimated that California sea lions consumed between 286 and 573 mt of Pacific hake in Puget Sound. Although estimates of the amount of hake consumed by harbor seals were not available, they believed that seals may be consuming similar amounts, or perhaps more. For the other stocks presented in this petition, the authors estimated that California sea lions in Puget Sound had annual consumption rates of 51 to 102 mt for Pacific herring (3rd overall behind spiny dogfish), 34-69 mt for Pacific cod (4th overall), and 16-32 mt for walleye pollock (6th overall behind shiner perch).

Olesiuk (1993) found that the diet composition of harbor seals in the Strait of Georgia varied seasonally. Pacific hake was dominant during April-November and Pacific herring was dominant during December-March. Combined, hake and herring accounted for 75% of the diet in terms of both energy and biomass. Total annual consumption was estimated at 9892 (range 6432-13359) metric tons, which included 4214 (2215-6664) mt of hake and 3206 (1679-5818) mt of herring.

ROCKFISHES IN PUGET SOUND

Over twenty species of rockfishes inhabit Puget Sound and this is a case where virtually an entire genus (*Sebastes*) is at-risk. The only exception is the diminutive, plankton-feeding Puget Sound rockfish (*Sebastes emphaeus*) whose small size makes it immune to significant fishery exploitation. At the present time, only five species are commonly caught in the commercial and sport fisheries. The others have largely disappeared from catch samples and are rarely seen during fishery -independent stock assessments. The most noticeable declines have been with tiger, canary and yelloweye rockfish. (Note: not much is known regarding the tiger rockfish, but they may be the most extreme example of small home ranges. They are extremely cryptic and only inhabit very rocky reefs.) In the mid-1960s, canary rockfish was named by Holmberg et al. (1967) as one of the three "principal species" taken by trawling in Puget Sound waters (along with copper and quillback rockfish). The species which are now the most common tend to be those with the greatest productivity and/or the greatest resistance to fishery exploitation. For example, Palsson and Pacunski (1998) categorized brown rockfish as "light" for their "fishing intensity" rating. This species has a significantly lower presence in recreational catches than would be expected from their dominant presence in many south Puget Sound reef habitats (as confirmed by fishery-independent population assessments). In salmonids, it is recognized that closely-related species have different susceptibilities to harvest. For example, Behnke (1985) cites a case where cutthroat trout were seven times more likely to be harvested than comingled brook trout. Behnke also stated that the vulnerability factor of brook trout is probably 5 to 10 times greater than that of brown trout. This may be what caused Palsson and Pacunski (1998) to find higher densities of brown rockfish at fished sites. The lack of "normal" interspecies competition from other rockfish species (as would be found in an unfished community of fishes) may have contributed to the population compositions that were actually observed.

Rockfishes are the most difficult group to manage since their life history characteristics make them extremely vulnerable to overfishing. They are slow growing, late maturing, long lived, and some species demonstrate extreme site fidelity. In addition, rockfishes (as well as Pacific cod) cannot compensate for the change in hydrostatic pressure when brought quickly to the surface by fishers. Hence, they typically die when caught (West 1997). This creates two resource management problems. First, traditional fishery management tools such as minimum size limits and species selective retention become useless. Even daily bag limits are of little use in mixed species fishery situations. Second, as the size distribution of the population is depressed and truncated due to fishing, more and more fish are discarded by anglers because they are too small. This new non-catch fishing mortality is virtually impossible to estimate with any degree of accuracy.

As adults and juveniles, rockfishes inhabit rocky and artificial reefs, nearshore vegetated habitats, and other habitats with vertical relief. Eggs hatch internally in the female and are released as larvae during the spring. Parental care in this genus is mainly lecithotrophic, characterized by primitive, unspecialized viviparity at an evolutionary stage when only eggs, embryos, and early larval stages are protected inside the female body (rather than born live as fairly advanced young). The more advanced matrotrophic viviparity has been demonstrated in at least four species. They occupy planktonic environments as larvae for several months (the primary opportunity for effective dispersal and gene flow) and settle on to marine vegetation and nearshore reef habitats. In general, rockfishes are mid-level consumers feeding on shrimp, crabs, and small fishes. There are differences in growth rates for some species between north and south Puget Sound. Growth differences have also been detected between two areas within south Puget Sound.

