Jefferson County
Marine Resources Committee

2000 Literature and Data Search

AN ANNOTATED BIBLIOGRAPHY ON THE STATUS OF MARINE RESOURCES IN JEFFERSON COUNTY

by
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Prepared for the Jefferson County Marine Resources Committee (MRC)

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DATA & INFORMATION WEB SITES

Information Web Site	URL Location
Jefferson County MRC	http://mrc.co.jefferson.wa.us
UW Fisheries Research Institute	http://www.fish.washington.edu/Publications/frireps.html
NOAA Regional Library	http://www.wrclib.noaa.gov/lib/
Washington Dept. Fish and Wildlife-Homepage	http://www.wa.gov/wdfw/
WDFW - Forage Fish	http://www.wa.gov/wdfw/fish/forage/forage.htm
NOAA Northwest Fisheries Science Center	http://research.nwfsc.noaa.gov/pubs/nwfscpubs.html
National Marine Mammal Laboratory	http://www.nmfs.noaa.gov/prot_res/PR2/Stock_Assessment_Program/sars.html
Department of Ecology-Publications Page	http://www.ecy.wa.gov/pubs.html
Dept. of Ecology Water Quality Data	http://www.ecy.wa.gov/programs/eap/mar_wat/mwm_intr.html
Dept. of Ecology-Environmental Assessment Bibliography	http://www.wa.gov/programs/eap/biblio/index.html
Puget Sound Health 2000 PSWQAT	http://www.wa.gov/puget_sound/Publications/pshealth2000/index.html
Wa. Dept. of Health Sehllfish PSP Hotline	http://www.doh.wa.gov/ehp/sf/biotox.htm
UW Library	http://catalog.lib.washington.edu/search~/

INTRODUCTION

There is ample evidence that marine resources of the Northwest Straits are in serious decline. Bottom fish, forage fish, salmon, sea birds, invertebrates, and some populations of marine mammals have declined precipitously since 1980. The Jefferson County Marine Resources committee is a citizen-based effort to identify regional marine issues, foster community understanding and involvement, recommend positive action, and develop support for various protection and restoration measures.

This annotated bibliography is a product of the Jefferson County Marine Resources 2000 literature review and data search on the status of marine resources in Jefferson County. Information was collected from an extensive review of existing literature. This included existing literature reviews, peer reviewed literature, agency reports, and a search of electronic databases for all documents pertaining to marine resources in Jefferson County with a particular focus on that region of Jefferson County that falls within the boundaries of the Northwest Straits Commission. The marine waters bounded by the Hood Canal Bridge, San Juan County, Island County, and Clallam County is the primary area of focus.

This search included interviews with leading experts and resource managers on specific species and ecosystem components and included, but was not limited to, a search of the following electronic databases: Aquatic Sciences and Fisheries Abstracts (ASFA), UW Fisheries Research Institute Reports, the National Technical Information Service (NTIS), and the University of Washington library database. The University of Washington Library, UW Fisheries Research Institute Reports, and NTIS electronic databases have unlimited internet access. The ASFA database has limited on-line membership access but is available on compact disk in the University of Washington, Fisheries and Oceanography library. The ASFA database includes literature dating back to 1982 covering science, technology, and management of marine and freshwater environments. It includes 5,000 international sources in the form of primary journals, source documents, books, monographic series, conference proceedings and technical research reports. The University of Washington library catalog has unlimited internet access at http://catalog.lib.washington.edu/search~/. Numerous agency reports and the UW School of Fisheries, Fisheries Research Institute Reports (UW-FRI) database which includes over 500 reports pertaining to research conducted by the Fisheries Research Institute (FRI) personnel from 1973 to the present are also available on the internet. In addition to the above literature and

data search, information has been collected through interviews with leading experts and resource managers. Through this process, we have assembled a comprehensive collection of literature and information regarding the status of marine resources in Jefferson County. In addition to this annotated bibliography, the products of this data search process include: a Jefferson County MRC on-line bibliography available on the MRC web site at http://mrc.co.jefferson.wa.us, a summary report, and an enhanced literature collection for the Jefferson County MRC physical library that is available to MRC members and interested members of the general public.

Annotated Bibliography

1. Angell, T. and K. C. Balcomb III. Marine Birds and Mammals of Puget Sound. Seattle, WA. Washington Sea Grant Program. University of Washington. 1982.

Keywords: marine birds//marine mammals//Puget Sound//northwest straits//straits

Abstract: Characteristic mammals, birds, fishes, invertebrates and plants are presented for different marine habitats in Puget Sound.

2. Antrim, L. D. R. M. Thom W. W. Gardiner V. I. Cullinan D. K. Shreffler and R. W. Bienert. Effects of petroleum products on bull kelp (*Nereocystis luetkeana*). Marine Biology. 1995. 122:23-31.

Keywords: kelp//water quality//nearshore vegetation//vegetation//nearshore

Abstract: Although research has been conducted on the effects of oil on the giant kelp *Macrocystis pyrifera*, no similar studies have been completed on bull kelp, *Nereocystis leutkeana*, the dominant kelp in Washington State, British Columbia, and Alaska. The effects of three petroleum products [diesel fuel, intermediate fuel oil (IFO) and crude oil] were tested before and after weathering on *N. leutkeana*. Whole plants were exposed to petroleum product for 4 or 24 h and then transferred to the field. Observations on the condition of the plants were made daily for 7 d. In addition, controlled bioassays were performed to measure the effects of petroleum exposure on net photosynthetic rate (NP) and respiration rate, using light and dark-bottle techniques. These experiments verified the susceptibility of *N. leutkeana* tissue to the damaging effects of direct exposure to several oil types. The 4 h exposures to weathered diesel and unweathered IFO, and 24 h exposures to unweathered and weathered diesel and IFO resulted in moderate to severe damage to kelp tissue (i.e. resulted in moderate to severe damage to kelp tissue (i.e. clearly delineated bleached line accompanied by tissue necrosis). Weathered diesel was more toxic than unweathered diesel. The most severe damage to bull kelp was concentrated at the meristematic zone (junction of stipe and bulb) where new tissue growth occurs. Petroleum type significantly affected stipe and blade NP, R and NP:R ratios. Diesel treatments had a greater negative effect on NP than did the IFO treatments. Based on these experiments, the relative ranking of the damaging effects of petroleum treatment on bull kelp ware weathered diesel>unweathered IFO>unweathered diesel>weathered IFO>unweathered crude>weathered crude.

3. Armstrong, J. W. and A. E. Copping. Status and Management of Puget Sound's Biological Resources. Conference Proceedings No. EPA 910/9-90-001Seattle, WA. EPA. 1990.

Keywords: marine resources/ marine biology/wildlife management/fishery management/Puget Sound

Abstract: A collection of papers presented to the Forum on the Status and trends of Puget Sound's biological Resources.: How well are we managing Puget Sound's Biological Resources; Commercial and recreational management of aquatic vegetation in Puget Sound; geoducks; Commercial geoduck Dive Fishery; Management of Nongame Marine Invertebrates; Puget Sound Crab and Shrimp Management; Management of the commercial dive fisheries for sea urchins and sea cucumbers; intertidal fisheries for hardshell clams and oyster, Puget Sound tribal fisheries management-a cooperative approach, status of anadromous game fish in Puget Sound, Hood Canal salmon, marine fish users and managers, cooperative management of marine birds in Washington, cooperative management of Puget Sound waterfowl resources, management of Washington marine mammals under the Marine Mammal Protection Act: paradox or opportunity; priorities in managing Puget Sounds' species.

4. Bargmann, G. C. Schmitt W. Palsson S. Hoffman G. Lippert and G. Davis. Management approaches for recreational fisheries for bottomfishing Puget Sound. WDFW. 1991. Washington Department of Fisheries Progress Report No. 288.

Keywords: fish//bottomfish//groundfish//cod//rockfish//lingcod//pollock//halibut

Abstract: WDFW is developing bottomfish management plans that incorporate angler and diver preferences with the goal to conserve fish resources. This report presents three general approaches for managing recreational fisheries for bottomfish in Puget Sound. These approaches represent various trade-offs between management simplicity and attainable harvest. Information about existing recreational fisheries for bottomfish, fish biology, and angler preferences, as well as expectations of increased fishing effort, are reviewed and analyzed in the development of a recommended management approach.

5. Bargmann, G. G. The biology and fisheries for lingcod (*Ophiodon elongatus*) in Puget Sound. WA. 1982. Wash. Dept. Fish. Tech. Rep. No. 66.

Keywords: Puget Sound/ lingcod/ fish

Abstract: Seasonal and annual harvest trends for lingcod are analyzed for the inland marine waters of Washington. Age analysis and length information resulted in year class strength trends, age at recruitmet, growth, and yield.

6. --. Studies on Pacific cod in Agate Pass, Washington. 1980. Wash. Dept. Fish. Prog. Rep. 123.

Keywords: fish//cod//bottomfish//groundfish//Puget Sound

WDF investigated the sport fishery for Pacific cod (*Gadus macrocephalus*) in Agate Pass, WA. Between December 20, 1976 and April 10, 1977. It is estimated that 3,840 angler trips harvests 12,200 fish, calculated at 39,200 pounds total weight. The mean length was 50.3 cm females significantly the larger fish, and males outnumbering females in the catch. During the study, fish were tagged and recoveries indicated that the Pacific tomcod were moving rapidly through the pass in a generally southerly direction, diminishing the effect of the fisheries on a particular groups of stock. Tag returns during the following year (1979) indicated a dispersion of the cod throughout Puget Sound and included one tag returned form coastal waters. The Pacific cod fishery is more widespread than when last studied, with sport efforts considerably enlarged.

7. Beamish, R. J. Protecting Plants and Animals in the Strait of Georgia: Ideas for Action by the Work Group on the Protection of Marine Plants and Animals in the Strait of Georgia. Draft.

Keywords: Northwest Straits//straits//nearshore//fish//northwest

Abstract: This report presents the set of action plans the Puget Sound/Georgia Basin International Task Force finalized in response to the 1994 Marine Science Panel recommendations. The Task Force divided into Works Groups. This is the report form the Protection of Marine Plants and Animals Work Group. In response to Immediate Policy Concerns the Work Group proposed the following actions: integrate and coordinate governing bodies and agencies responsible for the health of the Strait of Georgia ecosystem; create MPAs; prevent loss of nearshore and estuarine habitat; preserve biodiversity; develop new management methods; involve the public; establish a code of conduct of the environment; control pollution and toxic discharges in the Strait of Georgia; assess current policies and management activities in the Strait of Georgia, and take global warming seriously. In response to stewardship concerns with the loss of foreshore and estuarine areas, they identified the need to take action to: not divide management at the tideline; reduce urban and industrial pollution; prevent introduction of exotic species; exchange information, improve assessment of marine mammal abundance; preserve juvenile salmon rearing capacity; establish an ongoing program to assess the health of all species in the strait of Georgia, and communicate scientific and government information to the public.

A state of the strait is presented along with a series of papers on creating a sustainable future, share marine waters, fisheries sustainability, and contaminants in the Strait and Georgia and elsewhere. A series of papers and studies are summarized herein.

8. Bernthal, Carol T. Labbe and B. Rot. Hood Canal/Eastern Strait of Juan De Fuca Summer Chum Habitat Recovery Plan. Final Draft. 1999.

Keywords: Hood Canal/ Puget Sound/ Jefferson County/salmon/summer chum/Hood Canal Summer Chum/ salmon recovery/fish habitat/salmon habitat

Abstract: This is a preliminary assessment for identifying the limiting factors and establishing criteria for the development of a recovery plan for the Hood Canal summer chum who became listed as" threatened" in 1999, under the Endangered Species Act. The final version of this document is an implementation plan for summer chum recovery. It is the April 2000 Summer Chum Salmon Conservation Initiative.

9. Berry, Helen and B. Ritter. Puget Sound Intertidal Habitat Inventory 1995: Vegetation and Shoreline Characteristics. Olympia, WA: Washington State Department of Natural Resources (DNR); 1995.

Kewords: nearshore//nearshore vegetation//inventory//shorelines//habitat

Abstract: Summary of DNR intertidal habitat survey of 110 miles of shoreline in Whatcom and Skagit Counties in the DNR Nearshore Habitat Program as part of the Puget Sound Ambient Monitoring Program (PSAMP). Survey identified vegetation type and shoreline characteristics**.**

10. Berry, Helen T. F. Mumford G. C. Schoch M. N. Dethier. Mapping Shorelines in Puget Sound III: Management Applications for Inventory and Monitoring. In: Proceedings of Puget Sound Research '98 Conference. March 12-13, 1998. Seattle, WA. Olympia, WA. DNR.

Keywords: nearshore//vegetation//Puget Sound//straits

Abstract: Nearshore habitat degradation and loss are recognized to be major threats to the health of Puget
Sound (British Columbia/Washington Marine Science Panel, 1994). Inventory data is needed to characterize the quantity, location, and quality of habitats, and to guide land use planning.
Information on trends in habitat health is needed to identify the habitat features and functions that are most at risk, and to relate these changes to the state of the Puget Sound ecosystem.
The Nearshore Habitat component of the Puget Sound Ambient Monitoring Program (PSAMP) as the dual goals of inventorying nearshore habitat and monitoring trends in health. For the purpose of the monitoring program, nearshore habitat includes the physical and biotic components of intertidal and shallow subtidal areas. Monitoring habitat is a challenge due to the size and complexity of the study area, which includes approximately 2,400 miles of shoreline east of Cape Flattery, and encompasses a wide range of habitats, from

vertical rocky shores to wide, protected mudflats. Human activities range from intensive in the highly industrial urban embayments to relatively minor in the least developed areas.

The Nearshore Habitat Program inventories nearshore vegetation by collecting and classifying multispectral sensor data and inventories of shoreline characteristics using field surveys in conjunction with photo interpretation. At current funding levels, sound-wide mapping will be completed within 15-20 years. A PSAMP review in 1995 recommended examining alternative methods to map resources sound-wide in less than five years (Shen, 1995). Additionally, it recommended initiating a program to monitor trends in nearshore habitat health. This paper responds to those recommendations. It reviews user needs, how current systems fulfill user needs, and how inventory methods are being changed in response to those needs. It then reviews results of research which tested the feasibility of using a linked geophysical mapping and biota sampling model for inventory and monitoring called SCALE (Shoreline Classification and Landscape Extrapolation). Nearshore habitat degradation and loss are recognized to be major threats to the health of Puget
Sound (British Columbia/Washington Marine Science Panel, 1994). Inventory data is needed to characterize the quantity, location, and quality of habitats, and to guide land use planning.
Information on trends in habitat health is needed to identify the habitat features and functions that are most at risk, and to relate these changes to the state of the Puget Sound ecosystem.

11. Bertolotto, Chrys. The citizen shoreline inventory. Puget Sound Research '98. 1998 Mar 13-1998 Mar 14. Seattle, WA. Olympia, WA. PSWQAT.

Keywords: shoreline//Puget Sound//habitat

Abstract: This paper reports on a new inventory program uniting the need to fill information gaps on Puget Sound shoreline habitat conditions and provide education and training opportunities for the community as to the value of shorelines and the anthropogenic impacts to those nearshore habitats. The findings of this inventory will be displayed and updated in a Citizen Shoreline Atlas to be available on GIS through the internet.

12. Boersma, P. D. and J. K. Parrish. Limiting abuse: marine protected areas, a limited solution. Special Issue: Ecological Economics and Sustainable Governance of the Oceans.Ecological-Economics. 1999. vol. 31(no. 2): 287-304.

Keywords: marine protected areas//MPA

Abstract: Designation of marine protected areas (MPAs) is increasing as humans seek to combat over-exploitation of marine resources and preserve the

integrity of the ocean's unique biodiversity. At present, there are over 1300 MPAs. The primary legal responsibility for the designation of MPAs falls to individual countries, but protection of the marine environment at large scales is also critical because ocean circulation does not honor legal boundaries and often exceeds the influence of any one nation or group of nations. There are many reasons for establishing MPAs; the papers we surveyed principally referred to scientific, economic, cultural, and ethical factors. Two approaches predominated: fisheries management and habitat protection. Although the major threat to terrestrial systems is habitat loss, the major threats to the world's oceans are fisheries overexploitation, coastal development, and chemical and biological pollution. MPAs may provide conservation of formerly exploited species as well as benefits to the fishery through leakage of 'surplus' adults (spillover) and larvae (larval replenishment) across reserve boundaries. Higher order effects, such as changes in species richness or changes in community structure and function, have only been superficially explored. Because many MPAs are along coastlines, within shipping lanes, and near human centers of activity, the chance of chemical and biological pollution is high.
Use of MPAs to combat development and pollution is not appropriate, because MPAs do not have functional boundaries. The ocean is a living matrix carrying organisms as well as particles and therefore even relatively environmentally sensitive uses of coastal ecosystems can degrade ecosystem structure and function via increasing service demands (e.g. nutrient and toxics transformation) and visitation. Whether an MPA is effective is a function of the initial objectives.

13. Bradbury, Alex B. Sizemore D. Rothaus and M. Ulrich. Stock Assessment of Subtidal Geoduck Clams (*Panopea abrupta*) in Washington. Washington Department of Fish and Wildlife Fish Program, Fish Management Division, Marine Resources Unit. 2000 Jan. Report Number: FPT00-01

Keywords: Geoduck// clams// invertebrates//shellfish

Abstract: This report presents commercial tract densities and average weights. Biomass estimate calculations are presented and a model for an age-based equilibrium yield to predict long-term consequences of various harvest rates, using estimated geoduck life history parameters. The model predicts yield and spawning biomass per recruit over a range of fishing mortality rates. A strategy is recommended as a risk-averse policy for geoducks.

14. British Columbia/Washington Marine Science Panel. The shared marine waters of British Columbia and Washington. British Columbia/Olympia, WA. 1994.

Keywords: marine birds//fish//salmon//birds//invertebrates//water quality//shellfish//MPA//marine protected areas//Puget Sound//northwest straits//marine mammals//nearshore//human impacts//contaminants//straits

Abstract: Nearshore habitat degradation and loss are recognized to be major threats to the health of Puget Sound (British Columbia/Washington Marine Science Panel, 1994). Inventory data is needed to characterize the quantity, location, and quality of habitats, and to guide land use planning. Information on trends in habitat health is needed to identify the habitat features and functions that are most at risk, and to relate these changes to the state of the Puget Sound ecosystem.

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The Nearshore Habitat Program inventories nearshore vegetation by collecting and classifying multispectral sensor data, and inventories other shoreline characteristics using field surveys in conjunction with photo interpretation. At current funding levels, sound-wide mapping will be completed within 15-20 years. A PSAMP review in 1995 recommended examining alternative methods to map resources sound-wide in less than five years (Shen, 1995). Additionally, it recommended initiating a program to monitor trends in nearshore habitat health. This paper responds to the recommendations. It reviews user needs, how current systems fulfill user needs, and how inventory methods are being changed in response. It then reviews results of research which tested the feasibility of using a linked geophysical mapping and biota sampling model for inventory and monitoring called SCALE (Shoreline Classification and Landscape Extrapolation).

15. Broadhurst, Ginny and R. Wlakinshaw. Puget Sound nearshore habitat regulatory perspective: A review of issues and obstacles. Olympia, WA: Puget Sound Water Quality Action Team. 1998 (Puget Sound/Georgia Basin Environmental Report Series: Number 7).

Keywords: nearshore habitat//regulatory framework//permits//vegetation//docks//piers//runoff//shoreline armoring//growth management act//endangered species act//regulations//shorelines

Abstract: This report characterizes losses to nearshore habitat and provides an overview of regulatory mechanisms in place addressing causes of habitat losses and identifies current regulatory gaps relevant to the protection of nearshore habitat. It reviews the extent of nearshore habitat modifications throughout the Puget Sound and straits region and discusses industrial and residential impacts to habitats. It provides present regulatory structure, a brief regulatory analysis

presenting the regulatory framework, agency roles in the permitting process, and summarizes specific gaps in the current regulatory system.

16. Buckley, R. M. and G. J. Hueckel. The influence of prey communities on fish species assemblages on artificial reefs in Puget Sound, Washington. ENVIRON.-BIOL.FISH. 1987. vol. 19(no. 3):pp. 195-214.

Keywords: Puget Sound//fish//artificial reef

Abstract: Research on eleven artificial reefs in Puget Sound, Washington examined the relative importance of reef-produced prey items to recreationally important reef fish species assemblages.The colonization of potential prey items, and fish species assemblages to ten artificial reefs were examined for the reefs first two to five years, and observations were conducted on an eleventh reef during its forty-ninth productive year.

17. Buckley, Raymond M. Substrate associated recruitment of juvenile *Sebastes* in artificial reef and natural habitats in Puget Sound and the San Juan Archipelago, Washington. Olympia, WA: Washington Dept. of Fish and Wildlife, Fish Management Program, Resource Assessment Division; 1997.

Keywords: rockfish/juvenile rockfish/rockfish recruitment/Puget Sound/San Juan Islands

Abstract: Habitat pathways and temporal and spatial parameters of substrate associated recruitment have never been reported for juvenile quillback rockfish (*S.maliger*) in any ecosystem, and have never been described for juvenile copper (*S. caurinus*) and splitnose (*S. diploproa*) rockfish in Washington waters. In 1991-1994, juvenile quillback rockfish recruited only during July-August each cohort-year, correcting biannual recruitment errors in the literature for Puget Sound; first recruitment was apparently to offshore benthic habitats, with subsequent migrations to nearshore benthic macrophytes. Copper rockfish recruited during July-September each cohort-year; first recruitment was to surface and shallow water macrophytes attached to benthic substrates, with subsequent migrations to benthic macrophytes. During November-January, juvenile quillback and copper rockfish in natural macrophyte habitats migrated offshore associated with benthic drift macrophytes; juveniles in artificial and natural reef habitats migrated to deeper water associated with crevices in the substrates. Juvenile splitnose rockfish recruited during June-August each cohort-year; first recruitment was to surface drift macrophyte and seagrass habitats, which were vacated by December. Apparently co-occurring pelagic juvenile copper and splitnose rockfish selectively recruited to attached and detached vegetation habitats respectively.

Development of internal micro-tagging procedures for juvenile *Sebastes* enabled the first estimation of instantaneous natural loss rate (mortality and emigration)

for this genus, without non-immigration assumptions. The estimate of Z_{258d}=0. .0106 for quillback rockfish on an artificial reef recruitment habitat was lower than for a coastal pelagic species, the only other estimate for juveniles *Sebastes*. Nearshore artificial reef substrate manipulations functioned as juvenile rockfish recruitment habitats, providing preferred nursery and refuge habitats and enhancing local recruitment. Efficacies of artificial reef recruitment habitats located adjacent to, and isolated from, established reefs, were affected by variability in levels of juvenile rockfish recruitment, biogenic habitat parameters, and ecological maturity of the substrates. Micro-tagged juvenile rockfishes remained on artificial reef recruitment habitats during the cohort-year contrasting emigrations form natural macrophyte habitats during the cohort-year contrasting emigrations from natural macrophyte habitats. Increased densities of juvenile rockfish on artificial reef recruitment habitats late in the cohort-year indicated emigrations form natural habitats. Juvenile rockfish had average daily growth rates of 0.11-0.13 mm total length in both natural and artificial reef recruitment habitats.

18. Calambokidis, J. Contaminants in Puget Sound Marine Mammals: Temporal, Spatial, and Species-Related Patterns. Puget Sound Research '95; January 12-14; Bellevue, WA. Olympia, WA: PSWQA. 1995: pp. 901-908.

Keywords: marine mammals//contaminants//water quality//human impacts

Abstract: This paper reviews principal studies conducted on contaminants in Puget Sound marine mammals and examines the patterns in concentrations of chlorinated hydrocarbons among species, across locations , and over time. Habor Seals: PCB concentrations in blubber were found to be 50 to 100 times higher than the concentration in their prey reflecting the high proportion of contaminants they were absorbing from their prey and their limited ability to excrete or metabolize such compounds. Concentrations of PCBs and DDT were significantly higher in pups collected in southern Puget Sound than those from the Strait of Juan de Fuca. However concentrations of metals and trace elements showed no significant difference by site. Lead and silver were significantly higher in seals from the Strait of Juan de Fuca than from southern Puget Sound. Killer Whales: Concentrations of PCBs in blubber ranged form 0.9 to 250 ppm and total DDTs from 1.7 to 250 ppm and total DDTs from 1.7 to 640ppm. Spatial and temporal trends were not apparent. Unlike harbor seals, levels of DDT in killer whales were higher than PCBs. This was interpreted as indicating these animals were either primarily feeding outside of the greater Puget Sound region, a region predominating in PCBs, or their prey came from outside this region. For the Harbor porpoise, distinct differences in concentrations of contaminants were found among regions with a consistent increase in DDT concentrations along the coast of the Southern California Bight. PCBs in blubber ranged from under 1 ppm in an animal recovered on the Washington coast to 55 ppm in an animal from southern Puget Sound. Gray Whales: Concentrations of chlorinated hydrocarbons were low, PCBs in blubber ranged from 0.01 to 3 ppm. Higher

concentrations of aluminum were higher than other species. No significant differences were found by region. Concentrations of PCB's and DDT were lowest in minke whales and pygmy sperm whales. Much higher concentrations of PCBs and DDT were found in Dall's porpoise and river otters.

These studies reveal important patterns. The impact of contaminants are best aimed at harbor seals and killer whales which are the two species with highest exposure to contaminants. Monitoring of contaminant trends and patterns are recommended to be best conducted with harbor seals, where existing data already demonstrates clear regional and temporal patterns in contamination.

19. Calambokidis, J. and J. Quan. Gray whales in Washington State: report on research in 1996. Final report to National Marine Mammal Laboratory, Seattle, Washington. 1997.

Keywords: mammals//marine mammals//whales//gray whales

Abstract: This report summarizes research conducted by Cascadia Research in collaboration with the National Marine Mammal Laboratory during the 1996 field season. Cascadia Research has been conducting research on gray whales in Washington waters using photographic identification of individual animals since the mid-1980s (Calambokidis *et al.* 1994) with the goals of determining the number of whales using Washington waters, preferred areas for feeding, seasonality of use, and degree to which animals return year to year. Fifty boat surveys were conducted by biologists with Cascadia to observe gray whales between 15 March and 6 October 1996 totaling 243 hours of observation and 1,486 nmi of coverage. These included dedicated boats surveys conducted using a rigid-hulled inflatable and effort aboard whalewatch trips. The heaviest effort was in Grays Harbor, the western the Strait of Juan de Fuca, the northern Washington outer coast, and in the northern Puget Sound area. Data were also contributed by biologists at the National Marine Mammal Laboratory who provided identification photographs of gray whales made on an additional 13 days (between 13 June and 26 September) from surveys on the northern outer coast and the western Strait of Juan de Fuca. Gray whales were individually identified using photographs of the natural markings on the right and left sides. Comparisons of identified individuals were made to Cascadia's catalog of over 100 gray whales seen in previous years off Washington as well as catalogs of identification photographs taken by collaborating researchers in British Columbia. A total of 112 sighting reports of gray whales were received by Cascadia Research and the Whale Museum in 1996. A total of 47 different gray whales were identified on 1996 in the study. A high proportion of the whales identified in three regions (northern Washington coast, Strait of Juan de Fuca, and southern Vancouver Island) were seen multiple times (73-79% by region) and had been identified in a previous year (64-82%). Gray whales identified near Grays Harbor early in the season were less likely to have been seen multiple times (52%) or a previous year (26%). Because most of these whales were identified in the migratory corridor during the migration (26-52%) when we would expect to be

seeing migratory whales, this lower proportion of ‘resident’ whales was surprisingly high. Gray whales were frequently identified in multiple regions indicating movement patterns. Comparison of photographic catalogs with researchers working in British Columbia revealed that many of the whales that feed along the Washington coast through the summer range along the British Columbia coast to areas north of Vancouver Island. Conclusions of the research conducted through 1996 include: Gray whale use of southern and central Puget Sound is highly variable; few animals came into these waters in 1996. Previous research has shown whales that have been identified in these waters have never been resighted across years and have not been seen in other regions. A consistent group of individual gray whales had returned annually to the waters around Whidbey Island but the duration of their stay has become shorter. In 1996 we were not successful in finding these animals in this or any other region. ·A consistent group of individual whales feed each summer along the Washington outer coast and Strait of Juan de Fuca and range north past Vancouver Island. Some of these animals have returned over a 20 year period.

20. Calambokidis, J. and R. W. Baird. Status of marine mammals in the Strait of Georgia, Puget Sound, and Juan de Fuca Strait and potential human impacts. p 282-303 In: Review of the marine environment and biota of Strait of Georgia, Puget Sound, and Juan de Fuca Strait. [(R.C.H. Wilson, R.J. Beamish, F. Aitkens, and J. Bell, Ed.). Canadian Technical Report of Fisheries and Aquatic Sciences No. 1948.]. Proceedings of the BC/Washington Symposium on the Marine Environment, 1994 Jan 13; 1994.

Keywords: marine mammals/Puget Sound

Abstract: Nine species of marine mammals commonly occupy the trans-boundary waters of British Columbia and Washington (BC/WA). Animals of all species move across this international border. Of the four pinniped species common to these waters, harbour seals are the most numerous and the only one that breeds in these waters. Approximately 30,000 harbour seals occur in the trans-boundary area. Harbour seal populations have increased at 10-15% per year. The numbers of California sea lions and elephant seals have also been increasing steadily although neither breeds in BC/WA waters. Steller sea lions, a species that is declining through most of its range, also occur in this region. Of the five cetacean species common to the waters, harbour and Dall's porpoise are the most abundant and number in the several thousands. Harbour porpoise numbers in some areas have declined since the 1940s, though little data are available to assess current trends in populations of these two species. Killer whales are the best studied marine mammal species in the area, with most of the individuals in the populations that use these waters identified photographically. Over 20,000 gray whales migrate past the entrance to the Strait of Juan de Fuca and some individuals spend prolonged periods feeding in the spring and summer

in BC/WA waters. A small number of minke whales also return annually to these waters to feed during the spring, summer, and fall. Marine mammals are vulnerable to human activities in the BC/WA trans-boundary waters. High concentrations of contaminants, especially chlorinated hydrocarbons and some metals, have been identified in these animals. Highest concentrations of contaminants have been found in harbour seals (from southern Puget Sound) and killer whales. Determination of the impacts of these contaminants on marine mammals in these waters has been inconclusive, though in other areas contaminant exposure has caused reproductive failure and immunosuppression. Marine mammals are killed incidental to commercial fishing operations, particularly harbour porpoise, Dall's porpoise, and harbour seals. Information to assess human impacts on most marine mammals and to adequately evaluate their current status is extremely limited.

21. Calambokidis, J. G. H. Steiger B. D. McLaughlin and J. R. Evenson. Harbor seal haul-out habitat and the feasibility of shifting haul-out locations at Dosewallips State Park, Washington. Report to the Washington State Parks and Recreation Commission. Olympia, Washington. 1990.

Keywords: seals//marine mammals//washington//Jefferson County

Abstract: High fecal coliform concentrations found at the Dosewallips River delta on the Hood Canal appear to originate from harbor seals that use the sloughs and marsh on the southern portion of the delta to haul out (Calambokidis *et al.* 1989, Calambokidis and McLaughlin 1988, DSHS 1988). In other areas in Puget Sound, harbor seals regularly haul out on human-made platforms, such as recreational floats and log booms (Calambokidis *et al.* 1978, 1985, Johnson and Jeffries 1977). Harbor seals used to haul-out on a log boom that existed at the north end of the Dosewallips River Delta through the mid 1970s. Because seal-related contamination is closely associated with haul-out locations, it may be possible to alter the affected areas by shifting the areas used by seals to haul out. This study examines the feasibility of shifting the seal haul-out habitat at Dosewallips delta from the salt marsh areas used currently to human-made structures that would be located just off the delta. We summarize relevant findings about the biology of harbor seals at this location, harbor seal haul-out requirements, what steps would need to be taken to shift the location of haul-out, and limitations of trying to conduct such a project. This study was funded by the Washington State Parks and Recreation Commission. Counts made on 49 days from December 1989 to August 1990 at Dosewallips Delta ranged from 11 to 390 harbor seals and averaged 140 (n=49, s.d.=85). A number of factors were identified that were statistically associated with the variations in the number of seals counted at the Dosewallips Delta. These included time of day, temperature, and tide height and time to high tide. A major surprise from the results of this study was the significant decline in seal numbers at the Dosewallips River Delta in recent years. This trend data should be viewed with caution, especially because it does not cover some critical seasons. There were not significant increases or decreases in seal numbers observed at Duckabush River Delta or

Quilcene Bay. At the Dosewallips River delta, harbor seals haul out along the three main southern sloughs and along or on logs along the river. We found significant seasonal and annual changes in the use of different portions of the Dosewallips River Delta. A trial float placed at Dosewallips River delta on 16 May 1990 was not used by seals until 15 June 1990 and not regularly until late July. Females with pups occasionally hauled-out on the float in late August, towards the end of the pupping season. Exploratory behavior by seals in the water of the trial float was seen frequently. The amount of haul-out space required per seal was similar among locations and habitats and averaged about 2 m^2/seal. The area used by seals at human-made habitats tended to be slightly larger than natural habitats, though this difference was small. The mean shoreline distance per seal (the distance of shoreline or water access for a group of seals) was generally under 1 m/seal at natural habitats and greater than 1 m/seal at other human-made habitat. Human-made haul-out areas appear to provide some advantages over natural habitats, especially in their accessibility at all tides and their rapid access to deep water. The height above water for human-made structures used by seals, including log booms, floats, and a fish net pen, ranged from 12 to 54 cm with log booms lowest in the water. The height above the water of many floats used by seals appear to prevent newborn seal pups from getting out on the float for the first 1-2 weeks. An alternate haul-out structure able to accommodate the maximum seals seen using the current haul-out area (470) would need to be 1,175 m^2 using 2.5 m^2 per seal. Shoreline space would need to be at least 1 m per seal or about 500 m in total. This is less of a limiting factor since the haul-out area designs discussed below and human-made haul-out areas in general, easily meet this requirement. Two human-made structures, log booms and floats, represent the best choices for alternate habitat at Dosewallips and a combination of both structures would provide the best alternative habitat for harbor seals. To allow segregation between groups we recommend use of multiple small structures as opposed to one or two large structures. The ideal log-boom structure consists of three logs secured together by crosspieces with total width of 1.5 m. For the float design, the most suitable and compact structure would be a series of open-celled concrete floats. A fairly compact 12 x 17m structure would be suitable for up to 60 harbor seals. A marked barrier around the structures would be necessary to keep boaters away from hauled seals and restrict them from using the structures for recreational purposes. The best location for an alternate haul-out site is along the steep slope marking the edge of the delta just north of the main river channel. Seals may not readily adapt to new structures.

22. Calambokidis, J. J. L. Laake and S. D. Osmek. Aerial surveys for marine mammals in Washington and British Columbia inside waters. Final report to the National Marine Mammal Laboratory, Seattle, WA. 1997.

Keywords: marine mammals//san juans//straits

Abstract: Aerial line-transect surveys were conducted during August 1996 primarily to estimate harbor and Dall's porpoise abundance in five regions, encompassing US and Canadian waters of the Strait of Juan de Fuca, San Juan/Gulf Islands, and Strait of Georgia. A total of 6,263 km (3,382 nmi) of on-transect effort were completed using a twin-engine high-wing aircraft flying at 90 knots and an altitude of 600 feet. Three observers searched for marine mammals through side bubble windows and a downward viewing port. Out of 1,505 groups sighted (3,340 animals) while on-effort, 1,074 were harbor seals, 311 were harbor porpoise, and 76 were Dall's porpoise. We estimate abundance of harbor porpoise and Dall's porpoise using line-transect methods. A re-analysis of aerial surveys conducted in 1991 was also completed to provide a comparable dataset using similar regional boundaries and analysis methods to look at temporal trends.

23. Calambokidis, J. J. R. Evenson G. H. Steiger and S. J. Jeffries. Gray whales of Washington State: natural history and photographic catalog.Olympia, Washington: Cascadia Research Collective; 1994.

Keywords: whales//marine mammals

Abstract: This report provides a description of population status, migratory movements, feeding habits, sighting reports, behavior and feeding, and mortality statistics fo gray whales in Washington State.

