W A S H I N G T O N S T A T E

Potential Offshore Finfish Aquaculture in the State of Washington

Technical Report
Aquatic Resources Division
May 1999

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Jennifer M. Belcher - Commissioner of Public Lands

Acknowledgments

Department of Natural Resources
Jennifer M. Belcher, Commissioner of Public Lands

Core Net Pen Project Team
Ron Teissere, Assistant Division Manager, Aquatic Resources
Candis Ladenburg, DNR Intern, Aquatic Resources
Susan Sturges, DNR Intern, Aquatic Resources
Elizabeth Eberle, Cartographer, Engineering
Elizabeth Lanzer, Computer Information Consultant, Aquatic Resources

Aquatic Resources Division
Maria Peeler, Division Manager
Randy Acker, (Acting) Division Manager
Lisa Randlette, Environmental Planner
Tom Mumford, Scientist
Helen Berry, Scientist
Amy Sewell, Scientist
Martha Murrah, Cartographer
David Palazzi, Environmental Planner
Lee Stilson, Environmental Planner
Jim Thomas, Engineering Aide
Mary Morris, Secretary Senior

Northwest Region
Steve Jennison, Region Division Manager

Communications Product Development
Billi, Manager

Other Contributors
Debbie Barnes, Clallam County Department of Community Development
Harriet Beale, Jefferson County Department of Community Development
John Forster, Aquaculture Business Consultant
Jim Castle, Makah Fisheries Management
Lisa Veneroso, Point No Point Treaty Council
Mel Stanley, Washington Department of Fish and Wildlife
Greg Bargman, Washington Department of Fish and Wildlife
Steve Boessow, Washington Department of Fish and Wildlife
Sidney Stillwaugh, National Oceanic and Atmospheric Administration
Terry Nosho, Washington Sea Grant Program
Tom Croker, Ocean Spar Technologies
Kevin Bright, Scan Am Fish Farms
Helen Cooper, Irish Sea Fisheries Board

Cover Photograph
Shoreline along the Strait of Juan de Fuca at Slip Point
Photograph taken by Coastal and Ocean Resource, Inc.
Courtesy of the Habitat Section, Aquatic Resources Division

W A S H I N G T O N   S T A T E

Potential Offshore Finfish Aquaculture in the State of Washington

Technical Report
Aquatic Resources Division
May 1999

by
Candis Ladenburg
and Susan Sturges

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Jennifer M. Belcher - Commissioner of Public Lands

Acronyms

BCEAO	British Columbia Environmental Assessment Office
BIM	Bord Iascaigh Mhara
C.C.C.	Clallam County Code
CFR	Code of Federal Regulation
Corps.	U. S. Army Corps. of Engineers
CWA	U. S. Clean Water Act
DNR	Washington State Department of Natural Resources
DOH	Washington State Department of Health
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	U.S. Endangered Species Act
GIS	Geographic Information Systems
GMA	Growth Management Act
JARPA	Joint Aquatic Resource Permits Application
MLLW	Mean Lower Low Water
MT	Metric Ton
NOAA	National Oceanic and Atmospheric Administration
NOS	National Oceanic Service
NPDES	National Pollution Discharge Elimination System
NTU	Nephelometric Turbity Unit
NWFSC	Northwest Fisheries Science Center
PMEL	Pacific Marine Environmental Lab
RCW	Revised Code of Washington
RPAM	Resource Planning and Asset Management Division, DNR
SEPA	State Environmental Protection Act
SMA	Shoreline Management Act
USC	U.S. Code
USGS	U.S. Geological Service
WAC	Washington Administration Code
WDF	Washington Department of Fisheries (now known as WDFW)
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington State Department of Ecology

Contents

List of Tables

Introduction

Washington State Department of Natural Resources (DNR) was provided a general fund appropriation to study potential finfish net pen aquaculture sites in the Strait of Juan de Fuca and along the Pacific coast. Atlantic salmon was the cultured species included in our study.

The primary focus of this project involved compiling existing data to determine conflicts and restrictions that may be encountered in siting net pens in offshore and exposed areas. Currently, all commercial net pens in Washington are located within embayments or the protected waters of Puget Sound. Restrictions were obtained from local, state, and federal permits, management plans, and ordinances. Land-use, environmental, and water-use conflicts were identified. Study area characteristics, available offshore farming technology and costs, Atlantic salmon biological requirements, and risks associated with net pens were examined as well.
The integration of geographic information systems (GIS) with offshore farming was used to simply flag conflicts and restrictions and was not intended to be used as a primary planning tool. Most of the data collected are snapshots of what was available to date, dynamic in nature, and does not necessarily reflect conflicts that may be encountered in the future. Some data was limited and would need to be collected prior to site selection. This document and GIS generated maps should instead be used as a window to examine commercial opportunities, obstacles, and decisions to consider should one decide to pursue offshore farming in Washington State. Actually siting an offshore farm will require further evaluation of the data inventoried, a thorough cost analysis, and additional site information.

Study Area Description

The study area is defined by the marine waters of Jefferson and Clallam counties, but does not include the marine waters of South Puget Sound. The major water bodies include the Pacific Ocean, from Cape Flattery south to the northernmost area of the Quinault reservation, and the Strait of Juan de Fuca, from Cape Flattery east to Point Wilson. The Pacific coast is a national marine sanctuary, managed by Olympic National Park, and consists of Tribal land. The Makah reservation is on the northernmost tip, while the Ozette and Quileute reservations are along the coast in Clallam County. The Hoh reservation is in western Jefferson County, and the Quinault reservation is on the southern tip of the study area.

The northern coast is sparsely populated and remains largely unaltered with no large estuaries, good harbors, or industrial sites. The Pacific currents set toward the north in winter and south in summer. Summer currents (described as cold, high in salinity, low in oxygen content, and nutrient rich) are associated with surface water offshore movement resulting in an upwelling of water from lower depths. Such conditions are biologically significant in triggering blooms of marine plant life (Washington Department of Ecology (WDOE) 1978).

The Strait of Juan de Fuca is less sheltered than southern Puget Sound, but is more protected than offshore areas along the Pacific coast. The Strait is a U-shaped estuary which is approximately 100 miles long and has a surface area of 2,300 square miles with a mean depth of 656 feet (Thomson 1994). The Strait has seasonal extremes that are relatively small with vertically well-mixed water. The tidal currents are strongly influenced by tidal range and strong winds (National Oceanographic and Atmospheric Administration (NOAA) 1997).

The Strait of Juan de Fuca has been proposed as a potential area for offshore farming and has been tested with submersible cage technology near Whiskey Creek (Forster et al. 1995). Several factors initiated the proposal and trial. The Strait has great tidal circulation and inflow of ocean water, and is partially exposed with extended periods of favorable weather. Overall, the Olympic Peninsula has access to both infrastructure and markets, with a close proximity to Seattle. A seafood processing industry, expertise and history of aquaculture, and a shipping industry already exist in the region (Forster et al. 1995). The western portion has stretches of unpopulated or minimally populated shorelines. Jobs and revenue from farm-supporting services would be an economic benefit for the counties or Tribal communities, especially following recent timber and fishing industry declines.

The shift of the industry to offshore farming has surfaced for several reasons. Sheltered site locations are limited by:

- Topographical and bathymetric constraints
- Environmental conditions
- Availability
- Costs
- Legal-political factors for large-scale farms

New large-scale aquaculture in the U.S. is difficult in coastal waters unless exposed areas are utilized. Europe and Japan also have limited sites available. Underdeveloped countries with sheltered coasts have higher shipping costs since they are further away from markets (Willinsky and Huguenin 1996).

Salmon Farming in Washington and Worldwide

Salmon Farming in Washington

Salmon aquaculture facilities have been cultivating coho and Atlantic salmon in Washington since the 1970's (Washington Department of Fisheries (WDF); now known as Washington Department of Fish and Wildlife (WDFW) 1990). Presently, two companies farm Atlantic salmon and collectively, produce more than 12 million pounds of Atlantic salmon per year in Washington (Stanley 1998). This is about two percent of the salmon farmed worldwide (Forster 1995).

Worldwide Salmon Aquaculture

Farmed salmon production showed a steady increase from 1984 to 1992, and between 1988 and 1995 production increased by over 400,000 tons worldwide. Salmon farms now produce about one third of the world's total annual salmon harvest, and the United Nations Food and Agriculture Organization estimates aquaculture will provide about 35 percent of the total world fish supply for human consumption by the year 2010 (British Columbia Environmental Assessment Office (BCEAO) 1997).

Atlantic salmon is the species most commonly farmed, due to the market preferences and cost advantages (BCEAO 1997), and makes up nearly all salmon production in Norway, Scotland, Canada, and about 40 percent of the total in Chile (Forster 1995). The largest Atlantic salmon producers in the industry are Norway, Chile, and the United Kingdom. In 1995, the combined output of these countries comprised 80 percent of the world production of farmed salmon (see Appendix A) (BCEAO 1997).

Legal Framework

Laws and Regulations

Commercial aquaculture in Washington has an extensive list of statutes, regulations, and permits. Generally, aquaculture-related laws can be subdivided into three governed areas (see Table 1 and Appendix B):

- The environment
- The public and property owners
- Aquatic lands

Environmental concerns include impacts the farm would have on surrounding species and habitat, shorelines, and water quality. County development growth, aquaculture promotion, and multiple-use areas of state-owned land and water are points of interest which would reflect on public residences, businesses, the economy, and recreation. State-owned aquatic lands need to have a balance between public benefit and preference to water-dependent users.

Table 1. Aquaculture-related Statutes and Laws

Environmental Protection	
State Environmental Policy Act (SEPA) RCW 43.21C WAC 197-11	Requires proof the proposed facility will not have a significant adverse environmental and social impacts through completion of an environmental checklist prior to state or local approval. An environmental impact statement may be required if there are probable significant environmental impacts.
Shoreline Management Act (SMA) 1971 RCW 90.58	Protects shorelines and assures orderly development.
Clean Water Act (CWA) Section 401; WAC 173-225	Protects water quality.
Governing the Public	
Growth Management Act (GMA) RCW 36.70	Outlines land-use planning and regulates development in response to rapid growth challenges.
Aquaculture Marketing Act 1994 RCW 15.85.010	Encourages the promotion of aquaculture activities and programs since aquatic farming provides a consistent source of quality food, new job opportunities, farm income stability and improves balance of trade, and many Washington areas are scientifically and biologically suitable for it.
Multiple Use Concept in Management and Administration of State-owned Lands 1971, RCW 79.68.080	Requires Department of Natural Resources (DNR) to allow both commercial and recreational use of state-owned land and water for the production of food, fiber, income, and public enjoyment.
Aquatic Lands	
Aquatic Lands Act 1984 RCW 79.90	Requires DNR to work toward providing a balance of public benefits concerning state-owned aquatic lands.
Aquatic Lands Management WAC 332-30	Gives water-dependent users preference over other uses of aquatic lands.

(Stilson 1996)

County Comprehensive Plans

Used as a growth and development guide, county comprehensive plans are followed by officials, developers, and citizens for decision making. Aquaculture activities, depending on the county, are regulated by comprehensive plans to varying degrees.

The Clallam County-wide Comprehensive Plan (1996) expresses that the county will preserve shorelines, have land-use practices that protect habitat and wildlife, and prevent an impact on threatened or endangered salmon and steelhead stocks. Clallam County also encourages aquaculture and shellfish industry growth as an economic development goal. Clallam County has four regional comprehensive plans (of which, the following three cover our study area) including the Sequim-Dungeness Regional Plan (1995), Port Angeles Regional Plan (1995), and Straits Regional Plan (1995). Within these three plans are specifics on areas of concern for protection and details on aquaculture (see Appendix C).

The Jefferson County-wide Comprehensive Plan (1998) is less detailed than the Clallam County plan with regard to aquaculture. Net pens are not designated resource lands under their plan and are controlled under aquaculture activities regulations. Jefferson County's plan lists county critical areas such as historical and cultural resources, along with land-use patterns, which are important for site selection. The plan references their shoreline management plan for aquaculture.

Harbor Improvement Schemes

Siting an aquatic farm in a harbor would require examination of any guidelines and recommendations within a harbor improvement scheme. Clallam and Jefferson counties contain two large harbors, Port Angeles Harbor and Port Townsend Harbor, respectively. The Port Angeles Harbor Resource Management Plan (1989) expresses the harbor has the potential for an increase in aquaculture development. Two areas within the harbor are recommended as sites (see Plan for subareas) (Port Angeles 1989):

- Subareas 5, 6, and 7 along Ediz Hook
- Subareas 7 and 8 on the south side of the hook near the U.S. Coast Guard station entrance

A salmon farm currently operates in Port Angeles Harbor along Ediz Hook. Port Townsend does not have a harbor management plan, but instead, is specifically included in the Jefferson Shoreline Management Program.

Shoreline (Management) Master Programs

Shoreline programs outline goals and policies, including critical area ordinances, to be used by the county and followed by shoreline developers. They are designed to preserve natural environments and dynamic processes while allowing uses deemed essential for citizens that can coexist with minimal impact. Shoreline programs were developed as a result of the Shoreline Management Act. Natural, cultural, or historical characteristics and land-use patterns are inventoried within them.