Copper, quillback, and brown rockfishes are demersal or sedentary species and the most common species currently caught by Puget Sound fishers. Quillback rockfish have been shown to have small home ranges (approximately 30 square meters for high-relief reefs, Matthews 1990) and different growth rates between north and south Puget Sound. Growth studies also suggest that quillback rockfish grow at different rates between two sites in south Puget Sound. There is some anecdotal evidence that quillback rockfish from north Puget Sound have different color patterns from fish in south Puget Sound. Copper rockfish have similar life history traits and home ranges as quillback rockfish (Matthews 1990), but tend to inhabit shallower depths. Matthews (1990) also found that these two species (quillback and copper) not only maintain small home ranges but also return to their home sites when experimentally displaced by up to 6.4 km. Thus, factors leading toward reduced gene flow, such as homing behaviors and small home ranges in adults, will act to counteract those that increase gene flow, such as pelagic larval stages (Seeb 1998). Black and yellowtail rockfishes are pelagic, schooling species and were once common in sport catches but their occurrence dramatically decreased during the early 1980's. Both species have wider home ranges and make longer movements than the sedentary species.

The primary stock indicator for both north and south Puget Sound is the recreational catch rate in terms of fish per angler trip. Both of these areas show long-term downward trends. Available data through 1994 are presented by both West (1997) and Palsson et al. (1997), while Palsson and Pacunski (1998) provide statistics for the most recent years (in figures only, not tabular form - see Figure 1 from their report). Unfortunately, even though definite downward trends are obvious, these data provide an unrealistic sense of security or optimism concerning stock status. Fish resource managers often find that catch rates or other similar fishery-dependent indexes significantly underestimate the decline of a population. This is usually discovered when newer, fishery -independent indexes become available. This is exactly what has happened with Puget Sound rockfishes. Newer fishery-independent assessments have estimated that the present populations are only producing 10% (or less) of the larvae that were produced as recently as the 1970's. The populations are now considered to be critically depressed in terms of both numbers of fish and the average size of individual fish. One of the most compelling statements was the following by Palsson and Pacunski (1998, p. 13): "Many vacant habitats have been observed throughout Puget Sound during the VAT surveys" (VAT is the acronym for Video-Acoustic Technique). In many cases, the only genus member observed was the fishery-immune Puget Sound rockfish.