24. Calambokidis, J. J. R. Evenson J. C. Cubbage S. D. Osmek D. Rugh and J. L. Laake. Calibration of sighting rates of harbor porpoise from aerial surveys. Report to the National Marine Mammal Laboratory, National Marine Fisheries Service. Seattle, Washington. 1993.

Keywords: porpoise//marine mammals

Abstract: Harbor porpoise abundance estimates have been made for Washington and Oregon using aerial and vessel surveys (Barlow 1988, Barlow *et al.* 1988, Calambokidis In Press, Calambokidis *et al.* 1991, 1992, Green *et al.* 1992 Turnock *et al.* In press). A major limitation of these estimates, however, has been that the fraction of animals missed on the survey line was not known. The primary objective of this study was to experimentally determine a correction factor for harbor porpoise missed during aerial surveys. Two methods were used to evaluate the correction factor for animals missed. The primary method for obtaining a correction factor was to measure the sighting success by aerial observers of specific harbor porpoise groups being tracked from land. Harbor porpoise groups in the study area were tracked from land prior to the aircraft passes. Secondarily, we gathered breath rate data on harbor porpoise groups to determine the proportion of time they are at the surface and likely to be seen by aerial observers. This was similar to the method used by Barlow *et al.* (1988) in devising a correction factor. The calibration experiment was conducted off the

northwest side of Orcas Island in the San Juan Islands, Washington. Aerial surveys with a twin-engine aircraft were conducted in conjunction with land observations on 7 days between 3 August and 13 August 1992. A total of 547 transect lines were flown in 33 flight hours completing approximately 26 hours of transect surveys. Two teams, each consisting of 4-6 people made observations of harbor porpoise from land. Each team used an electronic theodolite interfaced with a computer data acquisition system. Radio contact between one of the aircraft personnel and the land teams was used to select aircraft transects that would include passing over a harbor porpoise group being tracked from land. To determine the proportion of harbor porpoise groups seen from the aircraft, several criteria were used to select the harbor porpoise groups that would be used for the calibration and to determine whether a group tracked from land was seen by the aerial observers. Harbor porpoise groups were included as a sample in the calibration only if: 1) they were seen from land within 4 minutes of the passage of the aircraft, and 2) were within 100m of the aircraft transect line. A harbor porpoise group being tracked from land was considered seen by the aerial observers if the position of the porpoise determined from land and air was less than 300m and if the number of porpoises in the group determined from the air was not more than twice or less than half the size determined from land. Using the parameters described above, 28 of 92 (30.4%) harbor porpoise groups within 100m of the transect line were seen by the aerial observers and 69.6% were missed. The point estimate for g(0) (the probability of sighting a group that was on the transect line) was 0.324 (SE=0.056). The sample size for this estimate was better than expected and provides a low enough variance that it will be able to be applied without greatly increasing the overall variance of abundance estimates. The correction factor for animals missed on the transect line was almost identical to that determined previously by Barlow *et al.* (1988) based on breath rate data of harbor porpoise. Seven different harbor porpoise groups whose surfacing were monitored spent an average of 36 sec (sd= 13.1) at or near the surface and 120 sec (sd=31.0) on longer dives of 30 sec or more. These values likely underestimate the time groups spend at the surface because some surfacings may have been missed. The proportion of harbor porpoise at the surface (potentially visible from the air) based on breath rates was slightly lower than the proportion seen in the calibration experiment. This may have been a result of our underestimating the time porpoise are at the surface (due to missing some surfacings). This also suggests that relatively few harbor porpoise on the transect line that were at the surface when the aircraft flew over were missed during the calibration experiment. The proportion of time we calculated harbor porpoise were at the surface from the breath rate data was similar to that reported by Barlow *et al.* (1988).

25. Calambokidis, J. S. J. Jeffries P. S. Ross and M. Ikonomou. Temporal trends in contaminants in Puget Sound harbor seals. Final Report to U.S. EPA and Puget Sound Water Quality Action Team. Olympia, WA. Cascadia Research. 1999.

Keywords: marine mammals//Puget Sound//contaminants//seals

Abstract: Harbor seals (*Phoca vitulina*) are the most abundant marine mammal species in Washington State and occur throughout the marine waters including Puget Sound. Extremely high concentrations of some chlorinated hydrocarbon contaminants, especially PCBs, were found in Puget Sound harbor seals in the 1970s and 1980s. One of the longest-term datasets on trends in contaminants in the Puget Sound region comes from harbor seals. Harbor seal pups from Puget Sound have been collected or biopsied for testing concentrations of PCBs and DDT compounds at 4-5 year intervals from 1972 to 1997 at several Puget Sound sites including Gertrude Island in southern Gertrude Island in southern Puget Sound and Smith Island in the Strait of Juan de Fuca. Samples from harbor seals are ideally suited for trend analyses because they are highly contaminated, represent an integration of concentrations in a broad selection of prey in a region, and, with the utilization of non-emaciated pups, provide limited inter-sample variability allowing sensitive detection of changes over time. The most recent analyses were of both dead harbor seal neonates collected in 1996 and 1997 and biopsy samples of blubber from weaned harbor seal pups collected in 1993 and 1996 at Gertrude Island. We determined current levels of a broad range of chlorinated hydrocarbon contaminants in Puget Sound harbor seals including congener-specific concentrations of PCBs, DDTs and other pesticides, and the first analyses of polychlorinated dibenzo dioxins and furans (PCDDs and PCDFs). We tested both the most recent samples and re-tested some of the historical samples from 1984 and 1990 to provide more detailed data on historical contaminants. Harbor seals have proven to be an excellent indicator of environmental contamination at the upper level of the food chain with clear spatial and temporal differences detected. While concentrations of PCBs and DDT have declined dramatically since the 1970s, concentrations have stabilized since the mid-1980s with only slight declines since then. Even though concentrations have declined, harbor seals are clearly still at risk, with the current concentrations of PCBs and the TEQ in pups within the range identified as causing immunotoxicity in seals. Most of the TEQ came from PCBs rather than PCDDs or PCDFs. The plan is to continue monitoring trends in harbor seal contamination in Puget Sound at regular intervals and update trend data from other sites in Washington State.

26. Calambokidis, J. S. M. Speich J. Peard G. H. Steiger J. C. Cubbage D. M. Fry and L. J. Lowenstine. Biology of Puget Sound marine mammals and marine birds: Population health and evidence of pollution effects. NOAA Tech. Memo. NOS OMA 18, National Technical Information Service. Springfield, Virginia. 1985.

Keywords: contamination//Puget Sound//birds//marine mammals

Abstract: The objective of this research was to determine whether detrimental effects possibly caused by toxic chemicals could be observed in Puget Sound marine mammals and marine birds. The study design was based on examination of a wide variety of indices of population and individual health and comparison of

these indices from areas of suspected high contaminant levels (target areas) to those from areas of suspected low contaminant levels (reference areas) and to those reported by other researchers. Recent research conducted in Puget Sound has revealed high levels of contaminants in fish, marine mammals, and marine birds. High contaminant levels in Puget Sound have been correlated to abnormalities and disorders in fish. Researchers have also reported possible linkages between contaminants and disorders in marine mammals and marine birds in other parts of the world. Primary species considered here are harbor seal, Glaucous-winged Gull, Great Blue Heron, and Pigeon Guillemot; these species were chosen because they reside, feed, and breed in some of the most contaminated portions of Puget Sound. Three other mammal species (killer whale, harbor porpoise, and river otter) were chosen as secondary study species either because they seasonally occur in contaminated areas of Puget Sound or they were found through previous research to be experiencing problems that might be pollutant-related. Target areas were chosen that were as close as possible to the heavily contaminated Elliott and Commencement Bays. Reference areas used for different species included sites north of Puget Sound, in the Hood Canal, and in Grays Harbor and Willapa Bay on the Washington outer coast. Several biological parameters were examined to evaluate the evidence for pollutant-related problems. These parameters included population distribution, population trends, measures of reproductive success, mortality, causes of death, incidence of gross and histological pathology, and incidence of physical deformities or disorders seen in the population. To detect a broad range of possible effects, both general population health as well as incidence of individual disorders previously linked to contaminants were examined and measured. Study methods varied by species. Censuses were made from the ground, boats, and from small aircraft and provided population figures for several species. Reproductive rates were determined from censuses and for birds, by observing marked nests. Mortality and the incidence of reproductive disorders were determined from breeding area searches and censuses made during the breeding season. Gross pathology was determined from necropsies of animals found dead and for some species from collected individuals. Samples for histopathology, microbiology, blood parameters, and eggshell thickness were collected from appropriate species and examined by specialists for comparison between locations. Tissues for contaminant analysis were collected and archived, but not analyzed. We found a wide variety of disorders in some marine mammal and marine bird species. Some of these disorders followed patterns consistent with known patterns of contaminant concentrations in Puget Sound. Evidence for possible pollutant-related disorders is summarized in Table 1. Overall, populations of the study species are doing very well, with the exception of the harbor porpoise and the killer whale; these two populations have declined in the Puget Sound area. For harbor porpoise the decline occurred prior to the 1970s and for killer whales the evidence of a decline is recent. Harbor seal numbers are generally increasing in all our study areas, however, an unusually high incidence of premature births and neonatal mortality was found at some sites. These disorders are similar to those that have been linked to effects of

contaminants in pinnipeds from other parts of the world. The high incidence of these disorders seen in Puget Sound seals, however, was found not at sites with suspected high contaminant levels but, rather unexpectedly, at study sites with suspected low contaminant levels. The most likely explanation for these problems is disease agents in these populations compounded by the possibility that these areas are nearing carrying capacity for seal numbers. A significantly higher incidence of pelage disorders and umbilical lesions seen in contaminated areas shows a pattern that suggests a relationship with contaminants. Puget Sound marine bird populations do not appear to be declining or experiencing major reproductive problems. Two of three primary study species (Glaucous-winged Gull and Great Blue Heron), however, did show significant eggshell thinning compared to pre-1947 measurements. In addition, Pigeon Guillemots had lower overall eggshell thickness than those reported for pre-1947, but the difference was not statistically significant. These findings suggest a possible persistent detrimental effect of the pesticide DDT (and its primary metabolite, DDE) as has been reported for a wide variety of bird species in other areas. We also found evidence of highly variable liver weights in gulls that may have been associated with contaminants. No conclusive statements regarding the association between contaminants and eggshell thinning or liver weights can be made until chemical analyses of archived tissues are conducted. Contaminant analysis of archived samples would greatly augment this study in several ways. This analysis is important in order to: verify our assumptions about contaminant exposure of different populations; provide a better comparison with findings in other areas;
allow correlation tests between disorders found in specific animals and their contaminant burdens; and describe trends in recent contaminant exposure of marine mammals and marine birds.

27. Calambokidis, J. and Baird, R. W. Status of marine mammals in the Strait of Georgia, Puget Sound and the Juan de Fuca Strait and potential human impacts [Review of the Marine Enviornment and Biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait Proceedings of the BC/Washington Symposium of the Marine Environment] Wilson, R. C. H.; Beamish, R. J.; Aitkens, F., and Bell, J. eds. BC/Washington Symp. on the Marine Environment, Vancouver, BC (Canada), 13-14 Jan 1994; 1994 Jan 13. Sidney, BC Canada. Institute-of-Ocean-Sciences. 1994: pp. 283-303.

Keywords: marine mammals//straits

Abstract: In this report the authors summarize what is known about the status of marine mammals that occur in the transboundary area, examine potential human impacts on marine mammals, and make research recommendations.

28. Calambokidis, J.; Speich, S. M.; Peard, J.; Steiger, G. H., and Cubbage, J. C. Biology of Puget Sound marine mammals and marine birds: Population health and evidence of
pollution effects.Off. of Oceanography and Marine and Assessment. Rockville, MD: National Ocean Serv. NOAA TECH. MEMO. 1985. NTIS Order No.: PB91-172734/GAR. NOAA/TM/NOS/CMA-18 (NOAATMNOSCMA18).

Keywords: birds//marine mammals//Puget Sound

Abstract: The objective of the research was to determine whether detrimental effects possibly caused by toxic chemicals could be observed in Puget Sound marine mammals and marine birds. The study design was based on examination of a wide variety of indices of population and individual health and comparison of these indices from areas of suspected high contaminant levels (target areas) to those from areas of suspected low contaminant levels (reference areas) and to those reported by other researchers. Primary species considered here are harbor seal. Glaucous-winged Gull, Great Blue Heron, and Pigeon Guillemot; these species were chosen because they reside, feed, and breed in some of the most contaminated portions of Puget Sound. Three other mammal species (killer whale, harbor porpoise, and river otter) were chosen as secondary study species either because they seasonally occur in contaminated areas of Puget Sound or they were found through previous research to be experiencing problems that might be pollutant-related. (DBO).

29. Calambokidis, J.; Steiger, G. H.; Lowenstine, L. J., and Becker, D. S. Chemical contamination of harbor seal pups in Puget Sound Puget Sound. Puget Sound Estuary Program. Bellevue, WA: PTI Environmental Services; 1991. NTIS Order. PB92-132778/GAR.

Keywords: marine mammals//Puget Sound//contaminants//water quality//seals

Abstract: Dead newborn harbor seals (*Phoca vitulina*) were collected from Smith Island in the Strait of Juan de Fuca and from Gertrude Island in southern Puget Sound. A variety of chemical contaminants were measured in different kinds of tissue from seven harbor seal pups from each location. Various tissues were also evaluated microscopically for histopathological abnormalities. Two methods for determining the concentrations of PCBs and DDE in blubber tissues were compared. Concentrations of PCBs, lead and silver were significantly higher in the seals from Gertrude Island than those from Smith Island. However, the concentrations of PCBs in seal pups from both locations have declined significantly since testing began in 1972.

30. Canning, Dougals J. and H. Shipman (Shoreland and Environmental Assistance Program). Coastal erosion management studies in Puget Sound, Washington: Executive Summary. Olympia, WA: Washington Department of Ecology; 1996 Jan. Report 94-74. (Coastal Erosion Management Strategy; Coastal Erosion Management Studies, Vol. 1).

Keywords: geology/coastal erosion/erosion management

Abstract: This report is an executive summary of reports by Department of Ecology Coastal Erosion management Studies contractors. It does not address commercial and industrial land uses. The study area was Puget Sound from Olympia north to the Canadian border. The report covers Puget Sound geology, shoreline stabilization techniques, shoreline armoring in Thurston County, management of coastal erosion and unstable shoreline, impacts of erosion management techniques and impacts to biological resources and ecological systems, institutional approaches and policy tools.

31. Cardwell, Rick D. and C. E. Woelke. Water Quality Compendium for Washington State. Washington State Department of Fisheries; 1979. Grant No. R80503210. (II. Data).

Keywords: water quality//Port Townsend

Abstract: Contains results of biomonitoring studies of Port Townsend with a majority of over thirty sampling stations located adjacent to the paper mill discharge pipe. One site south of Protection Island near diamond Point, two off of downtown Port Townsend, and one mid-basin in Discovery Bay.

32. Casillas, E. M. R. Arkoosh E. Clemons T. Hom D. Misitano T. K. Collier J. E. Stein and U. Varanasi. Chemical contaminant exposure and physiological efects in outmigrant juvenile chinook salmon from urban estuaries of Puget Sound, Washington. Puget Sound Research '95. 1995. Jan 12-14 1995. Bellevue, WA. Olympia, WA. 1995. pp. 657-665.

Keywords: water quality//salmon//Puget Sound//fish//contaminants

Abstract: Overview of data collected from studies over the period of 1989 to 1993 on the effects of chemical contaminant exposure on juvenile chinook salmon in polluted urban Puget Sound estuaries. The data collected reveals increased exposure of juvenile chinook salmon to toxic chemicals in these estuaries. Juvenile salmon inhabiting contaminated urban estuaries displayed immune system alterations and impaired growth when compared to juveniles from hatcheries or non-urban estuaries. Juveniles from the Duwamish Waterway showed immunosuppression and increased disease susceptibility to *Vibrio anguillarum.* Studies during this period provide evidence of linkage between

juvenile chinook salmon health and elevated contaminant levels in polluted estuaries.

33. Center for Marine Conservation, Marine Resources. A Citizens Guide to Marine Resources of the Northwest Straits. 1998.

Keywords: MPA//fish//marine birds//marine mammals//salmon//herring//rockfish//cod//nearshore//oil spills//water quality//impacts//shellfish//invertebrates//northwest straits//straits//nearshore

Abstract: A guide providing citizen access to information on the status and health of marine resources in the region of the Northwest Straits. It includes resource maps and information on invertebrates, marine fish, salmon, seals and sea lions, marine birds and marine mammals of the Northwest Straits and human impacts on habitats in the Northwest Straits.

34. Cohen, Andrew C Mills H. Berry M. Wonham B. Bingham B. Bookheim J. Carlton J. Chapman J. Cordell and L. Harris, T. Klinger A. Kohn C. Larbert G. Lambert K. Li D. Secord and J. Toft. A Rapid Assessment Survey of Non-indigenous Species in the Shallow Waters of Puget Sound. Lacey, WA: Washington State Department of National Resources. 1998 Puget Sound, Hood Canal, Strait of Georgia and adjoining waters.

Keywords: non-indigenous species//invertebrates/Puget Sound//shellfish

Abstract: This report presents the results of a sampling expedition of 32 sampling stations in Puget Sound and the San Juan area from southern most sites like Shelton and Mud Bay, central Puget Sound, Port Ludlow, Port Hadlock, Port Townsend, Port Orchard, Seabeck, Brownsville from Steilacoom to Blaine along the mainland, Friday Harbor, Argyle Lagoon, Anacortes, Samish River, Swinomish Cannel, Cornet Bay, Bellingham, and Blaine. This rapid assessment for non-indigenous marine organisms focused primarily on non-quantitative or semi-quantitative sampling of dock fouling organisms growing on floating docks.

35. Cox, Jack K. McDonald and T. Rigert. Engineering and Geotechnical Techniques for Shoreline Erosion Management in Puget Sound. Olympia, WA. Washington State Department of Ecology.1994.Report 94-77. Coastal Erosion Management Studies. Vol. 4 .Shorelands and Environmental Assist. Program.

Keywords: erosion//shoreline

Abstract: Reports on technically feasible shoreline protection techniques including soft solutions using natural site features and materials, composite systems combining hard and soft solutions, building setbacks and drain field

removal. Erosion processes are described including identification of an erosion problem, techniques for erosion control and a site-specific decision model to help landowners and regulators select solutions.

36. Cross, J. N. K. Fresh B. S. Miller C. A. Simenstad S. N. Steinfort and J. C. Fegley. Nearshore fish and macroinvertebrate assemablages along the Strait of Juan de Fuca including food habits of the common nearshore fish. Seattle, WA: UW, School of Fisheries, Fisheries Research Institute; 1978; FRI-UW-7818.

Keywords: fish//bottomfish//rockfish//cod//groundfish

Abstract: This reports on a baseline study to document the distribution, abundance, and biomass of nearshore fishes along the Strait of Juan de Fuca, to determine their food habits, and to identify the macroinvertebrates collected incidentally with the fish. A total of 93 species of fish was collected from 1976 to 1978. Trends in occurrence, abundance, and biomass for individual species were fairly consistent between 1976-77 and 1977-78. The predominant nearshore demersal fish species in beach seine collections were the Pacific staghorn sculpin, Eng. sole, and sand sole. The dominant neritic fish species in townet collections were the Pacific herring and longfin smelt. The predominant intertidal fish species were the northern clingfish, tidepool sculpin, and high cockscomb. Species richness generally increased from west to east in beach seines and townet collections while the opposite trend was observed in tidepool collections. Species richness and density was highest in summer and fall and lowest in winter. 53 of 55 common nearshore resident species preyed upon gammarid amphipods. Gammarids composed more than 50% of the total Index of Relative Important for 31 fish species and than 75% for 9 species. Calanoid copepods were the dominant prey of neritic fishes.

37. Deriso, R. B. T. J. Quinn II and P. R. Neal. Catch at age analysis with auxiliary information. Can. J. Fish. Aquat. Sci. 42:815-824; 1985.

Keywords: harvest//fish

Abstract: The authors review techniques for estimating the abundance of migratory populations and develop a new technique based on catch-age data from geographic regions and their earlier technique, catch-age analysis with auxiliary information. Data requirements are catch-age data over several years, some auxiliary information, and migration rates among regions. The model, containing parameters for year-class abundance, age selectivity, full-recruitment fishing mortality, and catchability, is fitted to data with a nonlinear least squares algorithm. A measurement error model and a process error model are presented and favor the process error model because all model parameters can be jointly estimated. By application to data on Pacific halibut, *Hippoglossus stenolepis* , the

process error model converges readily and produces estimates with no significant bias.

38. Determan, Tim. 1999 Status and trends in fecal coliform pollution in Puget Sound embayments. 2000 Washington State Dept. of Health and Office of Food Safety and Shellfish Program.

Keywords: shellfish//growing areas//Puget Sound//straits//water quality

Abstract: This report is a Department of Health (DOH) summary of fecal coliform pollution in 45 Puget Sound shellfish areas from January 1998-March 1999. It reports the status, trends and discusses sources. Jefferson County sites include Protection Island, Discovery Bay, Kilisut Harbor, Port Townsend Bay, and Dosewallips State Park. Dosewallips River delta was the only site in Jefferson County showing fecal coliform pollution in one or more stations. Maps of sites are provided.

39. Dethier, M. A Marine and Estuarine Habitat Classification System for Washington
State. Washington Natural Heritage Program. Olympia, WA. Washington State Department of Natural Resources. 1990.

Keywords: vegetation//habitat//vegetated habitat//nearshore

Abstract: Stresses on marine ecosystems due to changing global climate and the encroachment of human development are manifested in the Pacific Northwest by loss of habitat and the reduction or extinction of many important organisms. Studying the ecological functions of marine habitats and measuring the extent and rate of habitat loss is important to determining the health of Puget Sound. To monitor habitat changes in Puget Sound, there is a need to map shoreline types and inventory the marine biota for: 1) measuring change due to natural or human-caused perturbations; 2) mapping areas with key resources or potential for these, and 3) choosing sites for research and for monitoring programs. Our ability to detect changing the biota of the Sound requires that the information we gather about the biota has a sufficiently fine spatial scale of resolution, and that we take steps to minimize the inherent variability that exists in all ecological data sets. One way to do both is to take into account the geophysical features of the shorelines being mapped or studied as such features strongly affect biotic communities.

40. Doty, D. C. R. M. Buckley and J. E. West. Identification and protection of nursery habitats for juvenile rockfish in Puget Sound, Washington. Puget Sound Research '95 Proceedings; Bellevue, WA. Olympia, WA. 1995. pp.181-190.

Keywords: rockfish//Puget Sound

Abstract: Summary of a study identifying nursery habitats for three demersal Puget Sound rockfish species. Recruitment was concentrated along the northwestern shoreline of central Puget sound. Young-of-the-year (YOY) rockfish were found to use all three kelp, macroalgae, and eelgrass vegetated habitat types with kelp habitat supporting the highest densities. The vegetated habitats appeared to provide refuge for juveniles making the transition from pelagic to benthic habitats. The findings also suggested that vegetated habitats may be necessary for replenishing and maintaining adult populations of copper, quillback, and brown rockfish. Recommendations include using vegetated habitats for juvenile rockfish as a habitat management. The study supports the use of vegetated habitats to be considered in habitat management and mitigation. Most recruitment of YOY rockfish in theis study occurred in urbanized shorelines where habitat degradation and alteration were common. Such shoreline changes and habitat degradation may effect natural rockfish production. This study data is now incorporated into Washington Administrative Code (WAC).

41. Elston, Ralph. Pathways and Management of Marine Nonindigenous Species in the Shared Waters of British Columbia and Washington: Battelle Laboratories prepared for Puget Sound Water Quality Authority U.S. Environmental Protection Agency, Region 10 Department of Fisheries and Oceans, Canada; 1997.

Keywords: non-indigenous species//puget sound//straits

Abstract: This report was commissioned by the Puget Sound Water Quality Authority through an agreement between the U.S. Environmental Protection Agency (EPA) and the Canadian Department of Fisheries and Oceans (DFO). Its purpose is to assist the Washington and British Columbia Working Groups on Minimizing the Introduction of Exotic Species in developing their recommendations to the British Columbia Washington Environmental Cooperation Council. It assesses the status and management of NIS introductions into the shared marine waters of British Columbia and Washington. Pathways of NIS introduction are evaluated, and the management programs in place to reduce risks from these pathways are described. It is intended that from this report and from the work groups that will consider it, recommendations will emerge that address risk and management of NIS introductions, and needs for further information.

Pathways of NIS introduction to the shared marine waters include aquaculture activities; the aquarium trade; public aquaria; releases of NIS by individuals; commercial, military, and recreational marine vessels; research institutions; and seafood commodity distribution. Risk of NIS introduction from aquaculture is well defined, the industry is highly regulated, and active processes are underway for continuous review of aquaculture activities as they involve NIS. Risk of NIS

introduction from aquarium activities and release of NIS by individuals is poorly defined, and only limited information is available to define the risks from research, seafood distribution, and marine recreational vessel activities. The relative risk associated with the large inoculation of marine NIS from ballast water discharges is assessed from shipping industry data and relevant scientific literature. Management of NIS in other selected states and countries is briefly reviewed.

42. Engel, J. and R. Kvitek. Effects of otter trawling on a benthic community in Monterey Bay National Marine Sanctuary. Conservation Biology. 1998; 12:1204-1214.

Keywords: MPA//marine protected areas//commercial harvest//harvest//commercial fishery//trawl

Abstract: Bottom trawling is one of the most disruptive and widespread human-induced physical disturbances to seabed communities and has become a global environmental concern. We used a comparative approach to test the hypothesis that persistent otter trawling decreases bottom habitat complexity and biodiversity, increases the abundance of opportunistic species, and benefits prey important in the diet of some commercially valuable fish. We compared two similar and adjacent fishing areas at 180 m off central California in Monterey Bay National Marine Sanctuary: one inside the three-mile coastal zone of restricted fishing with light levels of trawling and one beyond the three-mile limit with high levels of trawling. Differences in fishing effort between the two areas were confirmed and quantified by means of data and tow number statistics from Pacific Fishery Management Council (PFMC) Trawl Logbook records. We used still photography, video footage, bottom grab samples, and experimental trawling to compare the physical and biological parameters of the two areas. The area with high levels of trawling had significantly more trawl tracks, exposed sediment, and shell fragments and significantly fewer rocks and mounds and less flocculent material than the lightly trawled area. Most invertebrate epifauna counted were significantly more abundant in the lightly trawled area. The density of polychaetes, *Chloeia pinnata*, as well as that of oligochaetes, ophiuroids, and nematodes, were higher every year in the highly trawled area, and there were significantly fewer polychaete species every year in the highly trawled area. Content analysis of fish guts showed that *C. pinnata* was a dominant prey item for some of the commercially important flatfishes in both lightly and heavily trawled areas. Our study provides evidence that high levels of trawling can decrease bottom habitat complexity and biodiversity and enhance the abundance of opportunistic species and certain prey important in the diet of some commercially important fishes. Our work also illustrates how constraints currently imposed on fisheries research by the near universal absence of true unfished control sites severely limit our ability to determine appropriate levels of harvest pressure for maintaining sustainable fisheries and marine biodiversity. Valid research in these areas will require marine reserves in which fishing effort and

methods can be manipulated in collaborative studies involving fishers, researchers, and resource agencies.

43. Erstad, P. S S. J. Jeffries and D. J. Pierce. 1994 preliminary report for areas 7 and 7A Puget Sound fishery observer program: non-treaty sockeye gillnet fishery. WDFW; 1994.

Keywords: marine birds//salmon//harvest//harvesting impacts

Abstract: Study objective was to determine the nature and extent of marine mammal and marbled murrelet interaction with commercial salmon gill net fishing gear.

44. Evanson, Joseph R. and Joseph B. Buchanan. Winter Shorebird Abundance at Greater Puget Sound Estuaries: Recent Census Results and Identification of Potential Monitoring Sites. Puget Sound Research Proceedings; 1995 Jan 12-1995 Jan 14; Bellevue, WA. PSWQA; 1995.

Keywords: marine birds//Puget Sound

Abstract: This paper reports on a shorebird counts at 59 sites in the greater Puget Sound area which includes the entire Puget sound basin, Hood Canal and the Strait of Juan de Fuca. Kilisut Harbor was the only site in eastern Jefferson County to have over 1,000 shorebirds. The high count at Kilisut was 1646 in 1992-93 counts and 796 in 1993-94. Sites with greater than 1,000 shorebirds are considered important for conservation and monitoring purposes. Sites with less than 5,000 shorebirds were found to support 27% of the winter population in both years of the study. Many disturbance factors threaten shorebirds and their winter environment. Most sites with over 1,000 birds occur in a cluster situated near major shipping channels, oil refineries and industrial centers. This makes such populations highly vulnerable to impacts of environmental pollution and habitat loss.

45. Everitt, R. D. C. H. Fiscus and R. L. Delong. Northern Puget Sound Marine Mammals. Washington, D.C.: DOC/EPA Interagency Energy/Environ. R&D Program.; 1980; Doc. #EPA-60099/78-80-139, U.S. EPA.

Keywords: marine mammals//Puget Sound//northwest straits//straits//seals

Abstract: Baseline study of marine mammals of northern Puget Sound and Strait of Juan de Fuca from November 1977 to September 1979. Emphasizing certain aspects of the biology of the harbor seal, which is the most abundant marine mammal in these waters. Additionally, abundance and distribution for 21 species of marine mammals is presented. Spring and summer months are the period

when marine mammals in these waters may be most vulnerable to environmental perturbations. Study areas of importance in descending order are: eastern Strait of Juan de Fuca, San Juan Islands, eastern bays, tideflat areas, and western strait of Juan de Fuca. Of the 5 species of pinnipeds present, only the harbor seal occurs throughout the year in significant numbers. The largest numbers of animals hauled out during late summer-early fall

The Calif. and northern sea lion were both present seasonally. Less than 300 sea lions. 15 species of cetaceans included gray whale, minke whale, killer whale, harbor porpoise and Dall's porpose. The river otter is common throughout the year in most parts of the study area.

46. Feist, Blake E. J. J. Anderson R. Miyamoto, University of Washington, Fisheries Research Institute, School of Fisheries. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. May 1992; FRI-UW-9603.

Keywords: pile driving/juvenile salmon/pink salmon/salmon behavior/salmon distribution/juvenile salmon impacts

Abstract: A pilot study assessed the potential effects of pile driving activities on the behavior and distribution of schools of juvenile pink and chum salmon. Sites studied included the Everett Homeport (near the mouth of the Snohomish River), Elliott Bay Marina (Seattle), and the Kingston and Bremerton Ferry Terminals. School size, frequency of occurrence, species distribution, and general fish behaviors were measured at the sites where pile driving and fish presence coincided. Individual fish were sub-sampled for total length, weight, and stomach contents. On sampling days, tidal stage, weather, salinity, and the underwater acoustic environment were also measured.

Pile driving did not occur at the Kingston site, and juvenile Pacific salmon were not present at the Bremerton site when pile driving was in progress. Therefore the data form these sites do not provide direct information on the imapcts of pile driving on juvenile salmonids. Very few fish were observed at the Elliott Bay site, with or with out pile driving.

The majority of results regarding the impacts of pile driving on juvenile salmonids ecology are form the Everett Homeport site. The following encapsulates the results: 1) within the range of salmonid hearing, the sound field generated by pile driving activities had a radius of at least 600 m.; 2) pile driving operations apparently affected the distributions and general behavior of fish schools about the site; 3) nearly twice as many fish schools were found on the construction side of the site on non-pile driving days compared to driving days; 4) fish schools were typically in water <1.5 m, within 2m from shore, and they were surface oriented. Fish school distances form shore did not change significantly as a result of pile driving. Average total length of fish did not increase significantly over the study period, suggesting fish were either transient and/or not growing. Stomach

content analysis indicated that most fish were feeding, and while salinity and tidal stage probably affected the vertical distribution of fish in the water column, it did not appear to alter fish behavior or distribution about the construction site as measured in this study.

47. Forney, K. A. J. Barlow M. M. Muto M. Lowry J. Baker G. Cameron J. Mobley C. Stinchcomb and J. J. Carretta. U.S. Pacific Marine Mammal Stock Assessments: 2000. NOAA/NMFS. 2000. Draft.

Keywords: marine mammals//Puget Sound//northwest straits//straits

Abstract: Description of the stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence numbers. This information is used to evaluate the progress of each fishery towards achieving its goal of zero mortality and serious injury.

48. Fresh, K. L. B. Williams D. Penttila. Overwater Structures and Impacts on Eelgrass in Puget Sound, Washington. Puget Sound Research '95; 1995 12; Bellevue, WA. Olympia, WA.

Keywords: Puget Sound/overwater structures/habitat impacts/eelgrass/impact assessment

Abstract: STUDY OBJECTIVES: Impact Assessment. Determine if small single-family residence docks cause a decline in eelgrass densities under and adjacent to piers and assess if the use of gratings mitigate the impacts. METHODS: Empirical: eelgrass density was measured under and adjacent to a selection of seven "single- family" dock sites in Puget Sound from Roche Harbor to South Hood Canal. Baseline measurements and one year of post-project monitoring were also taken for five sites to assess effectiveness of mitigating impacts with grating. OBSERVED DENSITY DECLINES: Six out of the seven sites selected to measure declines without mitigating construction methods demonstrated measurable declines and/or absence of eelgrass growing under the docks. The one site that did not show measurable impact appeared to have a mitigating aspect to its structure as the dock moved up and down and side to side with tidal fluctuations. Four of the five structures evaluated for alternative mitigating construction methods demonstrated eelgrass densities decline when compared to undisturbed reference areas. At the fifth structure site, eelgrass density increased but increased substantially less than it increased in the reference area. COMMENTS: Preliminary results support the hypothesis that shading is the major cause of eelgrass density loss. This is demonstrated by significant reductions in density under docks and diminished reductions under docks with grating used to mitigate shading impacts. Structure length, height over the

bottom, design, orientation, and local environmental conditions (i.e. current patterns) may also play a role in the nature and extent of impact.

49. Fresh, Kurt L. Distribution and abundance of fishes occurring in nearshore surface waters in northern Puget Sound. Seattle, WA: UW; 1979.

Keywords: nearshore//fish//Puget Sound//salmonids//salmon//rockfish//cod//lingcod//bottomfish

Abstract: Fishes occurring in the nearshore surface waters of northern Puget Sound, Washington were studied during 1974-1976 using a two-boat surface trawl (townet). Five sites, each representing a different habitat type were sampled in each of three geographic areas. Study objectives were to document the abundance, spatial and temporal distribution of fishes occurring in nearshore surface waters of northern Puget Sound. Nearshore surface waters were utilized as nursery and rearing areas by numerous fish species. While the townet was designed to sample larvae, larval fish were caught abundantly, primarily in spring. Mainly juvenile fish were found throughout the entire year in nearshore habitats. Few large fish were caught, perhaps because of avoidance. Of the 71 fish species captured, the 6 most abundant species comprised 98 percent of the total numerical catch. Twenty species were schooling whereas 51 were demersal; schooling species generally were more frequently occurring and more abundant than non-schooling species. Catches of most species were highly seasonal and indicated a lack of permanent resident species. Young-of-the-year Pacific herring were the dominant fish species occurring in nearshore surface waters. Herring catches were especially large at sites associated with protected eelgrass bays and in areas near known spawning grounds. Maximum catches of herring occurred during the spring and summer whereas minimum catches occurred in the fall and winter. Other abundant species included young-of-the-year Pacific sand lance, juvenile and adult threespine stickleback, larval to adult surf smelt, and larval to adult longfin smelt. While numerically not abundant, juvenile salmonids (mostly chinook salmon) occurred consistently in spring and summer primarily in the Cherry Point and Anacortes areas. The dominant nearshore pelagic species were present throughout the various nearshore habitats of northern Puget Sound with little evidence of distinct assemblages in different habitats. However, even though the dominant species exploit the entire nearshore spectrum of habitats, there were preferred habitats and areas.

50. Garrison, Kathryn J. and Bruce S. Miller. Review of the early life history of Puget Sound fishes. Seattle, WA: University of Washington, Fisheries Research Institute, School of Fisheries; 1982.

