

ALASKA LEGISLATURE SPECIAL COMMITTEE/SUBJECT FILE
1911 SCOMM 75: MARICULTURE (FISH FARMING); 1987-1990 8672

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areas of the state are not sensitive to the effects of nutrients from net pens. Meeting these considerations would prevent nearshore algal enrichment impacts that have occurred in the very shallow nearshore areas due to urbanized (nutrient rich) streamflow (Thom et al. 1984, 1988).

- Prior to siting of net pens, determine if the area is nutrient sensitive.
- Where available, examine existing data bases on nutrient sensitivity (for example, SAIC, 1986);
- Where data is unavailable or incomplete, require evaluation of nutrients and algal density (chlorophyll *a* or cell counts).
- If nutrient sensitivity is indicated, adverse impacts can be avoided by:
 - Restricting fish farms in areas already exhibiting hypereutrophication;
 - Limiting total fish production within a sensitive area to that which will not adversely affect existing biota. (Predictive models, such as those of Parametrix or Kiefer-Atkinson, can be used to estimate allowable fish production);
 - Locating pens where flushing will remove dissolved waste material from the area (for example, near bay entrances where flushing is likely to be greatest).

In sensitive areas, nutrient production could be minimized by operation changes, such as:

- Reducing feed wastage through careful fish cultural practices (pen design, stocking densities, feeding methods) and the use of slow-sinking feed.
- Reducing the amount of nitrogen in the feed or increasing the digestibility of the nitrogen in the feed to reduce ammonia excretion.
- Integration of fish culture with the culture of aquatic plants and shellfish which could utilize and remove nutrients and phytoplankton from the water.

(4) Unavoidable Adverse Impacts

Adverse impacts from nutrient input and phytoplankton productivity have not been demonstrated in nutrient-rich waters. Impacts in sensitive areas can be avoided if the proposed net-pen site has adequate water volume and flushing. In confined embayments, net-pen operations could result in adverse phytoplankton production if total fish production exceeds the assimilative capacity of the bay.

c. CHEMICALS

This issue involves the use of antibiotics and antifoulants in fish farm operations. Concerns include the environmental risks associated with chemical usage, accumulation of antibiotics in the tissues of indigenous biota, and whether use of antibiotics encourages growth of bacteria resistant to antibiotics.

(1) Affected Environment

Antibiotics. Three antibiotics are currently registered for use in fish farming applications by the U.S. Food and Drug Administration (FDA). These are (1) oxytetracycline (OTC), (2) a potentiated sulfonamide marketed under the trade name Romet, and (3) sulfamerazine. Other antibiotics, such as oxolinic acid, may be used on a limited basis if special permission is granted by the FDA.

OTC, marketed under the trade name Terramycin or TM-50, is the most commonly used antibiotic in salmon net-pen farms. It is generally regarded as highly effective against vibriosis. It is also used to treat furunculosis. (See Appendix D for a further discussion of fish diseases.)

Romet is a relatively recently-licensed antibiotic for use in fish farming. It has been demonstrated effective against furunculosis and enteric redmouth disease in freshwater fish hatcheries. Due to its relatively recent licensing, little information is available on its efficacy in seawater net-pen farming.

Sulfamerazine, while licensed for use on cultured fish, receives little use today in Washington for disease control in salmon culture because it is not as effective as OTC in controlling bacterial diseases of salmon.

The FDA practices a more conservative policy toward the licensing of drugs for use in aquaculture than do governments of many other countries. Thus, drugs such as oxolinic acid and chloramine-T, which are effective against certain bacterial diseases of salmon, are commonly used in other parts of the world, but are not used in the United States.

The digestibility of OTC, oxolinic acid, and chloramphenicol was tested in rainbow trout in freshwater by French scientists (Cravedi et al. 1987). These researchers found that the digestibility of OTC was 7 to 9 percent, in comparison with chloramphenicol's 99 percent and oxolinic acid's 14 to 38 percent. Chloramphenicol is not used in animal husbandry in the United States due to its high toxicity and, as noted above, oxolinic acid is not licensed for general use in aquaculture in this country. According to these authors, the relatively low level of digestibility of OTC may result from its affinity for calcium. The authors also note that since about 90 percent of OTC administered in fish feed is excreted in the feces in the form of the parent compound (that is, as the chemical form added to the feed). That means use of the drug could contribute to the development of antibiotic resistance in bacteria near the fish farm. Austin and Al-Zahrani (1988) found that OTC and other antibiotics altered the number and type of bacteria in the digestive tract of rainbow trout fed antibiotics.

Austin (1985) discussed the effects of antimicrobial compounds that are used in fish farming and that may escape into the environment. He noted that data are not available on the quantities of antimicrobial compounds entering the environment from fish farming. However, his research provides estimates of probable concentrations of antibiotics leaving freshwater fish farms. The estimated dilution of OTC, based on maximum allowable levels of administration, was 1 part in 50,000,000. This dilution was regarded as a worst-case estimate, based on no retention of the administered drug in the fish. Thus, Austin (1985) concludes that the concentrations of drugs reaching the environment are very small.

Austin (1985) noted that use of antibiotics in fish farms could lead to an increase in antibiotic resistance among bacteria in the farm effluent. Other authors have reported the phenomenon of antibiotic resistance of bacteria near fish farms in which the medications are applied (Aoki 1975, 1988; Aoki et al. 1971, 1972b, 1974, 1977, 1980, 1984, 1985, 1986a, 1987a; Aoki and Takahashi 1986; Takashima et al. 1985; Bullock et al. 1974; Toranzo et al. 1983). Bacteria can gain antibiotic resistance through the selection of bacteria which contain resistance factors, or plasmids, some of which may be transferable from one fish pathogenic bacterium to another under certain conditions (Akashi and Aoki 1986b; Aoki and Kitao 1985; Aoki and Takahashi 1987; Aoki et al. 1972a, 1986b, 1987b, 1981; Mitoma et al. 1984; Toranzo et al. 1984). It is also known that the plasmids, or resistance factors, can confer resistance to more than one antibiotic when transferred from one bacterium to another (Aoki et al. 1987a). The presence of plasmids has been documented in both fish pathogenic bacteria (see above citations) and in native aquatic bacteria (Burton et al. 1982).

A FDA study to evaluate the use of OTC for aquatic applications, analyzed the environmental impact of the antibiotic on disease control in lobsters held in impoundments Katz (1984). Based on seawater dilution and lack of long-term selective pressure favoring the persistence of OTC resistant organisms, Katz (1984) concluded that "there should be no build up of antibiotic resistant population of microorganisms from the use of OTC in treating gaffkemia in lobsters." In the same report, Katz concluded that "the potential of R-factor (resistance-factor) transfer between organisms should be minimal" as a result of dilution, low levels of nutrients, low temperatures, and high salinity of seawater.

The technical literature cited above indicates the several factors. They are occurrence of antibiotic resistant bacteria in association with aquaculture depends on the diversity, frequency, and dosage of antibiotic administration, and environmental conditions of culture including temperature, dilution of the antibiotics, and the containment of the fish and associated bacteria.

The reports of antibiotic resistance from Japan are from very intensive aquaculture sites characterized by warm temperatures, high densities of fish grown in confined ponds, and the use of a variety of antibiotics not registered for use in the United States. As well, the dosage and duration of antibiotic treatment in Japan appears to exceed both legal and general practices in the United States. Thus, while these studies document antibiotic

resistance in fish pathogenic bacteria as a result of the administration of antibiotics, they should not be interpreted to indicate that similar antibiotic resistance will occur under very different environmental conditions and fish husbandry practices.

Importantly, studies (Austin 1985; Austin and Al-Zahrani 1988; Aoki et al. 1984) have noted that the increased level of antibiotic resistance associated with antibiotic use around fish farms was soon reduced after antibiotic use stopped. This phenomenon has been observed in human medicine (Forfar et al. 1966) where dramatic declines in resistance levels of bacteria occur after antibiotic treatments are stopped.

The possibility of transfer of drug-resistance factors from a fish disease-causing bacteria to a potential human disease-causing bacteria, V. parahaemolyticus, was investigated in Japan (Hayashi et al. 1982). Using test tube conditions and temperatures of about 86°F to 96°F, these authors were able to transfer drug resistance to V. parahaemolyticus. These authors also noted that in Japan, where antibiotics have been extensively used in aquaculture, drug-resistant strains of the V. parahaemolyticus have never been found in the environment.

Toranzo et al (1984) reported the transfer of drug resistance from several bacteria isolated from rainbow trout to the bacterium, Escherichia coli. The transfer to resistance was performed under laboratory conditions at 25° C (77° F). The studies demonstrated the potential for transfer under controlled laboratory conditions and these authors concluded that "Responsible use of drugs in aquaculture will aid in minimizing the development and spread of R⁺ factor-carrying microorganisms that may confer drug resistance"

The accumulation of antibiotic residues in shellfish near fish farms has received little study. In the Puget Sound area (Tibbs et al. 1988) found that mussels, oysters, and clams suspended within a matrix of net pens in which coho salmon were being given food supplemented with OTC had no detectable levels of the antibiotic in their tissues. That study examined the phenomenon of antibiotic accumulation in shellfish under worst-case conditions with regard to the distance between the fish pen and shellfish (the shellfish were placed within the matrix of fish pens). Weston (1986) noted the large dilution factor that would occur when antibiotics are used in a net pen. He made conservative calculations and computed a diluted level of 3 parts per billion of OTC in a parcel of water passed through a fish pen receiving medicated feed. Given this dilution factor and the water-soluble nature of antibiotics like OTC, Weston (1986) concluded that there was little potential for bioaccumulation of antibiotics used in fish farming.

Jacobsen and Bergline (1988) reported the persistence of OTC in sediments from fish farms in Norway. These authors also conducted laboratory tests and concluded that the half-life (time required for a given concentration to decay to 50 percent of the starting concentration) for OTC in marine sediments was about ten weeks, but would likely depend on sediment type and other factors. They examined sediments from underneath four farms, but did not report the duration or quantities of OTC applied at each location. OTC was found in sediments from three of the four farms at levels from 0.1

to 4.0 mg/kg (ppm [parts per million]) of dry matter. This level would potentially be high enough to be inhibitory to marine bacteria (1-2 ppm is considered inhibitory) including vibrios. However, since the concentration is reported relative to dry weight, it overestimates the actual concentration in hydrated sediment. The study does demonstrate that measurable OTC can accumulate below fish farms. Conservatively, the study can be interpreted to show the highest concentrations were just above inhibitory levels on a dry-weight basis. The authors also noted that the oxidation state of the sediments would affect the half-life of OTC.

Another study, the Wekell and associates study (1989), included the analysis of shellfish tissues placed near fish farms in Puget Sound for the presence of OTC. In this preliminary study, no OTC was detected in the shellfish tissues.

An Environmental Assessment of OTC by the FDA (USFDA 1983) concluded that "the use of OTC is beneficial to control diseases in aquatic environment and does not pose adverse effects on this compartment. However, steps should be developed to avoid the emergence of drug-resistant organisms."

Accumulation of antibiotics in marine sediments is also a function of the dilution factor (which determines the level of antibiotic reaching the sediment), biotransformation of the compound in the sediment, oxidation state of the sediment, and water solubility of the antibiotic. Levels of OTC such as those calculated by Weston (1986) to reach sediments are not likely to have inhibitory effects on non-pathogenic bacteria, which are little affected at levels below 1 ppm (Carlucci and Pramer 1960). In their study of the microbial quality of water in intensive fish rearing, Austin and Allen-Austin (1985) note that while it is difficult to make generalizations, their study indicated that two freshwater fisheries they monitored did not produce "a major imbalance in the aquatic bacterial communities."

Antifoulants. Organic tin compounds, known for their toxicity to marine invertebrates (Hall and Pinkney 1985) and salmon (Short and Thrower 1987), were once used in Washington state. Their use for most purposes is now prohibited by state legislation. Therefore, organic tin antifoulants are no longer used by the net-pen industry in Washington. Their use has also been virtually eliminated in net-pen farming in other parts of the world as well. No other chemical means of reducing fouling on nets is in use.

In Norway, netting containing copper wire is used to reduce fouling, and in British Columbia, waxy antifouling compounds have been used recently for the same purpose.

(2) Impacts of Chemicals

Although some technical details require further study, the issues surrounding antibiotic use in fish farming have received some detailed study. Studies demonstrate that antibiotics will be released into the environment when used as a medication for farmed fish. Antibiotics have not been detected in shellfish held near salmon net pens. One Norwegian study found concentrations of one antibiotic may have been close to inhibitory

levels in three of four farms. The concentrations of antibiotics outside of the immediate proximity of the fish pens are regarded by most authors as being too low to have adverse effects.

The presence of plasmids, a mechanism by which bacteria transfer resistance, is documented in pathogenic and native aquatic bacteria. Antibiotic resistance has been recorded in bacteria around fish farms. Most of the technical literature describing antibiotic resistance in fish pathogenic bacteria is based on studies of aquacultural practices and environmental conditions not comparable with salmon net-pen farming in the Puget Sound region. These conditions include high temperatures, high densities of fish, close proximity of multiple farms, and use of a variety of antibiotics not used in fish farming in the United States. Conditions in the studies reporting antibiotic resistance favor the development of resistance. In comparison, salmon net-pen farming in the Puget Sound region would not favor the development of antibiotic resistance. In addition, the federal regulations that apply to the use of antibiotics in fish farming in the United States appear to be much more stringent than those that apply in Japan and Europe, where most of the technical literature has originated.

Antibiotic resistance tends to disappear when antibiotic administration is stopped. Shellfish held within a net-pen complex did not accumulate detectable levels of OTC. This observation and the calculated dilution of antibiotics away from the fish pens further suggest that any quantities of antibiotics accumulated in shellfish, or other benthic or planktonic marine invertebrates not near the pens would be substantially below levels of concern.

The lack of antibiotic resistance in a potential human disease-causing bacteria such as V. parahaemolyticus in Japan, despite the extensive use of antibiotics in aquaculture there, indicates the transfer of drug resistance from fish to human pathogenic bacteria is unlikely. It appears such transfer is a laboratory phenomenon which requires highly controlled conditions and is not representative of phenomena that occur in the environment. The Toranzo et al (1984) study further demonstrates the potential for drug resistance transfer under controlled conditions (77° F). The lower temperature range found in Puget Sound, and in fact, required for salmon net-pen farming, is one key environmental factor that can prevent the laboratory-documented resistance transfer from occurring in association with salmon net pens in Puget Sound.

(3) Mitigation Measures

No substantial environmental impacts were identified under the legal use of antibiotics in fish farming in Puget Sound. Nonetheless, since some risk of drug resistance can result from improper and excessive antibiotic use, such use should be conducted in a controlled and documented manner. Alternative means of health management should be employed where appropriate. To achieve this goal, the following measures are recommended:

- Vaccination by effective protocols currently in place can be considered an effective mitigation measure for limiting the use of antibiotics.

- Educational programs presented by appropriate state government agencies on the use of antibiotics for fish farmers are recommended.
- Control of the application of antibiotics by veterinarians or other appropriate professionals could reduce the likelihood of their misuse. In addition, or alternatively, a requirement for fish farms to report antibiotic use to a state regulatory agency could help ensure their proper use.
- Further research to verify that shellfish held outside an immediate net pen environment do not accumulate significant levels of antibiotic is desirable, as well as research to establish any potential amounts of the antibiotic in sediments near fish farms in Puget Sound.

(4) Unavoidable Adverse Impacts

Identified adverse impacts can be mitigated through the measures identified above.

d. SUMMARY

Net-pen aquaculture can potentially have a wide range of impacts on water quality. Some water quality determinants such as temperature, pH, fecal coliforms and toxicity are virtually unaffected by net pens. Other determinants are affected only during some periodic activities in the operation of net pens. This is the case for turbidity which may be impaired during net cleaning.

The primary water quality indicators of concern are dissolved oxygen, nutrients, and antibiotics. Nutrients are only a concern in certain nutrient sensitive embayments where they potentially cause large increases in phytoplankton populations and possibly causing nuisance algal species. Dissolved oxygen and nutrient impacts are usually very localized in the immediate vicinity of a net pen and decrease rapidly with distance away from the pens due to diffusion and biological activity. Antibiotics have not been shown to cause the development of antibiotic resistant bacteria except in highly controlled laboratory experiments. The development of antibiotic resistant bacteria in Puget Sound is virtually impossible at the low temperature and low concentrations of antibiotics around net pens in the Sound.

Mitigation methods are capable of reducing or eliminating all adverse water quality impacts from net pens. Mitigation methods fall into two broad categories: siting of net pens and operating procedures. Proper siting involves choosing sites with adequate circulation and tidal flushing and avoiding shallow, constricted embayments. Field studies are required to adequately identify the circulation and flushing characteristics of a proposed net-pen site. Model studies can be used to estimate the propagation of water quality impacts away from net pens. This is particularly true for dissolved oxygen and nutrients. Modelling becomes more critical if multiple net pens are proposed in the same embayment. In this case, modelling can be used to determine the location and

orientation of a net pen with respect to other net pens and to estimate the overall impact of the net pens on the embayment.

Operating procedures can be used to reduce a number of impacts from net pens. Choice of feed and feeding procedures can reduce feed loss and resulting dissolved oxygen depression and nutrient enrichment. Use of aerators in periods of low dissolved oxygen in late summer can reduce the possibility of dissolved oxygen being reduced to concentrations below state standards. Operation of aerators could also raise dissolved oxygen above ambient (existing) concentrations and result in net pens having a positive impact on dissolved oxygen. Careful and controlled use of antibiotics would virtually eliminate any adverse impacts associated with the use of antibiotics.

Water quality impacts from net-pen operations are a legitimate concern. However, through an analysis of operating practices, field studies, and mathematical modelling, mitigation methods are available to avoid significant water quality impacts.

3. IMPACTS TO AQUATIC ORGANISMS

a. FISH AND SHELLFISH

This issue concerns the potential effect net pens may have on existing fish and shellfish resources in Puget Sound. There is concern that farms may cause a degradation of commercially valuable species and potentially affect sensitive habitat.

The objective of the mitigation measures identified in this section is to prevent impacts that would adversely affect the habitat value to food fish and shellfish in the area around and under the proposed pens, and to prevent adverse impacts to fish and shellfish populations.

(1) Affected Environment

There are a number of commercially valuable species of fish and shellfish harvested in Puget Sound. Commercial landings of salmon average 44 million pounds (20,000 MT) per year in Puget Sound. Marine fish landings average 5000 metric tons (11 million lbs) and shellfish landings average 5.6 metric tons (13 million lbs). The total landings of all species in Washington have a process value of around \$300 million (Ward and Hoines 1987). The size of commercial fishing industry and the potential impacts of net pens on the industry are discussed in Section II.B.3.

In addition to the commercial fishing industry, recreational fishing is a major activity which is gaining increased emphasis. In 1986 about 1.2 million angler trips were made to catch 830,000 salmon, and 1.8 million trips were made to catch various species of shellfish 4.6 million pounds of clams, oysters, crab, and shrimp. In addition, 756,000 marine fish were taken by boat-based sport fishers.

Discussed below are some of the species that could be affected by net pens and important habitats to consider.

Clams and Oysters. A variety of clams are found on intertidal beaches and subtidally to about 21 m (70 ft.) in Puget Sound. Butter clam (*Saxidomus giganteus*), littleneck clams (*Protothaca staminea* and *Tapes japonica*), and horse clam (*Tresus capax*) are found in dense beds in substrates of mixed mud, sand, and gravel. There are an estimated 84 million kg (170 million pounds) of clams in beds covering about 5400 acres. Geoduck clams are taken commercially from depths of 6 to 18 m (18-60 ft), but they occur at depths of at least 110 m (360 ft). Subtidal sand and mud provide major habitat for geoducks. About 34,000 acres of geoduck beds exist in Puget Sound containing approximately 30,000 metric tons of clams. Approximately 1800 to 2300 MT (4-5 million lbs) of geoducks are harvested annually at a value of about \$5 million.

Two oysters are found in Puget Sound, the native oyster (*Ostrea lurida*) and the imported Pacific oyster (*Crassostrea gigas*). Oysters are generally limited to intertidal beaches where they would not be directly affected by net pens. All commercial oyster harvest is from farmed beds which also provide the basis for populations on recreational beaches.

Octopus. The giant octopus (*Octopus dofleini*) prefers rocky, high current areas for spawning and foraging. They appear to feed on any fish or invertebrate they can catch. They are commonly harvested from soft bottom areas by traps (Mottet 1975).

Sea Urchins. Three commercially harvested sea urchins occur in Puget Sound waters: the red urchin (*Strongylocentrotus franciscanus*), the green urchin (*S. droebachiensis*), and the purple urchin (*S. purpuratus*). They occur at depths extending from intertidal to depths of several hundred feet, generally on rock and other solid substrates, but also use soft substrates. Urchins tend to eat algae, but use many food sources including dead animals and algae. They will also eat organic matter discharged in sewage (Mottet 1976).

Crab and Shrimp. Dungeness crabs (*Cancer magister*) and red rock crab (*Cancer productus*) are common predator/scavengers of Puget Sound feeding on small clams, worms and other organisms. Both use intertidal and nearshore areas as nursery areas with adults found in nearby water offshore. Dungeness crabs are the primary species harvested commercially and recreationally, and are most abundant north of Everett and in Hood Canal. Red rock crab are found throughout Puget Sound. Seven species of shrimp such as the spot prawn (*Pandalus platyceros*), coonstripe shrimp (*P. danae*), and sidestripe shrimp (*Pandalopsis dispar*) are harvested in Puget Sound. They are generally harvested from soft bottom areas although coonstripes are common in rock riprap areas. Shrimp are also predator/scavengers feeding on small organisms in the sediments.

Salmon. The five species of Pacific salmon found in the northwest use shallow nearshore areas as juveniles for foraging on small epifaunal organisms. Adults migrate through Puget Sound concentrating near points of land and river mouths when returning to spawn. Some adult salmon are present in Puget Sound during the entire year.

Herring. Pacific herring (*Clupea harengus pallasii*) occur throughout Puget Sound. These pelagic fish spawn from late winter through spring in eelgrass and algae beds at certain locations. Herring tend to spawn each year in the same areas which have been mapped

by the Washington Department of Fisheries. All such areas are intertidal to shallow subtidal (about -20 ft MLLW) although herring spawn have been found as deep as 40 ft (Haegele et al. 1981).

Juvenile herring are commonly found in nearshore waters during spring and summer. These pelagic fish migrate in large schools, gradually moving into offshore waters as they grow. Adult herring occur throughout the deeper waters of Puget Sound at most times of the year. Herring are harvested for both food and bait.

Smelt. Surf smelt (*Hypomesus pretiosus*) are pelagic fish that spawn on some intertidal beaches in Puget Sound at tidal heights of about +7 to +13 ft MLLW. They spawn throughout the year on beaches of coarse sand to small gravel (Penttila 1978).

Lingcod. Lingcod (*Ophiodon elongatus*) spawn preferentially in rocky areas in the winter, and juveniles use nearshore areas as nursery grounds. They are found from intertidal depths to the deepest portions of Puget Sound. Lingcod are a bottom-oriented fish that preys on other fish and large invertebrates.

Rockfish. Rockfish of many species are taken both commercially and recreationally. Many species of rockfish are found in Puget Sound. They occur from shallow subtidal depths to the deepest portions of the Sound. Although they are often associated with rocky areas, they are found near all bottom types. They are predators of other fish and large mobile invertebrates. They are often attracted to submerged structures such as artificial reefs.

Perch. There are three seaperches that are common in Puget Sound, the pile perch (*Rhacochilus vacca*), the striped seaperch (*Embiotoca lateralis*) and the small shiner perch (*Cymatogaster aggregata*). Perch are harvested both commercially and by sports fishermen. Each of these species inhabits nearshore areas and are often attracted to submerged structures.

Cod. Pacific cod (*Gadus macrocephalus*) are harvested by sports fishermen in Puget Sound. Although they may be found at times throughout the deeper waters of Puget Sound, they are harvested primarily from channels where they congregate to spawn in late winter. The sports and commercial harvest of cod in Puget Sound is about 160,000 kg (350,000 lb) annually.

Flatfish. Flatfish of many species occur in Puget Sound. These fishes reside on the bottom at essentially all depths on the mud and gravel bottoms. They are harvested by both commercial and sport fishermen. Many species use shallow nearshore areas of nursery grounds.

(2) Impacts on Fish and Shellfish

The primary impacts net pens are likely to have on fish and shellfish populations are the result of the net-pen structure and sedimentation that may occur under the pens. The effects of sedimentation upon the benthic community have been discussed in Section

II.A.1. In general, at low rates of deposition, filter feeders such as clams will be enhanced, but at high levels immobile will be displaced from the area below the pens. Weston (1986) reported that mobile predators/scavengers are attracted to the area around aquaculture facilities to feed on excess feed and on the small organisms, including opportunistic worms, which are enhanced around the pens. Weston's review reported increased densities of crab, flatfish, starfish, perch, lobsters and other predators and surface feeders from sites in all around the world. In Puget Sound, Pease (1977, 1984) observed increased numbers of crab, and various fish around net pens and mussel rafts. It is likely that shrimp numbers in the immediate vicinity of net pens will also increase.

The net-pen structures also provide a habitat in the open water environment to attract fish such as seaperch and rockfish in larger numbers than would normally be found in an open-water portion of Puget Sound. Net pens and their floats also provide a substrate on which algae and invertebrates grow, providing a food source that increases the attraction of various fishes. These organisms, along with waste food, would provide an available food source attractive to many fish.

The presence of floating objects apparently provide protection from predation for small fish (Mitchell and Hunter 1970). In Japan floating structures have been used intentionally to attract fish and in Puget Sound, artificial reefs of rock and concrete have been constructed to provide vertical relief and substrate for benthic organisms. Fish reported associated with net pens in Puget Sound include shiner and surf perch, true cod, lingcod, dogfish, sculpins, and flatfish.

Fish and mobile invertebrates are expected to be enhanced around the periphery of net pens, unless organic deposition results in anoxic conditions in the water. This is only likely in areas of stagnant water with very poor circulation (Earll et al. 1984). In such situations, H_2S production would most likely have severe impacts on the fish held in the pens where they are unable to escape the toxic water. Consequently, the risk is somewhat self-limiting.

Fish and shellfish could also be adversely affected by the deposition of organic sediments upon important habitats. Clams and geoducks occur in dense beds. A net pen directly above such a bed in shallow water could create an azoic zone immediately below the pens, killing all the shellfish within this zone. In addition, sedimentation over spawning areas (such as for lingcod and octopus) could smother eggs and eliminate the area for future spawning use. For many species, the availability of spawning habitat determines the ultimate abundance of the species. Other species may have different habitats which are critical to specific life stages, which could be adversely affected by sedimentation.

The depths of water necessary for net pens preclude direct impacts to intertidal shellfish and fish habitats.

(3) Mitigation Measures

The presence of net pens may enhance several species, however, improperly sited or operated pens could adversely affect fish and shellfish or their habitats. Adverse impacts can be avoided by:

- Minimize sedimentation impacts as described under Mitigation Measures in Section II.A.1.
- If pens are located where sedimentation may adversely affect fish and shellfish, avoid important habitats.
- Require surveys of the proposed site to determine the presence or absence of significant habitats.
- Where adverse impacts are unavoidable, require mitigation through enhancement of the affected species at the site or in the immediate area.

(4) Unavoidable Significant Adverse Impacts

Potential adverse impacts to fish or shellfish can be avoided by proper siting and operation of the net pens. With the mitigation measures presented, no significant adverse impacts are anticipated.

b. IMPORTATION OF EXOTIC FISH SPECIES

Commercial farming of fish frequently involves the use of species which are not indigenous to the area or which have been specifically bred for use in net pens. There is a concern that Atlantic salmon would escape net pens and compete directly with native Pacific salmon populations. There are also concerns that Atlantic and Pacific salmon raised in net pens would interbreed with wild salmon stocks potentially causing a long-term genetic impact.