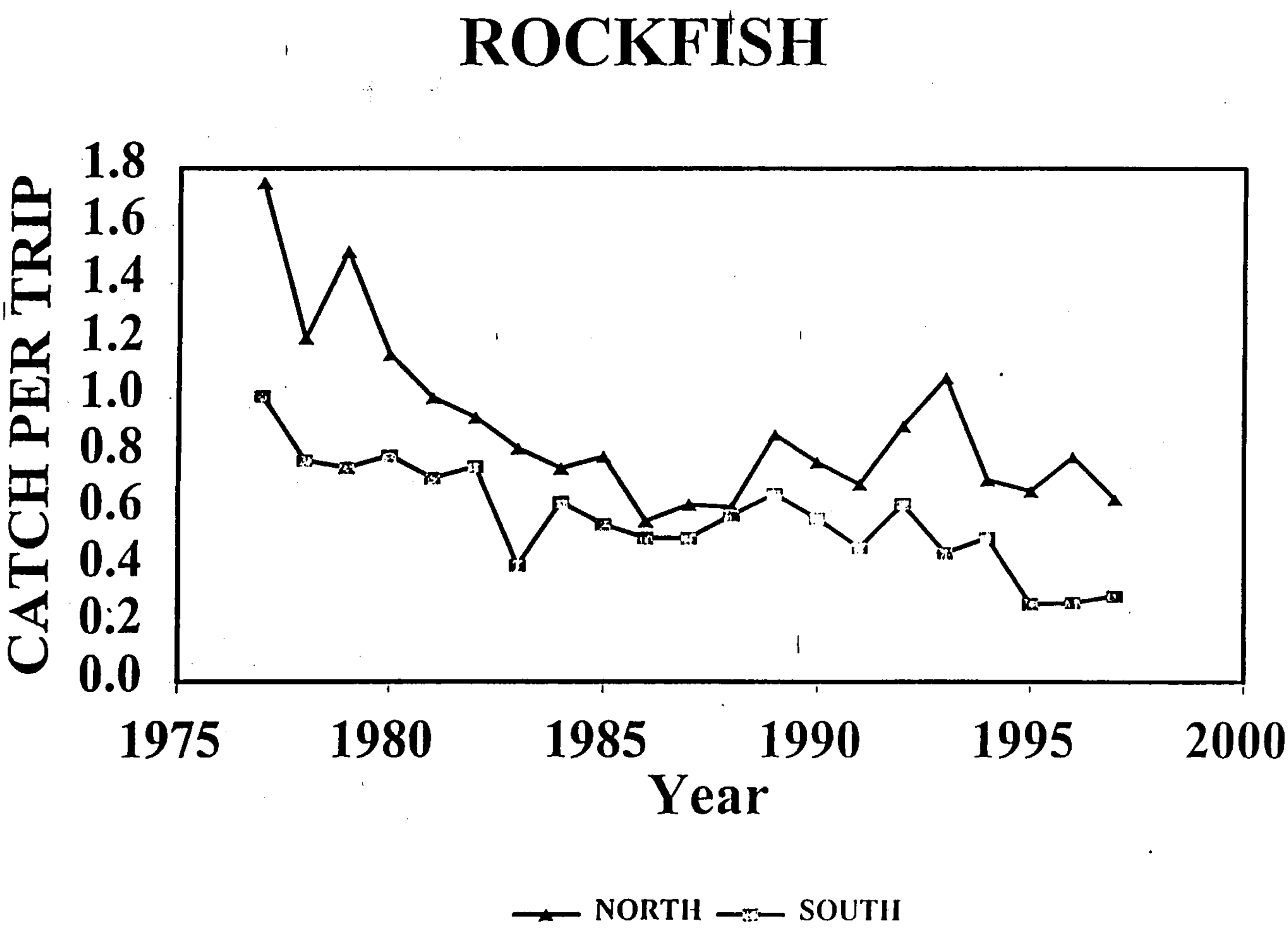


Figure 1. Recreational catch rates of rockfish (catch per trip) of bottomfish anglers in North and South Puget Sound.

Recreational fishery catch rates over time in Puget Sound have proven to have some utility as a relative measure of population abundance since WDFW generally lacks the age information needed to do catch-at-age type analyses. Palsson and Pacunski (1998) used available fish length information, catch rates and fecundity estimates to assess the condition of copper rockfish in the San Juan Islands area. Their analysis revealed that rockfish larger than 40 cm constituted a quarter of the catch in the mid-1970's. Presently, only 5% of the catch is comprised of large fish. The size truncation and decline in catch rates have resulted in a recent reproductive output that is estimated at only 10% of historic levels (see Figure 3 from their report). This level of reproductive output falls far short of the 40% level (or F40%) that is now being recommended to prevent overfishing and assure stable recruitment and populations (Clark 1993).

In many forums, "overfishing" has been defined as fishing rates which cause the spawning biomass to decline below a level which achieves the largest level of maximum sustainable yield. These levels have been suggested as F20%, F30%, and F40% which represent fishing mortality rates to achieve respective preservation of 20%, 30%, and 40% of the unfished spawning stock biomass. These are increasingly more conservative population thresholds and overfishing levels. This is intended to prevent low spawning stock biomass and related variability in recruitment. Many fishery management organizations have adopted F30% or more conservative guidelines, including the Pacific Fishery Management Council and the North Pacific Fishery Management Council. Available quantitative data demonstrate that Puget Sound rockfishes are far below any of the standards cited above. (Note: even the mid-1970's data used as a surrogate for an unfished population probably represents a significant reduction from "virgin biomass".)