Keywords: juvenile fish/Puget Sound/lifie-history strategies

Abstract: This report reviews the early life history information of Puget sound

fishes through 1981. Include distribution, reproductive timing and larval identification.

51. Gillespie, G. E. and Westrheim, S. J. Synthesis of information on marine fishes utilized as prey by marine and shoreline birds of the Queen Charlotte Islands. Vermeer, K. and Morgan, K. H. eds. THE-ECOLOGY, STATUS, AND CONSERVATION OF MARINE AND SHORELINE BIRDS OFTHE QUEEN CHARLOTTE ISLANDS. Ottawa, CA. Environment Canada Can. Wildl. Serv. 1997. no. 93, pp. 36-55.

Keywords: seabirds//sea birds//birds//straits

Abstract: This synopsis lists the birds reported to prey on marine fishes off the Queen Charlotte Islands, British Columbia, and provides an abbreviated account of the prey with respect to their habitat, abundance, life history, commercial importance, and avian predators. In total, 50 avian predators were reported. All preyed on pelagic fishes; 14 preyed on demersal fishes; and 221 preyed on inshore fishes. Twelve species preyed upon all three groups. Seventy-eight different prey were reported -- 62 identified to species, six to genus, nine to family, and one to order. Pacific herring *Clupea pallasi* attracted the most avian predators (40 species), particularly during inshore spawning and early life history stages. In many cases, predation on inshore and demersal species was during their early life history stages, either as pelagic larvae or juveniles or as recently settled juveniles in shallow water.

52. Golding, Steven. Port Townsend Paper Corporation November/December 1993 Class II Inspection. Olympia, WA: WA Dept. of Ecology; 1994 Sep; Publication No. 94-147. (Water Body No. WA-17-0030).

Keywords: NPDES permits/polllutants/bioassays/outfall/water quality/sampling procedures

Abstract: A Class II Inspection was documented at the Port Townsend Paper Company pulp and paper mill just south of Port Townsend, Washington, on November 15-17, 1993. Related sediment sampling was conducted December 15. The combined process water and sanitary discharges met all NPDES permit requirements. The sanitary effluent was also well within all permit requirements. All VOA and BNA compounds found were within applicable EPA water quality criteria. No pesticide/PCD compounds were found in the influent or effluent. Five priority pollutant metals were detected in the effluent. Copper was found in an estimated concentration of over four times Ecology water quality criteria. The fathead mminnow chronic test and bivalve larvae test demonstrated sensitivity to the pulp mill effluent. No VOA compounds were detected in the sediment samples. All BNA compounds and metals detected were below Ecology Marine Sediment Quality Standards. No toxicity was found in the Microtox test. Amphipod test results found one sample equal to 25 percent toxicity.

53. Goodwin, Lynn. Age, recruitment and growth of the geoduck clam in Puget Sound. WDFW; 1988; WDFW Prog. Report #215.

Keywords: shellfish//geoducks//Puget Sound

Abstract: This report describes the methods we used to collect geoducks, age the shells and estimate growth and recruitment rates. A discussion of the methods is discussed. Most shells used for age and growth determinations were collected from unharvested geoduck beds form 1979-1982. All samples discussed in this report were taken in water depths of between 10 and 20 meters. Many locations throughout Puget Sound were sampled. From 1970 to 1987 samples were taken to estimate recruitment in harvested and unharvested geoduck beds in small plots extensively disturbed by a venturi suction dredge.

54. Healy, M. C. Juvenile Pacific salmon in estuaries: the life support system. In: Kennedy V.S. (ed.). Estuarine Comparisons. New York. Academic Press. 1982.

Keywords: salmon//Puget Sound//estuaries//fish

Abstract: Three species of Pacific salmon (chum Oncorhynchus keta, chinook Oncorhynchus tshawytscha and coho Oncorhynchus kisutch), spend significant time rearing in estuaries following their seaward migration. Chum are abundant in estuaries for two months in early spring, coho for two months in late spring, and chinook throughout the spring, summer, and autumn. The specific habitats occupied by each species vary with the size of the fish, the stage of the tide, and the time of year. Tidal creeks through marshes, the junction of major and minor distributaries in the intertidal zone and the delta front are favored habitats. The diet of juvenile salmon in estuaries reflects a mixture of preference and availability, and the availability of food varies significantly between years and between estuaries. Major prey tend to be highly concentrated in the boundary layer at the mudwater interface, and many are detritus feeders, indicating that the food web leading to juvenile salmon is detritus based. The value of an estuary as rearing habitat for juvenile salmon appears to be influenced by delta configuration and by the efficiency with which allochthonous organic carbon is trapped.

55. Henwood, Bill J. Barr and K. Morrison. A marine protected areas strategy for the Pacific Coast of Canada . Puget Sound Research '98; Seattle, WA. Olympia, WA: PSWQAT; 1998.

Keywords: MPA's//marine protected areas

Abstract: This papers describes the development of an integrated strategy for the establishment of a comprehensive MPA system along the Pacific Coast of Canada. Parks Canada, BC Parks, the Dept. of Fisheries and Oceans, the BC

Land Use Coordination Office, Environment Canada and BC Ministry of Agriculture, Fisheries and Food have collaboratively developed a draft proposal describing the followeing: a common vision and definition of MPA's; common goals and objectives for an MPA system; guiding principles for the establishment and management of MPA's; possible management regimes and designations of MPA's, and a proposed process for the identification, evaluation, establishment and management of MPA's. A series of stakeholder forums have been held in three coastal communities to discuss these proposals with a wide variety of stakeholders. Implementation of the strategy will be linked with coastal area management planning.

56. Hirschi, Ron. Critical Nearshore Habitats Tala Point to Kala Point, Jefferson County. Jefferson County, WA: Jefferson County Planning Department and National Oceanic and Atmospheric Administration; 1999; Report to Jefferson County Planning Department.

Keywords: habitat//critical habitat/Jefferson County/Port Townsend/ Tala Point/ Kala Point/ surf smelt/sand lance/fish/salmon/juvenile salmon/marsh/drift cell/shoreline/nearshore/Chimacum Creek/Port Ludlow/Port Ludlow Bay/eelgrass/intertidal/Ludlow Creek/spawning/juvenile fish/prey resources/preyfeeder bluffs/Olele Point/bald eagles/Little Goose Creek/Oak Bay/shorelines//fish

Abstract: This report provides locations of critical habitats, including eelgrass beds, salt marshes, stream mouths, and documented spawning beds of sand lance, surf smelt, and herring. and documented salmonid use. Eelgrass beds were mapped with the aid of aerial photos, boat surveys, and beachwalks undertaken during this study. The purpose of the report is to further an understanding of the inter-related nature of these nearshore habitats and species, locational information is discussed in relation to several shoreline segments. Each segment corresponds to drift cells identified by geologist Johannassen.

57. Hixon. Mark. A. and B.N. Tissot. Fish Assemblages of Rocky Banks of the Pacific Northwest. U.S. Dept. of the Interioir, Minerals Management Service, Pacific OCS Region; 1992; OCS Study MMS 92-0025. Final Report-Supplement.

Keywords: fish//rockfish

Abstract: This report characterizes the benthic habitats and fish assemblages at Stonewall Bank Oregon by describing associations of bottom types, visually dominant invertebrates, and demersal fishes. Rockfish densities were correlated to bottom type, stations, and general behavioral patterns . Fish abundance was also compared between day and night.

58. Hueckel, G. J. R. M. Buckley and B. L. Benson. Mitigating rocky habitat loss using artifiicial reefs. Bull. Mar. Sci. 44:913-922.

Keywords: rocky reef//mitigation//habitat//fish

Abstract: An artificial reef was constructed on a featureless sand bottom as mitigation for the man-caused loss of rocky-type subtidal habitat in Elliott Bay, Puget Sound, Washington from a shoreline development (fill) project. Using a list of indicator biota developed for this region, it was predicted the mitigation reef would develop a greater number of economically important fish species and greater diversities of sessile and epibenthic biota assemblages than the development site. A total of 181,400 metric tons of quarry rock was used to construct fourteen 41 m multiplied by 15 m multiplied by 6 m (high) reef structures in a 2.83 ha area during May 1987. This design of a 1:2 ratio of reef material; sand bottom also accommodated the trophic level relationships normally occurring for fishes feeding from reef structures and surrounding natural habitats. The mitigation reef met the predicted development during the reef's first 8 months of submergence.

59. Hulsman, Steven G. and W. A. Palsson and G. J. Hueckel. An Annotated Bibliography of Puget Sound Nearshore Habitat and Marine Fish Life History Studies. Olympia, WA: Washington State Dept. of Fisheries; 1986; Technical Report 91.

Keywords: marine biota/fish/nearshore habitat/marine life history strategies/recreational fishery/lingcod/herring/Strait of Georgia/pollution/sole rockfish/greenling/enhancement structures/Puget Sound/water quality/salmon/cod/impact assessments/surf smelt/invertebrates/fish ecology/shellfish

Abstract: An annotated bibliography of 188 references on Puget Sound nearshore habitat and marine life history studies.

60. Janzen, C. D. and L. B. Eisner. Marine Water Column Ambient Monitoring Program: Annual Report for Wateryear 1991, Final Report. Olympia, WA: Department of Ecology. 1993: 93-13.

Keywords: water quality//Puget Sound//Jefferson County//Port Townsend//habitat

Abstract: During Wateryear 1991 (October 1990 through September 1991), the Washington State Department of Ecology monitored water quality monthly at 28 stations in Puget Sound, four stations in Grays Harbor, and five stations in Willapa Bay. Of the 28 stations in Puget Sound, 23 sites showed dissolved

oxygen concentrations below the water quality standards for marine waters one or more times, and 11 exceeded fecal coliform counts of 14 organisms/100 milliliters (mL) one or more times. Nutrient depletion was observed at 20 Puget Sound stations. Of the nine coastal stations, none violated dissolved oxygen standards, and four exceeded fecal coliform counts of 14 organisms/100 mL one or more times. Nutrient depletion was only observed at the Willapa Bay stations. Stations that did not experience nutrient depletion as defined by this report, were well mixed and lacked observable ongoing density stratification. At several Puget Sound stations, chlorophyll a concentrations were inversely proportional to nutrient concentrations, with maximum chlorophyll a concentrations and minimum nutrient concentrations observed simultaneously. Chlorophyll a concentrations were highest during the spring and summer months and lowest during late fall and winter months for Puget Sound stations. The coastal stations exhibited two chlorophyll a peaks, one during mid-summer and again in midfall. To assess the quality of the marine water column data, a detailed quality assurance assessment was conducted on the Wateryear 1991 (WY 1991) results. Ninety-four percent of the nitrite results were below detection limits. Discontinuing dissolved nitrite analysis until lower detection limits can be achieved by the laboratory was recommended. The quality assurance assessment also revealed that the fecal coliform bacteria results did not achieve precision objectives in either the field or laboratory replication. Procedures for future collection and analysis of fecal coliform bacteria should be amended to improve the quality of these data. In general, to improve temporal and spatial coverage for shorter term and episodic water quality events not caught by the monthly sampling component of the program, continued monitoring efforts should include a seasonal monitoring component. Sites showing signs of nutrient depletion and/or conditions that promote biological activity (stratification) should be priority candidates for seasonal monitoring.

61. Johannessen, Jim. Critical Shoreline Areas Relative to Critical Nearshore Habitats at Tala Point to Kala Point, Eastern Jefferson County, Washington. 1999: Jefferson County Planning Department and National Oceanic and Atmospheric Administration; Grant No. G9900057 NOAA/CZM/DOE.

Keywords: geology/drift cells/Tala Point/Kala Point/Olele Point/feeder bluffs/eastern Jefferson County/Jefferson County/Port Townsend

Abstract: This report was prepared to support a parallel effort of nearshore habitat mapping and characterization titled Critical Nearshore Habitats, Tala Point to Kala Point, Jefferson Counyt, by Ron Hirschi (1999). A good amount of the field observations for the two studies were conducted simultaneously by boat or on foot. Similarly, the focus and conclusions of the two studies were reached cooperatively. Therefore, each report should be used in conjunction with the other, as the intent was for each of the two elements to augment each other and

provide mapped features that represent the conclusions of the multi-disciplinary effort.

Accompanying this report are three original USGS 71/2 minutes quadrangles (Port Ludlow, Nordland, Port Townsend, South) that contain mapped critical shoreline areas discussed in the text. Portions of these three maps are reproduced within the report for convenience. Information in the Geology and Coastal Processes sections were compiled from existing published reports and maps as referenced, along with observations made while visiting the entire shore of the study area in the winter of 1998-99 and earlier. The study area for the project ran form Tala Point (east of Port Ludlow Bay) in the south end to Kala Point (in Port Townsend Bay) in the north.

62. Johnson, O. W. W. S. Grant R. G. Kope K. Neely K. F. W. Waknitz and R. S. Waples. Status Review of Chum Salmon from Washington, Oregon, and California. Northwest Fisheries Science Center, Seattle, WA: National Marine Fisheries Service; 1997; NOAA Technical Memorandum NMFS-NWFSC-32.

Keywords: salmon/estuaries/Puget Sound/nearshore habitat/life history strategies/prey resources/migration//Endangered Species Act/ESA/ESU/chum/summer chum/Washington/Oregon/California//fish

Abstract: This report reviews the ESA evaluation for chum salmon populations in the Pacific Northwest. It presents species and ESU definitions, listing petitions, and all aspects of chum biology. the biological description includes physical and biological features with life-history and ecological information. It examines and presents in-depth descriptions of all life-history stages, regional distributions, hatchery production, practices, and influences, stock abundances, history, and trends.

63. Karp, W. A. Biology and management of Pacific cod (*gadus macrocephalus*) in Port Townsend, Washington. 1982. PhD. Dissertation.

Keywords: cod//Pacific cod//Port Townsend//Puget Sound//bottomfish//groundfish//fish//Jefferson County

Abstract: Pacific cod migrate into the waters of Port Townsend Bay during the winter. An intense commercial set net and trawl fishery is directed at these Pacific Cod spawning aggregations. Life history parameters estimated during this study were consistent with those expected from a fast growing, early-maturing stock close to the southern limit of its range. Growth analysis of length frequency data and tag returns provided length-at-age estimates of 27.0, 43.5, 55.5 and 64.2 cm at ages of 1,2,3, and 4 years. Population estimates indicated that there were about 14,000 fish in the bay when the fishery began. The population increased rapidly and reached a peak of more than 1100,000 fish within 10 days of the start of the fishery. Peak abundances were observed for approx. 1 week

and then a gradual decline in the population size was observed. Seven weeks after the fishery began, population size was estimated to be 35,000 fish. Between 15-20 percent of the cod present in the bay on a given day emigrated or were caught during the subsequent 24 hours. Between 359,000 and 510,000 fish migrated into the bay during the season and 24 to 34 percent were harvested. The set net gar was more effective in harvesting larger fish, especially females.

64. Karp, William and B. S. Miller (University of Washington. College of Fisheries. Final Report to U.S. Navy). Pacific Cod (*Gadus macrocephalus*) studies in Port Townsend Bay, Washington. Seattle, WA: University of Washington, College of Fisheries; 1977 Aug; FRI-UW-7723. December 1976-August 1977.

Keywords: Port Townsend//Pacific cod/cod/fish/prey resourcessubstrate/Jefferson County

Abstract: Egg, larval, juvenile, and adult stages of the Pacific cod (*Gadus macrocephalus*) were sampled form the waters of Port Townsend Bay, Washington, to provide information concerning the life history and fisheries biology of this species. Trawl sampling, carried out in January and February 1977, provided material for the determination of basic statistics, age structure, stomach contents, and fecundity. The trawl-caught fish were found to be fast growing, early maturing, and with short lifespans; estimated fecundity at length was greater than published values for populations from more northern waters. Preferred food items were shrimp and small fish. Icthyoplankton sampling was carried out on seven occasions from February through June 1977. Gadoid (cod family) larvae were identified form many of the samples but poor documentation of the early life history fo Pacific cod precluded positive identification of these gadioid larvae to species. It was suggested that gadioid larvae observed in late April were probably Pacific cod, based on spawning time and published rates of development. Attempts to rear Pacific cod eggs and larvae were not successful but the experiments did confirm reports that the eggs are demersal. Diving operations failed to encounter spawning adults or eggs. Eggs were not detected from a series of bottom grab samples. Juvenile Pacific cod were identified from trynet samples taken in northern Kilisut Harbor and along the northwest shore if Indian Island in mid-June 1977.

65. Kent, M. and R. Elston. Toxicopathic Liver Disease of Pen-Reared Salmon in Port Townsend Bay - 1988 Studies. 1989; 89-e48.

Keywords: fish//water quality//Port townsend//Jefferson County//Puget Sound//salmon

Abstract: This report presents the results of an investigation in the occurrence of severe liver disease and 100% mortality observed in Sea Farm Washington's

pen-reared Atlantic Salmon in Port Townsend Bay in the summers of 1986 and 1987. A long-term bioassay of Atlantic salmon using mill effluence indicated that the pulp mill was not the likely source of the presumed toxicant. The disease has also occurred at several net-pen sites in BC but does not appear to be associated with chemical contamination. It was suggested that the disease could be caused by a natural toxin, possibly an algal toxin, a hypothesis to requiring further testing. Chemical analysis of affected liver and muscle tissues, sediments, effluents, and the water column in separate but coordinated studies did not identify toxicants of likely significance. Such liver disease in at least three salmonid species at several sites in the Pacific Northwest identify the conditions as a significant limiting factor to successful net-pen culture in particular Pacific Northwest locations. Coho net-pen operations in Port Townsend Bay did not appear to be affected, neither were non-salmonid fishes such as surf perch and English sole. However, small chinook were found to be affected.

66. Kyte, M. A. (Ardea Enterprises). The Nongame Marine Invertebrates of Washington: An Inventory of Species and Sources of Loss with a Status Evaluation and Management and Conservation Guidelines. Snohomish, WA; 1989.

Keywords:
invertebrates/nongame/invertebrates/worms/anemones/leeches/chitons/snails/oysters/
octopus/nudibranchs/clams/mussels/bivalves/invertebrate management/species status/shellfish

Abstract: This report presents an examination of nongame marine invertebrates (NGMI) situation for effective conservation and management. This report overview NGMI in Washington waters, sources of losses, species status, and conservation guidance. Although the quality of Puget Sound may be improving through agency efforts and a concerned public, individual invertebrate species and communities are disappearing or are threatened over large part so their ranges. Direct sources of loss include: collecting for teaching by schools, collecting for schools by commercial supply companies, collection for research or bioassays by scientists, collecting for public aquarium, harvesting for subsistence by citizens, collecting for bait to catch other species and collecting for souvenirs. Indirect sources of loss include: derelict commercial fishing gear, especially gill and seine nets, sport and commercial harvesting, water and sediment quality pollution, commercial developments with activities such as dredging, pile driving and log rafting, walking and vehicle driving in the intertidal.

67. Lash, Jennifer and M. Solin. In: (eds) P.G. Wells and P.J. Ricketts The role of No-Take Marine Protected Areas in Facilitating Coastal Zone Management in British Columbia. Canada Coastal Zone '94 Cooperation in the Coastal Zone: Conference Proceedings; Sept. 20-23; Halifax, NS

Keywords: Marine protected areas

Abstract: Canada does not have a national policy for the management of the coastal environment. Attempts to create and implement a policy have been futile due to the lack of public pressure and political will. Increasing public interest and concern in the marine environment can help motivate the political will. Public requests for increased marine protection has been successful in various states in the US and has become an effective tool in BC. The establishment of Whtyecliff Park in West Vancouver as a No-Take marine protected area was the direct result of a community initiative combined with academic and legal advisers. The establishment of no-take MPAs play a crucial role in developing a coastal management policy. Establishing a network of public initiatives will increase public awareness of the ocean as well as motivate the government to take action towards creating a national Coastal Zone Management Policy.

68. Laufle, J. C. Biological development and materials comparison on a Puget Sound artificial reef. 1982; Wash. Dep. Fish. Tech. Rep. 72.

Keywords: fish//reefs//artifical reef//rockfish//bottomfish//groundfish//Puget Sound

Abstract: Using SCUBA techniques, artificial reef colonization by algae, invertebrates, and fishes is documented. Habitat comparisons are made between different reef types. Diel and seasonal abundances are discussed. Lingcod nesting was observed. The topic of deployment and management of artificial reefs is discussed.

69. Lemberg, Norm A. M. F. O'Toole D. E. Penttila and K. C. Stick. 1996 Forage Fish Stock Status Report. Olympia, WA: WDFW; 1997.

Keywords: fish//puget sound

Abstract: The objective of this report is to provide an evaluation of current marine forage fish stock status in Washington. The significance of forage fish in the diet of many important marine fish is discussed. This report provides Puget Sound stock status profiles, stock status summaries for 1994 and 1996, a cumulative herring spawner biomass graph for 1977-96, annual natural mortality, and herring fisheries landing information followed by a synopsis for coastal herring.

70. Lemberg, Norm A. S. F. Burton and W. Palsson. Hydroacoustic results for Puget Sound herring, whiting, and Pacific cod surveys, 1986-1987. Olympia, WA: State of Washington, Dept. of Fisheries; 1988.

Keywords: fish//Puget Sound//herring//whiting//cod//bottomfish//groundfish

Abstract: Reports assessments in South Puget Sound, Northern Hood Canal, Strait of Georgia and Port Susan Northern Hood Canal is area between Hood Head and Port Gamble. Area covered was not as far north as Port Townsend.

71. Llanso, R. J. S. Aasen and K. Welch. Marine Sediment Monitoring Program 1. Chemistry and Toxicity Testing 1989-1995. Olympia, WA; 1998 Aug. Publication No. 98-323. Entire Puget Sound, West to Port Angeles and North to Canadian US border. Includes Strait of Juan De Fuca Haro Straits, Strait of Georgia, Admiralty Inlet, Port Townsend Bay, Discovery Bay, and Dungeness subestuary.

Keywords: water quality/carbon/sediment/bioassay/chemical analysis/sulfide/contamination/monitoring/ lead/zinc/PCBs/DDT/Puget Sound/cadmium/chromium/copper/silver/mercury/arsenic/

Abstract: Reports results from baseline sediment monitoring of conditions and trends throughout Puget Sound for the period 1989-1995. Data was collected annually at eighty-six stations throughout Puget Sound, Hood Canal, Strait of Georgia, and Strait of Juan de Fuca. Stations included Port Townsend Bay, southwest shore of Indian Island, and Discovery Bay. Target chemicals included antimony, arsenic, cadmuim, lead, selenium, silver, thallium beryllium, chromium, copper, nickel, zinc, mercury, aluminum, barium, calcium, cobalt, iron, magnesium, manganese, potassium, sodium, and vanadium. These include aromatic and chlorinated aromatic compounds, ketons, ethers, esters and carbon disqulfide and semivolatile organics, phenols chlorinated and nitro-substituted phenols, resin acids and low molecular weight polycyclic and chlorinated and aromatic hydrocarbons were amongst the contaminants identified and measured. Port Townsend was listed as one of ten stations having contaminated concentrations above state standards in any one year, which in the case of Port Townsend was 1989 only. Port Townsend also showed the presence of arsenic and nickel. Nickel was present in all years except 1995. Discovery Bay showed arsenic in 1994 only. These are the levels at which adverse biological effects are expected to occur. This was due to a high concentration of the resin bis(2-ethylhexyl)phthalate and dehydroabietic acid.

72. Llanso, R. J. S. Aasen K. Welch. Marine Sediment Monitoring Program II. Distribution and Structure of Benthic Communities in Puget Sound 1989-1993. Olympia, WA: Washington Department of Ecology ; 1998 Entire Puget Sound, Strait of Juan de Fuca west to Port Angles, Georgia Strait north to U.S./Canadian border, and Georgia Strait .

Keywords: sediments//Puget Sound//invertebrates//Jefferson County//Hood Canal//benthos

Abstract: Reports baseline data on contaminated and uncontaminated stations and evaluates condition of benthic macro-invertebrates in relation to toxic chemicals in sediments throughout Puget Sound, Hood Canal, and the Straits of Georgia and Juan de Fuca between 1989-1993. Stations included Port Townsend Bay, southwest shore of Indian Island, and Discovery Bay. Multivariate analysis techniques shoed that infaunal assemblages in Puget sound are primarily related to sediment composition and water depth, and secondarily to geographical location. This study represents the first system-wide effort to characterize benthic assemblages in the Puget Sound region.

73. Long, E. J. Hameedi A. Robertson M. Dutch S. Aasen C. Ricci K. Welch et al. Sediment Quality in Puget Sound: Year 1, Northern Puget Sound. Olympia, WA: Department of Ecology; 1999.

Keywords: sediment quality//Puget Sound//contaminants

Abstract: As a component of a three-year cooperative effort of the Washington State Department of Ecology and the National Oceanic and Atmospheric Administration, sediments from 100 locations in northern Puget Sound were tested to determine their relative quality. The purpose of this survey was to determine the quality of sediments in terms of the severity, spatial patterns, and spatial extent of chemical contamination, toxicity, and alterations to benthic infauna. The survey area encompassed the region from Port Gardner Bay north to the US/Canada border, excluding the San Juan Islands. Surficial sediments were tested and analyzed from each of the 100 locations. Data from the chemical analyses indicated that toxicologically significant contamination was restricted in scope to a relatively small portion of the region. The spatial extent of relatively severe contamination varied considerably among chemicals. However, less than 2% of the area was considered "contaminated" for most substances. Sediments from several sampling locations within Everett Harbor often had the highest chemical concentrations. In addition, samples from some stations in Bellingham Bay and other locations scattered throughout the study area had elevated concentrations of some substances. Data from four kinds of toxicity tests indicated a similar pattern: the degree of toxicity was highest in samples from Everett Harbor followed by those from other locations scattered within the survey region. The spatial extent of significant toxicity ranged from 0% to 5% among the toxicity tests. Wide ranges in several numerical indices of benthic infaunal structure indicated good correspondence with tests of toxicity and the concentrations of numerous chemical substances. That is, there was evidence of altered benthic populations in some areas nearest urban centers. Chemical contamination and toxicity of sediments were less severe in northern Puget Sound than in many other estuarine areas studied in the U.S. by NOAA. Results from similar analyses of samples from the central Puget Sound (sampled in 1998) and southern Puget Sound (sampled in 1999) will be compiled with the

data from northern Puget Sound, to provide a broad-scale evaluation and quantification of the spatial scales and patterns in sediment quality throughout the entire region.

SUBJECT WATERBODIES: Strait Of Georgia, Drayton Harbor, Bellingham Bay, Padilla Bay, Fidalgo Bay,Guemes Channel, Saratoga Passage, Penn Cove, Steamboat Slough, Port Gardner, Inner Everett Harbor, Ebey Slough, Skagit Bay, Similk Bay, Port Susan, Possession Sound WATERBODIES: Strait Of Georgia, Drayton Harbor, Bellingham Bay, Padilla Bay, Fidalgo Bay, Guemes Channel, Saratoga Passage, Penn Cove, Steamboat Slough, Port Gardner, Inner Everett Harbor, Ebey Slough, Skagit Bay, Similk Bay, Port Susan, Possession Sound

74. Long, Edward R. A Synthesis of Biological Data from the Strait of Juan De Fuca and Northern Puget Sound. Seattle, WA.NOAA-Office of Marine Pollution Assessment.1983 Feb.D6-E693-EN and EHE625-A.

Keywords: biota/Strait of Juan De Fuca/Puget Sound/food web/migration/reproduction/natural stresses/habitats/communities/trophic interactions/species richness/fish/invertebrates//shellfish

Abstract: Summarizes the biological data collected during a five-year research project including information on marine fishes, food webs, migration, reproductive processes, natural stresses, major habitat types and their associated biological communities, trophic interactions, organism densities, biomass and species richness.

75. Lubchenko, S. Palumbi, and S. Gaines. Developing a Theory of Marine Reserves. NCEAS Project accessed at http://www.nceas.ucsb.edu/fmt/doc?https://www2.nceas.ucsb.edu/admin/db/web.plist

Keywords: MPA//marine protected area

Abstract: This is a multidisciplinary working group organized through NCEAS working to make a significant contribution to our current understanding of marine reserves. This group is working towards the development of a theoretical basis for the design and establishment of marine reserves. Although there has been an increase in the number of marine reserves designated to manage marine resources, they do not believe that a concomitant increase in the understanding of marine reserve theory has occurred. As a result, reserve designs have often relied heavily on theory formulated for terrestrial ecosystems or on no theory at all. Recent research on open ecosystems suggests that marine reserves designed using these principles are likely to be ineffective at protecting marine communities over the long term. This fact, along with constantly increasing human pressure on marine ecosystems, indicates that a theory of reserve design

specific to marine ecosystems is urgently needed.

76. Lynn, Brian. Nearshore habitat loss in Puget Sound: recommendations for improved management. Puget Sound/Georgia Basin International Task Force; 1998 Nov.

Keywords: Puget Sound/Georgia Basin/nearshore habitat/habitat loss/habitat management/restoration/
inventory/non-indigenous species/marsh

Abstract: This report represents the findings of the British/Columbia Washington Marine Science Panel Work Group. It provides an overview of the status of nearshore habitats, describes how they are managed in Washington State and makes recommendations for solving the problem. The report focuses entirely on nearshore habitat and is intended as a tool for resource managers. It defines nearshore habitat, reasons for loss of nearshore habitat, discusses the protection of nearshore habitat. It provides background summaries along with the 79 recommendations for nearshore habitat protection and management put forth by the Work Group.

77. MacDonald, Keith CH2M Hill B. Witek Geo-Dynamics Consulting. [Shorelands and Environmental Assistance Program]. Management options for unstable bluffs in Puget Sound, Washington. Olympia, WA. Washington Department of Ecology. 1994 Aug. Report 94-81. (Coastal Erosion) Management Strategy: Coastal Erosion Management Studies, Vol. 8).

Keywords: erosion control/erosion/coastal bluffs/policy alternatives/shoreline armoring/engineering techniques/management/Puget Sound/vegetation management/runoff controls/seawalls/bluffs/setbacks/groundwater flows/shorelines

Abstract: This report provides a regional overview of shoreline slopes, geology and modifications; types and causes of slope failure and management options for managing shoreline slopes including establishment of construction setbacks, blufftop construction requirements, management of existing vegetation, surface runoff control, groundwater drainage systems and biotechnical slope protection.

78. MacDonald, Keith D. Simpson B. Paulsen J. Cox and J. Gendron (CH2M Hill). Shoreline armoring effects on physical coastal processes in Puget Sound, Washington. Olympia, WA: Washington Department of Ecology; Report 94-78. (Coastal Erosion Management Strategy: Coastal Erosion Management Studies, Vol. 5).

Keywords: erosion control/erosion/coastal bluffs/beach impacts/shoreline erosion/wood/sediment/seawalls/drift cells/net shore drift/wave refraction/wave diffraction bulkheads/longshore transport/beach profiles/Puget Sound/reflection/beach starvation/wave energy/intertidal/accretion beaches/shorelines

Abstract: This report summarizes the present understanding of shoreline physical process in Puget Sound and how shore protection structures interact with those process. It provides technical information on the interaction of these processes and structures in Puget Sound in order to describe the fundamentals of those processes acting upon nearshore and beach environments. Case studies and cumulative effects on physical coastal processes are also covered.

79. Mahaffy, M. S. D. R. Nysewander K. Vermeer T. R. Wahl and P. E. Whitehead. Status, trends, and potential threats related to birds in the the Strait of Georgia, Puget Sound and Juan de Fuca Strait.In R.C.H. Wilson, R. J. Beamish F. Aitkens and J. Bell eds. Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait. 1994; Canadian Technical Report of Fisheries and Aquatic Sciences.

Keywords: marine birds//Puget Sound//straits//northwest straits

Abstract: Systematic censuses or inventories of bird populations in British Columbia and Washington have
emphasized: (1) numbers and productivity at breeding colonies; and (2) over-wintering populations utilizing various marine habitats. Wintering populations of birds tend to be much larger than the summer breeding populations. Species diversity is also greater during winter due to an influx of waterfowl and marine birds. Birds are at risk in the marine environment due to commercial fisheries, oil and hazardous materials spills, human disturbance, habitat loss, degradation of water quality, and contaminants from point and non-point sources. Indicator species should be selected that are most vulnerable and represent the various niches in the marine ecosystem.

80. Malins, D. C., McCain, B. B., Brown, D. W., Chan, S. L Baalman, R. W. ed. 1985. HEALTH-AND-ENVIRONMENTALRESEARCH ON COMPLEX ORGANIC MIXTURES. Richland, WA.

Keywords:invertebrates//contaminants//sediments

Abstract: Hundreds of toxic chemicals occur in marine environments, and their potential for inducing; biological effects are of scientific interest. Because sediments are sinks for most chemicals, the transfer; of chemicals from

sediments to organisms and subsequent transmission through food chains are; especially important. Organic xenobiotics in sediments are readily transferred to marine organisms. Some xenobiotics are metabolically labile, whereas others are essentially resistant to metabolism. The metabolically labile aromatic hydrocarbons, for example are extensively transformed in the liver; of fish and the hepatopancreas of crabs. Substantial metabolism in fish markedly reduces the; potential for food-chain transfer of aromatic hydrocarbons; however, little is known about the; transfer of the metabolites. The metabolically resistant compounds have a high potential for; accumulating in marine birds, mammals and humans. The biological transport of sediment-associated metals has not received much attention. Field studies indicate that most metals are not extensively; bioconcentrated in marine fish; however, they are bioconcentrated in certain invertebrates such as, and molluscs. Toxic chemicals in marine environments: Food-chain transfers and biological effects.

81. Markey, Susan L. and L. M. Anderson. Progress Report No. 304. 1991 Results from micro-tagged salmon experimental groups. October 1993Puget Sound, Cape Flattery, Quillayute, Grays Harbor, Columbia River Areas.

Keywords: fishery stocks/commercial/recreational/salmon/Puget Sound

Abstract: This progress report documents the estimated recoveries of tagged fish in the Washington sport and commercial fisheries, plus escapement, during the 1991 season.

82. Matthews, K. Habitat utilization by recreationally-important bottomfish in Puget Sound: An assessment of current knowledge and future needs. 1987; Wash. Dept. Fish. Prog. Rep. 264 .

Keywords: fish//Puget Sound//habitat//bottomfish//groundfish

Abstract: This report presents available information on important habitat associations for ten recreationally-utilized marine fishes in Puget Sound: copper rockfish, quillback rockfish, brown rockfish, Pacific cod, striped and pile surfperches, walleye pollock, lingcod, kelp greenling, and cabezon. Information was gathered on general species information to include reproductive habits, habitat associations, movement patterns, and food habits. Graduate theses, technical reports, baseline surveys and published literature were evaluated with an emphasis on Washington and supplemented by information form Canada, Oregon, Alaska, and California. Important habitat associations for young and spawning fishes was identified as an area needing futher work.

83. Matthews, K. R. Habitat use and movement patterns of copper, quillback, and brown rockfishes in Puget Sound, Washington. Seattle, WA. UW. 1988 PhD. Dissertation.

Keywords: rockfish//bottomfish//groundfish//fish//Puget Sound

Abstract: Seasonal habitat use of young-of-the-year (YOY), subadult, and adult rockfishes (*Sebastes caurinus, S. maliger, and S. auriculatus*) were compared for four habitat types: high-relief rocky reefs, low-relief rocky reefs, high-relief artificial reefs, and sand/eelgrass. Diving surveys conducted December 1986 through October 1988 on two representative sites of each habitat type revealed significant seasonal changes in rockfish densities and habitat use. YOY recruitment varied between the two survey years: YOY were observed on all habitat types in the summer and fall of 1987, whereas they were observed at only one site (artificial reef) in a similar time period of 1988. High-relief rocky reefs had the most consistent densities of the three rockfish species with most fish>200mmTL. Adult and YOY copper, quillback, and brown rockfishes were observed on the low-relief rocky reefs primarily in the summer months coincident with summer algal growth; when the kelp died back in the fall, most rockfishes left these reefs. The highest densities of rockfishes, primarily 80-200 mm quillback rockfish (up to 420/90-m3 transect) and large copper rockfish (up to 56.3/transect), were observed on the artificial reefs. Here also, density fluctuations were dramatic; copper rockfish densities peaked in fall and winter and declined (to 0/transect) during the summer, and quillback rockfish densities also seasonally fluctuated. Sand/eelgrass areas were the least-utilized habitat type; only during July and August were young-of-the-year and low densities of adult copper and brown rockfishes observed on one sand/eelgrass site. Although all four habitats were used, natural reefs may represent source habitats that are used by and maintain rockfishes on less productive sink (artificial reef) habitat. Thus, the recent use of artificial reefs as mitigation for the loss of natural reefs could have negative impacts on rockfish populations.