Developmental restrictions can be found in them as well, such as (see Appendix C) (Clallam County Shoreline Advisory Committee 1992 and Jefferson County Planning Department):

- Important species habitats, conflicting use areas, and shipping lanes to be avoided or minimized
- Operational and design requirements

Both Clallam and Jefferson counties (beginning 9/1/98 for Jefferson County (Beale 1998)) are currently in the process of shoreline plan revisions for consistency with comprehensive plans.

Net Pen Guidelines and Permits

State net pen siting and operational guidelines are found in the Final Programmatic Environmental Impact Statement (EIS): Fish Culture in Floating Net Pens (1990). Prior to the completion of the EIS, the Recommended Interim Guidelines for the Management of Salmon Net-pen Culture in Puget Sound (1986) were initially intended to avoid significant adverse environmental effects from permitted net pens. Environmental protection was provided by the Interim Guidelines, but social, economic, aesthetic, and user conflicts were not addressed (WDOE 1986). Criteria in the Interim Guidelines is still referred to by the EIS and some county shoreline programs.

The EIS evaluated environmental impacts under two alternatives (WDF 1990):

- No-action, using existing regulations and guidelines
- Preferred alternative, using existing regulations to evaluate impacts with recommendations for expanded regulations, additional information, and scientific research

The EIS was designed to be non-project and not site-specific. By compiling existing knowledge regarding significant environmental impacts and identifying areas that need further information, the EIS assists state and local decision-makers in farm proposals.

Restrictions are outlined in both the EIS and the Interim Guidelines that will need to be considered when siting a farm (see Appendix D). The EIS covers depth and current requirements, water quality, and potential species impacts. The EIS recommends abiding by the depth and current restrictions given in the Interim Guidelines (see Table 2). The water quality restrictions are adopted from WAC 173-201A. Habitats are also protected by buffering distances given in the EIS, which were initially outlined in the Interim Guidelines (see Appendix D).

Table 2. Minimum Depth and Current Guidelines for Net Pen Siting

Class	Class size description	Minimum depths and current velocity
Class I	Production up to 20,000 pounds per year (9,072 kg per year)	Minimum depth of 35 feet for a current velocity of 5 cm/sec (0.1 knots) to a minimum depth of 20 feet for current velocities of 40 cm/sec (0.8 knots) or greater
Class II	Production between 20,000 to 100,000 pounds per year (9,072 to 45,360 kg per year)	Minimum depth of 45 feet for a current velocity of 5 cm/sec (.01 knots) to a minimum depth of 25 feet for current velocities of 50 cm/sec (1.0 knots) or greater
Class III	Production over 100,000 pounds per year (45,360 kg per year)	Minimum depth of 60 feet for a current velocity of 5 cm/sec (0.1 knots) to a minimum depth of 40 feet for current velocities of 50 cm/sec (1.0 knots) or greater

(Source: WDOE 1986)

Several local, state, and federal permits are required for net pen operations (see Table 3). The process can be complex, but attempts have been made to simplify it. The Joint Aquatic Resource Permits Application (JARPA) was designed to streamline the permitting process for aquatic projects by having a uniform application for several permits. It is a single application, and a copy is sent to each agency. The EIS and the Department of Ecology's (WDOE) On-line Permit Handbook are excellent resources for permit information (WDF 1990 and WDOE 1994).

Table 3. Federal, State, and County Permits for Net Pens

Federal Permits	
U.S. Army Corps. of Engineers	Section 10 Permit* Section 404 Permit*
U.S. Coast Guard	Navigational Markings
State Permits	
WA Department of Natural Resources (DNR)	Aquatic Lands Lease*
WA Department of Fish and Wildlife (WDFW)	Hydraulic Project Approval* Finfish Import / Transfer Aquatic Farm Registration
WA Department of Ecology (WDOE)	Statement of Consistency with Coastal Zone Management Act Section 401 Water Quality Certification* Water Quality Standards Modification* NPDES or Waste Discharge Permit (The NPDES or Waste Discharge permit requires a baseline and benthic community diver survey and annual environmental reports (see Appendix D))
County Permit	
Community Development Office	Shoreline Substantial Development Permit*

(*JARPA is used for permits indicated with an asterisk)

Aesthetics and Visual Impacts

Visual quality is an immense concern of citizens neighboring proposed net pen sites. Although individual net pens do not occupy large areas, farms consist of several net pens that may cover several acres. Careful considerations should be taken in siting and design to avoid or minimize public opposition. To date, policies regulating visual impacts do not exist in Washington, but recommendations are given in the EIS and county shoreline programs to minimize visual impacts.

The EIS suggests distances and design features to minimize visual impact. At least 1,500 to 2,000 feet is recommended for offshore distance from areas adjacent to culturally modified landscapes (preferably those with commercial and industrial maritime activity), rural or uninhabited shorelines, low banks, and open shorelines (WDF 1990). The farm should be horizontal in profile and designed to appear as docks or marinas. The farm should be limited in size and surface coverage so it occupies less than ten percent of normal cone vision. The pens should also compliment the blue/green color of water, and be of limited variations in material and color (WDF 1990).

The visual impact a farm will have on its surroundings differs from site to site. Farmers should refer to county shoreline programs for local visual quality recommendations and keep in mind that they may or may not apply to exposed and offshore locations since farms are traditionally sited inshore.

Offshore Farm Technology

Background and Review

Before discussing available cage technology, the differences of sheltered, exposed, and offshore sites need to be reviewed. Sheltered sites are typically large bays with protection on two or more sides. Exposed sites are partially sheltered, while offshore areas have little protection (Willinsky and Huguenin 1996).

Even with high tidal circulation, the same body of water may be returning on the next tide, so circulation does not always equate with flushing (important with large-scale siting) for sheltered areas, and inadequate flushing is a possibility. Weather extremes can vary water quality and stimulate fish culture problems such as ice in cold winters, triggered algal blooms in hot summers, or stir-ups of sediment in sudden high rainfall. The most severe environmental forces come from storm-induced tidal currents (Willinsky and Huguenin 1996). Coastal activities (recreational, commercial, and residential) tend to concentrate in sheltered areas and can be a source of user-conflicts or pollution threats to the farm.

For exposed and offshore sites, water quality is predictable, stable, and better when compared to sheltered areas. The tidal currents tend to be lower with better, more consistent circulation and flushing. Generally, fewer coastal activities occur in these areas that may cause conflicts, since they tend to be more isolated than sheltered areas. Indications of reduced mortality and higher quality fish have been shown. Storm-induced wave forces dominate in these areas which can be problematic to farms (Willinsky and Huguenin 1996).

Offshore farming has potential benefits. Landowner conflicts may be avoided. Competition with other water-users may be reduced. High volumes of quality, stable water may reduce stress on fish. Predator interactions may also be reduced. The stress on the coastal environment may be reduced if the nutrient loading is already at or near the carrying capacity of the system. Fewer regulatory and permit requirements are potential (Gustavson 1997). It is also believed that higher currents will result in healthier, faster growing fish (Croker 1998).

Although the benefits of offshore farming are promising, there are disadvantages to moving the industry to open waters. Larger scale and possibly, more expensive farms may be necessary, depending on the technology. The pen technology would require less vulnerability to storms. Servicing, monitoring, and maintenance methods need to be revised for offshore systems since operating logistics are more difficult than inshore sites. Knowledge and ability to culture candidate species may not be complete (although literature on Atlantic salmon is quite extensive). Uncertainty exists in leases, regulations, and permits for offshore sites. Government policy, government assistance, and necessary financing are generally lacking. Finally, there is a potential increase in vessel collisions (Gustavson 1997).

Offshore farming has been explored in West Ireland for ten years by two companies using Bridgestone and Dunlop cages in oceanic conditions (an average of 23 foot wave heights, constant wave action, and 26 cm/sec (½ knot) currents) (Croker 1998). The Irish state agency, Bord Iascaigh Mhara (BIM), has grant funded this technology in order to move the farming industry from inshore sites where seatrout populations, other environmental issues, and visual impacts have caused concerns. These concerns have made it difficult for Ireland to remain competitive in the market. Offshore technology is viewed as a potential answer. Since it is accepted that conventional gravity cages (such as Bridgestone or Dunlop) move in currents, Ireland is moving toward submersible technology through Ocean Spar cages. Benefits of a constant volume cage are extensive if the technology can be demonstrated successfully (Cooper 1998).

To date, there are no large-scale producing farms in offshore sites although there is potential for growth as the technology improves and inshore sites become more limited. Ireland and Eastern Canada are no longer allowing permits for inshore sites (Croker 1998). Attempts are being made worldwide for offshore and exposed farming. The Strait of Juan de Fuca, the Mediterranean, and Asia have been tried. New Brunswick, with currents as strong as the Whiskey Creek area in the Strait of Juan de Fuca, and Nova Scotia, with a 28 foot tidal variance, in Eastern Canada have been attempted. Work is also being done in the Gulf of Mexico testing the use of abandoned oil platforms as bases for offshore farms. Norway, the largest farmed salmon producer, and Scotland are still farming in fjords using traditional cages (Croker 1998).

Offshore Systems

Offshore technology can generally be divided into three system descriptions (Willinsky and Huguenin 1996):

- Bottom-mounted submerged cages and barrier systems
- Surface operated, bottom-moored cages
- Surface operated, moored, and mobile

The most extensive review of available offshore finfish farming technology is currently found in The Salmon Aquaculture Review Final Report of the British Columbia Environmental Assessment Office (1997) and Open Ocean Aquaculture (1996).

Bottom-mounted submerged cages are protected from storm forces, but the water current buffer between the cage and benthos is removed, hindering sediment and waste dispersal. Difficult operational conditions exist and these cages may not be ideal for salmonids since they need access to surface air. Barrier systems avoid storm forces and have considerable potential since they are bottom-based, but are futuristic and largely untested (Willinsky and Huguenin 1996).

Surface operated, bottom-moored cages include nested cages, large single cages (surface or semi-submersible), and fully submersible cages. Nested cages include semi-rigid float collars. Operational benefits include the close proximity of the units simplifying operations and established management methods for this type of technology. There have been problems with downstream shadowing (self-pollution) and these cages are considered high maintenance. Their uses in exposed sites have had a history of structural failures as well. Large single cages have the benefit of isolating cage problems so as to not impact neighboring cages. High currents can cause volume loss and fish may wash out from the top. The large cage sizes and distances between cages can complicate operations, and storm survival issues have brought about engineering problems. There has been a history of failures, but surface cages remain the most common approach to exposed site designs. Fully submersible cages avoid storm forces, but have separation and size complications as well. The cage design also needs to accommodate the salmonids' need to access surface air. There have been engineering problems, but there is extensive experience with these cages in Japan and China (Willinsky and Huguenin 1996).

The third system is represented by the barge or ship system. Although there is the advantage of being mobile and being based on known naval architectural principles, the system is costly (a barge system was estimated at $9.9 million in 1991) and needs to be of immense size (Willinsky and Huguenin 1996).

The following information represents a sampling of available sea cages and is not exhaustive. Specific attention should be paid to servicing and operational needs, which are just as important as the initial cage purchase. Each cage has different requirements, and these details should assist in system selection.

Submersible Cages

Ocean Spar Technologies is based locally in Washington. Ocean Spar currently has cages in higher energy areas including Cypress (the Mediterranean), Mexico, Eastern Canada, and soon, as previously mentioned, the west coast of Ireland (Croker 1998). Two designs by Ocean Spar can be used for Atlantic salmon: Ocean Spar Sea Cage and Ocean Spar Sea Station. The Sea Cage can handle tidal currents of 1.75 m/s (3+ knots). The Whiskey Creek trial suggested wave height tolerances of up to 12 m (39 feet) for a 5000 cubic meter cage. Siting is currently constrained by a maximum anchoring depth within access to divers (approximately 115 feet), although greater depths are possible with available and appropriate service support. It has been estimated that a 30,000 cubic meter volume can be accommodated by one cage (at a stocking density of 20 kg/cubic meter, it accommodates 600 metric tons (MT) of fish). A 4,800 cubic meter cage can handle stocking densities of 50 to 75 kg/cubic meter. These cages have taut nets, which provide excellent predator protection. Since the cages lack walkways, servicing is done from boats.

The most exposed site so far was located one mile offshore in the Strait of Juan de Fuca (15 miles west of Port Angeles near Whiskey Creek). The Sea Cage has weathered a 50 and 100 year storm without damage of stock loss in the Strait as well (Ocean Spar Technologies 1998). The Sea Station can handle tidal currents in excess of 1 m/s (2 knots) and wave heights over 7 m (23 feet). A typical cage has an 89 m (292 feet) rim and a 15 m (49 feet) cage depth. Volumes are limited, extending to 5000 cubic meters with present technology, but there are hopes to reach 20,000 cubic meters (Ocean Spar Technologies 1998). The Sea Cage has a self-supporting structure. Free floating Sea Station farms in cyclic tidal currents or setting the cages adrift in high current periods are futuristic concepts that may take advantage of its self-supporting structure (Polk 1996).