The objective of the mitigation measures discussed in this section is to minimize any adverse impacts to fish species indigenous to Puget Sound.

(1) Affected Environment

Net-pen farming in Washington state is presently limited to coho, chinook and Atlantic salmon and steelhead trout. In the future, other species may be employed if market conditions and culture technology permit profitable culture. For example, culture technology for turbot, halibut, cod, eel and other cold water species of fish are being developed in Europe and Asia, and some of these species may eventually be economically feasible for culture in Puget Sound. Atlantic salmon are presently the species of choice for the salmon aquaculture industry in Europe and Washington state. This preference is due to the established marketability of Atlantic salmon, and their

adaptability to culture (for example, tolerance to high density stocking and resistance to disease).

As with all exotic introductions, the importation of any plant or animal, terrestrial or aquatic, may pose a threat to native species if released into the wild. Many introductions of exotic species worldwide, however well meaning, have led to ecological disasters. Not only might the animal itself spread unchecked, but diseases these animals may carry might be spread to native species (see Section II.A.3. Disease). Exotic importations, thus, must be screened, evaluated and monitored with the utmost precaution. The actual risk of harmful impacts to native species depends upon the species proposed for culture and the culture system. Given the number of species which may be considered for culture in the future, it is impossible to examine the possible interactions with native. As an example of the possible genetic interactions and possible mitigative measures, the introduction of Atlantic salmon into Puget Sound will be evaluated.

(2) Impacts of Exotic Fish Importation

Genetic Impacts. There is a concern that Atlantic salmon raised in net pens would escape and interbreed with wild salmon stocks potentially causing a long-term genetic impact. Atlantic salmon belong to the genus Salmo. They are genetically very different from and genetically incompatible with Pacific salmon (chinook, coho, chum, pink, and sockeye), which belong to the genus Oncorhynchus. Thus, it is essentially impossible that Atlantic salmon pose any direct genetic threat to these species.

Available information indicates that Atlantic salmon introductions pose no direct genetic threat to steelhead or cutthroat trout stocks. Steelhead trout and cutthroat trout, formerly Salmo gairdneri and S. clarkii, have recently been reclassified by the American Fisheries Society. Their new names, Oncorhynchus mykiss and O. clarkii reflect fundamental differences to the genus Salmo. This reclassification is based in part on the inability of steelhead and cutthroat trout to successfully cross with other members of the genus Salmo. Under the best conditions (laboratory experiments), researchers have been unsuccessful at crossing these two groups (Lindbergh 1984; Refstie and Gjerdren 1975).

In addition, Atlantic salmon spawn several months earlier than Pacific Coast steelhead and cutthroat trout, and would not have the opportunity to attempt such hybridization (Heggberget 1988; Mahnken 1988). There are no native stocks of Atlantic salmon or other Salmo species with which the cultured stocks could interbreed.

Local experts agree that wide spread net-pen culture of Pacific salmon in Puget Sound poses a minimal threat to wild salmon populations in terms of genetic degradation (Mahnken 1988; Hershberger 1988; Waples 1988). However, because the subject is complex, a fairly detailed discussion is presented here. The issue centers around the scenario of net-pen farmed fish escaping, maturing and interbreeding with wild populations.

Different river systems generally have genetically different stocks of salmon. Because the characteristics of each river are unique, selective pressures on the populations in those

rivers have lead to genetic adaptations which favor their survival. For example, salmon that spawn in the upper reaches of long river systems (for example, the Fraser or Columbia) must make much longer journeys to spawn than salmon from shorter river systems (such as those of Puget Sound). Thus fish from the upper reaches of longer river systems have become more robust and store larger amounts of energy in order to sustain the long journey. Because introduced fish lack the energy reserves to make the entire trip to spawn, attempts to stock these upper reaches with fish from shorter rivers have been unsuccessful. Therefore, there is concern that if distinct fish stocks mix, that important adaptive genetic traits would be diluted.

Some interbreeding of stocks occurs naturally as fish stray from one river system to another. This is the mechanism by which rivers have been naturally propagated with fish, such as after major natural disasters in the river system (such as landslides and volcanic eruptions). In nature, the incidence of straying is limited, thus new genetic traits can be incorporated into an existing population without diluting the existing genetic traits. If large populations of genetically distinct fish were to interbreed, then such dilution could occur.

The Washington Department of Fisheries considers it undesirable to interbreed indigenous wild salmon populations with stocks of grossly different genetic character. Net-pen farmed fish may or may not be grossly different from stocks in adjacent rivers. This variation could lead to a concern of interbreeding with indigenous populations. While speculative in nature, there are theoretical grounds for this concern.

One concern is the potential for wild populations to be genetically altered by genes from net-pen farm escapees inappropriate for natural conditions. For net-pen farms, there are two potential sources of fish that may be grossly different genetically from wild fish. One source might be fish from a river system that is geographically distant and environmentally different from the river system closest to the pen site. The second source might be from fish from the nearby river system that are highly inbred due to long-term genetic manipulation within a hatchery environment.

In hatcheries, individuals are actively or passively selected for many genetic traits suiting them to that environment. These traits may be deleterious or useless in the natural environment. Passive selection includes such traits as tolerance to crowding stress, disease, and low water quality; reduction in fright susceptibility and aggressive behavior; and adaptation to hatchery diets. For example, aggressive behavior is a waste of energy to a fish in a hatchery. In the wild, it is a necessary behavior pattern. Traits actively selected for in-breeding programs--egg size, flesh color and taste, fat content, and maturation rate-- have no use in wild conditions. Traits such as rapid growth rates are only beneficial when food is very abundant. Where food is limited (as is usually the case in the wild), this trait might be detrimental. It should be noted, however, that a large portion of salmon in the North Pacific are from hatchery stocks. While in the natural environment, these fish are exposed to all the environmental pressures of wild fish which will tend to select out genetically maladapted individuals. The successful return of these fish to their hatchery streams indicates the retention of sufficient beneficial traits for survival.

The interbreeding of two grossly different wild stocks can occur by transplanting eggs from one distant river system to another. In the natural environment, salmonids tend to evolve into genetically discrete stocks adapted to specific ecological conditions within nearby river systems with similar geography (such as southern Puget Sound). In fact, there are over 100 stocks of chinook salmon in North America identified as genetically discrete (Mahnken 1988; Hershberger 1988). Genotypes (the genetic makeup of an organism) adapted to one region cannot be expected to survive as well in a distant region as the genotypes of the resident population. As such, interbreeding of two distant wild stocks could reduce the fitness of the progeny.

Another potential genetic impact concern is the high degree of genetic variability within salmon populations. Maintaining this variability may be important to the long-term fitness (reproductive ability) of wild populations by providing the plasticity they need to survive sudden changes in environmental conditions. Genetic variability may be reduced in hatchery populations even if random selection is practiced during spawning. Nonintentional (passive) selection occurs in the form of differential survival favoring fish best suited for hatchery conditions. Since hatchery conditions are relatively stable, genotypes capable of tolerating environmental extremes are gradually lost.

Several studies have demonstrated lower variability in hatchery stocks of trout (Salmo sp.) compared to wild stocks (Allendorf and Phelps 1980; Ryman and Stahl 1980; Stahl 1983). In some cases, this condition results in the development of undesirable traits such as lower viability of gametes (cells capable of participating in fertilization). While this has been demonstrated in trout and Atlantic salmon (Aulstad et al. 1972; Kincaid 1976a and 1976b; Ryman 1970) it has not been documented in Pacific salmon (Oncorhynchus sp.) This lack of documentation may in part be due to the lack of totally captive (captive throughout their life cycle) populations of Pacific salmon. The exception is Domsea Farms in Clam Bay, Washington, which has genetically manipulated coho for over 10 years. However, this effort only encompasses seven generations.

The degree of genetic degradation of wild populations by net-pen escapees depends on two basic factors. The first factor is the extent of genetic difference between the net-pen fish and wild fish. The second factor is the degree of interbreeding between the two groups. "Normal" hatchery fish (released into marine waters, growing to maturity in the wild) may or may not be very different from wild populations in the vicinity. Frequently, wild fish are used as supplementary broodstock in WDF and WDW hatcheries; and hatchery fish are frequently outplanted into wild populations. This can result in homogeneity in genetic character of the two groups.

Net-pen fish differ from "normal" hatchery fish in that natural selection in the ocean is replaced by artificial selection in the hatchery. This allows aquaculturists to genetically manipulate the stock more extensively. However, net-pen fish do not necessarily have to be very different from wild fish. Efforts can be made to infuse wild genes into the hatchery population if desired.

The degree of interbreeding between net-pen fugitives and wild fish depends on the proportion of the two populations within a stream and the spawning times of the two groups. For the net-pen and wild populations to interbreed, the spawn timing of the two groups must overlap. The greater the overlap, the greater the potential for interbreeding. If the two groups are widely divergent in spawn timing, no interbreeding can occur. Four factors affecting the number of net-pen fugitives entering any particular stream are: (1) the number of fish escaping; (2) the marine mortality rate (determining the number surviving to adulthood); (3) the success of homing these fish to the net-pen site; and (4) the proximity of the net pen to the stream of interest.

Homing ability in salmonids is influenced primarily by imprinting on the water odor components at the release site (Hasler et al. 1978). Imprinting ability is greatest during the smolting period when juveniles are typically transferred from freshwater hatcheries to net-pen sites. However, the homing/imprinting process in salmonids has a genetic factor (Bams 1976). This factor may either be diminished or inappropriate for successful homing in net-pen fish transplanted from distant locations. Such fish, fugitive from net pen farms, would be expected to stray more widely and thus disperse to a greater degree than strays from locally derived stocks (Quinn 1982). It should be pointed out that wild fish stray to some degree naturally. Quinn (1982) has proposed that straying is a evolutionary alternative to homing and that the two processes are in dynamic equilibrium.

If interbreeding does occur between net-pen fish and wild fish, any detrimental genes net-pen fish contribute to the wild population would tend to disappear over time. The mechanism causing detrimental genes to disappear is differential survival. Fish carrying detrimental genes will suffer higher mortality because they are less competitive. From the time of escape on, the potential for survival of fish bred for performance in net pens would be reduced compared to regular hatchery and wild fish. Such net-pen fish would be accustomed to regular feeding of pelleted food in a predator-free environment. The degree of competitive disadvantage of these fish is not presently known however.

Hatchery trout have demonstrated lower survival than wild trout in the natural environment (Chilcote et al. 1985; Reisenbichler and McIntyre 1977). In these experiments, hatchery/hatchery crosses survived best under hatchery conditions while wild/wild crosses survived best in natural streams (Reisenbichler and McIntyre 1977). Impacts to wild populations would then be temporary coming in the form of wasted reproductive effort (less fit genotypes would be lost due to natural selective pressures).

This discussion considers potential impacts of escaped fish interbreeding with wild stocks on purely theoretical grounds. Impacts associated with interbreeding between wild stock and net-pen fish is undocumented. Since potential impacts can only occur with returning, mature, escaped fish (and major escapements are rare), the numbers of fish involved are expected to be small. To put this in perspective, the present hatchery system (state, federal and Tribal) releases about 100 million chinook and coho smolts per year into Puget Sound waters (WDF 1988). If one percent of the returning adults stray from hatchery release sites (Quinn 1988), then one million smolts fit into this category. About eight million chinook and coho smolts are intentionally released from net pens in Puget

Sound by WDF and Tribal facilities (WDF 1988). Therefore, a total of about nine million cultured smolts are released into Puget Sound annually that would produce adults available to interbreed with wild stocks. Because it is highly unlikely that escapement from net-pen farms would approach this number, it would not produce a different or a greater effect.

Considerable interbreeding has already occurred between wild stocks in Puget Sound and stocks of different origin. Transplantation of stocks between river systems has been a common practice for nearly 90 years in Washington. In addition, straying rates for transplanted fish are greater than wild or established hatchery populations (Bams 1976). As a result, few if any wild populations of coho, chinook, or steelhead in Puget Sound have escaped at least some interbreeding with fish of different genetic character.

Because Atlantic salmon will not successfully hybridize with Pacific salmon or steelhead, the potential for genetic impacts of escaped Atlantic salmon from net pens to Pacific salmon and steelhead is slight to non-existent. Assessing the potential impact of farmed Pacific salmon or steelhead on wild populations is difficult given the speculative nature of the issue. Local experts agree that significant genetic impacts of wild populations due to widespread net-pen farming in Puget Sound is unlikely (Seidel 1988; Mahnken 1988; Herschberger 1988). The most likely scenario for an impact would be where large numbers of genetically different escapees ascended a stream with a relatively small wild population. The impacts to the wild population, if any, would be reduced fitness of the interbred progeny. Without constant infusion by escaped fish, these maladaptive genes would disappear gradually due to selective pressure, making any impacts temporary. Compared with the large numbers of hatchery releases, the genetic impact of escaped farmed fish on wild stocks would be negligible.

Impacts to Native Fish Populations. While the introduction of new or exotic fish species into habitats far removed from their native ranges has provided man with many benefits, each introduction poses a risk to the indigenous aquatic organisms of the new environment. Fish and shellfish have been and continue to be introduced into new areas to provide increase sport and commercial fishing opportunities; to replace native stocks which have been decimated by disease, environmental changes, and over harvest; for pest control; and for commercial culture. Examples in Washington include the introduction of Atlantic trout and salmon species into freshwater lakes and streams for sport fishing, mosquito fish (*Gambusia*) for insect control in eastern Washington, grass carp to control aquatic plants in small lakes, Pacific (Japanese) oysters which are the basis of the state's oyster industry, etc. Accidental introductions have also been common, for example a variety of invertebrates have been introduced around the world as fouling organisms attached to the hulls of ships or released with the discharge of ballast water.

The introduction of an exotic species into a new area always poses unavoidable risks. These risks can be minimized; however, all introductions involve a level of unpredictability and environmental risks cannot be completely eliminated.

Perhaps the greatest movement of fish species in history is occurring due to the development of salmon net pen culture. Pacific salmon from Washington state are being

farmed in eastern Canada, Chile, New Zealand, and Japan. Atlantic salmon, which are the basis for this industry, are now grown in the northeast Pacific.

The potential for impacts from introducing Atlantic salmon to Puget Sound depend on two variables: (1) that significant numbers of fish escape from the net-pen facilities, and (2) the ability of fugitive fish to out compete resident stocks of salmon and steelhead. The numbers of salmon escaping from existing net pens in Puget Sound is unknown. However, several hundred fish were captured in the commercial fisheries in 1988. There is a strong economic incentive to prevent this escape given that smolts are worth around \$3 each and a harvestable fish may be worth over \$60 to the grower. Technology in net-pen engineering is developed to the point where catastrophic structural failure is rare. There are, however, uncontrollable events, such as ships straying from shipping lanes or perhaps a 1000-year storm event, which may break up net pens. However, net-pen facilities are normally placed well out of shipping lanes and in relatively calm waters. The major source of escapement appears to be from "leakage" where a few fish at a time escape through small holes in the nets or during handling and transfer. The most critical stage may be as smolts when there is a wide range in fish size when they are introduced into the pens. If the mesh size of the net is too large, or if it is an old net with small holes, some of these small fish may pass through.

An ecological threat to Pacific salmon and trout is theoretically possible should Atlantic salmon establish a wild run in Washington waters. Atlantic salmon are reared commercially at 13 seawater sites in the Puget Sound vicinity (DNR 1987). Additional freshwater hatcheries produce smolts used to stock these net-pen operations. All culture operations have the potential to make inadvertent releases. Theoretically these releases could establish a wild population of Atlantic salmon in Washington.

In the past, the Washington State Departments of Fisheries (WDF) and Wildlife (WDW) have released Atlantic salmon into Washington waters with the intention of establishing permanent runs. They released Atlantic salmon smolts into two Puget Sound tributaries: Chambers Creek in 1950 and Minter Creek in 1980 (Lindbergh 1984). In addition, over the past 12 yrs. there have been over 3000 incidences of escapement from the National Marine Fisheries Service (NMFS) net-pen facilities at Clam Bay in Puget Sound. The escaped fish were sea-conditioned Atlantic salmon weighing between 1/2 lb. and 13 lb. (Waknitz 1988, personal communication). In 1988, commercial salmon boats reported picking up Atlantic salmon in their nets while fishing in northern Puget Sound and a few fish were reported caught by Canadian trollers of the west coast of Vancouver Island. All these fish ranged in size from 4 to 12 lbs. and indicate that Atlantic salmon are indeed escaping from netpens and surviving in the wild. Occasional Atlantic salmon have also been observed in the Nooksak, Skagit, and Nisqually Rivers and are being monitored by the Departments of Fisheries and Wildlife, and by tribal fisheries biologists. Lindbergh (1984) estimates that government agencies have released about five million Atlantic salmon in British Columbia, Washington, Oregon, and California waters. Despite these propagation efforts, intentional and accidental releases of Atlantic salmon into Puget Sound and other northeastern Pacific waters have all been unsuccessful in establishing self-sustaining runs. Similar introductions to establish wild populations have also been attempted in 36 countries around the world. The only successful introductions

have been in the Faeroe Islands near Iceland, which is in the natural range of Atlantic salmon, and in southern Argentina] (Lindbergh 1984; MacCrummon and Got 1979).

There have been scattered, qualified successes in maintaining Atlantic salmon populations in fresh water (Lindbergh 1984; MacCrummon and Got 1979). Attempts to establish Atlantic salmon in lakes have been moderately successful in Washington and Oregon. However, Atlantic salmon have only become established in lakes when planted as the only salmonid species in the system or in combination with brook trout (Salvelinus fontinalis). Atlantic salmon are apparently unable to compete with rainbow trout (Salmo gairdneri [now Oncorhynchus mykiss]) effectively. Lindbergh (1984) interviewed a number of researchers with WDF, NMFS, and the Oregon Department of Fish and Wildlife involved with the lake planting programs in Oregon and Washington. The consensus was that rainbow trout clearly dominate the Atlantic salmon and that Atlantic salmon would be displaced by native trout if not for continual restocking by the various natural resource agencies.

(3) Mitigation Measures

While the current culture of Atlantic and Pacific salmon appears to have little potential to significantly affect the genetic viability of native stocks, or to successfully compete with these stocks, future introductions of new species may pose potential threats. To minimize or prevent such threats, several measures can be taken:

- Review each application for the transfer or import of fish for culture and deny applications that pose a probable risk of adversely affecting native fish stocks or other aquatic organisms.
- Where indigenous species are cultured, use stocks approved by WDF which would have greatest similarity to local stocks near culture area or which would have least chance of interbreeding (for example, fish which do not spawn at the same time as the local stocks).
- Establish operational requirements for net pens, such as mesh size of smolt pens, to minimize risk of escape.
- Encourage commercial, sport, and tribal fisheries to harvest escaped fish, and/or permit farm operator to conduct a targeted fishery for escaped fish in the immediate vicinity of his pens.
- Where necessary, establish minimum distances net pens should be sited away from streams with wild populations vulnerable to genetic degradation.
- Where significant risk of interbreeding or establishment of deleterious self-sustaining populations exist, only permit the culture of sterile or mono-sexual individuals.

(4) Unavoidable Adverse Impacts

Some escapement of farmed fish is inevitable despite all practical efforts to contain them. While current culture activities do not appear to pose a significant risk to native species, future proposals may. It is impossible to predict what species may be proposed for future culture and decisions about these must be made on a case-by-case basis at that time.

c. DISEASE

Concerns about disease in the aquaculture industry involve the potential for introducing exotic harmful pathogens in eggs imported from other geographic areas, transfer of diseases from farmed salmon to wild salmon, and transmitting diseases from farmed salmon to shellfish near the aquaculture facility.

The objective of the mitigation measures discussed in this section is to prevent any adverse impacts to aquatic organisms through the importation of harmful pathogens, and transfer of diseases from farmed fish to wild fish and shellfish near the net pens.

(1) Affected Environment

Infectious Fish and Shellfish Diseases. Net-pen rearing of salmon is well established in Norway and Scotland and practiced in Chile, New Zealand, Japan and other countries as well. Coho salmon (*Oncorhynchus kisutch*) farming was developed in the Puget Sound region beginning in the 1970s by the National Marine Fisheries Service, the University of Washington, and at the commercial site near Manchester, Washington. Subsequently, farming of this species expanded in other countries, surpassing that practiced now in Puget Sound. Atlantic salmon (*Salmo salar*) is the species now most commonly reared commercially in seawater net pens in Washington state. Past research on diseases of salmonids has emphasized conditions occurring during their freshwater phase of development. With the increase in seawater aquaculture, infectious diseases of salmon from net pens in Washington waters have recently been described in the literature (Harrell et al. 1976; Hoffman 1984; Harrell and Scott 1985; Harrell et al. 1986; Elston et al. 1986, 1987; Kent and Elston 1987a; Kent et al. 1988a,b). The major issues are discussed in the sections immediately following this paragraph. See Appendix D for a discussion of the specific infectious diseases of salmon in the Pacific Northwest.

Introduction of Exotic Pathogens. Some fish diseases are restricted in their geographic distribution since the affected fish are limited to living in certain areas. Thus, a risk of introducing exotic fish pathogens (that is, those which do not exist in an area receiving imported fish) exists when fish are transported to a new location. Occurrences of exotic fish pathogenic parasites (Becker and Brunson 1968; Hoffman 1970; Bauer and Hoffman 1976; Hoffman and Schubert 1984; Johnsen and Jensen 1988), bacteria (Whittington et al. 1987) and viruses (Sano et al. 1977) in new locations have been attributed to the transfer of fish. However, the actual geographic and host distribution of many fish diseases is not known. Following more in-depth studies, some pathogens considered

"new introductions" have been found to have been established for many years but previously unidentified (Hedrick et al. 1985).

The study of diseases of net-pen reared fish has led to the discovery of previously undescribed diseases. Research on fish diseases has previously been directed towards those diseases occurring in freshwater because the major fish culture operations were freshwater hatcheries. Observations of new diseases in seawater net pens are indications that they occur naturally in wild salmon during their seawater phase of development, as a result of the intensive husbandry of the fish.

To prevent importation of exotic diseases, some states such as Alaska restrict aquaculture to indigenous stocks. A specific concern in North America are Atlantic salmon eggs imported from Europe and the potential risk of introducing viral hemorrhagic septicemia disease (VHSD). This viral disease may be transmitted vertically from the adult brood fish to eggs and fry. The virus can infect the egg while the egg is still in the mother and be passed to the offspring. Although the virus causes severe disease in salmonids in Europe, it has not been detected in North America.

Washington state importation laws (WAC 220-77), administered by the Washington Department of Fisheries, and federal statutes protecting fish (Title 50 of the U.S. Code of Federal Regulations, part 16.13), administered by the U. S. Fish and Wildlife Service (U.S. Department of the Interior) require certification that all salmon eggs not contain this virus or other significant fish pathogens before fish can be cultured in state waters. Such certification includes source site inspections, quality control specifications, inspection of arriving shipments, quarantine, and reporting requirements regarding the health of the received eggs by the importer. Thus, introduction of fish or eggs into Washington is limited under existing federal and state regulations. No salmon eggs or fish from Japan are allowed in Washington state. These federal and state regulations have been successful to date in preventing the introduction of exotic fish diseases such as VHSD.

Transmission of Disease to Wild Fish. Wild animals act as reservoirs for several diseases of domestic animals. The most dramatic example is probably in Africa where one-third of that continent is unsuitable for rearing domestic livestock because of the reservoir of Trypanosoma parasites in wild game (Murray and Trail 1986). Conversely, there are a few examples of transmission of disease from domestic mammals to wild mammals. An example of this phenomenon is also in Africa, where the viral disease "Rinderpest" is transmitted from domestic cattle to wild hoofed animals.

In the aquatic environment, wild fish can act as reservoirs for serious diseases of cultured fish. These include bacterial kidney disease (Evelyn 1988) and infectious hematopoietic necrosis (IHN) virus. IHN infects returning sockeye salmon in all major production populations in Washington (Amend and Wood 1972). Examples of this phenomenon also exist in net pens. Wild salmon and non-salmonid fish can be reservoirs for ectoparasitic sea lice (Copepoda) of pen-reared salmon; and cod are apparently the reservoir of Parvicapsula (Protozoa: myxosporea), which causes kidney disease in pen-reared coho salmon (Johnstone 1984). A significant risk exists for transfer of pathogens from captive to wild fish if the captive fish are infected by exotic

pathogens. Thus, the state and federal regulations now in place are essential for the protection of state resources.

There are, however, examples of diseases that have apparently been transmitted to wild fish from hatchery fish. The diseases were passed either following stocking of hatchery fish into natural waters, or to wild fish downstream from a freshwater hatchery containing diseased fish when the diseased condition of the stocked fish was not determined or recognized. Parasites can also be transferred by movement of an exotic species into a non-indigenous area. In fresh water, infections of an external parasite, Gyrodactylus salaris, occurred in wild and farmed Atlantic salmon in certain Norwegian streams following introduction of salmon parr from infected public hatcheries in Sweden (Johnson and Jensen 1988). The parasite, Nitsztchia sturionis, was introduced to the Aral Sea with sturgeon larvae transported from the Caspian Sea, and the parasite decimated the native sturgeon following its introduction (Dogel and Lutta 1937; Dogel 1954).

In Washington state, trout in two lakes became infected with the bass tapeworm (Proteocephalus ambloplitis) following the introduction of largemouth bass (Becker and Brunson 1968). The role of the tapeworm in disease was not determined and Becker and Brunson (1968) reported that "whether infections influence the survival of young rainbow trout is conjectural in the absence of controlled experiments." Yoder (1972) observed the parasite, Myxobolus cerebralis, which causes whirling disease in wild brook and brown trout, downstream from a hatchery with infected rainbow trout. From this observation he concluded that the source of the infection was the hatchery.

Transfer of Disease to Shellfish. Although at least one author has speculated that shellfish can be reservoirs for fish pathogens such as viruses, no definitive research has been conducted on this point (Meyers 1984). Meyers (1984) speculated that bivalve molluscs could serve as reservoirs for fish viruses such as infectious hematopoietic necrosis virus (IHNV), which occurs in wild stocks of sockeye salmon and other salmonids. Meyers (1979) demonstrated that viruses pathogenic for freshwater fish were isolated from oysters from Long Island Sound, New York. Although oysters are known to concentrate certain chemicals, there is no evidence this ability is a mechanism for disease transmission to wild fish and shellfish.

Many reports indicate that vibriosis is a significant disease of shellfish and fish in intensive husbandry (Elston 1984; Egidius 1987). Vibriosis can be an important problem in fish farming when proper husbandry and, in some cases, vaccination, is not performed. In bivalve mollusc hatcheries, vibriosis is considered a husbandry disease controlled by proper hygienic practices (Elston 1984). One report (Tubiash et al. 1973) cites "cardiac vibriosis" as a disease of adult American oysters, Crassostrea virginica. The disease, which occurred in about 0.04 percent of oysters in a sample from Chesapeake Bay, caused enlargement of the pericardium, but the oysters were otherwise normal. Although these authors suggested that the disease could be due to Vibrio anguillarum, a fish pathogen, they were not able to substantiate this claim with experimental research. Other reports (Brown 1981a,b and other authors; see Elston 1984 for review) indicate that V. anguillarum can cause disease in bivalve mollusc larvae in intensive shellfish

culture. In practice, this bacterium has not been important in mollusc husbandry in the Pacific Northwest. A relatively newly designated species, *V. tubiashii* (Hada et al. 1984), is recognized as a bivalve mollusc pathogen at certain locations in Europe and the east coast of North America. It should be noted that reports of vibriosis in mollusc larvae all refer to conditions and diseases in intensive hatchery culture of these animals. There is no evidence that vibriosis is important in limiting natural populations of bivalve mollusc larvae, but this has not been systematically investigated.