84. Matthews, Kathleen R. A comparative study of habitat use by young-of-the-year, subadult, and adult rockfishes on four habitat types in central Puget Sound. Fishery Bulletin, U.S. 1989; 88:223-239

Keywords: fish//rockfish//Puget Sound//bottomfish//groundfish

Abstract: Seasonal habitat use of young-of-the year, subadult, and adult rockfishes were compared for four habitat types: high-relief rocky reefs, low-relief rocky reefs, high-relief artificial reefs, and sand/eelgrass. Diving surveys conducted December 1987 through October 1988 on two representative sites of each habitat type revealed significant seasonal changes in rockfish densities and habitat use. Young of the year (YOY) recruitment varied between the two survey years: YOY were observed on all habitat types in the summer and fall of

1987, whereas they were observed at only one site (artificial reef) in a similar time period of 1988. High-relief rocky reefs had the most consistent densities of the three rockfish species, mostly fish>200 mmTL. Adult and YOY copper, quillback, and brown rockfishes were observed on the low relief rocky reefs primarily in the summer months coincident with summer algal growth; when the kelp died back in the fall, most rockfishes left these reefs. The highest densities of rockfishes, primarily 80-200 mm quillback rockfish (up to 420/90-m^3 transect and large copper rockfish (up to 56.3/transect), were observed on the artificial reefs. Here, also, density fluctuations were dramatic; copper rockfish densities peaked in fall and winter and declined (to 0/transect) during the summer, and quillback rockfish densities also seasonally fluctuated. Sand/eelgrass areas were the least-utilized habitats. Only during July and August were YOY and low densities of adult copper and brown rockfishes observed on one sand/eelgrass site. Although all four habitats were used, natural reefs may represent source habitats that are used by and maintain rockfishes on less productive sink (artificial reef) habitats. Thus, the recent use of artificial reefs as mitigation for the loss of natural reefs could have negative impacts on rockfish populations.

85. ---. An experimental study of the habitat preferences and movement patterns of copper, quillback, and brown rockfishes (*Sebastes* sp.). Environmental Biology of Fishes. 1990; 29:161-178.

Keywords: fish//rockfish//Puget Sound//reefs//artificial reef

Abstract: A study was designed to test whether habitat association affects the movement patterns and habitat preferences of copper, quillback, and brown rockfishes. Resighting of tagged rockfishes (512 tagged rockfishes and 726 resightings) from July 1986 through June 1988 indicated that home ranges, movements form reefs, and tendency to return from experimental displacement (up to 8.0 km) were significantly different on the three habitat types compared. On high relief rocky reefs, rockfishes maintained small home ranges (most within 30m^2), however, there were pronounced seasonal habitat references. In the summer, artificial reefs become less suitable; considerable off-reef movement occurred and rockfish did not return form displacements. In contrast, during fall and winter, rockfishes remained on artificial reefs and returned form displacements. On low relief rocky reefs, rockfishes maintained considerably larger home ranges (most within 400m^2 and some up to 1500 m^2).

Habitat use was affected by season; rockfishes only in low relief reefs in the summer and only returned form displacements in the summer coincident with peak algal cover. In addition, there was substantial movement between artificial reefs and adjacent low relief reefs; many rockfishes leave artificial reefs in the summer, move to low relief reefs and return to artificial reefs in the fall when kelp disappears on low relief reefs. Through habitat assessment, movements in response to habitat quality, and ability to home, these rockfish maintain a flexible behavior for optimal habitat use.

86. Mayer, L. M. Schick D. F. Findlay R. H. and D. L. Rice. Effects of commercial dragging on sedimentary organic matter. Mar. Environ. Res. 31:249-261.

Keywords: dragging/sedimentary organic matter/commercial harvesting impacts

Abstract: A study was conducted to assess the potential for uptake of toxic chemicals by down-stream migrant salmon in an urban estuary. Juvenile chinook salmon (*Oncorhynchus tshawytscha*) were collected from the Duwamish Waterway (located in Seattle, Washington) and from the Nisqually River (a reference site). The mean concentrations of aromatic hydrocarbons and polychlorinated biphenyls (PCBs) in the stomach contents (food organisms) of salmon from the Duwamish Waterway were approximately 650 times and 4 times, respectively, higher than those in salmon from the Nisqually River. Similarly, the mean concentration of bile metabolites of aromatic compounds which fluorescence at benzo(a)pyrene wavelengths was 24 times higher in the urban salmon compared to the reference salmon, whereas the mean concentration of PCBs in liver of urban salmon was 3 times higher than that in reference salmon. The study clearly demonstrated that, during their residency in this urban estuary, juvenile chinook salmon bioaccumulate substantial levels of toxic chemicals.

87. McCabe, Gretchen H. and K. F. Wellman (Battelle Seattle Research Center). Policy alternatives for coastal erosion management. Olympia, WA. Washington Department of Ecology. 1994 Jun. Report 94-79. (Coastal Erosion Management Strategy; Coastal Erosion Management Studies, Vol. 6).

Keywords: shoreline modifications//erosion control// shoreline policy

Abstract: This reports on a study of policy alternatives for coastal erosion management. It provides Washington's Department of Ecology with a menu and critical evaluation of coastal erosions management policy alternatives appropriate to Puget Sound. It addresses existing policy and regulatory framework, current issues in coastal erosion management such as inadequate landowner involvement in evaluations; inefficient and complicated shoreline permit processes; limited use of soft solutions; reliance on hard solutions; frequent use of variances; lack of familiarity with risks, and inadequate environmental designations and a lack of guidance. Policy alternatives and tools are presented and evaluated.

88. -- (Battelle Seattle Research Center). [Shorelands and Water Resources Program]. Regional Approaches to Address Coastal Erosion Management. Olympia, WA. Washington Department of Ecology. 1994 Jun. Report 94-82. (Coastal Erosion Management Strategy; Coastal Erosion Management Studies, Vol. 9).

Keywords: beach sediment supply/beaches/shoreline armoring/vegetation/shading/biological impacts/bulkheads/revetment/riprap/gabions/breakwaters/technical solutions/spawning habitat/finfish/vegetation loss/migratory corridor loss/cumulative effects//shorelines

Abstract: Reports on regional approaches that may be used to consider coastal erosion issues in the management of residential development and shoreline modification proposals. Research for this report results from a discussion paper, follow-up interviews and new case study summaries. A workshop was also held with decision makers who review shoreline development modification applications. The discussion paper was used extensively during the workshop for illustration of pros and cons of proposed regional policy approaches. This report describes: 1) command and control approaches to management of shoreline modification, 2) economic incentives and market-based solutions, 3) research monitoring data collection and education and outreach approaches, and 4) a summary of findings on approaches having the most merit in Puget Sound.

89. McCain, B. B. Malins D. C. Krahn M. M. Brown D. W. Gronlund W. D. Moore L. K. and and Chan, S. L. Uptake of aromatic and chlorinated hydrocarbons by juvenile chinook salmon (*Oncorhynchus tshawytscha)* in an urban estuary. ARCH ENVIRON.CONTAM.TOXICOL. 1990. vol. 19.no. 1:pp. 10-16.

Keywords: salmon//contaminants//Puget Sound

Abstract: A study was conducted to assess the potential for uptake of toxic chemicals by down-stream migrant salmon in an urban estuary. Juvenile chinook salmon (*Oncorhynchus tshawytscha*) were collected from the Duwamish Waterway (located in Seattle, Washington) and from the Nisqually River (a reference site). The mean concentrations of aromatic hydrocarbons and polychlorinated biphenyls (PCBs) in the stomach contents (food organisms) of salmon from the Duwamish Waterway were approximately 650 times and 4 times, respectively, higher than those in salmon from the Nisqually River. Similarly, the mean concentration of bile metabolites of aromatic compounds which fluorescence at benzo(a)pyrene wavelengths was 24 times higher in the urban salmon compared to the reference salmon, whereas the mean concentration of PCBs in liver of
urban salmon was 3 times higher than that in reference salmon. The study clearly demonstrated that, during their residency in this urban estuary, juvenile chinook salmon bioaccumulate substantial levels of toxic chemicals.

90. McMillan, R. O. D. A. Armstrong and P. A. Dinnel. Comparison of intertidal habitat use and growth rates of two northern Puget Sound cohorts of 0+ age Dungeness crab, *Cancer magister*. Estuaries. 1995. 18(2):390-398.

Keywords: shellfish//crabs//Port Townsend//Jefferson County//northwest straits//nearshore//Puget Sound//straits

Abstract: Density, habitat use, and growth of intertidal 0+ age Dungeness crabs, *Cancer magister*, were examined at five northern Puget Sound (Washington USA) sites between June 1984 and September 1987. Sampling was conducted biweekly during settlement, from June to September, and approximately monthly or bimonthly thereafter. Northern Puget Sound Dungeness crab populations appear to be largely supported by recruitment form inland parental stocks, but a smaller proportion of recruits originated from coastal or oceanic stocks, as evidenced by earlier settlement and larger size of the first instar. Settlement of Dungeness crabs in inland waters typically peaked in August, and interannual variation in year-class strength at settlement (measured as intertidal density) was low relative to that reported or coastal crab populations. Spatial and interannual differences in settlement densities were mediated by high post-settlement morality, which varied inversely with habitat complexity. Seasonal densities were highest in mixed sand and gravel with an overstory of attached or drift macroalgae, intermediate in eelgrass (*Zostera marina*), and lowest on open sand. Post-settlement growth rates corresponded to seasonal water temperatures and were greatest for the coastal cohort that settled in May and June. This cohort was larger as first juvenile instars (7.2mm carapace width, CW) and grew rapidly at summer temperatures in excess of 15 degrees C to a size (>30 mm CW) that allowed emigration from intertidal to subtidal areas by September. The late summer cohort settled in August at 5.3 mm CW and soon after was subjected to decreasing autumn water temperatures. These crabs experienced little growth while overwintering in the intertidal, but growth rates increased in March, and the crabs emigrated in April and May, approximately 10 mo. after settlement.

91. Melvin, E. F. and L. Conquest. Reduction of seabird bycatch in salmon drift gillnet fisheries: 1995 sockeye/pink salmon fishery final report. Seattle, Washington: Washington Sea Grant Program, University of Washington. 1996.

Keywords: harvesting//salmon//mariene birds//birds//harvest

Abstract: We compared seabird and marine mammal entanglement rates and fish catch among two gear treatments (modifications) and a control throughout the day-night cycle during the 1995 Puget Sound sockeye and pink salmon

fishery in Area 7 (San Juan Islands). The goal of this study was to test methods to eliminate or significantly reduce the incidental capture of seabirds in gillnet salmon fisheries without significantly reducing the fishing efficiency of the nets. The two gear modifications tested incorporate 10-inch mesh opaque netting at two depths in the upper quarter (50 Mesh) or upper eighth (20 Mesh) of a monofilament net and were compared to an unmodified monofilament control. The experimental nets were fished over a 24-hour period in a WDFW Test Fishery to determine if seabird entanglement and sockeye catch rates vary by time of day.

92. Melvin, E. F. Conquest L. L. and J. Parrish. New tools to reduce seabird bycatch in Puget Sound salmon drift gillnets. Puget Sound Research '98.

Keywords: harvesting//salmon//mariene birds//birds//harvest

Abstract: We compared seabird and marine mammal entanglement rates and fish catch among two gear treatments (modifications) and a control throughout the day-night cycle during the 1995 Puget Sound sockeye and pink salmon fishery in Area 7 (San Juan Islands). The goal of this study was to test methods to eliminate or significantly reduce the incidental capture of seabirds in gillnet salmon fisheries without significantly reducing the fishing efficiency of the nets. The two gear modifications tested incorporate 10-inch mesh opaque netting at two depths in the upper quarter (50 Mesh) or upper eighth (20 Mesh) of a monofilament net and were compared to an unmodified monofilament control. The experimental nets were fished over a 24-hour period in a WDFW Test Fishery to determine if seabird entanglement and sockeye catch rates vary by timeof day.

93. Melvin, E. F. Parrish J. K. and Conquest L. L. Novel Tools to Reduce Seabird Bycatch in Coastal Gillnet Fisheries. Conservation-Biology. 1999; vol. 13(no. 6):pp. 1386-1397.

Keywords: seabird//harvesting//fish

Abstract: We examined several strategies to reduce seabird bycatch, primarily of Common Murres (Uria aalge) and Rhinoceros Auklets (*Cerorhinca monocerata*), in a coastal salmon drift gillnet fishery in Puget Sound, Washington, U.S.A. Our goal was to significantly reduce seabird bycatch without a concomitant reduction in target catch or an increase in the bycatch of any other species. We compared fish catch and seabird bycatch in nets modified to include visual alerts (highly visible netting in the upper net) or acoustic alerts (pingers) to traditional monofilament nets set throughout the normal fishing hours over a 5-week fishing season. Catch and bycatch varied significantly as a function of gear. Relative to monofilament controls, murres responded to both visual and acoustic

alerts; auklets and sockeye salmon responded to deeper visual alerts only. Seabird abundance varied across multiple temporal scales: interannually, within fishing season, and over the day. At the interannual level, seabird entanglement was linked to regional abundance on the fishing grounds, a pattern that broke down at the local level. Within season, sockeye and murre abundance were negatively correlated, suggesting that if fishery openings were scheduled on peak abundance of the target species, seabird bycatch would be significantly reduced as a function of increased target fishing efficiency. Finally, both sockeye catch and auklet entanglement were found to be highest at dawn, whereas murre entanglement was high at both dawn and dusk. Our results identify three complementary tools to reduce seabird bycatch in the Puget Sound drift gillnet fishery - gear modifications, abundance-based fishery openings, and time-of-day restrictions - for a possible reduction in seabird bycatch of up to 70-75% without a significant reduction in target fishing efficiency. Although these tools are based on local conditions and will thus vary among years and locations, all might be exportable to other coastal gillnet fisheries worldwide.

94. Miller, B. D. C. A. Simenstad, J. M. Cross, K. L. Fresh and S. Steinfort. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan de Fuca including foraging habits of the common nearhsore fish. Energy/Environment R.D Program Report. EPA-600/7-80-027 and NTIS PB81-155435.

Keywords: Fish//san juan islands//San Juans//nearshore//straits

Abstract: Presents results of seasonal surveys of nearshore fishes in the Strait of Juan de Fuca between May 1976 and June 1978. Fishes and macroinvertebrates were collected by beach seining and townetting. Fish size, abundance, distribution, biomass, food habits, and extent of fitness were recorded. Discussion includes seasonal variations in nearshore fish composition, species richness, density, standing crop, health, food web relationships, and potential impacts of petroleum hydrocarbons.

95. Miller, Bruce S. and S. F. Borton (University of Washington, Fisheries Research Institute). Geographical Distribution of Puget Sound Fishes: Maps and Data Source Sheets. Vol I, II, III ed.. Seattle, WA: University of Washington, Fisheries Research Institute; 1980 Sep(Family *Cottidae* (sculpins) through Family *Molidae* (Molas); Volume 3).

Keywords: fish//sturgeon// herring//smelt//codfishes//cod//perch//sand lance//rockfish//fish distribution//salmon//Puget Sound

Abstract: Maps and data source sheets describing the distribution of Puget Sound fish.

96. Miller, Bruce S. C. A. Simenstad and Lawrence R. Moulton (UW,College of Fisheries Annual Report to Washington State Department of Ecology.). Puget Sound Baseline Program: Nearshore Fish Survey. Seattle, Washington; 1975 Oct; FRI-UW-7604.

Keywords: nearshore//fish//Puget Sound//straits//habitat//rockfish//sculpin//herring//smelt//perch//sand lance//sole//pollock//nearshore fish assesmblages//eelgrass//kelp beds//gravel//cobble//salmon

Abstract: Since July 1974, the Fisheries Research Institute's (FRI) Nearshore Fish Survey project has conducted an ecological survey of the nearshore fishes of north Puget Sound. The primary objective of this project was to document the seasonal occurrence, abundance, and distribution of the marine and estuarine fishes frequenting the waters adjacent to the shoreline. The survey was supported by the Washington State Department of Ecology (DOE) under the auspices of its Baseline Study Program, a comprehensive scientific and management research program designed to evaluate the biological and economic risk of oil and other pollution in northern Puget sound. Emphasis was placed upon biota of the nearshore (less than 20 m depth) environs because pollutant effects, especially those induced during oil spills, have been found to be most pronounced there. Reliable measures of the composition, distribution, and abundance of nearshore fishes permit both (1) evaluations of the economic and ecologic importance of these regions and their associate fish fauna, and (2) assembly of a data base (i.e. "pre-pollution") for future reference against similarly documented samples after a pollution incident.

Fish data were collected monthly in representative intertidal and shallow subtidal habitats using beach seines and SCUBA transect observations. Quarterly trammel net sampling also supplemented the SCUBA observations. In addition, periodic surface tow net sampling was conducted adjacent to the sampling sites about San Juan Island and sites established by Western Washington State college along the eastern margin of the North Sound.

This report discusses the characteristics of the type-habitats sampled, the sampling techniques utilized, and the results of the 1974-195 collections and observations. Discussion of these results will include descriptions of the characteristic fish assemblages found in each of the type-habitats, the variations inherent in the sampling and due to seasonal changes in the assemblages, and a preliminary examination of the trophic relationships between certain important members of these assemblages and the habitats they characterize.

97. Miller, Bruce S. L. L. Moulton and J. H. Stadler. Long-term trends in Puget Sound marine fishes: selected data sets. Fisheries Research Institute, School of Fisheries. 1991. FRI-UW-9105. (Final Report).

Keywords: Puget Sound//fish

Abstract: The primary objective of this project was to analyze long-term trends in Puget Sound marine fishes based on a synthesis of the available data. A secondary objective was to establish baselines against which future fish monitoring efforts could be compared and evaluated. An additional benefit of the project was the identification of the collection methods used over the years, which can be used to help define standardized methods so that future investigations can be conducted in a compatible fashion.

Results: Peak occurrences of rare species occurred during usually cold (1918-1919, 1971-1975) for warm (1963,1965, 1983-1984) years, except for the peak in 1932-1935, which was a transition period form warm to cold temperatures. We think that routine monitoring of rare and unusual Puget Sound fish species yields important data, which to the best of our knowledge has not been collected since 19176. Although we do not claim that keeping current records of unusual occurrences of rare and exotic fishes is the most important Puget Sound monitoring tool, we think such monitoring can provide an early warning of environmental changes to Puget Sound.

In general, the analysis marine fish trends in Puget Sound based on relative frequency of occurrence data (form of CPUE) indicated that while research data did seem to measure real change in the relative occurrence of marine fishes in Puget Sound, there was no indication of a serious change in the relative occurrence of marine fishes in Puget Sound.. We noted that, by itself, data on commercial species is often not very useful for looking at long-term trends in fishes other than trends in the fishery itself, which may be impossible to separate from trends due to natural environmental changes (e.g. El Nino) and unnatural perturbations to the environment such as habitat destruction and toxic pollutants. We believe that a strong case can be made for monitoring as many non-economically important fishes in Puget sound as possible, ideally, assemblages of fishes occupying the major habitats in Puget sound should be monitored.

Long Term Trends at Specific Sites: Species richness at Golden Gardens beach in Seattle declined significantly from 1950-1972. A suggested reason for this decline was the habitat disturbance and change that occurred with the construction of the Shilshole breakwater in 1957-59. At Port Gardner in Everett, fish community measures (species richness and species diversity) were stable, but the CPUE of three common flatfish showed a decline from 2165-1987. Although we do not have a specific suggestion as to why this decline may have occurred, Port Gardner is well known to be located in an urban environment that has undergone continual alterations induced by humans.

We think these site-specific results further indicate the value of long-term monitoring using both community indices and individual species (both

commercial and non-commercial "index" species) abundance measures of marine fishes in Puget Sound.

98. Mills, Mary Lou. Strategies for developing and applying marine protected area science in Puget Sound/Georgia Basin. 1999 May 17-1999 May 18. Bellingham, WA. Puget Sound/Georgia Basin International Task Force.

Keywords: MPA//Puget Sound//straits//marine protected areas

Abstract: The Marine Sciences Panel (194) recommended creation of marine protected areas as an important tool to reverse the declining population trends for a variety of resources in the Puget Sound-Georgia Basin. An international work group was established with both a British Columbia and a Washington branch. Efforts had been underway in British Columbia to establish marine protected areas and their work provided a valuable example to Washington staff. In January 1998, the Washington work group circulated a draft marine protected area strategy discussion paper. After the close in the comment period, this paper will be revised and submitted to the Puget Sound-Georgia Basin Task Force.

While the draft strategy was available for public comment, a Marine Protected Area Policy was elevated to the Dept. of Fish and Wildlife Commission. The policy calls for use of these areas as one of the working tools of the agency and it defines goals and principles for use regarding Marine Protected Areas. Adoption of this policy will be requested in June 1998. In January 1998, the Fish and Wildlife Commission adopted regulations creating the first "conservation areas' in Washington (Octopus Hole, Orchard Rocks and several beaches). These areas are closed to recreational harvest of all fish and wildlife. Restrictions on commercial harvest are being brought to the Commission for these areas.

99. Moulton, L. L. An ecological analysis of fishes inhabiting the rocky nearshore regions of northern Puget Sound, Washington.UW. 1977PhD. Dissertation.

Keywords: nearshore//Puget Sound//rockfish//bottomfish//groundfish//fish

Abstract: Presents information on abundance, frequency of occurrence, behavior, predation and seasonality of fish on nearshore rocky reefs in the San Juan Archipelago.

100. Murray, M. R. and L. Ferguson. The Status of Marine Protected Areas in Puget Sound. Volume I: MPA Site Profiles & Appendices ed. Olympia, WA. Puget Sound Washington Quality Action Team (Puget Sound/Georgia Basin Environmental Report Series; Number 8).

Keywords: fish//shellfish//vegetation//population growth//habitat//Puget Sound//straits//MPA

Abstract: This report characterizes and discusses the nature of the institutional framework supporting MPA's in Puget Sound and the San Juan Islands. Basically, it 1) reviews MPA basic concepts, including definitions, management models and benefits; 2) classifies and profiles existing MPAs in Puget Sound; 3) identifies and reviews existing institutions and designation mechanisms responsible for the establishment and management of the current system of MPAs; and 4) summarizes and evaluates the overall system of MPA sites and institutional arrangements. In summary, the existing institutional structure is fragmented and complex with many organizations governing and managing resources. The Washington Department of Fish and Wildlife, Washington Department of National Resources, Department of Ecology and Washington Parks and Recreation Commission share responsibility for the management of a variety of types of marine protected areas and associated activities.

101. Murray, Michael R. The State of Marine Protected Areas in Puget Sound. 1998 Mar(; Volume II).

Keywords: fish//shellfish//vegetation//population growth//habitat//Puget Sound//straits//MPA

Abstract: This report presents MPA site profiles for 42 of 102 Puget sound MPAs, presenting basic information on site designation, boundaries, special features, legal protection, management planning, supervision and programs. These sites include research and educational marine preserves, recreational marine preserves, marine species preserves marine habitat and mature preserves and multiple use protected areas. Out of 42 sites, 26 are in San Juan county with the remainder of sites being in southern Puget Sound, Protection Island, Dungeness, Padilla Bay, Edmonds and northern Puget Sound.

102. Myers, J. M. R. G. Kope G. J. Bryant D. Teel L. J. Lierheimer T. C. Wainwright W. S. Grant F. W. Waknitz K. Neely S. T. Lindley and R. S. Waples. Status Review of chinook Salmon from Washington, Idaho, Oregon and California. Seattle, WA, Long Beach, CA., Newport, OR, Tiburon, CA. National Marine Fisheries Service; 1998; NOAA Technical Memorandum NMFS-NWFSC-35.

Keywords: salmon//chinook/Washington//Idaho//Oregon//California//fish

Abstract: This report reviews the ESA evaluation for chinook salmon populations in the Pacific Northwest. It presents species and ESU definitions, listing petitions, and all aspects of chinook biology. The biological description includes physical and biological features with life-history and ecological information. It examines and presents in-depth descriptions of all life-history stages, regional distributions, hatchery production, practices, and influences, stock abundances, history, and trends.

103. Myers, M. S. Landahl J. T. Krahn M. M. and McCain B. B. Relationships between hepatic neoplasms and related lesions and exposure to toxic chemicals in marine fish from the U.S. West Coast. Symp. on Chemically Contaminated Aquatic Food Resources and Human Cancer Risk, Research. Triangle Park, NC. 1988 Sep 29-1988 Sep 30: pp. 7-15. Environmental Health Perspect.

Keywords: water quality//fish//sole//contaminants//human impacts//pollution

Abstract: English sole (*Parophrys vetulus*) inhabiting polluted waterways and embayments of Puget Sound, Washington, USA, are affected with a variety of multiple, co-occurring idiopathic hepatic lesions, including unique degenerative conditions, putatively preneoplastic foci of cellular alteration, and neoplasms. Results of a statistical analysis of the patterns of co-occurrence of these lesions in wild English sole are consistent with the concept that these lesions represent morphologically identifiable steps forming a sequence of progression ultimately leading to the development of hepatic neoplasms. The rationale for the hypothesis that these lesions in wild English sole can be caused by exposure to certain hepatoxic and hepatocarcinogenic xenobiotic compounds in the marine environment is based on the demonstration of significant and consistent statistical associations between levels of aromatic hydrocarbons in sediment and prevalences of
these idiopathic liver lesions. Idiopathic hepatic lesions have been detected in white croaker (*Genyonemus lineatus*) captured from contaminated marine sites in the vicinity of Los Angeles, California.

104. National Marine Fisheries Service, Northwest Fisheries Science Center. Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon and California. Seattle, WA; 1997 Mar; NOAA Technical Memorandum NMFS-NWFSC-28.

Keywords: salmon//sea lions//seals//marine mammals//Washington//Oregon//California//ecosystems//fish

Abstract: The report presents the findings of the NMFS Working Group on the issue of whether California sea lions and Pacific harbor seals are having a significant negative impact on the recovery of salmonid fishery stocks which have been listed as endangered species or threatened species. The Working group found that the presence of Calif. sea lions and Pacific harbor seals in rivers and estuaries concurrent with migrations of depressed salmonids. the working Group could not determine if either pinniped species is having a significant negative impact on any wild salmonid population, except winter steelhead that migrate through the Ballard Locks because of the limitations of the available data.

Although the Working Group concluded that substantial additional research is needed to fully address this issue, it found that existing information on the seriously depressed status of many salmonid stocks is sufficient to warrant actions to remove pinnipeds in areas of co-occurrence where pinnipeds prey on depressed salmonid populations. The Working Group identified the elements of a research program to assess impacts of pinniped predation on depressed salmonids, and identified the geographic areas of greatest concern of impacts on salmonids on each stage. The Working Group could not determine ecosystem-level impacts because of the complexity of ecosystems and the limited knowledge of how they function.

105. Nehlsen, W. J. E. Williams and J. A. Lichatowich. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries. 16(2):4-21.

Keywords: salmon//Puget Sound//northwest straits//straits

Abstract: The American Fisheries Society herein provides a list of depleted Pacific salmon, steelhead, and sea-run cutthroat stocks from California, Oregon, Idaho, and Washington, to accompany the list of rare inland fishes reported by Williams et al. (1989). The list includes 214 native naturally-spawning stocks: 101 at high risk of extinction, 58 at moderate risk of extinction, 54 of special concern, and one classified as threatened under the Endangered Species Act of 1973 and as endangered by the state of California. The decline in native salmon, steelhead, and sea-run cutthroat populations has resulted from habitat loss and damage, and inadequate passage and flows caused by hydropower, agriculture, logging, and other developments; overfishing, primarily of weaker stocks in mixed-stock fisheries; and negative interactions with other fishes, including nonnative hatchery salmon and steelhead. A new paradigm that advances habitat restoration and ecosystem function rather than hatchery production is needed for many of these stocks to survive and prosper into the next century.

106. Newton, J. A. Marine Water Column Ambient Monitoring Program: Wateryear 1995 Long-Term Monitoring Implementation Plan. Olympia, WA: Department of Ecology; 1995; 95-324.

Keywords: water quality
Abstract: Marine Water Column Ambient Monitoring Long-term Monitoring Implementation Plan

107. Newton, J. A. S. L. Albertson and A. L. Thomson. Washington State Marine Water Quality in 1994 and 1995. Olympia, WA: WA Dept. of Ecology ; 1997 Apr; Publication No. 97-316.

Keywords: water quality//marine water//Washington//Puget Sound//straits

Abstract: A report on water quality parameters, such as stratification, dissolved oxygen, fecal coliform bacteria, ammonium-N concentrations, salinity, temp, density, depth, chlorophyll. See abstract on Washington State Marine Quality in 1996-1997 for further details on information collected.

108. Newton, J. A. S. L. Albertson K. Nakata and C. Clishe. Washington State Marine Water Quality in 1996 and 1997. Olympia, WA: Department of Ecology; 1998; 98-338.

Keywords: water quality//Puget Sound//habitat//contaminants

Abstract: The Washington State Department of Ecology initiated monitoring of marine waters in 1967 in order to assess water quality in Puget Sound, Grays Harbor, and Willapa Bay. Data are currently collected monthly for this ongoing, long-term monitoring effort by the Marine Waters Monitoring program. Monitoring of various water quality parameters during wateryears (WYs) 1996 and 1997 occurred at 29 and 25 stations, respectively, in Puget Sound each WY (WY 1996 = October 1995 through September 1996). For both Water yrs, five stations in Grays Harbor and six in Willapa Bay were also monitored. In this report, along with the WY 1996-97 data, five indicators of marine water column environmental condition are discussed.

Climatic conditions of WY 1996-97 were characterized by higher than normal precipitation in both years, particularly during fall and winter. Air temperatures averaged close to normal throughout the two-year period. Annual runoff of two major Washington rivers (Skykomish and Chehalis) was quite high, at approximately 140-150 percent of the median flow in both years. These weather and flow conditions were evident in the sea-surface temperature and salinity of the monitoring stations. All stations showed predominately fresher sea salinity than the long-term average. Stations near rivers had a more extreme annual sea temperature range than those not near rivers.

The stratification characteristics of stations were classified into four groups: persistent, seasonal, episodic, and weak. The majority of the Puget Sound monitoring stations were either persistently (15 out of 38 stations) or seasonally (11 out of 38 stations) stratified. The degree of stratification has implications for water quality.

Dissolved oxygen (DO) concentrations <3 mg/L were measured at South Hood Canal, Penn Cove, and Discovery Bay; and <5 mg/L were found at 19 additional stations during WYs 1996-97. Observations of low DO primarily occurred in late summer to early fall but in South Hood Canal occurred year-round and reached anoxia at times. Persistent stratification co-occurred with low DO concentrations.

Very high ammonium-N concentrations (>0.14 mg/L) were seen in Budd Inlet and East Sound; high concentrations (>0.07 mg/L) were at 13 predominately South

Puget Sound stations. Occurrence of consecutive months with <0.01 mg/L surface dissolved inorganic nitrogen (nitrate+nitrite plus ammonium) in combination with stratification and other indicators was used to indicate stations potentially sensitive to eutrophication. Fecal coliform bacteria counts >14 organisms/100 mL were found at 12 Puget Sound stations and seven coastal estuary stations during WY 1996-97. Of these, contamination in Grays Harbor, Willapa Bay (near the Willapa River), Commencement Bay, and inner Budd Inlet appeared chronically persistent. Other stations (e.g., Elliott Bay and Bellingham Bay) showed wintertime highs in fecal counts. SUBJECT WATERBODIES Strait Of Georgia, Drayton Harbor, Bellingham Bay, Lummi Bay, Hale Passage, San Juans Outer West Side, Padilla Bay, Fidalgo Bay, Guemes, Channel, Saratoga Passage, Penn Cove, Port Gardner, Inner Everett Harbor, Elliott Bay, Commencement Bay, Thea Foss, Henderson Inlet, Budd Inlet, Squaxin, Peale, Pickering passages, Eld Inlet, Shelton Harbor, Hammersley Inlet, Oakland Bay, Eagle Harbor, Port Orchard, Agate Passage, Rich Passage, Sinclair Inlet, Dyes Inlet, Port Washington Narrows, Carr Inlet, Henderson Bay, Port Gamble Bay, Liberty Bay, Quartermaster Harbor Dabob Bay, Quilcene Bay, Port Townsend, Kilisut Harbor, Port Townsend, Sequim Bay, Port Angeles Harbor, Grays Harbor, Willapa Bay, Skagit Bay, Similk Bay, Port Susan, Possession Sound, Tacoma Narrows, Case Inlet, Dana Passage, Hood Canal, Samish Bay, Puget Sound, Great Bend, Lynch Cove, Nisqually Reach, Drayton Passage

109. NOAA. Juvenile Salmon Injury Study; NOAA Tech Memo NMFS NWFSC-36: Fish Injury in the Hylebos Waterway.

Keywords: salmon//fish//Puget Sound//contaminants

Abstract: Urban estuaries receive inputs of toxic anthropogenic substances from various sources. These chemicals can accumulate in sediments (Dexter et al. 1985) and thereby be retained in the estuary. The Hylebos Waterway in Commencement Bay, Tacoma is a severely contaminated estuary. During 1989 and 1990, juvenile chinook were sampled and found to be substantially exposed to a variety of contaminants including PAHs and CHs. Juvenile chinook from the Duwamish Waterway also show a variety of biological immunocompetence with increased mortality and reduced growth. A recent laboratory investigation demonstrates immunocompetece of juvenile chinook to be impaired by exposure to CHs and PAHs. This study focuses solely on characterizing possible exposure of juveniles.

Juv. chum from the Hylebos had significantly higher concentrations of HCB, HCBD, PCBs and DDTs,chlordanes, dieldrin, and lindane in live compared to chum from reference estuaries and hatcheries. Concentrations were 20 to 9 times higher for HCBD and HCB and 7 times higher for PCBs. Concentrations DDTs, chlordanes, dieldrin and lindane were twice as high in the livers of Hylebos fish compared to reference fish. Juv. chinook showed concentrations of

HCB and HCBD to be 4 times higher, PCBs about 3 times higher and chlordanes twice as high in the liver compared to liver from reference fish.

110. NOAA/NMFS. Marine Mammal Conservation Division [Web Page]. Available at: www.nmfs.noaa.gov/prot_res/overview/mm.html.

Keywords: marine mammals//northwest straits//Puget Sound/straits

Abstract: his site provides stock assessments and marine mammal fishery interactions.
Each stock assessment includes a description of the stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence hunters. Under the new regime, these data will be used to evaluate the progress of each fishery towards achieving its goal of zero mortality and serious injury.

111. Norman, D. M. The status of Great Blue Herons in Puget Sound: population dynamics and recruitment hypothesis. Puget sound Research '95 Proceedings; 1995: 638-645.

Keywords: birds//puget sound

Abstract: More than 100 heron colonies, including 4,600 birds, have lived in western Washington over the past 10 years. The largest Boundary Bay colony is located on Point Roberts with more than 500 nests. The largest Puget Sound colony resides at Nisqully Wildlife Refuge with over 100 nests. More than 500 herons are known to nest in South Puget Sound. The Christmas Bird Count data over the past 25 years have shown an index of increasing heron numbers. The cause for this increase is unknown. The mean number of young per active nest for Puget Sound is 1.6.

112. Norris, J. G. D. Llewellin A. Murphy and D. Nolan, Prepared for Port Townsend Marine Science Center. Recreational seaweed harvesting near Fort Worden State Park 1996-1998. Port Townsend, WA; 1999.