The Trident Submersible Self-Cleaning Sea Cage also has taut nets. Tidal currents up to 3.0 m/s (6 knots) and 6 m (20 feet) wave heights can be handled when the cage is surfaced. The cage is a 12 m (39 feet) sphere, although larger designs are possible. Also, an ellipsoidal structure can be designed (7,500 cubic meters with 20 X 30 m dimensions. In 1992, a cage was exposed to a severe storm with wind speeds of 19 to 75 miles/hr (16 to 65 knots) and breaking waves greater than 3.5 m (12 feet) while surfaced and was not damaged (Willinsky and Huguenin 1996). Although an impressive design, larger cages have not been tested, and scaling up becomes expensive (Forster 1998).

The Sadco-Shelf Submersible Cage technology comes from Russia. It can handle tidal currents of up to 1.5 m/s (3 knots) and 2 m (7 feet) wave heights in floating position, and wave heights of 15 m (49 feet) can be tolerated while submerged. Water depths between 15 and 80 m (49 and 262 feet) have been tested and are dependent on specific site limitations. The Sadco-Shelf Cage has been developed up to a volume of 4,000 cubic meters in capacity with salmon rearing densities up to 26 kg/cubic meter. Sites have been located up to 50 miles offshore (Polk 1996). Operating in offshore sites since 1985, Sadco-Shelf advertises to be the only, truly underwater fish farming system in the world proven for extreme weather conditions (Gustavson 1997).

Semi-submersible Cage

The Farmocean Offshore system operates semi-submerged with a pontoon 3 m (10 feet) below the water surface. The upper work platform and feeding silo are located approximately 3 m (10 feet) above the water surface. Maximum tidal currents of 2 to 2.5 m/s (4 to 5 knots) and 5.5 m (18 feet) wave heights can be handled by the cage. The Farmocean system has been shown to occasionally withstand waves in excess of 10 m (33 feet) in combination with 23 to 26 feet tides. Maximum wind speeds of 68 knots and a water depth minimum of 25 m (82 feet) are other restrictions of the cage (Gustavson 1997), and it is recommended to have a stocking density of 20 kg/cubic meters. The cage has a diameter of 20 m, weighs 20 MT, and is available in 4 sizes: 2,500, 3,500, 4,500, and 6,000 cubic meters (Olbing 1998).

Floating Net Cages

Floating net cages are the most common systems attempted in exposed and offshore sites, although there have been several problems with these cages in such areas. Structural strength and endurance are limited and have increased risks of structural fatigue and wave impacts due to the surface dependency of the cages (Gustavson 1997). Bridgestone and Stolt Sea Farms tested a floating net cage in the Strait of Juan de Fuca a few years ago and concluded the nets deformed too much from the currents to be workable (Forster 1998). These cages, also referred to as gravity cages, can lose up to 90 percent of their volume in 1 m/s (2 knots) of current, which is a typical velocity in the Strait of Juan de Fuca (Croker 1998). Operational limitations and worker safety are other issues to consider (Gustavson 1997). The technology does have a high failure risk for the study area due to the strong currents that are characteristic of the Strait of Juan de Fuca (Forster 1998). Since this system is the most commonly used, the following cages are described.

The Bridgestone Hi-Seas Cage is one of the first cages to be used in offshore locations. The Bridgestone design is a floating cage with a flexible rubber collar support designed to ride the waves. The cage has been known to withstand typhoon conditions with up to 10 m (33 feet) wave heights. Water depths of greater than 82 feet are required for site location. Square, octagonal, or hexagonal designs with 16 to 20 m standard side lengths are available (other lengths are available as well). The cage covers 2,000 square meters (about 4 square miles) of surface area and can have up to 160 m for a circumference. Nets can be 15 to 40 m (49 to 131 feet) deep, while most are 15 and 20 m (49 and 66 feet) deep. The production capacity of a 16 m octagonal, 20 m (66 feet) deep cage is at least 500 MT of fish. Stocking densities are recommended to be 12-20 kg/cubic meter with a maximum of 30 kg/cubic meter recorded, dependent on culture species. A half hour motor vessel steaming time is recommended for proximity to a service harbor (Gustavson 1997).

Unlike the Bridgestone cage, the Offshore Octagon Cage system is constructed of steel. Tidal currents must be less than 2 m/s (4 knots) otherwise the containment net will bag and smother the fish. A 20 foot swell is less dangerous for the Octagon Cage than a ten foot confused chop (Fox 1998). The Octagon Cage has a 25 m diameter, weighs 30,000 to 40,000 lbs, and the net is 40 feet deep. Based on the industry standard stocking density of 18 kg/cubic meters, the cage holds about 23,000 salmon of 4 kg weight each (Fox 1998).

The Aquasure Cage is a PolarCirkel type, polyethylene cage made in British Columbia. Wave heights up to 8 m (26 feet) can be tolerated by this cage. A 50 m diameter cage is available for salmon culture, and there is a 40 m diameter cage in development (Gustavson 1998).

Capital Costs

An economic analysis was not attempted due to site specificity, budget and time constraints, and data unavailability. A complete economic analysis would be best suited in a follow-up study. Capital costs can vary and depend on technology, site location, operation size, and proximity to land access.

Capital costs include facility equipment such as cages (see Table 4), nets, moorings, anti-predator devices or nets, a feeding and storage system, and generators. Communication systems, computers, boats, and lab equipment are also costs to consider. Other start-up costs involve leases, permit fees, and environmental and water quality surveys.

Table 4. Pricing of Various Offshore Cages

Cage	Cost
Submersible	
Ocean Spar	**Sea Cage** US $15 to $25 per cubic meter **Sea Station** US $ 25 per cubic meter for a 3,000 cubic meter system (excluding mooring)
Trident Submersible Self-cleaning Sea Cage	No cost information could be obtained
Sadco-Shelf	Generally not available, and must be based on site-specific data and system to be used
Semi-Submersible	
Farmocean Offshore System	US $524,000 for Farmocean 4500 cage
Floating Net Cages	
Bridgestone Hi-Seas Cage	Begin at US $150,000 (frame, nets, and moorings)
Offshore Octagon Cage System	US $170,000 plus freight to Washington (25 m steel cage, containment net, bird/seal net, anchors, chains, shackles, and anchor lines)
Aquasure Cage	US $24,000 for 30 m cage

Farm Operational and Production Costs

Infrastructure and land access are essential for offshore farm servicing and fish transport. Due to limited road access to shorelines, options are limited to existing boat launches or marinas. Although the eastern portion of the Strait of Juan de Fuca has better infrastructure, land and water-user conflicts are more likely due to a larger population. Eastern ports include Port Angeles Harbor, Port Townsend Harbor, Sequim Bay, and Discovery Bay. The western portion of the Strait of Juan de Fuca is less populated and has three ports: Neah Bay, Sekiu, and Clallam Bay.

Operational costs include equipment maintenance, fish husbandry, fish harvesting, staffing, insurance, and environmental monitoring. Monitoring is required for annual survey compliance and also necessary for water quality protection and avoiding algal blooms.

Alternative Finfish Farm Technology

Public concerns of environmental impacts have prompted net pen alternatives. Recirculation (using recycled water) or the use of a filtering system are alternative principles to open systems that utilize water currents to disperse fish wastes. Closed systems are divided into two categories:

- Closed circulating marine systems
- Land-based saltwater systems

For the purposes of this project, current alternative technology would not be viable in the study area due to siting constraints and is simply reviewed for completeness. The benefit of closed systems include being able to control the environment of cultured fish and reduce predation. There is also the potential to reduce impacts to the surrounding environment (Gustavson 1997).

Two types of cages are categorized as closed circulating marine systems. The closed-wall cage resembles the traditional cage but has impermeable walls and a pump; however, it is still a flow-through system. The second is the floating raceway, which is a variation of the closed-wall cage and designed to improve water flow. Metabolic and organic waste treatment is still under development. Cages are also restricted to sheltered areas due to sensitivity to current and wave forces. The start-up costs are more than twice that of sea cages. Bags cost six to seven times more than the standard nets. In order to make up for this cost difference, fish stocking densities need to be much higher. These systems also do not address the visual impact issue. In addition to the cage system, on-site housing is needed for equipment, generators, and employee work areas (Gustavson 1997).

Land-based saltwater systems have restrictive siting requirements. They need to be sited on a relatively large, flat shore which steeply declines for pump and pipe water access at a minimum distance. This system is very infrastructure dependent, where capital and operating costs, such as energy costs, are quite high. The shoreline location makes the initial land costs more expensive. Also, environmental conflicts would continue if recirculation and treatment technology is not applied (most current technology is experimental) (Gustavson 1997).

Biological Requirements of Atlantic Salmon

It is important to have an understanding of the physical and chemical parameters of the water environment, the needs of the fish, and to possess the skills necessary to provide a suitable environment in order for the venture to be successful. The focus is on the major factors and is not intended to be exhaustive. The physical, chemical, and biological parameters are interrelated and affect every aspect of fish culture (Lawson 1995).

Temperature

The ability to ward off diseases, and thus, the probability for culture success, is best near the optimum growth temperature. Temperatures on either side of optimum induce stress, which affects feeding, growth, reproduction, and disease inhibition (Lawson). The optimum temperature for Atlantic salmon is between 10°C to 15°C (Beveridge 1996), although they can survive in temperatures from 5°C to 19°C. Adults can even grow in temperatures as low as 2°C (Danie 1984).

Dissolved Oxygen

Dissolved oxygen, along with temperature, controls the metabolism of fish. Fish oxygen-consumption rates vary with water temperature, dissolved oxygen concentration, fish size, activity level, time after feeding, and other factors (Lawson 1995). Generally, a dissolved oxygen level greater than 7 mg/L is required, and the optimal range is between 9 and 10 mg/L (Beveridge 1996).

Salinity

The salinity of the water affects the fish's ability to regulate the concentration of dissolved salts in their body fluids (osmoregulation), and changes in salinity can result in physiological problems. The general tolerance range is between 15 and 35 percent, and the optimum level is greater than 24 percent (Beveridge 1996).

pH

Due to the buffering capacity of the oceans, the mean pH of ocean surface water remains fairly constant (Lawson 1995). The pH level in a farm environment should not fall below 5.0 or exceed 9.0, but the optimum range for Atlantic salmon is between 6.5 and 8.5 (Brown 1993).

Alkalinity

The higher the alkalinity measure, the more stable the water is against pH changes (Lawson). Because seawater has a mean total alkalinity of about 116 mg/L, it is rarely of concern in seawater aquaculture systems, but is recommended to be between 100 to 200 mg/L for fish rearing (Wedemeyer 1996).

Depth

While previously mentioned as an environmental concern, there is also a minimum depth requirement for the well being of the fish. The optimum minimal depth beneath where the fish are being held is between 20 and 49 feet (Beveridge 1996).

Current

Atlantic salmon also have a minimum current requirement of 5 cm/sec (or 0.1 knots) (Beveridge 1996). If current velocity falls below this, fish may be faced with dissolved oxygen depletion, nutrient loading, and conditions conducive to phytoplankton blooms. The average current over a site should not exceed 500 cm/sec (Sedgwick 1988). In high currents fish become exhausted from swimming against the current, and are then prone to stress related problems such as disease.

Characteristics of the Strait of Juan de Fuca

To successfully site an operation in the Strait of Juan de Fuca, it is important to know something about the area and water itself. For many of the characteristics, comprehensive coverage is scarce, but data was collected at several points within the Strait. Surface temperatures were available at three locations (see Table 5).

Table 5. Average Surface Water Temperatures for Select Areas of the Strait

Location	Average Low Temperature	Average High Temperature
Neah Bay	7.2°C	11.7°C
Port Angeles	7.0°C	12.2°C
Port Townsend	7.0°C	12.2°C

Data from the Neah Bay site was collected over 25 years, the data from Port Angeles was collected over two years, and the data from Port Townsend was collected over three years (Lilly 1983).

Currents

Currents within the Strait of Juan de Fuca may attain velocities of 1 to 2 m/s (2 to 4 knots) which are influenced by winds and vary with the tide range (The Tide Current Tables can give detailed predictions for currents and wave heights) (NOS 1998). Race Rocks and Discovery Island may have velocities higher than 3 m/s (6 knots). Flood current velocity is greater on the north shore of the Strait than on the south. The ebb current is stronger along the south shore of the Strait, and between New Dungeness Lighthouse and Crescent Bay (south and west) during large tides. Tide rips occur off the prominent points and in bank vicinities, and are particularly heavy at Cape Flattery, Race Rocks, Dungeness Spit, and Point Wilson. The Strait also has an average 14 foot tidal variance (NOAA 1997).

Wind

Winds are the strongest and gales are more frequent on the west end of the Strait. During the winter season (October through March), gales blow on four to six days per month, averaging 18 knots, and during the summer season (April through September), winds can reach up to 30 knots (see Table 6).

Table 6. Average Wind Speed

Location	Winter Months	Summer Months
Tatoosh Island	16.6 knots	8.7 knots
Port Angeles	7.7 knots	10.5 knots

(Source: (Lilly 1983) Data from Tatoosh Island was collected over 63 years, and the data from Port Angeles was collected over 4 years.)