(2) Impacts of Diseases

Introduction of Exotic Pathogens. A primary concern with the growth of the net-pen industry in Washington is the possible increased risk of introduction of exotic diseases. This increased risk is minimal because regulations are in place to restrict importation of serious exotic pathogens of salmon. One such pathogen, viral hemorrhagic septicemia (VHS), develops during the salmon's freshwater phase. All eggs imported into Washington must be certified free of VHS. Fry from these eggs are then maintained in quarantine for 90 days and, at the discretion of the WDF, any exhibiting abnormal mortality are subject to further examination. If no exotic pathogens appear during this quarantine period, the fry may be released from quarantine for eventual stocking into net pens.

Vibrio salmonicida is apparently the only known and exclusively marine pathogen of salmon exotic to the Pacific Northwest. This disease is contracted in seawater and only fish in their freshwater phase of development or eggs held in freshwater are transported into Washington. The risk of introduction of this bacterium, therefore, is minimal. A parasite occurring in Europe, *Gyrodactylus salaris*, has not been observed in the Pacific Northwest and salmon from Europe must be free of this parasite before importation. Eggs imported from Europe are disinfected as part of the requirements of the Washington Department of Fisheries. Thus, the risk of importation of this parasite is minimal. Other species of *Gyrodactylus* occurring naturally in the Pacific Northwest are associated with fishes, but are not considered a serious problem in salmon culture.

Fish eggs are currently being imported into Washington on a limited basis for existing freshwater aquaculture industries, with each case reviewed by the appropriate state agency. Live salmonids cannot be imported. State regulations (WAC 220-77) to control importation of exotic fish pathogens are administered by the Washington Department of Fisheries. In addition, salmonid eggs imported from foreign sources must be individually permitted and inspected by an agent of the U.S. Fish and Wildlife Service under Title 50 of the U.S. Code of Federal Regulations.

The level of fish farming in Puget Sound will not directly affect the implementation of the regulations designed to prevent the introduction of exotic fish pathogens. Additional staff time may be required from the Washington Department of Fisheries and the U.S. Fish and Wildlife Service if increased requests for importations are made. However, a higher level of Puget Sound net-pen production has already increased the financial incentive to maintain regional broodstock and egg production. This should reduce the number of salmon egg importations and the associated risk of disease introductions.

Transmission of Disease To Wild Fish. Review of the technical literature indicates the risk of transmission of disease from net pens to wild fish is possible but not likely a significant problem. Fish disease control regulations, cited above, are in place in Washington to prevent the importation of exotic infectious diseases. It is such diseases which could pose a significant risk to native fish. In addition, experience with other domesticated animals indicates that husbanded stocks of animals are usually at greater risk from the transmission of infectious diseases than wild stocks. Diseases observed in net-pen culture of salmonids in Washington are husbandry diseases resulting from holding the fish in captivity. Such diseases are non-exotic; infectious agents that cause such diseases originate from environmental sources or wild fish.

Cultured salmon and trout have been and will continue to be released throughout Washington by state and federal hatcheries. Though the risk is minimal, the possibility of transmission of pathogens from released hatchery-reared fish to wild fish exists today. This risk may, in fact, be greater from the large numbers of hatchery fish released into state waters, than from the relatively small numbers of captive fish in net pens.

Transmission of Disease To Shellfish. There is no impact related to infectious diseases on invertebrate populations that can be reasonably predicted as a result of salmon net pen farming practices. Fish pathogens are largely distinct from invertebrate pathogens. Although some technical reports cite *V. anguillarum*, a known fish pathogen, as a mollusc pathogen, the examples cited in these reports are exceptional cases from industrialized locations in Europe and the east coast of North America. They refer to cases occurring in intensive husbandry of bivalve larvae. Important mollusc pathogens such as *V. tubiashi* are distinct from fish pathogenic vibrios.

(3) Mitigation Measures

The risk of introducing exotic salmon pathogens could be reduced further by the following measures:

- Legal measures could be implemented to eliminate imported salmon eggs from other continents. However, the current system of certifying salmon eggs has been effective in preventing the introduction of exotic diseases such as viral hemorrhagic septicemia.
- Development of enough regional brood stock to support the salmon net pen industry. This would eliminate the risk of importing exotic salmon diseases with infected eggs. Thus, while the current regulatory policies allow some controlled risk, any trend in the industry to develop a local brood stock would further reduce that risk.
- Future introductions of fish to Washington waters could continue to be made from disease-free stocks by using the regulatory framework now in place.

- One of the most important mitigation measures would be educational efforts by regulatory agencies for the fish farming industry. Voluntary compliance with fish disease control regulations is the most effective insurance that regulations will be followed. Educational efforts will increase the level of awareness in the industry of the potentially damaging effects of infectious fish diseases.
- Technical certification procedures could be periodically revised as appropriate to incorporate new technology.
- A requirement for the reporting of fish disease outbreaks could contribute to the control of diseases. The diseases subject to reporting could be determined by representatives from government, academia, private institutions, and the fish farming industry.

(4) Unavoidable Adverse Impacts

Adverse impacts can be mitigated through the measures identified above and through the fish disease control regulations now in place.

4. MARINE MAMMALS AND BIRDS

There are two issues of concern regarding the relationship between wildlife and salmon net-pen facilities. First is the effect of animal predation on captive fish, and the counteracting effect of anti-predator measures on animal populations. Second is the impact of net pens sited near sensitive wildlife habitats.

The objective of the mitigation measures identified below is to prevent adverse impacts to marine mammals, birds, and other wildlife, especially those classified as threatened or endangered.

The following information and analysis is based on communications with people experienced in net-pen culture and resource managers familiar with marine bird and mammal habitats.

a. Affected Environment

Animal Depredation. The presence of captive fish and a floating habitat usually attracts predatory birds and marine mammals to net-pen facilities. Herons may land on walkways and attempt to capture small fish through the netting. Larger predators, such as harbor seals, California sea lions, and river otter, may attempt to get larger fish through the underwater netting. Attempts by these animals to capture penned fish can damage nets, and if the predators are successful, kill or injure fish. To protect their investments, net-pen operators have developed methods to discourage or prevent depredation by birds and marine mammals.

The severity of the problem to the fish farmer depends to some extent on the location of the site, and on the species that inhabit the area. Marine mammals are generally regarded as more damaging than birds.

The Recommended Interim Guidelines suggest that net-pen operators locate their pens at least 1500 feet (458 m) from bird and mammal habitats of special significance such as haulout areas (See Figure 12) to reduce potential conflicts.

The interim guidelines also recommend using non-lethal techniques to protect net-pen fish from predators. Predator control methods must follow federal and state rules, and net-pen operators must possess all necessary permits.

Predators have been successfully controlled in Washington waters with anti-predator nets. There are only isolated instances where intentional killing has occurred. Killing is usually the result of inadequate protection by harassment techniques or anti-predator nets (Forster 1988; Lindbergh 1988). Most available information shows that early preventative actions can reduce predator problems. Once predators establish use patterns around a facility, the problem is difficult to correct (Jefferies 1988; Scordino 1988).

Marine Mammals. Marine mammals live along much of the shoreline and in most of the open waters of Puget Sound. Four species are of concern to salmon net pen operations in Washington. These are the harbor seal, California sea lion, northern sea lion, and river otter.

Seals and sea lions rest or haul out on shorelines and floating objects such as log rafts. Both harbor seals and northern sea lions reside in Washington year round, with harbor seals being the most widely distributed of the two. California sea lions occur in Washington waters during the winter months (October through May) and use haulout sites in southern Puget Sound (near Fox Island), northern Puget Sound (Port Gardner), and in the northern San Juan Islands (Sucia Island) (EPA 1987).

California sea lions do not appear to use potential haulout sites in central Puget Sound. However, during the last several winters they have been consuming steelhead and salmon entering Lake Washington at the Ship Canal, and in the Duwamish River. Sea lions are also commonly observed in southern Puget Sound.

In 1972 Congress enacted the Marine Mammal Protection Act which prohibits the killing or harassment of any marine mammal, except in situations where life or property are in imminent danger due to the mammals (for example, commercial fishers may kill seals to protect their nets). Any lethal control may only be taken with permission of the National Marine Fisheries Service. Since implementation of the Marine Mammal Protection Act, seal and sea lion populations in Puget Sound and other Washington bays have increased in size and range. The Department of Wildlife estimates that the harbor seal population in Puget Sound is increasing at the rate of 8 percent annually.

River otters are found primarily in quiet shoreline areas containing freshwater streams (EPA 1987). Otters can be found in appropriate habitats throughout southern Puget



Updated: Jeffries (WDW) 1988
 Source: Puget Sound Water Quality
 Authority 1986

Figure 12.
Seal and Sea Lion
Haulouts in Puget Sound

Sound, around Vashon Island, in Hood Canal, and on the Kitsap Peninsula. Other areas where they forage offshore and along the shoreline include the Strait of Juan de Fuca, Whidbey and Camano Islands, Padilla and Skagit Bays, and the San Juan Islands.

Predation. Predation by marine mammals occurs at some Washington net-pen facilities. Most workers characterize predation by marine mammals as a minor to moderate problem (Gibson 1988; Lindbergh 1988). At the NMFS facility near Manchester, Kitsap County, fish have escaped through nets damaged by California sea lions (Scordino 1988). Gibson (1989) speculates that marine mammal predation could be a significant problem at the SeaFarm Washington facility in Port Angeles Harbor if predator control methods were not used.

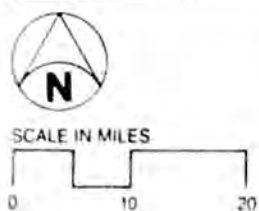
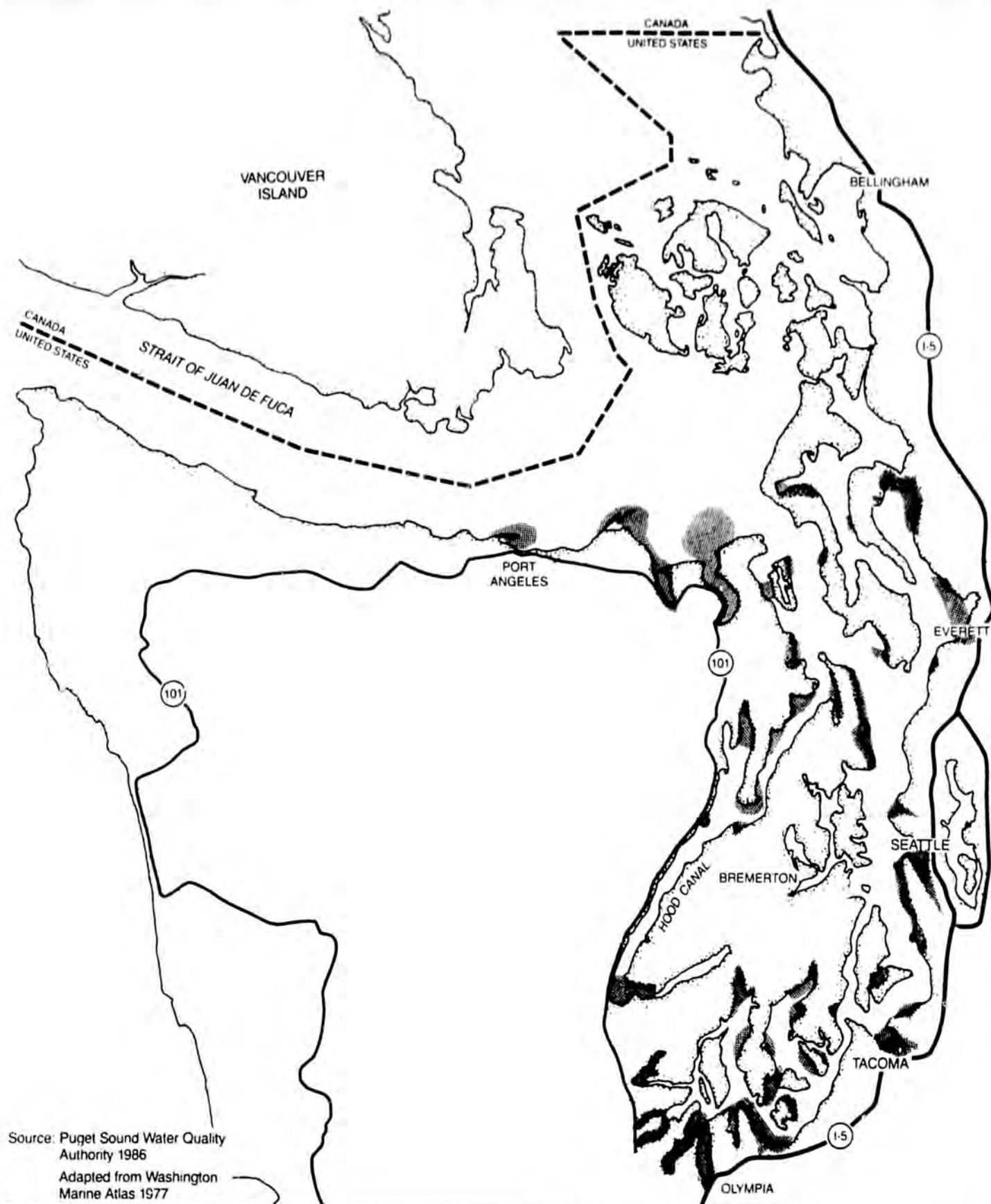
Harbor seals and sea lions may damage and kill fish by biting through the netting of the rearing pens. Occasionally the attacks damage the netting, which in addition to predation, may allow large numbers of valuable fish to escape. Observers often do not distinguish between California and northern sea lions, but biologists believe most sightings involve California sea lions (Jeffries 1988; Scordino 1988). Predation by marine mammals occurs throughout the year, but reports are most frequent during the winter, when California sea lions are present (Lindbergh 1988). Although river otters occasionally injure or kill fish without damaging the netting, they are the main predators on net-pen fish in some areas.

Birds. Puget Sound attracts both open-coast bird species and those common to protected marine habitats. See Figure 13 for a map of major waterfowl habitats in Puget Sound. Prevalent groups include grebes, alcids, shorebirds, gulls, cormorants, diving ducks, and birds of prey. Species that have been identified as predators on net pen fish include great blue herons, belted kingfishers, pigeon guillemots, cormorants, grebes, and mergansers.

Predation by birds is not a significant problem at most net-pen facilities due to the use of anti-predator nets, strings placed in parallel over the pens, and the normal level of human activity associated with net-pen operation. Birds are only a problem while small fish are available. Once net-pen fish have grown too large for birds to eat, there is little need for netting over the pens. Some net-pen farmers use dogs to chase birds off the pens.

Net pens may benefit some bird populations by providing food resources (such as algae, invertebrates, and herring, sticklebacks and other small fish attracted to the pens) and feeding and resting habitat. Observations by workers at the Domsea and NMFS net pen operations near Manchester suggest that bald eagles prey on waterfowl attracted to the net pens. No one has observed the eagles taking fish from the net pens (Mahnken 1988).

The U.S. Fish and Wildlife Service (USFWS) administers a permit system that allows selected killing and trapping of nuisance birds to protect aquaculture facilities (Juelson 1988). The Migratory Bird Treaty Act and various state statutes protect birds from unlawful killing or trapping.



 Waterfowl Area

Figure 13.
Major Waterfowl Habitats
in Puget Sound

Predator Control Methods. Surrounding the growing pens with protective nets is the primary predator control method at Washington net-pen facilities. These anti-predator nets prevent birds and marine mammals from reaching the interior pen below the water, or gaining access to the pen interior from walkways on the water surface. Anti-predator nets are typically attached to a walkway or outrigger approximately three feet from the inside net. The anti-predator net extends below the growing pen three to nine feet and loops back to the opposite side, enclosing the pen. Weights are attached to the predator net to keep it taut and reduce movement toward the fish-rearing pen.

Anti-predator nets generally provide effective control. With their use, marine mammal predation at Washington net-pen facilities is not a significant problem. Minor problems can occur when strong currents push the pen and anti-predator nets together, allowing seals or sea lions to reach the penned fish more easily than when the nets are not affected by the currents. In addition, marine mammals occasionally charge the net pens, driving the anti-predator and pen net together and biting through the nets.

Net-pen farmers also use other non-lethal methods to discourage predation by marine mammals. Acoustic harassment devices (AHDs) have been developed to create loud noises and scare animals away. These AHDs have been used extensively to attempt to control predation near the Ballard Locks in Seattle by sea lions which threaten the wild steelhead run. Experience in Puget Sound has shown that California sea lions initially respond to AHDs by leaving the area of the noise. However, the animals typically become accustomed to the disturbance and return because there is no negative stimulus to accompany the noise (Jeffries 1988).

A few net-pen farmers have also used AHDs. Marine mammals sometimes evade the noise by approaching the pens with their heads out of water, or approaching within the acoustic shadow formed by the pens (Boldt 1988). Resource agencies and net-pen managers report AHDs do not provide effective long-term control of marine mammals (Juelson 1988; Scordino 1988).

Chemical taste aversion using lithium chloride has also been tried in several experiments at the Ballard Locks and by a net-pen farmer, but has showed limited success in predator control (Forster 1988; Lindbergh 1988). No Washington net-pen facilities use lithium chloride for predator control (Gibson 1989).

The Marine Mammal Protection Act provides a permit system that allows harassment or selected killing of certain marine mammals that threaten aquaculture facilities. Non-lethal methods must be tried before lethal methods. The National Marine Fisheries Service (NMFS) has jurisdiction over marine mammal protection, with support from the Washington Department of Wildlife (WDW). NMFS has enforcement authority to fine or incarcerate offenders (Scordino 1988).

Sensitive Wildlife Species and Habitats. The USFWS, NMFS, and the WDW maintain data bases identifying sensitive wildlife species and habitats. Examples include bald eagle nesting and roosting sites, peregrine falcon nesting and wintering areas, marine bird nesting colonies, and marine mammal haulout areas.

Peregrine falcons and bald eagles are protected by the Endangered Species Act. Neither of these species is a threat to net-pen fish, but both may be affected by net pen siting decisions. USFWS has jurisdiction over federal permits for developments that may affect these birds. While USFWS has not issued permits for activities related to net pens in Washington, they do review Army Corps of Engineers permits and may attach conditions to the permit as necessary. When no federal permit is required for a development, WDW has protection responsibility for the bald eagle through its newly adopted Bald Eagle Protection Rules. The new rules require that individual site management plans be prepared for developments affecting eagle nest and roost sites on public and private lands. These management plans are based on local conditions and may include a zone of separation between development activity and eagle and roost sites.

b. Impacts on Wildlife

Construction and operation of floating net pens would alter habitats for birds and mammals. Some species can tolerate or benefit from the presence of a net-pen facility, while species sensitive to human activity are forced to seek habitat elsewhere. The significance of potential impacts to wildlife will be dependent upon site-specific considerations such as types and numbers of species in the area and proximity to sensitive habitat areas.

Net-pen operations may create disturbances through several types of activities. Noise and human activity would generally be low during operations and would not cause significant impacts on nearby wildlife populations. This assumes the facility is not located near habitats of special significance. Noise and activity would probably be greatest during construction of the facility.

The widespread use of lethal methods to control predators could have an adverse impact on marine mammal and bird populations. However, because non-lethal methods provide effective control, significant impacts on populations are not expected. Anti-predator nets have occasionally drowned marine mammals (Scordino 1988), but properly hung and maintained anti-predator nets should cause little harm to these creatures. Taste aversion and acoustic harassment appear to have no adverse impacts on marine mammal and bird populations.

c. Mitigation Measures

The following mitigation measures could be implemented to reduce the potential impacts of proposed net-pen facilities on wildlife:

- Identify all sensitive wildlife habitats and areas where animals congregate.
- Consult with appropriate resource agencies to determine potential predator problems and effective prevention techniques.

- In reviewing and approving projects, develop buffers separating net-pen facilities from habitats of special significance.
- During the siting process, develop site-specific distance standards separating net-pen proposals from habitats of special significance to account for local conditions.
- Install properly designed anti-predator nets before placing fish in the net pens, and keep the nets taut.
- Follow established federal and state guidelines and permitting procedures for controlling predators.

The proximity of feeding or breeding grounds, or other significant wildlife habitat, should be considered when siting a net-pen facility. Net pens should not be located near wildlife habitats of special significance. These include seal and sea lion haulout and resting areas, seabird nesting sites or colonies, and areas specifically identified as critical for feeding or migration of birds or mammals.

The Department of Ecology, with the Departments of Fisheries, Natural Resources and Agriculture, recommended interim guidelines to reduce potential conflicts between wildlife and net-pen facilities. These guidelines recommend that operators locate net pens at least 1500 feet (457 m) from bird and mammal habitats of special significance where the pens are incompatible with these habitats. Depending upon the characteristics of the site and the nature of the net-pen proposal, this separation may be increased or reduced as appropriate. Particularly sensitive features may require more than 1500 feet (457 m) as a buffer, while other features may require less.

Farmers could minimize problems with predatory animals by siting facilities away from areas where these animals congregate. During the proposal stage, operators should demonstrate they have consulted with appropriate resource agencies, determined the potential for predator problems, and evaluated preventive control measures.

All net-pen farmers should be encouraged to install anti-predator nets before beginning operation. The anti-predator net should be separated from the pen net by at least three feet (0.9 m), either by suspending it from the outside cage walkway or from an outrigger structure. The anti-predator net should extend 3 to 9 feet (0.9 to 2.7 m) below the bottom of the pen net, loop back up to create a bag-type structure and be weighted sufficiently to remain taut. The anti-predator net mesh size should be less than five inches (12.7 cm) to avoid accidental entrapment of animals. Perimeter fencing on the pens would prevent resting and haulout of seals and sea lions on the pens. A seven-inch (17.8 cm) stretch mesh net, or parallel strings over the top of the net pen would stop birds from entering from above.

d. Unavoidable Adverse Impacts

Properly sited and operated net pens will not have significant adverse impacts on marine mammals or birds. Some habitat loss may occur for some species, while other species may benefit. Specific impacts will depend on the pen site and the associated wildlife.

B. THE BUILT ENVIRONMENT

1. AESTHETICS

The issue of aesthetics (visual impact) involves how different people perceive the same structure, how structure design and location can be altered to reduce potential visual impacts, and what types of controls can be implemented to address cumulative impacts.

Net pens are commonly placed in open water where no man-made structures exist. The above-water portion of these pens alters views from adjacent vessels or boats moving through the area and may alter views from nearby land areas. Many people perceive any structure placed in open water as creating an adverse aesthetic impact.

The objective of the various possible mitigation measures discussed below is to minimize visual impacts that may reduce the aesthetic value of the area surrounding the net pen facility.

a. Affected Environment

Puget Sound and adjacent waters, where net pens would be located, provide views that are of interest to nearly all residents and visitors. These waters, which include the Strait of Juan de Fuca on the west, the Strait of Georgia on the north, Puget Sound on the south, and the waterways in between, form an intricate landscape of bays, channels, and islands. This inland embayment is the drowned portion of a broad hilly lowland flanked on the west by the Olympic Mountains and on the east by the Cascade Mountains. The Olympic Mountains rise above Hood Canal on the west side of Puget Sound and closely above the southern shore of the Strait of Juan de Fuca. The Cascade Mountains stand further back from the east shore of Puget Sound and the Strait of Georgia, except in the north where foothills extend to saltwater south of Bellingham. From most vantage points, these two ranges appear as rows of green-sloped mountains with craggy and snow-covered peaks forming a jagged skyline.

The nature of views from these shorelines and from the water vary considerably. Along the Straits of Juan de Fuca and Georgia, the opposite shoreline typically lies at a considerable distance from the observer so that views are dominated by the sky and a broad, flat expanse of water. Depending upon the weather and sun position, the water surface may appear monotonous and static on cloudy, calm days or dynamic and high-lighted on windy, sunny days.

In other locations, where the waterbody is not as broad, the shoreline and nearby land areas are more evident and form the dominant visual element. In these areas, the landscape appears more complex and intimate to the viewer. Tree-covered slopes, rocky headlands, or steep bluffs rise from the water in many areas and create a visually varied landscape.

Human activity affects views along the inland marine waters of western Washington. This activity varies from the intense and diverse activities associated with the metropolitan areas in central Puget Sound to the near absence of activity in sparsely inhabited areas. In no portion of these inland waters are views of human activity completely absent. Docks, boats, houses, or other signs of human presence are almost always within view of shoreline residents and visitors. In some areas of the Puget Sound region, overwater structures, such as log rafts, docks, boats, or marinas, dominate the marine view.

Despite the rather uniform views provided by the inland marine waters of western Washington, particular areas are aesthetically unusual or distinctive. An example of an aesthetically unusual location is Dungeness Spit. In its size and form, Dungeness Spit is a landform unique to the study area, and the view from the south across the spit and the Strait of Juan de Fuca beyond is therefore aesthetically unique.

Other locations may be aesthetically distinctive within the study area, but they are not unique because they share certain attributes with other portions of Puget Sound and adjacent waters. An example of such a distinctive area would be the west end of Fidalgo Island and the adjoining San Juan Island archipelago.

This PEIS does not attempt to identify unique or aesthetically distinctive views. These must be identified by shoreline regulators wherever any such views exist. This analysis discusses potential effects on these views from net pens and possible mitigation for impacts.

b. Impacts on Aesthetics

Aesthetic impacts are subjective and difficult to quantify. Attitudes and perceptions vary considerably, so that two observers often perceive their views to be differently impacted by the same facility. This section describes the features of salmon net pens that may affect views, how these features may be perceived, and how alternatives may affect views.

Background. Aesthetic impacts from floating net pens depend on several variables. These include: the location, size, and design of the facility, the number and location of observers and their attitudes about the facility, and the nature of the surroundings.

Net pens have floats and railings that typically extend about 1 m (39 inches) above the water. They also commonly include a small building extending about 3 m (10 ft) above the water (See Section I. B. Background and Figure 3).

Like many man-made objects, the form of net pens is dominated by straight lines and a regular pattern. These characteristics, together with the immobility of a net pen structure, contrast with the water surface and tend to draw the attention of observers.

Net-pen structures become less evident as the observer/facility distance increases. Typical net-pen facilities at distances greater than 450 - 600 m (1500 - 2000 ft) appear as a thin line on the horizon for observers at about the same elevation as the water surface (EDAW and CH2M Hill 1986). For two observers at the same distance from a net-pen facility, the facility would be more evident to the observer who is higher above the water surface. For two observers at the same height above the water surface, net pens would be more evident to the less distant observer (see Figures 14 and 15).

Structure color also affects visual distinctness. Brightly colored structures are generally more evident than somber-toned structures; and grays, blues, and greens are generally less evident than reds, yellows, or oranges. Structures composed of reflective materials are more evident to an observer than structures composed of materials with matte surfaces. Lights, particularly blinking or rotating ones, greatly increase the visual distinctness of a structure at night. The visual impact of structures varies with sun orientation, wave action, and cloud cover, factors that are not constant at any particular site.

Attitudes toward net pens vary significantly for different observers. Some observers consider a net-pen facility to be an aesthetic intrusion, while others consider the same facility to be a neutral or interesting part of the visual environment. Some observers find net-pen facilities interesting and attractive in a manner similar to a fish hatchery.

Observer attitudes will be affected by the overall visual environment near a net pen facility. Observers in an area with few human-made structures would probably perceive a net-pen facility as more visually intrusive than one in an area with many man-made structures. A net-pen facility in a complex landscape dominated by man-made objects, such as an urban area, may be visually unobtrusive.

