Race Rocks Pilot Marine Protected Area: An Ecological Overview

C. A. Wright and J. D. Pringle

Marine Environment and Habitat Science Division

Fisheries and Oceans Canada
Institute of Ocean Sciences
9860 West Saanich Road
P.O. Box 6000
Sidney, British Columbia,
V8L 4B2

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LIST OF ABBREVIATIONS

AVHRR	Advanced Very High Resolution Radiometer
BC	British Columbia
BCMEC	British Columbia Marine Ecosystem Classification
CHS	Canadian Hydrographic Service
CMRC	Classification of the Marine Regions of Canada
CORI	Coastal Ocean Resources Inc.
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CTD	Conductivity-Temperature-Density
CWS	Canadian Wildlife Service
DBK	Dark Brown Kelps
DFO	Department of Fisheries and Oceans
DO	Dissolved oxygen
EC	Environment Canada
GPS	Global Positioning System
HAB	Harmful Algae Blooms
IM	Integrated Management
IOS	Institute of Ocean Sciences
LUCO	Land Use Coordination Office
MPA	Marine Protected Area
MESA	Marine Ecosystems Analysis
PAH	Polyaromatic hydrocarbons
PCB	Polychlorinated biphenyls
SIMS	Seabed Imaging and Mapping System
SJF	Strait of Juan de Fuca
SOI	Southern Oscillation Index
SST	Sea surface temperature
STD	Salinity-Temperature-Density
TBT	Tributyl tin
TEK	Traditional Ecological Knowledge
US	United States

CONTACT ADDRESSES FOR FISHERIES AND OCEANS CANADA

Marine Environment and Habitat Science Division, Science Branch
Institute of Ocean Sciences
P.O. Box 6000, Sidney, BC, V8L 4B2 Canada

Catch Statistics Unit, Stock Assessment Division, Science Branch
555 West Hastings St., Room 420, Vancouver BC., V6B 5G3 Canada

Fisheries Management Branch
Regional Headquarters, 555 West Hastings St., Vancouver, BC., V6B 5G3 Canada

ABSTRACT

Race Rocks Ecological Reserve, off the southwest coast of Vancouver Island, B.C., was designated a Pilot Marine Protected Area (Area of Interest) in September 1998. The National Framework for the development of Marine Protected Areas includes a Code of Practice ensuring that Integrated Managers use all the available scientific and traditional ecological knowledge when drafting management plans for prospective MPAs. Ecosystem Overviews area a component of the Ecological Assessment step. This Overview is a synthesis of the information available for the marine component of Race Rocks and the contiguous waters of the Strait of Juan de Fuca. It includes a listing and review of the physical, chemical, and biological oceanographic components of this ecosystem along with natural history observations and some traditional knowledge. Included as well are recommendations for future scientific studies.

RÉSUMÉ

La réserve écologique de Race Rocks, sur la côte sud-ouest de l'île de Vancouver (C.-B.) a été désignée zone pilote de protection marine (zone d'intérêt marin) en septembre 1998. Le programme national pour la création de zones de protection marine comprend un code de pratiques visant à faire en sorte que les responsables de la gestion intégrée aient accès aux connaissances savoir scientifiques et au savoir traditionnel accumulé, pour l'établissement des plans de gestion des futures zones de protection marine. Le processus d'évaluation écologique comprend un examen environnemental de la zone concernée. Il s'agit d'une synthèse de l'information disponible sur la composante marine de Race Rocks et des eaux adjacentes du détroit de Juan de Fuca. L'examen comprend une liste et une revue des éléments physiques, chimiques and biologiques de cet écosystème, de même que des observation sur l'histoire naturelle et le savoir traditionnel accumulés sur l'endroit. Des recommandations sont formulées pour les études scientifiques futures.

INTRODUCTION

Canada's Federal government passed the *Oceans Act* in January of 1997, which provides Canada with a vehicle to move towards an integrated management of the oceans and its resources. The Federal Minister of Fisheries and Oceans is leading the development of an Oceans Strategy. Management strategies will be based on the concepts of sustainability, integration, and the precautionary approach. Legislated tools supporting Integrated Management (IM) are Marine Protected Areas and Marine Environmental Quality. The focus of this review involves Race Rocks as a Pilot Project Marine Protected Area (MPA).

The Department of Fisheries and Oceans (DFO) can designate MPA's for conservation and for the protection of habitats and species. These Areas can include regions of high productivity, high biodiversity, unique habitats, or for any other reason that falls within the mandate of the Minister.

According to the *Act* a MPA is:

> *"An area of the sea that forms part of the internal waters of Canada, the territorial sea of Canada or the exclusive economic zone of Canada and has been designated under this section [35.(1)] for special protection…"*

The objectives of the proposed MPA system are:

> *"To conserve and protect the ecological integrity of marine ecosystems, species, and habitats…"*

The National Framework outlines the approach for program development which includes the consideration of local concerns. The Framework emphasizes the "learn-by-doing" approach and a step-by-step process to determine whether or not a site will be designated a MPA. Four "Areas of Interest" were designated as Pilot Project MPAs (i.e. "Pilot MPAs"). These "Pilot" projects allow Regional Oceans managers to test, develop, and refine the MPA process in cooperation with other governments, agencies, and stakeholders (First Nations, Federal, Provincial, Municipal).

On September 1, 1998, the then Minister of Fisheries and Oceans Canada, David Anderson, announced that Race Rocks, presently a provincial Ecological Reserve, was to be one of two inshore Pilot Projects, the other being Gabriola Passage. In December of 1998, Minister Anderson announced two offshore Pilot MPAs: Bowie Seamount and the Endeavour Hot Vents Area.

Race Rocks has long been recognized as an important ecological area and was given Ecological Reserve status by the BC government in 1980, due to the efforts of the staff and students of Lester B. Pearson College of the Pacific. Race Rocks was listed as a Pilot MPA because it is representative of the transitional zone between the open waters of the Pacific Ocean and the coastal inshore waters; a region where marine biodiversity is high.

One step in the MPA Framework is an Ecological Assessment. This process allows for the compilation and evaluation of the ecological features of the Pilot MPA. As part of the Framework, a Code of Practice was developed to guide Integrated Management Coordinators with the development of MPAs. The Code refers to basing decisions on the best available scientific and traditional ecological knowledge. The Pacific Region's Oceans Director approached Science Branch (specifically Marine Environment and Habitat Science Division) personnel, Pacific Region, to perform the assessment.

In December 1998, Pearson College was contracted to provide an Ecosystem Overview for Race Rocks, given their daily contact with the area, their knowledge of its ecosystem, and their interest in its preservation. The overview entailed the compilation of all known literature (published and unpublished) that involved Race Rocks and the surrounding area. This library was then incorporated into a searchable meta-database that runs in Microsoft Access™. The Pearson College team compiled over 250 records which forms the base of an ongoing compilation (Fletcher 1999).

These records not only include the literature (including citations and in most cases abstracts), but also photographic images, herbarium records, and links to other regionally important databases. Thus all available scientific and traditional ecological knowledge (TEK) is available in one central location accompanied by a "user-friendly" relational database for searching. There are plans for the database to be continually updates.

To assist Integrated Management Coordinators with the task of making decisions concerning the status of Race Rocks, it was deemed important that there be a "Science Review" that synthesized the literature and other records of the Ecosystem Overview. This report consists of a number of sections, loosely based on a similar Science Review written for the Pilot MPA Gully (Harrison and Fenton 1998). Each section is a major facet of the marine ecosystem at Race Rocks. There are significant gaps in the information, hence data from the eastern and southern sections of the Strait of Juan de Fuca has been used. Attempts have been made to highlight the limitations of the data and also the gaps in our knowledge. It should be noted that this review encompasses only the marine component of Race Rocks. It does not review the terrestrial ecosystem or any socio-economic aspects.

CHARACTERIZATION OF RACE ROCKS

HISTORICAL ASPECTS

Race Rocks is located at 123° 31' .85 W latitude and 48° 17'. 95 N longitude in northeastern Strait of Juan de Fuca (SJF), 17 km southwest from Victoria and 1.5 km seaward of Vancouver Island. It consists of a large main island, Great Race, and 8 smaller islands for a total area of 220 ha (Figure 1). It's most impressive physical feature is the high velocity currents that move through the area, reflecting its name. In 1860 a lighthouse was established on Great Race to assist mariners with the navigation hazards the area presented.

Race Rocks is a place of considerable marine biodiversity, and in 1980 was declared an Ecological Reserve under the *Ecological Reserves Act* by the BC government. Presently, it is still under the *Ecological Reserve Act* and operates under a 1998 Draft Management Plan. The Reserve includes the land, the water column, and the seabed out to the 36.6 m (20 fathom) depth contour; the lighthouse property falls under Federal jurisdiction of the Canadian Coast Guard. The intent of the Reserve was to preserve a unique ecosystem, the intertidal communities, and encourage education and research. Non-consumptive use only is permitted unless otherwise authorized under permit.

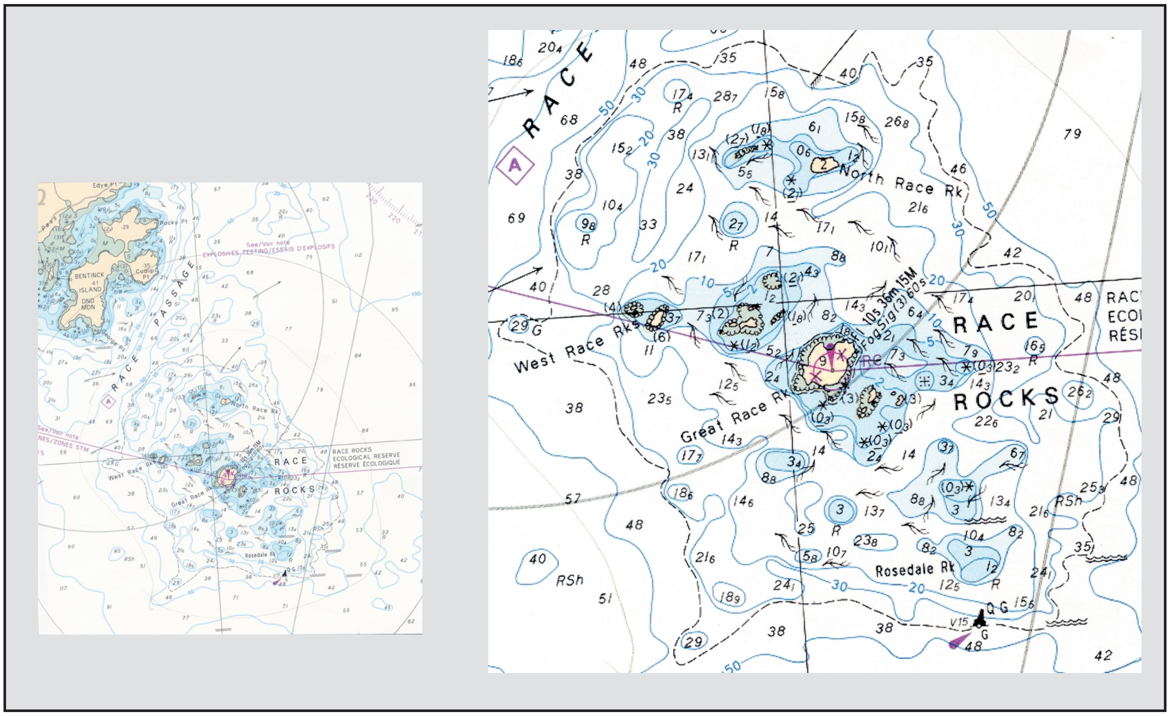

Figure 1. Race Rocks Ecological Reserve. Canadian Hydrographic Chart 3140. The dashed line represents the 20 fathom (approximate) contour that forms the boundary of the Ecological Reserve.

Pearson College is the Volunteer Warden for the Reserve. The College facilitates the permit process and also monitors activities that occur inside Reserve waters. Prior to destaffing the lighthouse, the keepers were the "eyes and ears" of the Reserve, ensuring users complied with the regulations. Pearson College employs the former lighthouse keepers (presently Mike and Carol Slater) at the site.

TRADITIONAL ECOLOGICAL KNOWLEDGE

Traditional Ecological Knowledge or TEK, involves the collection of information from sources that are often "non-scientific." It can include myths and stories ; information from elders and other commercial and sports fishers information; archaeological records; archive sources; and popular literature (Haggan et al. 1998). To date, the systematic collection of traditional ecological knowledge (TEK) for the SJF (and Race Rocks area) is limited. Pearson College has been working with both First Nations and non-First Nations in an effort to gather this type of information.

First Nations

The eastern section of the SJF is traditional territory for four Coast Salish Nations: the T'Sou-ke, Beecher Bay, Songhees, and Esquimalt Nations (Te'mexw Treaty Assoc., www.islandnet.com/~temexw/land.htm). All four are members of the First Nations South Island Tribal Council and the latter three are members of the Te'mexw Treaty Association. This association defines a territory as an area that provides for families and communities, allowing them to continue a way of life (www.islandnet.com/~temexw.htm). Mr. and Mrs. Thomas Charles, of the Beecher Bay Reserve, explain that Clallam was one of the Salish languages spoken in this area. They refer to Race Rocks as, , translated means area of "fast flowing water." They also recalled the Clallam name for Pedder Bay as Whoyinch and Church Island as Kqutong (Raven Hangout) (Fletcher 1999).

In addition to these four Nations, other Coast Salish nations likely used the area on a seasonal basis. For example, the Saanich Nations (Tsartlip, Tsawout, Pauquachin, Tseycum Bands) may have also utilized this area, as they are characterized as having variable food locations depending on resource availability and were known to travel, leaving their traditional core winter areas (Jennes 1938). They too have a word for Race Rocks in the lan-guage. This is XEL, LEN, meaning "very fast" (Paul et al. 1995).

It appears Race Rocks and the eastern SJF were visited seasonally depending on food availability. First Nations gathered a wide range of food from the coastal waters including gull eggs, sea cucumbers, sea urchins, chitons, snails, whelk, mussels, barnacles, seaweeds, as well as crab and fish. Seafood was not only eaten, but also traded with other nations including those from Washington State (Fletcher 1999). Race Rocks was known to be an area of bounty, and in recent times Thomas Charles sold Race Rocks lingcod to buyers in nearby areas (Fletcher 1999)

Non-First Nations

The coastal waters of the SJF have likely been exploited since the time of European contact. Pearson College personnel are working with local fishers to collect information about marine resource use at Race Rocks and its surrounding waters.

ECOSYSTEM CLASSIFICATION

There are a number of available marine ecosystem and/or marine habitat classification systems (for review see Watson 1994). Generally, these systems are based on physical (abiotic) factors, sometimes supplemented by biological components, to classify ecosystems. In 1993, Environment Canada initiated "A Classification of the Marine Regions of Canada" (CMRC) (Harper et al. 1993). This system was a hierarchical classification that defined areas based on uniform physical and biological components. The classification contained four levels (Table 1).