Wave Heights

It was difficult to obtain information on wave heights, as it is only routinely measured at a few stations. However, it is important to mention wave heights to know what forces farm technology must be able to withstand. The following are calculated predictions (which do not include storm conditions) and are reported in percentages for wave height ranges of .5 to 2 feet, 2 to 4 feet, and greater than 4 feet (WDOE 1978). A higher percentage of the occurrences fell into the .5 to 2 feet range throughout the Strait, but ranges of 2 to 4 feet wave heights are almost as common. Areas of the Strait where wave heights may exceed 4 feet are: east of Siebert Creek, the tip of Ediz Hook, the mouth of Morse Creek, between the Elwah reservation and Freshwater Bay, east of Crescent Bay to Nelson Creek, the mouth of East Twin River, Pillar Point, Slip Point, Eastern Clallam Bay, Kydaka Point, and the mouth of Bullman Creek.

Salinity

The salinity in the Strait of Juan de Fuca ranges from about 30 to 33 percent (PMEL 1996). The Strait has relatively small seasonal extremes and is vertically well-mixed, so salinity tends to be consistent at varying depths.

Other Water Properties

There is limited data available for dissolved oxygen, pH, and subsurface current measurements within the study area, so these values will have to be determined on a site-specific basis. An important note to consider: In Washington’s Final 1998 Section 303 (d) list of Impaired and Threatened Surface Waters, Port Angeles Harbor (Water Resource Inventory Area 18) was listed for dissolved oxygen, and Sequim Bay was listed for dissolved oxygen and pH (WDOE 1998).

Conflicts Illustrated Through GIS Data

Geographic Information Systems (GIS) is a computer system capable of displaying and, to varying degrees, analyzing data identified according to their locations. GIS has become a popular tool in landscape and regional planning with more than ten years of development and trials within aquaculture site selection and planning. Environmental, biological, and socioeconomic factors associated with aquaculture can be integrated with GIS (Ross et al. 1993). Obstacles encountered by previous attempts of GIS use in aquaculture planning include:

- scoring and weighing of data in selection criteria
- the need for further research on environmental impacts of aquatic farms
- insufficient data availability which may give misleading GIS results (Beveridge et al. 1994).

Selected data sets display concerns and conflicts for the study area which are outlined in a series of maps (see Appendix E for data sources). For protected resources and areas, buffer zones were used for this project in accordance with environmental policy for the state of Washington, including the State Environmental Policy Act (SEPA), Shoreline Management Act (SMA), and Growth Management Act (GMA). Map information can be provided in digital format upon request. File formats are shapefiles (for use in GIS software), DBase format (.dbf) database tables, and text documentation files, and will be made available on CD-ROM only. Contact the GIS Coordinator, Aquatic Resources Division, Washington Department of Natural Resources to request data.

A bathymetric contour of 90 to 120 feet was chosen as a potentially suitable location for net pens in the Strait of Juan de Fuca and is the focus of this study. This depth is generally far enough away from habitats of special significance, such as kelp and eelgrass beds, that potential impacts are minimized. It is also close enough to shore to be out of the high traffic areas of the shipping lanes. Additionally, this area has better depth and current conditions for minimizing sediment accumulation under the pens, especially for submersible technology that requires deeper water, and might be necessary for farming in offshore locations.

Three categories have been identified to help prioritize the information to be considered when evaluating a site for a salmon farm operation. The first includes areas that are excluded through local, state, or federal restrictions. The second category covers conditional conflicts which are broadly discussed in local and state policy and need to be considered site-specifically. The third includes other potential conflicts with limited regulations or data to base decisions upon without specific project details. In such cases, information will need to be obtained during project planning and permitting.

Restrictive Conditions

The first category identifies locations or areas that are likely to be excluded for any floating aquaculture development. A primary reason behind these restrictions is tied to the protection of the environment and the importance of the sensitive species and their habitats present in the area. These habitats have been identified as critical to the survival of many endangered, threatened, or sensitive species, such as salmon, herring, true cod, marbled murrelets, and other marine birds. Buffering distance requirements are set around such areas through local, state, and federal policy.

The environmental parameters that are protected include:

- Kelp and eelgrass beds
- Large geoduck tracts
- Other shellfish beds
- Baitfish spawning and holding areas
- Seal and sea lion haulout sites
- Other priority habitats and species

Data is available for priority habitats and species, but is not formatted to display information at this project's scale. Some data such as the geoduck tracts and baitfish spawning areas are only shown in a select area of the Strait. This is not to say that they only exist in these locations, but rather, that this is where most of the data collection has been done. For baitfish, commercial geoduck tracts, wildlife refuges, and kelp beds, a 300 foot buffer zone is required by SMA and SEPA policies. Seal and sea lion haulouts are also buffered at 1,500 feet in compliance with environmental policy. In Jefferson County, the mouths of type I and type II rivers and streams have required distance buffer zones (Jefferson County Planning Department 1998). The farmer should also carefully consider federal and state Endangered Species Act (ESA) listings (particularly, current, proposed, salmon listings) that will restrict siting in sensitive areas.

Eelgrass (*Zostera spp.*) and surfgrass (*Phyllospadix spp.*) provide important intertidal habitats. Both are vascular plants commonly and collectively referred to as seagrass, with eelgrass found in muddy and sandy substrates, and surfgrass typically found on rocky bottoms. The language of environmental policy addresses eelgrass bed protection, but we included surfgrass data as well since both provide equally essential habitat for intertidal species. The seagrass data is only available in select areas and as arc segment data (illustrated as line segments along the shoreline, indicating the presence of seagrass somewhere between the shoreline and the 30 foot contour depth). In Puget Sound, eelgrass typically grows in depths up to 30 feet, and just seaward of surfgrass (Thom et al. 1998). The seagrass data were projected out from the arc endpoints seaward to the 30 foot bathymetric contour to form polygons. A buffer of 300 feet was then added in accordance with SMA and SEPA policy.

Shoreline or comprehensive plans will restrict development in culturally or historically sensitive areas, as well as some areas with high public traffic or uses. Shipping lanes are also excluded. These areas are designated for the high volumes of vessel traffic that navigate through the Strait, and other operations must stay clear of these paths. The shipping lanes traverse the entire Strait, except near heavily used ports where boats are going to and leaving the shore from Port Angeles to Dungeness Spit, and near Port Townsend. These locations have Precautionary Areas where vessels need to be aware of others around them and plan their route accordingly. Siting a net pen in a precautionary area may be a higher risk**.** A map of available environmental and shipping lanes data for Clallam and Jefferson counties can be seen in Appendix F, Figure 1.

Conditional Concerns and Conflicts

Some conflicts do not restrict aquaculture through policy or the permit process, but are highlighted to be addressed by the proposed farm within a project plan and through the SEPA process. If an impact is determined to be significant and cannot be adequately mitigated, the farm may be denied a permit. Uses vary in intensity and area, so site-specific information is needed to weigh the impact an offshore farm would have on the local residents and industries. Shoreline or land-use designations for the counties describe the environment, population, current uses, and allowed uses for stretches of shoreline. The shoreline designations (urban, suburban, rural, conservancy, or natural) can reflect potential conflicts or pristine areas to be avoided. For example, in Clallam County, natural designations only allow aquaculture to propagate, enhance, or rehabilitate naturally occurring stocks (see Appendix F, Figure 2). Certain limitations may be placed on designation types for aquaculture activities and should be examined within the shoreline plan of the site's county. County-determined critical areas are also conditional and not restrictive, but should be reviewed in making site selection decisions. Public and private ownership information is also important to determine land, tideland, and resource uses that may conflict with an aquatic farm (see Appendix F, Figure 3).

Public opposition can play a role in prolonging a shoreline permit approval process or lead to denial, so it is essential to gain favorable support of local residents or to locate in less populated areas. In Jefferson County, water quality problems in Discovery Bay and public concerns for Atlantic salmon escapement are issues the county will focus on when considering net pen sites (Beale 1998). In Clallam County, residents included in the eastern portion of the Straits Regional Plan are more cautious about aquaculture than residents of the western portion (west and east coverage is divided at range 9/10) (Barnes 1998). Their concerns involve fish wastes, medicated food, and impact on native stocks (Clallam County County-wide Comprehensive Plan 1998).

Economic goals and policies of the Straits Regional Plan encourage the fish farming industry in two areas (see Appendix F, Figures 4 and 5):

- The west end of the planning region
- On the east end where the shorelines abut commercial forestlands between East Twin River and Murdock Creek

The selected areas were determined to be areas where land-use and visual conflicts are reduced. Prior to development, the plan notes that workable technology and economic feasibility for the area need to be carefully studied (Clallam County County-wide Comprehensive Plan 1998). Paying particular attention to the concerns of local residents and implementing effective measures to avoid or minimize these conflicts may facilitate permitting and reduce start-up costs. Clallam County does recognize the employment opportunities fish farming may bring, so development would likely be more acceptable in areas where new job growth is important. For Port Angeles and Sequim-Dungeness regional planning comprehensive codes, see Appendix F, Figure 6.

Equally important is the awareness of sewage treatment plant locations and the Department of Ecology's list of Candidate Impaired Waterbodies (303(d)) throughout the study area for the health and success of the cultured fish. Avoiding these areas also prevents problems with public concern regarding cumulative impacts on the marine environment. Commercial shellfishing beaches are also concerns. The Department of Health maintains a listing of these beaches and determines whether or not the beach is suitable for shellfishing. A site near a prohibited beach is probably not a good site for fish farming since organisms grown there are most likely not fit for human consumption. Sewage outfalls, candidate impaired waterbodies, and commercial shellfishing beach conditions are shown in Appendix F, Figure 7.

Other Potential Conflicts and Issues to Address

The Strait of Juan de Fuca is rich with resources and resource users, and consequently, other stakeholders with overlapping or adjacent areas of interest to a farm's proposed area should be considered in site selection and planning. Tribal, recreational, and commercial activities dot the shorelines and are not static in coverage or time span. At this stage of exploring offshore farming opportunities, it would be beneficial to identify the stakeholders and their activities rather than simply determining where those activities are currently occurring since they are subject to changes. At the time of site selection and planning, the location and intensity of these activities should be identified and addressed to see if an aquatic farm would have any negative impacts on these resources and their users.

Several Tribes have interests within the marine waters of Jefferson and Clallam counties. Marine salmon fishing grounds for the Puget Sound Treaty Tribes lie within the study area and may involve the following Tribes (WDFW 1997):

- Makah
- Port Gamble S'Klallam
- Jamestown S'Klallam
- Lower Elwha S'Klallam
- Lummi
- Suquamish
- Swinomish
- Tulalip
- Skokomish

Other Tribal harvests include:

- Other finfish
- Geoducks
- Other hardshell clams
- Red and green sea urchins
- Crab
- Sea cucumbers
- Octopus
- Shrimp

Contacting the Washington Department Fish and Wildlife, the Northwest Indian Fisheries Commission, or the Point No Point Treaty Council would be important to determine which Tribes have interests within or near the proposed farm site. Contacting individual Tribal fish and shellfish managers demonstrates that the farmer is willing to work towards addressing and minimizing possible Tribal use conflicts. Tribes review the Corps permit and have input at the federal level, so favorable Tribal relations are an asset.

Recreational activities include fishing, shellfishing, and boating. Public boat accesses and beaches reflect where most of these activities may be occurring. Olympic National Park occupies most of the inland portion of the Olympic Peninsula as well as the outer coast. State parks are mostly concentrated on the eastern portion of the Strait, with the westernmost marine park in Sequim Bay.

Gillnet, purse and beach seine, terminal net, and troll fisheries exist in Washington. Although commercial salmon fisheries have been closed for several years in the Strait of Juan de Fuca due to low fish numbers, WDFW should be consulted to determine what commercial fish and shellfish activities exist. Recreational and commercial closures are consistently updated by WDFW and set by Washington Administration Code (WAC).

Some electronic data sets were included in the GIS database, but were not included in the maps generated for this report. Although the information is viewed as informative, the data sets did not provide enough information to support being viewed as conflicts. These include public boat access areas, status of recreational shellfish beaches, other public beach locations, and shoreline geology.

Discussion

The Pacific Coast of the Olympic Peninsula is not recommended for offshore farming since most of shoreline is National Park land, national marine sanctuary area, or Tribal land. Taking into account the decisions that encompass offshore farm planning and the available data for the study area, the following discussion highlights areas within the Strait of Juan de Fuca that appear to have the greatest conflicts for a farm site. To avoid residential conflicts and public concerns, Jefferson County and both the Port Angeles and Sequim-Dungeness regional planning areas in Clallam County are not encouraged for farms. Based on the recommendations from the Clallam County Straits Regional Plan, efforts would be best received west of Murdock Creek.

Within the coverage of the Straits Regional Plan, the stretch between Slip Point (east of Clallam Bay) and Pillar Point (near Pysht) is not a good location as kelp beds and their buffer zones lay within the bathymetric contour. The shoreline is steep, and the water is deep close to shore.