Keywords: elgrass//seaweed//seaweed harvest//vegetation
Abstract: We estimated that during the three year period 1996 to 1998 about 200 to 300 recreational seaweed harvesters removed 2,000 to 4,000 lb of A*laria* from North Beach County Park each year. In 1997 and 1997, the percent cover of *Alaria* dropped form over 50% to about 15%. Compliance with the 10 lb wet weight per person daily bag limit imrpoved significantly over the three year study, with near full compliance in 1998. Most harvesters used the recommended harvest method (cutting the leafy portion and leaving the holdfast), and at least half of the harvesters carried visible licenses. About 75% of the harvesters were

female. If gender equity is a management objective, seaweed harvesting offers an important recreational opportunity for women. Harvest effort was concentrated around minus-tide series from late March to early July. The most readily accessible *Alaria* in the higher intertidal region was removed first. *Alaria* recruitment varied significantly between years, with 1997 having 5 to 6 times as many plants per quadrat as the other 2 yrs. We used a control (unharvested) beach and a treatment (harvested) beach to estimate the population, community, and ecosystem impacts of seaweed harvesting. Our sampling plan used 2-5 times as many quadrats as other Puget Sound studies reported in the literature. In 1996, both beaches showed sharp declines in *Alaria* percent cover suggesting a dominant natural die-off effect. In 1997, only the harvested beach showed a sharp decline suggesting a dominant harvesting effect and in 1998 neither beach showed much decline. We concluded that the control beach may have been unsuitable, because it was too far (about 4,800 ft) from the treatment beach and had somewhat different physical characteristics (e.g. more gradual slope). Our project demonstrated that there is an ample and capable volunteer workforce in the Port Townsend area to conduct a comprehensive beach monitoring program. We recommend that monitoring recreational seaweed harvest include non-game marine invertebrates (NGMI). Given the labor intensive data gathering requirements of such a program, we feel that citizen volunteers can significantly expand the capabilities of government agencies and research universities. Our vision is a well-trained state-wide labor force available to augment professional data collection activities. We make some specific recommendations that may be incorporated into state-wide beach monitoring and sampling protocols.

113. Norris, J. G. S. Wyllie-Echeverria T. Mumford A. Bailey and T. Turner. Estimating basal area coverage of subtidal seagrass beds using underwater videography. Aquatic Botany. 1997.(58):269-287.

114. Norris, James E. Habitat associations of juvenile rockfishes form inland marine waters of Washington State: an annotated bibliography and review. Olympia, WA. WDF.1991. Technical Report Number 117.

Keywords: rockfish//fish

Abstract: The report and annotated bibliography gathers and summarizes information on the benthic juvenile hase of *Sebastes* spp. and their habitat association in Washington State inland marine waters. Three fishery-important species of rockfish domainate Puget Sound's adult rockfish fauna. These are the copper rockfish (*Seastes caurinus*), quillback rockfish (*S. maliger*), and brown rockfish (*S. auriculatus*). These are the primary subject of this report.

115. Norris, James. G. Abundance estimates for demersal fish populations in Port Townsend Bay, Washington. July 1991. Marine Resources Consultants. 1991.

Keywords: fish//herring//cod//pollock//sole//Port Townsend

Abstract: This report presents the results of a July 1991 Port Townsend Bay survey estimating absolute abundance of demersal fish occupying offshore soft-bottom habitat assemblage between 10-30m. spotted ratfish, Pacific sanddab, Dover sole, and rock sole were more abundant in the northern part of the bay while spiney dogfish, flathead sole, English sole, Pacific tomcod (adults and juveniles), Pacific herring (adults), tadpole sculpins, snake prickleback, and blackbelly eelpout were more abundance in the southern portion. Juvenile Pacific tomcod were by far the most abundant species followed in order of abundance by snake prickleback, spotted ratfish, juvenile walleye pollock, Pacific herring, sculpins, English sole, blackbelly eelpout, flathead sole and spiney dogfish.

116. Norris, James G. Abundance estimates for demersal fish populations in Port Townsend Bay, Washington, June 1992. Port Townsend, WA: Marine Resources Consultants; 1992.

Keywords: fish//cod//herring//sole//Port Townsend//pollock

Abstract: This report presents demersal fish hauls over 19 stations in Port Townsend Bay in June 1992. used to: 1) estimate the absolute abundance of demersal fish populations occupying the offshore soft-bottom habitat assemblage between 10-30-m, 2) estimate the abundance of juv. Pacific cod in depths less than 30 m, and 3) compare the catching characteristics of 2 otter trawls. 53 species were captured. Spotted ratfish, Pacific sanddab, and speckled sanddab were more abundant in the northern portion of the bay while spiney dogfish, flathead sole, Pac. tomcod (juv and adults), Pacific herring (adults), snake prickleback, shortfin eelpout, and blackbelly eelpout were more abundant in the southern portion. Juv. tomcod were the most abundance species followed by snake prickleback, Pac. herring, shiner perch, blackbelly eelpout, English sole flathead sole, spotted ratfish, Pacific tomcod adults, and shortfin eelpout. Mean lengths were significantly different between strata for English sole, rex sole and juv. Pac. tomcod.

117. --. Union Wharf Eelgrass Survey, Port Townsend, Washington, October 7, 1995. Port Townsend, WA: Marine Resources Consultants; 1995; For City of Port Townsend.

Keywords: eelgrass//Port Townsend//monitoring//vegetation

Abstract: We conducted an underwater video and snorkel survey of the subtidal regions in the immediate vicinity of the Union Wharf, Port Townsend Washington. The purpose of the survey was to delineate the edge of eelgrass (*Zostera marina*) beds adjacent to the dock prior to dock reconstruction. Dense

eelgrass beds were observed immediately adjacent to both the north and south sides of the outer portion of the approach ramp to the Union Wharf in depths between -4 and -10 ft. MLLW. Sparse eelgrass was observed off the southwest corner of the main dock in depths between -10 and -14 ft MLLW. Some eelgrass also was observed in the north central region of the destroyed portion of the ramp. No eelgrass was observed near the dock outside the inner harbor line. An oversize map, video of the survey, and floppy disk with integrated data is included with this report.

118. Norris, James G. and T. Hutley. Habitat utilization/water quality study Port Townsend Bay, Washington. Port Townsend. 1997. Prepared for Port Townsend Marine Science Center.

Keywords: Port Townsend//fish//sp;e//cod//herring//pollock

Abstract: Water quality data collected during the period 1991-1997 by the Port Townsend Marine Science Center citizen-based monitoring program indicate that most of Port Townsend Bay meets Washington State marine water quality standards for temperature and dissolved oxygen. Although temperatures were occasionally above state standards in the southern portion of the Bay and inside Kilisut Harbor, these readings only occurred during the warmest summer months and are most likely a natural occurrence. Occasional low dissolved oxygen readings were observed in the outer portions of the bay near Admiralty Inlet. We believe these low readings were due to significant upwelling and were not caused by human activities. Waters inside the Port of Port Townsend Boat Haven had low dissolved oxygen readings during October and November of 1996. These readings may be caused by human activities and deserve further monitoring. High fecal coliform readings were observed in the Point Hudson Marina immediately following the 1996 Wooden Boat Festival. Semi-annual underwater video eelgrass surveys indicate extensive eelgrass beds along the entire Port Townsend waterfront from the Port of Port Townsend Boat Haven to Point Hudson. Annual demersal fish abundance surveys indicate significantly different species compositions in the northern and southern portions of Port Townsend Bay. Spotted ratfish, Pacific sanddab, Dover sole and rock sole were more abundant in the northern region, while spiney dogfish, flathead sole, English sole, Pacific tomcod, Pacific herring, snake prickleback, and blackbelly eelpout were more abundant in the southern region. Juvenile (young-of-the-year) Pacific tomcod and walleye pollock showed highly variable recruitment between years. Pacific tomcod had significantly higher recruitment in 1991 and 1993, whereas walleye pollock had highest recruitment in 1996 and 1997. Spiney dogfish and spotted ratfish virtually disappeared from the survey catches starting in 1994. Snake prickleback catches during 1996 and 1997 were significantly lower than 1991-1993. Only three juvenile Pacific cod have been observed during the seven years of surveys.

119. --. Monitoring Basal Area Coverage of Eelgrass in Port Townsend Bay. Port Townsend, WA ; 1998Port Townsend Bay, July 1994 to February 1998.

Keywords: eelgrass//Port Townsend//monitoring//vegetation

Abstract: Although seagrasses have been identified as vital living marine resources, their distribution has not been rigorously quantified at main locations. This fact is often due to the high cost of sampling seagrass habitats, especially those with deep-water plants that cannot be sensed form aerial platforms. We present a cost-effective method of estimating basal area coverage of submersed vegetation that uses differential global positioning system data linked to underwater video images of the bottom. Our sampling design and statistical procedures are identical to estimating proportions using cluster sampling with unequal cluster sizes. This method has several advantages over other techniques: 1) confidence intervals around basal area coverage estimates permit hypothesis testing of changes over time; 2) sampling efficiency is better than simple random sampling with quadrats; 3) deep-water zones out of the range of aerial platforms can be sampled; 4) video images provide positive identification of plants which is not possible with acoustic techniques; and 5) the techniques provide a permanent archive of visual images that can be analyzed for other bottom attributes, such as other vegetation, macro-invertebrates, and gross sediment types. This method has the following limitations: 1) it is not possible to sample extremely shallow or turbid waters and under some physical structures: 2) it is impractical to sample very large regions: 3) errors in differential global positioning system data must be accounted for; and 4) seagrass density must be measured subjectively. We illustrate our sampling methods and data analysis with an example from Puget Sound, Washington, USA.

120. North Pacific University Marine Mammal Research Consortium. North Pacific University Marine Mammal Research Consortium Web Site [Web Page]. Available at: www.marinemammal.org/resrch.htm.

Keywords: marine mammals

Abstract: This is the consortium's web site. The Consortium studies are a balance of short term and long term projects designed to test the various hypothesis that have been put forward to explain the decline of Steller sea lions. The studies are integrated and draw on the expertise and talents of university based physiologists, ecologists, marine mammalogists, fisheries specialists and oceanographers. Only a concerted effort and a commitment to long term research will determine the causes of changes in the North Pacific. Solutions are unlikely to come quickly and need a concerted effort.

121. Nowlis, J. S. and C. M. Roberts. Fisheries benefits and optimal design of marine reserves. Fishery Bulletin. In press.

Keywords: MPA//fish//reserves

Abstract: We used fishery population models to assess the potential for marine fishery reserves, areas permanently closed to fishing, to enhance long-term fishery yields. Our models included detailed life history data. They also included the key assumptions that adults did not cross reserve boundaries and that larvae mixed thoroughly across the boundary but were retained sufficiently to produce a stock-recruitment relationship for the management area. We analyzed the results of these models to determine how reserve size, fishing mortality, and life history traits, particularly population growth potential, affected the fisheries benefits from reserves. We predict that reserves will enhance catches from any overfished population that meets our assumptions, particularly heavily overfished populations with low population growth potential. We further predict that reserves can enhance catches when they make up 40% or more of fisheries management areas, significantly higher proportions than are typical of existing reserve systems. Finally, we predict that reserves in systems that meet our assumptions will reduce annual catch variation in surrounding fishing grounds. The fisheries benefits and optimal design of marine reserves in any situation depended on the life history of the species of interest as well as its rate of fishing mortality. However, the generality of our results across a range of species suggest that marine reserves are a viable fisheries management alternative.

122. Nyblade, Carl F. [Report prepared for EPA]. The Strait of Juan de Fuca Intertidal and Subtidal Benthos. Friday Harbor, WA : Friday Harbor Laboratories, UW; 1979 Mar; PB80-142136.

Keywords: benthos//straits//prey resources//nearshore//nearshore habitat//algae//invertebrates

Abstract: This study was undertaken to document pre-pollution shallow water habitats along the Washington coast and the Strait of Juan de Fuca. The study objectives were to adequately describe the distribution, abundance, seasonal variations and annual variation of the intertidal and shallow subtidal benthos of the area. Representative ranges of habitats were sampled quarterly. Over 1,000 different plant and animal species were collected during the two years. The dominant groups were algae, molluscs, annelids, and crustaceans. In the intertidal, rock habitats were the richest in terms of number os species, density and biomass (and probably productivity), followed by cobble, protected soft sediment, exposed sand, and exposed gravel habitats. Strong intertidal vertical zonation was found at all but the most exposed gravel and sand sites. Subtidal study sites were consistently rich. Summer was most often the peak for species richness, abundance, and biomass and winter most often the low. The rich, complex, productive communities are to be found in rock and protected soft-

sediments sites. These communities were the least variable over time and are the most vulnerable to long term damage form an oil spill.

123. Nysewander, D. R. and J. R. Evenson. Status and trends for selected diving duck specis examined by the marine bird component, Puget Sound Ambient Monitoring Program (PSAMP), Wahsington Department of Fish and Wildlife. Puget Sound Research '98; 1998 Mar 12-1998 Mar 13; Seattle, WA.

Keywords: birds//Puget Sound

Abstract: This paper reports on the PSAMP Monitoring Management Committee efforts to monitor the abundance of selected bird species to identify any significant changes or trends that may be related to pollution, habitat loss, or disturbance and monitor reproductive success and contaminant levels in birds. Certain species were selected for emphasis in monitoring using criteria related to usage of or dependence upon marine waters of Puget Sound, to peaks of abundance during survey periods, and to other concerns due to limited numbers or special vulnerability to human-caused mortality. Changes observed included the following: increased bird numbers in summer (63,187-105,094) over winter (131,674-273,712); a larger number of birds using southern Puget Sound during winter than summer; increased waterfowl usage in winter along shorelines, with some estuaries (including Skagit, Padilla Bay) containing large numbers of waterfowl and geese, and winter migration of grebes and loons into the Sound to use protected waters (deeper with relatively low currents) in all of Puget Sound (excluding the Strait of Juan de Fuca and portions of the San Juan Islands).

Conclusions and Concerns: Significant declines are being recorded in portions of the Pacific flyway for at least two commonly found Puget Sound diving ducks - the scoters and scaup. The rate of decline in wintering areas for declining diving ducks in Puget Sound is equal to or greater than that recorded in Alaska breeding grounds. Since 1978, there has been a significant decline in wintering scoters. Bufflehead and goldeneyes have shown a stable or slight increase in winter use of Puget Sound. Scoter decline is similar to herring spawner declines.This would be expected due to their historic reliance on forage fish spawning occurrences. Scoters and scaup were noted to use marine habitats in Puget Sound with different duck species overlapping in usage of nearshore marine habitats and different species varying with prey types, foraging style, and the portion of nearshore habitat used.

Scoters accumulate contaminants during their wintering stay. It is unknown what level of contamination will cause deleterious population effects. Scoters are environmental indicators to evaluate the health of Puget Sound. due to their widespread occurrence and consumption of shellfish and forage fish eggs. Harlequin ducks also rely on forage fish roe. The same food chains that support these migratory bird populations also sustain both anadromous and non-anadromous fish.

124. Nysewander, David R. Overview of the Marine Bird, Waterfowl, and Marine Mammal Monitoring Task within the Puget Sound Ambient Monitoring Project, July 1992 to March 1994. Puget Sound Research '95; 1995 Jan 12-1995 Jan 14; Bellevue, WA. Olympia, WA: PSWQA; 1995.

Keywords: marine birds//marine mammals//northwest straits//Puget Sound//straits

Abstract: This overview reports on the Puget Sound Ambient Monitoring Program (PSAMP) monitoring of bird resources in 1988. The PSAMP monitoring committee set out to monitor the abundance of selected bird species for identification of significant changes or trends potentially related to pollution, habitat loss, or disturbance. It also set out to monitor reproductive success and contaminant levels in birds. The marine mammal component was intended to provide consistent Puget Sound marine mammal population estimates and add to the body of knowledge about the effects of contaminants on marine mammals. Surveys include shorebirds, gray whales, marbled murrelets, and harbor seals.

125. Osmek, S. J. Calmabokidis and J. L. Laake. Abundance and distribution of porpoise and other marine mammals of the inside waters of Washington and British Columbia. Puget Sound Research '98; 1998 Mar 12-1998 Mar 13; Seattle, WA. 1998.

Keywords: marine mammals//straits

Abstract: This paper reports the preliminary results of aerial survey for marine mammals in the inside waters of Washington and British Columbia. Objectives: estimate abundance of harbor porpoise and Dall's porpoise; examine geographic distribution of above species and harbor seals. Results: three most common species are harbor seals, harbor porpoise, and Dall's porpoise. killer, gray and minke whales, steller sea lions, Calif. sea lions, and sea otters were also observed. Only harbor seals and harbor porpoises were seen in Strait of Georgia. The lack of marine mammal sightings in the Strait of Georgea was surprising. This is thought to be related to animals leaving or avoiding the region. The lack of Dall's porpoise in Strait of Georgia is historically consistent.

126. Pacunski, Robert E. and W. A. Palsson. The distribution and abundance of nearshore rocky-reef habitats and fishes in Puget Sound. Puget Sound Research '98.

Keywords: fish//rockfish//Puget Sound//lingcod

Abstract: Rockfishes (*Sebastes* spp.), lingcod (*Ophiodon elongatus*), and kelp greenling (*Hexagrammos decagrammus*) are the most popular bottomfish species targeted by recreational anglers in Puget Sound. In nearshore waters, these species typically inhabit rocky and irregular bottoms, including natural reefs, artificial reefs, shipwrecks, jetties and breakwaters. A large proportion of the recreational bottomfish effort in Puget Sound occurs in the nearshore environment. Thus, in order to provide adequate protection and management for the species and their habitats, it is critical that fishery managers know how much rocky-reef habitat exists and to what extent these areas are utilized.

Since 9193, the Washington Department of Fish and Wildlife (WDFW) has used a video-acoustic technique (VAT) to conduct in-situ fish population surveys throughout the inland marine waters of the Washington. The primary objective of the VAT surveys is to provide regional estimates of nearshore rocky-reef fish populations. By using an underwater video camera, it is possible to characterize the habitat observed at each survey station. Thus, a secondary objective of the VAT surveys is to quantify the type and amount of the various habitats encountered. Using geographic information systems (GIS) software, the habitat data collected during these surveys will be used to produce maps of the nearshore rocky-reef habitats within Puget Sound. This habitat data will serve as the basis for future fish population surveys and habitat assessment studies. By identifying the rocky-reef habitats and major concentrations of rocky-reef fishes, smaller scale surveys will be signed to provide more accurate population assessments and produce more detailed maps of individual rocky reefs in Puget Sound.

127. Palsson, W. A. and R. E. Pacunksi. The response of rocky reef fishes to harvest refugia in Puget Sound. Puget Sound Research '95Olympia, WA. Puget Sound Water Quality Authority. 1995: pp224-234.

Keywords: rockfish//rocky reef fish//refugia//Puget Sound//fish//fish distribution//harvest//fish harvest

Abstract: This paper discusses the effects of harvest refugia at several sites in the San Juans and Puget Sound region. It was found that the site protected from harvest for 24 years showed a dramatic difference in its abundance of large copper and quillback rockfish and lingcod compared to harvested areas. At the Edmonds refuge, copper rockfish density was 6 times greater and lingcod density was twice as great as fished sites. This response to refugia is consistent with other findings around the world. Refuge fish and shellfish are often in 2 to 25 times greater abundance than fished sites. Size increases are also commonly found in refugia areas even after only a few years. It was also noted that fishing in areas adjacent to refugia may increase catch rates with Puget Sound anglers benefiting from a system of harvest refugia.

128. Palsson, Wayne. Management of recreational bottomfish. Washington: WDFW; 1999; Segment 7, State Project-568109,568119 & E94230.

Keywords: fish//bottomfish//cod//lingcod//pollock//halibut

Abstract: In February 1999, NMFS received a petition to consider 17 species of marine fishes in Puget Sound as threatened or endangered under the provisions of the ESA. The species include Pacific cod, walleye pollock, Pacific whiting, Pacific herring, and copper, quillback, and brown rockfishes. Most of these species are targeted in recreational fisheries in Puget Sound, and the petitioner used much of the information developed under preivous Sportfish Restoration segments of this project. The WDFW, to the best of its ability, is taking measures to avert the siting of any species and to provide for the conservation of the species in question. The Puget Sound Groundfish Management Plan, developed in part under previous Sportfish Restoration activities, provides the framework to achieve precautionary and effective management. As such, during the present segment activities, a draft Conservation Plan was developed focused on conservative harvest strategies and a system of no-harvest refuges as the means to achieve conservation. In addition, staff developed and recommended a new daily bag limit for rockfish (one fish per day) that will begin to provide stock rebuilding for these sensitive species. Staff also consulted on other sportfish management proposals including an equitable adjustment of the lingcod fishery and removing an aggregate bag limit for bottomfish.

Catch and effort estimates were generated for bottomfish harvested in recreational fisheries in Puget Sound during 1997 and a detailed analysis of recreational bottomfish estimates was undertaken. The analysis revealed that wide disparities in catch and effort estimates occurred among state and federal creel surveys. State estimates were consistently lower than the federal Marine Recreational Fisheries Statistical Survey (MRFSS) and halibut catch estimates were far lower than the MRFSS. At present, the reliability of any survey cannot be substantiated, and the inability of state estimation system to provide an estimation framework during extensive salmon fishery closures leaves bottomfish biologist wanting for reliable recreational estimates for management.

129. Palsson, Wayne A. 1984.Egg mortality upon natural and artificial substrata within Washington State spawning grounds of Pacific herring (*Cupea harengus pallasi*). University of Washington. M. Sc. Thesis.

Keywords: herring//herring reproduction//egg mortality//spawning//herring spawning

Abstract: This thesis reports on the fate of herring eggs spawned in Quartermaster Harbor and Birch Bay using SCUBA techniques. Egg mortality causes were assessed. Six artificial spawning and natural substrata were compared for effectiveness.

130. --. Management of rocky reef fishes with no-take refuges. 1998(Annual Job Performance Report on Management of Recreational Bottomfishes in Puget

Sound; Segment 6 State Project-568108 & 568118).

Keywords: rockfish//bottomfish//groundfish//Puget Sound

Abstract: Rockfish and lingcod populations are in poor condition in many areas of Puget Sound. A system of no-take refuges is proposed to achieve long-term sustainable populations and fisheries. A preliminary plan suggests goals, objectives, and approaches to implement a refuge system. Project work was completed monitoring refuges in central Puget Sound and in the San Juan Islands. Future monitoring includes surveying a new Conservation Area at a former fished study site.

131. --. Pacific cod (*Gadus macrocephalus*) in Puget Sound and adjacent water: biology and stock assessment. Olympia, WA: Washington State Dept. of Fisheries. 1990.

Keywords: Pacific cod//cod//Puget Sound//straits//biology//stocks//Port Townsend

Abstract: A stock assessment of Pacific cod was undertaken for Puget Sound. The biology of Pacific cod was reviewed to provide insights into stock structure and population dynamics. Tagging data for Puget Sound revealed that three stocks exist: a stock in the Gulf-Bellingham and San Juan Island Regions, a stock in the Strait of Juan de Fuca and Port Townsend Bay, and a stock south of Admiralty Inlet.

Catch data showed periods of high catches alternating with periods of low catches. Six of these cycles were observed since 1942 with a peak catch of 3.5 million pounds in 1980. Catches in recent years have been below the last ten-year average of 2.5 million pounds per year. Catch patterns differed among regions. The Gulf-Bellingham Management Region typically produced over half of the catch of Pacific cod during a year.

Catch rates form trawl and recreational fisheries were used as an index of abundance to assess stock condition. Catch rates in most regions and fisheries were lower in the 1980s than in the 1970s, but catch rates have been stable until 1990 in the Gulf-Bellingham Region. Catch rates for fisheries in the eastern portion of the western stock have declined, especially for the Port Townsend area. Recreational catch rates for the southern stock were higher during some years in the late 1970s and early 1980s than during recent years. The causes of the decreased catch rates are not clear. Lower catch rates corresponded to a change in oceanographic conditions but also follow a period of increased fishing effort and harvest and increased marine mammal abundance.

132. --. Stock Assessment of Recreational Bottomfish. 1998; Segment 6, State Project-568108 &568118.

Keywords: fish//rockfish//lingcod//flatfish//Puget Sound//straits

Abstract: The 1997 recreational catch rates from the Washington Department of Fish and Wildlife (WEFW) creel survey were estimated for rockfish, flatfish, and lingcod. Updated stock assessments reveal depressed rockfish populations in South Sound, depressed lingcod populations in North Sound, below average populations for rockfish in North Sound and above average lingcod populations in South Sound. A more detailed assessment was conducted for rockfish based upon indices of spawning. The declining catch rates combined with decreasing size composition over time resulted in depressed copper and quillback rockfish populations in North and South Sound. Further work is being developed to model lingcod and rockfish populations in Puget Sound. Surveys for Pacific cod revealed continued absence of spawning adults at their spawning grounds in central Puget Sound. However, high abundances of young-of-the-year cod were observed in the San Juan Islands during August 1998.

133. ---. Strategies for Developing and Applying Marine Protected Area Science in Puget Sound/Georgia Basin; 1999 May 17-1999 May 18; Bellingham, WA. Puget Sound/goergia Basin International Task Force.

Keywords: Puget Sound//MPA//marine protected areas//straits//fish

Abstract: This paper reviews potential threats to Puget Sound fish communities that can likley be reduced by MPAs. Habitat alteration, particularly bulkheading and pier construction can dramatically alter habitat and exclude fishes or alter beach characteristics thereby disrupting nearshore habitats and inhabitants. Such activities include scientific or education collection, harvest of non-traditional invertebrates and intertidal fish, targeted fisheries upon intertidal vegetated habitats, shading caused by pier and dock construction, and disruption from vessel prop wash can cause a loss of eelgrass beds and disrupt the nearshore food web. Anchorages, fishing on rocky reefs, divers disturbing reproduction and egg guarding, mobile fishing gear, and dredges can cause significant disruption to food web and reproductive processes. MPAs can reduce human disturbance due to boating and fishing activities that disrupt schooling and feeding. Rocky reef fishes in Puget Sound have responded to no-take refuges with increased density, size and reproduction. Full MPA system design requires monitoring and evaluation to test if system goals and objectives are being achieved. Regional basin fish population surveys, catch and fishery monitoring, marking and tagging experiments, age-structured models, and habitat and ecosystem research are needed to answer questions on the effects and benefits of MPAs. Without testing and evaluation, MPA implementation could pose as great a risk to marine fish as continuing with the status quo. Design and siting may not match resource needs, testing and evaluation will be required to understand the resource response to the MPA and accurately predict resource responses in order to reach MPA

objectives.

134. Palsson, Wayne A. J. C. Hoeman G. G. Bargmann D. E. Day. 1995 Status of Puget Sound Bottomfish Stocks. Washington Department of Fish and Wildlife, Fish Management Program, Marine Resource Division.

Keywords: sole//cod//Pacific cod//hake//pollock//rockfish//perch//halibut//bottomfish//Puget Sound//straits//Washington//fish//fish status//groundfish

Abstract: Stock assessments were conducted for thirty-six bottomfish stocks in Puget Sound. Catch, effort, and survey data were assembled for North and South Sound regions for each of 18 species or species complexes. Only 28 stocks had sufficient information to determine stock status and recent trend. The majority of these stocks were in below average, depressed or critical abundance conditions. Thirteen of the 28 stocks were in decline while eight were increasing. North Sound had more stocks at average or above average conditions than South Sound., where eight of eleven stocks were at below average or critical conditions. South Sound had seven stocks which lacked recent information to assess stock status.

Spiny dogfish, skates and ratfish appeared to be in satisfactory condition. In contrast, virtually all of the codfish stocks (Pacific cod, walleye pollock, and Pacific whiting) were in depressed or critical conditions or were in decline. Rockfishes and lingcod, species living in association with rocky reefs, showed mixed patterns of stock condition. Lingcod were declining in North and South Sound, and populations were depressed in North Sound but were at average levels in South Sound. Rockfish populations showed no trend in either area and were at average levels in North Sound and at below average conditions in South Sound. English sole and starry flounder, key flatfish stocks in North Sound, were increasing in abundance but the fisheries remove a substantial proportion of the adult population which are over-utilized. In South Sound, the lack of recent fisheries precluded the determination of stock condition, but trawl survey data suggested the stocks are under-utilized. A variety of species including greenlings, sculpins, and sablefish had very poor information to assess stock condition.

135. Palsson, Wayne A. T. J. Northup and M. W. Barker. Puget Sound Groundfish Management Plan (revised). Washington Department of Fish and Wildlife, Fish Program, Marine Resources Division; 1998 Dec.

Keywords: groundfish//bottomfish//fish//rockfish//pollock//halibut//lingcod//cod

Abstract: This report describes the policy, goals objectives for managing Puget Sound groundfish resources. It identifies the resource species, discusses

commercial, recreational, and tribal fisheries, discusses bycatch management, uses of groundfish, possible listing of groundfish as endangered, discusses artificial reefs and presents licensing, allocation, transboundary, ecosystem management, and marine mammal interaction issues.

136. Parametrix, Inc. Stage I Technical Assessment, Water Resource Inventory Area 17; 2000. Draft.

Keywords: watersheds//salmon//water quality//habitat

Abstract: Presents comprehensive data on all watersheds in Water Resource Inventory 17 (WRIA 17) including fish species, habitat issues, water quality and quantity. The most comprehensive watershed analysis undertaken for Jefferson County to date. Presents existing surface water quality data, pollutant sources, groundwater quality data, water allocation and use data and issues, groundwater recharge, hydraulic continuity, water budget, habitat and stock assessments, instream flow, restoration projects overview, land use impacts, and identifies data quality, gaps and limitations.

137. Parrish, J. K. Do predators "shape" fish schools: Interactions between predators and their schooling prey. Neth Zool. 1992; 42(2-3):358-370.

Keywords: marine birds//fish

Abstract: Membership in a stable aggregation may afford the individual with a reduction in the probability of being successfully attacked, when compared with isolated individuals. This mitigation of predation accrues passively through the effects of dilution and confusion, and actively through the differential value of spatial position and the evolution of group avoidance maneuvers. The relative safety of a given spatial position can change drastically, depending on attack strategy. Aquatic vertebrate predators (fish, birds, and marine mammals) display a wide variety of strategies when attacking schooling prey, ranging from marginal and invasive to exploitative. Evolution of avoidance maneuvers by the school is dependent on the individual correctly assessing the potential for danger and responding in a timely, coordinated fashion. Whether safety accrues differentially among school members or between school members and isolates, depends upon the size and shape of the school, the individual member's behaviour, the "behaviour" of the group, and, most importantly, the relative frequency and abundance of each predator type.

138. ---. The influence of colony size and habitat quality on reproductive success in Common Murres (*Uria aalge*). Auk. 1995; 112:390-401.

Keywords: birds***//***marine birds//murres//straits//puget sound

Abstract: On Tatoosh Island, off the Olympic Peninsula in Washington, Common Murres (*Uria aalge*) nest either in small subcolonies located in crevices in

vertical, rocky cliff walls, or in large subcolonies located on the island top, usually at cliff's edge. Nesting murres are subject to predatory pressure form Glaucous-winged Gulls (*Larus glaucescens)* and Northwestern Crows (*Corvus caurinus*), which are resident egg predators, as well as from Peregrine Falcons (*Falco peregrinus*) and Bald Eagles (*Haliaeetus leucocephals)*, which are transient predators on adults. Although subcolony size dilutes the effects of egg predators, the presence of raptors in the system negates this simple effect of dilution. Relative to conspecifics in crevice subcolonies, murres in cliff-top subcolonies are more likely to be attacked by raptors as well as to temporarily evacuate the subcolony in response to the presence of raptors. During subcolony evacuations, egg predators gain unhindered access to abandoned eggs. As a result, murres nesting in cliff-top subcolonies experience both delays in phenology and lowered reproductive success relative to murres nesting in crevice subcolonies. Despite continued raptor-facilitated egg predation, the majority of the murre population nests in cliff-top subcolonies, which are less than 20 years old and are growing rapidly. This suggests that new colonists are constrained by a lack of accurate information into making incorrect decisions about which subcolonies to join.

139. Parrish, J. K. and P. D. Boersma. Muddy Waters: seabird mortality following the Exxon Valdez oil spil. Am. Sci. 1995. 83:112-115.

Keywords: marine birds//oil spill

Abstract: This paper reviews the estimates of seabird mortalities attributed to the Exxon Valez oil spill. It presents a much smaller number, 30,000, murres killed by the spill rather than 350,000 to 500,000 as claimed in previous statements. It does not support the notion that the spill caused devastation or extinction.

140. Parrish, R. Symp. of the CalCOFI Conference: A Continuing Dialog on No-take Reserves for Resource Management. Asilomar, CA. 1998 Nov 4: pp. 77-86. v. Reports of California Cooperative Oceanic Fisheries Investigations 1999).

Keywords: fish//MPA//marine protected areas

Abstract: Marine reserves have recently become a politically correct way of viewing the management of marine resources. Much of the reason for this is due to the depressed state of many of the populations that have been the mainstay of both commercial and recreational marine fisheries. The apparent failure of past management has led to a headlong rush for a paradigm shift. Marine reserves that occupy no more than about 5% of the productive habitat can provide sites for research, for monitoring natural variability, and for preserving habitat and diversity for heritage purposes. But the case for large marine reserves for fisheries management purposes has not yet been adequately made. The few available modeling studies suggest that for fisheries management purposes, marine reserves need to be on the order of 50% of the productive habitat.

Analyses presented here suggest that, with reserves this large, current yields can be obtained only with a considerable increase in total fishing effort and a very large increase in the mortality rates in areas open to fishing. This implies a large increase in the trawling rate, and probably associated ecological damage, in the exploited area. Even if it were desirable to manage an individual species with large marine reserves, the concept breaks down when applied to the West Coast trawl fishery, which is based on many species, each with a different habitat. A marine reserve established for overexploited groundfish provides little real protection for migratory species such as Pacific hake, but may greatly increase the cost of fishing for these species.

141. Patten, B. G. Biological information on copper rockfish in Puget Sound, Washington. Trans. Am. Fish Soc. 1973. 102:412-416.

Keywords: fish//rockfish//Puget Sound

Abstract: This paper reports on a SCUBA study conducted at Zenith and Alki Point investigating growth parameters, age at maturity, food habits and the ecology of copper rockfish (*Sebastes caurinus*). No differences was found in growth between the sexes. Fish were found to mature at age four and they were found to primarily feed upon crustaceans and fish.

142. Pedersen, M. Activity profile of the Puget Sound groundfish fleet. 1984; Wash. State Prog. Rep. 220.

Keywords: fish//groundfish//bottomfish//Puget Sound//commercial harvest//commercial fishery

Abstract: Since the mid-1970's there has been a large increase in the number of licenses for the commercial fisheries for groundfish in WA inside waters (those waters east of the Sekiu River). Production by all commercial gears increased as well, and since 1978, it has averaged over 20 million pounds annually. Several key stocks are at or near full exploitation (Pacific whiting, Eng. Sole, starry flounder, lingcod, and rockfishes) and several other stocks cannot support any substantial increase in harvest. The purpose of this report is to provide an activity profile of the commercial groundfish fleet in terms of licenses issued, vessels actively fishing, and the distribution of catch among vessels of each gear type. This information is used in discussions of fleet harvest capacity and related to the potential production from stocks of key species.

143. Penttila, D. Documented Spawning Areas of the Pacific Herring (clupea), Surf Smelt (hypomesus)and Pacific Sand Lance (ammodytes) in Eastern Jefferson County. La Conner, WA: Washington Department of Fish and Wildlife; 2000 Jan.

Keywords: Puget Sound//straits//Discovery Bay//herring//surf smelt//smelt//fish//sand lance//fish//spawning//forage fish//Jefferson County

Abstract: This report identifies and maps out herring stock and spawning ground areas, surf smelt and sand lance spawning beaches in Jefferson County based on WDFW sampling during the 1995-1999 period. These areas include Discovery Bay, Kilisut Harbor, Port Gamble, Quilcene Bay, Port Townsend Bay, Port Ludlow Bay, Bywater Bay, Dabob Bay, and the Pt Whitney area.

144 Penttila, D. and D. Day. Baitfish management ctivities in Washington State form July 1, 1974 to December 31, 1975.: Wash. Dept. Fish.; 1976; Prog. Rep. No. 76-02.