The CMRC system was used as a basis for the British Columbia Marine Ecosystem Classification (BCMEC), developed by the Land Use Coordination Office (LUCO) of the BC government. This approach was developed to assist with planning, resource management, and conservation issues (Zacharias et al., 1998). In addition to four tiers, it has a fifth level consisting of smaller ecounits, based on areas of physical homogeneity along with five physical characters; wave exposure, depth, subsurface relief, current speed, and substrate (Table 2). They are mapped on a 1:250,000 scale. For a review of the thematic components see Zacharias et al. (1998) or www.gis.luco.bc.ca. There are 619 ecounits (Zacharias et al, 1998). The ecounits are not given formal names but are based on the five themes; Race Rocks is classified as MCHHH. This coding stands for; moderate wave exposure, 20-200 m depth, high subsurface relief, hard seabed substrate, and high current regime (LUCO/Howes pers. comm. 1999).

Table 1. Hierarchical classification scheme taken from Classification of Marine Regions of Canada (Harper et al. 1993).

ECOZONES	ECOPROVINCES	ECOREGIONS	ECODISTRICTS
Pacific	Subarctic Pacific	Subarctic Pacific	Subarctic Pacific
	Transitional Pacific	Transitional Pacific	Transitional Pacific
	Pacific Shelf	Strait of Georgia/ Puget Sound	Johnstone Strait
			Central Strait of Georgia
			Juan de Fuca Strait
		Dixon Entrance	Dixon Entrance
		Pacific Marine Shelf	Mainland Fjords
			Hecate Strait
			Vancouver Island Shelf
			Queen Charlotte Sound

Table 2. Marine ecosystem hierarchical classification system of the Land Use Coordination Office, BC (From Zacharias et al. 1998).

ECOZONES	ECOPROVINCES	ECOREGIONS	ECOSECTIONS	ECOUNITS
Pacific	Northeast Pacific	Subarctic Pacific	Subarctic Pacific	Wave Exposure: **H**igh, **M**oderate, **L**ow Depth: 0-20 m **B** 20-200 m **C** 200-1000 m **D** >1000 m **E** Seabed Relief: **H**igh, **L**ow Seabed Substrate: **H**ard (gravel-rock) **S**and **M**ud Current Regime: **H**igh (>3 kts), **L**ow (>3 kts)
		Transitional Pacific	Transitional Pacific	
	Pacific Shelf & Mountians	Outer Pacific Marine Shelf	Continental Slope	
			Vancouver Island Shelf	
			Queen Charlotte Sound	
			Dixon Entrance	
			Hecate Strait	
		Inner Pacific Marine Shelf	North Coast Fjords	
			Queen Charlotte Strait	
			Johnstone Strait	
	Georgia-Puget Basin	Georgia Basin	Juan de Fuca Strait	
			Strait of Georgia	

There have also been efforts, led by LUCO, to standardize the biological and physical shoreline mapping of BC's coast (Howes et al. 1994). The shoreline is divided into zones (i.e. backshore, intertidal, subtidal) based on physical characteristics that are then used to group biotic assemblages across the zones, however, the present biological database is small. Physical and biological data are deduced from aerial surveys/photographs and ground surveys.

Using this shoreline mapping system, Zacharias et al. (1999) determined biotopes (contiguous areas of a dominant biotic community) within the southern Strait of Georgia, including the eastern SJF. Major abiotic components include maximum fetch, area extent and length. The SJF, and consequently Race Rocks, were found to be in the *Egregia/Hedophyllum* biotope; waters close to the SJF that are cold with high salinity and may be affected by currents. The dominant species assemblage includes *Hedopyllum*, *Egregia*, *Phyllospadix*, *Agarum*, *Endocladia*, *Halosaccion* (algae), and *Semibalanus cariosus* (barnacle) (Zacharias et al. 1999).

Seabed mapping and classification systems are useful when attempting to understand the relationship between physical and biological factors. However, for the Race Rocks area, the LUCO scheme is too large a scale (over kilometres) to describe the special features of the Race Rocks Ecological Reserve.

REGIONAL GEOLOGY

Vancouver Island developed as a submarine island arc sometime in the Devonian (~380 Ma), and attached to North America in the Cretaceous (~100 million years) (Yorath and Nasmith 1995). It is known as the Wrangellia terrane, and has accumulated other terranes from collisions. The geological terrane that includes Race Rocks is known as the Cresent Terrane (Figure 2). It formed approximately 54 million years ago and docked with Vancouver Island (Wrangellia) approximately 42 million years ago. It is separated from the Pacific Rim Terrane by the Leech River Fault (Massey 1986).

The most prominent feature of this region is the Metchosin Igneous Complex (Figure 2). This package of rocks are fine grained basalts (extrusive ocean crust) and their coarse grained equivalent, gabbros (intrusive rocks). The primary minerals of the Complex are feldspar and pyroxene (Massey 1986). This basaltic sequence has its equivalent across the SJF in the form of the Olympic Mountain range (Yorath and Nasmith 1995).

During the Pleistocene (80,000-10,000 years ago) this region experienced three glaciations interrupted by two interglacial periods. Alpine glaciers extended into valleys as the climate cooled. These glaciers were responsible for carving out what is today, the Strait of Juan de Fuca and the Strait of Georgia. The Fraser was the last of the glaciations. Evidence of the last glaciation can be seen at Race Rocks in the from of small erratics and scour marks (Fletcher pers. comm., 1999).

SEISMICITY

There are no known active faults specifically associated with Race Rocks, however, the SJF is a region of high seismicity with several active and inactive faults, some of which are close to Race Rocks. Natural Resources Canada, in association with the United States Geological Survey, have compiled a geological and seismic database for the eastern SJF in the form of a CD-ROM atlas (Mosher and Johnson 2000). Additional information, including maps is available on this CD. For further information contact the Geological Survey of Canada/Pacific Geoscience Centre, 9860 West Saanich Road, Sidney, British Columbia, V8L 4B2.

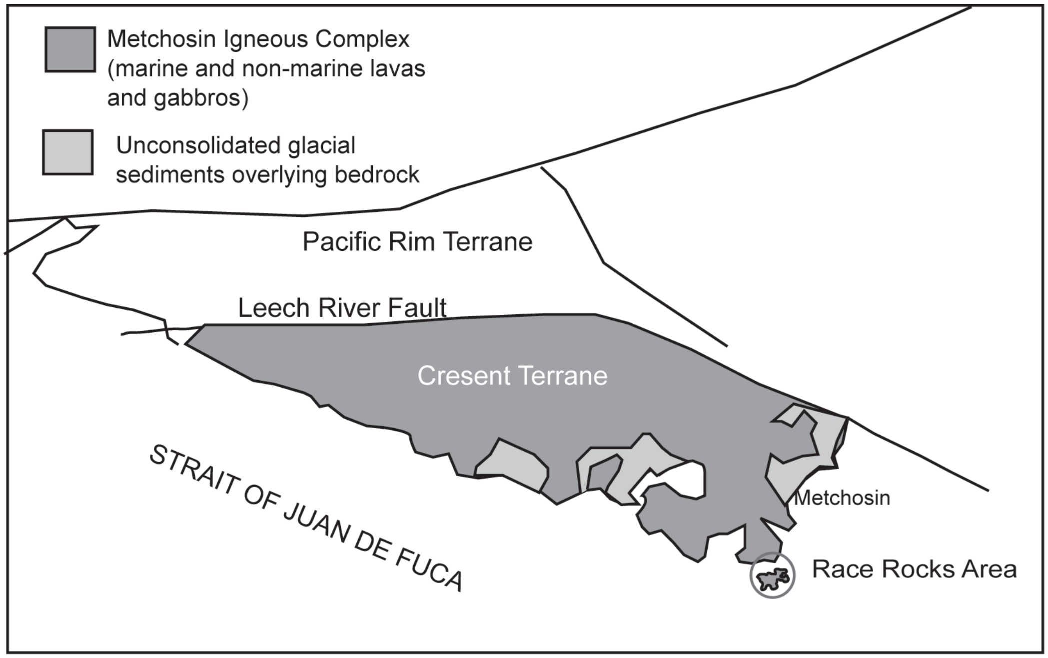

Figure 2. Geology of the Cresent Terrane, including the Race Rocks area (Modified from Massey 1986).

SEDIMENTOLOGY

Most of BC's coastline is resistant (low rate of erosion) extrusive rocks. As such, there is little sediment produced and available for transport and deposition. Generally, marine sediments in SJF are coarse grained with the finer material, coming in from riverine sources (Macdonald and Crecelius 1994). Race Rocks is unlikely to be an area of high sediment deposition as most particulates would be carried out of the area with current flow. However, some degree of sediment (e.g. sand) deposition does occur in deeper water. The sand at depth, as confirmed by benthic grabs, is especially hardpacked and is likely extremely well sorted. It is not certain how deep the sediments are, what the rate of deposition is, or their source.

SEABED CLASSIFICATION

The Canadian Hydrographic Service (CHS) oversaw three seabed classification studies at Race Rocks in the spring of 1999. The first project involved a high resolution multibeam bathymetric survey. The sonar beams of this system fan outwards in an overlapping fashion thereby covering 100% of the seabed. The sonar data were processed in colour (Figures 3 and 4) and grey-scale, sun-shaded images (Figure 5). From these images, the rocky outcrops and flat hardpack sand regions are evident.

The second project was a seabed resource survey using underwater video imagery, a protocol using a towed underwater camera, developed by Coastal & Ocean Resources Inc. (CORI), of Sidney, BC. The images are classified, frame-by-frame, for substrate and biotic classes. The imagery is geo-referenced with differential GPS which allows for a degree of interpolation among tracklines resulting in the creation of polygons that represent substrate classes. The tracklines for the Race Rocks survey extended from a depth of 20 m shoreward. However, some shallow areas were not accessible (Figure 6). The results of the survey (Harper et al. 1999) are discussed in the relevant sections.

The third project involved an acoustical seabed classification system (QTC View) developed by Quester Tangent, of Sidney, BC, using dual frequencies of 38 and 200 kHz. The 200 kHz beam provides the surface substrate information, while the 38 kHz beam penetrates the substrate approximately 10-20 cm. The acoustical signal classification was ground-truthed against benthic grab samples taken at the same time as the acoustics. Videos of the grab samples ensured true representations of the substrate were taken. Preliminary analysis suggests four classes; bedrock, vegetation, clastics, and sand. Bedrock and vegetation are the most prominent classes, particularly in shallow waters; sand is a predominant class but only at depth and in rock fractures.

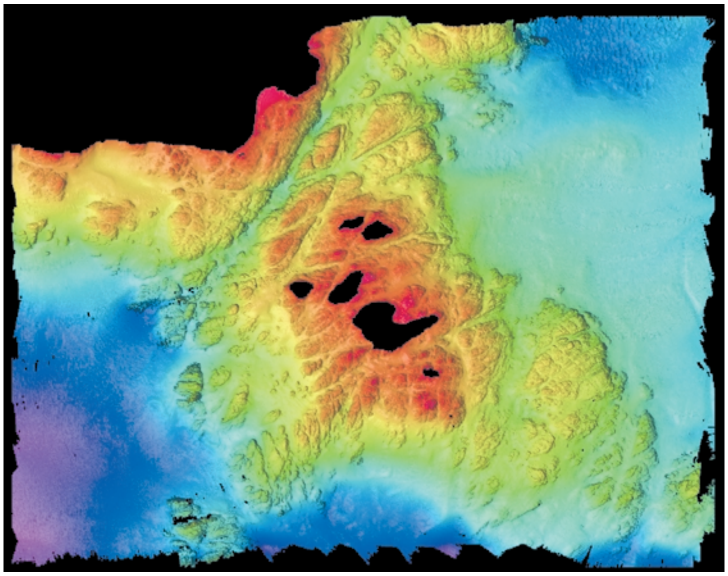

Figure 3. Two-dimensional sun-illuminated bathymetry of the Race Rocks Pilot MPA including approximately 1 km of contiguous waters. Image by the Canadian Hydrographic Survey, Pacific Region.

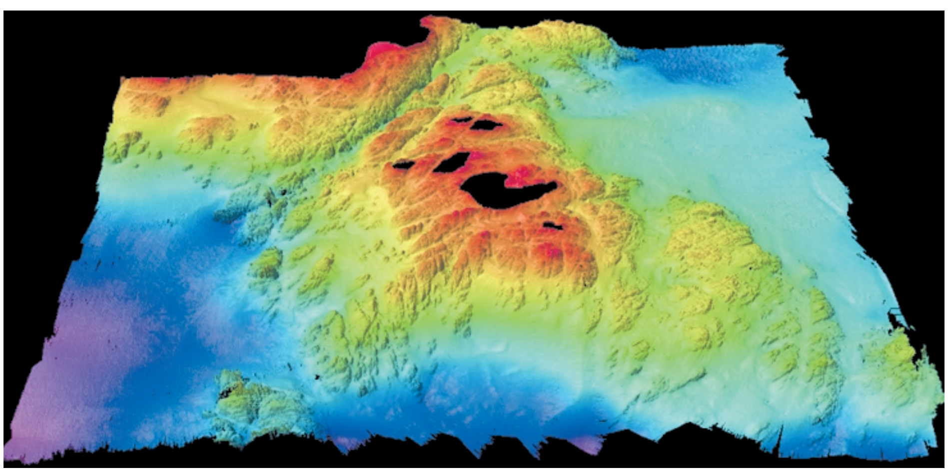

Figure 4. Three-dimensional sun-illuminated bathymetric image of the Race Rocks Pilot MPA including approximately 1 km of contiguous waters. Image by the Canadian Hydrographic Survey, Pacific Region.

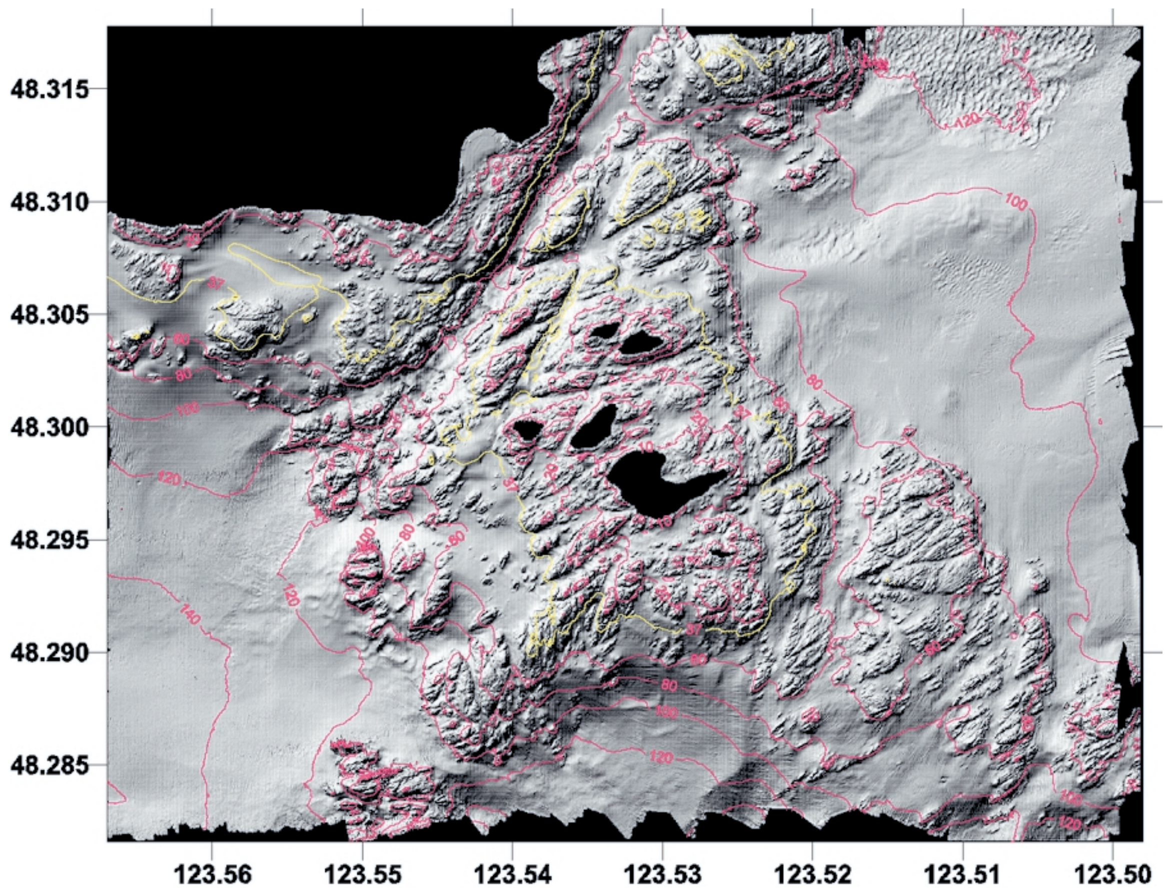

Figure 5. Grey scale sun-Illuminated bathymetry of the Race Rocks Pilot MPA plus approximately 1 km of contiguous water. Pink contours are 20 m intervals; Yellow contour is the 37 m contour giving an approximate outline of the Ecological Reserve boundaries. Image by the Canadian Hydrographic Survey, Pacific Region.