One good thing has happened to Puget Sound rockfishes. In 1970, a fortuitous decision was made to establish a refuge from fishing at a small, 27-acre site now known as the Edmonds Underwater Park (EUP). This now 28-year-old no-take site currently provides unambiguous empirical evidence of true rockfish capabilities. Palsson and Pacunski (1998) found a mean density (fish per transect) of 30.7 copper rockfish at EUP. Four heavily fished central Puget Sound sites at Port Blakely, Blake Island, Boeing Creek and Orchard Rocks had mean copper rockfish densities

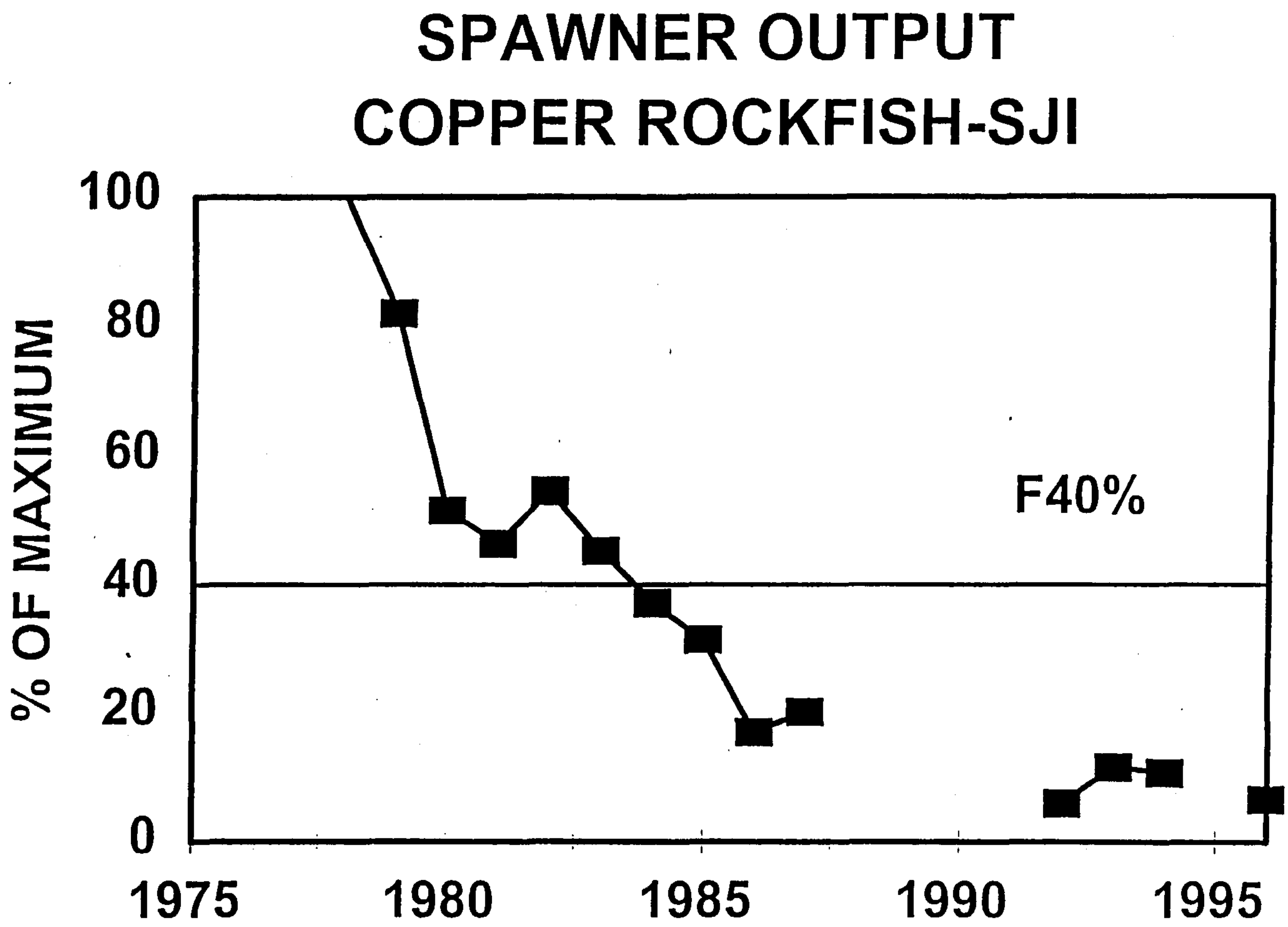


Figure 3. Historical reproductive output of copper rockfish in the San Juan Islands.

of 4.2, 1.8, 2.4, and 0.6, respectively. For large copper rockfish (greater than 40 cm), EUP had a density of 26.1, while the other four areas had densities of 1.1, 0.5, 0.1, and 0.2, respectively. Palsson and Pacunski (1998) estimated that the reproductive potential of copper rockfish at EUP exceeded the potential of the average fished site in central Puget Sound by a ratio of 55 to one. The difference due to the different length frequency distributions between no-take and fished sites accounted for a four-fold increase in estimated egg production while the difference due to densities accounted for almost a fifteen-fold increase in estimated egg production.