Keywords: fish//forage fish//puget sound

Abstract: This report presents acoustic, spawning grund, larval and juvenile results of surveys for Pacific herring, surf smelt, and sand lance in central and southern Puget Sound. It also reports on herring spawnoing on ariticial substrata at the Brownsville Marina.

145. Penttila, D. and D. Doty. Results of 1989 eelgrass shading studies in Puget Sound. Washington Department of Fisheries, Marine Fish Habitat Investigations Division. 1990.

Keywords: eelgrass//Puget Sound//shading//nearshore habitat

Abstract: STUDY OBJECTIVES: Mitigation/Impact Assessment. Determine effects of direct shading on marine vegetation community, in particular beds of eelgrass. METHODS: quadrat, diver eelgrass surveys. Three Puget Sound study sites with littoral zone structures were selected on the basis of the presence of homogenous eelgrass, homogenous bottom topography and bottom topography unaffected by the construction or long term presence of the structure itself. The sites were surveyed for assessment of plant stature and counts per area during July-September 1989. A qualitatively different fourth site was also sampled at an intertidal eelgrass bed near an "oyster rack" culture structure. FINDINGS: All fixed dock structures reduced eelgrass density to zero even when visual light attenuation did not approach full darkness with little or no evidence of impacts on the stature of the surviving plants. The oyster rack site also significantly reduced eelgrass density from 244.5 plants per m 2 to 10.6 plants per m 2 directly beneath racks. In contrast, the floating dock site with the chained-anchor moorage system that allowed a swing with wind and tidal currents showed no negative impacts on the density of the eelgrass in the structure's vicinity. This may be due to the flexible nature and movement of the dock and the resulting lack of shading cast continuously over any given bottom area. CONCLUSIONS: The authors concluded that construction of partially shading types of structures, floating or on pilings, can be expected to largely eliminate the existing macroflora

with little chance for replacement plant growth on new introduced solid structures. Algae species also appear to be impacted by shading structures. Other impacts they would expect over time include: altered sediment distribution and topography along piling lines, tidal drainage streams created by topographic changes, and substrates in the immediate vicinity of piling structures to be enriched with calcareous debris from barnacles and mollusks inhabiting the structures hard surfaces.

146. Penttila, Dan. Studies of the surf smelt (*hypomesus pretiousus*) in Puget Sound. Olympia, WA: Washington State Department of Fisheries; 1978.

Keywords: smelt//fish//surf smelt//Puget Sound//fish//forage fish

Abstract: The purpose of this study was to determine the current status of known surf smelt-spawning beaches in Puget Sound. Objectives included collecting data on time and age of spawning, intensity of egg deposition, egg development, mortality, and dispersion. Physical environmental factors, such as spawning depth, substrate composition, temperature regimes, and preferred range of tidal elevation during spawning, were also investigated. Field observations resulted in supplementary bulkhead and landfill construction criteria.

147. Penttila, Daniel E. Impacts of overhanging shading vegetation on egg survival for summer-spawning surf smelt, hypomesus, on upper intertidal beaches in northern Puget Sound Wa. La Conner, WA: WDFW, Marine Resources Division; 2000 Mar; Draft.

Keywords: marine riparian vegetation//riparian//riparian vegetation//surf smelt//smelt//spawning//spawning beaches//Puget Sound

This study investigates the potential habitat quality element of shade by overhanging trees and other vegetation on upper intertidal surf smelt spawning beaches suggested by previous Puget Sound surf smelt studies describing sun-exposed spawn as "dried to a crisp" in exposed worse-case conditions during hot summer months. This report summarizes preliminary data comparing *in situ* incubating surf smelt mortalities found in coupled pairs of adjacent shaded and sun-exposed spawning sites in northern Puget Sound in the summers of 1990-1998.

The data indicated a very significant difference between the shaded and unshaded mortality data supporting the notion that overhanging shade positively impacts surf smelt survival during summer months in the Puget Sound basin by lowering ambient temperatures on a micro-habitat scale.

148. Phillips, R. C. Ecological life history of *Zoster marina L*. in Puget Sound Wahsington [PhD. Dissertation]. Seattle, WA. University of Washington. 1972.

Keywords: eelgrass//Puget Sound//nearshore//vegetation/

Abstract: This thesis presents observaitons and experimental results concerning the ecology of eelgrass and the flora and fauna supported by eelgrass in the Puget Sound region.

149. --The ecology of eelgrass meadows in the Pacific Northwest: a community profile. USFWS; 1984; FWS/OBS-84/24.

Keywords: eelgrass//Puget Sound//nearshore//vegetation/

An extensive community profile and literature review providing a general description of the ecology and function of Pacific Northwest eelgrass systems. The literature cited is extensive and provides a listing of studies that examine the fish and invertebrates associated with these systems.

150. Piatt -J.F., Lensink C. J. Butler W. Kendziorek M. and Nysewander D. R. Immediate impact of the Exxon Valdez oil spill on marine birds. 1990. vol. 107. vol. 107.

Keywords: birds//oil spill

Abstract: On 24 March 1989, the oil tanker "Exxon Valdez" spilled 260,000 barrels of crude oil in Prince William Sound, Alaska. Oil eventually drifted over 30,000 km super(2) of coastal and offshore water occupied by approximately one million marine birds. More than 30,000 dead birds of 90 species were retrieved from polluted areas by 1 August 1989. Of those identified, murres (74%), other alcids (7.0%), and sea ducks (5.3%) suffered the highest mortality from oil, and most (88%) birds were killed outside of Prince William Sound. A colony of 129,000 murres at the Barren Island was probably devastated. Another 7,000 birds were retrieved between 1 August and 13 October, but most of those birds appeared to have died from natural causes. This later die-off was composed largely of shearwaters and other procellariids (51%), gulls (22%), and puffins (14%). Based on aerial and ship-based surveys for populations at risk, and extrapolating from the number of dead birds recovered, we estimate that the total kill from oil pollution was from 100,000 to 300,000 birds.

151. Povey, Anna and M. J. Keough. Effects of trampling on plant and animal populations on rocky shores. Oikos. 61:355-268.

Keywords: rocky shores//human impacts//nearshore//shorelines

Abstract: We examined experimentally the effects of disturbances caused by pedestrian traffic on the animals and plants living on an intertidal rocky shore in south-eastern Australia. Individual footsteps damaged some animals, but the percentage of animals that was crushed was low, Molluscs, except large limpets, were more often dislodged than crushed, and some damage was sustained by barnacles and mussels. The survival of individuals of two gastropod species, *Bembicium nanum* and *Austrocochlea constricta*, was not affected by dislodgement, because they quickly righted themselves. The limpet *Cellana tramoserica* was not damaged by being kicked on stepped on. The dominant plant on these shores, the brown alga *Hormosira banksii*, was easily damaged, with 20% of the biomass of individual plants being removed by a single footstep. The amount of tissue lost increased with the number of footsteps, with a maximum loss of approximately 75%. We investigated the effects of three levels of sustained trampling (33 d of trampling, spread over 4 mo) on the organisms in three habitats: *Hormosira* Mats, *Coralline* Algae Mats, and Bare Rock. The algal mats were most affected by trampling. *Hormosira* Mats were damaged severely by high- and low-intensity trampling. Upright C*oralline* algae located in the *Coralline* Algal Mats were damaged by high-intensity trampling. Numbers of the gastropod *Turbo undulatus* in both of these habitats were reduced. The Bare Rock habitat was not affected significantly by trampling. Even after > 400 d of recovery, *Hormosira* cover was only 60%, three quarters of the value of control areas. The indirect effect of increased mollusc abundance was still apparent. Trampling by visitors could result in replacement of the *Hormosira* mat species assemblage with "bare" rock and grazing molluscs, and trampling should be considered as a disturbance capable of directly and indirectly influencing intertidal populations on rocky shores.

152. Puget Sound Water Quality Action Team. 1998 Puget Sound Update. Olympia, WA: Puget Sound Water Quality Action Team. 1998 Feb.

Keywords: Puget Sound//monitoring//straits//water quality//ecosystem//contaminants//PSAMP//sediments//nearshore habitats//nearshore

Abstract: Sixth report of the Puget sound Ambient Monitoring Program: Recent findings about the health of Puget Sound indicate that, although some aspects of the Sound's environmental health may be improving, its ecosystem and biological resources continue to suffer damaging effects resulting form the actions and by-products of our society.

Improvements documented over the past several years include steady or increasing populations of some organisms in Puget Sound and decreases in some types of contamination in some areas of Puget Sound. Evidence of continued problems, including the poor or declining condition of a wide variety of marine organisms in Puget Sound, tempers these observations. The continuing problems may be related, at least in part, to changes our society has made to the

physical environment and to contamination of the environment by toxic chemicals, fecal bacteria and excess nutrients.

This is the sixth Puget Sound Update, a report for residents of the region about the overall health of Puget Sound. The conclusions in the Update are based mainly on scientific results of the Puget Sound Ambient Monitoring Program (PSAMP). This report looks beyond the PSAMP as well, including monitoring data from other important efforts to evaluate Puget Sound's waters, sediments, nearshore habitats and biological resources. Information generally reflects conditions through 1995, though in some cases only older data were available and in other cases results were able to access data through 1995 and 1997.

153. Puget Sound Water Quality Action Team. 2000. 2000 Puget Sound Update: Seventh Report of the Puget Sound Ambient Monitoring Program. Olympia, WA: Puget Sound Water Quality Action Team.

Keywords: salmon//fish//contaminants//Puget Sound

Abstract: This update presents the findings of the Puget Sound Ambient Monitoring Program (PSAMP), a long term effort to investigate environmental trends and improve decision-making and monitoring. It reports well-documented environmental degradation in Puget sound with degradation signs reflected in a variety of organisms appearing to be in poor condition with declining numbers. Signs of degradation include increased levels of fecal contamination in shellfish growing areas near increasing residential and commercial land development and increased incidence of liver lesions in Eng. sole possibly reflecting increased levels of such contaminants as PAHs from highly developed urban and industrial areas. Many species relying on Puget Sound are in decline, including Pacific herring, rockfish, coho salmon, scoters grebes, great blue herons and orca whales. Species numbers and diversity has been declining suggesting widespread habitat loss or degradation, harvest pressure impacts to the food web and natural variations in marine productivity. Increased scientific assessment is needed to understand causes and implications of these declines.

154. Rash, J. A. Marine mammal sightings and standings in Puget Sound from 1980 to 1994: Who, what, when, where and why. Puget Sound Research '95; 1995 Jan 13-1995 Jan 14; Bellevue, WA. Olympia, WA: PSWAQ; 1995: pp. 623-629.

Keywords: marine mammals//Puget Sound

Abstract: This paper reports on pinniped deaths over the last 18 years responded to by the Marine Animal Resource Center (MARC). These pinnipeds were: Pacific harbor seal, California sea lion, northern fur seal, northern elephant seal, and steller sea lion. The harbor seal is the most abundant marine mammal

in Puget Sound and is therefore the seal to receive the most calls on. The majority of calls concerning harbor seal pups occur between April and October during birthing period. Many Calif. sea lions have died as a result of gunshot wounds. On the Washington coast, a chemical spill caused the death of 40 northern fur seals due to chemical exposure. Northern elephant seals were found during molting. The most significant event for the steller sea lion (now on the endangered species list was the finding of 32 animals along Washington coast dead form gunshot wounds. Sightings and deaths are increasing. Results of herpes virus, distemper, and toxicological problems in gray whales, and with a disturbing trend of shootings of harbor seal pups and yearlings was documented.

155. Raum-Suryan, K. L. and Harvey J. T. Distribution and abundance of and habitat use by harbor porpoise, *Phocoena phocoena*, off the northern San Juan Islands, Washington. Fishery-Bulletin. 1998. vol. 96(no. 4):pp. 808-822.

Keywords: marine mammals//porpoises//straits

Abstract: Boat surveys along randomly placed line transects were conducted from June to August 1991 and June to October 1992 to determine distribution and abundance of and habitat use by harbor porpoises (*Phocoena phocoena*) off the northern San Juan Islands, Washington. There were 301 sightings (average 4.4 sightings/h) of 526 harbor porpoise during 73 random boat surveys, with group sizes of 1 to 8 individuals (mean=1.87, SE=0.06, n=278). An estimated 299 harbor porpoise (1.26 porpoise/km super(2), SE=0.20) were distributed in an aggregated pattern within a 237 km super(2) area (10% of Washington Sound), indicating that a large proportion (30%) of harbor porpoise in Washington Sound occur in the northern San Juan Islands. Harbor porpoise were distributed over a depth range from 20.1 to 235.0 m (mean=141.6 m, SE=2.43, n=275) and were observed more than expected (P<0.05) in depths greater than 125 m and over shallow slopes (<10%) and observed less than expected (P<0.05) in depths less than 75 m. Porpoise occurred at sea surface temperatures of 10.1 degree to 16.3 degree C and were sighted more frequently than expected (P<0.05) in water temperatures of 11 degree to 12 degree C. Boat surveys along fixed location transects indicated distribution was similar between 1991 and 1992. The occurrence of harbor porpoise in deep water, at cooler sea surface temperatures, over shallow sloping seafloor, and in tidally mixed regions (owing to currents and tide rips) within our study area may, collectively, affect prey distribution and associated harbor porpoise distribution.

156. Richards, L. J. Copper rockfish (*sebastes caurinus*) and quillback rockfish (*Sebastes maliger*) habitat in the Strait of Georgia, British Columbia. Can. J. Zool. 65:3188-3191.

Keywords: straits//rockfish//fish//bottomfish//groundfish

Abstracts: Densities of copper rockfish (*Seabstes caurinus*) and quillback rockfish (Sebastes maliger) differ significantly among sites in the northern Strait of Georgia. To determine whether among-site density differences are associated with habitat characteristics of the sites, rockfish densities and habitat characteristics were measured at 12 sites during SCUBA surveys in 1984 and 1985. Quillback rockfish densities were greater in areas of high relief, broken rock, and high percentage cover of flat-bladed kelp, especially on deep transects. Copper rockfish densities were also greater in high relief areas, but effects of other habitat characteristics were not significant. Copper rockfish appeared to be more widely distributed than quillback rockfish over the range of habitats and depths surveyed.

157. ---. Depth and distributions of three species of rockfish (*Sebastes*) in British Columbia: observations from the submersible PSCES IV. Env. Biol. Fish. 1986; 17(1):13-21.

Keywords: fish//rockfish//straits

Abstract: Observations on habitat requirements of three juvenile rockfish species were made from a submersible at depths >20m. The author notes that two species (*S. maliger and S. ruberrimus*) were strongly associated with more complex rock habitats but were segregated by depth while the other (*S. elongatus*) was more commonly associated with mud/cobble areas. Sizes of the three species increased with depth.

158. Ritter, Rebecca and E. L. Lanzer. Remote Sensing of Nearshore Vegetation in Washington State's Puget Sound. In: Proceedings of 1997 Geospatial Conference, Seattle, WA, Olympia, WA: Department of Natural Resources (DNR); 1997: pp. 527.

Keywords: nearshore//nearshore habitats

Abstract: The Washington State Department of Natural Resources, in cooperation with other state and federal agencies, has developed a program to remotely sense nearshore vegetation (intertidal and shallow subtidal). The classified nearshore data are integrated into an existing geographic information system for spatial analysis to support aquatic land use planning and management decisions. In 1996, a data set for the greater Bellingham Bay area in Northern Puget Sound was completed. Program methods incorporate advances in remote sensing technologies to overcome the constraints of the target geography, which prevent the use of more traditional inventory methods. The multispectral image data were collected by a Compact Airborne Spectrographic Imager (CASI) sensor, configured to collect 11 bands of data (from the visible to the near infrared range) with square, four meter pixels. Color infrared (CIR) photography was acquired simultaneously from the same aerial

platform. Marine scientists collected field data located by a differential Global Positioning System (DGPS) or annotated aerial photographs during the same season as the image data were collected. A hybrid of supervised and unsupervised image classification techniques produced mapping of eight vegetation types. Field data were used to conduct a classification accuracy assessment. As a result of the project, two digital and two hard copy products have been defined.

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

Keywords: fish// salmon//overwater structures//shoreline//nearshore//Port Townsend//Jefferson County//Puget Sound//Hood Canal

Abstract: REGION: PNW Species: chum and pink juvenile salmon STUDY OBJECTIVES: Assess the effects of wharf lighting at the U.S. Naval Submarine Base Bangor on outmigrating juvenile salmon in Hood Canal. Chum being the principal salmonid in Hood Canal and pink the second most abundant. METHODS: Net sampling, hydroacoustic monitoring and visual observations in areas adjacent to the wharf. Stomach analysis. RESULTS: Although salmon were observed to congregate below the lights. Increased salmon catch in the nearshore areas at the wharf were most likely caused by the presence of prey. No large-scale aggregation in the wharf area appeared to result from Mode I lighting of 2-13 lux. Mode II and III lights in intensities of 200-400 lux appeared to attract and delay chum for 1-2 days. It was also speculated that they remained in the area due to food availability. It was concluded that too few tests were run under these conditions to be conclusive. Predation on outmigrating salmon in the wharf area was considered insignificant, as <4% of the predators caught contained salmonid remains, and few of the predators were implicated in consumption of salmonids (cutthroat and staghorn sculpin in Hood Canal) were present with a total catch of <10 during February-July 1979 which included 310 purse seine sets, 58 beach sets and 35 townet sets. Catch of coho and cutthroat trout did not increase with lighting.

160. Schmitt, C. S. Quinnell M. Rickey and M. Stanley. Groundfish statistics form commercial fiseries in Puget Sound, 1970-1988: WDF; 1991; Progress Report No. 285.

Keywords: harvest//fish

Abstract: Groundfish catch, effort, and value statistics are presented for commercial fisheries in Puget Sound during the years 1970 through 1988. Catch

is presented in pounds, effort is the number of landings by each gear type and value represents the ex-vessel dollars paid to fishers by processors. In addition, effort for the bottom and midwater trawl fisheries is reported in hours fished. Monthly catch, effort, and value estimates are presented for thirty-six species categories during the nineteen-year period, and annual estimates are presented for seven management regions.

161. Shaffer, J. A. and Anita Cook. Olympia oyster stock rebuilding plan for Washington State. Puget Sound Research '98.

Keywords: shellfish//Puget Sound//straits//Jefferson County

Abstract: The Olympia oyster (*Ostrea lurida*) is a native to the state of Washington. Once the basis for a thriving, statewide oyster industry, its numbers were drastically reduced by the mid 1940's. Water quality and overharvesting are thought to be the major factors in its near demise. The Pacific oyster (*Croassostrea gigas*) has since replaced the Olympia oyster in Washington and world markets. The Washington Dept. of Fish and Wildlife is now developing an Olympia oyster stock rebuilding strategy. The tools of the strategy to restore the Olympia oyster within its historical geographic range are quite simple, but offer many challenges. Key elements of the draft strategy include historical and current distribution, habitat and water quality impacts, interspecies interactions, and Tribal co-management. Partnering with Tribes, local commerical shellfish interests, and the public provide new opportunities for restoring the Olympia oyster. It is a top priority for state management of this species.

162. Shaffer, J. A. and D. S. Parks 1994. Seasonal variations in and observations of landslide impacts on the algal composition of a Puget Sound nearshore kelp forest . Botanica Marina. 37:315-323.

Keywords: algae//Puget Sound//nearshore//vegetation//kelp//shoreline//shoreline impacts//human use

Abstract: A medium scale landslide (2153 m^3) deposited sediment on to an intertidal beach on the north side of Point Williams, Seattle, Washington on 4 April 1991. Within 23 days of the slide, high tides and rain carried 77% of the sediment to nearshore waters and north through a seasonal kelp bed immediately adjacent ot the slide area. Transects were placed in north and unimpacted south kelp beds and monitored seasonally for algal community and densities. Significant differences in north and south kelp bed *costaria costata, Laminaria* sp. and *Nereocystis luetkana* densities occurred during spring. No other community or density differences were found. Irradiance values of the two beds differed during winter months but were similar for the rest of the year. Significant differences in spring kelp densities may be attributed to short-term impacts of landslide sediment introduced to the kelp bed during early kelp growth stages. However, the landslide did not appear to effect the kelp community after

the observed spring depression. Larger landslides may have more extensive impacts.

163. Shaffer, J. A. D. Doty and J. West. Crustacean community composition and trophic use of the drift vegetation habitat by juvenile splitnose rockfish Sebastes diploproa. Marine Ecology Progress Series. 1995. 123:13-21.

Keywords: rockfish//vegetation//straits//nearshore vegetation//nearshore//vegetation//fish

Abstract: The community composition and trophic use of the drift vegetation habitat by pre-settlement juvenile splitnose rockfish was documented in June, August, and October 1992 in the San Juan Archipelago, Washington, USA. *Fucus* spp., *Zostera* spp., and *Nerocystis leukeana* were dominant vegetation for the months sampled. Juvenile S. diploproa collected from the drfit vegetaiton habitat fed mainly on planktonic organisms, including copepods and cladocernas, during June and August. In October, diets shifted to larger epiphytic prey and were dominated by 1 amphipod species. Of 5 major prey taxa, 3 had significanlty different densities in drift vegetation and nearby open water habitats. Prey taxa were not dominant in the drift vegetation habitat in June and August, indicating a high degree of prey selection during these months. In October, dominant prey taxa made up a large proportion of the crustacean community in the drift vegetation habitat and less prey selection occurred. Community indices of the drift vegetation habitat were up to twice as high as those of the adjacent open water habitat for the 3 mo sampled due to vegetation associated crustaceans. Drift vegetation provides nearshore habitat features to pelagic systems. It provides food, refuge, and possibly transport from offshore to nearshore habitats for a number of recreationally and commercially important species.

164. Shaffer, J. Anne. Kelp bed habitats of the inland waters of western Washington.

Keywords: kelp//admiralty inlet//Port townsend//Puget Sound//straits//vegetation//nearshore//nearshore vegetation

Abstract: This paper presents the findings of two pilot studies defining basic features of the two dominant understory habitats in Puget Sound and the Straits of Juan de Fuca. These are bull kelp, *Nereocystis leutkeana,* and giant kelp, *Macrocystis integrigolia*, which together support wonderfully complex nearshore fish and plant assemblages. The two pilot studies defined the basic features of the understory habitats. A number of striking differences within and between kelp beds in Puget Sound compared to Strait of Juan de Fuca were documented. Variations in understory communities with bed type, location, and season highlights the need to define the specific goals of preservation and restoration activities prior to implementation of management activities such as Marine Area Preserves. Preservation and restoration efforts will be less effective if species

targeted for restoration and preservation are not well defined relative to the location and species of habitat under consideration. The variation in this study also highlights the need for detailed long-term studies for successful habitat restoration and preservation.

165. ---. Seasonal variation in understory kelp bed habitats of the Strait of Juan de Fuca. Journal of Coastal Research. 1999. 16.

Keywords: Puget Sound//commercial fishery//shellfish//kelp//nearshore vegetation//vegetation

Abstract: Kelp habitats in Washington state, including the Strait of Juan de Fuca, are classified as a critical habitat for a number of federally listed, proposed listed, and declining stocks, including chinook, coho and chum salmon, quillback, copper and brown rockfish, surfsmelt, sandlance and northern abalone. The Strait of Juan de Fuca supports the majority of kelp resources in the state of Washington. Despite this importance, virtually no information exists on kelp habitat community structure for the Strait of Juan de Fuca. This study defined understory composition of dominant kelp habitats of the Strait. the understory composition of two *Macrocystis integrifolia* and *Nereocystis leutkeana* beds were sampled seasonally for one year. Variables assessed included macroalgal composition and three commercially and recreationally important species of urchin and one species of abalone. Similarities and differences were found with bed type, season, and geographic location. Similarlities included strong seasonal variation in understory cover, and the dominance of the perennial, understory kelp *Pterygophora californcia*. Both types were also similar in their difference form understory communities described for Puget Sound kelp beds.

Differences between the two kelp bed types included variation in total algal cover. *Macrocystis* beds showed a seasonal variation in total cover and algal composition and had greater overall percent cover, to which *M. integrifolia* contributed seasonally. *Nereocystis* beds showed seasonal changes in precent algal cover. However *N. leukeana* did not contribute to the understory algal over of these beds. *Neocystis* beds had higher total number of urchins and abalone than *Macrosystis* beds.

Recent increases in kelp habitat management activities, combined with differences in kelp community with seabed type, and location observed in this study underscore the need for well defined goals and detailed site studies on successful kelp habitat manangement, including restoration and preservation.

166. Shreffler, D. K. and R. A. Moursund. Impacts of Ferry Terminals on Juvenile Salmon Migrating Along Puget Sound Shorelines Phase II: Field Studies at Port Townsend Ferry Terminal . Seattle, WA. Washington State Transportation Center (TRAC). 1999 Dec. GCA-1723. (Final Research Report).

Keywords: salmon//overwater structures//human impacts//hearshore fish

Abstract: This report presents the results of Phase II of a 3-phase research program to determine whether ferry terminals affect migrating juvenile salmon, and if so, how future design of ferry terminals and modifications to both terminals and operations can mitigate those impacts. Phase I resulted in a report synthesizing the technical knowledge regarding the potential effects of shoreline structures on migrating juvenile salmon. This report summarizes our results form Phase II pilot field studies at the Port Townsend ferry terminal in spring 1999 and provids recommendations for proposed on-site tests of the effects of a range of different WSDOT ferry terminals and vessel activity patterns in Phase III(spring-winter 2000). The overall goal of Phase II was to perform pilot field experiments with releases of hatchery chum and chinook fry to test whether the Port Townsend terminal stops or delays the natural migration of juvenile slamon. Monitoring methods included diving surveys, beach seining survyes, single-beam and split-beam hydroacoustics, remote underwater video and in situ light sensors. The surfaceobservations, underwater video, and the single-beam and split-beam hydroacoustics confirmed that the chinook migrated from the release point directly to the shadow line underneath the terminal. The chinook fry stopped at the shadow line and then displayed consistent behavior of swimming from the darkness of the shadow line and remained near the bottom into the light to feed at the surface. As the sun set and the sahdow line progressed further under the terminal, the school apperared to follow the shadlowline under the terminal. The fundamental question of whether ferry terminals present a barrier to juvenile salmon migration remains unanswered.

167. Shreffler, D. K. R. M. Thom and K. B. MacDonald. Shoreline armoring effects on biological resources and coastal ecology in Puget Sound. Puget Sound Research "95 Proceedings. 1995 Jan 23-24. Bellevue. Olympia, WA. Puget Sound Water Quality Authority. 1995: pages 121-131.

Keywords: vegetation//nearshore habitat//nearshore//eelgrass//kelp//erosion control//shoreline hardening//shorelines

Abstract: This paper provides an overview of the effects of shoreline armoring on habitat structure, ecological processes, and selected biological resources of the nearshore zone of Puget Sound. In addition, it briefly addresses cumulative ecological effects--potentilaly the most damaging but least understood effects of shoreline armoring.

168. Shreffler, David. Chimacum Creek Estuary Eelgrass Survey and Restoration Assessment. 1995 Aug.

Keywords: eelgrass//Port Townsend//Chimacum Creek//vegetation//transplant

Abstract: This study describes an attempt to enhance the eelgrass beds at the mouth of Chimacum Creek in an effort to enhance juvenile summer chum rearing habitat along the migratory corridor at the mouth of the creek in Port Townsend Bay. The mouth of the creek lies along a regional migratory corridor for juvenile Hood Canal summer chum and the creek supports its own populations of summer chum, coho, fall chum, steelhead, and cutthroat populations.

169. Simenstad, C. A. B. J. Nightingale R. M. Thom and D. K. Shreffler. Impacts of Ferry Terminals on Juvenile Salmon Migrating Along Puget Sound Shorelines Phase I: Synthesis of State of Knowledge. Washington State Transportation Center (TRAC); Research Project T9903, Task A2.

Keywords: overwater structures//overwater//human impacts//salmon//juvenile salmon//migration//predation//prey resources//vegetation//fish//fish vision//Puget Sound

Abstract: This project is assessing whether ferry terminals affect juvenile salmon migrating along estuarine and nearshore marine environments and, if so, how design of and modifications to both ferry terminals and operations can mitigate those impacts. This project has three phases. This report summarizes results from Phase I (status of knowledge, initial terminal surveys) and implications for Phase II and III research.

This study addressed three issues about over-water structures impacts on juvenile salmon: 1) alteration in migratory behavior, 2) reduction in prey production and availability, and 3) increased predation. An assessment of over 60 direct sources of information found evidence that juvenile salmon react to shadows and other artifacts in the shoreline environment created by shoreline structures. While changes in light have been shown to affect salmon migration behavior and thus potentially place them at increased mortality risk we found no quantitative information on the significance of these behavioral responses to juvenile salmon survival. Juvenile salmon also encounter limited prey resources under shoreline structures when important habitat such as eelgrass (*Zostera marina*) are disturbed. Modifications to light, temperature, salinity, nutrient levels, and wave action beneath an overwater structure influences the rate of photosynthesis, plant distribution, and surival of specific plant species that directy or indirectly support prey resource composition and production. Despite considerable speculation about increased predation around docks, quantitative evidence for significant increases in predation on salmon associated with docks is lacking.

It also conducted short-term underwater diving and video surveys at five ferry terminals (Clinton, Kingston, Port Townsend, Seattle, and Vashon) to gather preliminary information on the relationships among variations in overwater structures, fish distribution and relative abundance, light conditions, biological

communities, and potential predators. Juvenile salmon were observed migrating under several strctures.

Existing information indicates that the effects of shoreline structures on migrating juvenile salmon may vary, depending on the design and orientation of the shoreline structure, extent of alteration of the underwater light field, and presence of artificial light. However, our understanding of the significance of short-tem delays in the salmons' migration and cumulative or synergistic effects is insufficient to provide the quantitative relationship that would be necessary as the basis for developing, retrofitting, or making design modifications. Field studies are recommended.

170. Simenstad, C. A. B. S. Miller C. F. Nyblade K. Thornburgh and L. J. Bledsoe. Food web relationships of northern Puget Sound and the Strait of Juan de Fuca. Seattle, WA. 1979(EPA Interagency Energy/Environment R&D Program Report prepared for the MESA Puget Sound Project).

Keywords: food web//Puget Sound//straits/fish//vegetation//habitats
Abstract: A synthesis of extensive baseline survey data into a report on prey availability and higher trophic levels. Food web relationships are identified along with the relative importance of autotrophic versus heterotrophic energy bases. Species lists for algae, invertebrates, fishes, birds, and mammals are included. This is likely the most extensive baseline survey identifying habitat use and food web relationships compiled for this region.

171. Simenstad, C. A. C. D. Tanner R. M. Thom and L. L. Conquest., Prepared for U.S. Environmental Protection Agency, Puget Sound Estuary Program. Estuarine habitat assessment protocol. School of Fisheries, University of Washington; EPA 910/9-91-037.

Keywords: fish//vegetation//substrate//fish//commmunities//assemblages//marine birds//invertebrates//marine birds//shellfish

Abstract: Developed in response to the need for procedures that quantitatively assess the function of estuarine wetlands and associated nearshore habitats for fish and wildlife. Thus far, a systematic approach for measuring the function of estuarine wetlands and nearshore habitats that considers the factors has not been available. Consequently, restoration and creation of estuarine habitats have proceeded haphazardly. Without such procedures, the scientific knowledge required to link the characteristics of estuarine habitats to their function in support of fish and wildlife will not emerge. The approach of the Protocol, and of the procedures and measurements it recommends, is intended to bridge the gap between estuarine habitat characteristics and the habitat's function to support fish and wildlife.

172. Simenstad, C. A. K. L. Fresh J. Flemma and D. Clarke, Wetland Ecosystem Team (University of Washington, Fisheries Research Institute). Effects of estuarine habitat modifications on anadromous salmonids: a literature survey. Seattle, WA; FRI-UW-9123.

Keywords: salmon//human impacts//habitat modifications//habitat//salmon habitat/

Abstract: An extensive literature review of the impacts of estuarine abitat modification to salmonids.

173. Simenstad, C. A. W. J. Kinney and B. S. Miller. Epibenthic zooplankton assemblages at selected sites along the Strait of Juan de Fuca. 1979; NOAA Tech, Memo. ERL MESA-46.

Keywords: nearshore/straits//vegetation//neashore vegetation

Abstract: Extensive survey and identification of epibenthos assemblages along the Strait of Juan de Fuca.

174. Simenstad, C. A. W. J. Kinney S. S. Parker E. O. Salo J. R. Cordell and Hannle Buechner. Prey Community Structure and Trophic Ecology of Outmigrating Juvenile Chum and Pink Salmon in Hood Canal, Washington: A Synthesis of Three Years' Studies 1977-1979. UW Washington, Seattle, WA: Fisheries Research Institute. 1980. FRI-UW-8026.

Keywords: salmon//prey resources//invertebrates//nearshore food web//food web//juvenile salmon//trophic ecology//ecology//shellfish

Abstract: Study Objectives: Describe the functional trophic relationships between juvenile chum and pink salmon and their food resources as interpreted from the results of over three years of studies in hood Canal specifically describing: 1) the temporal and spatial prey composition and consumption by juvenile chum and pink; 2) the temporal and spatial composition of epibenthic and neritic zooplankton communities; 3) evaluate the characteristic selective predation by juvenile chum and pink salmon upon "available" zooplankton; 4) evaluate the trophic importance of representative nearshore habitats; 5) relate the observed outmigration behavior of juvenile chum and pink salmon with their food habits and distribution and composition of prey resources, and 6) evaluate the potential for a limited "carrying capacity".Methods: Beach seine, townet, stomach content analyses, epibenthic pump sampling, neritic zooplankton net sampling, otolith determinations. **Results: Prey**: Immediately upon entry into Hood Canal fry (30-40mm) fed predominately on epibenthos, including harpacticoid copepods, gammarid amphipods, pholychaete annelids and crustacea eggs. After reaching 45-55 mm, they fed upon neritic organisms such as euphausiids, calanoid copepods, and hyperiid amphipods. Pink fry prey was

dominated by calanoid copepods and copepod larvae. Epibenthic organisms were not prevalent in their diet. For chum, harpacticoid copepods formed the major dietary components. Diel shift in prey composition for chum and pink were found with both chum and pink feeding at a reduced level throughout the day. Densities of total epibenthic organisms were similar across sites. However, densities of harpacticoid copeods tended to be more variable with the highest densities found in eelgrass habitat. A general decline in harpacticoid copeod densities appeared to coincide with the early spring peak densities of juvenile chum in shallow sublittoral habitats. This suggests that epibenthic-feeding chums could be involved in depressing harpacticoid populations during the most intensive outmigration period. Intense size-specific predation depressed the mean size distributions of harpacticoids during the peak salmonid outmigration.

Migration Behavior and Prey Resources: Speed of outmigration and length of residence in shallow sublittoral and neritic habitats appeared to be directly related to availability and density of preferred prey organisms. Residence times were shorter due to low prey availability. The chum may vary their migration rate according to the availability of large neritic zooplanktors. Chum 48-53mm migrated at a rate of approximately 8 km/day in April and 5 km/ in June. Schools of juvenile chum appear to disperse at night and move slightly offshore. Until reaching 45-50 mm, they continue to migrate through shallow sublittoral habitats during the day. Findings indicated that Hood Canal chum fry (30-45mm) fed extensively upon small, densely distributed harpacticoid copepods, appearing to select the largest copepods available. Depending upon fish size, residence time may be a function of prey abundance in both epibenthic and neritic zooplankton communities.
Prey Abundance: The highest standing stock estimates of these organisms occurred at an eelgrass covered delta, Devil's Hole Delta. This is consistent with other studies, where the highest densities of harpacticoid copepods occur in thick eelgrass stands of 4-5 times higher in sand habitat without eelgrass. Standing stocks of gammarid amphipods, appear to be higher in more current swept habitats with coarser substrates. Gammarids, a principal prey of alge (45-60mm) chum are important prey resources. The extensive growths of marine macroalgae, (*laminaria, ulva*) typify the more current swept, shallow sublittoral habitats that contribute significantly to gammarid standing stocks. Neritic habitat with large zooplankters is the principal foraging habitat of juvenile chum over 50-55m with intense feeding on the diel-migrating calanoid copepods.

