FINAL REPORT
NORTHWEST STRAITS NEARSHORE HABITAT EVALUATION

Prepared for

Northwest Straits Commission (NWSC)
10441 Bayview-Edison Road
Mt. Vernon, Washington 98273

Prepared by

Anchor Environmental, L.L.C.
1411 4th Avenue, Suite 1210
Seattle, Washington 98101
and
People for Puget Sound
911 Western Avenue, Suite 580
Seattle, Washington 98104

January 2002

This report was funded in part through a cooperative agreement with the National Oceanic and Atmospheric Administration.

The authors of this report would like to extend their gratitude to the efforts of the many individuals who helped formulate and execute this project.

- **Project Sponsor and Funding Agent**

  The Northwest Straits Commission

  Tom Cowan, Director

  Andrea Copping, Project Manager

- **Participants of the Technical Advisory Group**

  Doug Bulthuis, Padilla Bay NERR

  Duayne Fagergren, Puget Sound Water Quality Action Team

  Terrie Klinger, University of Washington

  Scott McCreery, BP Cherry Point Refinery

  Kevin Ranker, Friends of the San Juans

  Ann Shaffer, Washington Department of Fish and Wildlife

  Charles Simenstad, University of Washington

  Suzanne Shull, Padilla Bay NERR

  Ron Thom, Battelle

- **MRC Leads**

  Laura Arnold, San Juan County

  Andy Brastad, Clallam County

  Mike Cawrse, Skagit County

  Larry Fay, Jefferson County

  Will Hall, Snohomish County

  Don Meehan, Island County

  Erika Stroebel, Whatcom County

- **Consultants**

  Anchor Environmental, L.L.C.

  Tom Schadt, Fisheries Biologist, Project Manager

  John Small, Landscape Planner

  Elizabeth Appy, Fisheries Biologist

  Paul Schlenger, Fisheries Biologist

  Betsy Yanasak, Document Production

  People for Puget Sound

  Jaques White, Ph.D., Habitat Program Director

  Philip Bloch, Landscape Ecologist and GIS Manager

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EXECUTIVE SUMMARY

The overall goal of this project was to evaluate nearshore habitat conditions in the Northwest Straits region by compiling, organizing, and analyzing existing nearshore habitat and resource datasets. The project was funded by the Northwest Straits Commission (NWSC), which oversees the operations of county-based Marine Resource Committees (MRCs) in the Northwest Straits. This project was designed to address a Benchmark of Performance detailed in the Northwest Straits Marine Conservation Initiative (1998). The benchmark specifies the need to restore and protect nearshore habitats that support marine resources in the Northwest Straits region.

The results of this project lay the groundwork for the MRCs to assess nearshore habitat conditions and identify priority restoration and/or conservation sites. The existing dataset compilation provides a common starting point for each MRC to assess county-specific nearshore habitat conditions. A database of bibliographic documentation for each relevant dataset is also provided to aid the MRCs in choosing appropriate datasets to use in a nearshore assessment and in evaluating the quality of each dataset. Data gaps were also identified to guide new data collection efforts the MRCs may initiate in the future to enhance and expand the existing knowledge base of nearshore habitats.

Habitat characterization maps were created using the identified regional datasets to characterize the physical, biological, and anthropogenic features used to describe habitat conditions in the Northwest Straits. These maps provide a general overview of nearshore habitat conditions in each of the counties in the Northwest Straits by displaying the following information:

- Map 1: Intertidal vegetation and subtidal vegetation
- Map 2: Substrate and shoreline modifications
- Map 3: Tributary streams, salmonid distributions, groundfish distributions, forage fish spawning, and holding areas
- Map 4: Shellfish distributions and beach closure areas, marine mammal distributions, and seabird distributions

The datasets used for this mapping exercise were limited to regional coverages given the large project area.

Three species-based habitat analyses were conducted to demonstrate various methods for evaluating habitat condition and assigning priorities for restoration and/or conservation using the compiled regional datasets. The species were chosen by a Technical Advisory Group (TAG) to reflect a common interest among the MRCs and on the ability to model the species' habitat quality with available data. The groups chosen were: 1) forage fish, specifically with regards to the use of the nearshore by adults for spawning; 2) nearshore rockfish, specifically with regards to juvenile and adult use of nearshore habitats; and 3) salmon, specifically with regards to the use of the nearshore by juveniles for rearing and migration.

The approach for evaluating nearshore habitat conditions based on forage fish and salmon were similar. The evaluation of habitat function for these two species was based on a conceptual framework linking shoreline modifications to ecological functions (Williams and Thom 2001). The basic premise behind this approach is that unmodified habitat types inherently provide a certain level of ecological function based on a target species (benefits). Furthermore, this level of function may be impacted to varying degrees by shoreline modifications (impacts). The habitat analyses for forage fish and salmon attempt to quantify these benefits and impacts to prioritize potential nearshore habitat restoration and conservation areas. The approach for the nearshore rockfish assessment was very different; no evaluation of habitat function was performed. Instead, a map was created detailing nearshore rockfish distributions and habitat preferences. Rocky shorelines, steep slopes, and rockfish distributions were used as an indication of potential nearshore rockfish habitat areas.

Once again, regional datasets were used in the habitat analysis due to the large extent of the project area. However, it is recommended that the MRCs incorporate existing and new local site-specific information into the analysis to address their individual restoration and/or conservation goals.

This final report includes a set of CD-ROMs containing the following items:

- All relevant regional and local datasets identified for the Northwest Straits describing nearshore habitats
- A database of bibliographic documentation for the digital datasets
- A bibliography containing reports relevant to nearshore habitats
- Nearshore habitat characterization maps by county
- Potential conservation and potential restoration maps by county and species

1 INTRODUCTION

Puget Sound is a unique environment consisting of a diverse array of marine resources. These inland marine waters serve as a center of economic activity for national and international interests, which have resulted in an influx of human settlement and development throughout the region. The heavy concentration of shoreline development has caused the modification and destruction of nearshore habitats and the depletion of important marine resources. Since 1980, populations of invertebrates, bottom fish, salmonids, marine birds, and marine mammals have declined precipitously (Washington Sea Grant 1998).

The Northwest Straits ecosystem is an integral component of the Puget Sound region encompassing the marine waters of the Strait of Juan de Fuca and northern Puget Sound from the Canadian border to the south end of Whidbey Island (Washington Sea Grant 1998). The depletion of marine resources in Puget Sound has harmed the economies and communities around the Northwest Straits, and continued rapid increases in development and population in the region foreshadow serious impacts in the future (Washington Sea Grant 1998).

In response to the indicators of marine resource depletion in the Northwest Straits, U.S. Senator Patty Murray (D) and U.S. Congressman Jack Metcalf (R) convened a citizen's panel in 1997 to identify possible strategies and solutions to the dramatic resource decline in the region. The resulting Northwest Straits Marine Conservation Initiative established the Northwest Straits Commission (NWSC) to provide oversight and coordination of restoring and protecting the marine resources of the Northwest Straits ecosystem. The NWSC is a voluntary panel of citizens who are charged with recommending steps to improve the region's sustainability. County-based Marine Resource Committees (MRCs) were formed in each of the seven northwest counties of the state including Clallam, Jefferson, San Juan, Whatcom, Skagit, Snohomish, and Island counties to support the mandates of the Initiative. The MRCs coordinate all their activities through the NWSC.

The Northwest Straits Marine Conservation Initiative outlines Benchmarks for Performance, which guide the work of the MRCs and the NWSC and provide measures of success for the program. This project was developed to inventory and evaluate nearshore habitats in order to address the benchmark specifying the need to restore and protect nearshore habitats that support marine resources in the Northwest Straits. The project was designed to compile,

organize, and analyze existing information and datasets on nearshore habitats and their condition in the region. The results intend to accomplish the following:

- Assist the MRCs in compiling existing datasets characterizing nearshore habitats
- Identify gaps in nearshore habitat information
- Identify high priority areas for habitat restoration or increased levels of conservation
- Integrate longer-term data collection efforts throughout the region

1.1 Project Goals and Objectives

The overall goal of this project was to evaluate nearshore habitat conditions in the project area by compiling, organizing, and analyzing existing nearshore habitat and resource datasets. Criteria for prioritizing potential conservation and/or restoration areas within the Northwest Straits region were developed to aid in the organization and understanding of that data. To reach this goal, the following specific objectives were determined:

- Compile and organize existing datasets on nearshore habitat conditions and marine resources in the project area and provide available documentation for each dataset.
- Develop maps of nearshore habitat conditions and marine resources in the Northwest Straits region using ArcView GIS.
- Identify gaps in nearshore habitat datasets in the Northwest Straits region.
- Develop criteria for prioritizing areas for nearshore habitat restoration and conservation.
- Evaluate habitat conditions based on their ability to support forage fish, nearshore rockfish, and salmon species and apply criteria for prioritizing nearshore habitat restoration and conservation areas.