The shoreline between the Makah Reservation and Shipwreck Point consists of commercially zoned lands which are a good distance away from kelp, but infrastructure, marine conditions, and extreme weather are problems that may be encountered by being too far west on the peninsula. The towns of Sekiu and Clallam Bay are located between Shipwreck Point and Slip Point, where aesthetic quality concerns may be triggered if farms are sited too close to residential areas.

Considering environmental conditions, the 90 to 120 foot zone between Pillar Point and Tongue Point (just east of Crescent Bay) represents a location which is a good distance away from seal and sea lion haulouts and known kelp beds (see Appendix F, Figure 8). During the writing of this report, the Makah Tribe expressed harvesting interests in this same area (Castle 1998), so they, in particular, should be informed and involved in the initial decision making process. The Whiskey Creek area (site of Ocean Spar Sea Cage trial) is also located within this area, about 2 ½ miles west of Crescent Bay. Murdock Creek is centrally located within this stretch of shoreline as well, so residential concerns may be minimized. If marine and other environmental conditions are favorable, this area may be the most optimal in pursuing offshore farming ventures.

Risks

Several risks are associated with fish farming, and while the risks can never be completely eliminated, they can be minimized through education and planning. It is important to minimize or mitigate these risks to avoid adverse environmental impacts.

Fish Releases

Atlantic salmon are a favored species for commercial farming, because they have a faster growth rate than Pacific salmon. They also have a higher tolerance to stress and disease, and thus can be stocked at a higher density. With farming salmon in a natural environment, however, there is a risk of escapes, and the effect of introducing an exotic species to already depressed wild stocks could have a significant impact. Concerns center around the ecological effects resulting from predation on the wild stocks or competition for food, space, and other resources by escapees. The introduction of diseases to the wild stocks, for which they have no defenses, is another concern. For farmed fish to have a consequential impact on native populations; however, the following conditions must occur (WDF 1990):

- There must be a significant number of escapees
- Escapees must survive and return to spawning grounds to mix with native stocks in adequate numbers
- Escapees must have the genetic capacity to breed with (altering their genetic makeup) or out-compete wild populations if they have mixed in sufficient numbers

Another significant concern is the genetic impact that might occur as a result of escaped Atlantic salmon. It has been proposed that farming poses a minimal threat to wild populations in terms of genetic degradation (Alverson and Ruggerone 1997). Atlantic salmon cannot genetically mix (or interbreed) with wild populations of Pacifics (WDF 1990), and additionally, there is little opportunity for hybridization because Atlantics spawn several months earlier than Pacifics (Alverson and Ruggerone 1997). In theory, however, spawning populations of Atlantics could reduce natives to low enough levels that a genetic component is diluted (WDF 1990).

There have been recent news events of Atlantic salmon found to be spawning and reproducing outside of their endemic range. Reports from the British Columbia Ministry of Fisheries state that there is evidence of naturally spawned juveniles in the Tsitika River on north Vancouver Island (Stringer 1998). DNA analysis confirmed the species as Atlantic, and a preliminary analysis suggests that the fish are not of hatchery origin. There are no nearby hatcheries or other sources for the fish, except farms. Further testing was to be done to determine the true origin of these fish, and the findings are controversial. Some say that there is fairly strong evidence that spawning has been going on as long as two years outside their endemic range (Howard 1998). Others are skeptical, and say that the evidence is inconclusive and needs further study (Taylor 1998).

As long as fish are being farmed in the aquatic environment, the risk of escapes will always exist; however, there are ways of minimizing the risk. The most crucial is escape prevention. Other proposed ways of mitigating fish releases areas are as follows (Goldburg and Triplett 1998):

- To have a threshold number (of fish released) and work to decrease that number to zero
- Having an accurate inventory system or a computerized tracking system
- Growing reproductively sterile fish to reduce potential for exotic species to establish populations

Sedimentation and Pollution on Benthos

Uneaten fish food and excretory wastes may settle under and nearby the farms and have an impact on bottom-dwelling plants and animals (benthos). The severity of these impacts depends on several factors. The efficiency and effectiveness of feeding is probably the largest influence. The food amount used depends on the food type, fish size, and water temperature. The relationship between pen size and stock density is another factor that may contribute to the extent of sedimentation. The positioning of the cages on site in relation to the current, water depth, and current velocity also may contribute. Swifter currents in deeper water may suspend and carry away some of the organic sediment. Bottom topography also plays a role; smooth sand is more susceptible to the scouring and resuspension action of the currents than an irregular bottom. The bottom sediments and community itself is also a large factor. High biological productivity can metabolize higher organic deposition, but adverse impacts may have greater significance in such circumstances (WDF 1990).

Low levels of waste deposition may be beneficial as an additional food source for the benthos (WDF 1990). At higher levels, however, it can clog the filtering apparatus of filter-feeding organisms, suffocating them, or eventually burying them, resulting in anoxic conditions. Organic matter on the substrate is subject to bacterial and chemical decomposition. Both consume oxygen, reducing that available for exchange into sub-surface sediments (WDF 1990).

Some methods of mitigating or reducing sedimentation are (WDF 1990):

- To periodically move pens and allow sediment fallowing
- Site farms in areas of high current and/or deep water
- Site in areas of low biological productivity
- Different orientations and configurations of the farms, i.e., place the long axis perpendicular to prevailing currents (although this may increase the potential of navigation or aesthetic conflicts)
- To use slow-settling, highly digestible feed to maximize food conversion

Chemicals

There are several types of chemicals that have been used in salmon farming. This issue raises concerns of environmental risks and chemical accumulations in the farmed salmon and surrounding organisms. Pesticides have previously been administered externally to the fish to control parasites, and disinfectants (or antifoulants) have been applied to the nets to control net fouling. Currently in Washington, there are no chemical pesticides or antifouling agents being used, and thus, the associated risk is eliminated. Instead, fish are routinely vaccinated prior to introduction to the pens, and netting containing copper wire, or other safe antifouling agents are being used (WDF 1990).

Another concern is the use of antibiotics to control disease on salmon farms. While use has been significantly reduced in recent years due to the increasing use of vaccines, antibiotics are still occasionally used**.** This repeated use could potentially lead to an increase in antibiotic resistance among bacteria near farms where the medication is applied as well as a build up of antibiotics in the tissues of living organisms in and near the farm. The resistance level is dependent on the diversity of antibiotic administration as well as the frequency of use, the dosage, the type of antibiotic administered, as well as environmental factors such as water temperature and dilution rate (WDF 1990). Studies show that there is no evidence of resistance in Puget Sound waters (WDF 1990). Ways of mitigating the widespread use of antibiotics are to continue routinely vaccinating before introduction to the farms, and any use of antibiotics should be strictly controlled and documented.

Phytoplankton Blooms

Phytoplankton is made up of diatoms, dinoflagellates, and flagellates, which are the base of the marine food chain (WDF 1990). When large numbers bloom (usually occurs in spring and summer), the effect can be detrimental to other organisms, including fish and humans. Because the growth rate is so high, they deplete nutrients from the water, particularly dissolved oxygen (Northwest Fisheries Science Center (NWFSC) 1998). When this happens, fish can suffocate. While farmers can monitor phytoplankton cell counts and identify population increases, there is presently no way to determine the blooms' toxicity level (Nosho 1998). The sudden depletion of dissolved oxygen in a contained area can be a serious problem in aquaculture since the fish are contained in pens and cannot escape into more oxygenated waters. This problem has resulted in millions of dollars in losses in the salmon aquaculture industry.

There are two organisms that are the most common threat in Washington waters, also referred to as a brown tide. One species is *Heterosigma akashiwo*. The mechanism of its toxicity to fish is still unknown, but it is thought that these organisms produce superoxide radicals or hydrogen peroxide. It is proposed that these blooms have the ability to vertically migrate through the water column, allowing them access to light near the surface during the day, and to nutrients in the depths at night (Nosho et al.1998).

The other organism that typically makes up phytoplankton blooms is *Chaetoceros* which has three species. These organisms are common in Washington waters but seldom bloom. *Chaetoceros* do not produce a toxin, but can kill fish even when present at low densities. They have long spiky spines which can become lodged in fish gills, causing an overproduction of mucus. This reduces the exchange of oxygen across the gill surface, and the fish suffocate (Nosho et al. 1998).

Phytoplankton blooms tend to occur in areas of higher temperatures, increased nutrient levels, and lower currents (WDF 1990). Net pen farms can increase the level of nutrients present in the water, however, there is no evidence of net pens ever causing blooms in the Puget Sound area (Levings 1994). There are two areas within the Strait of Juan de Fuca that are known to be nutrient sensitive and are not good locations for siting. Discovery Bay and Sequim Bay have poor flushing, density stratification, and fluctuating levels of nitrogen, which are ideal environments for phytoplankton blooms (WDF 1990).

A phytoplankton hotline is maintained year round in the University of Washington School of Oceanography and is based primarily on information obtained from existing aquaculture sites. The number is (206) 685-3756 (Taylor and Horner 1994). Currently, towing pens to safer waters is the most frequently used method of risk management in Puget Sound (NWFSC 1998), but there is also an associated risk of fish escapes during the move.

Disease

The risk of introducing exotic pathogens is minimal due to regulations on the importation of fish, fish eggs, and other fish products. Eggs can be imported only with a permit, while importing live salmonids is strictly prohibited. The risk of transmitting disease to wild stocks does exist, but has not been shown to be a problem up to this point. There is no risk of farmed fish transferring disease to shellfish, because fish pathogens are largely distinct from invertebrate pathogens (WDF 1990).

Interactions with Other Species

The most common interaction with other wildlife that fish farms face is predation on the captive fish. Marine mammals and birds find penned fish an easy target if protective measures are not taken. The result may be damage to the nets and facility, which may lead to fish escapes. It may also lead to injured and/or killed fish which ultimately results in a loss of investment and revenue for the fish farmer (WDF 1990). There is also the risk of injury to the predator itself if preventive measures are not taken.

There are several non-lethal methods of predator control that are effective, so impacts of lethal control are not expected (see Table 7). Some experts believe that killing predators is ineffective at stopping predation anyway, because dead predators are rapidly replaced by others unless the facility is made less inviting as a foraging site (Goldburg and Triplett 1998).

Some ways to reduce the risk of predation are by using anti-predator nets, or strings placed parallel over the farm. Human activity is also a good deterrence, as is the use of acoustic harassment devices (although some report habituation to the noise, thus it becomes ineffective). Perhaps the best method is to develop a control program that combines several nonlethal methods and avoids habituation by consistently substituting different methods (Goldburg and Triplett).

Table 7. Some Non-lethal Methods of Deterring Predators

Method	Avian Predation	Seal Predation
Facility Modification	-Increase water depth of culture unit -Increase slope of culture unit embankments -Remove perches and feeding platforms -Remove cover and concealing vegetation -Disperse roost/nest site	-Increase tension of nets -Use rigid nets
Operational Modification	-Modify feed type and delivery method -Relocate young/small stock -Remove dead fish promptly	-Remove dead fish promptly
Auditory Harassment	-Predator distress calls -Automatic exploders -Pyrotechnic devices -Sirens -Electronic noisemakers	-Predator vocalizations -Explosive underwater devices (seal bombs) -Underwater acoustic deterrence devices
Visual Harassment	-Lights -Scarecrows -Reflectors -Model airplanes -Trained falcons -Human presence	-Predator models (killer whale scarecrows) -Patrol with boats
Barriers	-Perimeter fencing and protective netting -Water spray	Perimeter nets around entire site

(Source: OTA 1995 and NMFS 1996 from Goldburg and Triplett 1998)

References

Alverson, D. and G. Ruggerone. 1997. Escaped farm salmon: environmental and ecological concerns. 3: Bi-B99 in: Salmon Aquaculture Review: Technical Advisory Team Discussion Papers. Environmental Assessment Office, British Columbia, Canada.

Barnes, C. and N. McGary. 1974. Atlas of physical and chemical properties of Puget Sound and its approaches. University of Washington Press, Seattle.

Beale, H. 1998. Personal communication of August 5. Associate Planner, Jefferson County Long-range Planning Division.

Berry, H. and T. Mumford. 1998. Draft DNR landscape planning list of marine environmental data currently or soon available for large areas in Washington state. Washington State Department of Natural Resources, Olympia.

Beveridge, M. 1994. Geographic information systems (GIS) for coastal aquaculture site selection and planning. Pages 26-47 in: K. Koop (ed.), Ecology of Marine Aquaculture. International Foundation for Science, Stockholm.

Beveridge, M. 1996. Cage aquaculture (2nd edition). Fishing News Books, London.

British Columbia Environmental Assessment Office (BCEAO). 1997. Salmon aquaculture review: report of the environmental assessment office. Chapter 2: The salmon aquaculture industry. Environmental Assessment Office, British Columbia, Canada.

Brown, L. (ed.). 1993. Aquaculture for veterinarians: fish husbandry and medicine. Pergamon Press, Inc, New York.

Castle, J. 1998. Personal communication of October 20. Groundfish / Shellfish Biologist, Makah Fisheries Management.