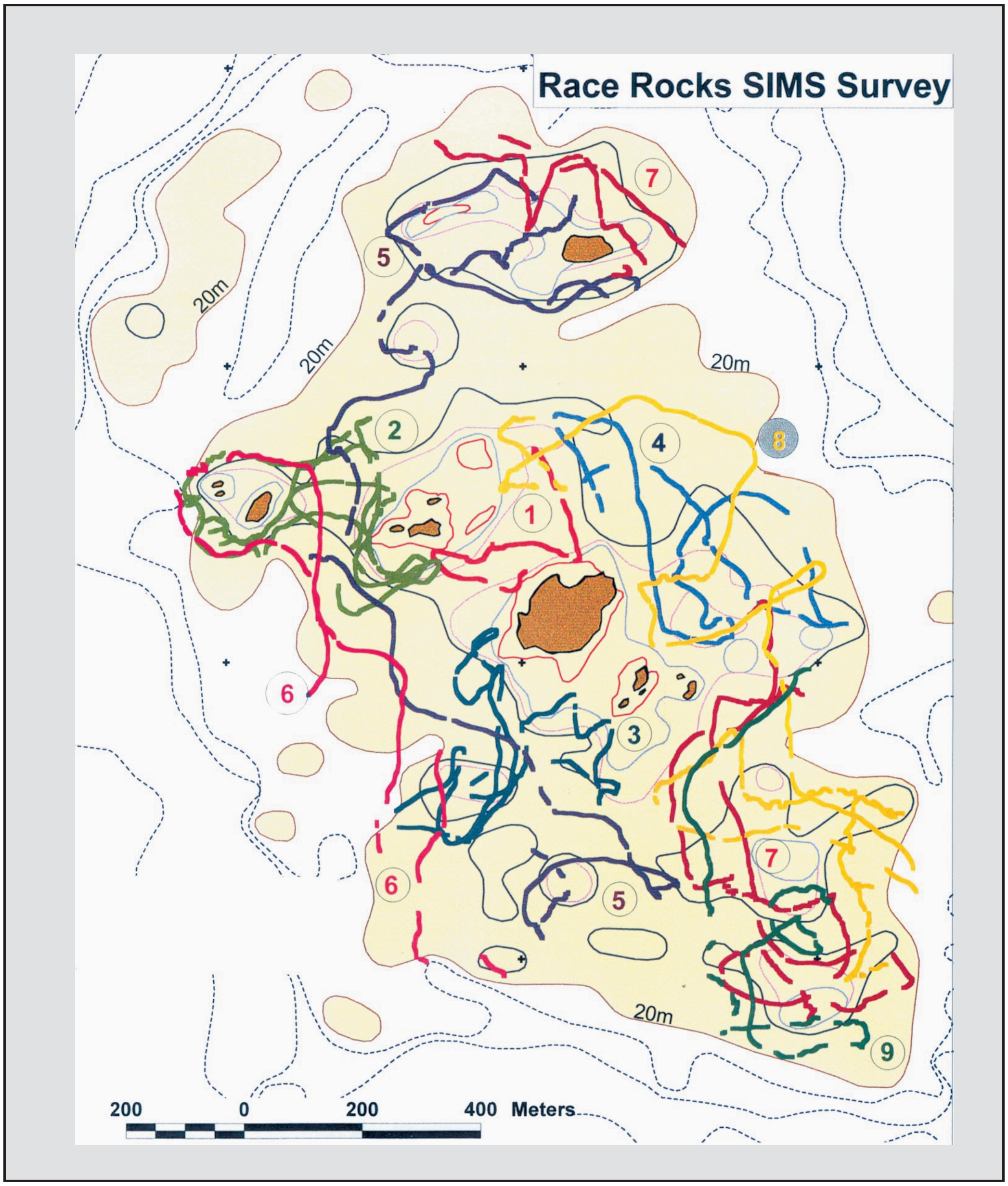

Figure 6. Area of the Race Rocks Pilot MPA surveyed by Coastal Ocean Resources Inc. using SIMS Survey technology. Coloured lines represent boat tracklines. Image from Harper et al. 1999, and courtesy of the Canadian Hydrographic Survey, Pacific Region.

CLIMATE AND WEATHER

AIR TEMPERATURE AND PRECIPITATION

The southern tip of Vancouver Island is in the Coastal Douglas Fir biogeoclimatic zone. It is a cool Mediterranean-type climate characterized by warm, dry summers and wet, mild winters. Ambient air temperature and precipitation are collected at Race Rocks, however, these data are proprietary with Environment Canada (EC). A long time-series (1967-1990) exists for Victoria Marine region (Environment Canada 1999), although there may be some slight variations between this location and Race Rocks

Figure 7 illustrates both the average monthly maximums and minimums for the station Victoria Marine (48° 22' N/123° 45' W). Ambient average temperatures peak in August and are coldest in January.

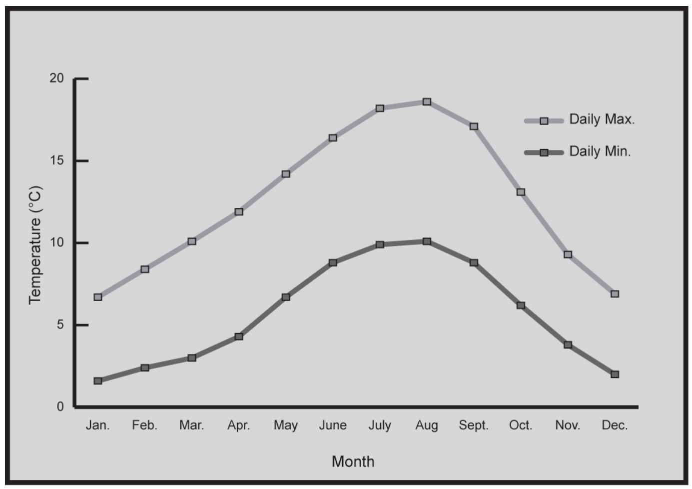

Figure 7. Averaged monthly minimums and maximum air temperatures (1967-1990) taken at station Victoria Marine. Data from Environment Canada 1999.

Race Rocks and southern Vancouver Island are in the rainshawdow of the Olympic Mountains and the Sooke Hills, thus they receive less precipitation than the Lower BC Mainland. Average precipitation peaks November through February. Snow is a minor component with December and January having the highest average accumulations of snow; 8.2 cm and 11.7 cm, respectively. The dry months are May through September (Figure 8).

WINDS

Although ambient temperature and precipitation from Victoria can be used as a proxy for conditions at Race Rocks, winds cannot because of local orographic conditions. In the SJF, winds are influenced by the surrounding mountains. The winds, in general, are a function of air circulation in the pressure cells that differ seasonally.The North Pacific High Pressure cell off California moves northward in the summer, resulting in the winds being predominantly from the northwest (Figure 9). These winds are then redirected down the SJF

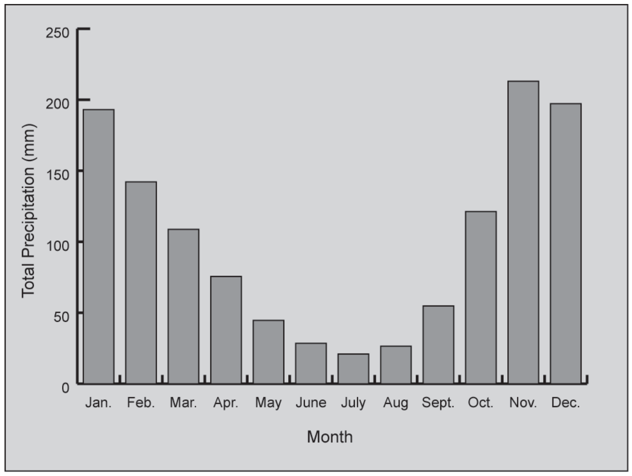

Figure 8. Averaged monthly total precipitation (1967-1990) at station Victoria Marine. Data from Environment Canada 1999.

to become westerly. In winter, the cyclonic Aleutian Low Pressure system intensifies and reverses the winds, bringing them in from the southeast (Figure 9). Winter winds are also heavily affected by storms that move through the region and with the movement of frontal passages, the winds can become westerly (Holbrook et al. 1980; Thomson 1981). Wind patterns at Race Rocks reflect this with 89% of July winds being westerly, while in October and January, the frequency of easterly winds is 57% and 69% respectively (Lange 1989).

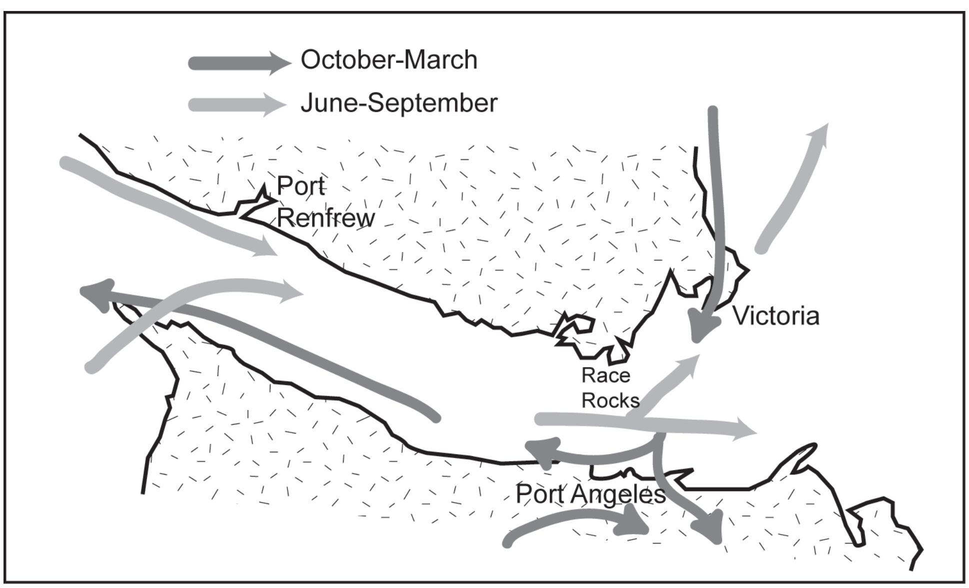

Figure 9. Dominant wind directions in the eastern section of SJF during summer and winter months. Figure modified from Barker 1974.

Gap winds are those that get funnelled and channelled down a topographic constriction resulting in increased wind speed. In SJF, the region between Race Rocks and Port Angeles (Figure 9) forms such a topographic constriction. During low pressure periods, these gap winds will be easterly (occurring predominantly in the winter), and if the system is high pressure, the winds will be westerly (predominately in the summer) (Lange 1998).

Environment Canada operates a wind station at Race Rocks. Unfortunately, historical and present day data obtained from this station are proprietary though they can be purchased from EC. Thomson (1981) reported the range of mean monthly wind speeds from July of 1969 through to January of 1974: the winds were 8-14 knots from October to March and from April to September they were 12-14 knots. These average speeds hide a wide range in values. For example, Holbrook et al. (1980) reported that in January 1978, the highest winds reported for this area were 42 knots over land and 38.5 knots over water. Overall, the majority of winds over a year fall into two ranges, 1 to 7 knots and 8 to 16 knots. A lesser percentage of the winds are are between 17 to 25 knots, and an even smaller percentage are greater than 25 knots (Lange 1998).

PHYSICAL OCEANOGRAPHIC CONDITIONS

WATER CIRCULATION

There are three components to water movement in the SJF; estuarine circulation, tidal flow (ebb and flood, and winds (discussed in the previous section).

Estuarine Circulation

The SJF is characterized by weak stratification and strong tidal currents. The circulation is typical estuarine with the surface waters having net seaward flow and the bottom waters having net landward flow. Alterations in this pattern are infrequent (usually in winter) and are generally caused by high winds (Holbrook et al. 1980; Thomson 1981). Crean et al. (1988) estimated the freshwater component of the SJF to average 7%. Because of estuarine conditions the ebb is generally stronger than the flood in the top 100 m of the water column, while the flood is stronger at depth (> 100 m) (Godin 1984; Thomson 1981). The flow can be highly variable, but in general, the surface waters show a 0.2-0.4 knot net seaward flow that can become as high as 0.8 knots during the early summer freshet.

Tides, wind, basin topography, and coastal oceanic forcing affect circulation. Cross-channel flow is a result of Coriolis forcing and channel curvature. This results in outflow and inflow waters favouring the northern and southern shores respectively. (Thomson 1981).

Reversals in estuarine flow can occur in response to wind direction, possibly the higher frequency of storms, and from the low amounts of freshwater input. Southerly winter winds reduce freshwater outflow from the Strait of Georgia, thereby causing sea level to rise in the western region of SJF. This differential causes surface waters to flow landward and the deep waters to flow seaward (Thomson 1981).

Tidal Circulation and Current Flow

Tides are progressive waves, propagating eastward along the SJF from the open ocean, resulting in a mixture of semi-diurnal (two per day) and diurnal tides. Harmonic analysis of tides involves combining elementary constituent tides that are the result of harmonic astronomical constants. These include:

T the rotation of the earth on its axis with respect to the sun, 15 degrees/hour;

h the rotation of the Earth about the sun, 0.04106864 degrees/hour;

s the rotation of the Moon about the Sun, 0.54901653 degrees/hour;

p the precession of the Moon's perigee, 0.00646183 degrees/hour; and

N the precession of the plane of the Moon's orbit, -0.00220641 degrees/hour.