1.2 Project Area

The project area encompasses the Northwest Straits region, which includes the nearshore areas and marine shorelines on the U.S. side of the Strait of Juan de Fuca and Strait of Georgia, and the waters of Puget Sound as far south as the southern tip of Whidbey Island including the entire marine shoreline of Snohomish and Jefferson counties (Figure 1). The region falls under jurisdiction of seven counties including Clallam, Jefferson, San Juan, Whatcom, Skagit, Snohomish and Island counties, and the state of Washington. The project area does not include the outer Pacific coast of Clallam county. The project area contains

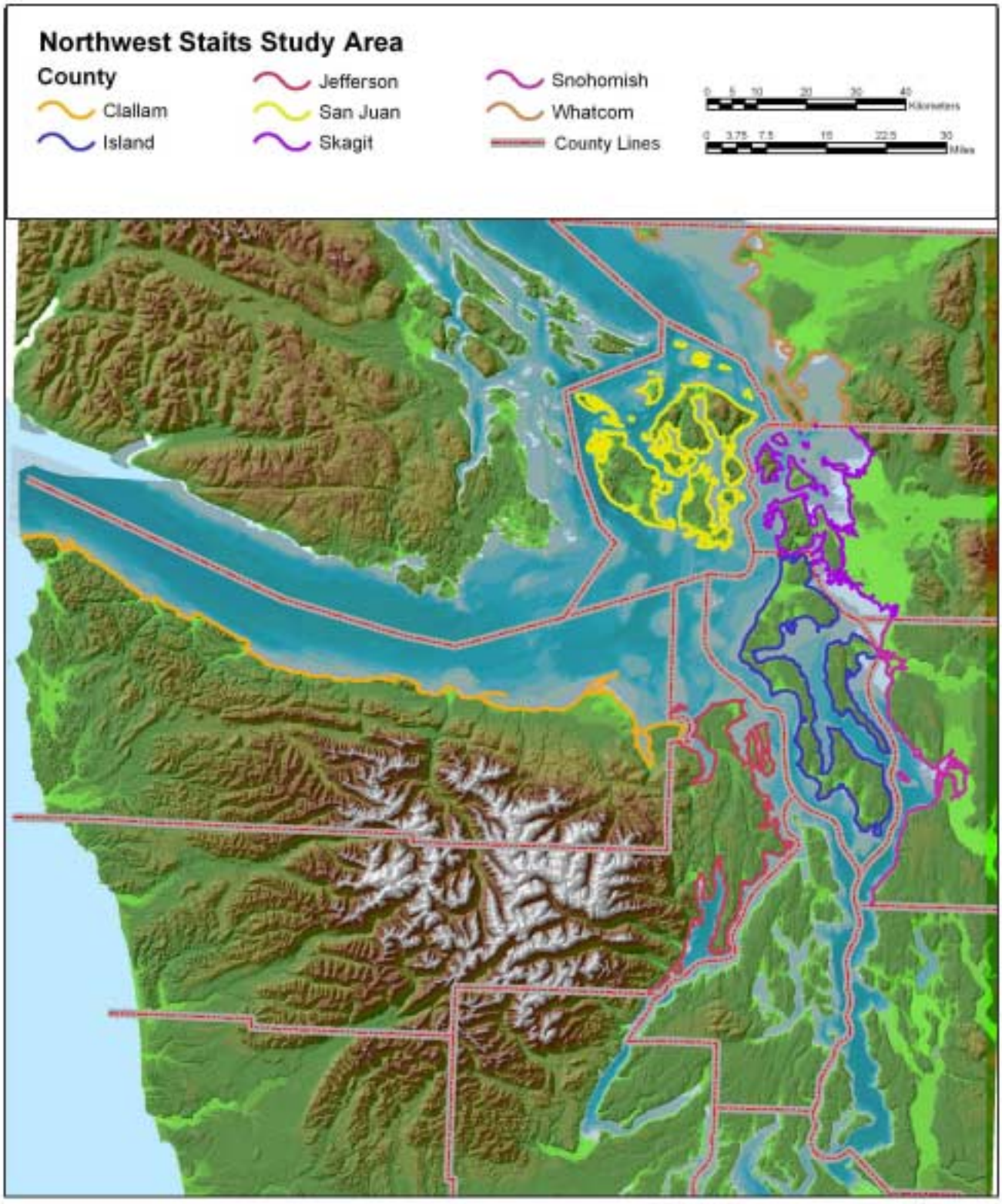


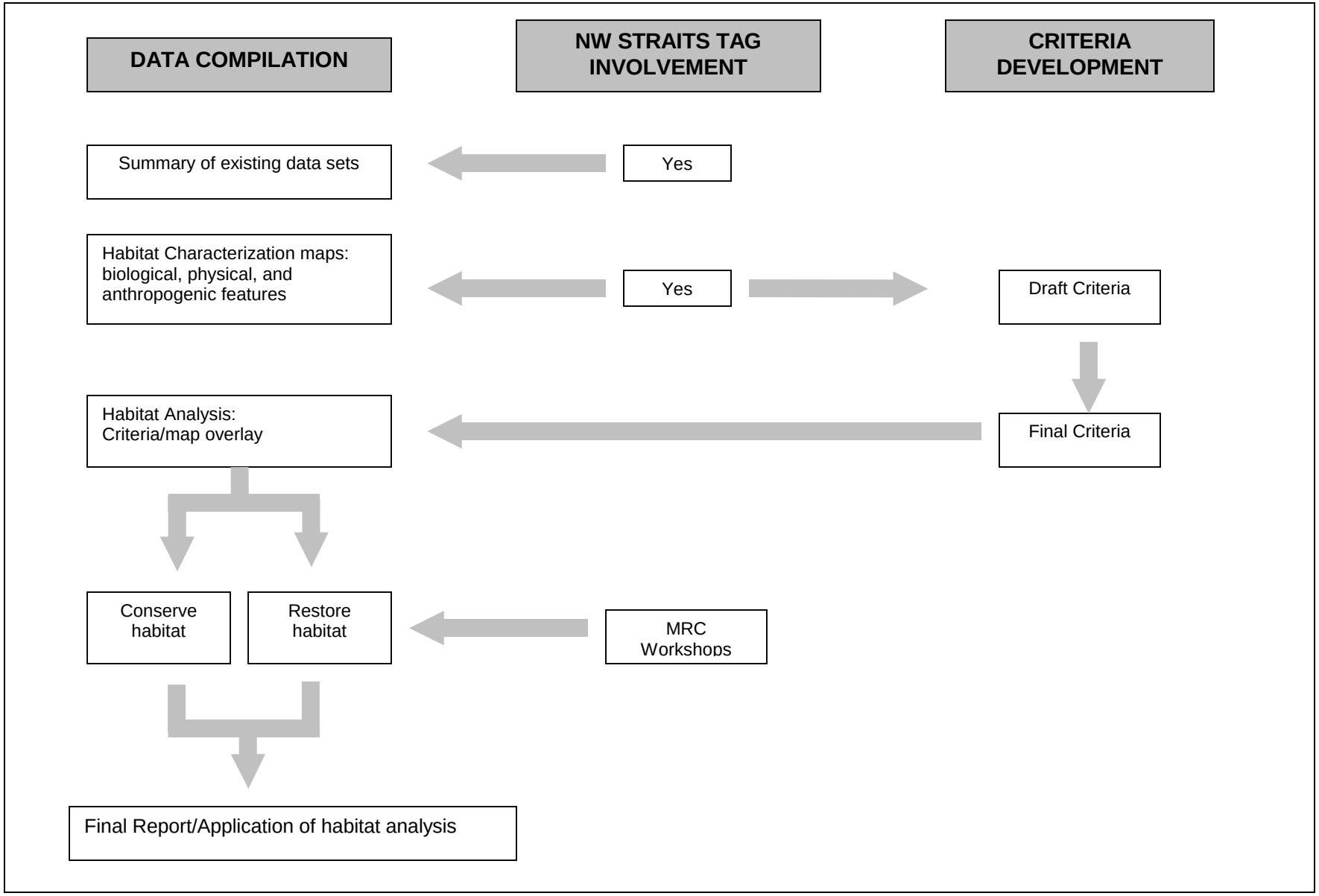
Figure 1
Vicinity Map

portions of ten separate Water Resource Inventory Areas (WRIAs) including WRIA 1,2,5-8, and 16-19.

Specifically, the project area includes the nearshore habitats contained in the geographic area previously defined. For this project, nearshore habitats are defined from a depth of 10 meters (33 feet) below Mean Lower Low Water (MLLW) to Mean Higher High Water (MHHW), including adjacent backshore areas. The lower extent of the nearshore zone (–10 meters MLLW) is based on the upper limit at which healthy benthic vegetation can be found in Puget Sound. At –10 meters MLLW down to –30 meters (98 feet) MLLW, there is a strong coupling between benthic processes (i.e., nutrient cycling) and the overlaying water column (Williams and Thom 2001). The nearshore zone also includes backshore and upland areas in which the strongest intertidal-upland coupling occurs. This is where bluffs provide the sediments that nourish beaches, the upland transition vegetation stabilizes beaches, and the fringing vegetation shades the intertidal zone and contributes insects, leaf litter, and woody debris directly into the aquatic environment (Williams and Thom 2001).

1.3 Project Approach

The project approach follows the five specific objectives identified in Section 1.1 as well as input from a Technical Advisory Group (TAG) assembled by the NWSC and individual MRC workshop reviews. An overview of the approach is depicted in Figure 2. The TAG consisted of representatives from resource agencies, the University of Washington, and county MRCs. The TAG provided input and feedback on the compilation list of existing datasets to ensure that no important sources had been overlooked. Additionally, the advisory group provided expertise on the criteria developed to determine high priority restoration and/or conservation areas. Written comments were also received from individuals who were unable to attend the two TAG meetings. In addition to the TAG meetings, individual MRC workshop reviews were conducted to present the project approach and preliminary results and solicit feedback from the public. A separate report including an outline of the public involvement process and a summary of received input is included as Appendix A.