Clallam County County-Wide Comprehensive Plan. 1996. Department of Community Development, Port Angeles.

Clallam County Shoreline Advisory Committee. 1992. Clallam county shoreline master program. Clallam County Department of Community Development, Port Angeles.

Cooper, H. 1998. Personal communication of November 23. Bord Iascaigh Mhara (BIM) - Irish Sea Fisheries Board.

Croker, T. 1998. Personal communication of September 23 and November 3. President, Ocean Spar Technologies.

Danie, D., J. Stanley, and J. Trial. 1984. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic) Atlantic salmon. US Fish & Wildlife Service, Department of the Interior, Washington D.C.

Forster, J. 1995. Cost trends in farmed salmon. Section 2: Farmed salmon industry background A report prepared for the Alaska Department of Commerce and Economic Development, Division of Trade and Development. Juneau, Alaska.

Forster J. and et al. 1995. Aquaculture in the Strait of Juan de Fuca: A survey of community and agency attitudes. Clallam County Economic Development Council, Port Angeles, WA.

Forster, J. 1998. Personal communication of August 29 and September 27. Aquaculture Business Consultant.

Fox, T. 1998. Personal communication of September 1, 4, and 21. Southold Maritime Services Corp.

Goldburg, R. and Triplett, T. October 1997. Murky Waters: Environmental Effects of Aquaculture in the US. Online. Available: http://www.edf.org/pubs/reports/aquaculture/AQUA.PDF. 12 October 1998.

Gustavson, K. 1997. Overview of existing and developing technologies for commercial salmon culture. 4: D1 - D37 in: Salmon Aquaculture Review: Socio-economic Impacts and Related Technical Papers. Environmental Assessment Office, British Columbia, Canada.

Howard, C. 23 September 1998. "Wild Atlantic salmon now reproducing off B.C. coast " Vancouver Sun. p. A1, col 5.

Jefferson County Board of County Commissioners. 1998. Jefferson county comprehensive plan. Long Range Planning Department, Port Townsend, Washington.

Jefferson County Planning Department. 1998. Shoreline management master program for Jefferson county and Port Townsend, Washington. Long-Range Planning and Growth Management, Port Townsend, Washington.

Lawson, T. 1995. Fundamentals of aquacultural engineering. Chapman and Hall, New York.

Levings, C. 1994. Some ecological concerns for net-pen culture of salmon on the coasts of northeast Pacific and Atlantic Oceans, with special reference to British Columbia. Journal of Applied Aquaculture. 4(1): 65-133.

Lilly, K. 1983. Marine weather of western Washington. Commander, NOAA, StarPath School of Navigation, Seattle.

National Ocean Service (NOS). 1998. Tidal current tables 1998: Pacific coast of North America and Asia. International Marine, Camden, Maine.

National Oceanographic and Atmospheric Administration (NOAA). 1997. United States coast pilot: California, Oregon, Washington, and Hawaii (31st edition). NOAA, US Department of Commerce, Seattle. Vol. 7.

Northwest Fisheries Science Center (NWFSC). 3 September 1998. Marine Biotoxins on the West Coast and Alaska. Online. Available: http://research.nwfsc.noaa.gov/ec/tox. 23 October 1998.

Nosho, T. 1998. Personal communication of July 27 and October 19. Aquaculture specialist, Washington Sea Grant Program.

Nosho et al. Harmful Algal Blooms in Washington. 29 June 1998. Online. Available: http://www.wsg.washington.edu/outreach/mas/aquaculture/algalfacts.html 12 August 1998.

Ocean Spar Technologies. 5 February 1998. Sea Station. Online. Available: http://www.oceanspar.com/seastation.html. 8 September 1998.

Ocean Spar Technologies. 19 February 1998. The Ocean Spar® Sea Cage System. Online. Available: http://www.oceanspar.com/OceanSpar.html. 8 September 1998.

Olbing, J. 1998. Personal communication of August 28. Sales manager, Farmocean International.

Pacific Marine Environmental Lab (PMEL). EPIC Data Selection - Data Rescue: Puget Sound. 22 October 1996. Online. Available: http://www.epic.noaa.gov/epic/select/rescue_puget_ctd.html. 18 September 1998.

Polk, M. (ed.). 1996. Open ocean aquaculture. Proceedings of an International Conference, May 8-10, 1996. University of New Hampshire and University of Maine Sea Grant College Program, Portland, Maine.

Port of Port Angeles. 1989. Port Angeles Harbor resource management plan. Port Angeles, Washington.

Ridler, N. 1995. The economics of aquaculture. Pages 559-582 in: Andrew Boghen (ed.), Cold-Water Aquaculture in Atlantic Canada (2nd edition). The Canadian Institute for Research on Regional Development, New Brunswick, Canada.

Ross, L. et al. 1993. The application of geographic information systems for coastal aquaculture: An example based on salmonid cage culture. Aquaculture 112: 165-178.

Sedgewick, S. 1988. Salmon farming handbook. Fishing News Books LTD, England.Stanley, M. 1997. Washington state Atlantic salmon production. Memo from 9 November 1998. Washington Department of Fish and Wildlife, Resource Statistics, Olympia, Washington.

Stilson, L. 1996. Selected laws, regulations, case law, and shoreline hearings board cases related to aquaculture. Memo, June 27. Aquatic Resources Division, Department of Natural Resources, Olympia, Washington.

Stringer, L. 23 September 1998. Province moves to eliminate salmon escapes. News release #98 - 36. British Columbia Ministry of Fisheries, Communications Branch.. Online. Available: http://www.fisheries.gov.bc.ca/news/News98/NR36Sept231998.htm. 24 September 1998.

Taylor, B. 24 September 1998. “New salmon threat spawned--escaped Atlantic farm fish may be reproducing in BC river.” Seattle Post Intelligencer 1A.

Taylor, F. and R. Horner. 1994. Red tides and other problems with harmful algal blooms in Pacific Northwest Coastal Waters. Pages 175-181 in: R. Wilson et al. (eds.), Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound, and Juan de Fuca Strait. Proceedings of the BC/Washington symposium on the marine environment, Jan 13 & 14, 1994. Canadian Technical Report of Fisheries and Aquatic Sciences 1948.

Thom, R., L. Antrim, A. Borde, W. Gardiner, D. Schreffler, P. Farley, J. Norris, S. Willey-Echeverria, and T. McKenzie. 1998. Puget Sound's eelgrass meadows: Depth distribution and spatial patchiness. Puget Sound '98, Conference Proceedings, March 12-13, 1998, Seattle, WA.

Thomson, R. 1994. Physical oceanography of the Strait of Georgia-Puget Sound-Juan de Fuca Strait system. Pages 36-100 in: R. Wilson et al (eds.), Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound, and Juan de Fuca Strait. Proceedings of the BC/Washington symposium on the marine environment, Jan 13 & 14. Canadian Technical Report of Fisheries and Aquatic Sciences 1948.

Washington Department of Ecology (WDOE). 1978. Coastal zone atlas of Washington (Volume 12). Department of Ecology, Olympia, Washington.

Washington Department of Ecology (WDOE). 1986. Recommended interim guidelines for the management of salmon net-pen culture in Puget Sound. Department of Ecology, Olympia, Washington.

Washington Department of Ecology (WDOE). 1992. 1992 statewide water quality assessment section 305(b) report. Department of Ecology, Water Quality Program, Olympia, Washington.

Washington Department of Ecology (WDOE). November 1994. Permit Handbook--Commonly Required Environmental Permits for Washington State. Online. Available: http://www.wa.gov./ecology/sea/pac/permit.html. 15 September 1998.

Washington Department of Ecology (WDOE). October 1998. Water Quality Data Sources. Washington's Final 1998 Section 303(d) list (Impaired and Threatened Surface Waters). Online. Available: http://www.wa.gov/ecology/wq/303d/index.html. 15 September 1998.

Washington Department of Fish and Wildlife (WDFW) et al. 1995. 1994 Washington state baitfish stock status report. Washington Department of Fish and Wildlife, Olympia, Washington.

Washington Department of Fish and Wildlife (WDFW). 1997. Tribal salmon marine fishing areas. Outline, February 26. Washington Department of Fish and Wildlife, Olympia, Washington.

Washington Department of Fisheries ((WDF) now known as Washington Department of Fisheries and Wildlife (WDFW)). 1990. Final programmatic environmental impact statement: fish culture in floating net-pens. Washington Department of Fisheries, Olympia, Washington.

Washington Department of Fisheries (WDF). 1992. Salmon, marine fish and shellfish resources, and associated fisheries in Washington's coastal and inland marine waters, Technical Report 79. Habitat Management Division, Olympia, Washington.

Wedemeyer, G. 1996. Physiology of fish in intensive culture systems. Chapman and Hall, New York. pp. 60-104.

Willinsky, M. and J. Huguenin. 1996. Conceptual, engineering, and operational frameworks for submersible cage systems. Pages 41-92 in Marie Polk (ed.) Open Ocean Aquaculture. Proceedings of an International Conference, May 8-10, 1996. University of New Hampshire and University of Maine Sea Grant College Program, Portland, Maine.

(This page was intentionally left blank)

Appendices

Appendix A

A1 Major salmon farming regions and their reported 1993 production figures

Country	Metric Tons	Pounds
Norway	170,000	374,000,000
Chile	60,700	133,500,000
Scotland	48,600	106,900,000
Canada	32,400	71,280,000
Japan	21,000	46,200,000

The world's major salmon farming regions and their reported 1993 production figures are shown above. In 1994, production is estimated to have increased by 24 percent to 210,000 metric tons in Norway; by 28 percent to 78,000 metric tons in Chile, and by 32 percent to 64,000 metric tons in Scotland. Other important producing countries include Ireland and the Faroe Islands. The U.S.A. comes eighth in the list with an estimated 1994 production of about 12,000 metric tons (Forster 1995).

A2 World Production of Farmed Salmon, 1988 and 1995

	1988 Production		1995 Production	
	x 1000 Tons	% Share	x 1000 Tons	% Share
Norway	80.3	57.5	251.0	45.5
Chile	3.1	2.2	126.3	22.9
United Kingdom	17.6	12.6	65.0	11.8
British Columbia	6.6	4.7	23.8	4.3
Ireland	4.2	3.0	16.0	2.9
Eastern Canada	3.3	2.4	14.7	2.7
United States	2.0	1.4	14.7	2.7
Japan	14.1	10.1	14.1	2.5
Faeroe Islands	3.4	2.4	12.4	2.2
Other Countries	5.1	3.7	13.9	2.5
TOTAL:	139.7	100.0	551.9	100.0

Source: Price Waterhouse (1993) and Kenney (1996) from EAO 1997

Appendix B

Aquaculture-Related Laws and Associated Permits

Law	Purpose of Law	Associated Permit	Permit Requirements	Permitting Agency
Shoreline Management Act of 1971: RCW 90.58	To assure appropriate and orderly development of the state's shorelines, and provide for state shoreline management by planning for and fostering all reasonable and appropriate uses in a manner that enhances the public interest, protects against adverse environmental impacts, and preserves the natural character of the shorelines.	Shoreline Substantial Development Permit	Required for projects exceeding $2,500 in value. Requires submitted information including a management plan, monitoring and surveying details, and relevant reports and records which are outlined in the Shoreline Plan.	Relative County Community Development Office
The Aquatic Lands Act: RCW 79.90-.96	DNR shall strive to provide a balance of public benefits concerning state-owned aquatic lands such as: direct public use and access; fostering water-dependent uses; ensuring environmental protection; utilizing renewable resources. Water-dependent uses shall be given preference over other uses of aquatic lands. Aquaculture will be fostered through research, flexible lease fees, and assistance in permitting and planning.	Aquatic Lands Lease	Required if a project involves the bedlands, tidelands, or shorelands of navigable waters since DNR is the proprietary manager of state-owned lands. Includes location, structural development, operational practices, lease terms, environmental monitoring, rent and other requirements.	Washington State Department of Natural Resources
Federal Water Pollution Control Act: 33 USC 1251	To restore and maintain the chemical, physical, and biological integrity of the Nation's waters.	Section 404	Requires a permit for any activity that discharges materials into all U.S. waters.	U.S. Army Corps of Engineers

Law	Purpose of Law	Associated Permit	Permit Requirements	Permitting Agency
Rivers and Harbors Act of 1899 33 USC 403	Requires a permit for any activity that discharges materials into all U.S. waters	Section 10	Prohibits the commencement of any work in traditional navigable waters of the U.S. without a Corps permit.	U.S. Army Corps of Engineers
		Navigational Markings	To assure fish farm proposals are not navigational hazards. May require farmer to supply navigational aids through lights and signals.	U.S. Coast Guard (also reviews section 10 and 404 permits)
Construction Projects in State Waters: RCW 75.20 WAC 220-110	To preserve, protect, perpetuate, and manage the food fish and shellfish in state and offshore waters. Establishes regulations for the construction of hydraulic projects or performance of other work that will use, divert, obstruct, or change the natural flow or bed of any of the salt or fresh waters of the state, and sets forth procedures for obtaining a Hydraulic Project Approval Permit.	Hydraulic Project Approval	Projects must be designed to provide for adequate fish life protection to include fish habitat. Ensures food fish and shellfish and their habitats, are protected for all construction projects.	Washington Department of Fish and Wildlife
Aquatic Disease Control: RCW 75.58, WAC 220-77-030	To protect the aquatic industry and wildstock fisheries from a loss of productivity due to aquatic diseases or maladies.	Finfish Import / Transfer	To allow stocking, transfer, import or export of live finfish, viable eggs or gametes. The intent of this requirement is to protect the finfish resources of the state form introduction of deleterious species and/or pathogens or disease.	Washington Department of Fish and Wildlife