Existing data supports the following assumptions: 1) salmon fry are morphologically and bioenergetically constrained in the sizes and species of prey organisms which they can consume and still obtain a daily ration sufficient to maintain growth; 2) the response of the outmigration of fry to inadequate prey composition or density is an increased migration rate which reduces marine survival, and 3) the availability of these "optimal" prey resources is finite and a function of time given the recent history of predation by outmigrating salmon fry and other planktivorous predators. **Epibenthic Carrying Capacity:** Juvenile

chum demonstrate a preferred harpacticoid prey size range. The chum daily ration was estimated to be 25% at 35-40 mm size and 20% at 40-50mm size. Residence in Hood Canal was estimated to be two weeks which enables 30-35mm fish growth to 50+mm and effective feeding upon neritic organisms. **Chum Outmigration and Carrying Capacity:** Estimates of epibenthic prey abundances suggest the need to adjust total hatchery release timing and densities to the availability of preferred prey. Diverse times and size distributions of released fry could minimize overexploitation of prey taxa. **Conclusions:** Otolith markings could document estuarine and nearshore residence. Very limited information on neritic feeding is available. Predator-prey interactions require further study of copepod prey communities.The hypothesis of low survival for juvenile chum with short residence estimates in Hood Canal require further analysis and stock comparisons. The use of light, temperature, nutrients, detritus decomposition, and microbial colonization, chlorophyll *a* production, which could be directly involved in zooplankton population expansion and timing, could be used as predictors of prey availability.

175. Simenstad, C. A. B. S. Miller J. N. Cross K. L. Fresh S. Steinfort and J. C. Fegley. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan de Fuca inlcuding food habits of nearhshore fish. NOAA Tech. Memo. ed.. Boulder, Colorado: MESA Prog. Environmental. Res. Lab. 1979. ERL MESA-20 and NTIS PB-297406.

Keywords: fish//straits//invertebrates

Abstract: This baseline survey documents distribution, biomass and abundance of nearshore fines. Stomach analysis reuslts are presented by individual species.

176. Speich, S. M. and T. R. Wahl. Catalog of Washington seabird colonies. Portland, Oregon: US Fish and Wildlife Service. 1989. Biological Report 88 (6), OCS Study MMS 899-0054.

Keywords: birds//marine birds

Abstract: The report is a summary of data collected from 1972 to 1982 on the location, size, and species composition of seabird colonies in Washington. It documents more than 440 nesting areas, with a total of more than 300,000 birds, within the marine shoreline habitats of the State. Eighteen species of seabirds are discussed in the report. For each colony described, the report contains a map showing the location and size of the colony and a table with the colony name, location by latitude and longitude, species present, number of breeding birds, sources of information, survey dates and types, and data quality. (Library of Congress catalog card no. 88-600461. Sponsored by Minerals Management Services, Los Angeles, CA. Pacific OCS Region.).

177. Speich, S. M. and Wahl T. R. Marbled murrelet populations of Washington -- marine habitat preferences and variability of occurrence. Ralph, C. J. Hunt G. L. Jr. Raphael M. G. and Piatt J. F. eds. In: ECOLOGY-AND-CONSERVATION-OF-THE-MARBLED-MURRELET. 1995; pp. 313-326.

Keywords: birds//seabirds//murrelet//Puget Sound

Abstract: Marbled Murrelets occur in Puget Sound marine habitats in relatively low numbers. The rates of occurrence of murrelets on censuses within marine habitats is generally low. Further analysis is required to determine if low occurrence rates are a general function of the movement of birds, or their consistent occurrence on particular censuses and not on others. Qualitative data indicate that Marbled Murrelet abundance in Puget Sound is now lower than earlier this century. Such long-term information is unavailable for Marbled Murrelets along the Pacific Ocean coast of Washington. Census data from nearshore water of the Pacific Ocean off Grays Harbor indicate that Marbled Murrelet abundance is reduced there since 1989 and especially in 1993. This pattern is also reflected in several other more oceanic species suggesting basic and wide-spread changes in marine carrying capacity.

178. Speich, S. M. and Wahl, T. R. Rates of occurrence of dead birds in Washington's inland marine waters, 1978 and 1979. Murrelet 1986; vol. 67(no. 2):pp. 51-59.

Keywords: seabirds//birds

Abstract: The rates of occurrence of dead birds were determined for beach and water segment censuses in 1978 and 1979 in the inland marine waters of Washington. There were 110 birds of 25 species found dead on beach censuses. The rates of occurrence of dead birds were low in comparison with other studies: beach censuses--0 to 1.47 birds/km; aerial-shoreline censuses--0 to 4.7 birds/10 super(3) km; aerial-open water censuses--0 to 9.0 birds/10 super(3) km; ferry-shoreline censuses--0 to 6.9 birds/10 super(3) km; and ferry-open water censuses--0 to 9.3 birds/10 super(3) km. The rates of occurrence of dead birds on study area beaches were decidedly lower than comparable values from Washington beaches facing the Pacific Ocean. Aircraft, small boat, and ferry observation rates were much lower than beach rates.

179. Strickland, R. M. The Fertile Fjord: Plankton in Puget Sound. Seattle, WA. Washington Sea Grant, University of Washington. 1983.

Keywords: Puget Sound//water quality

Abstract: Detailed oceanographic and biological overview of the Puget Sound marine ecosystem.

180. Strickland, Richard N. Lerner and D. G. Gordon. Northwest Straits Overview: A science gap report (Draft). Seattle, WA: Washington Sea Grant, Office of Marine and Environmental and Resource Programs, UW. 2000 Apr.

Keywords: straits//fish//vegetation//habitatas//nearshore//invertebrates//marine mammals//harvest//shellfish

Abstract: An overview of the status of knowledge and knowledge gaps on the biology, oceanography and plant and animal assemblages in the Northwest Straits. The status of knowledge on the following topics included: oceanography, nearshore habitat, invertebrates, fish, marine mamals, and seabirds.

181. Sumaila, U. R. Protected marine reserves as fisheries management tools: a bioeconomic analysis. Fisheries Research. 37:287-296.

Keywords: MPA//fish//harvest//fishery//economics

Abstract: This paper develops a dynamic computational bioeconomic model with the objective of assessing protected marine reserves as fisheries management tools. Data on the North East Atlantic cod stock are used to determine the bioeconomically optimal size of a marine reserve for the Barents Sea cod fishery, as a function of the net transfer rate between the protected and unprotected areas of the marine habitat. The single agent model developed, allows for the occurrence of a shock to the system in the form of severe recruitment failure in the non-protected area. Two key results emerge from the study. First, establishment of marine reserves are bioeconomically beneficial when net transfer rates for cod are 'reasonably' high and reserve sites are large: large reserves provide good protection for the stock in the face of the shock, while high transfer rates make the protected fish available for harvesting after the shock has occurred. Further, optimally chosen reserve size when net transfer rates are high, also mitigates against biological losses. Second, when net transfer rates are low, the establishment of marine reserves does not mitigate against losses in the discounted economic rent, while they tend to be efficient in mitigating against biological losses.

182. Suryan, R. M. and Harvey J. T. Tracking harbor seals (*Phoca vitulina richardsi*) to determine dive behavior, foraging activity, and haul-out site use. Mar. Mamm. Sci. 1998; vol. 14(no. 2): pp. 361-372.

Keywords: harbor seals//marine mammals

Abstract: Movements and haul-out patterns of the harbor seal (*Phoca vitulina richardsi*) have been studied with a variety of methods, including observations of seals with distinctly marked pelages, colored tags, or radio transmitters attached to rear flippers. We radio-tagged harbor seals to assess diving behavior and

haul-out site use off the San Juan Islands, Washington; an inland waterway characterized by numerous islands, a tidal range of 3.6 m, strong currents (maximum 7.7 km/h) and a rocky shoreline. Haul-out sites include reefs and rocky intertidal zones of islands. Our objectives were to: (1) determine duration of dive and time at surface for various aquatic behaviors; (2) compare behaviors and duration of dives in the daytime and at night; (3) locate foraging areas, and (4) determine faithfulness to particular haul-out sites.

183. ---. Variability in reactions of Pacific harbor seals, *Phoca vitulina richardsi*, to disturbance
Fishery-Bulletin. 1999. vol. 97(no. 2):pp. 332-339.

Keywords: marine mammals//northwest straits//straits

Abstract: Disturbances to harbor seals, *Phoca vitulina richardsi*, during 1991 and 1992 pupping seasons were observed at Puffin Island, Clements Reef, and Skipjack Island in Washington state. Harassment (greater than or equal to one seal entering the water) of seals ashore was common (greater than or equal to 71% of survey days) and primarily caused by powerboat operators approaching to observe seals. Recovery (number of seals on a haul-out site returned to preharassment levels) following harassment was less at Puffin Island (19%) than at Clements Reef(54%) and Skipjack Island (45%). Additionally, seals were more vigilant ($P<0.003$) at Puffin Island than at the other two locations. These results indicated that seals at Puffin Island were less tolerant of disturbance than seals at other sites. This could possibly be attributed to a greater ($P<0.05$) percentage of pups ashore (17%) than at Clements Reef (3%) and Skipjack Island (3%). Because of this, we expected that powerboats would disturb seals from greater distancesat Puffin Island. To test this, we used a theodolite to determine distance between seals and an approaching vessel at Puffin Island and Clements Reef. There was, however, no significant ($P>0.05$) difference in distances at which disturbances occurred. The most notable difference in distance of disturbance was between initial and subsequent harassments during a haul-out period. Those seals remaining or returning to shore after harassment were more tolerant of powerboats, allowing significantly ($P<0.05$) closer approaches than those initially harassed. Seals detected (head raised and oriented toward the potential disturbance) a powerboat at a mean distance of 264 m, and harassments occurred when boats approached, on average, to within 144 m. Results of this study exemplify the variability in reaction to disturbance and the necessity for considering these differences for minimizing disturbance.

184. Terich, Thomas A. M. L. Schwarz and J. Johannessen (Western Washington University). [Shorelands and Environmental Assistance Program]. Annotated bibliographies on shoreline hardening effects, vegetative erosion control, and beach nourishment. Olympia, WA: Washington Department of Ecology; Report 94-75. (Coastal Erosion Management Strategy; Coastal Erosion Management Studies, Vol. 2).

Keywords: shoreline hardening//shoreline armoring//armoring//shorelines//erosion control//vegetation

Abstract: This report consists of a collection of annotated bibliographies prepared for the Shorelands and Coastal Zone Management Program. It is a collection of three annotated bibliographies covering the effects of seawalls and other shoreline hardening structures, vegetative erosion control, and beach nourishment.

185. The Whale Museum, San Juan Island. Available at: www.whale-museum.org.

Keywords: marine mammals//whales//northwest straits//straits

Abstract: This web site provides abundant information concerning marine mammals and in particular to killer whales local to the Northwest Straits region.

186. Thom, R. M. A. B. Borde M. A. Kyte, Prepared for Seattle District, U.S. Army Corps of Engineers. Port Townsend Marina Mitigation Identification Study. Sequim, WA. Battelle Marine Sciences Laboratory.1999 Jul.

Keywords: Port Townsend//fish//salmon//sand lance//vegetation//eelgrass//Chimacum Creek//intertidal

Abstracts: Plans presented to the US Army Corp of Engineers on mitigation possibilities for the potential expansion of the Port of Port Townsend Boat Haven in front of the derelict transfer span. Identifies plant and animal species and communities that may be affected by the project and suggests methods of mitigating for adverse affects.

187. Thom, R. M. and D. K. Shreffler. Eelgrass meadows near ferry terminals in Puget Sound: characterization of assemblages and mitigation of impacts. Battelle Marine Science Laboratory. 1996 Aug 23.

Keywords: eelgrass//overwater structures//overwater impacts//shading//prop scour//vegetation//nearshore vegetation//nearshore//habitat

Abstract: Region: PNW **Species:** eelgrass**Study Objectives:** Mitigation/impact Assessment. Understand the effects of ferry terminals and ferry operations on eelgrass meadows in Puget Sound. Investigate mitigating technological and transplantation measures. **Methods: Empirical:** field studies at three ferry terminals located at Clinton, Edmonds and Port Townsend, Washington, two days for each terminal from July 29- August 6, 1994. Eelgrass survey included

three transects with quadrats placed at 5 m intervals w/ recordings of shoot density, depth and time. Shoot samples harvested, dried and weighed with epiphytes scraped. Photosynthetically active radiation (PAR) recorded at 5-minute intervals throughout the day. Sensors were placed at mid-depth of each transect with the mean of 5-10 readings collected over a 1-minute interval being recorded. At the Clinton Terminal, divers observed and mapped propeller wash plumes for nine arrivals and departures on October 3, 1994. On August 5, 1995, at a point where eelgrass was absent but would normally occur, PAR and bottom currents. Between June 1991 and April 1996, long-term *in-situ* growth studies were conducted near Battelle Marine Sciences Laboratory with a growth rate and PAR measured and recorded. Irradiance requirements were evaluated in a divided tank at Battelle. Evaluation of alternative technologies to mitigate light reduction included clear plastic inserts, aluminum foil and halogen lamps. The study included an assay of sediment substrata requirements for six substrates with five replicates for each substrata types. **Observational:** divers made qualitative observations on macrofauna and flora as to species present and differences among terminals.

Physical and Biological Disturbance Assessment Results: Irradiance measures under the terminals are very low likely causing eelgrass loss near the terminals. Propeller wash, bioturbation and other physical disturbances may be contributing to the loss. Hydraulic pile insertion and maintenance activities have likely eliminated eelgrass around the terminals. Seastar and crab densities may be responsible for retarded recruitment of eelgrass.The "reef" effect of the terminal, its pilings and piling communities enhance habitat for seastars and crab whose foraging disrupts eelgrass. The propeller plume is believed to frequently induce reduced irradiance. The propeller wash was observed to scour and redistribute sediments and associated biota and lower irradiance beyond a critical threshold of survival. A "disturbed" ring barren of eelgrass is evident adjacent to the slip channel. A bubble plume was observed to persist following arrivals and departures. Bubbles were believed to reduce irradiance on the bottom similar to suspended sediments. Erosion of eelgrass by propeller wash has likely caused some loss. Eelgrass does not generally occur in high current areas in Puget Sound. Propellers accelerated current much faster than tidal forces. It is believed that this acceleration can have a major influence on erosion of established meadows and establishment of new seedlings.

Long term growth monitoring, both in the field and in the chambers, indicate a strong seasonal growth pattern tied to irradiance with low growth in the winter, dramatic increases in early spring, intermediate growth in summer, and declines in autumn. Studies have shown that if light is reduced below a given level for a week, the plants will die. Studies indicated that eelgrass possesses a strategy for maintaining growth under less than optimal light conditions which could help sustain growth near or under terminals. This strategy includes seasonal changes in plant biomass allocation, respiration, and chlorophyll concentrations.

Eelgrass grows in a wide variety of sediment types: fine sands, mud gravel and cobble. Although, the plants grow best in organically rich fine sediments, they are also able to grow on larger substrates due to their assimilation of inorganic nutrients through roots and leaves. Therefore eelgrass can be planted in a variety of sediment types as long as nutrients are available and physical disturbances such as waves and currents don't dislodge plants.

Expected Terminal Expansion Impacts: Ferry propeller wash impacts can be avoided by moving slips further offshore. Use of glass inserts, lengthening the terminal, reflective paint and halogen lights could enhance light conditions required for eelgrass growth. However, more energy conservative measures such as the use of plastic deck materials and the use of reflective material under the dock are more highly recommended. Changes to substrate and piling communities can be reduced by using concrete pilings requiring 1/3 fewer pilings. This will reduce bioturbation while allowing in increased light. Specific terminal areas were identified as potential areas where disturbances can be eliminated and eelgrass transplants can be most successfully established.

188. Thom R.M. and LK. Hallum (Wetland Ecosystem Team). Long-term changes in the areal extent of tidal marshes, eelgrass meadows and kelp forests of Puget Sound. Final Report to EPA ed. Seattle, WA: Fisheries Research Institute. 1991. FRI-UW-9008 an EPA 910/91-005.

Keywords: eelgrass//kelp//vegetation//marsh//Puget Sound/log-term trends//trends//shorelines//shoreline impacts//nearshore

Abstract: Eelgrass, kelp and macrophytes.**Study Objectives:** Impact Assessment. Summarizes the spatial extent of the wetland and nearshore plant assemblages in Puget Sound and contrasts this with historical distributions. **Methods:** literature/data search summarizing quantitative data. **Results:** Declines in tidal marshes are the most well quantified indicating 73% decline in area since the late 1800's due to diking, filling, and dredging for agriculture and port development. Due to the lack of comprehensive eelgrass data, a similar assessment is not possible for eelgrass. However, loss has definitely taken place due to similar development and water quality. In contrast, kelp forests have been on the rise due to changes in substrata and water quality. Sediment reduction and increased nutrient runoff (i.e. high nitrate concentrations) increase kelp colonization. In addition, a significant introduction of macrophytes (i.e. spartina, z. japonica, sargassum weed, etc.) has occurred throughout Puget Sound. The quantification of these specific changes is not possible due to a lack of earlier comparable data. The general lack of comprehensive and quantitative historical data limits an analysis of historical changes. **Conclusions:** New records should be developed for documenting changes in specific habitats for the purposes of detecting changes. Changes in kelp distribution require further exploration as to causal factors. Subtidal distribution of eelgrass and the factors affecting that distribution (i.e. increased phytoplankton blooms, river-borne sediment changes

etc.) should be mapped, monitored and investigated. Development of quantitative records in the form of GIS including habitat, water quality, and physical alternations should be undertaken.

189. Thom, Ronald M. CO2-enrichment effects on eelgrass (Zostera marina L.) and bull kelp (*Nereocystis leutkeana* (Mert.) P.& R.). Water, Air and Soil Pollution. 1996; 88:383-391.

Keywords: kelp//nearshore vegetation//vegetation//eelgrass//water quality//nearshore

Abstract: Investigated the effect of CO^2-enrichment on productivity of two acquatic plant species [*Zostera marina L.l Nereocystis leutkeana* (Mert.) P. & R.] that form significant components of coastal ecosystems in the Pacific Northwest. Short-term (i.e. 2-hr) experiments showed that doublingCO^2 resulted in up to a 2.5 fold increase in *Zostera* net apparent productivity (NAP). *Nerocystis* NAP was increased 2.2-2.8 fold. In experiments involving seven enrichment treatments, NAP increased with increasing CO^2 between ambient (1.0x) and s.5x CO^2 concentrations. In growth experiments, mean growth rate of *Zostera* increased with increasing CO^2 during one of the two trials. I conclude that increased CO^2 in the surface waters of the coastal ocean would predictably result in increased NAP of these two species. These results supplement limited published data showing that shallow estuarine and marine systems are vulnerable to increased carbon dioxide.

190. Thom Ronald M., D. K. Shreffler and Keith Macdonald (Battelle Marine Sciences Laboratory, Sequim, WA and CH2M Hill, Seattle, WA). Shoreline Armoring Effects on Coastal Ecology and Biological Resources in Puget Sound, Washington. Olympia, WA: Shorelands and Environmental Assistance Program, Washington Department of Ecology. 1994 Aug. Report 94-80. (Coastal Erosion Management Strategy, Coastal Erosion Management Studies, 7).

Keywords: Puget Sound//Washington//armoring//hardened shorelines//shorelines//erosion//erosion control//nearshore

Abstract: This report covers the general ecology of Puget Sound shorelines, armoring effects on physical processes, habitat structure, ecological processes, biological resources and cumulative ecological effects.

191. Tynan, Tim. Life history characterization of summer chum salmon populations in the Hood Canal and eastern Strait of Juan de Fuca regions. WDFW; 1997 May; Report #H97-06.

Keywords: salmon//Puget Sound//straits

Abstract: Reports on summer chum production in streams in Hood Canal from 1990-1996 and Strait of Juan de Fuca 1968-1996. Summer chum production streams in the Strait of Juan de Fuca region were identified as Chimacum Creek (extirpated), Snow Creek, Salmon Creek, Jimmycomelately Creek, and Dungeness Creek. Population genetic characteristics, adult migration and spawning characteristics, egg/fry development, emergence by stream location, spawn timing, estuarine residence and migration timing, and summer chum life history summary are presented.

192. Varanasi, Usha Donald W. Brown Tom Hom Douglas G. Burrows Catherine A. and Sloan, L. Jay Field* John E. Stein Karen L. Tilbury Bruce B. McCain and Sin-Lam Chan. Volume I: Survey of Alaskan subsistence fish, marine mammal, and invertebrate samples collected 1989-91 for exposure to oil spilled from the Exxon Valdez. Seattle, WA. National Marine Fisheries Service Northwest Fisheries Science Center, Coastal Zone and Estuarine Studies Division. October 1993. NOAA Technical Memorandum NMFS-NWFSC-12.

Keywords: marine mammals//oil spills/

Abstract: The Exxon Valdez ran aground on Bligh Reef, Prince William Sound, Alaska on March 24, 1989, spilling millions of gallons of Prudhoe Bay crude oil (PBCO). During the weeks following the spill, large amounts of oil flowed towards southwestern Prince William Sound, and as a result, many shorelines were oiled. The spreading of spilled oil raised concerns of native Alaskans that their subsistence seafoods (fish, marine mammals, and invertebrate organisms) were contaminated by the spilled petroleum. At the request of native Alaskans, a study was conducted as a cooperative effort among NOAA, Exxon, and the Alaska Department of Fish and Game to assess the degree of contamination of subsistence organisms by PBCO. In this study, edible flesh of fish, marine mammals, and shellfish from 22 native subsistence food collection areas and from two reference areas (Angoon and Yakutat) were analyzed for aromatic compounds (ACs). The results to date provide important information on the level of contamination of subsistence fish, shellfish, and marine mammals from fishing areas of native Alaskan villages in and near Prince William Sound. In an advisory opinion, the Food and Drug Administration has indicated that little risk is involved in the consumption of the nonsmoked subsistence foods studied. Subsistence food gatherers were advised not to collect or consume food if oil was observed to be present. The results also show that in future oil spills, shellfish tissues should be given the highest priority for analysis, whereas rapid screening of bile from fish and marine mammals should be sufficient to provide information on level of exposure.

193. Wade, Paul R. and Robyn P. Angliss. Guidelines for Assessing Marine Mammal Stocks: Seattle, Washington. National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service. February, 1997. NOAA Technical Memorandum NMFS-OPR-12**.**

Keywords: marine mammals//straits//Puget Sound

Abstract: You can access this report at this web site which sets out the guidelines for assessing marine mammal stocks. http://nmml.afsc.noaa.gov/library/gammsrep/gammsrep.htm

194. Wahl, T. R. A and D. R. Paulson. Marine Bird Populations of the Strait of Juan de Fuca, Strait of Georgia and adjacent waters in 1978 and 1979. U.S. Environmental Protection Agency, DOC/EPA Interagency/Environment R&D Program Report EPA/600/f-81-156. 1981.

Keywords: birds//marine birds//northwest straits//straits

Abstract: Baseline study of marine birds in the Northwest Straits area.

195. Wahl, T. R. and S. M. Speich. Marine Bird Populations in Washington Waters, Impact Documentation and Long-Term Monitoring. State of Washington Department of Ecology and Department of Game. 1980.

Keywords: marine birds//Puget Sound//northwest straits//straits

196. Walters, C. J. and V. Christensen. Ecospace: Prediction of mesoscale spatial patterns in trophic relationships of exploited ecosystems, with emphasis on the impacts of marine protected areas . Rev. Fish. Biol. Fisheries.

Keywords: MPA//marines reserves//trophic ecology

Abstract: The growing disillusion with the predictive capability of single species assessment methods, and the realization that the management approaches they imply will always fail to protect bycatch species has led to growing interest in the potential of marine protected areas (MPAs) as a tool for protecting such species, and allowing for rebuilding populations of target species and damaged habitat. Evaluating MPAs' abilities to meet these requirements will demand both field experiments and simulations. However the tools required for the latter need not be as detailed as is often thought, and particularly, need not include detailed links between resource species and physical processes. Ecospace is a spatially explicit model for policy evaluation which allows considering the impact of MPAs in an ecosystem (i.e., trophic) context, and which relies on the Ecopath mass-balance approach for most of its parameterization. Additional inputs are

movement rates, used to compute exchanges between grid cells, the settings (top- down vs. bottom up control) also required for Ecosim, the dynamic simulation routine derived from the system of linear equations in Ecopath, and habitat preferences for each of the functional groups included in the model. Convergence from the homogenous distribution assumed in the Ecopath base model to highly patterned distributions, simultaneously accounting for the habitat preference and food requirements of predators and preys, the distribution of fishing effort (driven by local abundances and fishing costs) and the existence of MPAs is extremely rapid. This is due to an integration scheme with different step sizes for the 'fast' and `slow' groups, allowing the former to track the population changes of the latter. Color figures documenting the ability of Ecospace to generate realistic spatial distributions of functional pools, under constraints of habitat preference, distribution of fishing effort, etc. may be accessed from the publications section on the Ecopath home page (www.ecopath.org.), from which the software itself may also be downloaded. `Cascade' effects, wherein prey organism are low where predators are abundant, e.g. in areas onto which high fishing costs have been mapped, or in MPAs are discussed. It is then shown that the potential benefits of local effort reductions can be easily negated by high movement rates, and especially by the concentration of fishing effort at the edge of the MPAs, where cascade effects generate prey gradients which attract predators out of the protected areas. Despite various limitations (e.g., no explicit consideration of seasonal changes or directed migration), the outward simplicity of Ecospace, and the information-rich graphs it generates, coupled with the increasingly global availability of the required Ecopath files, should ensure a wide use for this approach. This will be of use for both generating hypotheses about ecosystem function and for evaluating policy choices

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197. Walters, G. A. Ecological aspects of larval and juvenile Pacific cod (*gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), and Pacific tomcod (*Microgadus proximus*), in Port Townsend, Washington. Seattle, WA. UW. 1984. Master's Thesis.

Keywords: Pacific cod//cod//fish//Port Townsend//Jefferson County//Puget Sound//pollock.

Abstract: This thesis reports on Pacific cod, walleye pollock and Pacific tomcod larvae and juveniles in Port Townsend Bay. Morphology, growth rates and food habits were determined and described. Pacific cod eggs and larvae were found to be demersal while walleye pollock and Pacific tombod larvae were found to be pelagic.

198. Walton, J. M. Puget Sound artificial reef study. 1979.

Keywords: fish//reefs//puget sound

Abstract: This dissertation compares fish communities utilizing rocky habitats, eight artificial (tire) reefs and surrounding sand bottom off Edmonds, Washington. Thirty recreationally important species were found to be associated with the rock and tire habitats. Flatfish dominated these areas while rockfish and surf perch dominated the reef habitats. Fish density was greater on the tire reefs compared to open sand bottom habitats. Tagging studies showed localized migration to occur between the reef habitats. Fish densities in these respective habitats exhibited seasonal fuctuatuion.

199. Washington Department of Fish and Wildlife. Summer Chum Salmon Conservation Initiative (Final Hood Canal ESU Summer Chum Recovery Plan) [Web Page]. 2000. Available at: http://www.wa.gov/wdfw/fish/chum/chum.htm.

Keywords: salmon//salmon recovery//juvenile salmon//habitat impacts//nearshore ecology//prey resources//freshwater//vegetation//fish//nearshore

Abstract: This report and implementation plan documents the status, history, and future actions recommended to recover Hood Canal summer chum populations formally listing under the Endangered Species Act in March of 1999. It describes all ongoing activities including: wild stock restoration, artificial production, stock distribution, life-history strategies, reasons for decline, abundance trends, escapement, harvest, run size and age data, negative impacts on abundance, ecological interactions, habitat impacts, mitigating factors for decline, and management strategies for harvest, habitat and production.

200. Watling, L. and E. Norse. Physical disturbance of the sea bottom by mobile fishing gear: A comparison with forest clear-cutting. Conservation Biology. In press.

Keywords: harvesting practices//harvest//benthos//benthos impacts//commercial fishery//harvest

Abstract: Bottom trawling and use of other mobile fishing gear have effects on the seabed that resemble forest clearcutting, a terrestrial disturbance recognized as a major threat to biological diversity and economic sustainability. Structures in marine benthic communities are generally much smaller than those in forests, but structural complexity is no less important to their biodiversity. Use of mobile fishing gear crushes, buries, and exposes marine animals and structures on and in the substratum, sharply reducing structural diversity. Its severity is roughly comparable to other natural and anthropogenic marine disturbances. It also alters biogeochemical cycles, perhaps even globally. Recovery after disturbance is often slow because recruitment is patchy and growth to maturity takes years,

decades, or more for some structure-forming species. Trawling and dredging are especially problematic where the return interval--the time from one dredging or trawling event to the next--is shorter than the time it takes for the ecosystem to recover; extensive areas can be trawled 100-700% per year or more. The effects of mobile fishing gear on biodiversity are most severe where natural disturbance is least prevalent, particularly on the outer continental shelf and slope, where storm-wave damage is negligible and biological processes, including growth, tend to be slow. Recent advances in fishing technology (e.g., rockhopper gear, global positioning systems, fish finders) have all but eliminated what were de facto refuges from trawling. The frequency of trawling (in percentage of the continental shelf trawled per year) is orders of magnitude higher than other severe seabed disturbances, annually covering an area equivalent to perhaps half of the world's continental shelf, or 150 times the land area that is clearcut yearly. Mobile fishing gear can have large and long-lasting effects on benthic communities, including young stages of commercially important fishes, although some species benefit when structural complexity is reduced. These findings are crucial for implementation of "Essential Fish Habitat" provisions of the U.S. Magnuson-Stevens Fishery Conservation and Management Act which aim to protect nursery and feeding habitat for commercial fishes. Using a precautionary approach to management, modifying fishing methods, and creating refuges free of mobile fishing gear are ways to reduce effects on biological diversity and commercial fish habitat.

201. Watling, L. and Norse, E. A. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Forest Clearcutting. Conservation-Biology. 1998; vol. 12 (no. 6):pp. 1180-1197.

Keywords: harvesting//fish

Abstract: Bottom trawling and use of other mobile fishing gear have effects on the seabed that resemble forest clearcutting, a terrestrial disturbance recognized as a major threat to biological diversity and economic sustainability. Structures in marine benthic communities are generally much smaller than those in forests, but structural complexity is no less important to their biodiversity. Use of mobile fishing gear crushes, buries, and exposes marine animals and structures on and in the substratum, sharply reducing structural diversity. Its severity is roughly comparable to other natural and anthropogenic marine disturbances. It also alters biogeochemical cycles, perhaps even globally. Recovery after disturbance is often slow because recruitment is patchy and growth to maturity takes years, decades, or more for some structure-forming species. Trawling and dredging are especially problematic where the return interval--the time from one dredging or trawling event to the next--is shorter than the time it takes for the ecosystem to recover; extensive areas can be trawled 100-700% per year or more. The effects of mobile fishing gear on biodiversity are most severe where natural disturbance is least prevalent, particularly on the outer continental shelf and slope, where storm-wave damage is negligible and biological processes, including growth, tend to be slow. Recent advances in fishing technology (e.g., rockhopper gear,

global positioning systems, fish finders) have all but eliminated what were de facto refuges from trawling. The frequency of trawling (in percentage of the continental shelf trawled per year) is orders of magnitude higher than other severe seabed disturbances, annually covering an area equivalent to half of the world's continental shelf, or 150 times the land area that is clearcut yearly. Mobile fishing gear can have large and long-lasting effects on benthic communities, including young stages of commercially important fishes, although some species benefit when structural complexity is reduced. These findings are crucial for implementation of "Essential Fish Habitat" provisions of the U.S. Magnuson-Stevens Fishery Conservation and Management Act which aim to protect nursery and feeding habitat for commercial fishes. Using a precautionary approach to management, modifying fishing methods, and creating refuges free of mobile fishing gear are ways to reduce effects on biological diversity and commercial fish habitat.

202. WDF, WDW Western Washington Treaty Indian Tribes. 1992 Washington State Salmon and Steelhead Stock Inventory. Olympia, WA. 1993.

Keywords: salmon//fish

Abstract: Summary report on an inventory of stock status of wild salmon and steelhead populations in Washington State. Stock identification by stream, stock status, rating and status summary. This includes Puget Sound, Washington coastal and Columbia river salmon and steelhead stocks. Stock status is presented by region, by stock and by stream. Current and future management policies and actions are also presented.

203. WDFW. Pacific Salmon and Wildlife: Ecological Contexts, Relationships, and Implications for Management . Olympia, WA: WDFW; 2000; Johnson and O'Niel 2000.

Keywords: salmon//fish

Abstract: This report describes the are seven indigenous salmon and trout of the genus *Oncorhynchus* in Washington and Oregon (chinook, coho, chum, sockeye, and pink salmon, and steelhead and cutthroat trout), for this paper we will collectively call them salmon. Their habitat extends from the smallest inland streams to the vast North Pacific Ocean, an area of freshwater, estuarine, and ocean habitats in excess of 4 million km^2. Due to past commercial fisheries, habitat loss, hatchery problems, and more recently a changing ocean environment, salmon populations have shown substantial decline over the past several decades. Many salmon stocks in Washington and Oregon are now listed as either threatened or endangered, under the Federal Endangered Species Act.

Early in this century and up until relatively recently, commercial fishing permanently diverted massive quantities of nutrients away from Washington and Oregon rivers, and their respective fish and wildlife inhabitants. Recent calculations indicate that only 3 percent of the marine-derived biomass once delivered by anadromous salmon to the rivers of Puget Sound, the Washington Coast, Columbia River, and the Oregon Coast currently reaches those streams. There have also been many other losses of salmon habitat during this period caused by: river channel clearing and channelization; log driving and splash damming; extensive land clearing; major water diversions; livestock grazing; mining runoff pollution; logging road associated erosion and removal of the old growth forest; filling and diking of wetlands and estuaries; hydroelectric dam development; urban runoff; water and sediment contamination with toxicant, and recently recognized human induced oligotrophication of waterways. Over fishing and habitat degradation, together with a background of a changing ocean environment, have cumulatively reduced stock resilience. A century of hatchery programs have failed to rebuild the wild runs, and in many cases, likely contributed to their further declines. Modern salmon management techniques have become highly sophisticated, however, they have not been able to keep pace with the salmon population declines.

204. WDFW Forage Fish Unit. Puget Sound Herring Fact Sheet. LaConner, WA. http://www.wa.gov/wdfw/fish/forage/herring.htm#hbiology

Keywords: fish//herring

Abstract: Describes reproduction, timing, and life-cycles of Pacific herring.

205. --. Washington State Sand Lance Fact Sheet. La Conner, WA. http://www.wa.gov/wdfw/fish/forage/lance.htm#lbiology
.

Keywords: fish//sand lance

Abstract: Describes reproduction, timing, and life-cycles of Sand lance.

206. --. Washington State Surf Smelt Fact Sheet. LaConner WA. http://www.wa.gov/wdfw/fish/forage/smelt.htm#sbiology

Keywords: fish//surf smelt

Abstract: Describes reproduction, timing, and life-cycles of surf smelt.

207. WDOH. 1999 Annual Inventory: Commercial and Recreational Shellfish Areas of Puget Sound Office of Food Safety and Shellfish Programs: Washington State Department of Health. 2000.

Keywords. invertebrates//shellfish//Puget Sound//straits

Abstract: This report presents health information relative to shellfish resources in Puget Sound. This publication presents 12 county maps showing current shellfish area classification as of December 31, 1999 including definitions, commercial classifications, stream, sewage treatment outfalls, and classified recreational shellfish beaches. http://www.doh.wa.gov/ehp/sf/

208. Wedemeyer, G. A. McLeay D. J. and Goodyear C. P. Assessing the tolerance of fish and fish populations to environmental stress: The problems and methods of monitoring. Cairns, V. W. Hodson P. V. and Nriagu J. O. eds. Contaminant Effects on Fisheries. 1984. pp. pp. 163-198.

Keywords: salmon//fish//water quality//contaminants//human impacts

Abstract: Tolerance to environmental change depends, at least in part, on the individual fish's ability to regulate stabilizing processes that will effect the required physiological or behavioral adaptation. An understanding of the stress response, and the environmental alterations to which fishes can adapt through this response, is important to a definition of the limits of change in the aquatic environment that can be tolerate. Although most species can tolerated relatively severe stress for limited periods because of their homeostatic capabilities. These should not be used as an excuse for allowing marginal conditions to occur in the aquatic environment. Instead, these capabilities should be used to set priorities and limits for species-habitat relationships so that environmental alterations can be correctly evaluated in terms of their biological costs or benefits. This monograph discusses concepts and methods for developing the improved species-habitat database required to correctly evaluate the tolerance limits of fish and fish populations to single and multiple environmental stress factors.