ANCHOR ENVIRONMENTAL, L.L.C.

Figure 2
Overview of Project Approach
Northwest Straits Nearshore Habitat Evaluation

The key component of this project was to compile and organize regional and local datasets to be used in a GIS-based spatial nearshore habitat analysis. The nearshore habitat analysis was designed to be adaptive to the goals of individual MRCs and to incorporate new and updated datasets as they become available. A species-based approach was adopted to facilitate the adaptation of the analysis to the individual goals of each MRC. Therefore, the analysis illustrates three different approaches for using the compiled datasets to determine priority restoration and conservation areas based on three indicator species groups. The TAG selected the species groups to reflect, as much as possible, a common interest among the MRCs and on the feasibility of modeling habitat conditions with available data. The three groups chosen were: 1) forage fish (specifically with regards to the use of the nearshore by adults for spawning); 2) nearshore rockfish (specifically with regards to juvenile and adult use of nearshore habitats); and 3) salmon (specifically with regards to use of the nearshore by juveniles for rearing and migrating). The various approaches used in the habitat analysis reflect the amount of data that is currently available to describe habitat conditions and its relation to the target species. The datasets used for these analyses were limited to regional coverages given the large project area. However, it is expected that the MRCs will incorporate existing and new local and/or site-specific information into these analyses to address their individual restoration and/or conservation goals.

2 NEARSHORE HABITAT INVENTORY

The first task of this project was to compile and organize existing data sources that characterize the nearshore habitat conditions in the Northwest Straits. Identified datasets and reports characterizing nearshore habitats and species distributions are detailed in Appendix B and relevant digital datasets are provided on the accompanying CD ROM. A database of bibliographic documentation was developed to aid the MRCs in evaluating the quality of each identified dataset. A summary of the data documentation is provided in Appendix C, and the actual database is also provided on the accompanying CD ROM.

The habitat characterization focuses on the physical, biological, and anthropogenic features of the nearshore that define or affect the condition or function of nearshore habitats. For example, physical features and some biological attributes, such as vegetation, of the nearshore environment define the habitat setting that determines which species occupy an area. Similarly, individual species distributions indicate areas currently meeting the habitat requirements of that species. Furthermore, nearshore modifications including bulkheads, docks, and piers directly affect nearshore processes and the ecology of nearshore species (MacDonald et al. 1994; Thom et al. 1994).

The physical, biological, and anthropogenic features of the nearshore chosen to characterize nearshore habitats for this inventory include:

- Substrate
- Subtidal vegetation
- Intertidal vegetation
- Forage fish spawning distributions and holding areas
- Shellfish distributions/shellfish beach closures
- Salmon distributions
- Groundfish distributions
- Marine mammal distributions
- Seabird distributions
- Tributary streams
- Shoreline modifications

2.1 Existing Data Compilation and Data Documentation

Existing datasets were compiled from a variety of sources including state and federal agency surveys and reports, local and county research, tribal research, and university research. State and federal agency publication lists including Washington Department of Fish and Wildlife (WDFW), Washington Department of Natural Resources (WDNR), Washington Department of Ecology (WDOE), Washington Department of Health (WDOH), National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), United States Fish and Wildlife Service (USFWS), United States Geological Service (USGS), and the United States Army Corps of Engineers (USACOE) were searched for documents and datasets detailing nearshore habitat conditions in the Northwest Straits region. Individual County MRC lead contacts and tribal contacts were polled for identification of local efforts to collect nearshore habitat and species information. Identification of local datasets relied heavily upon "word of mouth" recommendations from county representatives. Additionally, the University of Washington Library databases were searched for any publications and/or datasets describing nearshore habitat conditions in the Northwest Straits region.

The key regional datasets identified for the habitat inventory included Washington State's ShoreZone Inventory (WDNR), WDFW's Priority Habitats and Species Database, Streamnet, WDFW's Rockfish Distribution in Puget Sound dataset, WDFW's Atlas of Seal and Sea Lion Haulout Sites in Washington, the Puget Sound Ambient Monitoring Program's marine mammal and bird distribution database, the Puget Sound Water Quality Action Team's 1992 Puget Sound Environmental Atlas Update, and WDOH's Annual Inventory of Commercial and Recreational Shellfish Areas. A detailed description of each dataset is given below:

- WDNR's ShoreZone Inventory: this inventory characterizes the geomorphic and biological resources of the intertidal and nearshore habitats of the entire Puget Sound coast, including the Northwest Straits region. Aerial imagery was taken at low tide providing a "snap-shot" in time of habitat conditions. This dataset was used to map substrate, subtidal and intertidal vegetation, and shoreline modifications.
- Priority Habitats and Species Database: this database includes information collected by WDFW based on field surveys, reports from reputable sources, and best professional judgment of their biologists. Datasets contained in this database

include the Marine Resource Division's data on shellfish distributions (crabs, clams, and oysters) and forage fish spawning areas; mapped areas that support diverse, unique, and/or abundant communities of fish and wildlife (i.e., eelgrass); wildlife heritage points including non-game species of concern and state and federal listed species; marbled murrelet distributions; and seabird distributions.

- StreamNet: this database is a cooperative venture among the Pacific Northwest's fish and wildlife agencies and tribes containing statewide anadromous fish distribution information compiled by fish experts from many different agencies and organizations.
- Rockfish Distribution: this dataset details density of rockfish derived from underwater video surveys of rocky reef areas conducted by Wayne Palsson of WDFW.
- The Atlas of Seal and Sea Lion Haulout sites: this dataset contains information on haulout sites for Harbor seals (*Phoca vitulina*), Steller sea lions (*Eumetopias jubatus*), California sea lions (*Zalophus californianus*), and Northern elephant seals (*Mirounga angustirostris*) located in Washington waters.
- Puget Sound Ambient Monitoring Program: this dataset contains seasonal (summer and winter) sightings of marine bird and mammal species observed during aerial surveys between 1992 and 2000.
- 1992 Puget Sound Environmental Atlas Update: this data source is a compilation of marine resource datasets for the Puget Sound region. Information contained in the atlas includes shellfish distributions (clams and oysters); pinniped haulout sites, marine mammal distributions (whales and porpoises); seabird nesting areas; groundfish distributions; tribal, commercial and recreational fishing areas; and wastewater discharge sites.
- The Annual Inventory of Commercial and Recreational Shellfish Areas: this database contains WDOH's information on state-owned beaches including those on WDNR property and county owned beaches open to recreational shellfish harvesting; and information on beach closures.

Additionally, a number of relevant datasets were identified that are not currently available, but will be released some time in 2002. The key regional datasets in this category are summarized below and all (local and regional) are detailed in Appendix B.

- Net shore-drift: this dataset depicts the net longshore drift of sediment between two points representing a closed or nearly closed system in areas throughout the Northwest Straits. The Washington Department of Ecology and Western Washington University cooperated in a series of net shore-drift studies of the Washington marine shoreline, including Schwartz's report for the Pacific Ocean and Strait of Juan de Fuca Region and Northern Bays and Straits Region, and Johannessen's report for San Juan, and parts of Jefferson, Island, and Snohomish Counties.
- NOAA/USGS LIDAR Bathymetry: this dataset depicts bathymetry readings obtained from Light Detection and Ranging (LIDAR), a technology that utilizes a laser transmitter and receiver for water surface and sea bottom detection. Each depth measurement is referenced to a horizontal position accurate to three meters and a vertical position accurate to 15 centimeters.
- WDNR Marine tidelands and subtidal ownership: this dataset details the ownership of marine tidelands and subtidal areas.

Additional datasets from a variety of sources were identified at the local level, which are detailed in Appendix B and C and are supplied on the accompanying CD ROM.

2.2 Habitat Characterization Maps

Habitat features and shoreline configurations were mapped using ArcView GIS. Data layers were grouped together in appropriate subsets and are displayed separately for each county. The maps are provided electronically on the accompanying CD ROM. The data layer subsets displayed in each map are listed below:

- Map 1: Intertidal vegetation and subtidal vegetation
- Map 2: Substrate and shoreline modifications
- Map 3: Tributary streams, salmonid distributions, groundfish distributions, forage fish spawning areas, and herring holding areas
- Map 4: Shellfish distributions and beach closure areas, marine mammal distributions, and seabird distributions

Together, the maps characterize the physical, biological, and anthropogenic features that are used to define the habitat conditions in the Northwest Straits region. Maps 1 and 2

(included on the accompanying CD ROM) show the physical, biological and anthropogenic features that define a habitat setting. Maps 3 and 4 (included on the accompanying CD ROM) illustrate areas utilized by marine fauna and indicate that these areas are providing at least some of the habitat requirements necessary for the survival of these species.

These maps were created using only those datasets with regional coverage due to the extensive regional scale of this project. They are intended to give a general overview of the resource and habitat conditions found throughout the Northwest Straits region. It is anticipated that the individual MRCs will adapt these maps to include local datasets. It should be noted that the identification of specific habitat features in specific areas should be either ground-truthed or checked against more detailed local datasets (if they exist) or local knowledge for accuracy due to the limited resolution of the regional datasets.

2.3 Identification of Data Gaps

Data gaps for nearshore habitat information were identified through the data compilation and habitat characterization maps. The identification of data gaps is intended to guide future nearshore habitat data collection efforts that may be initiated by the individual MRCs.