Description of Impacts. The aesthetic impact of net pens depends on the distance between the observer and the pens, on the altitude of the observer, and on the surrounding views. In general, only viewers within about 2000 ft (600 m) are likely to see the net pens as anything more than a thin line on the horizon. Only viewers in the immediate vicinity of the net pens will have their scene substantially altered by the presence of the net pens.

The relationship between the location of the observer and the distance of the facility from shore affects visual impacts. In general, views from residences on the shoreline are primarily oriented toward the water. Figure 16 is a schematic representation of the impacts associated with the placement of a net pen relative to the shoreline. Situation A of Figure 16 places the net pen 300 feet from shore. While the facility will be visible for 4,434 ft (1351 m) along the shoreline, it will not be a major visual impact to the observer in the example. However, when the net pen is moved 1000 ft (305 m) from the shoreline as in situation B, it falls within the predominant viewscape of the observer.

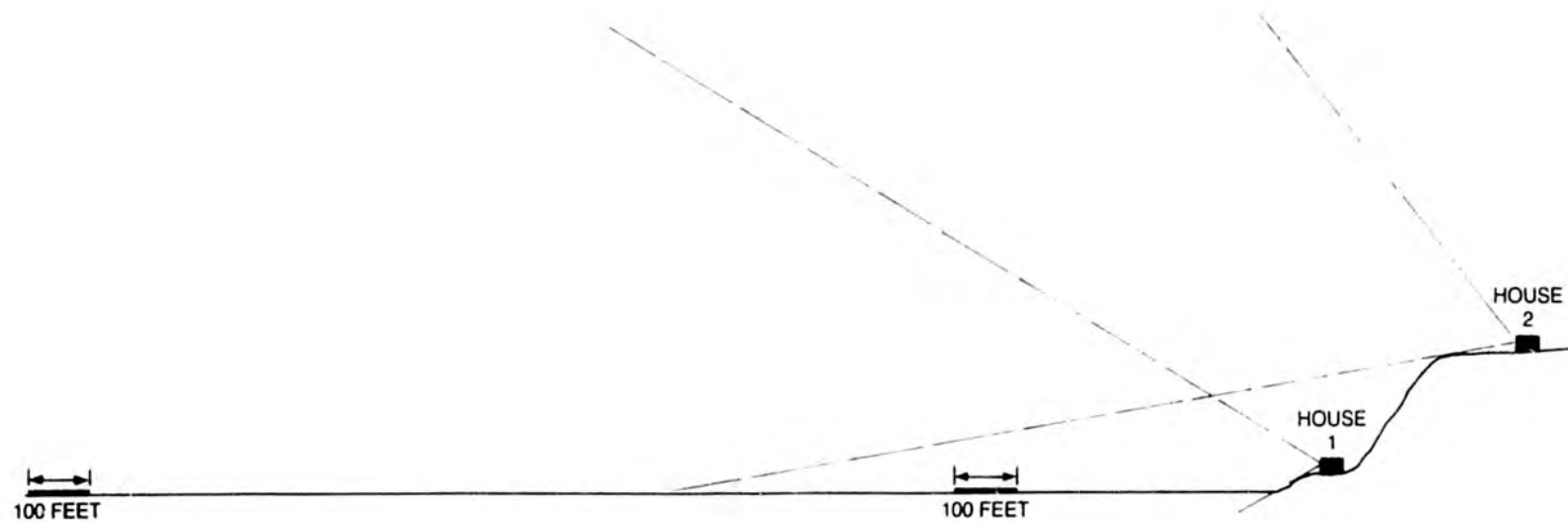
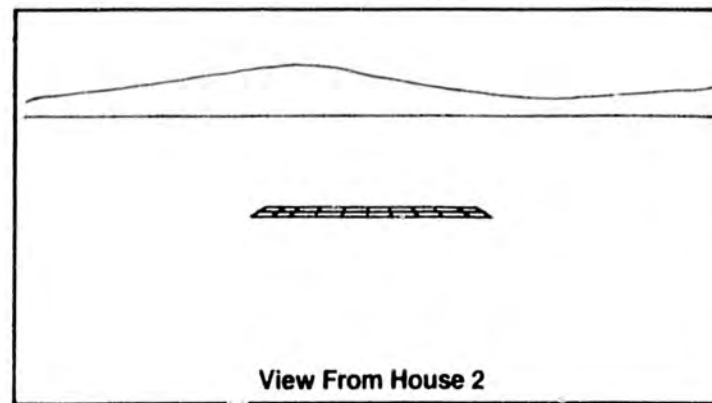
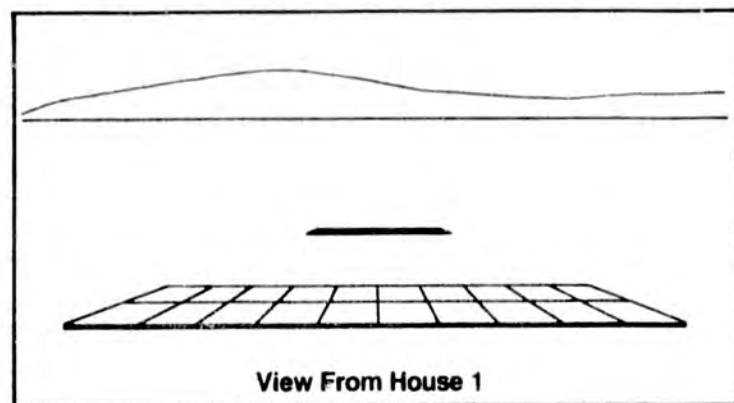
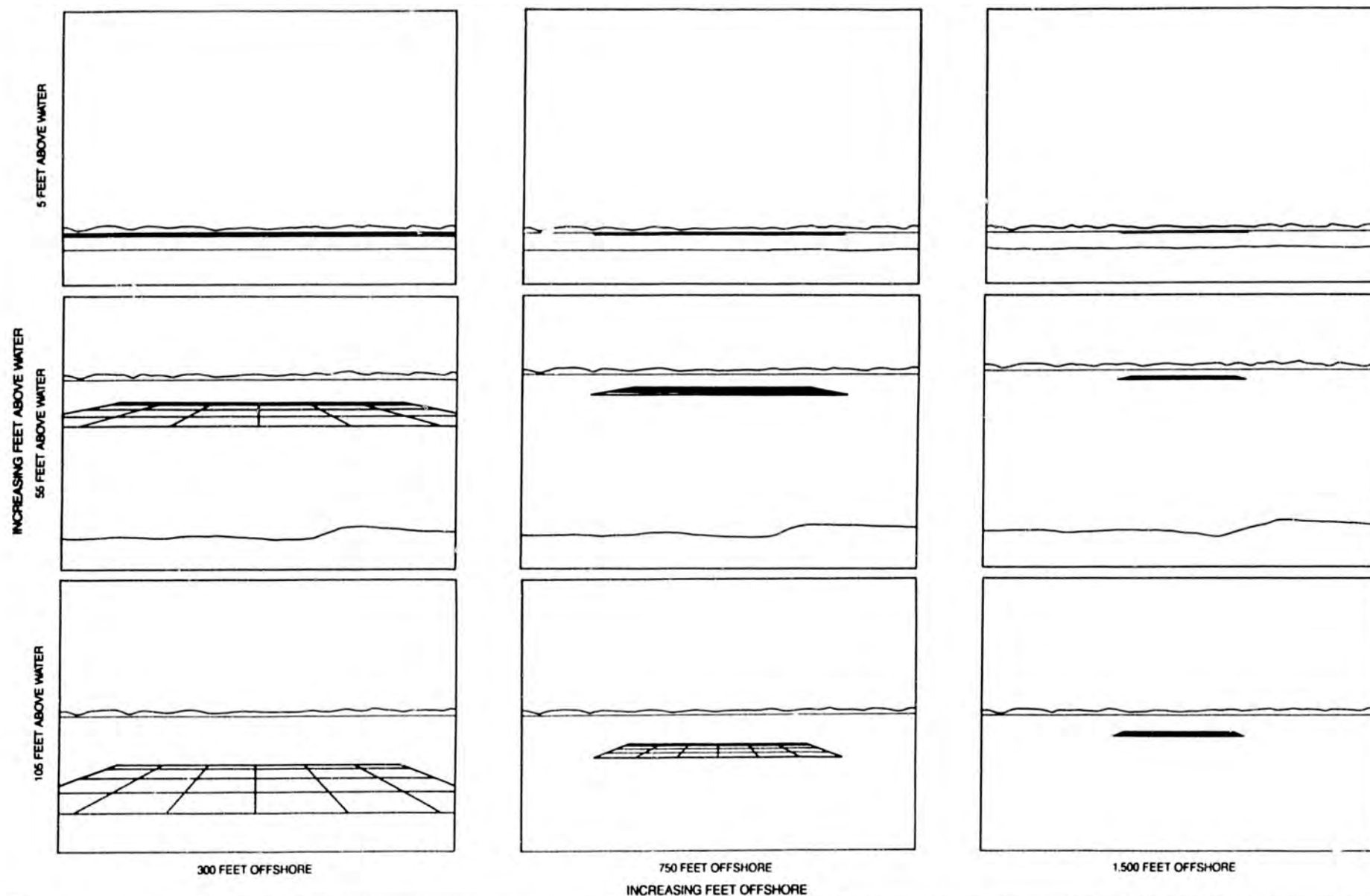


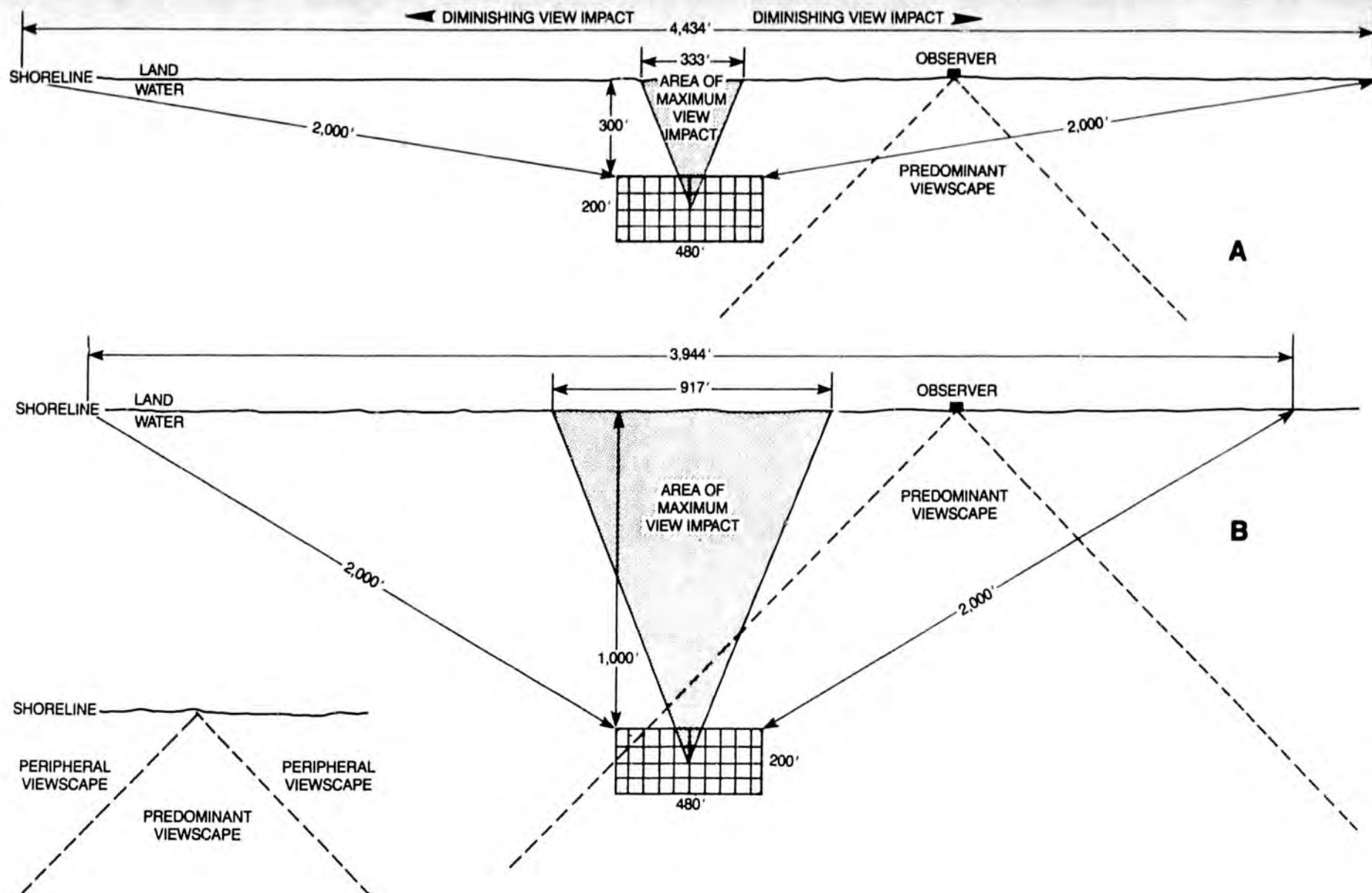
Figure 14.
Topography of the Shoreline
and Views of Net Pen Facilities



Source: EDAA, 1986

Note: 60° angle of view, facility covers 5 acres and consists of a 100 foot spaced grid

Figure 15.
Visual Effect of
Distance and Observer Position



Note: Refer to text for discussion of this figure.

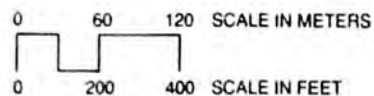


Figure 16.
Schematic Example of
View Impacts Related to
Distance and Orientation
of Net-Pens

Yet, now, the facility in situation B is visible from only 3,944 ft (1202 m) of the shoreline. This hypothetical example is included to indicate that placing a net pen as far from shore as possible is not always the most effective way to minimize aesthetic impacts. Because the orientation and location of views will vary from case to case, each net-pen proposal should be evaluated separately to determine the effect of distance and orientation on views.

Figure 17 illustrates the horizontal angle of view occupied by a net pen depending on its orientation and the position of the observer. There are a variety of pen configurations; however, a net-pen facility (200 feet by 480 feet [61 m by 146m]) at a distance of 300 feet (91 m) from shore is used as an example. For observers on the shore immediately in front of the net pen, an orientation with the long dimension parallel to the shore results in a substantially greater impact than an orientation with the long dimension perpendicular to shore. As an observer moves along the shore in either direction, the net-pen orientation with the long dimension perpendicular to shore begins to have the greater visual impact, although, at these distances, the visual impact in either case would probably not be substantial. Although the net pen would occupy a definite horizontal angle in the field of view of an observer at water level, at distances approaching or exceeding 2000 feet (610 m), the net pens would tend to merge with the water line and be nearly indiscernible to the observer.

Some residents and visitors will be aesthetically affected by the presence of net pens. Whether or not it substantially alters their view, these people will be impacted because they consider any structure and its operation, such as a net pen, an undesirable intrusion into what they perceive as an unaltered natural environment.

Placement of several net pens in proximity to each other can result in cumulative aesthetic impacts. A greater number of net pens would probably increase the number of observers whose views would be potentially impacted. For a particular observer, an increase in the number of net pens in an area may or may not result in greater potential impacts. Additional net pens placed at greater distances from an observer than existing net pens would probably not result in substantially greater visual impacts. The nearer, existing net-pen structure or structures would have the primary effect on views. Conversely, additional net pens placed closer than or at similar distances from an observer may substantially increase aesthetic impacts.

The overall cumulative impact resulting from five net-pen farms in an embayment, for example, would vary considerably depending on whether there were other man-made structures in the area and on observer attitudes. Placement of several net pens in an embayment that had few other man-made structures might be perceived by some observers as altering a natural environment to an urbanized environment. Other observers may not perceive any significant aesthetic change due to an increase in the number of net pens because either they do not perceive net pens as a visual intrusion. Or, they may perceive any net pen to be a visual intrusion.

Figure 18 illustrates a hypothetical placement of five net pens in a typical Puget Sound embayment using the upper end of Carr Inlet as an example. A 2000-foot (610 m)

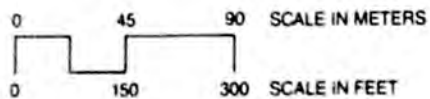
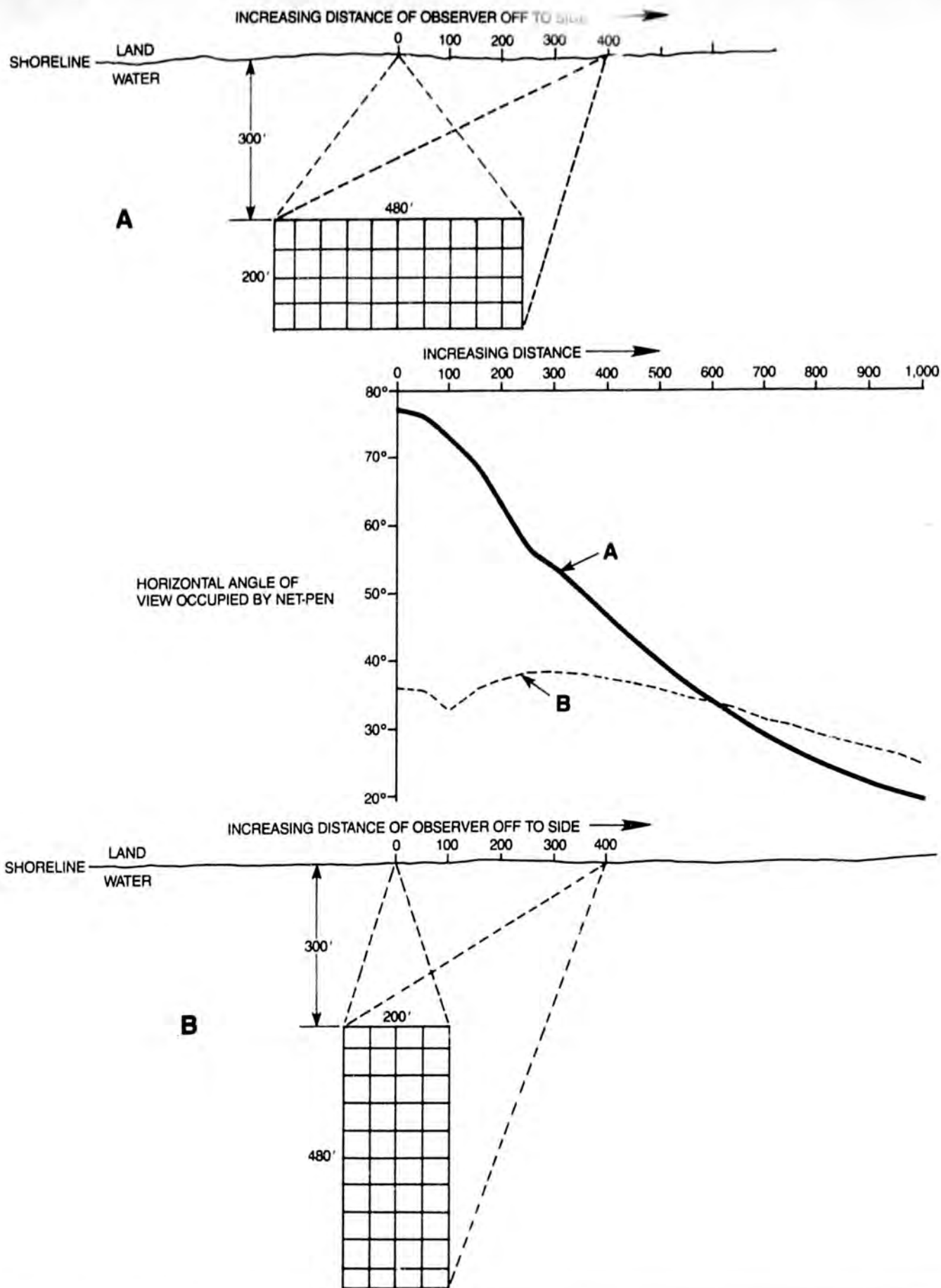
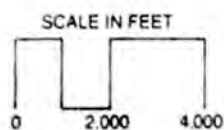
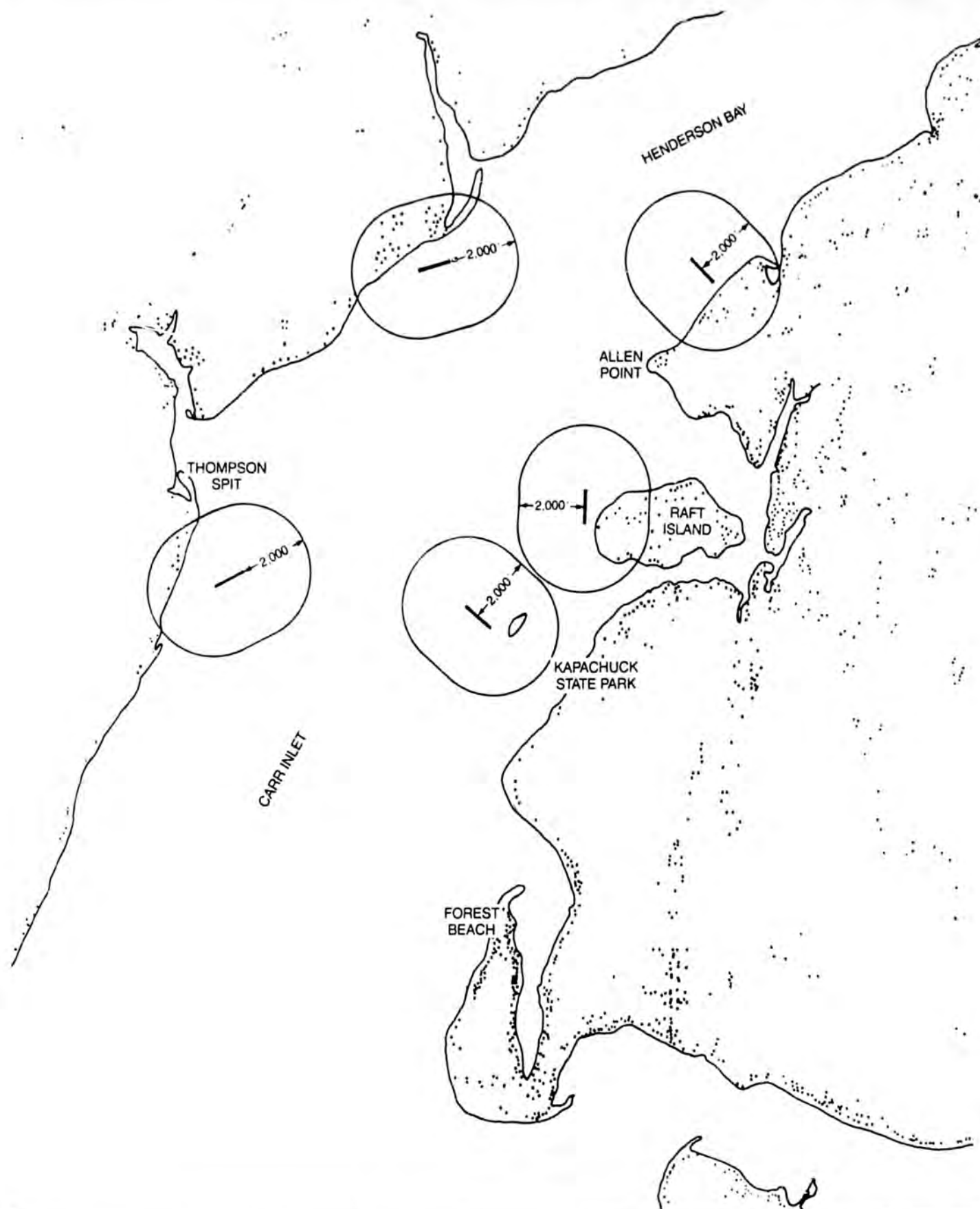


Figure 17.
Effect of Net-Pen
Orientation and Observer
Distance on Visual Impact



Households

Figure 18.
Hypothetical Layout of Five
Net-Pens in a Puget Sound
Embayment: Carr Inlet Sample

radius is drawn around each net pen to illustrate the probable maximum extent of visual impact. This figure illustrates that at a density of more than five net pens per embayment, the net pens could be spaced so that no shore observer is within 2,000 feet (610 m) of more than one net pen at any time. This indicates that with adequate spacing of pens, the cumulative impact of several net pens in an embayment could be minimal. In other situations where there are few aesthetically sensitive observers, it may be appropriate to more closely space pens to avoid placing net pens in areas having more observers.

The cumulative effect of multiple pens sited closely together would be another potential impact on aesthetics. Figures 19, 20, and 21 illustrate how net-pen density could be controlled through spacing of pens. Similar measures could be adopted into local shoreline master programs.

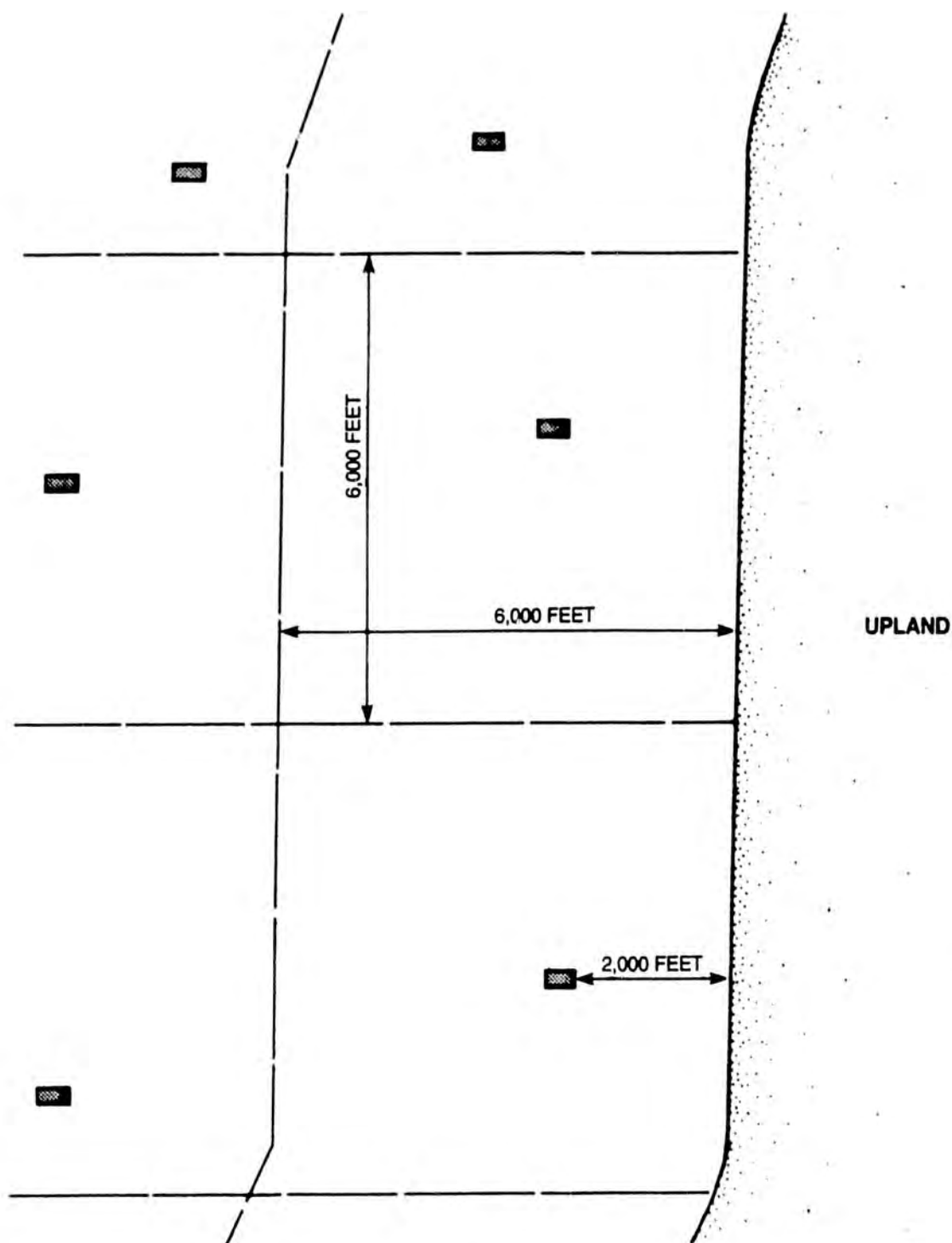
c. Mitigation Measures

Mitigation measures for aesthetic impacts can modify either the design or location of net-pen facilities.