Palsson and Pacunski (1998) recommended that an extensive system of no-take refuges be established to rebuild depressed populations and maintain them in perpetuity. They also acknowledged that recent regulation changes - mainly reduced daily bag limits - have completely failed to halt population declines. Their project results indicated that one-third of all rocky reef habitat should be placed in no-take status to rebuild the level of reproduction to assure a sufficient level of recruitment to maintain the populations. The primary benefit of the no-take refuges will be to produce eggs and larvae within the refuges that will be exported to vacant or depressed reef habitats in remaining fished areas. Other benefits include fishery benefits from movement of large fish to fished areas, maintaining genetic integrity, maintaining natural age and size distributions, establishing baseline areas for research, preserving ecosystem function and others suggested by Bohnsack and Ault (1996).

However, the current situation is far from what is needed. WDFW established two new small no-take areas in 1998 that will benefit rockfishes. Previously, three other areas had been established - San Juan Marine Preserves in 1990, Sund Rocks in Hood Canal in 1994, and Titlow Beach near Tacoma in 1994. In addition, the County of San Juan recently created (in 1997) eight small Voluntary No-Take Bottom Fish Recovery Areas in recognition of the depressed status of marine fish populations. The perception exists that these types of efforts can, by themselves, be successful in resource restoration. In aggregate, they involve less than 1% of the habitats utilized by rockfishes.

Leaman and Beamish (1984) discussed the biological advantages of longevity and the implications to population dynamics from management policies that ignore these evolved advantages. They defined "longevity"

(15-50 yr) and "extreme longevity" (> 50 yr) in fishes in reference to species that have life spans that are long when compared with all fish species. Rockfishes certainly fit these categories, since Leaman and Beamish (1984) gave maximum Canadian age records for five of the species listed in this petition (widow rockfish, 58 years; yellowtail rockfish, 64 years; bocaccio, 36 years; canary rockfish, 75 years; and redstripe rockfish, 41 years). They also stated that maintenance of unique age compositions among geographically proximate stocks of Pacific ocean perch (*Sebastes alutus*) implied little mixing of adult fish among stocks.

Leaman and Beamish (1984) found that the most obvious potential benefit of a relatively long life was a long reproductive life. The extension of the period of reproduction reduces the risk that a long period of unfavorable environmental conditions will result in loss of a stock. When the period between favorable environmental conditions for a species was relatively long (5-15 yr), it appeared that the life span was also relatively long. Extreme life spans appeared to be an adaptive feature for ensuring evolutionary persistence under reproductive uncertainty rather than for maximization of population growth rate. There are additional ecological considerations such as the importance of continuously occupying a space, the importance of dispersed spawning, or the selective advantage of specific reproductive products. It has been shown that the viability of eggs and larvae of many fishes is dependent on maternal condition, including size (Ellertsen and Solemdal 1990 cited in West 1997). Extreme longevity in fishes can also allow adults to exist in low productivity environments where the probability of regular recruitment is very low. The production and growth-oriented contemporary management strategies derived for shorter-lived species can result in rapid over-exploitation of accumulated biomass and a prolonged period of rehabilitation for the long -lived fishes. Worse yet, a competing species can capitalize on vacant space or resources and prevent the over-exploited species from ever regaining its former abundance.