The following list represents lapses in information common to nearshore datasets in general:

- A lack of complete coverage by region and county exists in most of the available nearshore habitat data. Only a few datasets cover the entire Northwest Straits region (i.e., ShoreZone) or an entire county. Most of the identified datasets cover only a portion of the region and/or county of interest.
- The regional datasets are limited in resolution at specific sites (i.e., +/- 0.25 miles).
- There is limited knowledge of species-habitat associations for marine species, especially rockfish. Species-habitat associations are important for determining the effect of impaired habitat condition on biological resources.

The following data gaps were identified in specific physical, biological, or anthropogenic features defining distinct nearshore habitat areas:

- There is a lack of subtidal/intertidal vegetation and substrate data. The main source of marine vegetation and substrate data for the Northwest Straits region is

ShoreZone, which is limited by two factors: 1) the ability of the surveyor to determine vegetation type in each zone from a helicopter 300 feet off the ground traveling 60 miles per hour; and 2) much of the area is under water.

- There is limited information on shellfish distributions throughout Puget Sound. A majority of the shellfish distribution information is derived from recreational and commercial harvest areas. There is a need to determine all areas where shellfish are located, whether they are harvested or not.
- There is a lack of information on groundfish, specifically rockfish, distributions and life history traits.
- Very little current information exists on the benthic invertebrate (i.e., polychaetes, molluscs) species found in the inter- and shallow sub-tidal areas of the Northwest Straits region.
- Additional information is needed to determine where forage fish spawning surveys have and have not occurred. WDFW has an extensive dataset detailing areas where forage fish have been identified spawning, but it is unclear where surveys have and have not been performed.
- Historic observation data seldom indicates the date of observation. It is important to consider the date of observation for any analysis, especially for species that are highly mobile or use habitat infrequently, as is the case with forage fish spawning locations.

3 NEARSHORE HABITAT ANALYSIS

3.1 General Methods and Objectives

The overall objective of the habitat analysis was to provide the MRCs with a cursory interpretation of the regional datasets that have been compiled. Three key species groups were selected by the TAG to characterize habitat quality for the entire nearshore study area, and to identify general areas for conservation and restoration. The selection of these species groups greatly affects the habitat types and qualities that are considered preferable in the analysis. The three species chosen represent a compromise among the myriad of species that use the nearshore, the limited time and resources of the project scope, and the data available to support such analysis. The species groups chosen were forage fish, specifically with regards to the use of the nearshore by adults for spawning, juvenile salmon, specifically with regards to the use of the nearshore by juveniles for rearing and migration, and nearshore rockfish, specifically with regards to juvenile and adult use of nearshore habitats. Three different approaches were used to determine priority restoration and conservation areas for the target species to demonstrate how these datasets may be interpreted. Each approach reflects a specific restoration and/or conservation goal related to a target species and is limited by the nearshore habitat datasets that are available.

The three approaches provide a starting point for each MRC to consider when beginning to evaluate nearshore habitat restoration and conservation potentials in their specific counties. Any habitat analysis carried out at this regional scale should be considered very coarse. The results of this analysis are useful for considering the type and intensity of restoration required at the landscape scale, but should not be used to make specific site recommendations. The integration of higher resolution data is recommended for making site-specific restoration or conservation decisions.

The general method of analysis employed for determining priority restoration and/or conservation areas for forage fish and salmon habitat was an evaluation of habitat criteria to determine habitat function related to the target species. The evaluation of habitat function was based on the Williams and Thom (2001) conceptual framework linking shoreline modifications to ecological functions (Figure 3). In this framework, the habitat functions that nearshore areas provide are the result of the biological resources (i.e., nearshore vegetation communities providing shade or cover) and landscape context (i.e., proximity to a herring holding area) of that area. In turn, the biological resources and landscape context

are controlled by the physical features of the habitat (i.e., sand beach, bluff). Physical features may be impacted to varying degrees by shoreline modifications. In this way, the impacts of shoreline modifications on physical features, landscape context, and biological resources are manifested as changes to the ecological function of a habitat. Given these linkages, and the difficulty in directly quantifying habitat functions, information on physical features, biological resources, and landscape context were used to evaluate the ecological function of habitats in the Northwest Straits.

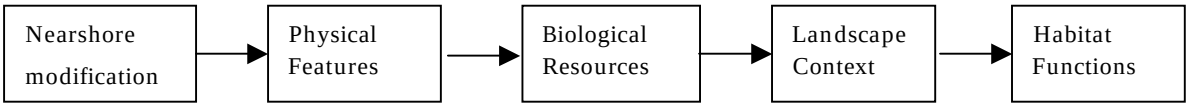


Figure 3
Conceptual Model Linking Shoreline Impacts to Ecological Functions (from Williams and Thom 2001).

A different method was used for evaluating nearshore rockfish habitat than for the other two species and was limited to identifying potential rockfish habitat areas through mapping rockfish distributions and habitat preferences. No evaluation of habitat function was performed. Maps featuring rocky shorelines, steep slopes, and rockfish distributions were used as an indication of potential nearshore rockfish habitat areas.

The resolution of the maps generated for the habitat analysis is dependent on the resolution of the datasets supporting them. In many cases, the dataset is WDNR's ShoreZone. The stated resolution of this data is, "approximately 0.5 mile." In practice, the Northwest Straits study area contains ShoreZone units that range from less than 60 feet in length to over 30,000 feet. Other datasets used in these analyses have unique limitations to their resolution and accuracy. The results of each analysis have been manually calibrated individually for each county. This is to provide some useful qualitative direction to the MRC's restoration and conservation efforts. The included bibliographic database and metadata resources contain information about these limitations from both the original authors and the Northwest Straits Nearshore Habitat Assessment Project Team.

3.2 General Assumptions

The habitat analysis conducted for forage fish and juvenile salmon relies on an evaluation of habitat criteria to determine the ecological function of the habitat. In order to conduct such an evaluation, a number of assumptions are made. The first assumption is that nearshore habitats provide key functions, which promote forage fish and salmon survival. These specific assumptions are described in more detail in Sections 3.3 (forage fish) and 3.4 (salmon). The second assumption behind the habitat analysis is that habitat quality and function can be considered the sum of the following four distinct categories:

- **Physical Features:** The distinct geomorphic habitat type as characterized by surficial geology and shore slope.
- **Landscape Ecology:** The landscape scale context of the site. For example its proximity to a feeder bluff or salmon bearing streams.
- **Biological Resources:** The biological condition of the site as characterized by the nearshore vegetation communities present.
- **Nearshore Modifications:** The anthropogenic modification of the shoreline, namely the presence, nature, and magnitude of bulkheads, armoring, docks, and piers.

3.3 Forage Fish Spawning Habitat Analysis

For this project, forage fish include populations of Pacific herring (*Clupea harengus*), surf smelt (*Hypomesus pretiosus*), and Pacific sand lance (*Ammodytes hexapterus*). While relatively little is known about adult life stages of forage fish, an understanding of their spawning preferences and requirements is developing. This understanding is based both on detailed scientific studies and long-term monitoring efforts. Washington Department of Fisheries (now part of the Department of Fish & Wildlife) began shoreline surveys focused on identifying forage fish spawning areas in 1972. Based on information obtained during these surveys, surf smelt and sand lance are thought to spawn selectively on shorelines that have large continuous deposits of either sand or pea-gravel sized sediment in the upper intertidal zone (Bargmann 1998). In addition to specific substrate preferences and requirements, forage fish eggs tend to have lower mortality when there is riparian vegetation, which can shade the shoreline and moderate temperatures, adjacent to the shoreline. (Robards et al. 1999). Pacific herring vary slightly from the other species of forage fish in that their spawning is primarily in the lower intertidal and shallow subtidal zones, and therefore their habitat requirements are focused on vegetation such as eelgrass or algal turfs (Penttila personal communication 2001).

The approach for the forage fish habitat analysis is based primarily on determining characteristics that are consistently found at locations where forage fish are found to spawn. These characteristics were derived by examining known spawning locations to develop a conceptual model of habitat preferences for forage fish. Such a conceptual model creates a search image that aids in the detection of current and potential forage fish spawning habitat. It is especially important to determine both current and potential spawning habitat because forage fish tend to use locations inconsistently – a site may be abandoned for no apparent reason only to become used again at some point in the future.

A conceptual habitat model was developed to identify potential and actual forage fish spawning habitat. This analysis relies on two primary information types: 1) expert opinion including correspondence with field biologists (i.e., Dan Penttila, WDFW) and literature reviews; and 2) identifying habitat conditions at known spawning locations throughout Puget Sound.

3.3.1 Habitat Function Scores

The analysis consists of two primary components. The first component evaluates habitat function assuming unmodified shoreline conditions (i.e., no shoreline armoring). This unmodified shoreline component of the analysis characterizes the potential habitat function that can be provided in the absence of modification by humans and is based upon the inherent differences in the level of ecological function (i.e., spawning habitat) provided by different habitat types. This portion of the analysis is divided into four subsections: 1) historic site specific-spawning records; 2) physical habitat types of the area; 3) biological resources at or adjacent to the area; and 4) landscape context of the area.