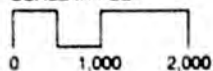
Design. The design of net-pen structures may serve to either increase their visibility or to visually submerge them in their surroundings. Increasing visibility, which could, for example, serve as an architectural statement, could be appropriate in some urbanized areas. In many areas, however, net-pen structures should be designed to be visually unobtrusive. The following items describe some design measures that serve to help visually submerge a net-pen structure.

- Structures should project the minimum distance above the water surface necessary for safe and efficient operation of the facility.
- Net-pen facilities could consist of small sets of pens grouped together instead of a large pen complex to avoid extensive visual elements.
- Materials used in net-pen structures should be non-reflective, somber-hued, and gray, green, or blue in color.
- Lighting provided on the structure should be the minimum necessary for safe operation and navigation and directed away from land areas, if possible.
- Equipment used in the net-pen operation and not a functional part of the net-pen structure should be stored on land.
- The number and size of buildings on the floats should be kept to a minimum.

Location. The distance between net pens and adjacent shorelines can mitigate the aesthetic impacts on views, but may increase conflicts with navigational use and

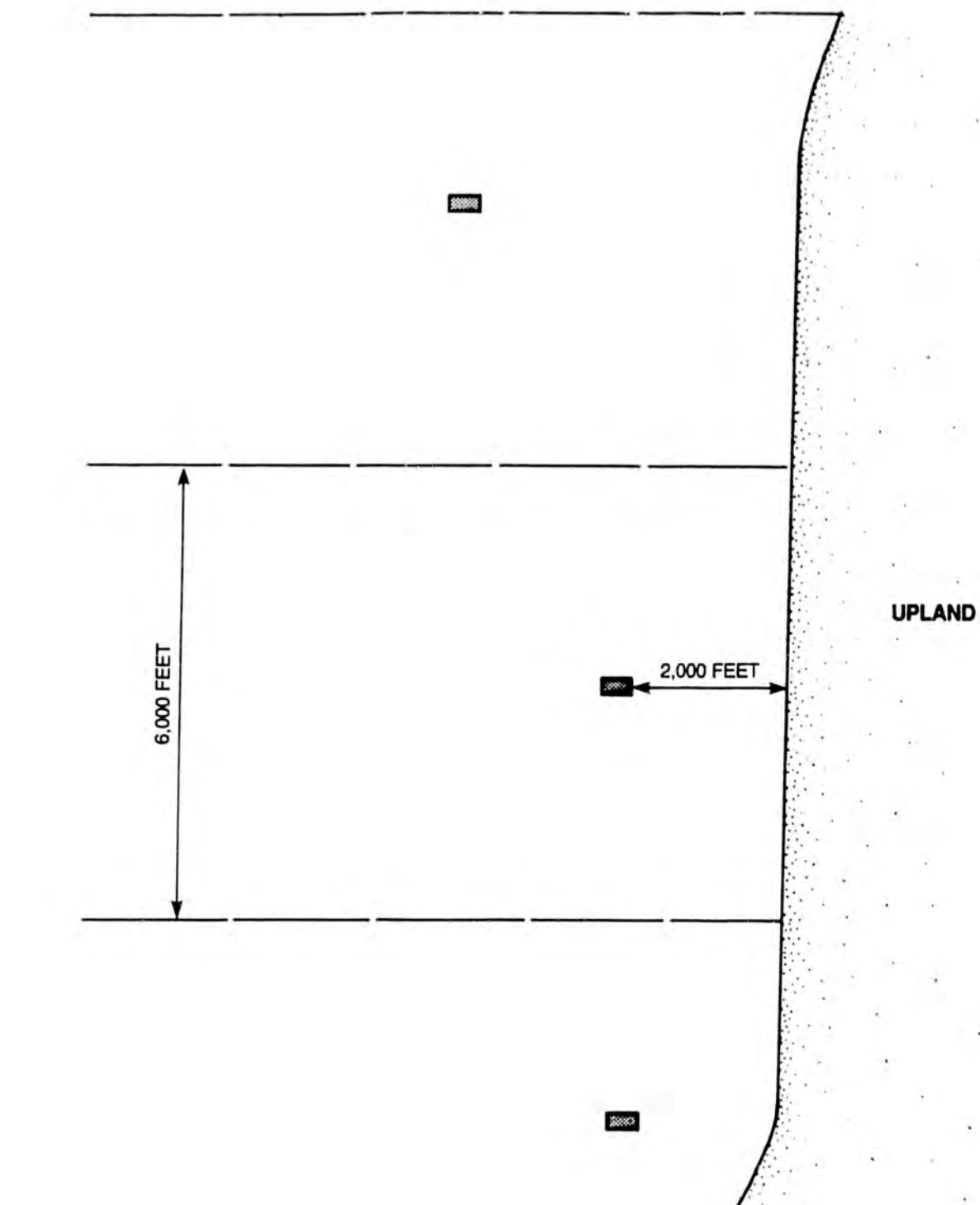


SCALE IN FEET



 Two Acres
of Net Pens

Figure 19.
Net-Pen Density Control,
Area by Square Footage

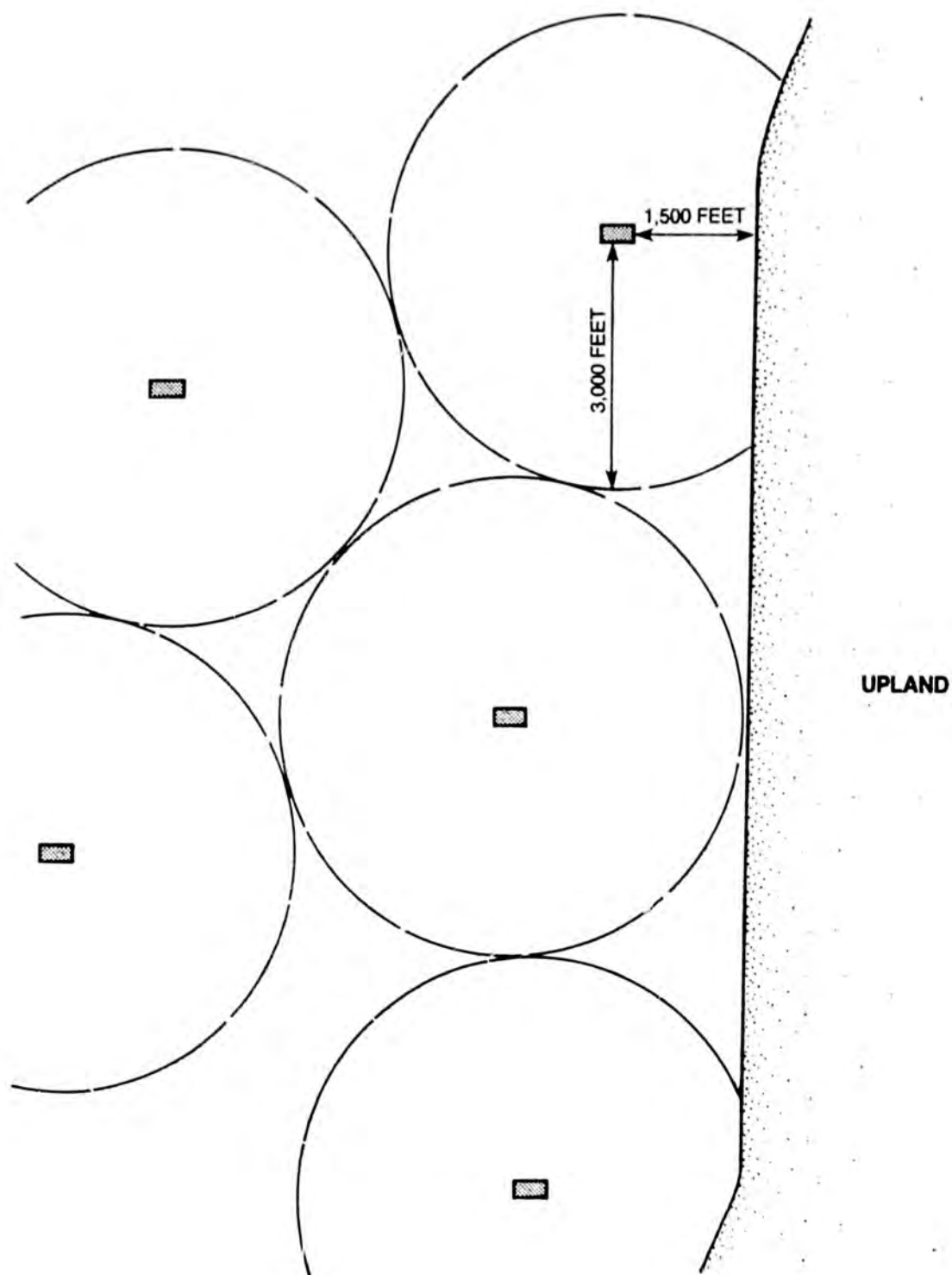


SCALE IN FEET

0 1,000 2,000

Two Acres
of Net Pens

Figure 20.
Net-Pen Density Control,
Area by Shoreline Footage



SCALE IN FEET
0 1,000 2,000

Two Acres
of Net Pens

Figure 21.
Net-Pen Density Control,
Area by Radius

commercial fishing. Where low-level shorelines are nearby, the net pens can be sited 600 m (2000 ft) or more away to minimize visual detection of the pens. In areas of high shoreline bluffs, the visual impacts may be minimized by placing the pens close to the shorelines where they can only be seen from the edge of the bluff.

Implementation. Mitigation described in the preceding paragraphs would be applicable to most net-pen proposals. Ideally, an aesthetic analysis taking account of each site's particularities should be prepared for each proposed net-pen facility.

One method of aesthetic analysis is set forth in the Aquaculture Siting Study (EDAW and CH2M Hill 1986). This consists of a series of formalized rating sheets which provide an inventory of existing conditions (including scenic quality, sensitivity level, and visibility) and an assessment of visual impact. Visual impact can be rated by considering the various elements of the existing conditions inventory. Thus, a facility with high visibility in an area of high scenic quality with viewers or uses with high sensitivity was rated as having a high visual impact. This method has the advantage of providing a structure and consistency to aesthetic analyses. On the other hand, this method tends to be rigid and may be insufficiently detailed to adequately distinguish the range of situations occurring in the Puget Sound area.

As an alternative, design and location guidelines could include the requirement that applications for aquaculture facilities include an aesthetic analysis describing the proposal's compliance with those guidelines. Without prescribing the nature of the aesthetic analysis, this requirement would not be particularly rigid and it could be adapted to the needs of each local jurisdiction.

d. Unavoidable Adverse Impacts

Despite application of mitigation measures discussed in earlier paragraphs, some adverse aesthetic impact would occur as a result of locating net pens in Puget Sound and surrounding waters.

2. NAVIGATION

Concerns have been raised that net-pen facilities will impair normal navigation routes and present a hazard to commercial and recreational vessel traffic. In addition, the potential impact of numerous aquaculture facilities in an area restricting access to popular cruising, fishing, and moorage areas is an issue.

The objective of the various mitigation measures discussed in this section are to minimize interference by the net-pen structures with normal, safe navigational use of the surrounding waters by commercial and recreational vessels.

a. Affected Environment

The waters of Puget Sound comprise roughly 6500 km² (2500 sq mi) of surface area. Vessels using Puget Sound vary from large ocean-going bulk cargo and container ships,

to ferries, towboats, commercial fishing boats, recreational boats, and other assorted water craft.

Nautical charts showing depths, obstructions, and aids to navigation are available for all of Puget Sound. In addition, boaters can receive the Notice to Mariners publication. This publication identifies changes in navigation aids and new obstructions in the water since the latest chart was issued.

Most large ocean-going ships travel within the established shipping lanes clearly marked on nautical charts. Vessels in the state ferry system have established routes in Skagit, San Juan, Island, Snohomish, King, Kitsap, and Pierce counties. In addition, some counties such as Skagit and Whatcom provide their own small ferry service.

Other commercial shipping does not have established routes identified on nautical charts. For example, the towboat industry hauls barges and logs all over Puget Sound. Towboats use the main shipping lanes, but will also hug shorelines if they offer protection from wind, strong currents, or wave conditions that would jeopardize the cargo or delay delivery.

Puget Sound is also the location of some of the finest recreational boating opportunities anywhere in the nation. Data are not available on the densities of recreational boaters at specific locations and the routes used by boaters to get from their point of origin to their destination. However, destinations usually have some amenity such as access to a state marine park, public beach, recreational fishing "hole," marina, or retail goods like restaurants and stores. In addition, many commercial and recreational boats will use protected bays for shelter during storms. (See II.B.8, Recreation).

Presently, siting decisions for net-pen proposals are made on a case-by-case basis. The U.S. Coast Guard (USCG) has the responsibility for reviewing all proposed structures in Puget Sound for potential navigation hazards through the Army Corps of Engineers permitting process. Any structure that may interfere with navigation must receive permission from the Corps (Section 10 permit). The impacts of a structure on navigation are considered by local government as part of the permitting process under the Shoreline Management Act. In addition, the Washington State Parks and Recreation Commission reviews applications for proposed net pens. This review specifically evaluates the potential navigation hazard to recreational boaters visiting Washington marine parks.

The Coast Guard is also responsible for establishing and maintaining a series of public buoys and lights to aid navigation through Puget Sound and may require structures such as net pens to install private aids to navigation to reduce the potential for collision. The number and placement of any required private aids to navigation is at the discretion of the USCG District Commander (Title 33 CFR Part 66). Also, structures in the water that receive the appropriate permits will be included in the Notice to Mariners and will be placed on charts when updated.

b. Impacts on Navigation

A group of floating net pens, like an island or dock, is a fixed object in the water. Net pens can impact navigation if sited in established navigation lanes, narrow channels, or where boats would be unable to navigate safely around them. In addition, if net pens break loose from their anchors during severe weather conditions they could become a hazard to vessel traffic. If net pens are inadequately lighted or made visually unobtrusive, they pose a greater risk to navigating vessels and may be a significant safety hazard, especially at night or during inclement weather.

Placement of a net-pen facility in an embayment may affect safe anchorages. During inclement weather recreational boaters and towboats may seek sheltered bays for protection from storms. If floating structures restrict the use of a sheltered bay for anchorage by blocking channels or limiting maneuverability, towboats and other boaters may have to travel to the next available safe anchorage. Depending on the weather conditions, this could create a hazard for the boat, passengers, or commercial cargo.

Pens located near shore would affect navigation in a manner similar to a long dock, a marina, or a series of anchored boats. Commercial traffic will tend to stay in deeper water, thus avoiding such areas and boaters must always be wary of anchored vessels near shore. The further offshore the structure is located, the greater the navigational risk because structures are not expected, reference points are not nearby, traffic is more intense, and vessels are usually travelling faster.

Net pens may also have a beneficial impact on navigation. In more remote areas, typical of recently permitted pen sites, net-pen facilities can provide a point of assistance/refuge for boaters. The net-pen sites are usually staffed 24 hours a day and have some form of sea-to-land communication.

c. Mitigation Measures

In addition to the existing Coast Guard review, the following measures could be implemented to reduce potential impacts to navigation.

- Encourage consultation with major recreational and commercial boating organizations during the siting evaluation process to identify areas of special importance to boaters.
- Avoid placing net pens in established navigation areas.
- Notify all marinas and ports near the net-pen facility, recreational boating groups, and commercial shipping associations of the precise location of net pens and their aids to navigation.
- Using site-specific conditions, establish a distance around net pens that would provide adequate clearance for navigation.

- Where necessary, require navigation lights on all four sides of net pen facilities as a minimum number necessary for safety.
- Use highly visible colors in the design of the facility.
- Assure that bonding is established to facilitate rapid clean up of net pens broken loose by severe storms.
- Site pens close to shore.
- Place pens adjacent to existing structures.
- Consolidate farms into areas of limited navigational use.

Mitigation measures that make net pens more visible and reduce potential navigation impacts (such as bright colors and numerous aids to navigation lights) may increase aesthetic impacts.

d. Unavoidable Adverse Impacts

Siting net pens in Puget Sound would create some unavoidable adverse impacts to navigation by the addition of new stationary objects in the water that boats would have to navigate around.

3. COMMERCIAL FISHING

Since net pens occupy space in the water, there is the potential for commercial and tribal fishing boats to run into or have their nets become entangled with net pen facilities. The resulting displacement of fishers from accustomed fishing areas is then the larger issue. This displacement could reduce the overall catch to a fishery, or affect the attainment of court-ordered allocations between tribal and non-tribal fishers.

The objective of the mitigation measures discussed in this section is to minimize any impacts on the opportunities for commercial fishers to successfully harvest wild fish and shellfish from waters near net-pen operations. A further objective of the mitigation measures in this section is to prevent disruptions of the equitable allocation of fish between fishing groups and between tribal and non-tribal fisheries as directed by federal court orders.

a. Affected Environment

The State of Washington has an active commercial fishing industry. Ward and Hoines (1986) estimate the total catch value of all Washington sea products (salmon, halibut, shellfish, bottomfish, and other marine fish) caught by the industry in 1986 was worth roughly 132 million dollars. Many boats in the fleet will pursue more than one species of fish during the year. While there are many different fish species caught by the

commercial fishing industry, the dominant species sought in Puget Sound are salmon: Chinook, Coho, Chum, Pink, and Sockeye. Gillnetters are the dominant salmon fishery in Puget Sound with almost 1200 licensed boats in 1986 that harvested 19 million pounds. Table 3 lists the number of licenses issued to various segments of the Puget Sound commercial fishing industry in 1986.

Management of fishery resources in Washington is complex. In an effort to effectively manage fishery resources to achieve a sustainable yield, the state regulates where, when, and for how long the commercial fishing industry can fish for specific species. The Washington Department of Fisheries administers many different management programs for commercial finfish and shellfish harvesting, but the most complex is the salmon program. The salmon harvest management program is designed to the specific spawning requirements for each salmon stock, and designed to maintain the court-ordered balance of allocation between treaty and non-treaty fishers.

Table 3. Number of Puget Sound salmon, bottomfish, and shellfish commercial fishing licenses by gear type, 1986.

<u>Gear Type</u>	<u>Number</u>
<u>Salmon</u>	
Gill Net	1188
Purse Seine	343
Reef Net	50
Troll	707
<u>Bottomfish</u>	
Bottomfish Pot	9
Dip Bag Net	84
Drag Seine	66
Handline/Jigger	595
Lampara/Round Haul	19
Otter Trawl	108
Purse Seine	2
Set Line	278
Set Net	55
Troll	232
<u>Shellfish</u>	
Beam Trawl	26
Geoduck Clam	13
Ring Net	178
Shellfish Pot (Crab)	247
Shellfish Pot (Non-crab)	173

Source: Ward and Hoines 1986.

A primary consideration in the Puget Sound harvest management process is the determination of the harvestable amount of each salmon run returning to Puget Sound. The process begins with estimates of expected populations of returning runs for each species on each river. The optimum number of fish needed for hatchery and natural spawning is then determined. This escapement goal is subtracted from the total run forecast to achieve a harvestable number of fish.

Each year a management plan is established between the Tribes and WDF for each salmon species. These management plans include harvestable amounts for each species, the time periods during which fish will be harvested, and specific harvest plans and conservation measures. Federal court rulings dictate the amount of fish that will be allocated to treaty and non-treaty fishers from the harvestable total.

Treaty tribes are constrained to fish only in "usual and accustomed" fishing areas, and non-tribal fishers generally fish only in marine areas. The marine areas of Puget Sound and the Strait of Juan de Fuca have been divided into numerous management areas to create discrete geographical areas within which distinct populations of fish can be managed. The number of areas and the locations of boundary lines vary between fisheries (marine fish, shellfish, and salmon). Figures 22 and 23 show the Puget Sound salmon management and catch reporting areas. Within these areas, fishery managers can reasonably predict the origin of a particular stock of fish, or the mix of stocks. To control both the increased fishing effort of recent years and provide court-mandated allocations to tribal and non-tribal fisheries, fishing areas and seasons have been reduced. As a result, when fishing is allowed, virtually all areas within an open management area are fished to one extent or another.

Management periods define the time "window" during which fishery managers will regulate the harvest of each fish stock. Table 4 provides the basic management periods for each species and management area. Management periods are based on the central 80 percent of the run, and considering "early arrivals" and "stragglers," fish runs extend over a lengthy time period. These management periods are individually established by WDF and the Tribes for specific runs of fish in specific management areas. The specific dates for harvesting of fish during these management periods are established annually by the Tribes and WDF for all salmon species that originate in Puget Sound, and by the Fraser River Panel of the Pacific Salmon Commission for Canadian origin Pink and Sockeye salmon.

The active use of Puget Sound waters for commercial fishing varies in intensity. Some areas experience extreme congestion during a commercial opening while other areas are not used at all. As discussed in the previous paragraph, the state establishes which management areas will be open for commercial fishing at a particular time during the season and for how long a specific gear type can fish during the opening. Table 5 shows the number of salmon caught in 1986 by various gear types for the various management areas.

The number of areas in Puget Sound open simultaneously for commercial salmon fishing ranges from 1 to 9 (Clocksin 1988, personal communication). When only a few areas

Table 4. Generalized salmon management periods by management area.

AREA	SP CHIN	S/F CHIN	PINK	COHO	CHUM	E. STUART AND PUGET SOUND SOCK.	MID-LATE FRASER R. SOCK.
4B	4/15-6/15	6/26-8/16	8/14-9/9	8/13-10/5	10/5-12/14	6/1-7/28	6/20-10/1
5	4/15-6/15	6/26-8/16	8/14-9/9	8/13-10/5	10/5-12/14	6/1-7/28	6/20-10/1
6	4/15-6/15	7/1-8/29	8/14-9/11	8/21-10/13	10/3-12/17	6/3-8/4	6/20-10/1
6A	4/15-6/15	6/16-9/6	8/4-9/13	8/29-10/21	10/3-12/17	6/3-8/4	6/20-10/1
6B	4/15-6/15	7/7-9/4	6/30-9/11	8/24-10/15	8/7-12/19	6/3-8/2	
6C	4/15-6/15	7/1-8/21	8/14-9/9	8/13-10/5	10/5-12/14	6/1-7/28	6/20-10/1
6D	4/15-6/29	7/21-9/21	6/30-9/21	9/20-10/28	10/27-12/7		
7	4/15-6/15	6/16-9/6	8/22-9/13	9/1-10/12	10/1-12/17	6/5-7/28	6/20-10/1
7A	4/15-6/15	6/16-9/13	8/25-9/14	8/22-10/18	10/3-12/17	6/5-7/28	6/20-10/1
7B	4/15- <2>	-9/7 <2>	6/30-8/17	9/8-10/26	10/27-12/14	---	
7C	4/15-	-MID OCT		10/15-10/26	10/27-12/7		
7D		-9/7		9/8-10/26	10/27-12/14		
8	4/15- <2>	-8/13	8/22-9/15	9/2-10/27	10/25-11/28	6/24-7/13	
8A	---	7/21-9/9	8/9-9/9	9/10-10/21	10/22-11/30	---	
8D		7/21-9/21		9/22-11/12	11/11-12/17		
9	4/15-6/15	7/12-9/4	7/11-9/5	8/24-10/15	8/12-12/25	6/3-8/4	
10	4/15-6/29	7/1-9/7	8/18-9/19	9/8-10/12	9/8-1/1	6/10-8/4	
10A		7/1-9/14		9/15-11/2	11/3-11/30	6/10-8/4	
10C		7/1-9/28		9/28-11/30		6/10-12/31	
10D		7/15-10/5		10/6-12/14		6/10-12/31	
10E		7/1-9/13		9/14-10/11	9/28-12/31		
10F		7/1-9/14		9/15-11/30		6/10-8/4	
10G		7/1-9/28		9/29-11/30		6/10-12/31	
11	4/15-6/29	7/1-9/10	8/18-9/10	9/11-10/21	9/10-1/8	---	
12	4/15-6/29	7/17-9/6	7/16-8/24	9/7-10/18	8/16-12/7		
12A	4/15-6/29	---	---	9/6-10/7	8/26-12/21		
12B	4/15-6/29	7/17-9/6	7/16-8/24	9/7-10/18	8/16-12/14		
12C	4/15-6/29	7/24-9/6	7/23-8/31	9/11-10/25	8/26-12/21		
12D	4/15-6/29	7/24-9/6		9/11-10/25	8/26-11/27		
13	4/15-6/29	7/1-9/24	8/10-9/25	9/25-11/6	9/17-1/15	---	
13A	4/15-8/10	8/8-9/16	8/16-9/17	9/17-11/9	10/23-12/31		
13C		7/15-10/13		10/14-11/30	10/12-1/16		
13D		7/1-9/21		9/22-10/12	9/17-12/31		
13E		7/1-9/21		9/22-10/12	10/12-12/31		
13F		7/1-9/21		9/22-11/6	11/7-12/12		
13G		7/1-9/21		9/22-11/6	11/7-12/12		
13H		7/1-9/21		9/22-10/12	10/12-12/31		
13I		7/1-9/21		9/22-10/12	10/12-12/31		
13J		7/1-9/21		9/22-10/12	9/22-12/31		
13K		7/1-9/21		9/22-11/6	9/22-12/31		

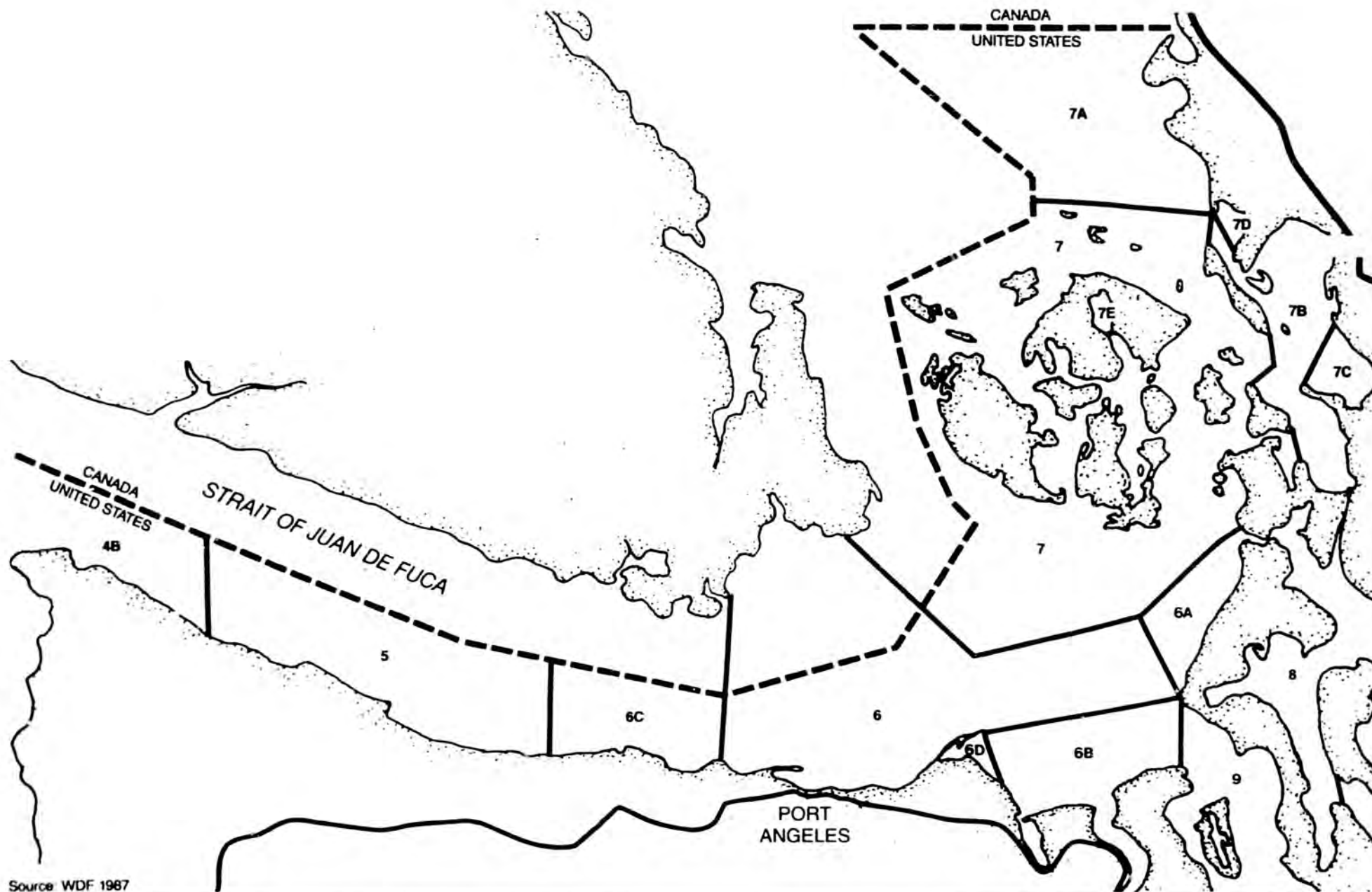
<1> MANAGEMENT PERIODS ADJUSTED ANNUALLY FOR ADMINISTRATION OF FISHERIES

<2> MANAGEMENT PERIOD CURRENTLY UNDER TECHNICAL DISPUTE; SUBJECT TO CHANGE ACCORDING TO LONG RANGE MANAGEMENT PLANNING.