The diurnal constituents are K_1, O_1 and P_1 (1=one cycle per day) while the semi-diurnal constituents are M_2, S_2, N_2, and K_2 (2=two cycles per day). The elementary constituents combined to form the total composite tide. K_1 and M_2 are the principle components, respectively. Because it takes different lengths of time for the principle components to travel the SJF, the region has a mixture of diurnal and semi-dirunal tides. The ratio, $(K_1+O_1)/(M_2+S_2)$, determines the importance of each constituent. At Race Rocks, the tides are mainly mixed/semi-diurnal (ratio=0.25-1.5) because the M_2 components outweighs the K_1. East of Race Rocks, the K_1 becomes increasingly important, resulting in mixed/mainly diurnal (ratio=1.5-3.0). The tidal harmonics change as water moves eastward into the SJF causing the semidiurnal component to become less important. The harmonics associated with Race Rocks is dominated by the diurnal component (Figure 10) (Parker 1977).

Mean tidal ranges at Race Rocks are less than 1.85 m (Thomson 1981 citing Barker 1974). Low tides occur in the spring and summer during daylight hours, and at night during fall

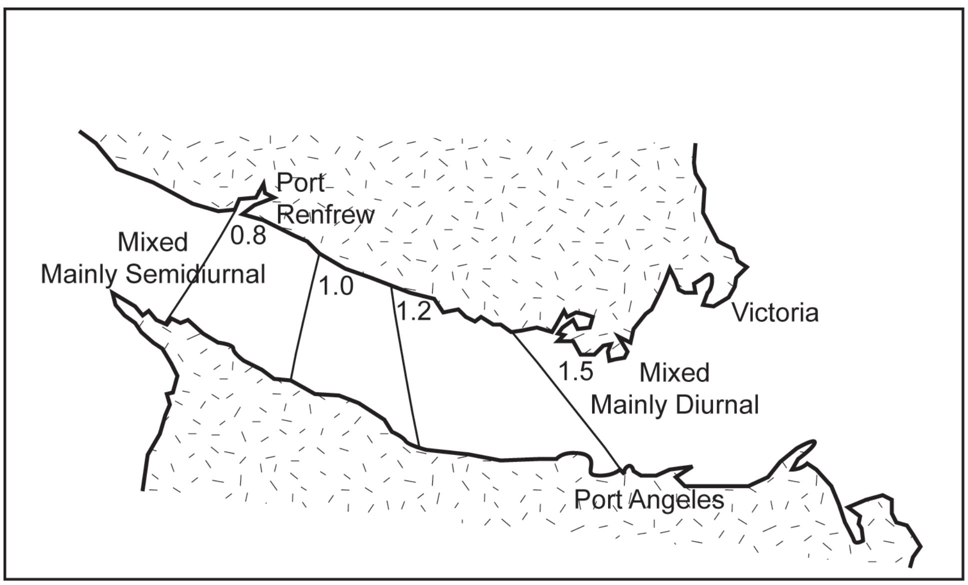

Figure 10. Tidal harmonics in SJF. Numerical values represent the ratio of diurnal tides to semidiurnal tides. The diurnal component becomes increasingly more dominant at values of 1.5 or greater. Figure adapted from Parker 1977.

and winter . Topography and the time required for the wave to travel the length of the Strait alters wave height. Data modelling (Thomson 1981) shows that significant wave heights in the SJF can be from 1.5 m to 2.7 m, with 10% of them being over 3 m if conditions are appropriate.

In 1980-1981, current metres placed in Race Rocks Passage by CHS personnel, yielded more accurate predictions of tides and currents. Present day predictions are still based on this time series. The Foreman et al. (1995) model for the SJF shows that the strongest tidal currents and maximum mixing occurs at Race Rocks (Figure 11). Flood currents reach up to 6 knots through the narrow reaches of the channel.

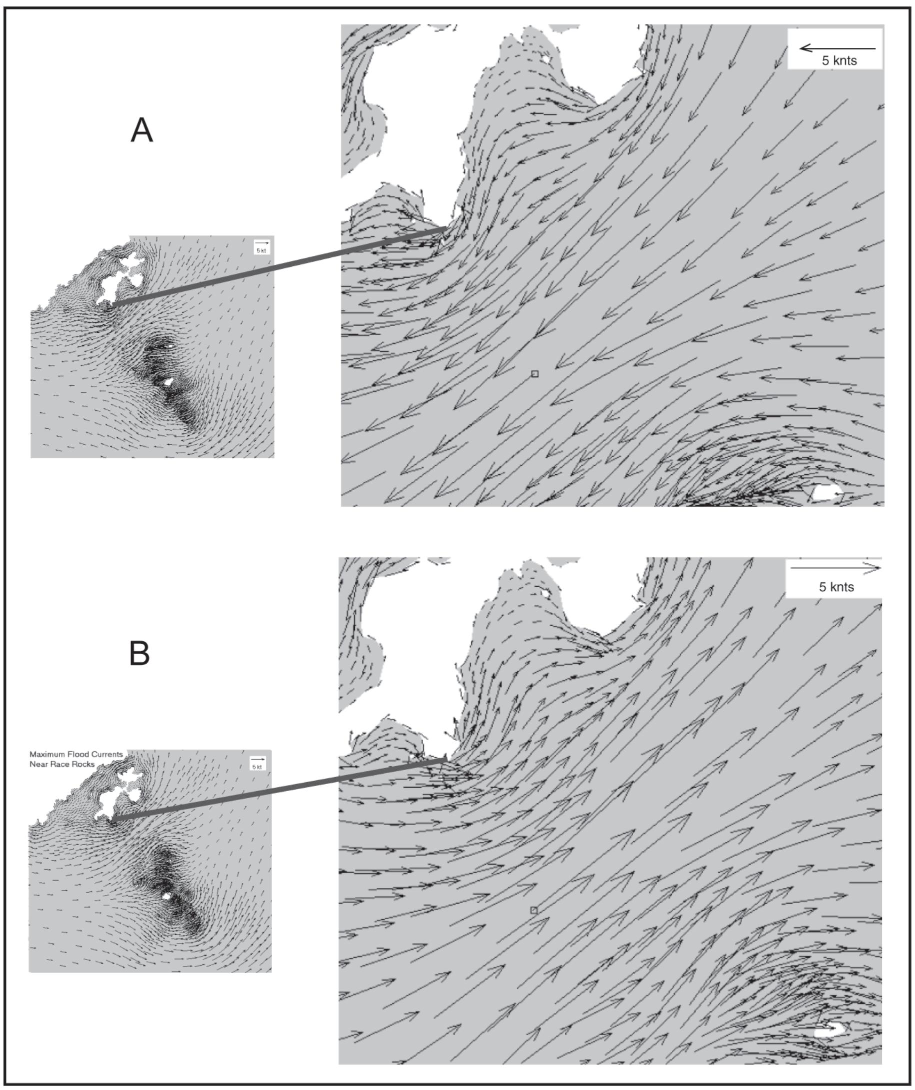

Figure 11. Current direction and velocity at Race Rocks based on Foreman et al. (1995). Image A represents maximum ebb conditions; image B represents maximum flood conditions. Images courtesy of the Canadian Hydrographic Survey.

Summer and winter current speeds are highest in June/July and in December/January, respectively, and are at a minimum in the spring and fall, correlating with the tidal cycle. Tidal rips form during flood conditions if the winds are from the northeast or southeast, which is common during the winter season.

Computer-generated current models show that east of Race Rocks, a large counter-clockwise backeddy forms in the bay between Rocky Point and Victoria on the larger of the two daily floods. This backeddy also appears to be large enough to initiate a westward current flow (Thomson 1981). Backeddies do not form on the west side of Race Rocks during ebb conditions.

Currents in the SJF are generally parallel to the shoreline. There are however, areas where currents are diverted such as east of Race Rocks. Ebb waters swing southward past Victoria, and while some smaller currents do flow along the curvature of the coastline, the major flow moves southwest from Victoria, then heads northwest past Race Rocks. In some conditions there can also be a strong cross-channel flow (Thomson 1981, 1994).

It is the strength and speed of the currents at Race Rocks that makes it a unique site in the SJF. This intense vertical mixing brings nutrients up from depth. This likely provides the basis for the highly productive and diverse ecosystem.

SEA SURFACE TEMPERATURE

Race Rocks has been a shoreline station for surface temperature and salinity measurements since 1941; prior to then, the station was at William Head from 1921 (salinity was not measured until 1936). These data represents one of the longest time series available for the British Columbia coast.

The waters are well mixed and turbulent, thus temperature and salinity show only small intra-annual ranges. Conditions are a function of interacting water masses between the western and eastern sections of the SJF, and input from the Strait of Georgia. The flux from the Strait of Georgia is especially critical, affecting both surface salinity and sea surface temperature (SST) throughout the eastern portion of the SJF.

Figure 12 shows the average annual monthly SST at Race Rocks. Like much of the eastern SJF, winter months are the coldest with temperatures between 7°C and 8°C. Surface temperatures warm up in response to increaseed solar exposure and also to warmer waters flowing out of the Strait of Georgia from the Fraser River freshet. Summer temperatures peak in August with temperatures averaging 11°C.

“El Niño” events are monitored using sea level atmospheric pressure records from Tahiti and Darwin, Australia. An index, the Southern Oscillation Index (SOI), closely tracks changes in heat distribution in the equatorial ocean. When the SOI is negative, there is generally a persistent warming of the central and eastern tropical Pacific SST. When this signal is particularily strong it is indicative of El Niño conditions. The Pacific coast of North America is affected by El Niño events, through changes in both atmospheric and oceanic circulation. Coastal waters are warmed, such that in 1997-1998, the El-Niño brought one of the highest recorded SST at Race Rocks—a temperature of 13.8°C on August 13, 1997. Warmer SST are also generally accompanied by a weakening of coastal upwelling conditions along the Pacific.

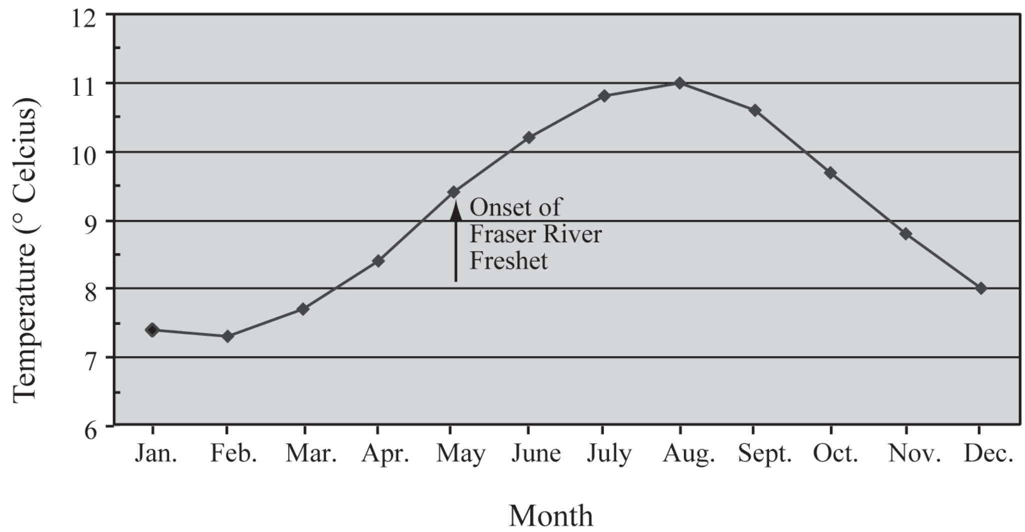

Figure 12. Average monthly (1921-1998) sea surface temperature at Race Rocks . Data from Ocean Sciences and Productivity Division, Institute of Ocean Sciences, Pacific Region, DFO.

When the SOI is persistently positive, it is indicative of La Niña conditions where the central and eastern Pacific sea surface temperatures (SST) are cooler than normal. The accompanying tradewinds move water off the equator enhancing equatorial upwelling. Historically, El-Niño and La Niña intervals last 3-7 years, however, since 1976 the frequency has increased to ~2.2 years (www.wrcc.dri.edu/enos/esnofaq.htm).

The SOI is calculated from conditions in the eastern tropical Pacific. How El Niño and La Niña conditions manifest themselves and how long they last in the northeastern temperate Pacific depend on several factors including north Pacific atmospheric warming, surface wind patterns, and interference/enhancement from more localized events.

There is a general correlation between the SOI and SST in BC waters as recorded by the lighthouse stations. Figure 13 shows the sea surface temperature anomalies for Race Rocks and the SOI. Anomalies are those temperatures that are above or below conditions which are considered normal (calculated averages from long time-series data). Not all SST anomalies are connected with El Niño events. Since the mid-1970s there has been a general warming of the surface ocean along the North American coast which is coincident with global warming (www.cru.uea.ac.uk/cru/data/temperat.htm).

SALINITY

Figure 14 illustrates the average annual seawater surface salinity values for Race Rocks. Although surface salinity, on average, only appears to change by 0.7‰, the intra- annual cycles are important. This cycle is marked by two salinity minima and two maxima. This is characteristic not only at Race Rocks, but for most of the SJF. With the onset of the spring freshet from the Fraser River, the Strait of Georgia becomes weakly stratified with a surface freshwater lens. This lens warms as it travels out of the Strait of Georgia, via Haro and Rosario Strait, into eastern Juan de Fuca.