The second component of the analysis characterizes habitat function impacts resulting from human habitation and development. In this modified habitat component of the analysis, each type of shoreline modification (i.e., bulkheads, overwater structures, fill, etc.) is assigned a negative score in order to characterize the relative detrimental impacts of the modification. Scores were developed based on an interpretation of a literature review of the relative impact of each modification on the identified ecological function

(i.e., spawning habitat). Shoreline modification data used for this component of the analysis were taken from WDNR's ShoreZone.

Unmodified Habitat Function Scores

Intertidal and shallow subtidal physical habitat types provide the basis of the unmodified component of the analysis. Forage fish rely on a healthy intertidal and nearshore subtidal zone for spawning habitat. Different species utilize different parts of the intertidal and subtidal zones; with sand lance and surf smelt spawning primarily in the substrate of the upper intertidal and Pacific herring spawning primarily on intertidal or subtidal vegetation. The presence of riparian, and inter- and shallow subtidal vegetation was incorporated into the model as a modifier to physical habitat type that added to the habitat function score. Each physical habitat type and modifier was assigned a score for the degree of function it provides for forage fish spawning, and where relevant, habitat scores are associated with specific species. Scores were developed based on an interpretation of a literature review, expert consultation, and correlation analyses on the relative contribution of each physical habitat type and modifier on the identified ecological function.

For each physical habitat type and habitat modifier, scores were assigned for the key ecological function. Each score ranged from 0 (no function) to 100 (full function). Total scores were established by summing the individual scores assigned for each ecological function. The scoring system assigned for unmodified habitat conditions is presented in Table 1.

Table 1
Unmodified Habitat Scores for Forage Fish

Habitat Condition	Ecological Function Spawning Habitat	Score Justification
Historic Habitat Use	35	Historical spawning activity is an excellent indicator
Intertidal Habitat Type		
Sand or Gravel Substrate 1	15	Appropriate spawning substrate
Protected Bays or embayment	10	Maintains appropriate habitat
Bluffs adjacent to shoreline	5	Potential indicator of sediment source and maintains natural shoreline character
Intertidal Habitat Modifier		
Riparian Fringe	5 to 10	Shades incubating eggs and indicator of natural shoreline character
31% - 100% of shoreline	10	
1% - 30% of habitat	5	
Eelgrass – Continuous	10	Food source, source of refuge and spawning substrate for herring
Eelgrass – Patchy	5	
Salt marsh	5	Food source and indicator of natural shoreline character
Kelp	5	Potential spawning substrate for herring and indicator of natural shoreline character
Site Location		
Proximity to documented Herring Holding Areas 2	5	Integral link for herring that typically spawn near their holding areas

[1]Substrate scores are important primarily for surf smelt and sand lance, but also provide an indicator of suitable habitat for vegetation.
[2]Proximity to holding areas is primarily important for herring.

Modified Habitat Function Scores

The modified habitat scores represent the negative impact that shoreline modifications have on an area's ecological function for forage fish. The modified habitat component

used a similar design and scoring system as the unmodified habitat component so that comparisons can be made between the two components.

For each habitat modification type, scores were assigned for each key ecological function. Total scores for each area ranged from 0 (no impact) to -100 (maximum impact). Scores were developed based on an interpretation of a literature review on the relative impact of each modification on each of the identified habitat functions. Total scores were established by summing the individual scores assigned for each ecological function. The scoring system assigned for modified habitat conditions is presented in Table 2.

Table 2
Modified Habitat Scores for Forage Fish

Nearshore Modification	Ecological Function Spawning Habitat	Score Justification
Residential upland development	- 10	Potential or actual impacts to shoreline
Industrial upland development	- 10	Potential or actual impacts to shoreline
Agricultural upland development	- 5	Potential or actual impacts to shoreline
Overwater Structure	- 15	Shades intertidal vegetation and may alter nearshore hydrology
Rip-rap Revetment	-5 to –20	Alters nearshore hydrology and may increase wave energy on intertidal
51-100% of shoreline	- 20	
31-50% of shoreline	- 10	
1- 30% of shoreline	- 5	
Vertical Bulkhead	- 5 to – 20	Alters nearshore hydrology and may increase wave energy on intertidal
51-100% of shoreline	-20	
31-50% of shoreline	-10	
1- 30% of shoreline	- 5	
Maritime Development (e.g. marina or boat ramp)	- 10	Potential for repeated damage and potentially altered nearshore hydrology
Sewer Outfalls	- 10	Introduction of pollutants and nutrients to nearshore

3.3.2 Conservation and Restoration Areas

The unmodified and modified components of the analysis were combined to show the existing levels of habitat function throughout the Northwest Straits. The two components of the analysis were combined by summing, such that the positive value associated with a given habitat type and modifier is reduced by the negative value

assigned to the shoreline modification for the shoreline segment. It is here that a distinction can be made between priorities for restoration versus priorities for conservation.

The results of the nearshore forage fish spawning analysis are presented as two maps for each county: one depicting potential conservation areas (Map 5), and one depicting potential restoration areas (Map 6).

Potential Conservation Areas

Scoring for potential conservation priority is relatively straightforward. The scores for the unmodified habitat index (ranging from 0 (no function) to 100 (full function)) are added to the modified habitat index (scores ranging from 0 to –100 with lower scores reflecting higher levels of modification). This total score should range between 100 and –100 with higher scores representing higher habitat functionality. Using this index a score of approximately 30 or higher is very likely to support either known spawning habitat or potential spawning habitat.

Areas that are to be considered a high priority for conservation should provide a great deal of habitat function for the target species while being relatively unmodified, so that active restoration is not required. The area should also have significance at the landscape scale; for example, as part of a continuous or sub-continuous high quality nearshore corridor, as a unique habitat type at the meso-scale, or as part of an important long shore dynamic process.

Potential Restoration Areas

For identification of potential restoration areas, it is thought that relatively minor modification impacts represent the areas with the highest likelihood of being successfully restored to functioning habitat in a cost-effective manner. For this reason, the modified habitat scores are manipulated by adding 100 to the cumulative modified habitat score so that relatively low modification scores (i.e., a cumulative modified habitat score of - 5) become relatively high scores (following this example, the restoration value becomes 95). This index is added to the unmodified habitat score to create the restoration index. This has the effect of raising the site score for those sites with the least amount of habitat modification. Those areas with no habitat modification

(i.e., a score of 0 in the modified habitat index) are excluded from this analysis since they presumably cannot be restored in a meaningful way for these focal species. This however, does not necessarily indicate the highest priority for restoration. Lightly modified habitat may be very close to fully functional habitat and the ecological gains for restoring these sites may be substantially less than for an area where multiple features impacting the habitat are removed.

Areas that are a high priority for restoration may have a high potential habitat function but currently are impacted by some level of modification. Restoration activities may include the removal of shoreline modifications to open tributary mouths and increase overhanging riparian vegetation, the repair of nearshore habitat by removing overwater structure, or restoring beneficial vegetation such as eelgrass beds. The types and degree of nearshore modification should be considered carefully. The extent of modification beyond the area and the economic feasibility and implications of the removal of those modifications are similarly important. Additionally, the landscape scale relationships of the potential restoration area are important in a restoration prioritization as well. The effect of area restoration should have positive impacts well beyond the area as a result of habitat connectivity and dynamic processes.

3.3.3 Application of Results

These maps are intended to be interpreted at the 1 to 75,000 scale at which they are presented. Interpretation at a smaller scale would require refinements to the analysis process as well as the input data. The results are qualitative in nature despite having a numeric value. They are more useful in comparing the shorelines of a single MRC than in making comparisons between MRCs. This is due to the fact that the overall use of the intertidal by forage fish will vary widely from county to county. Forage fish use of the shoreline of Clallam county might be expected to be very limited because of the rocky nature of the intertidal zone and the relative absence of protected embayment, while the shoreline of Skagit and San Juan counties would be expected to be more heavily used.

The results presented here can be useful in examining the overall pattern of habitat available to forage fish for spawning and for comparing the quality of forage fish habitat to the habitat quality for other species groups. An important consideration not included in this analysis might be the proximity of high quality habitat to local fish populations.

Additionally, while the results presented here are intended to provide an indication of potential and known spawning locations, forage fish are known to vary their shoreline habitat use in an unpredictable manner. Because many inputs are susceptible to misclassification errors, in particular the sediment size and amount of riparian vegetation, it is valuable to ground truth both input variables and results of these analyses. Additionally, since forage fish spawning records are known to be generalized descriptions of field records, it may be valuable to critically examine sites indicated in this analysis. The results of all the analyses presented here will be most useful when used in combination with other information about the density of target species populations, changes in land and shoreline uses, and information on the integrity of shoreline process.

3.4 Juvenile Salmon Habitat Analysis

The salmon habitat analysis relies on the assumption that nearshore habitats provide five key functions to juvenile salmon. These key functions include migration corridors, food production, physiological refuge, refuge from predators, and high-energy refuge (i.e., high flows, wave action) (Mason 1970; MacDonald et al. 1987, Thorpe 1994; Levings 1994; Spence et al. 1996). These five functions are integral to the survival and growth of all salmon. All juvenile salmon utilize the shallow waters of estuaries and nearshore areas as migration corridors to move from their natal streams to the ocean (Williams and Thom 2001). Suitable corridors provide important predation refuge opportunities by spatially separating juvenile salmon from predators in shallow water or providing habitat structure for them to use. Juvenile salmon feed on an array of organisms found in shallow estuaries and nearshore areas including emergent insects, epibenthic crustaceans (harpacticoid copepods, gammarid amphipods, mysids, cumaceans), decapod larvae, larval fish (i.e., sand lance, surf smelt, herring), drift insects, dipterans, euphausids, and polychaetes (Aitkin 1998).