<3> MANAGEMENT PERIOD CURRENTLY UNDER TECHNICAL REVIEW

(---) STOCK PRESENT BUT NO MANAGEMENT PERIOD ESTABLISHED.

() STOCK NOT PRESENT

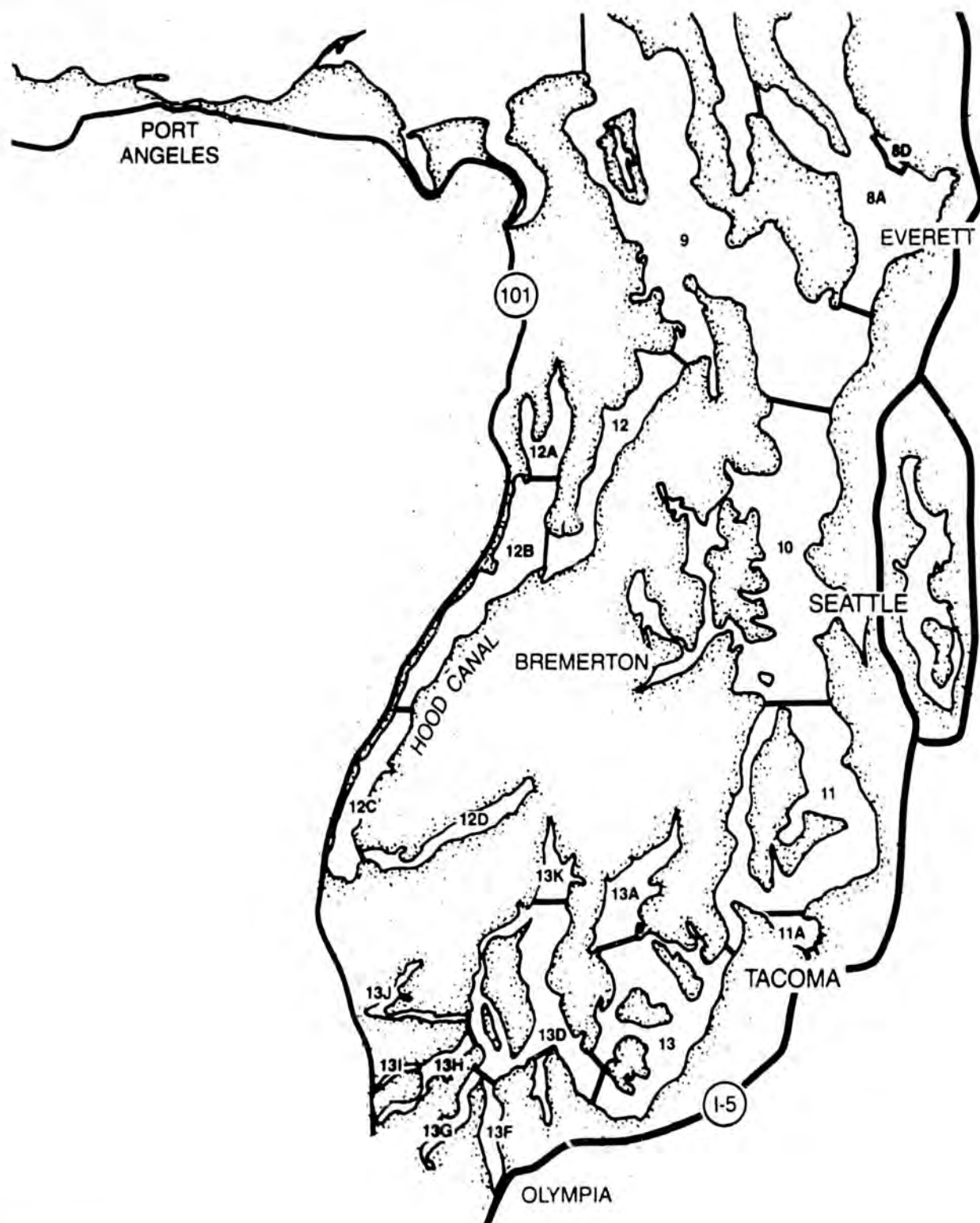


Source: WDF 1987

SCALE IN MILES
0 5 10



Figure 22.
Northern Puget Sound Commercial Salmon
Management and Catch Reporting Areas



Source: WDF 1987



SCALE IN MILES

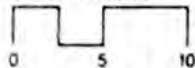
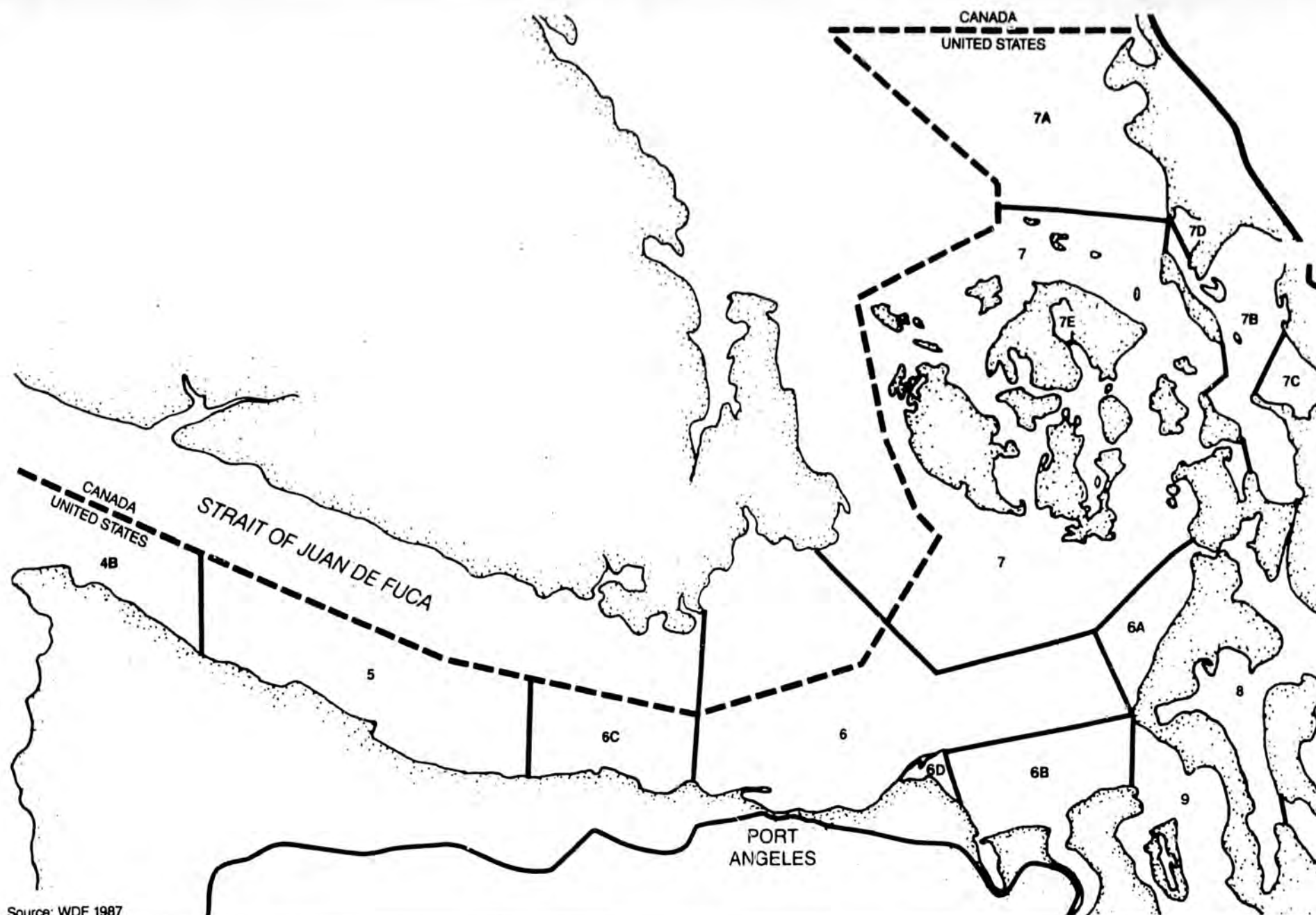


Figure 23.
Southern
Puget Sound Commercial
Salmon Management and
Catch Reporting Areas

CORRECTION

**THIS DOCUMENT
HAS BEEN REPHOTOGRAPHED
TO ASSURE LEGIBILITY**



Source: WDF 1987

SCALE IN MILES
0 5 10



Figure 22.
Northern Puget Sound Commercial Salmon
Management and Catch Reporting Areas

are open at one time, commercial boats from all over the Sound will congregate in these areas, creating an intensive use of the water. This congestion is exacerbated at some management area boundary lines where fishers line up to get "first crack" at fish entering the management area open for fishing. The Hood Canal bridge is the northern boundary line of management area 12 and is a prime example of this congestion. At times when area 12 is open for commercial salmon fishing, as many as 100 boats will congregate at the bridge to catch fish bound for streams that drain into Hood Canal.

Puget Sound Commercial Fishing Techniques. The Puget Sound commercial fishing fleet uses a variety of techniques to catch fish, and these techniques can be categorized into three groups (stationary, powered, and drifting) according to how they move through the water.

Stationary techniques include reef nets, set gillnets, and crabbing. The technique of fishing with reef nets involves creating a false reef using stationary nets near the shoreline that intercept fish in their migration routes. Fish swim between two nets hung vertically in the water forming a "V" that leads into a bag-like net where they are captured. Reef netting zones established by statute, are primarily located in the San Juan Islands.

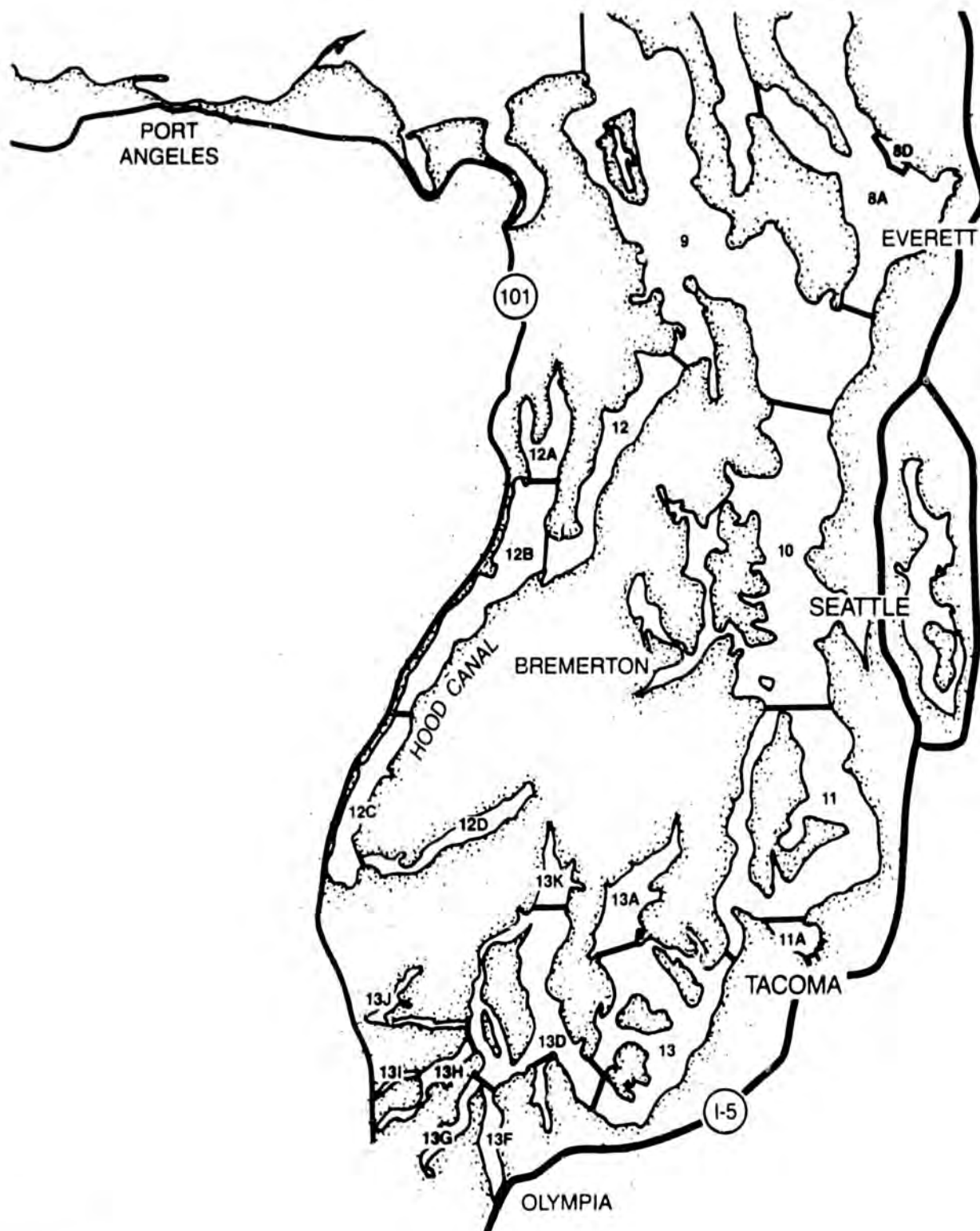
Set gillnets are vertically hung nets anchored in migration routes where fish will swim into the mesh of the net and become entangled. To help keep the net vertical in the water, it is supported at the surface by a series of floats and weighted at the bottom. Set gillnets can be attached to shore, dock, or other shoreline feature, and are usually anchored to the bottom at the net's other end.

The crabbing industry uses round traps (1-meter-diameter pots) that rest on the bottom. Each crab boat has many baited crab pots, that are attached to a line with a float, and then dropped overboard. The pots sit on the bottom until they are retrieved for harvesting. The smaller commercial shrimp fishing industry uses similar gear.

Commercial fishing techniques that use motor power to fish include purse seining, trolling, and trawling. Purse seine fishing involves encircling a school of fish with a net and then gathering the bottom of the net, forming a purse that traps fish inside. While setting the net, usually about 550 m (1800 ft) long, a small power skiff is used to hold the end of the net in place, during which time they drift with the current. When the school is completely surrounded by the net, the bottom is closed off and the fish are trapped. The seine boat will then retrieve the net from the water and harvest the fish.

Trolling involves a boat slowly moving through the water, trailing lines with baited hooks in the water. Fish are retrieved from the lines after they take the bait, and then the hooks are baited again and set back into the water.

Another technique for catching fish using motor power is the trawl. Various types of trawls (for example, otter and beam) are used to catch several species of bottomfish and shrimp. This method consists of dragging a large bag-shaped net at various depths,



Source: WDF 1907



SCALE IN MILES

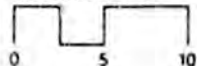


Figure 23.
Southern
Puget Sound Commercial
Salmon Management and
Catch Reporting Areas

most commonly along the bottom. Fish are caught in the net as the boat drags the net through the water.

Gillnetting is the primary commercial fishing technique that involves drifting with the current. As with set gill nets, the intent of the fisher is to block the path of the fish so they swim into the vertically hung net and become entangled. Most gillnet boats will use a net 550 m (1800 ft) long by 9 to 30 m (30 to 100 ft) deep. The net is supported at the surface by floats and kept relatively vertical in the water by weights on the bottom of the net.

Gillnetters set their nets perpendicular to the prevailing current to block the migration route of the fish. They then drift with the current, and when the skipper determines that sufficient time has passed, the net is pulled back on the boat by a power-operated drum and the fish are removed from the net. During the process of retrieving the net and harvesting the fish, the boat continues to drift.

b. Impacts on Commercial Fishing

Net pens are a physical obstruction in the water which, along with their anchor lines, pose a threat to commercial fishing like that described in Section II.B.2, Navigation. This potential problem is complicated by the complex nature of fisheries management, especially for managing the various salmon species.

The direct impact of floating net pens on commercial fishing is the potential for collision or entanglement of the fishing nets with the pen, resulting in a loss of available fishing area. The probability of such an occurrence depends upon the location of the net pens, and the type and intensity of fishing the area. Results of this impact can be displacement of fishers from a productive and accustomed fishing area, lost harvest potential, and reduced opportunity of the fishers to catch their allotment of salmon.

Gillnetters are, by their numbers and by their limited maneuverability, the group potentially most affected by the placement of net pens. Placing a fixed object in the middle of a drift forces gillnetters to avoid the immediate area or to attempt to pull their nets near the pens and risk entanglement. Drift netters must also avoid natural and man-made obstacles as part of their fishing. These include island, points of land, rocks, docks, buoys, and bridge supports.

The potential conflict is increased because drift netters rely on currents to carry their nets while fishing. Similar current areas are also desirable for net pens which need moderate currents to flush the pens and to minimize sediment accumulations. The areas of greatest conflict, however, are not only determined by current or other factors, but also by the location of WDF management area boundaries along which most fishing is concentrated.

The size of the area from which drift netters would be prevented from fishing will depend on many factors, especially the distance of the pen from shore. The further offshore the pens extend, the greater the area affected. Moving pens offshore 610 m

(2000 ft), as suggested to minimize aesthetic impacts (Section II.B.1, Aesthetics), maximizes the impacted area by extending the pens far into fishing channels, while also excluding the standard 550 m (1800 ft) net inshore of the pens. In intensely fished areas, such as the waters near the Hood Canal Bridge, the presence of a net-pen facility could result in intense conflicts with fishers and significant risk of collision and entanglement during the fishing season. In other areas, fishing is much less congested and a net pen would have proportionately less impact.

While the fishing area for gillnetters affected by net pens is relatively large due to the size of the nets used and the limited maneuverability of the boats, other types of gear would be less affected. Purse seiners have greater control over the location of their sets and could fish close to the pens, especially on the down current side. Trawlers could fish close to the pens, excluded only from the area occupied by the net pen and anchor lines. Crab and shrimp fishers could set pots within the perimeter of the anchors. For those gear types able to fish close to the pens, there may actually be benefits to the fishers because of local enhancement or attraction of commercially desirable fish and shellfish to the area, especially crab. Migratory fish may also be concentrated as they navigate around the pens.

While the area actually occupied by 100 pens, as an extreme example, would only occupy 1000 to 2000 acres of bottom (0.3 percent of the Puget Sound Basin), if they were located in areas of highly concentrated, highly competitive fishing, accidents would be inevitable. Because they need to take advantage of areas open for a very short time, commercial fishers may risk collision or entanglement in these areas.

The displacement of fishers from an established fishing area may have an effect on the commercial fishing industry, but the significance of the potential impact depends on site-specific conditions. If they have the opportunity to catch the same fish elsewhere, displacement of fishers from a particular site may not exclude those fishers from catching fish. This may be the case in situations where a relatively large area is open beyond the net-pen site.

In some cases, however, fish may not be available to the same fishing group. If opportunities for harvest are reduced in established non-tribal fishing areas, and the fish migrate into areas open only to tribal fishing (generally closer to the mouths of spawning rivers), then the non-tribal fishers may lose part of their court ordered allocation of salmon. This would disrupt the current salmon management plans and place the state in violation of these federal court orders.

A third potential impact would be that the fishing opportunity is lost to all fishers and fish return to their native streams. Because salmon are already managed to assure that adequate numbers of fish return to the streams to maintain viable runs, these additional fish would be surplus. This surplus to the needed number of spawners would represent an unnecessary loss to the fishing industry.

c. Mitigation Measures

The following are measures that could be implemented in siting of net pens to avoid or minimize displacement of existing tribal and non-tribal fishing. Appropriate measures will depend upon the extent of the potential conflict at the proposed site and the other impacts discussed in this PEIS (such as sedimentation, aesthetics, and navigation).

- Site net pens away from areas of intensive fishing. Such areas can be identified by consulting with commercial fishing organizations and WDF.
- Locate net pens near existing obstructions that must be avoided by drift net fishers.
- Notify all commercial fishing organizations of the location of net pens (for example, via the USCG Notice to Mariners) and provide schematic drawings showing the location of anchor lines.
- Locate pens near the shore and align the pen complex parallel to the shore.
- Locate pens away from WDF salmon management boundaries.

While not reducing the direct impact, salmon farmers and fishers suggest that some impact to fishers may be offset by net-pen farmers using available pen space to rear Pacific salmon for release. Final approval of such an action would be dependent upon approval by WDF and tribal biologists to assure that such releases were consistent with salmon management and enhancement objectives.

d. Unavoidable Adverse Impacts

It is unavoidable that some potential fishing area would be excluded from commercial harvest by the presence of a net pen. However, through appropriate mitigation significant adverse impacts on commercial fishing can be avoided.

4. HUMAN HEALTH

Human health concerns have centered around the possible bacterial contamination of shellfish by fish farming practices. This issue is discussed below in addition to the risks of parasitic diseases that might be contracted from pen-reared fish.

The objective of the mitigation measures in this section is to assure that no increased risk to human health shall result from net-pen activities.

a. Affected Environment

The primary concern with bacterial contamination in the marine environment affected by fish farming practices has centered around members of the bacterial genus Vibrio.

Vibrios are one of the most commonly occurring bacteria in the marine environment and include a diversity of species that are non-pathogenic, human pathogenic, or animal pathogenic. Many environmental isolates of this common group do not appear to fit into presently described species. The animal pathogenic species are known primarily for their effects in intensively cultured animals. Thus, vibriosis of fish and shellfish is regarded as a disease of animal husbandry.

Vibrio anguillarum is the best known and most widely distributed of the fish pathogenic vibrios. There are four other species of fish pathogens: V. ordalii, V. damsela, V. carchariae and V. salmonicida (Egidius 1987). Other authors (Colwell and Grimes 1984) have cited vibrios known to be human pathogens as fish pathogens. These pathogens include V. alginolyticus, although this is not generally regarded as a fish pathogen, and V. parahaemolyticus, which the authors describe as rather obscure in fish. As cited by Egidius (1987), an isolate of V. cholerae has been associated with fish disease in Japan by Muroga et al (1979) and Yamanoi et al. (1980) and V. vulnificus, biogroup 2 (Tison et al. 1982), is reported to cause disease in eels. However, as also noted by Egidius (1987), the literature on these four species of Vibrio as fish pathogens is "restricted and somewhat contradictory," and they have only been reported from warm water aquaculture sites. Thus, there is no literature citation from the large knowledge base on vibriosis which demonstrates that the vibrio pathogens of salmon are human disease-causing organisms.

The documented fish pathogenic species which affect salmonids in intensive husbandry--V. anguillarum, V. ordalii, and V. salmonicida--are distinct from the known human pathogenic vibrios potentially causing gastroenteritis. The vibrios that cause gastroenteritis include V. cholerae and the closely related V. mimicus and V. parahaemolyticus. Other species such as V. alginolyticus and V. vulnificus may be pathogenic through the infection of wounds or other means (Blake 1984). However, V. alginolyticus is one of the most commonly occurring species in marine coastal environments and is not generally regarded as pathogenic for humans.

Vibrio parahaemolyticus can cause gastroenteritis following consumption of contaminated fisheries products. The number of cases of V. parahaemolyticus gastroenteritis is small in the United States and the disease is not considered "reportable" by the Centers for Disease Control. In the Puget Sound area, only three cases were reported between 1982 and 1986 (Weston 1986). Environmental isolates of V. parahaemolyticus are common and more than 99 percent are considered non-pathogenic (Sakazaki et al. 1968; Thompson and Vanderzant 1976). The pathogenicity of isolates of V. parahaemolyticus is practically determined by the presence of a thermostable hemolysin (Miyamota et al. 1969) in an assay known as the Kanagawa test. This species of Vibrio increases in abundance in the summer and fall (Bartley and Slanetz 1971). Thus, both the known human pathogenic species, if not the actual pathogenic strains of Vibrio, as well as non-pathogenic species are indigenous, if not common, in the marine environment at certain times of the year. The probability of encountering Kanagawa-positive strains of V. parahaemolyticus increases during warm months and in embayments susceptible to warming as the overall concentration of V. parahaemolyticus increases. In Puget Sound,

the highest concentrations of this species of bacteria occur in summer months in warm shallow embayments such as Oakland and Rocky Bays (Kaysner and Weagant 1982).

Watkins and Cabelli (1985) investigated the relationship of sewage enrichment in Narragansett Bay to the concentration of V. parahaemolyticus. They reported that nutrient enrichment did not produce an effect on V. parahaemolyticus levels but hypothesized an indirect effect. The bacteria did increase in conjunction with some types of particulate matter. The concentrations of this vibrio decreased sharply with depth and distance from the sewage source. There are no reports of a change in the prevalence of V. parahaemolyticus gastroenteritis in association with fish farming (Weston 1986).

Blake (1984) notes that "Vibrio parahaemolyticus, the most common cause of disease among these Vibrio species, in this country is almost invariably associated with eating cooked seafood which has been mishandled after cooking, allowing the organism to multiply." Vibrio parahaemolyticus gastroenteritis can result from eating raw shellfish contaminated with the bacteria although the number of such cases is small. Blake (1984) also notes the importance of water temperature, season and adequate cooking for reducing the risks due to this disease. Greenberg et al. (1984) reported preliminary data which suggested that the risk of parahaemolytic food poisoning is no greater from eating clams from a polluted area than that of eating clams from a relatively clean area. Thus, while vibrios are commonly found in the marine environment, the problems of seafood contamination and subsequent gastroenteritis with this species are most often linked with poor food handling processes.