Law	Purpose of Law	Associated Permit	Permit Requirements	Permitting Agency
Aquatic Farm Registration: RCW 75.58.040	All aquatic farmers as defined in RCW 15.85 shall register with the Department. The director shall develop and maintain a registration list of all aquatic farms. These farms shall provide the department production statistical data.	Aquatic Farm Registration	Mandatory registration for all aquatic farms with WDFW.	Washington Department of Fish and Wildlife
Water Pollution Control: 40 CFR 122.21 RCW 90.48	To maintain the highest possible standards to insure the purity of all waters of the state consistent with public health and public enjoyment thereof, the propagation and protection of wildlife, birds, game, fish and other aquatic life, and the industrial development of the state, and to that end require the use of all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state of Washington.	National Pollution Discharge Elimination System (NPDES) or Waste Discharge Permit	NPDES: For commercial farms with over 20,000 pounds of annual fish production, Waste Discharge Permit: for farms with less than 20,000 pounds annual production. Required for all point source discharges, includes siting and monitoring requirements to ensure compliance with state and federal water quality laws.	Department of Ecology (EPA for federal facilities and Tribal projects on Tribal Lands)
Clean Water Act (CWA): section 401 WAC 173-225	Sets the basic structure for regulating discharges of pollutants to waters of the United States. The CWA makes it unlawful for any person to discharge any pollutant from a point source into navigable waters unless a permit (NPDES) is obtained under the Act.	Section 401 Water Quality Certification	Required to conduct any activity that may result in any discharge into surface waters. Corps is provided state certification that the discharge complies with federal discharge requirements and state aquatic protection requirements. Usually, the Corps requests this certification on behalf of the applicant.	U.S. Army Corps of Engineers

Law	Purpose of Law	Associated Permit	Permit Requirements	Permitting Agency
U.S. Coastal Zone Management Act: 16 USC 1451 et seq, 15 CFR 923-930	To encourage the states to exercise their full authority over the lands and waters in the coastal zone by assisting the states, in cooperation with federal and local governments and other vitally affected interests, in developing land and water use programs for the coastal zone, including unified policies, criteria, standards, methods, and processes for dealing with land and water use decisions of more than local significance.	Statement of Consistency with Coastal Zone Management Act	Required for Corps. authorized projects, and other federally licensed or permitted projects. Unlike other state-issued certifications, the project proponent prepares the Coastal Zone Certification, which includes a project description, a brief assessment of the impacts, and a compliance statement with the Coastal Zone Management Program. Ecology reviews the Certification and the proposed project. If the project is consistent with state requirements, certification is concurred with, in writing.	Washington State Department of Ecology
Water Quality Standards for Surface Waters of the State of Washington: RCW 90.48, WAC 173-201A	To establish water quality standards for surface waters of the state consistent with public health and public enjoyment thereof, and the propagation and protection of fish, shellfish, and wildlife, pursuant to the provisions of Chapter 90.48 RCW and the policies and purposes thereof.	Water Quality Standards Modification Certification	Required for activities in or near water that will unavoidably violate state water quality criteria (turbidity in particular) on a short-term basis (also referred to as a short-term exception to water quality standards).	Washington State Department of Ecology

Appendix C

C1 Clallam County Critical Areas as Outlined in Comprehensive Plans

The following areas are considered critical areas relevant to the study by the county and are not necessarily deemed 'restrictions', but play a major role in development decisions. In particular, these areas that have marine shorelines as borders may either include all or some of the following: - Shellfish beds - Fish and/or wildlife habitat - Trees along shoreline bluffs which may be critical for eagles, peregrine falcons, or other birds for perching or nesting. - Designated Critical Wildlife Corridors or contain important fish / wildlife corridors
Sequim-Dungeness Regional Comprehensive Plan Critical Area Locations - Diamond Point/Sunshine Acres Rural Center - Miller Peninsula Neighborhood - Palo Alto-Chicken Coop Neighborhood - Blyn Rural Center - Dungeness-Jamestown Neighborhood - Dungeness Valley Neighborhood - Agnew Neighborhood
Port Angeles Regional Comprehensive Plan Critical Area Locations - Gales Addition Neighborhood-Port Angeles Urban Growth Area - Lee's Creek Neighborhood-Port Angeles Urban Growth Area - Fairview Neighborhood - Deer Park Neighborhood - Monroe Road/Foothills Neighborhood - Place Road/Eden Valley/Little River Neighborhood

(Source: Clallam County County-wide Comprehensive Plan 1996)

C2 Port Angeles Regional Comprehensive Plan Marine Waters Section 31.04.140 Selected Net Pen-related Comments

- Many commercial and recreational shellfish are found immediately offshore of Port Angeles regional watershed with Dungeness crab, shrimp, sea cucumbers, and red sea urchins as primary harvest species, whereas octopus, green sea urchins, squid, and pink shrimp are harvested to a lesser degree, and geoduck and hardshell clam beds in the Strait.

- Port Angeles Harbor is listed for prohibition of shellfish harvest by Washington Department of Health (DOH) and for low levels of dissolved oxygen on the State 303(d) list by Washington Department of Ecology (WDOE).

- Notes the presence of current commercial fish pens in the harbor as well.

(Source: Clallam County County-wide Comprehensive Plan 1996)

C3 Straits Regional Comprehensive Plan Selected Net Pen-related Comments

- Urban areas are Joyce near Crescent Bay, Clallam Bay, and Sekiu.

.

- Clallam Bay and Joyce communities have experienced job growth from aquaculture developments from the uplands and the Straits.

- C.C.C. 31.05.060 Economic Development Issues
    - A source for additional local employment opportunities can be considered by encouraging careful development of the aquaculture industry.

    - The eastern portion of the region is much more reserved in aquaculture support. Concerns include: fish wastes, medicated food, and impact on native stocks. The Plan notes Whiskey Creek net pen trials indicated workable technology and economic feasibility must be carefully studied prior to aquaculture development.

- C.C.C. 31.05.070 Economic Goals and Policies
    - Access to Clallam Bay and Sekiu marine shorelines should be improved for local resident and tourism access.

    - Goal to maintain the Sekiu Airport in full operation by the Port of Port Angeles for it's vitality in attracting fly-in tourism to this remote location .

    (The above are both potential beneficial uses by the industry)

(C.C.C. 31.05.070 Economic Goals and Policies continued)

- Aquaculture (freshwater and saltwater) research projects should only be encouraged in designated areas in the Straits Planning Region. Clallam County should support industries seeking grant funding for research projects. Research should focus on the development of an aquaculture industry that does not pollute or endanger native stocks, that enhances rather than displaces recreational and native commercial fishing, and that evaluates the effect of private use of a public resource. Clallam County should encourage the development of a locally based toxic shellfish monitoring program.

- Development of a shellfish and algae farming industry is strongly encouraged in the Straits Planning Region.

- Continuing research and development of upland aquaculture projects and onshore hatcheries, including freshwater projects, are encouraged in the Straits Planning Region. Aquaculture research projects, development of a fish farming industry, and development of onshore hatcheries is encouraged in the west end on the Straits Planning Region.

- Clallam County should identify areas in the Strait of Juan de Fuca that would be appropriate locations for aquaculture research and aquaculture development projects. Shorelines which abut commercial forestlands between the area west of Murdock Creek and east of the East Twin River are appropriate locations for aquaculture projects in the Eastern Straits Region as land use conflicts and visual conflicts are reduced.

- Clallam county should support the aquaculture industry in development of a programmatic environmental impact statement on use of identified areas in the Straits for aquaculture. Permitting processes for aquaculture projects should be streamlined.

- C.C.C. 31.05.120 Eastern Straits Transportation Issues and Goals plans for a permanent marina at Sekiu (potential beneficial use for industry). Also to relieve the impacts to the roads by allowing accessability year-round.

(Source: Clallam County County-wide Comprehensive Plan 1996)

C4 Clallam County Shoreline Master Program Selected Net Pen-related Comments

- Natural areas: only allow aquaculture to propagate, enhance, or rehabilitate naturally occurring stocks. Conditional uses are for mechanical/hydraulic dredge harvesting of subtidal hardshell clam beds. Aquaculture development with shore-based structures are not permitted. The Pacific Ocean and five locations along the Strait of Juan de Fuca are designated natural areas.

- Aquaculture developments utilizing submerged or floating structures are permitted uses that are subject to policies and regulations for conservancy, rural, suburban, and urban environments.

- Structures shall be limited to a maximum height of 25 feet, as measured from the average grade level.

(Source: Clallam County Shoreline Advisory Committee 1992)

C5 Jefferson County Shoreline Management Master Program Selected Net Pen-related Comments and Restrictions

- Under section 5.30, net pens are classified under both “intensive aquaculture development” and “floating aquaculture” subdivisions of aquaculture.

- (Net pens) Not approved in narrow channels, shipping lanes, or other areas where significant hazard to navigation.

- Intensive aquaculture developments shall be sited no closer than two nautical miles from the mouths of Type I rivers and streams and one nautical mile from Type II streams, unless provided on a finding by the WDFW that no adverse impact would result.

- Intensive aquaculture developments shall not be located within 300 feet of habitats of special significance as defined in the Recommended Interim Guidelines if those habitats are located in depths less than 75 feet at mean lower low water (MLLW). Habitats of special significance include eelgrass and kelp beds, rocky reefs, geoduck, and hardshell clam beds, as well as significant populations of Dungeness crabs, herring, and finfish such as ling cod, true cod, sole and flounder rock fish, cabezone, and sea perch.

- Not located within 1,500 feet of bird and mammalian habitats of special significance including seal and sea lion haulout areas, seabird nesting sites or colonies, and areas specifically identified as critical for feeding or migration of birds and mammals.

- Located so not to materially interfere with navigational access to waterfront property and public recreation areas.

- Maximum surface area encompassed by subtidal development shall not exceed two acres.

- Over water structures appurtenant to floating aquaculture development such as work shelters, sleeping quarters, and storage sheds shall be prohibited. A work boat to provide above functions may be conditioned and approved.

- Floating structures and equipment not to exceed six feet in total height above water’s surface.

- Floating aquaculture developments shall not be located within 1,500 feet of public parks and designated Historic Districts unless a visual assessment demonstrates that no significant impact of those areas would result (In Port Townsend, the Water Street National Historic District extends from Polk to Jackson Streets).

- Net pens are classified as intensive subtidal and considered a secondary use in all environmental land classes (urban, suburban, conservancy, and natural). Net pens do require structures, so natural designated areas may need to be avoided.

(Source: Jefferson County Planning Department 1998)

Appendix D

D1 Overview and Restrictions from the Final Programmatic Environmental Impact Statement (EIS)

Overview

The EIS evaluates impacts including sedimentation, water quality, and aesthetics on both biological and human environments. Permits required for fish farms and relationships to land-use plans and regulations are also listed within the EIS. The area of coverage includes the Strait of Juan de Fuca and all of Puget Sound (The Pacific coast is not described as an area of coverage).

Restrictions and Requirements in EIS

- Bottom sediments and benthos
- Water quality: NPDES permits and state compliance
- Phytoplankton: references Interim Guidelines' sensitive areas and suggests farm production limits be adopted into WACs
- Chemicals (antibiotics and antifoulants)
- Potentially affected fish and shellfish habitats
  - Butter, littleneck, horse, and geoduck clams
  - Octopus, sea urchins, crab, and shrimp
  - Salmonids, herring, smelt, Pacific sand lance, lingcod, rockfish, perch, cod, and flatfish
- Marine mammals and birds
  - Specifically lists harbor seals, California sea lions, northern sea lions, and river otters as sensitive species.
  - Anti-predator nets
    - 3 feet from fish net, extending 3 - 9 feet below bottom of fish net, looping back to create a bag-type structure while weighted to remain taut.
    - Less than 5 inch mesh to avoid accidental entrapment of animals
    - Perimeter fencing should be installed to prevent resting and hauling of marine mammals on pens.
    - 7 inch stretch mesh not or parallel strings over the top of the pens to prevent bird predation should be installed
- Land-use/water-dependent user conflicts (Navigation, commercial fishing, human health, recreation, noise, odors, upland, and shoreline uses)
- Visual quality: local government (SMA and Comprehensive Plans) should define regulations, and when feasible, facilities should be sited or designed to be at least 1,500 to 2,000 feet offshore and horizontal in profile.