Monthly discharge of the Fraser peaks in June. This freshwater export can been seen in the summer salinity minima (LeBlond et al., 1994). There are usually two pulses of freshwater

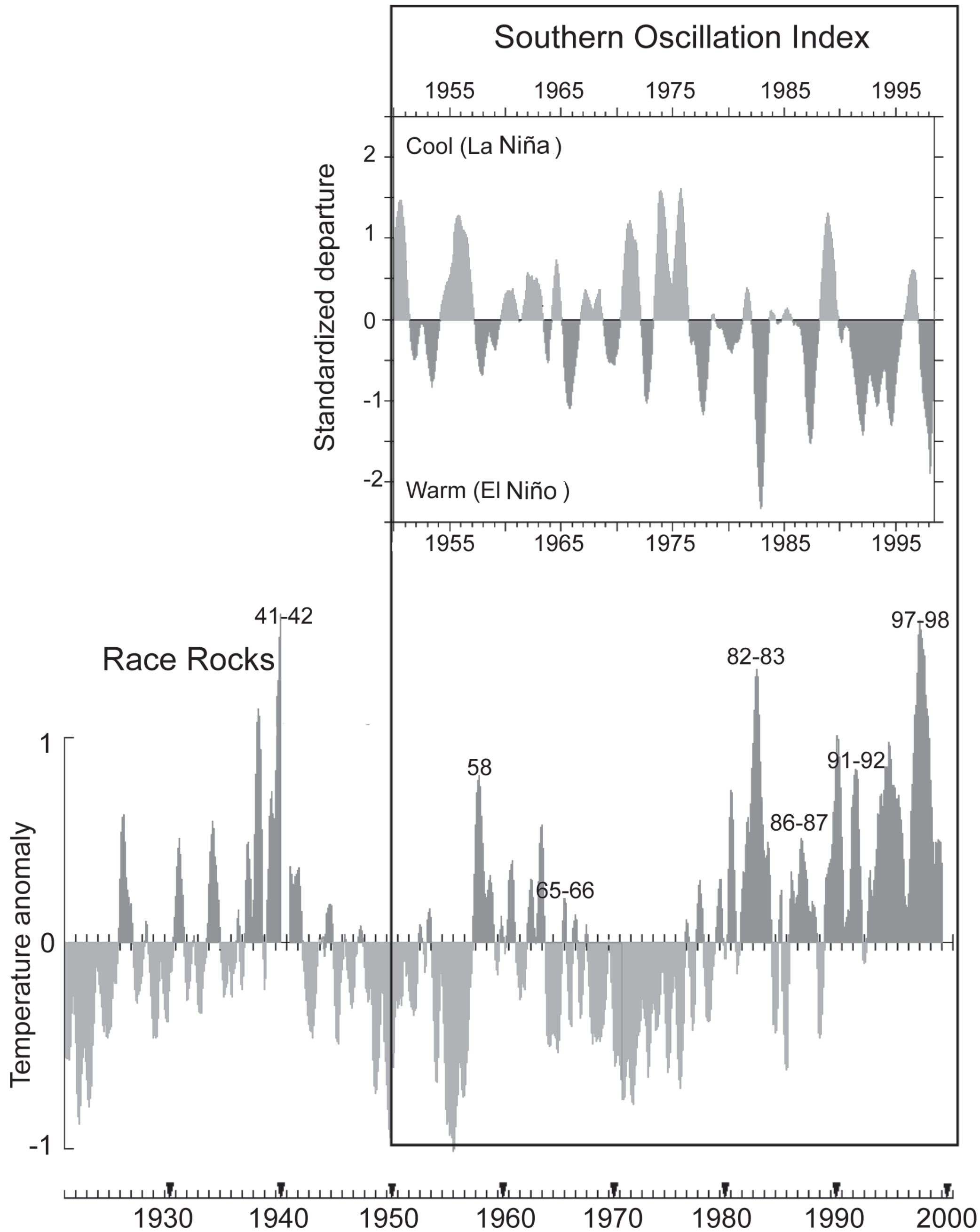

Figure 13. Southern Oscillation Index and sea surface temperature anomalies from Race Rocks, SST anomaly data compliments of Ocean Sciences and Productivity Division, Institute of Ocean Sciences, Pacific Region, DFO.

entering the SJF; one in June, the other July. These dates correspond with the spring-neap tidal cycle and with the summer northwest winds that blow over the Strait of Georgia (LeBlond et al. 1994). Figure 15 illustrates the fluxing of buoyant warm/fresh water leaving the Strait of Georgia and flushing into the SJF. The combination of a high level of freshwater export, neap tides, and northwest winds are all critical to the movement of buoyant freshwater export in SJF. By August, this freshwater flux has ceased and salinity rises. The freshwater discharge

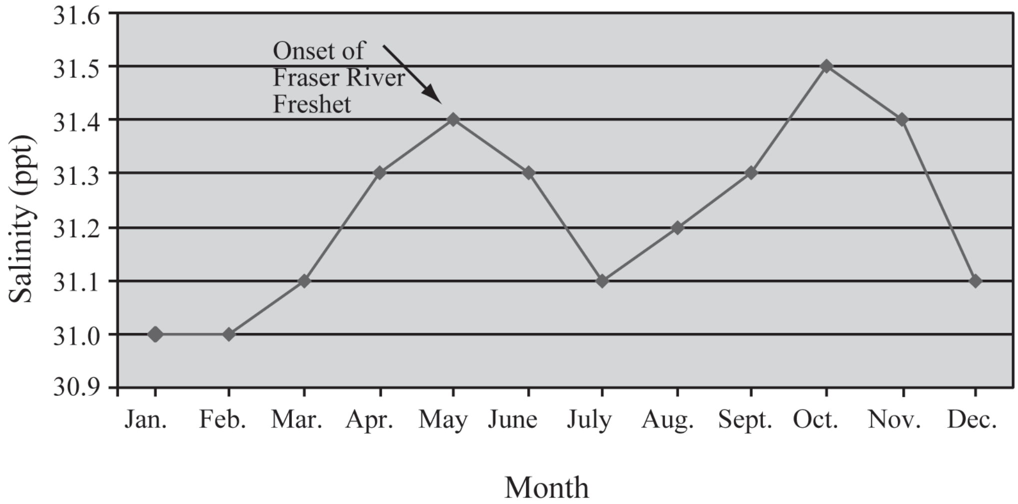

Figure 14. Average monthly sea surface salinity at Race Rocks 1921-1998). Data from Ocean Sciences and Productivity Division, Institute of Ocean Sciences, Pacific Region, FOC.

is an important event that keeps the SJF weakly stratified in the summer; it may also play an important role in the freshwater lens found outside the Strait (Hickey et al. 1991). It is also an important consideration for issues
such as transport of suspended loads, pollutants, and larval dispersal. By November/December, freshwater runoff from coastal watersheds, due to seasonal precipitation, lowers surface salinity.

As mentioned, the stratification in the SJF is weak but present in the summer. However, it is nonexistent in the winter. Neither temperature nor salinity have been monitored in the deep waters near Race Rocks, but inferences can safely be made from STD observations made throughout the SJF. Temperatures stay relatively cold throughout the year; between 7°C and 9°C, with the waters east of Race Rocks and Port Angeles (see Figure10) being uniform with depth due to the high degree of mixing. Salinity ranges from 32.5-33.5‰ year round (Thomson 1981 based on Crean and Agnes 1971).

Regardless of time of year, it is unlikely waters in and immediately adjacent to Race Rocks experience stratification for any appreciable length of time. There may be short-lived pycnoclines associated with the freshet, but the tidal and current mixing would rapidly break this down.

CHEMICAL OCEANOGRAPHY

NUTRIENTS

Dissolved nutrients and sunlight are the basis for primary production and thus drive the vast majority of marine food webs. Nitrogen, phosphorous, and silicon, in various chemical forms, are the key nutrients. The three most important forms of dissolved nitrogen are nitrate (NO_3^-), nitrite (NO_2^-), and ammonium (NH_4^+). Phytoplankton utilize ammonium quickly so it is rarely in excess; the most commonly measured constituents are nitrate and nitrite. Dissolved

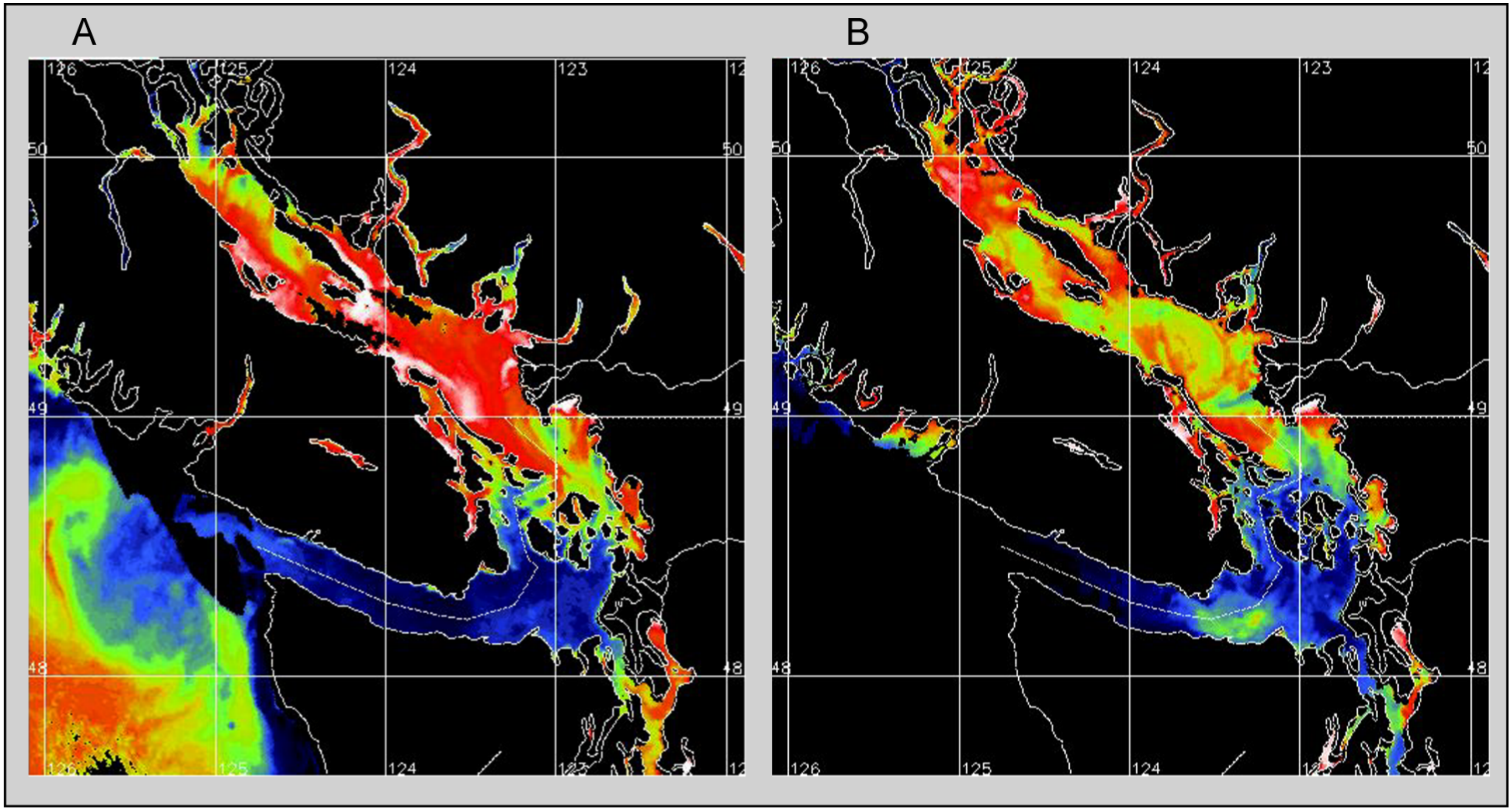

Figure 15. NOAA AVHRR sea surface temperature images from July, 1999. The colours represent thermal regimes from blue (cold) to red (warm). Cloud and land masked to black and digital coastline added in white. Image A illustrates the flushing of the Fraser River on July 13, at 13:38 UTC. Image B was taken on July 19 (neap cycle) at 23:11 UTC and illustrates the warm waters of the Strait of Georgia and a warm surface water mass that has moved out of the Strait of Georgia on the ebb and is now flushing in eastern SJF on the ensuing flood. Images compliments of Ocean Sciences and Productivity Division, Institute of Ocean Sciences, Pacific Region, DFO.

inorganic phosphate (PO_4^{3-}) is critical for phytoplankton growth but is rarely limiting in marine waters; nitrogen, however, is frequently limiting. Dissolved silica, in the form of $Si(OH)_4$, is important for the growth of diatoms and is frequently limiting. The major input of silica to marine waters is river runoff, resulting in coastal waters having higher concentrations that the open ocean.

Since these nutrients play a key role in productivity and are most heavily utilized in the euphotic zone (upper water column where ambient sunlight penetrates), vertical profiles through the water column typically show surface water depletion with increased concentrations at depth. However, it may be expected that in areas of high mixing/turbulence, the water column would not show any significant vertical change.

Nutrient concentrations and cycling have not been well quantified in the SJF. It is generally accepted that nutrients in both surface and deep waters are high and rarely limiting, with nitrate values regularly in excess of 10 µM (Mackas and Harrison 1997). The deeper inflow waters brings nutrients into the Strait where they eventually mix with the upper waters in regions of high turbulence and mixing. The SJF is also a major source of nutrients to the coastal shelf waters west of the Strait (Crawford and Dewey 1989).

In the SJF, the surface nitrate values range from 8-25 µM and the deeper waters range from 20-35 µM (Harrison et al. 1994; Mackas and Harrison 1997). Sea surface nitrate minimas coincide with the salinity minimas during the summer that are associated with the neap tide cycle and the Fraser River freshet. Indeed, nitrate is directly proportional to salinity (Harrison et al. 1994; Mackas and Harrison 1997). The deep waters in the SJF originate with upwelling processes off the open coast. These waters are generally nutrient rich, though richer in the summer than in winter (Lewis 1978). This is the case for nitrate concentrations which are always highest at depth regardless of season. As well, due to the effects of cross-channel flow, the southern Strait (US waters) has higher concentrations than the northern sections (Canadian waters) (Lewis 1978).

Eutrophication due to nutrient loading from anthropogenic sources can be a concern for coastal waters. Mackas and Harrison (1997) estimated anthropogenic input of nitrogen at approximately 15 tonnes N day^{-1}. The oceanic (non-anthropogenic) input from estuarine circulation was estimated to be between 2, 600-2, 900 tonnes N day^{-1}, greatly exceeding the anthropogenic input. It is unlikely that large scale eutrophication will be a problem for the SJF, where the net nutrient flux is considered a substantial source of nutrients for the coastal offshore waters. There may be some degree of seasonal eutrophication in small isolated bays or inlets where there is a lower rate of turnover or more pronouced seasonal stratification.

There are few studies of phosphate in the SJF. Lewis (1978), in transects across the SJF, 55 km west of Victoria, sampled for phosphate. Although in some sections, and at certain times of the year, he did find surface depletions, there were no consistent trends. He did note that some of the highest summer values were associated with the ebb flow. Phosphate values ranged from 1-6 µM depending on location, season, and depth. Surface values ranged from 1-6 µM and the deep waters from 1.7-2.5 µM. There also seemed to be no real trend associated with the seasonal cycle although the winter values were somewhat lower than summer values at certain stations.

There are only a few available measurements of silica for the SJF, and these were recorded by by DFO (Institute of Ocean Sciences) personnel. Values for May samples ranged from

30-40 µM, with surface values being only slightly lower (by 2-3 µM) than deeper water values. In June, surface values increased to 50-60 µM.

There have been no nutrient or chemical studies at Race Rocks. Since this is a highly mixed system, one assumption is that nutrients are high and would show a similar concentrations to other stations in SJF.

Ocean Sciences and Productivity Division, Science Branch, DFO, is responsible for most of the oceanographic data held in different databases. They are in the process of standardizing the database systems. More data has been collected than reported here, but was unavailable.

DISSOLVED OXYGEN

Dissolved oxygen (DO)is critical to almost all forms of marine life. At greater than 5 mg/L waters are considered aerobic (sufficient levels of DO for life processes). At levels between 0.5-3.0 mg/L waters are considered to be hypoxic and disruption in biological processes can be expected (Newton et al. 1994). DO levels are a function of production vs. uptake, of which each are mediated by biological and chemical processes.

In the SJF, DO shows seasonal stratification with deeper waters having lower concentrations. These waters are supplied by coastal upwelling and generally have lower DO values (Newton et al. 1994). However, at Race Rocks, the degree of current flow and mixing between water masses and at the air-water interface, would likely result in high DO concentrations throughout the water column.

CONTAMINANTS

Chemical contaminants can exist in two phases in aquatic systems: dissolved and particulate. Many contaminants are chemically active and bond to particulate matter (e.g. minerals, detritus) where they eventually sink and are incorporated into the food chain. Many of these chemicals have long-term persistence in the environment and thus will remain problematic until broken down or covered over with sediments.