Wekell and associates (1989) conducted a preliminary study between December 1987, and August 1988, comparing the bacteriological characteristics of shellfish held near three salmon net-pens sites in Puget Sound to those of shellfish from three comparable sites not near net pens. In this study, the researchers examined the shellfish for the presence of a variety of human pathogens (indicators) including Vibrio cholerae, V. parahaemolyticus, Yersinia, Listeria, Campylobacter, Salmonella, and Clostridium perfringens, and fecal coliforms as well as other non-pathogenic species including aeromonas and V. alginolyticus. Sediment samples were also taken from beneath the pens and at nearby control sites. The preliminary study found no differences in the bacteriological character of the shellfish from the net-pen sites compared to the other sites. No Vibrio cholerae, Yersinia, Listeria, or Campylobacter were found in any samples. V. parahaemolyticus was found in a few samples.

These authors also performed bacteriological test on several lots of fish feed and isolated Salmonella cubana from one sample of moist feed as well as other bacteria. No Salmonella was found in oyster, sediment, or water samples from the net-pen sites or other sites.

Three parasites of salmon have been reported to infect humans in the Pacific Northwest: Nanophyetus salmincola (Digenea, a trematode worm) (Eastburn et al. 1987), Diphyllbothrium sp., a tapeworm, (Margolis et al. 1973; Ruttenber et al. 1984), and anisakine nematode worms (Deardorff et al. 1986, 1987). Salmon are infected with Nanophyetus and Diphyllbothrium during their freshwater phase of development. Nanophyetus infects

fish by direct penetration of the cercarial stage of the worm, whereas fish become infected with Diphyllbothrium by ingesting infected copepods. Fish are infected with anisakine worms by ingesting infected arthropods or fishes in seawater.

These parasites are prevalent in wild salmon throughout the Pacific Northwest (Margolis 1982), and all reported human infections from salmon have been associated with wild caught fish. Deardorff and Throm (1988) found a mean of 46 anisakine worms per fish in wild salmon examined from fish markets in Seattle. Wild salmon from drainages in Washington, where the snail intermediate host is present, show a high prevalence and intensity of infection of Nanophyetus (Milleman and Knapp 1970), and Diphyllbothrium spp. occur frequently in wild Pacific salmon (Margolis 1982). In contrast, a survey of salmon from two net-pen farms in Washington revealed none of these parasites in 236 market-size fish (Deardorff and Kent, in press). Absence of anisakine worms was attributed to the fish feeding almost exclusively on pelleted feed through their grow-out phase in seawater. Nanophyetus and Diphyllbothrium infections were apparently prevented at the freshwater hatcheries before introduction to net pens.

b. Impacts on Human Health

Because the bacteria associated with salmonid and other cold water fish farming are distinct from human pathogens, there is no foreseeable way fish farming activities will contribute bacterial human pathogens to the environment. In addition, it is clear that the occurrence of V. parahaemolyticus gastroenteritis is relatively rare and is most commonly associated with poor food handling processes. Fish farming appears unlikely to have an effect on cases of parahaemolytic gastroenteritis associated with eating contaminated raw shellfish.

The single isolation of Salmonella from fish feed (Wekell 1989) indicates that care must be exercised in the storage of fish feeds.

The vibrios of fish are distinct from the human pathogens. While highly contaminated areas of Puget Sound may contain shellfish, such areas are not suitable for fish farming. Furthermore, there is no direct correlation between human sewage enrichment and concentrations of V. parahaemolyticus (Watkins and Cabelli 1985). Fish farming may help prevent shoreline activities that contribute bacterial contamination to embayments around the Sound because such contaminated activities would degrade water quality, making the areas less suitable for fish farming.

Sale of salmon for raw consumption is a relatively small portion of the salmon market today. However, raw salmon is eaten as sushi and sashimi. It seems likely that parasitic human diseases from the consumption of raw salmon would decrease as a result of fish farming activities if farmed salmon products have an absence of parasites as research indicates. While examining fish from only two fish farms, the studies by Deardorff and Kent (in press) indicated that the pen-reared fish had no worms infectious to humans. This absence of parasites, the study concluded, occurs because pen-reared salmon live in a controlled environment during their freshwater development and are fed commercially prepared diets during seawater growth. However, further studies should be conducted

over a broader geographic range to determine whether these findings have general applicability.

c. Mitigation Measures

Siting aquaculture projects in areas that provide water quality compatible with good husbandry practices and productivity will ensure that farms are not placed in the warm rich embayments of Puget Sound susceptible to increased levels of V. parahaemolyticus in the summer and fall. The typical levels or significance of bacteria in fish feed is not known. Although there is no information to indicate the presence of a significant human health risk, the preliminary findings of Wekell and associates (1989) indicate that further research to determine bacteriological characteristics of fish feed would be desirable. Advisory notices to fish farmers on proper storage conditions for fish feed would also be desirable. These researchers did not find Salmonella in any oyster, sediment, or water samples collected from the same site as the feed or at any other sites.

Fish farming activities may increase the safety of eating raw salmon. Further research to validate the geographic distribution of lowered parasite loads in farmed fish would be desirable.

d. Unavoidable Adverse Impacts

No unavoidable adverse impacts were identified.

5. RECREATION

This section discusses the potential impact of aquaculture facilities on both aquatic and shoreline recreation.

The objective of the mitigation measures discussed below is to minimize any impacts on recreational opportunities in water or on beaches near net pens, including consumptive and non-consumptive use activities.

a. Affected Environment

Puget Sound offers some of the finest opportunities in the country for recreation in a marine environment. The area is popular both with boaters and with persons using its beaches. Although recreation occurs in a variety of settings, areas with public access are generally more heavily used than are other areas. For example, recreational boaters will typically seek a destination that provides an amenity such as a state marine park, public beach, or access to retail goods such as shops or restaurants. If a destination does include an onshore amenity, boaters will try to anchor close to shore to reduce the distance necessary to row to shore in a dinghy.

The depth of water in an embayment is also a factor in deciding where to anchor a boat. Because of the average length of anchor line on recreational boats, most boats will anchor in water that is less than 15 meters deep (Boyce 1988).

Boaters also use embayments for temporary or overnight protected moorage during inclement weather. Wind direction, wave conditions, water depth, and currents, are factors boaters will consider when deciding which bays to pull into to wait out storms for safety.

Other recreational users of the state's beaches usually seek a destination with good road access and intrinsic natural values. Many people use the public shorelands around Puget Sound for sunbathing, picnicking, birdwatching, beach combing, and general relaxation. In addition, persons with waterfront property use their own private beaches for recreational pursuits.

Recreational fishing can occur throughout the Puget Sound, but tends to concentrate in specific areas at certain times of year. The areas used intensively for recreational fishing at any particular time depend upon the species of fish being sought and the accessibility of the area.

In addition to boating, fishing, and recreational use of the shoreline, other recreational pursuits in Puget Sound include activities such as SCUBA diving, water skiing, swimming, kayaking, and windsurfing. Swimming and SCUBA diving generally take place in waters less than 30 m (100 ft) deep; the other activities can occur anywhere in Puget Sound.

Several agencies have authority over public recreational lands in and near Puget Sound. These agencies include the Department of Natural Resources, the State Parks and Recreation Commission, the Department of Wildlife, the Department of Fisheries, the National Park Service, and the U.S. Fish and Wildlife Service. There are also a variety of county and local parks located on the Sound.

b. Impacts on Recreation

Floating net pens have the potential to impact recreational activities by obstructing access to shore or water areas traditionally used for recreation, or disrupting the intrinsic and aesthetic value of the area (see Section II.B.1, Aesthetics). Net pens may positively affect recreation by causing local increases in the numbers of crab and finfish near the pen site.

If net pens are located in areas used for recreational boating or fishing, they could reduce the use of these areas or require recreational boaters to travel around the facility (See Section II.B.2, Navigation). Recreational anglers could entangle their fishing lines on net-pen anchor lines. In general, net-pen anchors are placed at a distance away from the pens equal to about three times the water depth. Thus, trollers may risk entanglement within about 100 yards (91 m) of a net pen. Other fishers who are mooching, jigging, or trolling near the surface could fish closer to the pens or in between the anchor cables. Shoreline use could also be reduced by boat docks or other land-based installations associated with the net-pen facility. Odors and noise resulting from net-pen operations may also adversely impact recreational users (See Sections II.B.6 and 7, Noise and Odors). Net pens could also adversely affect the aesthetic value of an area (See Section II.B.1, Aesthetics) which may reduce the value of an area for recreational use.

Floating net pens can also have positive impacts on recreational activities. Personnel from net-pen facilities could provide assistance during boating emergencies, and the net pen structure itself could be used for temporary moorage during an emergency.

c. Mitigation Measures

Recreational activities within an area proposed for a net-pen facility will be dependent upon the nature of the area, its intrinsic value, presence of destination objectives, and its accessibility to the public. Efforts to avoid or minimize adverse impacts on recreation must, therefore, be based upon an evaluation of the specific nature of recreation in the area. Below is a list of some measures that could be used to reduce any impacts.

- Avoid the placement net pens in areas of high recreational use or value when the farm will adversely affect those values.
- Consult with resource agencies (especially WPRC and WDF), with the local planning department, and with local user groups (fishing clubs, dive clubs, yacht clubs) to identify current recreational uses and potential conflicts.
- Avoid areas of intense recreational use (such as fishing "holes", SCUBA dive sites, or destination moorage areas).
- Avoid areas where pens would adversely affect the intrinsic recreational value (for example, within 2000 feet (610 m) of state park beaches).
- In other areas, minimize adverse impacts on recreational use, including navigational, aesthetics, noise and odor. Specific mitigation measures are discussed in the appropriate sections of this PEIS.
- Provide public benefits to offset any adverse impacts to recreation. Specific activities will be project specific and would depend upon agreement between the net-pen proponent and interested parties. Such activities could include:
 - improving public access at access sites used for farm operations;
 - cooperative projects with fishing clubs, schools, tribes and the state to use available pen space to enhance wild fish stocks.

d. Unavoidable Adverse Impacts

With proper net-pen site selection, there will be no significant adverse impacts to recreational activities. Where lesser impacts are unavoidable, these can be minimized through the design, configuration, and placement of the pens at the site. In addition, activities can be undertaken in association with the net-pen operation to enhance recreational uses in the area.

6. NOISE

Sources of noise from aquaculture facilities include boats to service net pens, pumps and generators necessary for operation, and communication between workers. Concerns have been raised about the potential impact to nearby residences.

The objective of the mitigation measures discussed in this section is to prevent increases in the existing noise level that will adversely affect human activities near the net-pen site, especially increased noise to shoreline residents.

a. Affected Environment

Existing noise levels on and along the shore of Puget Sound vary due to differing land uses and overwater activities. Daytime noise levels (measured L_{eq} , see below) are about 45 dBA to 50 dBA in areas adjoining rural residential land uses and having little overwater activity. Daytime noise levels can be 70 dBA or higher in areas adjoining urban land uses and having considerable overwater activity (EPA 1974). The unit dBA indicates decibels, which are units of sound measurement weighted to approximate the response of the human ear to sounds of different pitches. Noise levels in some sheltered bays during calm weather have been measured to be less than 30 dBA (Hurlburt, personal communication 1988). The designation L_{eq} indicates equivalent constant sound level and is used to compare noise sources whose levels vary over time.

To help evaluate noise impacts, the EPA has developed a guideline to assess increases in ambient (existing) sound levels. If there is less than a 5 dBA increase, little or no impact is expected. Increases between 5 and 10 dBA may result in some impact, and increases greater than 10 dBA generally produce significant impacts. This guideline, known as the non-degradation guideline, is not a regulation and is not enforceable.

Noise is regulated by the Department of Ecology, which has established noise standards for various environments and activities (see below). Local government may adopt stricter noise standards or standards for nuisance noise. Most jurisdictions, however, have not adopted such standards and noise is regulated by the state standards.

Noise sources other than recreational watercraft are subject to Chapter 173-60 Washington Administrative Code (WAC), Maximum Environmental Noise Levels. Maximum environmental noise levels are defined by this regulation and depend on the type of activity, source, and receiving property. The highest noise levels are allowed where both the source and receiving properties are used for economic or industrial activity (including agriculture). The lowest noise levels allowed occur where both properties are used for residential or similar uses. Table 6 shows the maximum allowable one-hour noise levels. Depending upon the categorization of net-pen activity as a commercial or industrial use, the maximum allowable daytime one-hour noise level at a residential receiving property is 57 dBA or 60 dBA.

Table 6. Maximum allowable one-hour environmental noise levels. (These levels are 10 dB lower during nighttime hours.)

<u>Activity at Source Property</u>	<u>Activity at Receiving Property</u>		
	<u>Residential</u>	<u>Commercial</u>	<u>Industrial</u>
Residential	55 dBA	57 dBA	60 dBA
Commercial	57	60	65
Industrial	60	65	70

Source: WAC 173-60

The State also regulates noise created by waterborne activities. Chapter 173-62 WAC, Watercraft Noise Performance Standards, sets noise standards for recreational watercraft, but exempts commercial watercraft from its specific regulation. Recreational boats may not exceed 64 dBA between sunset and sunrise or 74 dBA during the day when measured at a residential property.

EPA Region Ten (Washington and other northwest states) has set forth guidelines for evaluating the impact of increased noise levels on residential or other sensitive receptors. These guidelines state that an increase of less than 5 dBA would have a slight impact. Increases between 5 and 10 dBA have a significant impact, and increases greater than 10 dBA would have a very serious impact (EPA 1980). The Federal Interagency Committee on Urban Noise (FICUN) has established guidelines for maximum noise levels considered allowable for residential environments. The maximum 24 hour L_{dn} or daytime L_{eq} level is 65 dBA (FICUN 1980).

b. Impacts of Noise

Potential noise impacts would primarily occur during daytime hours when net pen operations take place. Sources of noise from net pens would include boats servicing the pens, motors, and compressors for aeration, and incidental noise from personnel working on the facility. Actual noise levels would vary depending on the equipment being used and the activities taking place. Pumps and compressors are only used during unusual conditions. Usually they are used during certain summer-time periods when algal blooms or low oxygen conditions necessitate aeration to circulate the water. Because of the usual absence of obstructions above the water surface, any noise produced by net-pen operations will tend to carry further than would be expected for a similar noise source located on land. Some noise would also result from truck traffic servicing the land-based portion of the facility.

In rural areas, the relatively low existing noise levels would make additional noise noticeable, even though resulting noise levels may be allowable under state regulations. Hurlburt (1988) observed that under unusually quiet conditions (background noise < 30 dBA) the sound of a small engine-driven pump (74 dBA at 4 feet [1.2 m]) was still detectable to the human ear at 158 m (520 feet), although the measured level was less than 5 dBA above existing levels. Noise from 5 to 8 cm (2-3 inch) waves produced similar noise levels at the receiving property during the same study. In non-rural areas, noise generated by a net-pen facility may not be noticeable because of higher levels of surrounding activity.

An acoustical evaluation prepared for a proposed salmon net pen in south Puget Sound predicted noise levels that would be generated by that facility (Towne et al. 1988). This study estimated an ambient peak hour L_{eq} of about 43 dBA at a distance of 488 m (1600 ft) with levels up to 48 dBA occurring under certain weather conditions. Results of the study predict that under the observed conditions the increase in noise levels due to the net-pen facility would be less than 3 dBA. Depending on facility-receiver separations and the nature of equipment used in the net-pen operation, noise levels could vary from those just described. Noise-producing equipment such as generators, pumps, and boats are usually only in operation intermittently.

c. Mitigation Measures

In areas where noise from the pens would disturb shoreline residents and users, noise from net-pen facilities could be mitigated by several methods:

- Require the installation and proper maintenance of mufflers on all motorized equipment and enclose equipment to reduce noise.
- Limit activity on the facility to daytime hours.
- Require commercial boats serving net pens to meet the noise performance standards set for recreational watercraft.
- Require net-pen operations to meet the non-degradation guideline. This would prohibit an increase to existing sound levels on receiving properties of more than 10 dBA.
- Locate pens far enough away from residential properties to prevent disturbing noise levels.
- Use electric motors to operate pumps and compressors.
- Avoid siting of pens in small, populated, sheltered bays where low background noise levels would increase the impact of any noise emanating from the pens.

d. Unavoidable Adverse Impacts

Some increase in local noise levels would result from the operation of floating net-pen facilities. However, this increase is not expected to have significant impact on shoreline residents or other users of the adjacent water and shoreline. Where noise from the pens might adversely affect residential use of the adjacent shores, this noise could be reduced to acceptable levels by proper site selection and minimization of unnecessary noise.

7. ODORS

Concerns have been raised about the potential smell of aquaculture facilities. There is concern that odors will occur near the net pens from rotting dead fish, drying nets, and fish feed left out in the sun.

The objective of the mitigation measures identified in this section is to prevent odors emanating from the net pens from adversely affecting nearby residents.

a. Affected Environment

Existing odors along the shore of the Puget Sound are mostly the result of natural processes. The predominant source of natural odor along a shoreline is from the decay of organic material such as algae and zooplankton on the beaches. On muddy beaches at low tide, especially during warm summer weather, the predominant odor can be from hydrogen sulphide (rotten egg smell) release from the anaerobic decay of organic material in the sediments. Additional odors are produced by vegetation, animals and decay of organic material from these sources. In residential and rural areas, additional odors result from a number of sources: fireplaces, furnaces, burning yard debris, automobile exhaust, fertilizer applications or domestic animals. In commercial and industrial areas a wide variety of odors may result from these activities.

The nature and extent of these odors will depend upon the type of odor and its source, the location of the receiver (people) relative to the source, the sensitivity of the receiver, the direction and velocity of the wind that carries and dilutes the odors, and other factors such as temperature and humidity. Another factor affecting how odors are perceived is the environment and the appropriateness of the odor to that environment (for example, the natural aroma of a marine beach would be very noticeable in a forest environment).

b. Impacts of Odors

Because a large amount of organic matter is associated with marine facilities and with fish farming, net pens have the potential to be a concentrated source of additional odors. Most of these odors are similar to those occurring naturally on beaches (for example, decay of organic matter in a saline environment). The major potential sources of odors are spilled or improperly stored fish food, air drying of nets fouled with attached marine

life and dead fish. In addition, decaying organic matter from all of these sources can accumulate on the pen walkways.

Finally, boats servicing the facility and internal-combustion motors used to power pumps and aeration equipment would contribute minor amounts of exhaust fumes to the immediate area of the facility. In many cases, attributing particular odors to a net-pen facility may be difficult, because other activities, man-made or natural, in the area may produce similar odors.

All odor impacts would be occasional and intermittent. The significance of net-pen odors on people in the area of the pens would depend upon the factors presented above, such as odors from other sources, the distance between the facility and the receiver, and weather. There is a potential for strong, unpleasant odors in the immediate vicinity of net pens if good management practices are not followed. These practices include removal of dead fish, cleanup of spilled feed, and general maintenance of the facility.

The placement of several net-pen facilities in a localized area could result in cumulative odor impacts. With an increased number of net pens in an area, odor impacts would probably be more frequent although still intermittent due to weather. The extent of odors at some locations could increase depending on facility locations.

c. Mitigation Measures

In situations where odors would affect users of the waters and shorelines, especially shoreline residents, measures to mitigate potential odor impacts include:

- Following best management practices and maintaining the general cleanliness of the facility. These practices include the immediate removal and disposal of dead fish and cleanup of spilled feed.
- Regular cleaning of nets or the use of nets that are less likely to become fouled, including the use of nets treated with approved antifoulants.
- Storage of feed in closed containers, storage of only essential amounts of opened food on the pens, and/or the use of dry feeds.
- Use of easily washable pens that have open walkways to allow spilled food and other matter to fall through into the water.
- In situations where odor may be a problem to nearby residents, sites can be selected to:
 - increase the distance between the facility and the shoreline receiver,

- place the pens downwind (prevailing distance, especially in summer) of the residences, or
- locate pens in areas already experiencing high levels of odor from other sources.

d. Unavoidable Adverse Impacts

Through site selection and management practices, significant effects of odor on human activities can be prevented. Occasional increases in local odors are an unavoidable adverse impact of net pens, but these can be further reduced through the mitigation measures presented above.

8. UPLAND AND SHORELINE USE

The issue in this section involves the potential displacement of existing and potential uses of shoreline and upland uses near an aquaculture facility.

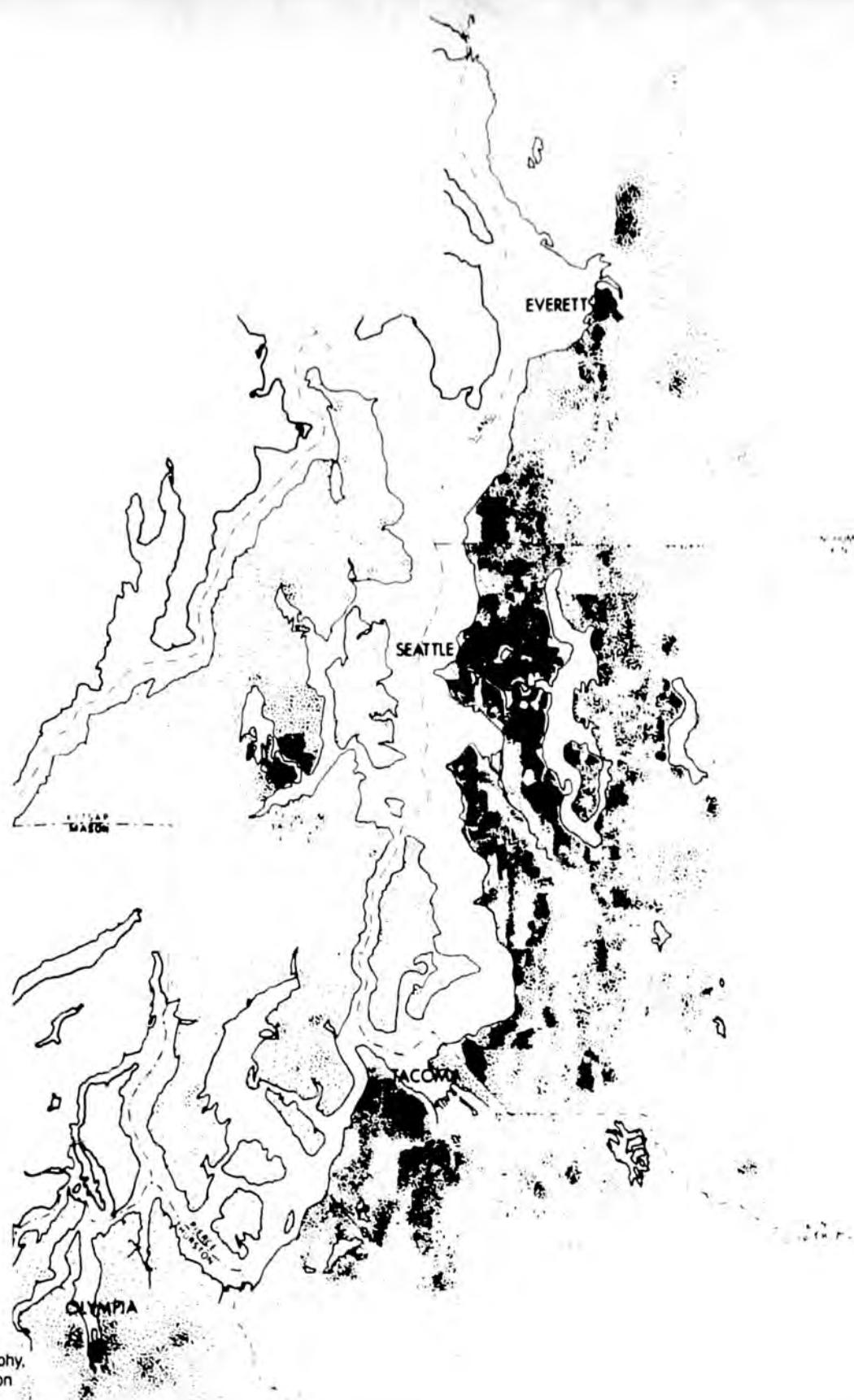
The objective of the mitigation measures described in this section is to minimize conflicts that may adversely affect current uses of the uplands and shorelines near net pen facilities.

a. Affected Environment

Over 2000 miles of shoreline wrap around the inland marine waters of Washington state. Twelve counties with a combined population of 2.9 million people share this shoreline. This corresponds to 65 percent of the state's population in only one-quarter of the state's land area. Figure 24 shows the spatial distribution of the population. The greatest concentration of people occur on the eastern coastal plains of Puget Sound, particularly in King, Pierce, and Snohomish counties. Figure 25 shows general land use patterns in the Puget Sound area.

Since 1940, when the growth rate in the 12 county region intensified, the population has been increasing at a rate of nearly half a million people every 10 years (approximately 50 percent of the statewide growth). In the next several decades, population in the Puget Sound region is expected to grow moderately, between 1.6 to 2.0 percent. The most rapid percentage growth has been in the more rural counties outside incorporated areas, such as San Juan, Island, and Thurston counties.

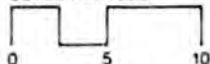
This increasing population will have several impacts, including a growing demand for residential property, especially along the water front. This growth will continue to displace forest and agricultural uses of the uplands adjacent to the water. With this increasing development will come growing problems of water pollution from point sources (sewer and industrial discharges) and non-point runoff from uplands. In addition, the growing population will expect recreational activities associated with the water such as marinas, parks, and fishing opportunities. At the same time, existing commercial users, such as fishing and towboat industries, and public ports will demand



Source: Mary Stewart,
Department of Geography,
University of Washington
1987 Puget Sound
Water Quality Management Plan



SCALE IN MILES



Each Dot
Represents 100 Persons

Figure 24.
Population Distribution
in the Central Puget Sound Region

- place the pens downwind (prevailing distance, especially in summer) of the residences, or
- locate pens in areas already experiencing high levels of odor from other sources.