209. Wellman, Katherine F. and C. Cluett. Proposed Northwest Straits National Marine Sanctuary Designation: Assessment of Economic and Social Activities. 1996. Prepared for NOAA, NOS.

Keywords: economics//straits

Abstract: The objective of this study is to collect and report on basic social and economic data related to resource uses (and passive uses) in the Northwest Straits study area in order to compare differences in social and economic impacts among the management alternatives that may be considered for the Draft environmental Impact Statement and Draft Management Plan for the proposed Northwest Straits National Marine Sanctuary. This study includes: 1) a review and analysis of the issues that have been raised and identified to date, 2) a description of the affected environment, 3) an assessment of the key economic activities in the sanctuary study area, 4) an assessment of the social and demographic makeup of the study area, 5) an assessment of potentially related socioeconomic effects of concurrent activities as a basis for ascertaining the

potential for cumulative effects, and 6) a description of the makeup and perspective of the key stakeholders in this matter and related issues.

210. West, J. E. R. M. Buckley D. C. Doty and B. E. Bookheim. Ecology and habitat use of juvenile rockfishes (*Sebastes* spp) associated with artificial nursery habitat in Puget Sound, Washington. Puget Sound Research '95,Olympia, WA. PSWQA. pp. 191-202.

Keywords: rockfish//fish//Puget Sound

Abstract: In this study, patterns were compared of settlement, recruitment, abundance, growth, and habitat associations of juveniles of a guild of three strongly substrate-associated rockfishes-copper (*S.caurinus*), quillback (*S. maliger*), and brown rockfish (*S. auriculatus)*--on two types of artificial nursery habitat. One type of reef was designed to provide refuge habitat for small, juvenile forms only, and the other to provide habitat for adults as well as juveniles. We tested functional differences of the reefs in terms of densities of juvenile rockfish they supported without attempting to separate specific effects attributable to differential predation or habitat quality. This study suggests that existing artificial reef systems targeting *Sebastes* spp. can be more finely tuned by providing refuge and foraging habitat for the complete demersal phase of target species.

211. West, James E. Protection and Restoration of Marine Life in the Inland Waters of Washington State. Olympia, WA: Puget Sound Water Quality Action Team; 1997 May(Puget Sound/Georgia Basin Environmental Report Series; Number 6).

Keywords:
cod//hake//rockfish//shellfish//invertebrates//birds//pollock//lingcod//nearshore ecology//harvesting impacts//fish abundance//bycatch//marine mammals//herring//puffin//porpoise//water quality//murre/marbled murrelet//eages//seabirds//oysters//abalone//human impacts//anthropogenic impacts//nearshore//harvesting//harvest//harvest//marine birds//shellfish

Abstract: Overview of the status of declining fish, shellfish and marine mammal stocks**.**

212. Westley, Ronald E. A. J. Scholz and Richard T. Burge. The Puget Sound Oyster Reserves: a history and inventory with recommendations for the future. Report to the Washington State Legislature ed. 1986.

Keywords: shellfish//Jefferson County//Puget Sound//oyster

Abstract: This report submitted to the Washington State Legislature, summarizes the history of the Puget Sound Oyster Reserves and identifies 4,500 acres as originally included inthe reserve system with all but 1,000 acres of the

least productive ground having been sold to private growers. Out of 1,003 acres of reserves, 21 acres are prime clam producing areas with three tracts suitable for Olympia oyster enhancement, five for shellfish produciton and two for long-term lease. This report identifies those tracts suitable for public recreation, clam enhacement, for private leases, or tracts considered unproductive for clams or oysters.

213. Westrheim, S. J. and R. P. Foucher. Stock assessment of Pacific cod (Gadus macrocephalus) in Georgia and Juan de Fuca Straits, 1954-1984. Can. Manu. Rep. Fish. and Aqautic Sci. No. 1905. 1987.

Keywords: fish//cod//straits

Abstract: Four important stocks of Pacific cod (*Gadus macrocephalus*) were delineated in the straits, primarily based on results of extensive Canadian and U.S. tagging experiments during 1954-79. All four stocks were exploited seasonally, almost exclusively by on-bottom trawls. Two stocks were resident year-round (MSA 14 and Gulf Islands), and two were itinerant and seasonal (Nanoose and MSA 19). Standardized landing statistics and landings-at-age were employed to assess each stock. Yield-per-recruit (YPR) analysis indicated that maximizing YPR was impractical because the required mesh size was too large for the mixed-species fishery. Current legal, minimum mesh (4.25", synthetic materials) was satisfactory for maximizing catch profitability (YPR/F).

214. White, Jacques. The loss of habitat in Puget Sound. People for Puget Sound; 1997 Mar.

Keywords: water quality//human impacts//anthropogenic impacts//freshwater//habitat loss/habitat/geology//eelgrass

Abstract: This report reviews the geology, climate and hydrology determining habitat types and functions. It reviews habitat losses in streams and wetlands along with loss of river deltas for the Nooksack, Lummi, Snohomish and Puyallup Rivers. It reviews the status of introduced species such as spartina, zostera japonica and sargassum and reviews shoreline armoring trends Thurston County. Toxic contaminants threaten water column and benthic habitatas. Point source discharges of toxic materials include sewag etreatment plants and industrial facilities discharging to rivers and the sound. Stormwater runoff is an important source of toxic pollution carrying pesticides, PAHs and other toxins. Stormwater toxic load is believed significant. Puget Sound populations have grown from 1 million in 1950 to 4 million in 2000 and an expected 4.5 million in 2010. Human population growth presents a very large challenge to biological integrity in marine waters.

215. Williams, B. C. Betcher. Draft Report Washington Department of Fish and Wildlife. Impact of mooring buoy installations on eelgrass and macroalgae. 1996.

Keywords: buoys//moorings//eelgrass/human impacts

Abstract: Study Objectives: Observe different mooring buoy installations in the San Juan Islands and their impact on eelgrass and macroalgae habitats. **Study Methods:** SCUBA survey of sixty five different mooring buoy installations representing different current regimes, prevailing wind/wave patterns and water depths throughout the San Juan area over a two day period in August of 1996. **Results:** Buoy designs were grouped into six different design categories: 1) mid line float, 2) all rope lines, 3) rope to chain lines, 4) all chain lines, 5) other (i.e. stainless cable, steel rods, tires etc.), and 6) mid line float with counterweight. Properly installed midline float systems demonstrated the least impact to marine vegetation with the mid line float preventing the anchor to surface line from contacting the bed. The all rope designs demonstrated minor impacts to marine vegetation with only 14% disturbing marine vegetation. The weight and diameter of lines used and growth on the lines determines its success in preventing disturbance. Eighty six percent of the rope to chain design disturbed marine vegetation with the magnitude of impact depending upon chain size and weight of rope material. Mid-line float with counterweight appeared to have the potential for significant impacts to vegetation given current, tidal height, wind, and wave regimes. Low tide cycles offer the greatest opportunity for contact with marine vegetation with disturbance usually resulting from the anchor to surface line contacting the bed during low tides. Mooring buoys located in higher current areas have a greater potential for disturbing marine vegetation than those in sheltered bays. Buoys in areas with prevailing wind/wave patterns that counteract current regimes tend to show a "v" shaped disturbance impact on vegetation. Vegetation types were Z. marina, ulva and laminaria. Laminaria may be more resistance to disturbances than eelgrass or ulva. This may be due to its laying prone to the bed rather than vertical in the water column.**Conclusions:** Marine vegetation can be impacted by a single mooring surface line scouring the bed. The cumulative impact of mooring buoy installations in our marine waters is probably significant. Mooring buoy installation design, tides, water, depths, water currents, prevailing wind/wave patterns, and marine vegetation type are variables that determine the shape and extent of the disturbance. Moorings using designs 1 and 2 demonstrated little or no impact where 93% of designs 3, 4, and 5 demonstrated impacts. Design 6 appears to have the greatest potential for significant marine vegetation impact if improperly installed. The effectiveness of designs 1 and 2 rely on using the proper rope lengths relative to maximum water depth, sizes and types of rope used.

216. Wilson, R. C. H. R. J. Beamish F. Atkins and J. Bell. 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 EnvironmentNanaimo British Columbia: British Columbia/Washington Environmental Cooperation Council; 1994. v. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1948).

Keywords: straits//Puget Sound//biota//status/fish//vegetation//salmon/birds//marine mammals//water quality//sediments//MPA//reserves//habitat impacts//oceanography//marine birds

Abstract: This report describes the shared waters of the Strait of Georgia/Puget Sound ecoysstem, characteristics of the area, transport mechanisms, contaminant transport, status and trends of biological resource populations, anthropogenic impacts on habitat, aquatic biota, salmonids, bottomfish, invertebrates, marine birds and mammals, ecosystem sensitity to anthropogenic impacts, harm and management priorities, needs and principles of sound ecosystem management, and recommendations for more effective environmental management.

217. Wilson, Ulrich W. and J. B. Atkinson. Black Brant winter and spring staging use at two Washington coastal areas in relation to eelgrass abundance. The Condor. 97(1):91-98.

Keywords: birds//straits//eelgrass//nearshore/

Abstract: We monitored numbers of black Brant (*Branta bernicla nigricans*) in Washington from fall 1980 through spring 1992 at Willapa Bay, and from fall 1986 thorugh spring 1993 in the Dungeness area. We estimated brant use by converting the counts into use days. Coincidentally, we also monitored variation in the extent of eelgrsas (*Zostera marina)* beds by remote sensing techniques. At Willapa, brant use was positively correlated with the total textent of eelgrass beds and negatively correlated with the extent of oyster beds that were located within eelgrass beds, and where eelgrss had been removed by mehanical means. A 52% decline in brant use was associated with a 22% decline in eelgrass. At Dungneess, there was a signficant negative trend in spring-staging brant use. Overall, a 63% decline in brant use coincided with a 31% decline in eelgrass. The Dungeness eelgrass beds may have declined because of natural factors. In both areas, brant use during the spring-staging period was more related to eelrass extent than brant use during the winter months. These results suggest that Black Brant use in coastal Washignton is limited by eelgrass availability. Immatures averaged 10.4% of the population at Willapa and 9.9% at Dungeness and are amongst the lowest reported. A shortage of eelgrass during the critical spring-staging period may have led to reduced endogenous reserves and associated low reproductive success of Black Brant that staged in coastal

Washington. The sthortage of eelgrass may have contributed to the observed southward shift to Mexico by wintering brant.

218. Wingert, R. C. and B. S. Miller. Distributional analysis of nearshore and demersal fish species groups and nearshore fish habitat associations in Puget Sound. UW, Fisheries Research Institute. 1979. FRI-UW-7901.

Keywords: fish//nearshore//Puget Sound//bottomfish//groundfish

Abstract: This study, at three sites in central Puget Sound, provided extensive documentation on the seasonal occurrence abundance, and distribution of many nearshore and demersal fishes. In addition, the dominant nearshore and demersal species assemblages which occurred at the study sites were determined. Objective: 1) better understand the ecological relationships among the fishes which compose nearshore and demersal species assemblages, 2) predict the possible effects of chronic or catastrophic pollution on the nearshore environment, and 3) determine the food web pathways through which pollutants introduced to the marine environment might be transferred to man.

This report summarizes 1) the food habits of most ecologically important nearshore and demersal fishes in central Puget Sound, 2) the life history stage and seasonal changes in dietary composition for the most abundant species, and 3) preliminary food webs for the important nearshore and demersal fishes.

219. Wingert, R. C. C. B. Terry and B. S. Miller. Food and feeding habits of ecologically important nearshore and demersal fishes incentral Puget Sound.Final Report ed.. Olympia, WA: Dept. of Ecology; 1979.

Keywords: fish//Puget Sound//nearshore

Abstract: This study synthsized food habit data collected from previous sampling of nearshore and demersal fishes. Dietary composition, functional feeding groups, and food web relationships of flatfishes, sculpins, ronquils, poachers and water column fishes are discussed.

220. Wolfenden, J F. Cram and B. Kirkwood. Marine reserves in New Zealand: a survey of community reactions. Ocean and Coastal Management.25: 31-51.

Keywords: MPA//marine reserves//marine protected areas

Abstract: Social aspects in relation to the establishment of marine reserves have received little attention compared with the study of bio-physical phenomena. Subsequent to the passing of the Marine Reserves Act (1971), New Zealand led

the world in protection of the marine environment with an area of non-extraction at Goat Island, Leigh. During the intervening years, no additional mainland marine reserves were created until the designation of Cathedral Cove marine reserve in1993. The present study examined the nature of community reactions to marine reserve proposals. Beliefs, attitudes and knowledge regarding marine reserves were explored and related to the stance of the respondent (i.e. supporting or opposing a proposal for a marine reserve in their vicinity). Sample populations of 200 rate-payers from four target areas (two high-impact and two low-impact control areas) participated in a questionnaire study. Results confirmed the hypotheses that the establishment of marine reserves would be supported by the majority of respondents, dependent on the implementation of comprehensive social and environmental impact assessments, resulting in the identification of appropriate sites. Public involvement in the planning process, concomitant with information, communication and compromise were identified as strategies for reducing intergroup conflict. The findings of the present research have implications for legislation, implementation, policy-making, management and public relations relevant to the establishment of marine reserves.

221. Woolrich, B. and G. Patrick. Puget Sound Ambient Monitoring Program - shellfish monitoring. Puget Sound Research '95; 1995 Jan 12-1995 Jan 14; Bellevue, WA. Olympia, WA: Puget Sound Water Quality Authority; 1995: pages 51-56.

Keywords: shellfish//chemical contaminations//contaminants//fecal coliform//PSP//water quality//

Abstract: This paper summarizes results of shellfish tissue monitoring form the Pugeet Sound Ambient Monitoring Program (PSAMP) carried out by the Washignotn Department of Health's Office of Shellfish Programs.

222. Wright, Sam. 1999. Petition to the Secretary of Commerce to list as threatened or endangered 18 species/populations or ESUs of Puget Sound marine fishes and to designate critical habitats.

Keywords: fish//cod//hake//pollock//lingcod//herring//rockfish//Puget Sound//straits//vegetation//habitat

Abstract: This is a petition to list as threatened or endangered eighteen (18) species/populations of marine fishes and to designate critical habitats. The petition identifies the species: Pacific herring, Pacific cod, walleye pollock, Pacific hake, brown rockfish, copper rockfish, quillback rockfish, greenstriped rockfish, widow rockfish, yellowtail rockfish, black rockfish, China rockfish, tiger rockfish, bocaccio, canary rockfish, redstriped rockfish and yelloweye rockfish. The petition summarizes the reasons for the proposed listings. Seven of these species were selected for status review.

223. WSDA. 2000 Spartina Management Plan for the Strait of Juan de Fuca/Pacific Ocean: Washington State Department of Agriculture.

Keywords: nearshore//vegetation

Abstract: Maps and describes spartina infested areas. Spartina infestation sites include: Kala Point, Oak Bay, Scow Bay, Mats Mats, Whalan Point, Fort Flagler, Indian Island and Discovey Bay.

224. Wyllie-Echeverria, S. A. M. Olson and M. J. Hershman eds. Seagrass science and policy in the Pacific Northwest: Proceedings of a seminar series1994. v. (SMA 94-1).

Keywords: seagrass//seagrass policy//Washington//vegetation//nearshore

Abstract: This collection of papers presents recent scientific work on the distribution and species of seagrasses in the Northeast Pacific, faunal association and ecological interactions in seagrass communities in the Pacific Northwest Coast, incorporating eelgrass population biology into management, light environment implications for management, critical seagrass inventory needs. It addresses Washington State seagrass management, eelgrass restoration issues, and suggests a framework for evaluating and developing seagrass policy in the Pacific Northwest.

225. Yake, Bill S. Singleton and K. Erickson. Washington State dioxin source assessment. Olympia, WA: WA Dept. of Ecology. 1998 Jul; Publication No. 98-320.

Keywords: contaminants//water quality//dioxin

Abstract: Reports on findings of chlorinated dioxins and furans that bioaccumulate in human and animal tissue. This dioxin source assessment sought to summarize what is known about dioxin sources in Washington State and recommend actions. Potential sources of dioxin include contaminated sites. For the purposes of this report, a "source category" is defined as a group of sources engaging in a similar process (e.g. incineration or wood-treating with pentachlorophenol). Wood treating, municipal and medical waste incinerators. bleached pulp process, cement kilns, hog-fuel boilers and structure fires are examples of sources. Municipal wastewater treatment plants can pass on dioxins in discharge from sources discharged to the plant. The report reviews the structure of such chemicals and into incorporation in the human and animal food web. Port Townsend Paper Corp. is listed as a hog fuel burning facility.

226. Yoklavich, Mary M., editor. Marine harvest refugia for west coast rockfish: a workshop. La Jolla, CA: NOAA, NMFS, Southwest Fisheries Science Center (Springfield, VA): available from National Technical Information Service; 1998; NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-255.

Keywords: rockfish//fish//harvest//fish//MPA//reserves

Abstract: This paper describes the methods used to monitor the response of rockfishes to no-take refuges in Puget Sound. Differences in density, size and reproductive output between fished rock areas and no-take refuges were compared. These results confirm size truncation, decreased population abundance, and a reproductive potential that is less than 10% that of historical levels for heavily fished rockfishes.High site fidelity and small home ranges make copper, quillback and brown rockfishes suitable candidates for a no-take refuge management regime. This paper discusses techniques and methods used to monitor rockfish and other fish populations in no-take refuges.

APPENDIX A

Figure 1. Puget Sound Stations with DO<3mg/l (black), <5 mg/l (gray), >=5 mg/l (clear) during Wateryear 96-97

Figure 2. Puget Sound Stations with >0.14 mg/l (black), >0.07 mg/l (gray), and<=0.07 mg/l (clear) ammonium-N concentrations during Wateryear 96-97

Figure 3. Puget Sound Stations with fecal coliform counts >50 org/100 ml (black), >14 orgs/100ml (gray), and <= 14 orgs/100 ml (clear) during wateryear 96-97

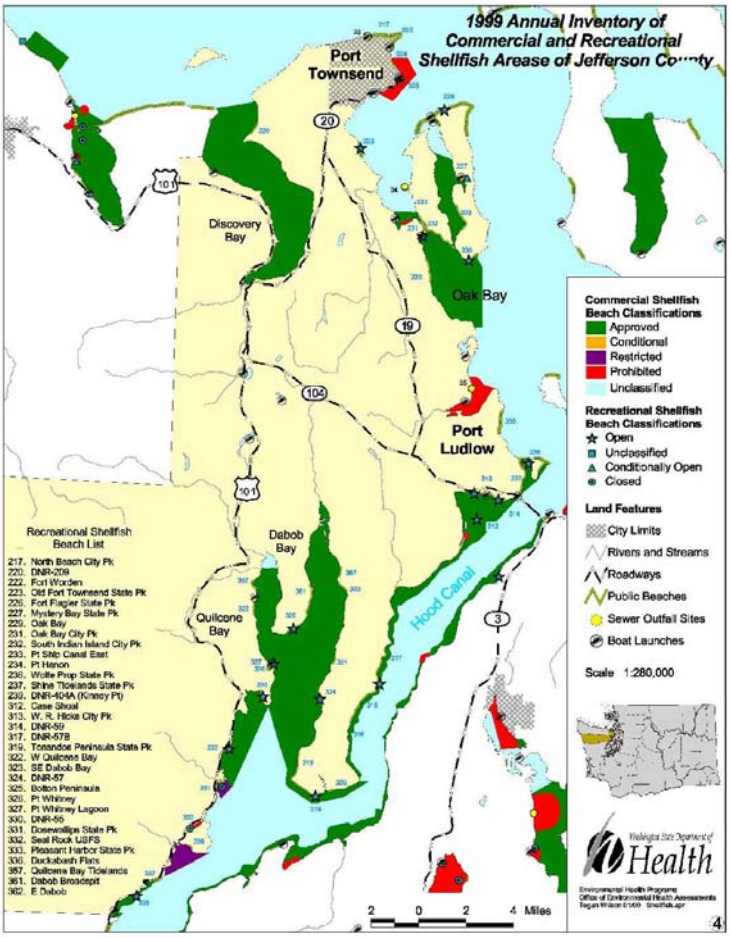


Figure 4: Shellfish Classification

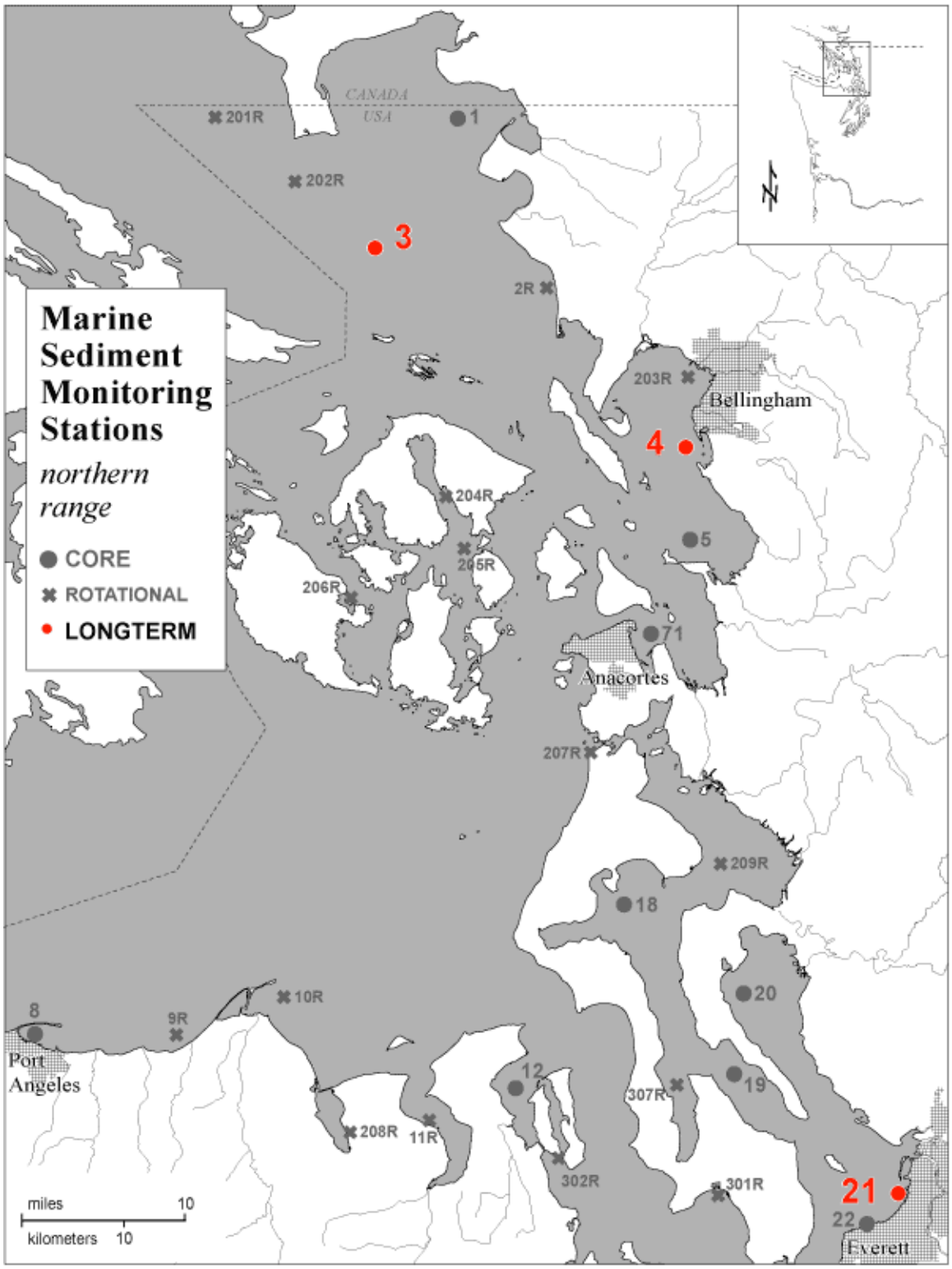
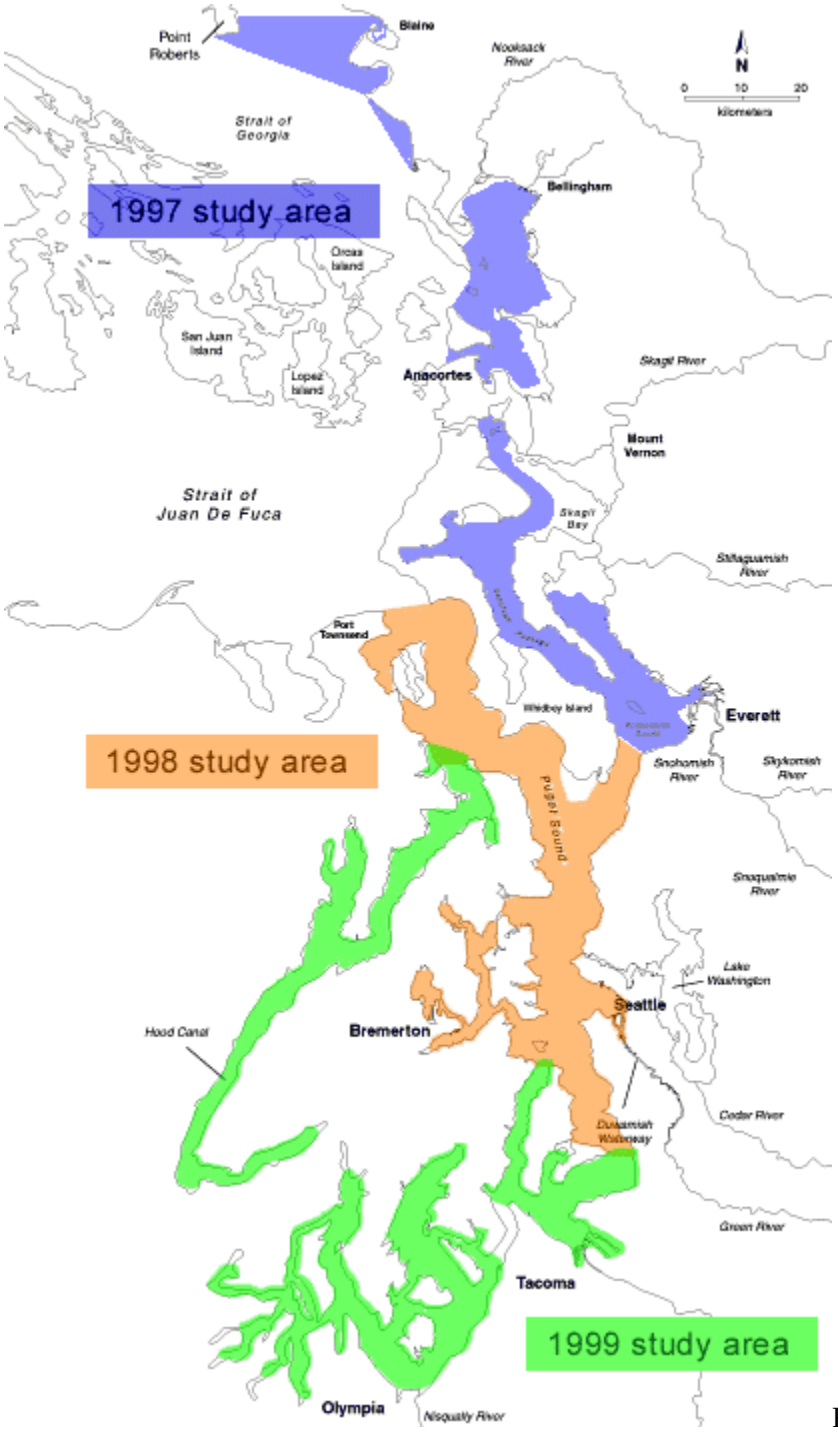


Figure 5: DOE Marine Sediment Monitoring Stations



Figure

Figure 6: DOE Marine Sediment Study Areas

APPENDIX B

Table 1: Estuarine and Marine Classification -Natural Heritage Program

System	Substrate	Wave Energy	Depth	Plants	Fish	Shellfish
Marine Intertidal	rock	exposed partially exposed semi-protected	eulittoral	rockweed, algae, kelps, surfgrass coralline algae,	sea perch, sculpins, rockfish, cod, high cockscomb, sculpins, clingfish, prickleback	mussels, barnacles, crab, limpets, chitons
	cobble	partially exposed		algae	herring spawn, sculpins, clingfish, gunnels	barnacles, clams, crab, shrimp
	mixed-coarse	semi-protected protected		seasonal drift algae		shrimp, clams
	gravel	partially exposed		none	shiner perch, juv. tomcod Eng. sole, starry flounder, gunnels, sculpins, surf smelt spawn, sand lance larvae	amphipods, shrimp
	gravel	semi-protected		algae	shiner perch, juv. Eng. sole, flounder, sculpins	clams, crab
	sand	exposed partially exposed		none	sole, flounder, Pac. sand lance, Pac. tomcod, perch, sculpins, gunnels, surgeon poachers, Pac. herring, surf smelt	clams, shrimp
	sand	semi-protected protected		eelgrass, algae,	sole, juv.salmonids, sculpin, surf smelt, sand lance and candlefish larvae	clams, shrimp
	mixed fines	semi-protected protected		eelgrass, algae, drift algae	juv. Pac. tomcod, lingcod, tube-snout, pipefish, perch, prickleback, gunnels, sculpin, poacher, sanddab, surf smelt, juv. Eng. sole flounder	clams, crabs, shrimp
	mud	protected		eelgrass, algae	flounder, juv. Eng. sole, tube-snout, perch, pipefish, guennl, goby, sculpins, herring spawn	
Marine Subtidal	rock & boulders	mod to low energy	shallow	surfgrass, eelgrass, algae	greenlings, rockfish, sculpins, cabezon, gunnels, perch	crabs, scallops, chitons, abalone, snails, urchins
	gravel	high & low energy	shallow	algae	greenlings, rockfish, sculpins, cabezon, gunnels, perch, flatfish	snails
	mixed-fines	moderate to high energy	shallow	algae	juv. Eng. sole, sole, flounder, juv. Pac. tomcod, poachers, sculpins, perch	bivalves, scallops, crabs, snails, geoducks, clams
	mud mixed-fines	low energy	shallow	algae	tube-snout, pipfish, greenling, sulpins, Pac. sand lance, flouder, juv. Eng. sole, sole, perch, gunnel, juv. lingcod, sanddab	crabs, snail, bivalves
Estuarine Intertidal	mixed-coarse	open	euittoral	algae; often eelgrass beds lie just subtidally of these beaches	sculpins, juv. salmon, trout, blennies, gunnels, clingfish, perch, surf smelt, sole, stickleback, herring spawn	bivalves, clams, crabs, oysters, limpets
	gravel	open	eulittoral	ulva, algae	juv. Eng. sole, perch, cabezon, flounder sculpins, greenling, gunnels, poachers	
	gravel	partly enclosed	eulittoral marsh	pickleweed, saltwort, rockweed, sedge, martima		
	sand	open	open	eelgrass, gracilaria, drift algae	juv. salmon, flounder, goby, sculpin, Eng. sole,	clams, shrimp

Table 1 (Continued)

System	Substrate	Wave Energy	Depth	Plants	Fish	Shellfish
Estuarine Intertidal	sand mixed-fine mud	partly enclosed lagoon	eulittoral (marsh)	vascular plants, bulrush,sedge, pickleweed (depending on salinity)	perch, juv. salmon, cutthroat, stickleback	clams, crabs
	mud	partly enclosed enclosed		eelgrass		
	organic sand mixed-fine mud	partly enclosed	lagoon, marsh, backwaters	sedge, grasses, vascular plant (depending on salinity) marsh plants,ulva, eelgrass	Pac. herring, Pac. sand lance, tube-snout, juv. Eng. sole, flounder, sculpins, stickleback, pipefish, prickleback, gunnels, surf smelt, perch, juv. salmon	shrimps, crabs, moon snails, oyster,
	mixed-fines mud	channel/slough		eelgrass, lined with marsh plants	juv. salmon, stickleback, flounder, sculpin	clams, crabs
EstuarineSubtidal	rock	open	shallow	algae		chitons, limpet, crabs, snails
	cobble	open	shallow	eelgrass		crab, clams
	sand mixed fines	open	shallow	eelgrass, algae, kelp		bivalves, crabs
	mud	open	shallow	eelgrass, algae, ulva, kelp	sculpins, sole	bivalaves
	mud	partly enclosed	shallow		Pac. tomcod, flounder, sole, sculpin, smelts	bivalves, geoducks
	sand mud	channels	shallow/deep		Eng. sole, sanddab, sculpns, prickleback, Pac. tomcod, perch, peamouth, juv. salmon, flounder	crab, shrimp

Source: Estuarine and Marine Classification System - Natural Heritage Program (Dethier 1990)

Table 2: Nearshore Habitat Classificaiton for Specific Jefferson County Locations

System	Subsystem	Substrate	Wave Energy	Depth	Jefferson County Locations
Marine	**Intertidal** **Areas:** **Pt. Wilson to Cape George, Discovery Bay, and Protection Island**	**Consolidated:** bedrock, boulder, hardpan **Unconsolidated:** cobble, mixed coarse, gravel, sand, mixed fine, mud, organic **Reef** **Artificial**	**Exposed** **Partially Exposed** **Semi-Protected** **Protected**	**Eulittoral:** Areas between MHWS and ELWS **Backshore:** Areas above MHWS but receiving marine influence through spray or irregular flooding	**North Beach - cobble partially exposed and sand: exposed and partially exposed** **Beckett Pt. gravel-semi-protected**
Marine	**Subtidal** **Areas:** **Pt Wilson to Cape George, Discovery Bay, and Protection Island**	**Consolidated:** bedrock, boulder, hardpan **Unconsolidated:** cobble, mixed coarse, gravel, sand, mixed fine, mud, organic **Reef** **Artificial**	**High:** exposed to oceanic swell or very strong currents **Moderate:** exposed to wind waves and moderate tidal currents **Low:** exposed to only very weak or no currents with little wave action	**Shallow:** 15 m or less below MLLW **Deep:** over 15m below MLLW	**Beckett Pt mixed-fines: moderate to high energy, shallow**
System	**Subsystem**	**Substrate**	**Wave Energy**	**Depth**	**Jefferson County Locations**
Estuarine	**Intertidal** **Areas:** **Port Townsend Bay, Marrow- stone (west), Indian Island (east), Kilisut Hrbr, Oak Bay**	**Consolidated:** bedrock, boulder, hardpan **Unconsolidated:** cobble, mixed coarse, gravel, sand, mixed fine, mud, organic **Reef** **Artificial**	**Open:** exposed to moderate to long fetch, windwaves and/or current **Partly Enclosed:** partially enclosed with minimal wave action **Lagoon:** Protected, largely enclosed embayment **Channel/Slough:**inlets submerged w/tidal backup at high tide	**Eulittoral:** Areas between MHWS and ELWS **Backshore:** Areas above MHWS but receiving marine influence through spray or irregular flooding	**Scow Bay-sand:partly enclosed eulittoral, marsh** **Chimacum Creek marsh-channel intertidal**
Estuarine	**Subtidal** **Areas:** **Port Townsend Bay, Protection Island, Marrow- stone (west), Indian Island (east), Kilisut Hrbr, Oak Bay**	**Consolidated:** bedrock, boulder, hardpan **Unconsolidated:** cobble, mixed coarse, gravel, sand, mixed fine, mud, organic **Reef** **Artificial**	**Open:** exposed to moderate to long fetch, windwaves and/or current **Partly Enclosed:** partially enclosed with minimal wave action **Lagoon:** Protected, largely enclosed embayment **Channel/Slough:** inlets submerged with tidal backup water at high tide	**Shallow:** 15 m or less below MLLW **Deep:** over 15m below MLLW	**Admiralty-cobble: open deep** **Chimacum Creek marsh-channel**

Source: Estuarine and Marine Classification System - Natural Heritage Program (Dethier 1990)