(Source: DFW 1990)

D2 Overview and Siting Restrictions from the Recommended Interim Guidelines

Overview

The Guidelines list recommendations for project siting, operational practices, and an annual monitoring program; however, it was not intended to replace existing regulations, master programs, or local ordinances. It was designed for operations not yet permitted and salmon grown with the intent to harvest and market. The areas covered by the Guidelines encompass marine waters of Puget Sound, Strait of Juan de Fuca, and the Strait of Georgia.

Restrictions and Requirements Contained in Guidelines

- Current velocities
  - Determine minimum depths under pens.
  - Are mean current velocities as measured mid-way between net-pen bottoms and the sea floor and are based on mean and not maximum current velocity.
  - Surface current velocity is not an appropriate substitute.

- Habitats of special significance, along with bird and mammal restrictions
  (If these habitats are present in depths of 75 feet or less at MLLW, no net pens should be sited over these areas, within 300 feet in the direction(s) of prevailing tidal currents, or within 150 feet in any other direction).

- No net pens should be sited within 1,500 feet of any of the following:
  - Seal and seal haulout areas
  - Seabird nesting sites or colonies
  - Critical areas for feeding/migration of birds and mammals

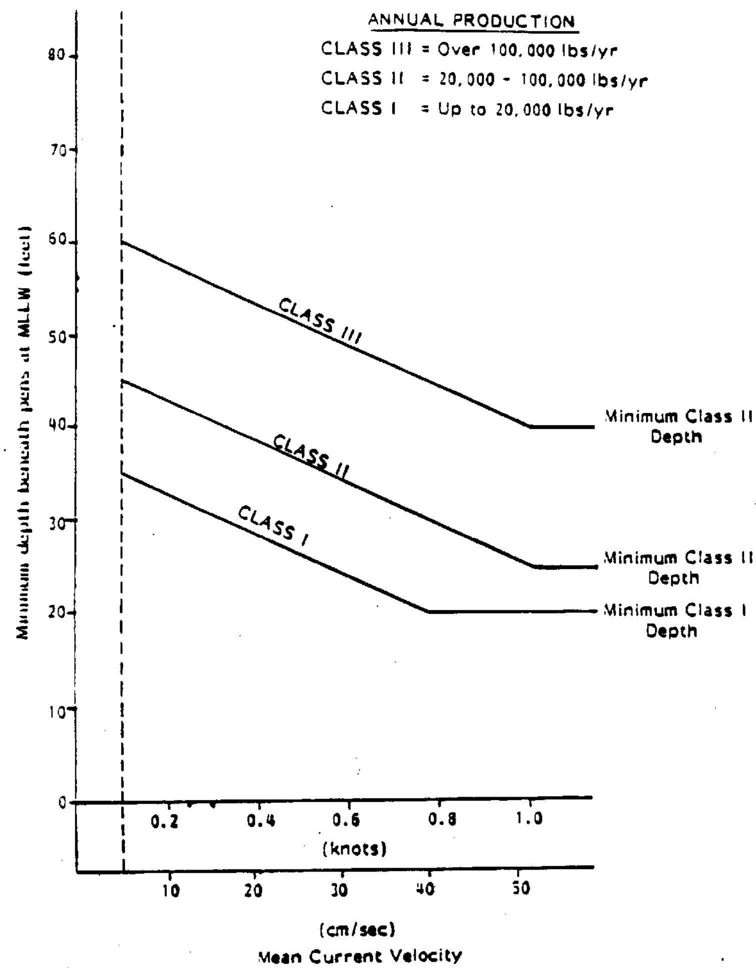
- Water quality restrictions
  - Sequim Bay has a maximum annual salmon production limit of 50,000 pounds per year (for the entire bay, not per operation. Annual production density should not exceed one million pounds per square nautical mile).
  - Discovery Bay has a maximum annual salmon production limit of 540,000 pounds per year (for bay, not per operation. Not to exceed 1 million pounds per square nautical mile).
  - No limits are placed on the number of net-pen operations or total allowable production for the Strait of Juan de Fuca. Density cannot exceed one million pounds annual production per square nautical mile (defined as 6,076 feet on all sides).

- Gives criteria for bathymetric, hydrographic, diver, and benthic baseline surveys.

- Gives criteria for feed, predators, antibiotics, and antifouling agents.

Additional information can be found in the "background information and discussion" of the Guidelines. (Source: DOE 1986)

D3 Minimum Depth and Current Guidelines For Net Pen Siting



(Source: DOE 1986)

D4 Water Quality Standards for Surface Waters of the State of Washington

(Restrictions as required by WAC 173-201A for the Strait of Juan de Fuca--Class AA)

Water Quality Criteria

- Fecal coliform organisms (marine water): level shall both not exceed a geometric mean value of 14 colonies/100 mL and not have more than ten percent of all samples obtained for calculating the geometric mean value exceeding 43 colonies/100 mL.

- Dissolved oxygen (marine water): level shall exceed 7.0 mg/L. When natural conditions, such as upwelling, occur, causing the dissolved oxygen to be depressed near or below 7.0 mg/L, natural dissolved oxygen levels may be degraded by up to 0.2 mg/L by human-caused activities.

- Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.

- Temperature shall not exceed 13.0°C (marine water) due to human activities. When natural conditions exceed 13.0°C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C. Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=8/(T-4) (marine water). Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C. For purposes hereof, "t" represents the maximum permissible temperature increase measured at a mixing zone boundary; and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.

- pH shall be within the range of 7.0-8.5 (marine water) with a human-caused variation within a range of less than 0.2 units.

- Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a ten percent increase in turbidity when the background turbidity is more than 50 NTU.

- Toxic, radioactive, or deleterious material concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department (see WAC 173-201A-040 and 173-201A-050).

- Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

D5 Habitats of Special Significance

- Eelgrass (*Zostera marina*) beds having densities exceeding 13 turions (i.e., “shoots”) per 0.25 m^2 in summer or 10 turions per 0.25 m^2 in winter. These densities should be based on 20 random 0.25 m^2 quadrat samples taken in the eelgrass bed. In addition to the density criteria above, culture should not be permissible if more than ten percent of the samples exceed 20 turions per 0.25 m^2. These guidelines are those used by the Washington Department of Fisheries (now WDFW) in defining areas unacceptable for hardshell clam harvesting (DNR/WDF, 1981).

- Kelp beds (i.e., dense beds of attached macroalgae, especially bull kelp, *Nereocystis luetkeana*).

- Rocky reef habitats (high profile rock outcrops colonized by organisms such as hydroids, macroalgae, abalone, sea urchins, sea anemones, starfish, and other attached organisms).

- Geoduck (*Panope abrupta*) populations with densities exceeding 1.2 kg (2.5 lbs) per m^2. This density is that required for hardshell clam harvest (DNR/WDF, 1981).

- Habitats having significant populations of, or which are important to the feeding, reproduction, or other life stages of Dungeness crabs (*Cancer magister*), herring (Clupea), lingcod/greenling (Hexagrammidae), true cod (Gaddidae), soles and flounders (Pleuronectiformes), rock fish (Scorpaenidae), cabezone and other large sculpins (Cottidae), or sea perch (Embiotocidae). The occurrence of these species in a potential culture area does not necessarily exclude it from development. The determination of whether the site is of special significance to these species will be determined by WDFW on a case-by-case basis.

- Wildlife refuges and habitats of endangered or threatened species. (A 300 foot separation from net pens is recommended regardless of current direction.

- Other habitats of special significance, regardless of depth, as determined on a case-by-case basis.

(Source: Recommended Interim Guidelines for the Management of Salmon Net-Pen Culture in Puget Sound 1987)

D6 NPDES Permit Restrictions

- Specific Water Quality Parameters:
  - Dissolved oxygen: minimum of 7.0 mg/L or if less, no more than 0.2 mg/L at mixing zone outer boundary, up to 100 feet from the outside edge of the net pens.
  - Turbidity: No increase of more than 5 NTU (Nephelometric Turbidity Units) at mixing zone outer boundary.
  - Settling solids and debris: Annual accumulation from pen operations limited of amounts on the sea floor under and adjacent to the pens which do not result in the establishment of anoxic zone.
- All other requirements are for operation plans, best management practices (BMPs), and annual monitoring programs for water quality and the benthic environment.

Appendix E

Net Pen Project Geographic Information Systems (GIS) Data Sources

Data Layer	Source	Specific Contact	Valid / Source Date
Baitfish, including Pacific Herring holding areas and spawning grounds, and Surf Smelt spawning beaches (BAITFISH) Buffered Baitfish Layer at 300 feet (BFISHBUF)	WA Department of Fish and Wildlife	---	1991
Study Area Bathymetry Grid (BATHY) 90' to 120' Depth Zone (ZN90_120)	WA Department of Fish and Wildlife	Shelly Snyder 360-902-2483 Dave Nysewander 360- 902-2693 Brian Cosentino 360-902-2376	30 Nov 98
Boat Launches (BTLAUNCH)	WA State Interagency Committee for Outdoor Recreation	---	24 Mar 98
County Boundaries (COUNTY)	WA Department of Natural Resources (derived from poca layer)	Dave Steele (RPAM) 360-902-1181	weekly
Clallam County: Straits Region-West and East Zoning (ZONESTRW, ZONESTRE) Clallam County: Sequim Region Zoning (ZONESQM) Clallam County: Port Angeles Region Zoning (ZONEPA) Clallam County: Shoreline Management Plan (SMP)	Clallam County, Department of Community Development Planning Division	Tom Shindler, Data Technician-Cartographer 360-417-2322	1998
DNR Managed Lands (DNRDISS)	Federal/State survey documents; etc. (DNR poca layer)	Dave Steele (RPAM) 360-902-1181	---
Public Recreational Shellfishing Beaches (DOHRECB) Sewer Treatment Plant Outfalls (DOHSEWER)	WA Department of Health, Office of Shellfish Programs	360-236-3324 for current information	Dec 98

Data Layer	Source	Specific Contact	Valid / Source Date
Commercial Geoduck Tracts - 1998 edition (GDUCK98) Buffered Commercial Geoduck Tracts - 1998 edition at 300 feet (GEOBUFF)	WA Department of Fish and Wildlife's January 1998 Geoduck Atlas WA Department of Natural Resources Geoduck Management Program	WDFW GIS contact: Randy Butler, Point Whitney Lab, Brinnon DNR GIS contact: Martha Marrah, Olympia Aquatic Resources Division	Jan 98
Kelp Inventory 1995-1996 (KELP1995, KELP1996) Buffered Kelp Inventory at 300 feet (KLP95BUF, KLP96BUF)	Coastal Zone Management Grants (Custom aerial flight and resource mapping by EcoScan, Inc. (California))	WA Department of Ecology, Coastal Zone Management Program WA Department of Natural Resources, Aquatic Resources Division	Summer months (July-Sept) of each year
Major Rivers of Washington (MJRRIVER)	Exact source unknown, but it is known that this cover is from a public source, possibly the U. S. Environmental Protection Agency. Murdock Creek was added from DNR's database, Hydro layer	WA Department of Natural Resources	---
Major Public Lands (MPL)	WA Department of Natural Resources Resource Mapping Section	Data maintenance contact name: Elizabeth Eberle 360-902-1222	1994 to present
Seagrass (SEAGRASS)			
Seal and Sea Lion Haulouts (SEALS) Buffered Seal and Sea Lion Haulouts at 1500 feet (SEALBUFF)	WA Department of Fish and Wildlife	Don Saul 360-902-2491	Nov 98

Data Layer	Source	Specific Contact	Valid / Source Date
Commercial Shellfish Growing Area Classifications (DOHSHELL)	WA Department of Health, Office of Shellfish Programs	360-236-3394 for current information	Dec 98
Shore Zone 1996 (SHZONELN) Shore Zone 1996 (SHZONEPY)			
Shipping Channels (SHPCHAN)	Screen digitized at WA Department of Natural Resources from scanned NOAA Charts	---	1995
Public Tideland 'strings' (TIDE24K)	WA Department of Natural Resources, Aquatic Resources Division	Data steward contact name: Elizabeth Lanzer	23 Jun 98
Township Boundaries (TOWNS)	WA Department of Natural Resources (derived from DNR poca layer)	Data maintenance contact name: Lowell Thacker 360-902-1551	weekly
Vancouver Island shoreline (VANCISL)	Portions are from British Columbia Provincial Government and the rest was digitized from USGS 1:100,000 quad maps	---	---
1998 Impaired Waterbodies Listed Water Grid Cells (WGCAND98) Listed Water Bodies (WBCAND98) Listed Water Courses (WCCAND98)	WA Department of Ecology with WA Department of Natural Resources, Aquatic Resources Division updates and changes	---	Nov 98
Shoreline (WTRLEVLN)	WA Department of Natural Resources	---	Mar 96

Geographic extent for the project data: Net pen study area, Strait of Juan de Fuca, and outer northern Washington coast (from Washington Department of Natural Resources, Netpen Feasability Study Database 1999)

--- indicates a specific contact or valid / source date was not given or available.

APPENDIX F

Environmental and Land-use Data Maps

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Jennifer M. Belcher - Commissioner of Public Lands

OLYMPIA, WASHINGTON 98504-7027

Equal Opportunity Employer
Printed on recycled
and recyclable paper.

Printed in the U.S.A.