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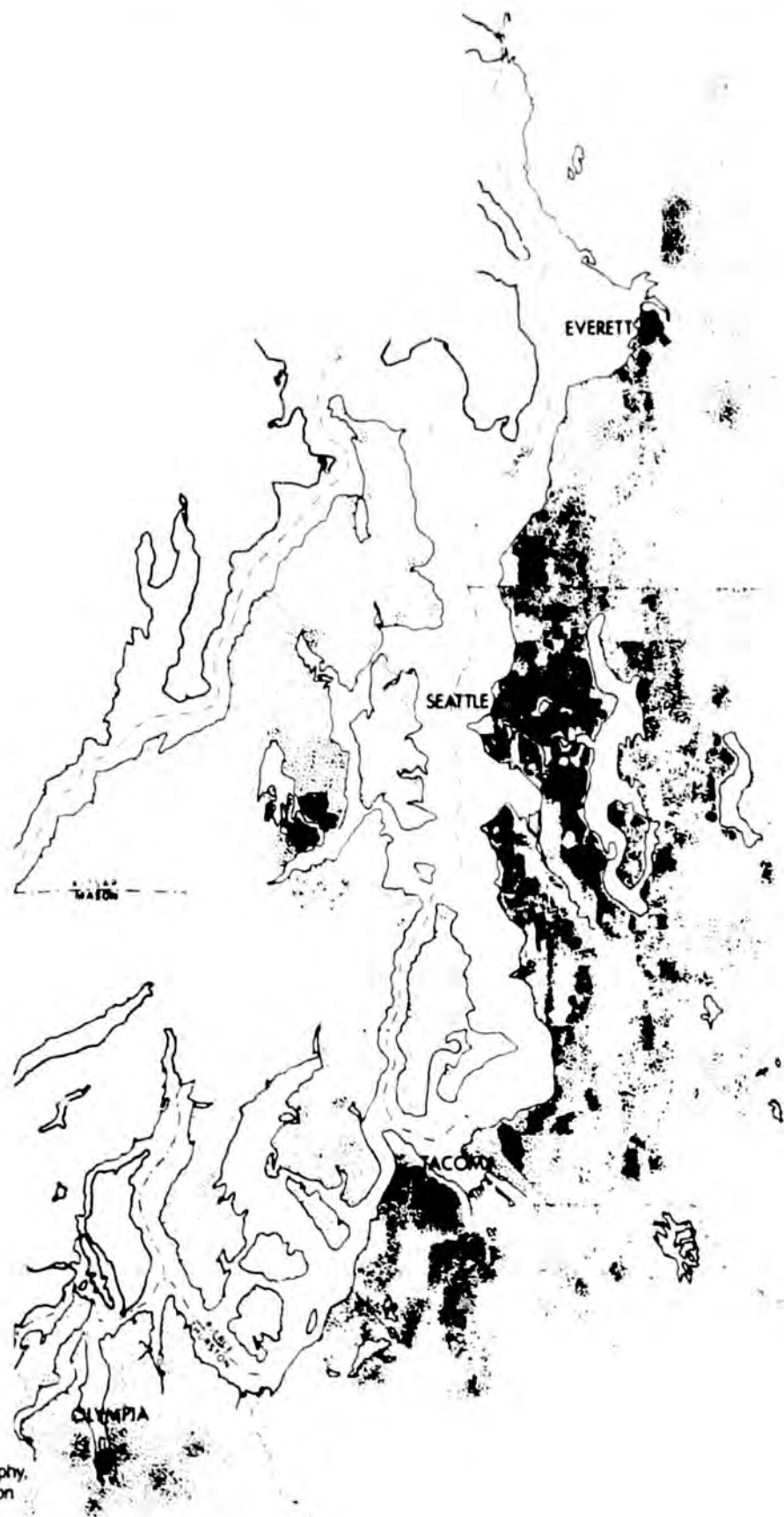
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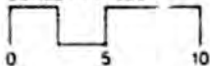
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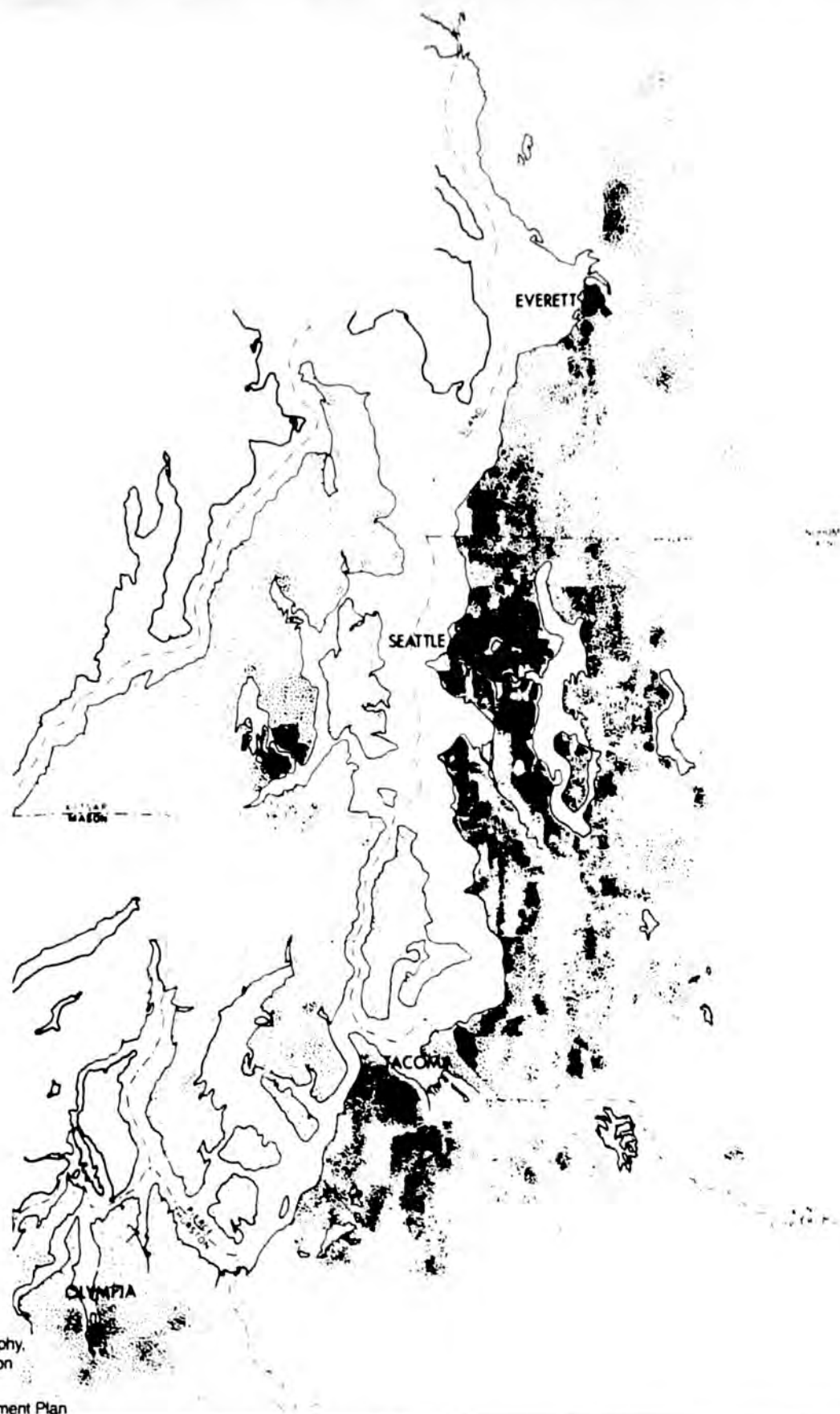
The objective of the mitigation measures described in this section is to minimize conflicts that may adversely affect current uses of the uplands and shorelines near net pen facilities.

a. Affected Environment

Over 2000 miles of shoreline wrap around the inland marine waters of Washington state. Twelve counties with a combined population of 2.9 million people share this shoreline. This corresponds to 65 percent of the state's population in only one-quarter of the state's land area. Figure 24 shows the spatial distribution of the population. The greatest concentration of people occur on the eastern coastal plains of Puget Sound, particularly in King, Pierce, and Snohomish counties. Figure 25 shows general land use patterns in the Puget Sound area.

Since 1940, when the growth rate in the 12 county region intensified, the population has been increasing at a rate of nearly half a million people every 10 years (approximately 50 percent of the statewide growth). In the next several decades, population in the Puget Sound region is expected to grow moderately, between 1.6 to 2.0 percent. The most rapid percentage growth has been in the more rural counties outside incorporated areas, such as San Juan, Island, and Thurston counties.

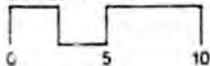
This increasing population will have several impacts, including a growing demand for residential property, especially along the water front. This growth will continue to displace forest and agricultural uses of the uplands adjacent to the water. With this increasing development will come growing problems of water pollution from point sources (sewer and industrial discharges) and non-point runoff from uplands. In addition, the growing population will expect recreational activities associated with the water such as marinas, parks, and fishing opportunities. At the same time, existing commercial users, such as fishing and towboat industries, and public ports will demand



Source: Mary Stewart,
Department of Geography,
University of Washington
1987 Puget Sound
Water Quality Management Plan



SCALE IN MILES



Each Dot
Represents 100 Persons

Figure 24.
Population Distribution
in the Central Puget Sound Region

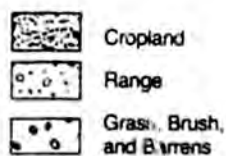
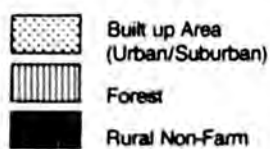
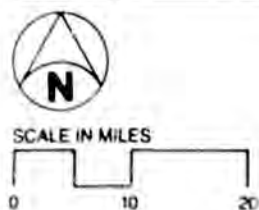
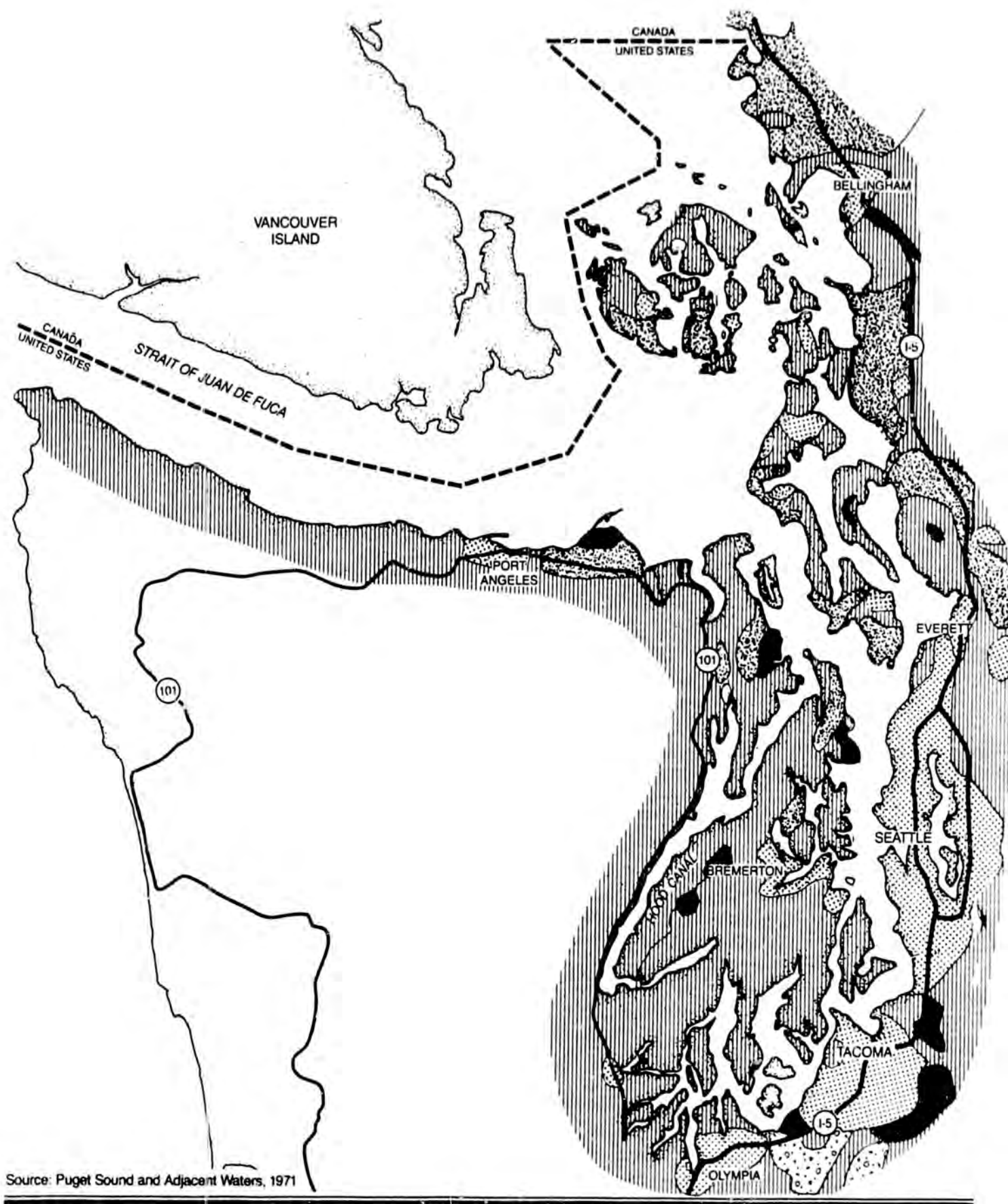


Figure 25.
Land Use in
the Planning Area

maintenance of their existing activities. Thus, population growth will only increase the existing conflicts between these diverse users of the state's shorelines and aquatic areas.

b. Impacts of Alternatives

The potential impacts of floating net pens on these various activities have been discussed in Section II.B. An impact to land and shoreline use that is not discussed in other sections of this PEIS is the potential for net pens to influence future development patterns in an area.

Fish held in pens are particularly sensitive to degradation of water quality. Salmon have been held in small cages near industrial and municipal outfalls to monitor compliance with discharge standards (if the fish die, the discharge is not meeting state and federal standards). The presence of commercial net pens will serve a similar function to monitor water quality.

Fish growers will obviously avoid areas of potential poor water quality, such as near industrial and municipal sewage outfalls, and large storm water outfalls. A grower may also want to avoid sites near marinas, shoreline facilities that handle petroleum products, and areas dredged or used for dredge disposal which could potentially introduce pollutants into an area.

Once a net-pen facility is installed, it will highlight water quality concerns in the area. Therefore, greater attention may be brought to bear on activities that are not now meeting water quality standards, or proposed activities which could adversely affect water quality. This increased concern about water quality may result in local and state agencies placing additional restrictions on upland projects to prevent water quality degradation. Upland users may also be subject to liability if their actions, in violation of pollution laws, were to damage the fish in the pens.

c. Mitigation Measures

The possible highlighting of activities that may degrade water quality and subjecting them to greater regulatory control is not considered an adverse impact. All activities along the shoreline should minimize or prevent water quality degradation. If a net-pen facility serves to increase awareness of water quality needs, or results in changes to upland activities that are degrading water quality, it is considered a beneficial impact and needs no mitigation.

d. Unavoidable Adverse Impacts

None.

9. LOCAL SERVICES

The issue here is whether the presence of aquaculture facilities will impair the ability of governments and utilities to provide their services.

The objective of the mitigation measures discussed in this section is to minimize the requirements for additional services by local governmental agencies except where additional services are compensated for either directly or indirectly by the net pen operators.

a. Affected Environment

Most local services in the Puget Sound area are provided by local agencies or utilities. Fire and emergency services are usually provided by either a district within the local county or by a municipal jurisdiction. Police services are provided by county or municipal jurisdiction. Sewer and water service, where available, are usually provided by purveyor districts in rural areas and by municipalities in more urbanized areas. Electrical power is supplied by state regulated utilities throughout the Puget Sound area.

b. Impacts on Local Services

The operation of floating net-pen facilities does not require large amounts of fresh water or electricity. If the project is located close to shore, a waterline could be installed to provide fresh water for drinking, spraying down nets, and rinsing walkways. Otherwise, bottled water would be used for drinking and a pump installed to wash down nets and walkways.

When located near shore, an electric cable can power electrically powered pumps, feeding mechanisms, and lights. When located a considerable distance offshore, sites use portable generators. In remote areas without available water or electricity, wells and electrical lines may have to be installed.

Net pens would not have a significant impact on other local services. Portable toilet units are used on the floating net-pen facilities. Net-pen facilities are not expected to have significant demands for police or emergency services. Use of existing boat ramps during net-pen operations may impact ramp facilities but the impact is not expected to be significant because net-pen operations involve only a few boat trips per day.

Increasing the number of net pens in a localized area such as an embayment would probably result in a cumulative impact on local services, because any particular service would likely be provided by a single purveyor. Because any one net pen results in an insignificant demand on local services, the size of the cumulative impact of several pens would be minor.

c. Mitigation Measures

No significant impacts are anticipated. Costs incurred by service purveyors would be reimbursed through utility fees paid by facility owners.

d. Unavoidable Adverse Impacts

No unavoidable adverse impacts on local services are anticipated from any of the alternatives.

C. CUMULATIVE IMPACTS IN PUGET SOUND

Analysis of the impact of various levels of net-pen development on the entire Puget Sound is an exercise to estimate if there is an upper limit on the capacity of Puget Sound for net pens. This upper limit is the point beyond which additional net pens will reduce water quality in the Sound as a whole. The intent of such analysis is to show if projected levels of net pen development will adversely affect the Puget Sound by exceeding the assimilative capacity of the Sound. This analysis assumes that the net pens are dispersed throughout the Sound. It is not intended to supplant the need for a thorough and detailed analysis of localized environmental effects around a net pen.

In addition basin-wide analysis serves to put the inflow of nutrients and organics from net pens in perspective by comparing them to other sources of nutrients and organics, both man-made and natural. If the amount of nutrients from net pens is extremely small compared to the amount from naturally occurring inflows, then it is reasonable to argue that the Sound can sustain that level of impact without excessive degradation.

For purposes of analysis, four hypothetical production levels were selected for the typical pen discussed in Section I.C, Background:

1. 13 farms, 4400 metric tons (10 million pounds) production
2. 25 farms, 8600 metric tons (19 million pounds) production
3. 50 farms, 16400 metric tons (38 million pounds) production
4. 100 farms, 34100 metric tons (75 million pounds) production

The first production level of 4400 metric tons is approximately equal to the estimated production from the 13 existing farms in Puget Sound. Production levels 2 through 4 are the upper limits of the production ranges given in Section I-D (Description of Alternatives). The production levels represent an approximately two-, four-, and eight-fold increase over current production. The 100-pen production level is considered by some to be in excess of the maximum number of pens that could be permitted, considering the number of competing uses for potentially suitable sites.

A summary of loading rates for various water quality indicators is given in Table 7. The values in the table were computed from loading analyses for Discovery Bay net pens (Kieffer and Atkinson 1988; Parametrix 1988) assuming loading rates of 0.59 kg BOD/kg fish produced, 0.55 kg feed+feces/kg fish, and 0.074 kg N/kg fish.

While net-pen effluents cannot be directly compared with sewage, components like BOD (Biochemical Oxygen Demand) and dissolved nitrogen loads were compared to various other sources of loading to Puget Sound. The BOD was compared to wastewater

Table 7. Loading of BOD, particulates (feed+feces), and dissolved nitrogen from different levels of fish production in net pens.

Number of farms	Production (MT/yr)	Total BOD (MT/day)	Feed+feces (MT/day)	Dissolved Nitrogen (MT/day)
13	4400	7.3	6.8	0.9
25	8600	14	13	1.8
50	16400	27	25	3.3
100	34100	55	52	6.8

treatment effluents from two Metro treatment plants and to one industrial source (Figure 26). In this comparison, 25 and 50 net-pen capacities are similar to a large wastewater treatment plant while 100 net pens is considerably larger than any single treatment plant on the Sound. However, the net pens represent a more diffuse source of BOD loading than a treatment plant.

For nitrogen loading, the net-pen production levels were compared to two wastewater treatment plants and to the inflow of nitrogen to the main basin of Puget Sound from the surrounding land (Figure 27). The nitrogen inflow to Puget Sound is dominated by the natural movement of nitrogen with the tides and with fresh water inflow. Compared to the tidal inflow, all other nitrogen sources are insignificant and even the 100-pen production level does not represent a large input of nitrogen. It should be noted that not all of the nitrogen sources shown in Figure 27 are for the same nitrogen compound. Tidal fluxes are only for nitrate, the treatment plant loadings are only for ammonia, and the net-pen loadings are for nitrate plus ammonia. A comparison of nitrate and ammonia for all sources would increase the inflow of nitrogen from tides and treatment plants, but net-pen sources would remain unchanged.

The impact of net pens can on Puget Sound can also be evaluated by presenting the loading from net pens as an overall change in nitrogen concentration throughout the Sound. This analysis treats the entire Sound as a well-mixed water body. A more conservative approach is to assume that the loading only affects the surface mixed layer such as the case of a dissolved substance released near the surface. Assuming a mixed layer from mean lower low water to approximately 20 meters (66 ft), the total loading from the net pens would mix with 36 km³ of water (McLellan 1954). The mass loading of 1.8 MT/day of dissolved nitrogen would result in an increased nitrogen concentration of 0.05 ug/l/day. Similarly, loading from 50 and 100 net pens would increase dissolved nitrogen concentrations by 0.09 and 0.19 ug/l/day. These concentrations are one hundred to one thousand times lower than levels that could have an impact on Puget Sound. Given the strong tidal exchange and the high nutrient outflow rate, the small daily increase in nitrogen would not accumulate to problem levels.

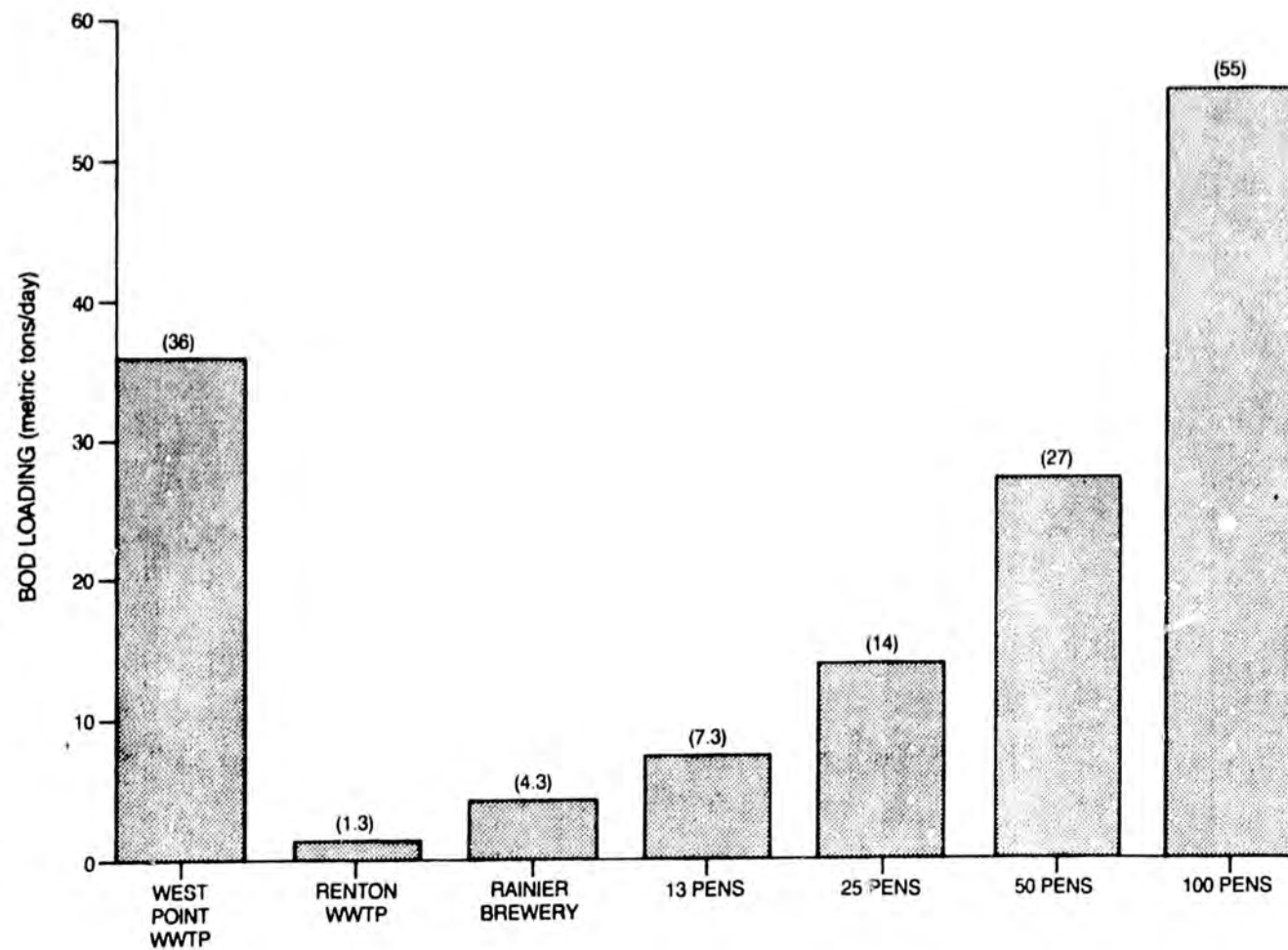


Figure 26.
BOD loading from West Point and Renton Wastewater Treatment Plants, Rainier Brewery, and different levels of net-pen development.

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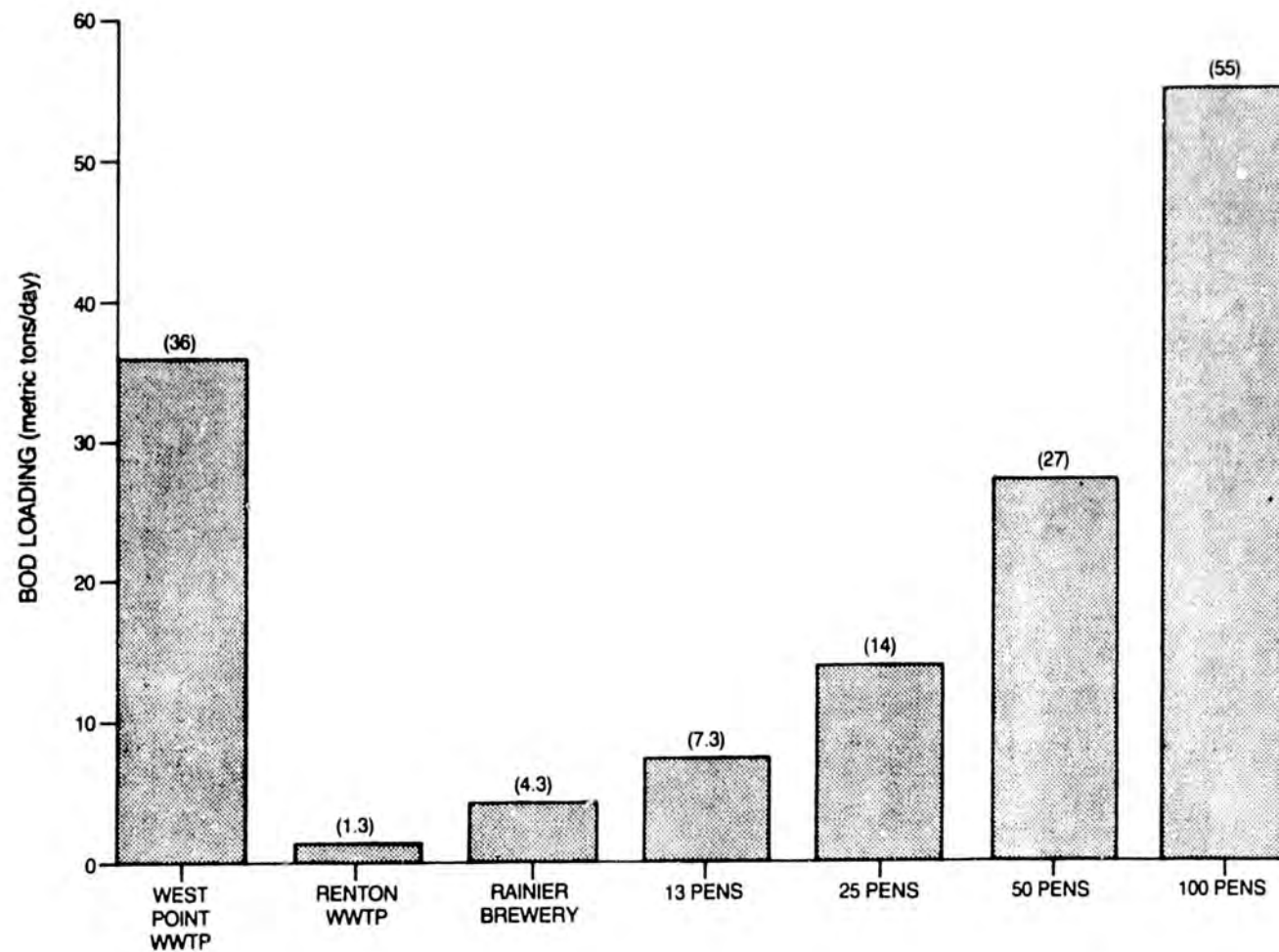


Figure 26.
BOD loading from West Point and Renton Wastewater Treatment
Plants, Rainier Brewery, and different levels of
net-pen development.