During migration, anadromous salmon must undergo a physiological transition from retaining salts and excreting water in fresh water to excreting salt and retaining water in salt water. Due to the complex physiological transition from fresh to salt water, the estuarine environments provide a gradual transition area for juvenile salmon to adjust (Simenstad et al. 1982). As mentioned above, estuarine and nearshore habitats provide shallow water areas for juvenile salmon migrations that spatially separate them from larger predators providing refuge (Williams and Thom 2001). The complex and dynamic morphology of

estuarine and nearshore habitats also provide juvenile salmon refuge from high river flows and wave action (Aitkin 1998). The channels draining an estuary may protect juvenile salmon from being swept downstream by high river flows or tidal currents (Levy et al. 1979). Marine vegetation associated with estuarine and nearshore marshes protect juvenile salmon from turbulent wave action. These five key functions provide a rationale for scoring a given unit of nearshore habitat in terms of juvenile salmon habitat function.

3.4.1 Habitat Function Scores

It is important to note that this analysis is primarily intended to identify the importance of marine shorelines to salmon. Major river mouths and other freshwater habitats are examined in detail by other sources. The salmon analysis also consists of two primary components: unmodified and modified shoreline conditions. The unmodified shoreline component characterizes the potential habitat function that can be provided in the absence of modification by humans and is based upon the inherent differences in the level of ecological function provided by different habitat types. In the modified habitat component of the analysis, each type of shoreline modification was evaluated based on the detrimental impacts of the modification.

Unmodified Habitat Function Scores

Similar to the forage fish analysis, intertidal and shallow subtidal physical habitat types provide the basis of the unmodified component of the analysis. Biological resources were incorporated into the analysis as a modifier to physical habitat type that added to the overall habitat function score. Scoring for the Biological resources category was based on the presence or absence of key species groups of vegetation. Landscape context was also incorporated into the analysis as an additional descriptor of habitat function. The presence and proximity of salmon bearing streams was included in this analysis and is perhaps the most critical in assessing nearshore habitat for juvenile salmon at a landscape scale. These streams and their estuaries play a critical role for both juveniles outmigrating from a specific stream as well as those that are simply migrating along shore past the estuary. Landscape context scores were determined based on the closest distance detectable within a ShoreZone segment that would still benefit from the effects of a stream mouth.

Landscape context could also include numerous large-scale processes and landscape patterns. Data on processes such as longshore drift were not available for use in this analysis, but could make an important contribution in the future. Land use and land cover data was not used because the direct and indirect effects of these conditions on nearshore habitat function are not sufficiently understood. Other categories already being used such as shoreline modifications (i.e., revetments, bulkheads, etc.) already address some processes indirectly. The term landscape context also suggests the temporal dynamics. These are also difficult to address with available data although they are indirectly addressed with subcategories such as wave exposure.

Scores were developed for unmodified habitat conditions based on an interpretation of a literature review and best professional judgment. Each physical habitat type, biological resource, and landscape context was assigned a score for each key ecological function. Each score ranged from 0 (no function) to 1 (full function). Total scores were established by summing the individual scores assigned to each ecological function. The scoring matrix assigned for unmodified habitat conditions is presented in Table 3.

Table 3
Unmodified Habitat Scores for Salmon

Habitat Categories	Habitat Functions					Total Raw Score	Normalized Score (Scale 0-1)
	Food Production	Migration Corridors	Predator Refuge	Physiological Refuge	High Energy Refuge		
Physical Features (Geomorphology from ShoreZone's [BC_CLASS]							
Estuarine mudflat	1.00	1.00	1.00	1.00	1.00	5.00	1.00
Non-estuarine mudflat	1.00	1.00	1.00	0.00	1.00	4.00	0.80
Sand/sand-gravel/gravel beaches*							
sand-low energy	0.75	1.00	0.75	0.00	0.75	3.25	0.65
sand-high energy	0.50	0.50	0.50	0.00	0.00	1.50	0.30
sand/gravel-low energy	0.50	1.00	0.50	0.00	0.75	2.75	0.55
sand/gravel-high energy	0.25	0.50	0.25	0.00	0.00	1.00	0.20
gravel-low energy	0.25	0.50	0.25	0.00	0.50	1.50	0.30
gravel-high energy	0.13	0.13	0.00	0.00	0.00	0.26	0.05
Sand/sand-gravel/gravel over rock							
sand-low energy	0.50	0.75	0.50	0.00	0.75	2.50	0.50
sand-high energy	0.25	0.25	0.25	0.00	0.00	0.75	0.15
sand/gravel-low energy	0.25	0.75	0.25	0.00	0.75	2.00	0.40
sand/gravel-high energy	0.13	0.25	0.13	0.00	0.00	0.51	0.10
gravel-low energy	0.13	0.25	0.13	0.00	0.50	1.01	0.20
gravel-high energy	0.00	0.13	0.00	0.00	0.00	0.13	0.03
Bedrock**							
platform/ramp	0.00	0.13	0.00	0.00	0.00	0.13	0.03
steep-faced	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Man-Made	0.13	0.00	0.00	0.00	0.00	0.13	0.03
	Physical Score (1 of the above)						**0.00-1.00**
Biological Condition:							
Riparian fringe	0.50	0.50	0.50	0.25	0.00	1.75	0.37
Emergent marsh							
continuous	1.00	1.00	1.00	1.00	0.75	4.75	1.00
patchy	0.50	0.50	0.50	0.50	0.38	2.38	0.50
Intertidal vegetation							
Eelgrass (Zostera sp.)							
continuous	1.00	1.00	1.00	0.25	1.00	4.25	0.89
patchy	0.50	0.50	0.50	0.13	0.50	2.13	0.45
All Kelp (giant, bull, soft brown and chocolate brown)							
continuous	0.75	0.75	1.00	0.25	0.75	3.50	0.74
patchy	0.37	0.37	0.50	0.13	0.37	1.74	0.37
	Biological Score (Sum of the above normalized to 1.00)						**0.00-1.00**
Landscape Context							
Minimum distance to salmonid bearing stream less than 100 feet	1.00	1.00	0.00	1.00	0.00	3.00	1.00

Habitat Categories	Habitat Functions					Total Raw Score	Normalized Score (Scale 0-1)
	Food Production	Migration Corridors	Predator Refuge	Physiological Refuge	High Energy Refuge		
Minimum distance to salmonid bearing stream 100 to 1,500 feet	0.50	0.50	0.00	0.50	0.00	1.50	0.50
Minimum distance to salmon bearing stream greater than 1,500 feet	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Landscape Score (1 of the above)						**0.00-1.00**

*Sand includes particles 0.5mm to 2.0mm in diameter; gravel includes granules (2mm - 5mm), pebbles (5mm - 6cm), cobbles (6 - 25cm), and boulders (>25cm)

**Platform/ramp bedrock= < 20 degree slopes; steep face= > 20 degree slopes

Modified Habitat Function Scores

Similar to the forage fish analysis, the modified habitat scores represent the negative impact that shoreline modifications have on an area's ecological function for salmon. The modified habitat component used a similar design and scoring system as the unmodified habitat component. The net detriment of modifications to key habitat functions for salmon has been estimated based on a literature review and best professional judgment. The scoring for this category represents degradation of habitat function and is scored as negative numbers. A score of 0 represents no level of degradation and –1 represents a high level of degradation. The scoring system assigned to modified habitat conditions is presented in Table 4. The scores for a shoreline segment were weighted based on the percent that each segment was modified by a particular structure (i.e., a given segment that is 50 percent modified by revetment would be given a score of –1 (-2 * 0.50)).

Table 4
Modified Habitat Scores for Salmon

Habitat Categories	Habitat Functions					Raw Score	Normalized Score
	Food Production	Migration Corridors	Predator Refuge	Physiological Refuge	High Energy Refuge		
Nearshore Modifications							
Overwater structure	-0.75	-0.75	-0.50	0	0	-2	-0.73
Shoreline bulkhead							
Revetment	-0.50	-0.50	-0.25	0	-.75	-2	-0.73
Vertical concrete/wood	-0.50	-0.50	-0.75	0	-1.0	-2.75	-1.00
	Modification Score (Sum of the above normalized to 1.00)						**0.00-1.00**

3.4.2 Conservation and Restoration Areas

The scores for each individual category are calculated by summing each of the five habitat function scores. The resulting score is then normalized to a value range from zero to one or negative one. It is here that a distinction can be made between priorities for restoration versus priorities for conservation.

The results of the nearshore juvenile salmon habitat analysis are presented as two maps for each county depicting conservation (Map 7) and restoration (Map 8) areas for the Northwest Straits region.

Conservation Areas

Scoring for potential conservation priority is relatively straightforward. First the scores for each of the four categories are normalized to between 1 and zero. Then the scores for each of the four categories are added together (The Nearshore Modifications score is a negative number) and the total raw score is considered that units potential conservation priority with higher numbers being higher priorities.

Areas that are to be considered a high priority for conservation should provide a great deal of habitat function for the target species while being relatively unmodified, so that active restoration is not required. The area should also have significance at the landscape scale; for example, as part of a continuous or sub-continuous high quality nearshore corridor, as a unique habitat type at the meso-scale, or as part of an important long shore dynamic process.