Thus, the genus *Sebastes* in Puget Sound faces a multitude of at-risk factors. Species diversity has been markedly reduced, abundance of the genus has declined precipitously, and the average fish size has become much smaller. The last factor adds the further problems of fewer mature females (as a percentage of the population) and lower fecundity per female. South Puget Sound, with its characteristic isolated "islands" of suitable rocky reef rockfish habitat, has experienced numerous localized population extinctions (the petitioner personally contributed to one *Sebastes* "extinction" at the Steamboat Island "hole" near Olympia, WA.). The consequences can be serious since Allendorf et al. (1987, p. 2) warn that "Differential survival and reproduction of fish with different genotypes will change the genetic composition of the harvested population." This should be a source of concern since "high externally -imposed adult mortality, such as from fishing, selects for increased reproductive effort at younger ages, resulting in early maturity, shorter life spans, smaller sizes, and semelparity (single reproductive episodes)" (NMFS 1990, p. 9). According to Allendorf et al. (1987), all populations of fish that are included in a sport and/or commercial fishery will inevitably be genetically changed by harvesting. Shortened life spans because of fishing pressures can void protection against long-term environmental fluctuation provided to species by long life spans achieved through eons of evolution (Leaman and Beamish 1984).

Genetic studies using conventional techniques have not consistently shown substantive population differentiation or structuring for Puget Sound rockfishes. However, it is not clear whether these species have undifferentiated populations or whether the conventional approach is not the correct technique to answer the question. Various biochemical approaches to species and population identification, including allozyme and mitochondrial DNA (mtDNA), have been employed on rockfishes but each of the approaches suffer some drawbacks. It is possible that future work should focus on different techniques. A new approach, genetic profiling of microsatellite DNA markers, may help clarify the influence of local Puget Sound hydrographic and bathymetric features on population structures of rockfishes.

Allozyme studies have shown some Pacific Coast rockfish species to be divided into northern and southern populations, or that variation is clinally distributed (Wishard et al. 1980, Seeb 1986, and others). However, in other rockfish species, allozymes and mtDNA RFLPs failed to indicate any obvious separation. Conventional techniques have sometimes failed to even separate closely-related rockfish species. For example, Heusch (1995) was unable to show differentiation between three populations of quillback rockfish from Puget Sound but was also unable to separate two closely-related species (coppér and quillback rockfish). Gove (1996) also failed to show differences for quillback rockfish but was able to demonstrate population structuring for copper rockfish. This structuring has also been demonstrated for coastal black rockfish populations and the different groups paralleled results gained independently from tagging studies (WDFW Genetics Unit, unpublished data). In a preliminary (small sample size) survey of population subdivision in quillback rockfish in Puget Sound using one microsatellite locus, heterozygosities for two populations from different areas were slightly greater than 80% (Paul Bentzen, University of Washington, unpublished data). In addition, he detected four alleles in central Puget Sound that were not present in the San Juan Islands, suggesting differentiation and population structuring. In the most recent pertinent published report on the subject, Seeb (1998) supported the case for genetically isolated populations of brown, copper, and quillback rockfish. Geographic differentiation was detected within each species in collections ranging from California to Alaska. In addition, significant shifts in allozyme frequencies were noted for copper rockfish in going the short distance (about 70 km) from south Puget Sound to the San Juan Islands. Alleles characteristic of the two other species were absent from samples of copper rockfish taken outside of Puget Sound but were consistently observed within Puget Sound. Seeb (1998) believed that introgression may be occurring between all three species in Puget Sound and that it may be an important source of diversity in rockfishes.

Another compelling argument for the uniqueness of Puget Sound rockfishes comes from the species composition of the genus. In the early 1960s, Holmberg et al. (1961) stated that six species constituted "the great majority" of ocean trawl fishery landings (*Sebastes alutus, S. brevispinis, S. pinniger, S. flavidus, S. rubrivinctus, S. diploproa*). They also named four species that were commonly caught but usually discarded at sea (*S. paucispinis, S. entomelas, S. saxicola, S. elongatus*). Only half (5 of 10) of these species are even listed as "important" species in Puget Sound (Bargmann 1998a). More importantly, none of the ten are among the five most common species currently found in Puget Sound and Holmberg et al. (1961, p. 43) stated that "The rockfish catch in Puget Sound is composed of two species not caught in the offshore grounds, namely *S. caurinus* and *S. maliger.*" (copper and quillback rockfish).