Chemical contaminants, especially by-products of industrial processes, enter Georgia Basin and the SJF where they may or may not present a biological or human risk. To date, contaminants have not been a large concern in the SJF due to the high mixing rates and rapid flushing time. Either in dissolved or particulate phases, most contaminants would be carried out of the Strait (Carpenter and Peterson 1989). Baker et al. (1978) measured and modelled the seasonal trajectory of particles in the Strait of Georgia/Puget Sound/SJF system. Most of the SJF, particle concentrations were <1 mg/L in both surface and deep samples. The exception was the month of March where concentrations were >2 mg/L near the bottom.

Much of the material on the contaminants discussed below are taken from Harrison et al. 1994 and Macdonald and Crecelius 1994.

Metals

Due to the physical oceanography of the Race Rocks area and the SJF, it is unlikely that metals, such as lead, copper, zinc, and cadmium would have an opportunity to accumulate and adversely impact the bioata.

Organics

Effluents from industrial processes include polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons (PAHs). These active compounds attach to particulates and deposit in sediments where they persist. There have been few studies on these chemicals in the SJF, thus the distribution is unknown.

Tributyl tin (TBT) is an organotin compound used internationally in antifouling paint. The butyl tins leeches from ships hulls and persists in the environment, but, the mode of transfer to the biota is not clear. The use of TBT has recently been restricted to boats >25 m long. Its most obvious effect is the phenomena of imposex [imposing male reproductive characteristics (e.g. penis, vas deferens) on females] on gastropod whelks. The development of male reproductive structures often disrupts the female reproductive structures, making fertilization/egg release difficult or impossible. Certain gastropod whelk populations in BC have suffered decreased numbers due to imposex. It is not documented if these populations have rebounded since the limits on TBT were imposed.

Many marine nations continue to indiscriminately use organotins in antifouling paints. TBT does exist in all marine waters of BC. Whelks at Race Rocks do exhibit imposex (Macintosh 1991). It is not known if the whelk population at Race Rocks is in decline from imposex, recovering due to Canadian restrictions on TBT, or stable.

Oil Spills

This section is not intended as an overview of the hazards associated with oil spills or of the contingency plans in place. Reviews of these issues can be found in Anderson (1989), Castillo et al. (1995) and Dickins and Associates (1995). Since the 1970s there has been increasing concern about the potential and hazards of oil spills occurring in the SJF. This stems from an increase in tanker traffic to refineries in both the Georgia Basin and Puget Sound. US concerns led to the Marine Ecosystem Analysis (MESA) Project which included a biological and physical evaluation of the US marine waters of the region. In BC, both provincial and federal governments have contingency and operative plans in the event a spill and also work with the US on a Spills Task Force. The SJF is considered at moderate risk with 1-30 tankers per month in waters that are moderately congested (Wolferstan 1993).

Oil in contact with water spreads in a surface slick; dispersal is thereby highly dependent on winds and currents. Some oil remains in suspension, while the remainder adheres to particulates and sinks to the sediments. The severity and impact of an oil spill depends on many factors, including location, weather conditions (especially wind and storm conditions), season, shoreline type and exposure, and the size of the spill (Wolferstan 1993). Tides and currents in the SJF would play a major role in dispersal; waters in ebb state tend to curve to the northern side (Canadian) of the Strait.

For the eastern region of the SJF, the area is well mixed and water residency time is short; dispersion of an oil slick would be quick. Since the SJF is not a sediment sink, deposition of oil adsorbed particles is less likely to occur. Slick deposition in isolated inlets and bays is a concern.

Due to the high public profile and the biological diversity at Race Rocks, an oil spill in the region is of considerable concern. The rocky intertidal and subtidal community have diverse food webs that are deitrital and macroalgal-based. These communities are generally long-lived and well established, making them highly vunerable to oil and subsequent clean-up processes (Nyblade 1978). Also at Race Rocks, there is a great concern for marine birds. It should be noted that rocky headlands that are moderately exposed and have high currents and wave action are considered less susceptible to oiling (Environment Canada 1992).

In planning for oil spills , LUCO produced the Coastal Resources Oil Spill Response Atlas for the Southern Strait of Georgia (Howes et al. 1993). It characterizes the biological resources, physical components and analyzes the vulnerability of the coastline to oil spills. Included in the atlas are sensitivity maps, resource and logistic maps, and countermeasures. For the area that includes Race Rocks, there are high quality and accurate maps. Race Rocks has been labelled area 1702 (Howes et al. 1993).

In terms of relative biological importance, the ranking system lists this area as "very high" for cormorants, loons, grebes, gulls, sea lions and seals. It is listed as "high-medium" for transient killer whales; "medium" for diving ducks, shorebirds, alcids and harbour porpoises. It is "low" and "very low" for Great Blue Herons, geese and swans, dabbling ducks, Bald Eagles, Black Oystercatchers, and Dall's porpoise. It is also listed as "medium" for recreational fisheries. In terms of important biological resources, it lists the presence of bird colonies, seal and sea lion haulouts and rafting sites, and kelp beds. Physically, it characterizes Race Rocks as rocky platforms with rock cliffs that are semi-exposed to waves.

With respect to the actual sensitivity of the area to oil spills the area is listed as "very low" to "low" for the entire year. It is also listed in this category for it's sensitivity to oil cleanup procedures. For cleanup, it lists shallow obstructions as constraints to possible boom operations and suggests that viable clean up options include manual cleanup, spot washing, debris burning, and natural recovery. Oil residency is expected to last weeks to months but cleanup procedures are deemed highly effective. There is some concern for marine birds which are considered vulnerable to oil spills throughout the year, and are listed as having "very high" sensitivity to

BIOLOGICAL COMPONENTS

MARINE ALGAE

Algae are a diverse group of plants that inhabit a wide range of aquatic habitats. Macroalgae are conspicuous on rocky intertidal/subtidal environments. They provide food, cover, and protection from desiccation for many intertidal organisms. In the Pacific Northwest they are prominent members of the subtidal community down to a water depth of 30 m, providing structurally diverse habitats. They are a major producer of organic carbon, and can be the foundation for nearshore marine foodwebs (Simstead and Wissmar 1985). Algae are classified into various groups generally on the basis of pigmentation and storage products (Bold and Wynne 1985). The three Divisions that comprise the macroalgae are: Phaeophyta (brown algae); Rhodophyta (red algae); and Chlorophyta (green algae). An additional Division, the Anthophyta (flowering vascular plants), also have marine benthic representatives including *Phyllospadix* (surfgrass) and *Zostera* (eelgrass). These do not belong to the algae; their habits and habitats are similar and as such, are included in this section.

Biomass and distribution can vary greatly with the seasons. Some species are annuals while others are perennials. Some perennials can suffer large tissue loss through wave surge action during winter storms but growth initiates the next spring. In the waters of the Pacific Northwest, the peak growth period for benthic algae is March through June with decreasing levels of growth from July through October (Webber 1981). The largest contributor of biomass/ standing stock, relative to the other Divisions, is the Phaeophyta (e.g. kelps the Order Laminariales). Examples include species of *Nereocystis*, *Macrocystis*, and *Laminaria*.

In 1988, the BC government commissioned a standing stock survey of kelp in the eastern SJF (Sutherland 1989). Sampling included the month of August and covered *N. leutkana* and *M. integrifolia*. Plant density per hectare increased dramatically in spring. Survey block "A" (Race Rocks to Sooke) recorded 67 metric tonnes ha^{-1}, for a total of 5395 metric tonnes for the survey block. This was approximately 12% of the total biomass for 105 km of coast-line surveyed. Although the grid lists survey block A as being from Race Rocks, it appeared not to include the pilot MPA. Hence there are no estimates of macroalga biomass for the Pilot area.

In 1975 Dobrocky Seatech performed an intertidal, subtidal macro-algae survey and included Race Rocks (Goddard 1975). A subtidal survey only was performed and it was conducted in March. The survey results showed that from 0-10 m, species of *Pterygophora*, *Laminaria*, and also *N. leutkana* were present, as were extensive mats of *Corallina*. At >10 m, macroalgae were rare except for a few *Laminaria spp*. and *Lithophyllum sp*. Figure 16 shows the basic

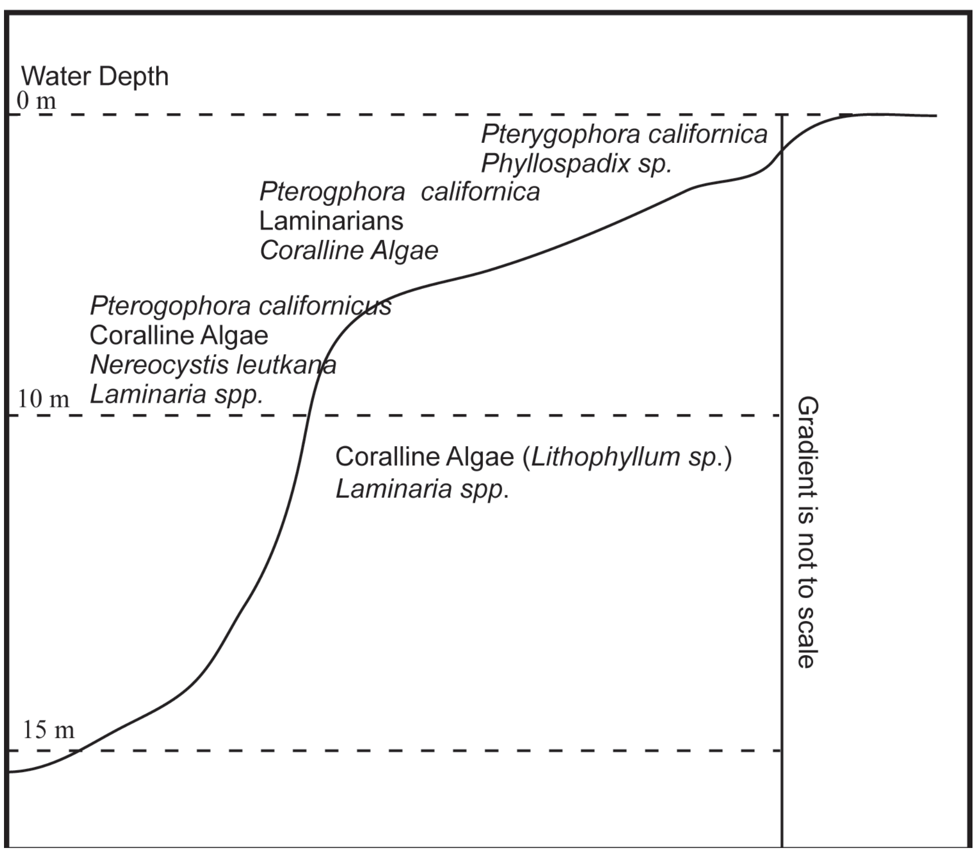

Figure 16. Macroalgal subtidal zonation pattern at the Race Rocks Pilot MPA. Data from Goddard 1975.

zonation pattern from Goddard (1975). However, the exact location of the transect was not given and this zonation pattern would likely differ depending on such features as slope gradient and current regime. For example, some species such as *Phyllospadix*, *Porphyra*, and some coralline species prefer areas with high currents such as surge channels. It should also be noted that the survey was performed in March and would not show the full distribution, peak abundance, or peak biomass of the various algal species.

In 1999, CORI was contracted by Fisheries and Oceans Canada to perform a Seabed Imaging and Mapping Survey (SIMS) of Race Rocks as part of the Ecosystem Overview process (Harper et al. 1999). This survey was performed in March of that year. This is important to consider as the SIMS results would not record the peak abundance or biomass of algae as compared to if the survey had been performed at the height of the growing season. CORI classifies vegetative cover by groupings of species: for example, "Dark Brown Kelps", or DKB, includes *Laminaria setchelli*, and species of *Pterygophora*, *Lessoniopsis*, *Alaria*, and *Egregia*. However, that does not mean that in an area of DBK that all those genera would be present. The SIMS results found that 51% of the vegetation consisted of DBK. Foliose Reds, that could include species of *Gigartina*, *Iridea*, *Rhodoymenia*, and *Constantina*, made up 5% of the vegetation. *Agarum* accounted for 3% and the Filamentous Reds (species of *Gastroclonium*, *Odonthalia*, *Prionitis*) were 2%. The remaining vegetation categories–Coralline Algae, *Nereocystis*, and Bladed Kelps–each constituted less than 1%. The amount of substrate categorized as "without vegetation" was 37% (Figure 17).

DBK has a large circum-islet distribution, and with the Foliose Reds, occur both in the north and south regions of the surveyed area (Figure 17). Percent distribution generally appears to be linked to depth. The areas where there is the highest percentage (27%-75%) of DBK are in the shallow areas around the islets. The 5%-25% category for DBK seems to fall into areas of deeper water.

Over the years, Pearson College students have performed subtidal transects around Great Race. They follow a lead line down the slope faces and perform quadrat surveys. They record the presence of several macroinvertebrates, but also the relative percent coverage of macroalgae in the quadrats. When the results of these transects (Pearson College, unpublished data), and the single transect from Goddard (1975) are compared with the SIMS survey there are some slight differences with respect to the percentages of *Nereocystis* and the Coralline algae. Pearson College and Goddard assign them higher percent abundance. Although strict comparisons between these three sets of data may not be entirely appropriate (Goddard performed only one transect and the location is not given; CORI's percentages are based on a larger surveyed area than a typical quadrat transects; shallow areas are more accessible by SCUBA), the differences may also lie in where the surveys were done. Any surveying from a boat at Race Rocks is a delicate trade-off between safety and area coverage. Many of the areas CORI classified as "no survey" are in the shallow areas around the islets. This is where there would be an abundance of macroalgae, especially the coralline species.

Appendix 1 lists the species of algae recorded from Race Rocks compiled using student records (from transects), swim line data, and the Pearson College Herbarium Database.