Restoration Areas

The scoring for potential restoration priority areas involves adding the scores from the categories Physical Features, Landscape Context and Biological Resource scores for each ecological function. Then the Nearshore Modification score (a number between 0 and -1) is subtracted from that sum. This, in effect, raises the resultant restoration score if the unit is more heavily modified. This however, does not necessarily indicate the highest priority for restoration. Heavily modified areas may be too expensive to restore and may not provide the greatest benefits to juvenile salmon.

Areas that are a high priority for restoration may have a high potential habitat function but currently are impacted by some level of modification. Restoration activities may include the removal of shoreline modifications to open tributary mouths and increase overhanging riparian vegetation, the repair of nearshore habitat by removing overwater structures, or restoring beneficial vegetation such as eelgrass beds. The types and degree of nearshore modification should be considered carefully. The extent of modification beyond the area and the economic feasibility and implications of the removal of those modifications are similarly important. Additionally, the landscape scale relationships of the potential restoration area are important in a restoration prioritization as well. The effect of area restoration should have positive impacts well beyond the area as a result of habitat connectivity and dynamic processes.

3.4.3 Application of Results

These maps are intended to be interpreted at the 1 to 75,000 scale at which they are presented. Interpretation at a smaller scale would require refinements to the analysis process as well as the input data. The results are qualitative in nature despite having a numeric value. They are more useful in comparing the shorelines of a single county than in making comparisons between counties. This is due to the fact that the overall use of the shoreline by juvenile salmon will vary widely from county to county. Juvenile salmon use of the shoreline of San Juan County might be expected to be very limited, while the shoreline of Skagit County would be expected to be more heavily used.

The results presented here can be useful in examining the overall pattern of habitat available to juvenile salmon and for comparing the quality of juvenile salmon habitat to the habitat quality for other species groups. If information regarding species use and land use pressure is added to the final analysis then decisions regarding where to focus restoration and conservation efforts can be made. The results of all the analyses presented here will be most useful when used in combination with other information on the density of target species populations, changes in land and shoreline uses, and information on the integrity of shoreline process.

Potential priority restoration and conservation areas should be explored specifically either in the field or against higher resolution datasets given the coarse resolution and provisional nature of this habitat analysis.

3.5 Nearshore Rockfish Habitat

Historically, there has been a lack of information on the West Coast regarding rockfish use of nearshore habitats and their specific habitat condition preferences. Resource agencies have only recently begun monitoring and assessing rockfish in their natural habitat. Previous assessment efforts relied primarily on estimates from commercial and recreational catch rates and overall harvests. Currently, efforts to directly assess rockfish populations in Puget Sound have focused on quantitative video surveys. While some of this survey data is currently available for analysis, its primary value is in providing indications of regional stock levels and for examining species habitat preferences.

There is a paucity of available nearshore rockfish information; therefore this habitat analysis approach is focused on identifying areas in the Northwest Straits region with nearshore rockfish habitat condition preferences. The habitat preferences of several species of rockfish are summarized below (Palsson in press):

- Adults: The relationship between rockfishes, lingcod (*Ophiodon elongates*), and other rocky habitat species and their preferred habitats has been investigated by a number of researchers in Puget Sound and in the Georgia Basin. Copper (*Sebastes caurinus*), quillback (*S. maliger*), and brown rockfishes (*S. auriculatus*) prefer high relief rocky habitats (Matthews 1990) and habitats with high complexity (crevices) and relief (Pacunski and Palsson in press; Murie et al. 1994; Richards 1987). Piled boulder fields and walls were found to contain the greatest complexity and relief, and hence the greatest abundance of sedentary rockfishes.
- Juveniles: While the requirements mentioned above are for the adult rockfish habitat, juveniles prefer small rocks and nearshore vegetated habitats (West et al. 1995; Buckley 1997).

3.5.1 Nearshore Rockfish Approach

The nearshore rockfish habitat analysis attempts to identify locations in the Northwest Straits that fit the general habitat preferences detailed above for rockfish. Due to the scale and scarcity of appropriate data, this analysis is necessarily limited to a few data sources. The first layer of this analysis uses data collected by WDFW through quantitative video surveys. This data is presented as binary observations and stations

with no observations. Since this data is known to be incomplete, it has been supplemented with additional datasets describing terrain (People For Puget Sound unpublished data; WDFW 1999), substrate types (NOAA 2000) and historical fishing effort (People For Puget Sound unpublished data; Squire 1977). These data and there applicability are summarized in Table 5

Table 5
Rockfish Map Data Summary

Habitat Feature	Importance to Rockfish
Rockfish observations	Washington Department of Fish and Wildlife has located and monitored much of the shallow (less than 28 meters in depth) rocky habitat. Observations provide a snapshot of rockfish at each site.
Historical Fishing	Indicator of historical harvestable abundances. This data provides very coarse descriptions of historical commercial and recreational fishing areas in Puget Sound.
Slope of Seafloor	Habitat complexity is known to be an important indicator of rocky habitat and habitat quality. Steep slopes are often associated with rocky areas, but can also indicate steep mud or sandy areas which are not appropriate rockfish habitat.
Substrate Type	Substrate type is possibly the best indicator of potential rockfish habitat. These data were derived from original bathymetric soundings. This data is currently only available for the Strait of Juan de Fuca.

Since rockfish are often associated with rock outcroppings and steep slopes (slopes greater than 25 degrees), areas with these characteristics were identified based on calculations from bathymetric data. Substrate information indicating rock is also available from nautical charts and is used to supplement the terrain data. Finally, a map of known historical groundfish fishing locations (People For Puget Sound unpublished data; Squire 1977) is used to help provide indications of where harvestable numbers of fish are known to have occurred historically. This information provides an indicator of where rockfish habitats occur.

3.5.2 Conservation Areas

The results of the rockfish analysis are presented as one map for each county (Map 9) depicting the conservation areas identified for the Northwest Straits region. Nearshore

modification impacts were not evaluated in this analysis because rockfish preferred habitat areas are located in the subtidal zone, which is not generally impacted by shoreline modifications. Therefore, the resulting map only depicts areas that could be used as a starting point for identifying conservation areas.

3.5.3 Application of Results

These maps are intended to be interpreted at the 1 to 75,000 scale, slightly coarser than they are presented. Interpretation at a smaller scale would require refinements to the analysis process as well as the input data. Data used during this analysis has a maximum stated resolution of 1:40,000 scale. As is typical of analyses, the resolution of the coarsest data used in this analysis is the maximum resolution at which results should be interpreted. In this case many of the inputs are presented at a 1:100,000 scale. The results are qualitative in nature and are primarily intended to indicate the location of and relation between variables that have historically been indicative of rockfish presence. Many input variables are representative of a feature, but are not exhaustive for that feature. For this reason, all representations should not be considered exhaustive (i.e., representations of rockfish observations indicate locations where rockfish were looked for and observed and do not indicate that other areas do not have rockfish).

This analysis is primarily intended to provide users with visual representations of those features believed to be important for identifying and correctly classifying rockfish habitat. Some sources of data used in this analysis have a temporal component and care should be taken to recognize that dated information might no longer be valid nor indicative of current conditions. This is especially true for fish observations and historic fishing areas. Because of certain errors inherent in analyzing data at this scale, in particular indications of slope steepness and the edges of any feature, it is valuable to ground truth all variables used in this analysis. While information indicating sites where fish were observed versus those sites where no fish were observed is presented here, the results of this analysis may be most useful used in combination with other information on the density of target species populations, and harvest or disturbance intensity.

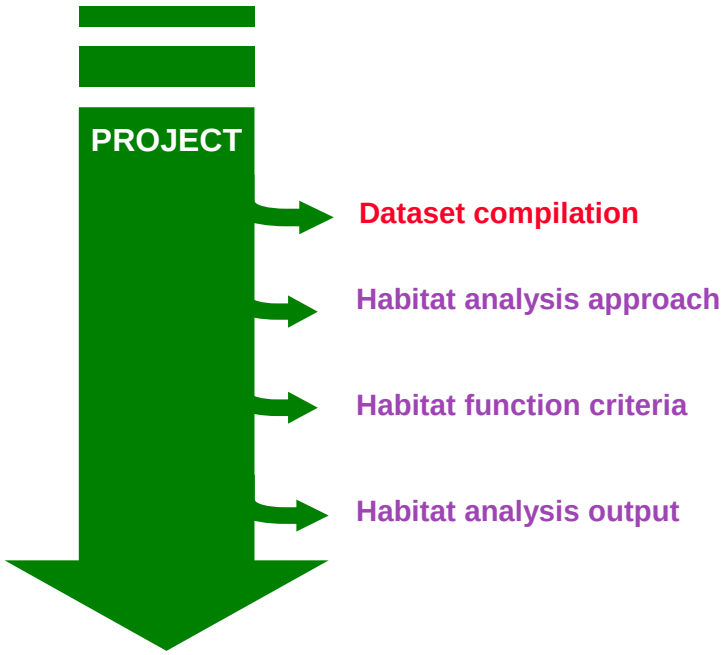
4 CONCLUSIONS

This project was designed to compile, organize, and analyze existing information and datasets on nearshore habitats supporting marine resources in the Northwest Straits region. The results provide the NWSC and individual MRCs with a common starting point for designing specific local nearshore habitat analyses to identify priority restoration and conservation sites. It is important that the specific nearshore habitat analysis reflects the restoration/conservation goals of the individual MRC.