Longevity can also come into direct conflict with adverse anthropogenic stressors. Some of the highest levels of contaminants such as mercury and polychlorinated biphenyls (PCBs) found in Puget Sound fishes have been measured in quillback rockfish (multiple references cited in West

1997). Because this species is long-lived, relatively high in the food chain, and non-migratory, it tends to accumulate persistent pollutants when present in their environment. The effects of these contaminants is unknown; however, reproductive impairment documented in English sole (*Pleuronectes vetulus*) occurred at lower contaminant concentrations, so it is likely that impairment exists in demersal rockfishes. (Note: relatively high levels of PCBs have also been observed in Pacific herring. Although this species is short-lived, its tissues contain naturally high levels of lipids, so lipophilic compounds such as PCBs are more likely to be retained after ingestion.) This is one of many problems that justify the designation of critical habitats, which is addressed in the next section.

CRITICAL HABITATS FOR AT-RISK PUGET SOUND FISHES

Any designation of critical habitat should encompass all marine and estuarine areas. Both of these habitats in turn have intertidal and subtidal elements, and can be soft or hard bottom, vegetated or unvegetated (Dethier 1990). The designation zone should begin 200 feet upland of the ordinary high-water mark and go seaward. For tributaries, upstream extent of the zone should be the uppermost point of tidal influence. While these parameters are somewhat artificial in an ecological sense, intent is to keep the designation proposal focused on a discrete and definable zone. The upland is included to recognize the important habitat functions of these adjacent areas. The 200 feet figure is given because it represents the state's current Shoreline Management Act jurisdiction, and allows some accounting for physical activities that can effect nearshore habitats.

It is significant that the zone encompasses an upland buffer. For example, the substrate temperature-moderation effects of intact bordering forests and water seeps have values to marine fishes analogous to the "riparian" habitat situation for salmonids. A buffer will also encompass many sediment "feeder" bluffs. Thus, the zone would recognize the importance of continued sediment supplies to shorelines for habitat maintenance. The continued maintenance of free-flowing streams from the adjacent uplands will also be essential for the maintenance of sediment inputs, particularily in areas susceptible to beach sediment "starvation" from heavy shoreline armoring. Even tiny seasonal streams often have sizeable intertidal sand-gravel deltas at their mouths, replenishing beaches downdrift.

There are a myriad of laws and actions that currently affect habitat protection and restoration. However, without continued modification and significant improvement in management programs, marine life habitats will continue to decline in extent and productive capacity, contributing to reductions in marine life populations and changes in other important ecosystem parameters. It will be important to recognize the inter-relationships between habitat components. Inadequate attention to one or more habitat components can reduce, or eliminate, the benefit of achieving the performance measures of another. For example, copper rockfish use pelagic habitats as larvae, submerged marine vegetation habitats as juveniles, and rocky reef habitats as adults. Many fish and wildlife resources indirectly rely on a number of different habitats because their primary forage species use these habitats as spawning and/or rearing substrates.

It is important to focus on the fundamental importance of habitat function versus habitat presence, even though the latter is typically the only measurable surrogate. For example, recent work on juvenile rockfish recruitment pathways and processes (Buckley 1997) highlighted the specific temporal and spatial partitioning of some habitats critical to successful recruitment and survival of juveniles - habitats not only need to be present, they need to be free of impacts that affect their functions at specific times.

There are three general areas of marine and estuarine habitat: (1) tidally influenced (intertidal) lands and estuaries; (2) nearshore (subtidal) marine habitats; and (3) open water habitats. Levings and Thom (1994) described nine categories of "nearshore" habitats in Puget Sound and Georgia Basin that actually encompass the first two categories listed above:

- Marshes
- Riparian vegetation
- Sandflats
- Mudflats
- Rock-gravel habitats
- Unvegetated subtidal
- Kelp beds
- Intertidal algae
- Eelgrass