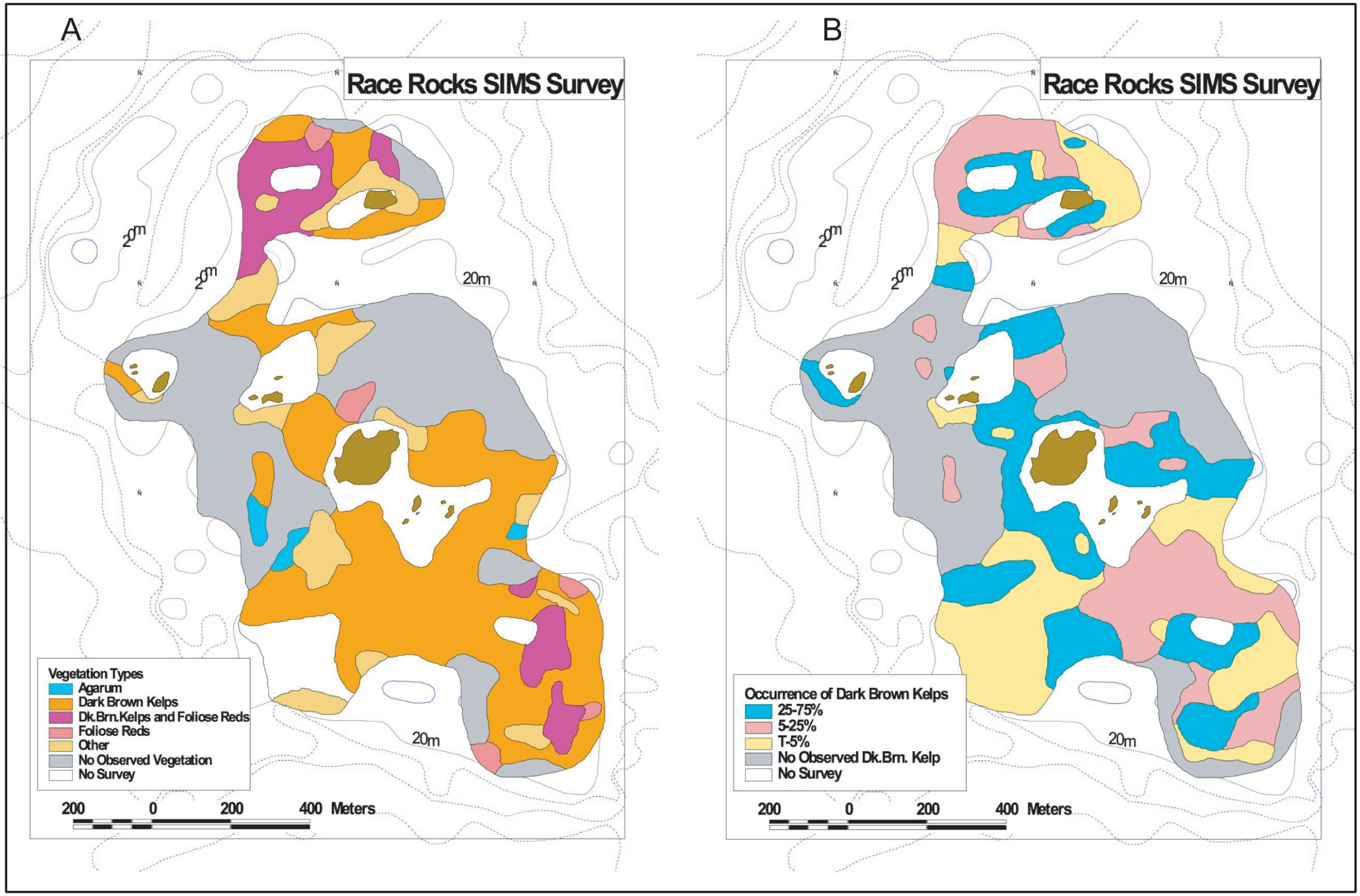

Figure 17. Polygon plots of vegetation at the Race Rocks Pilot MPA from the March 1999 SIMS Survey. Plot A illustrates the distribution of vegetation types. Plot B illustrates the occurrence of Dark Brown Kelps. Images from Harper 1999, courtesy of the Canadian Hydrographic Survey, Pacific Region.

PHYTOPLANKTON

Phytoplankton are photosynthetic organisms, usually single-celled algae, that live in the water column, primarily in the the euphotic zone. Phytoplankton are a critical trophic level in marine food webs. They are responsible for the primary production in the water column that is subsequently grazed by the larger zooplankton.

Several factors control phytoplankton production including incident light, hydrographic features, winds, freshwater runoff, etc. Their distribution is controlled by water mass movement (e.g. currents, tidal circulation). In most temperate waters, there is a seasonal cycle. In the late winter/early spring, there will be a diatom bloom. As spring progresses, the diatom numbers decline while the dinoflagellates increase in number. By fall, other microflagellates dominate in numbers and are generally high throughout the fall and winter. The increase in concentration and succession of phytoplankton is generally in response to increasing light availability, and in some cases, increased concentrations of nutrients supplied by upwelling along coastal regions.

Biomass is a balance between growth of the population and the loss of cells due to mortality. A system can have low biomass but high primary production if grazing pressure is sufficient. Estimates of phytoplankton biomass are usually determined by measuring the chlorophyll *a* concentrations in the water, and also by direct cell count. Chlorophyll *a* values are measured using *in vivo* fluorescence and reported as mg/m^3. Direct cell counts provide an estimate of biomass in terms of the number of cells per given volume or area. However, this method is more time consuming, and expensive.

In the SJF there has been only a few studies done on phytoplankton and there are no reported phytoplankton studies conducted within the waters of the Pilot MPA. The US Marine Ecosystem Analysis (MESA) project in the late 1970s did characterize the composition and biomass of phytoplankton in the SJF, and because of the nature of phytoplankton distribution in the water column, some assumptions can be made. The phytoplankton species that are found in the vicinity of Race Rocks are representative of the SJF. Estimates of biomass, however, will vary along the distance of the Strait as phytoplankton distributions are seldom homogenous between locations and even within the same water mass.

Chester et al. (1980) measured chlorophyll *a* along the SJF and quantified the species composition. They found that diatoms formed the bulk of the species in the spring and early summer Dinoflagellates were high in late summer/early fall, and microflagellates dominated in the fall and winter. Overall, biomass was highest in the spring.

Chlorophyll *a* values from the SJF are between 1 and 5 mg/m^3 with lower values in the fall/winter and higher values in the spring/summer (Lewis 1978; Mackas et al. 1980). Chester et al. (1980) found values as high as 25 mg/m^3 in unusually high bloom conditions. At the northern Puget Sound monitoring station, ADM002, values are similar with a range from 0.1to 2 mg/m^3 depending on the time of year (Newton et al. 1994).

Chester et al. (1980) provided a species list of the phytoplankton found in their study. They found 32 genera of diatoms with 93 species. In the spring *Skeletonema costatum*, *Chaetoceras spp.*, and *Thalassiosira spp*. dominated. By mid-winter *Melosira sulcata* and *Thalassionema* *nitzchiodes* were the most abundant. The dinoflagellate composition was variable from season to season. Samples taken in the mid-Strait in the eastern section (Station JDF-Figure 18) in August of 1980 found that the dominant diatoms were still *Thalassiosira spp.*, *Chaetoceras spp.,* and *Skeletonema spp.* There was also a high number of the coccolithophorid, *Imantonia rotunda* (Forbes and Waters 1993).

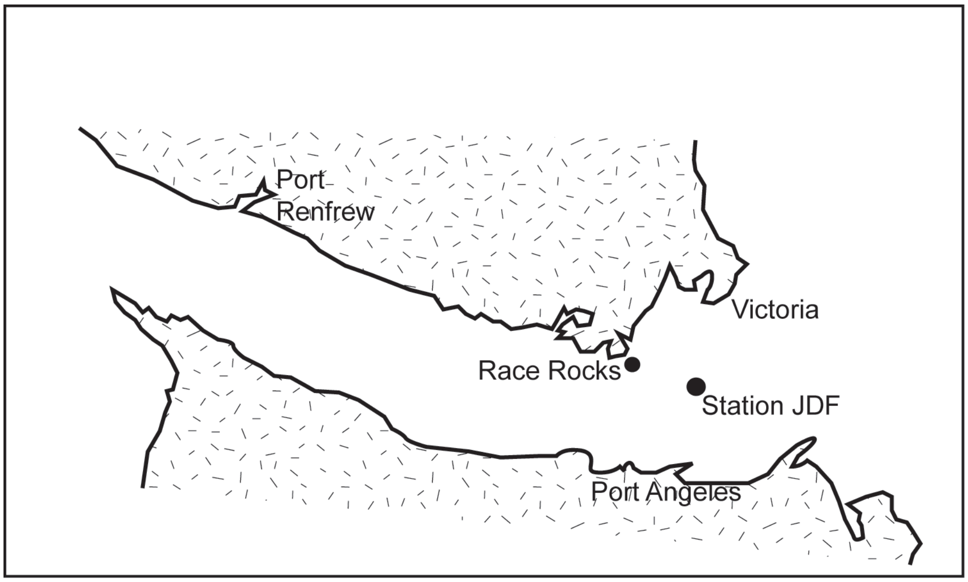

Figure 18. Position of Station JDF with respect to Race Rocks. JDF is approximately 9.5 km SE of Race Rocks at 48°16'N and 123°25'W.

Phytoplankton blooms can be harmful either in terms of high numbers and/or neurotoxins that are produced when there is a high cell count. The term used to describe this conditions is Harmful Algae Blooms, or HAB. High phytoplankton biomass is often a problem for fish farms since some species of algae can cause mucosal damage to fish gills. Neurotoxins can be harmful to fish, wildlife, and humans. Taylor and Horner (1994) give a concise overview of the HAB species and toxins found in BC waters. Generally, blooms are not common in the more open waters of the SJF. Either the production is quickly grazed, or the phytoplankton are carried out of the Strait quickly enough so that blooms do not appear to be a large problem. However, conditions that favour blooms likely occur in areas such as restricted embayments or inlets where water turnover is slower and water column stratification is more pronounced.

Appendix 2 provides a species list taken from Chester et al. (1980). Included are those species that have been identified by DFO at Station JDF.

ZOOPLANKTON

Zooplankton are those animals that live in the water column but have limited swimming capabilities and their movement is generally dictated by the water mass they inhabit. Many types perform diurnal vertical migrations while others are quite passive in their movements. They include a wide variety of organisms, including many of the larvae of benthic invertebrates and fish. Many researchers divide the zooplankton up on the basis of size fraction, from ultrananozooplankton (<2 µm) to macrozooplankton (>2 cm). They are an important trophic link, grazing on the primary production of phytoplankton, while being primary prey for those species up the food chain (e.g. other zooplankton, fish, marine mammals, etc.). In the SJF, zooplankton distributions and abundances have been studied but long scale time-series are not available.

Chester et al. (1980) reported the results from a year-long study of the zooplankton in the SJF. They found microzooplankton can respond quickly to rising primary production and productivity peaked in the spring. The most prominent member of the microzooplankton were ciliate protists such as *Helicostomella subulata*, *Eutintinnus spp.*, and *Strombidium spp.*

Macrozooplankton abundances showed that copepods, particularly the calanoids, were generally the most abundant, especially in the spring/summer versus the fall/winter. However, the fall/winter samples tended to show a higher level of overall species diversity. In the spring and summer, approximately 80% of the taxa were species of *Pseudocalanus* with a small percentage of *Acartia longirenus* and *Oithona similis* (a cyclopoid copepod). Other important members of the zooplankton were various species of euphasiids, chaetognaths, fish eggs, and fish larvae. This study found that in the upper 50 m of the water column, the seasonal distribution and abundance of zooplankton followed the seasonal production cycle of chlorophyll *a*.

It should be pointed out that there have been no zooplankton studies conducted at the Race Rocks Pilot MPA. Pearson College students collect some samples in the surrounding area (e.g. Pedder Bay), but the results of this sampling are not available. The closest station to Race Rocks, that has accessible zooplankton data, is station JDF (Figure 18). The taxonomic composition and seasonal relative abundance from samples taken at JDF are representative of the SJF and likely representative of the Race Rocks Pilot MPA. One of the most recent time series to span a year was the sampling period April, 1996-February, 1997. Tows were taken at both 50 m and as close to bottom as possible, ranging from 98 m to 150 m. The abundance is integrated over tow depth and reported as the number of individuals per m^2.

The data from this time series shows a very similar trend to that seen in Chester et al. (1980). Calanoid copepods were, for most of the year, the dominant member of the community. Their percentage is generally high in the spring/summer; from 70% in April to 93% in August. Their percentage goes down to 24% by February, with cyclopoid copepods comprising 47% of the sample. Calanoid dominance is is especially apparent in the upper 50 m of the water column, except in February. The remaining percent of the zooplankton community is distributed amongst the Crustacea, Cnidaria, Mollusca, Urochordates, and unidentified fish (Figure 19). For the dominant species of the copepods, the data is similar to Chester et al. (1980) with *Pseudocalanus minimus* being the most prominent, followed *Paracalanus parvus* in the summer, and *Metridia sp.* and *Ctenocalanus vanus* in the winter.

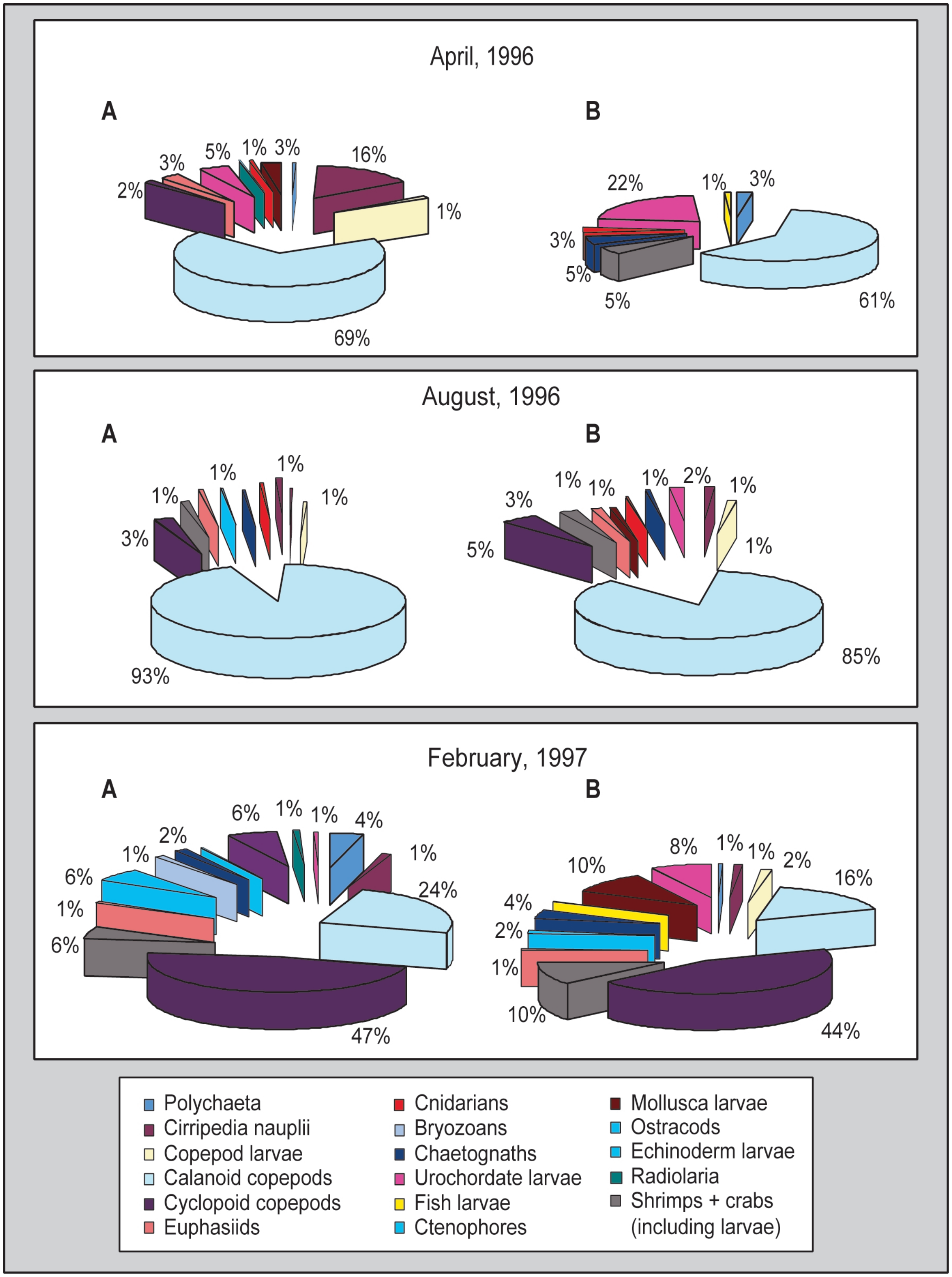

Figure 19. Zooplankton composition and abundance taken at Station JDF by IOS personnel. Charts A in deep water (98 m, 149 m, 135 m, respectively). Charts B are at 50 m. Pie slices without a corresponding numerical percentage are those groupings that are less than 1% of the total sample.This data is unpublished and courtesy of the Ocean Sciences and Productivity Division, Institute of Ocean Sciences, Pacific Region, DFO.