The dataset compilation provides each MRC with the appropriate datasets necessary to conduct a nearshore habitat analysis in a specific county. Additionally, the data documentation database provides important information on the quality of the identified digital datasets, which the MRCs can use to determine which datasets are best to use to meet the goals of their restoration/conservation activities. The identification of data gaps in the Northwest Straits region is provided to guide future data collection activities initiated by individual MRCs. Finally, the nearshore habitat analysis provides three approaches that demonstrate various methods that can be used to evaluate habitat condition given available nearshore habitat datasets.

These products were designed to be adaptive to new and updated datasets that become available in the future as well as to the goals and objectives of each individual MRC. It is encouraged and recommended that each MRC assess their restoration/conservation goals and objectives to determine how these products will be used to fit their individual needs. Figure 4 depicts potential product applications. Specific applications are described below:

- Compilation of datasets: some of the MRCs may wish to only use the dataset compilation products to develop their own nearshore habitat analysis.
- Habitat analysis approach: Some of the MRCs may wish to use the datasets as well as one of the species-specific approaches described in the report.
- Habitat function criteria: Some of the MRCs may wish to use the datasets, one of the species-specific approaches, and the habitat function criteria developed for the target species.
- Habitat analysis output: finally, some of the MRCs may wish to use all of the products including the habitat analysis outputs.



ANCHOR ENVIRONMENTAL, L.L.C.

Figure 4
Potential Product Applications
Northwest Straits Nearshore Habitat Evaluation

5 REFERENCES

Aitkin, J.K. 1998. The importance of estuarine habitats to anadromous salmonids of the Pacific Northwest: A literature review. In cooperation with USFWS, Western Washington Office, Aquatic Resources Division, Puget Sound Program. Lacey, Washington.

Bargmann, G. 1998. Forage fish management plan. Washington Department of Fish and Wildlife. Olympia, WA.

Buckley, R.M. 1997. Substrate associated recruitment of juvenile Sebastes in artificial reef and natural habitats in Puget Sound and the San Juan Archipelago, Washington. Washington Department of Fish and Wildlife Technical Report No. RAD97-06, 320.

Levings, C.D. 1994. Feeding behaviour of juvenile salmon and significance of habitat during estuary and early sea phase. Nordic Journal of Freshwater Research 69:7-16.

Levy, D.A., T.G. Northcote, and G.J. Birch. 1979. Juvenile salmon utilization of tidal channels in the Fraser River estuary, British Columbia. Westwater Research Centre, Technical Report No. 23, The University of British Columbia, Vancouver, British Columbia.

Macdonald, J.S., I.K. Birtwell, and G.M. Kruzynski. 1987. Food and habitat utilization by juvenile salmonids in the Campbell River Estuary. Canadian Journal of Fisheries and Aquatic Sciences 44:1233-1246.

Macdonald, K.B., D. Simpson, B. Paulsen, J. Cox, and J. Gendron. 1994. Shoreline armoring effects on the physical coastal processes in Puget Sound, WA. Coastal Erosion Management Studies, Volume 5. Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, WA.

Mason, J.C. 1970. Behavioral ecology of chum salmon fry (*Oncorhynchus keta*) in a small estuary. Journal of the Fisheries Research Board of Canada 31:83-92.

Matthews, K.R. 1990. A comparative study of habitat use by young-of-the-year, subadult, and adult rockfishes on four habitat types in central Puget Sound. Fisheries Bulletin 88:223-239.

Murie, D.J., D.C. Parkyn, B.G. Clapp, and G.G. Krause. 1994. Observations on the distribution and activities of rockfish, Sebastes spp. in Saanich Inlet, from the Pisces IV submersible. Fishery Bulletin 92: 313-323.

National Oceanic and Atmospheric Administration. 2000. NOAA NOS Hydrographic Survey Bathymetric Fishing for the Olympic Peninsula and Strait of Juan de Fuca as digitized by the NOAA Coastal Services Center, Protected Areas Geographic Information System.

Pacunski, R.E., and W.A. Palsson. In Press. Macro- and micro-habitat relationships of sub-adult and adult rockfish, lingcod, and kelp greenling in Puget Sound. In: Puget Sound Research 2001 Proceedings. Puget Sound Water Quality Action Team, Olympia.

Palsson, W.A., J.C. Hoeman, G.G. Bargman, and D.E. Day. 1996. 1995 status of Puget Sound bottomfish stocks. Washington Department of Fish and Wildlife, Olympia, WA, 98 pp.

Palsson, W.A. and R.E. Pacunmski. 1995. The response of rocky reef fishes to harvest refugia in Puget Sound. In: Puget Sound Research '95, Vol 1, pp 224-234. Puget Sound Water Quality Authority, Olympia.

Palsson, W.A. In Press. The Development of Criteria for Establishing and Monitoring No-take Refuges for Rockfishes and Other Rocky Habitat Fishes in Puget Sound. Puget Sound Notes.

Penttila, D. Personal Communication between Philip Bloch, People for Puget Sound and Dan Penttila, Washington Department of Fish and Wildlife. June 8, 2001.

Richards, L.J. 1986. Depth and habitat distributions of three species of rockfish (*Sebastes*) in British Columbia: observations from the submersible PISCES IV. Env. Biol. Fishes 17: 13-21.

Richards, L.J. 1987. Copper rockfish (Sebastes caurinus) and quillback rockfish (*Sebastes maliger*) habitat in the Strait of Georgia, British Columbia. Can. J. Zoology 65:3188-3191.

Robards, M.D., J.F. Piatt, and G.A. Rose. 1999. Maturation, fecundity and intertidal spawning of Pacific sand lance in the northern Gulf of Alaska. Journal of Fish Biology 54: 1050-1068.

Simenstad, CA, K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: An unappreciated function. *In: V.S. Kennedy ed.* Estuarine Comparisons. pp. 343-365. Academic Press, Toronto.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6507. ManTech Environmental Research Services Corp., Corvallis, OR.

Squire, J.L. and S.E. Smith 1977. Anglers' guide to the United States Pacific Coast: marine fish, fishing grounds & facilities. Seattle, WA: U.S. Dept of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. 139 pp.

Stout, H.A., B.B. McCain, R.D. Vetter, T.L. Builder, W.H. Lenarz, L.L. Johnson, and R.D. Methot. 2001. Status Review of Copper Rockfish (Sebastes caurinus), Quillback Rockfish (S. malinger), and Brown Rockfish (S. auriculatus) in Puget Sound, Washington. NOAA Technical Memorandum NMFS-MWFSC-46.

Thom, R.M, T.L. Parkwell, D.K. Shreffler, and K.B. MacDonald. 1994. Shoreline armoring effects on coastal ecology and biological resources in Puget Sound. Coastal Erosion Management Studies, Volume 7. Shorelands and Coastal Zone Management Program, WDOE, Olympia, WA.

Thorpe, J.E. 1994. Salmonid fishes and the estuarine environment. Estuaries 17(1A):76-93.

Washington Department of Fish and Wildlife. 1999. Washington State Marine Bathymetry Mosaic. Olympia, WA.

Washington Sea Grant Program. 1998. Murray-Metcalf Northwest Straits Citizens Advisory Commission: Report to the Convenors. Washington Sea Grant, University of Washington.

West, J.E., R.M. Buckley, D.C. Doty, B.E. Bookheim. 1995. Ecology and habitat use of juvenile rockfishes (Sebastes spp.) associated with artificial nursery habitats in Puget Sound, Washington. Pp. 191-202. In: Puget Sound Research '95. Puget Sound Water Quality Authority, Olympia, WA.

Williams, G.D. and R.M. Thom. 2001. White Paper: Marine and Estuarine Shoreline Modification Issues. Battelle Marine Sciences Laboratory. Prepared for Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation.

APPENDIX A
PUBLIC INVOLVEMENT REPORT

APPENDIX B
LISTS OF IDENTIFIED DIGITAL AND NON-DIGITAL DATA SOURCES

APPENDIX C
DATA DOCUMENTATION SUMMARY FOR DIGITAL DATA SOURCES

Data Documentation Database

An Access database was developed to provide documentation for all relevant nearshore habitat data sources identified for the Northwest Straits region. The database consists of a table containing general information about the identified data sources, and separate tables describing specific fields contained in each data source. The information included in each type of database table is given below:

General Information:

File name: actual name given to the data file

Layer name: Name/identification of layer (may be the same as the file name)

Data set Description: more detailed description of the dataset and what it represents

Study area: geographic area of data collection activities

Original author of data: Agency or person responsible for compiling data

Source publication title: title of publication related to data

Source format: format of data file (i.e., export files, shape files, etc.)

Source description: detailed description of reference; other relevant bibliographic information

Collection Date: date(s) of data collection

Publication Date: date data was published or released

Feature types: (i.e., point, polygon, line)

Data scale: (i.e., 1:24,000)

Resolution:

Accuracy:

Accuracy notes: any qualifications on accuracy

Data acquisition method: description of how data was collected

Known limitations: limitations of data or data collection methods

Comments: any relevant additional comments

Tabular designations available: denotes whether or not data set has a table associated with it (yes, no)

Data Manager: person in charge of dataset

Tabular Definitions

Field: individual field names in table

Content: description of field

Comments: any relevant comments

A summary report including a few of the fields described above for all the identified nearshore habitat data sets is provided in Appendix B.