Levings and Thom (1994) reported estimates of significant changes in areal extent on a Puget Sound-wide basis for only three categories: A 75.9% loss in tidal marshes and riparian habitat, as a direct result of infilling, diking, and other shoreline development, and a 52.7% increase in areas of bull kelp, probably as a result of shoreline armoring. This generally consists of changing unconsolidated, soft substrate to consolidated, wave and erosion-resistant substrate, including installation of bulkheads and jetties (Note: while this seems to sound positive, these kelp beds could be in inappropriate juxtapositions with essential recruitment habitat pathways, and thus create "recruitment traps" that result in reduced survival of juvenile rockfishes (Buckley 1997)). Mumford (1990) did indicate that regional losses of bull kelp forests have occurred in areas such as south Puget Sound. Losses of other habitat types have proven to be more difficult to measure even though there is a general concern that seagrass habitats have suffered major losses or degradation in recent years (Wyllie-Echeverria 1994 cited in West 1997). An additional emerging problem in recent years has been a greatly increased recreational harvest of kelps and other nearshore macroalgae. Aquaculture operations have also been cited as a potential source of habitat loss or degradation in Puget Sound. For example, loss of nearshore vegetative habitat occurs in areas where Pacific oysters are cultured. Potential conflicts between "wild" marine fish resources and the massive public and private aquaculture of salmonids are often suspected (West 1997) but never pursued to a meaningful conclusion. Critical issues such as carrying capacity, competition and predation are very difficult to study, much less resolve. Unfortunately, the "burden of proof" continues to be placed on marine fish resources.

West (1997) stressed the importance of submerged marine vegetation (SMV) which he defined as marine vegetation which is submerged during some part of the tidal cycle, including seagrasses, overstory and understory kelps, and turf algae. West (1997) reported that a number of marine life species rely on SMV for successful completion of their life cycle and, in addition, SMV habitats support a high diversity and abundance of organisms, and provide (1) a source of energy (through primary production), (2) refuge and foraging habitat for myriad organisms, (3) substrate for attachment of sessile organisms, (4) dissipation of wave and current energy, (5) stabilization of sediments, and (6) transfer of energy to deep or other habitats. He also stated that if the location of nursery habitat beds are changed through mitigation (e.g., transplanting eelgrass) or other human activities, then existing patterns of supply of juveniles may not match the altered habitat distribution.

Thus, essential habitats can be lost or damaged by:
Shoreline armoring, which can lead to beach erosion, interrupt sediment flow, adversely affect biotic systems dependent on those sediments, physically displace (and destroy) high intertidal habitats (e.g., forage fish spawning habitat), eliminate riparian habitat (e.g., overhanging vegatation).
Land filling, which can cover spawning habitat and physically displace and destroy algae and other marine vegetation.
Diking and channeling, which can change salinity and water regimes and result in the complete loss of natural habitats.
Dredging, which can destroy marine plants and animals (during dredging), remove habitat (e.g., by deepening dredged areas beyond species' ability to survive), adversely affect water quality by releasing toxins (when sediments are contaminated), or by removing sediment-trapping vegetation.
In-water structures, which can shade algae and marine vegetation and reduce species abundance.
Clearing and grading, which can result in increased sediments in the water column (from runoff) that can smother or shade marine plants and sessile or slow-moving invertebrates, and can remove overhanging riparian vegetation.
Nutrient enrichment from point and non-point pollution, which can lead to proliferation of algae that can shade or smother eelgrass or other marine plants.
Exotic species, such as *Spartina*, which can displace native plants and adversely affect ecosystem function.
Water pollution from storm water runoff, malfunctioning septic systems, agricultural practices, point source discharges, and oil spills, which can contaminate and degrade nearshore habitats.
Shifts in water flow regimes, which can result in changes in salinity and adversely affects estuarine systems.
Recreational harvest of algae (e.g., kelp) which can result in loss of food source and cover for marine species.
Aquaculture, which can affect habitats by beach graveling, spraying of pesticides, removal of attached vegetation, or competing with indigenous species for a finite primary productivity.

At least some of these observable adverse physical impacts can be quantified. By analyzing sampling data for Puget Sound habitats, Bailey et al. (1997) made the following point estimates for percentage of shoreline length with human modifications:

South Puget Sound - 34.4%
Central Puget Sound - 52.1%
North Puget Sound - 35.7%
Hood Canal - 32.4%
San Juan/Straits - 20.2%

The loss of nearshore habitat was identified as the most significant threat to the health of marine waters in the Puget Sound and Georgia Basin (British Columbia/Washington Marine Science Panel 1994 cited in West 1997).

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