In terms of total zooplankton abundance for this time series, fall and winter (November and February) show the lowest values (4.3×10^4 and 1.96×10^4 individuals/m^2 respectively). These values increased through spring/summer and were highest in August (9.47×10^5 individuals/m2). The data shows zooplankton following a seasonal trend similar to phytoplankton, with production is highest in the spring and summer. Appendix 3 lists the taxa collected at Station JDF during the 1996/1997 time series.

BENTHIC INVERTEBRATES

Benthic refers to conditions or organisms that live on or in the bottom substrate. The term benthos can refer to the habitat and/or the organisms. The majority of organisms that are benthic are invertebrates. Benthic invertebrate communities have spatial and temporal dynamics that are often substrate, and in many instances, site specific. Factors controlling community type include substrate type, exposure (tides, currents, elevation), topography, and water depth.

Most benthic studies in the eastern SJF are a result of the City of Victoria's discharge of sewage at Macauley Point. Only a few of the studies focused on community composition and ecology with respect to understanding the shallow marine ecosystems of this region. The benthic invertebrate database for Race Rocks is probably the largest dataset of all the species groups, however, there are significant gaps in the information.

Characterization of the Benthic Habitat

The Land Use Coordination Office of BC (LUCO) classifies the physical shoreline in the Race Rocks area as rocky platform with rock cliffs (Figure 20) (Howes 1993). According to the SIMS survey (Harper et al. 1999) 69% of the area surveyed was bedrock and 27% was bedrock with a veneer of boulders and cobbles (Figure 21). Even in the shallow areas where SIMS was not able to survey, the substrate is likely bedrock. The QTCView (acoustical) seabed classification also indicates bedrock as a dominant class with a predominance of hard packed sand at depth and also in crevices along rock structures (CHS/Galloway pers. commun. 1999).

Exposure to wave action on the benthic habitat is also a critical factor. Race Rocks is exposed to progressive oceanic waves, tidal action, and high-velocity currents. These factors lend themselves to the establishment and proliferation of macroalgal beds (Figure 22) that provide habitat for invertebrate communities. Race Rocks is also structurally complex. There are numerous crevices, holes, and sheltered areas along the many faces of Great Race and its islets, providing habitat that is less exposed to currents and wave action.

Benthic Community Studies

Goddard (1975) is the first recorded systematic subtidal transect at Race Rocks. It was stated in the report that Race Rocks was "unique" in both composition, abundance, and diversity when compared to nearby subtidal sites. Figure 23 illustrates a basic invertebrate distribution pattern from this study. At 0-9 m, species of the hydrocoral *Allopora* and the soft coral *Ballanophylla elegans* were present, as were the sea urchins *Strongylocentrotus droenbachiensis* and *S. franciscanus*. Also present was the predatory starfish *Solaster dawsoni*. Smooth rock

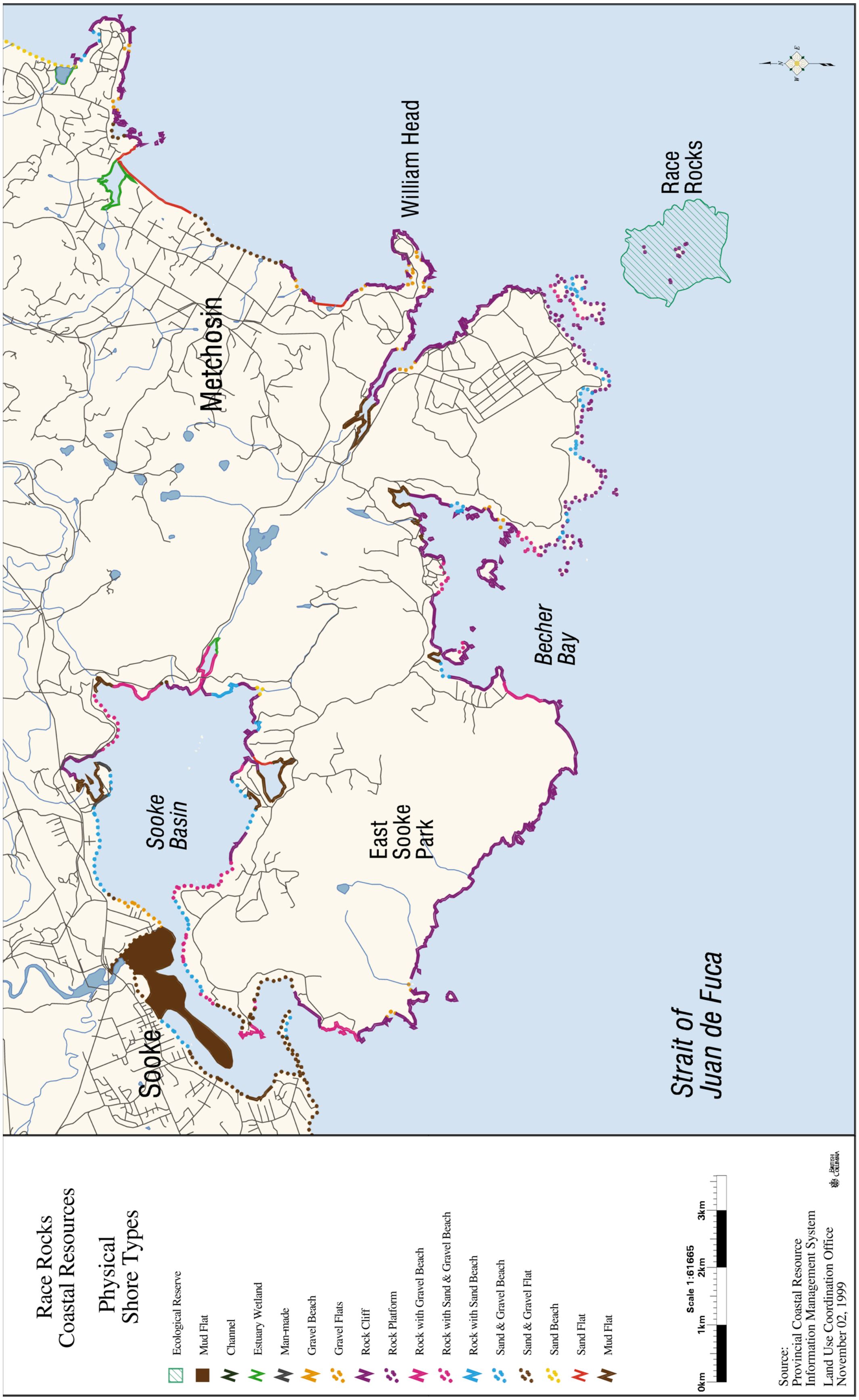

Figure 20. Physical shore types of the Race Rocks Pilot MPA and surrounding area. Map courtesy of the Land Use Coordination Office (LUCO), BC Provincial Government.

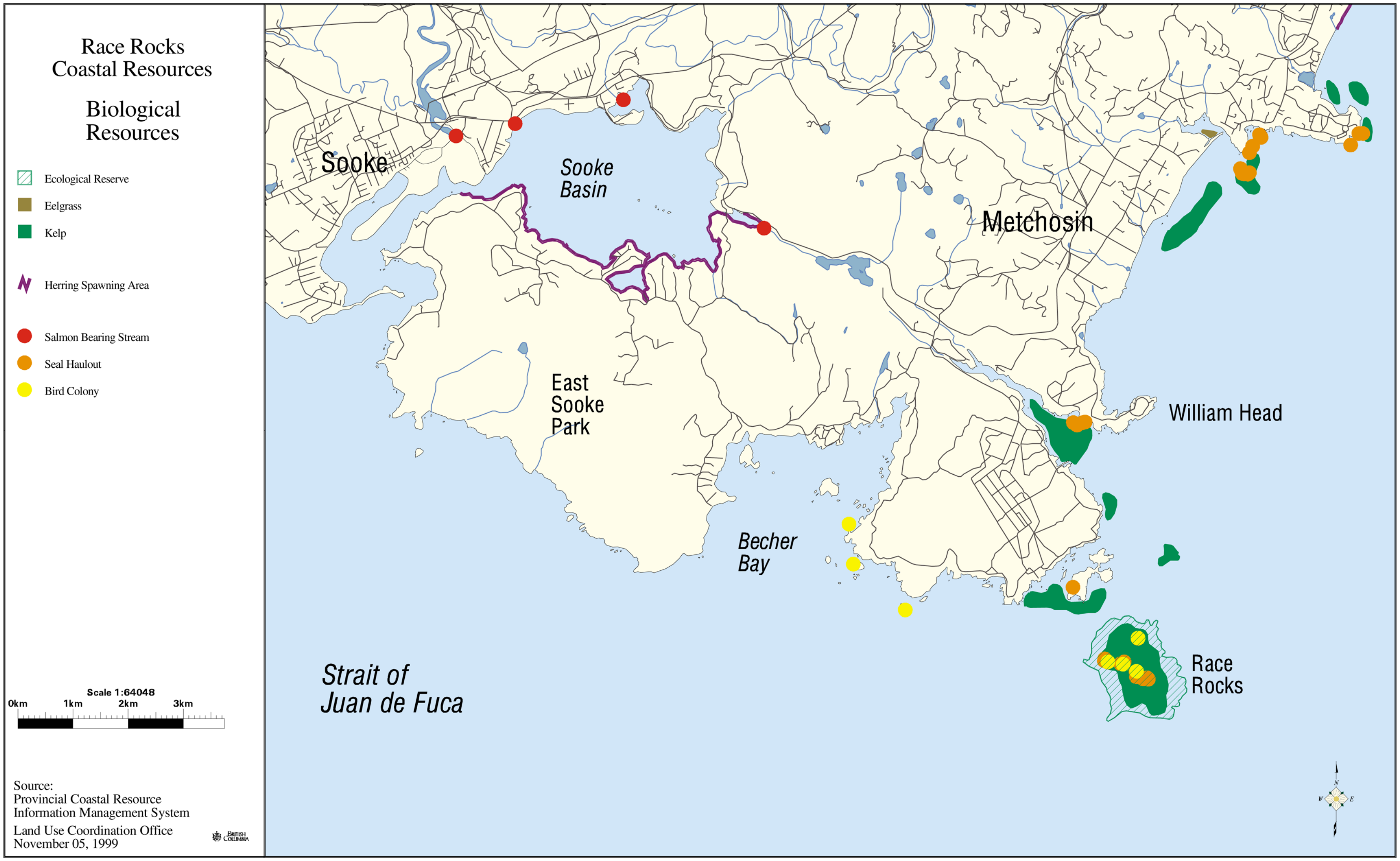

Figure 22. Biological resources including the distribution of major macroalgae (kelp) beds at the Race Rocks Pilot MPA and surrounding area. Map courtesy of the Land Use Coordination Office (LUCO), BC Provincial Government.

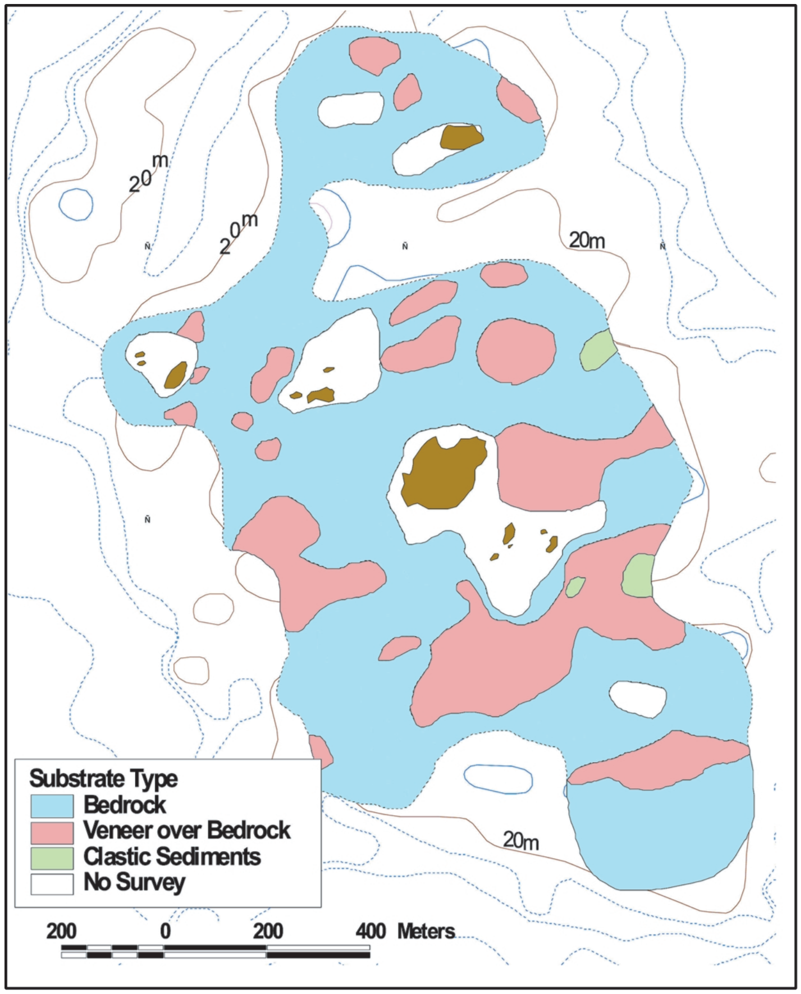

Figure 21. Polygon plots of substrate types at the Race Rocks Pilot MPA from the March, 1999, SIMS Survey. Images from Harper et al. 1999, courtesy of the Canadian Hydrographic Survey, Pacific Region.

areas where there were backeddies supported the abalone *Haliotis kamtschatkana*. Also found were large clusters of the California mussel, *Mytilus californianus*, and the brooding anemone, *Epiactis prolifera*, was abundant and present in different colour variations. Associated fauna included various gastropods, nudibranchs, and hydrocoral species.

At deeper depths (9-15 m) the study noted clusters of hydroid colonies, the giant barnacle *Balanus nubilus*, and numerous individuals of the anemones *Metridium senile* and *Epiactis prolifera*. Also “unique” to the site were the presence of the soft coral *Gersemia sp.* (likely *rubiformis*) and the brittle star, *Gorgonocephalus sp.* (likely *eucnemis*). Other echinoderms, including *Orthasterias spp.*, *Solaster stimpsoni*, *Henricia leviuscula*. The red sea urchin, *S. franciscanus*, were present in greater density than above 10 m.

Hardie and Mondor (1976) studied the Race Rocks area in an assessment of the region as a potential national marine park. It is not clear if they performed an intertidal/subtidal survey or relied on Goddard (1975) for their information. Their study cites that in the high intertidal zone, in locations such as Albert Head, Becher Bay, and Rocky Point, the zone is dominanted by *Balanus glandula*, *B. cariosus*, *M. californianus*, *Acmaea spp.*, and *Littorina spp*. Predators

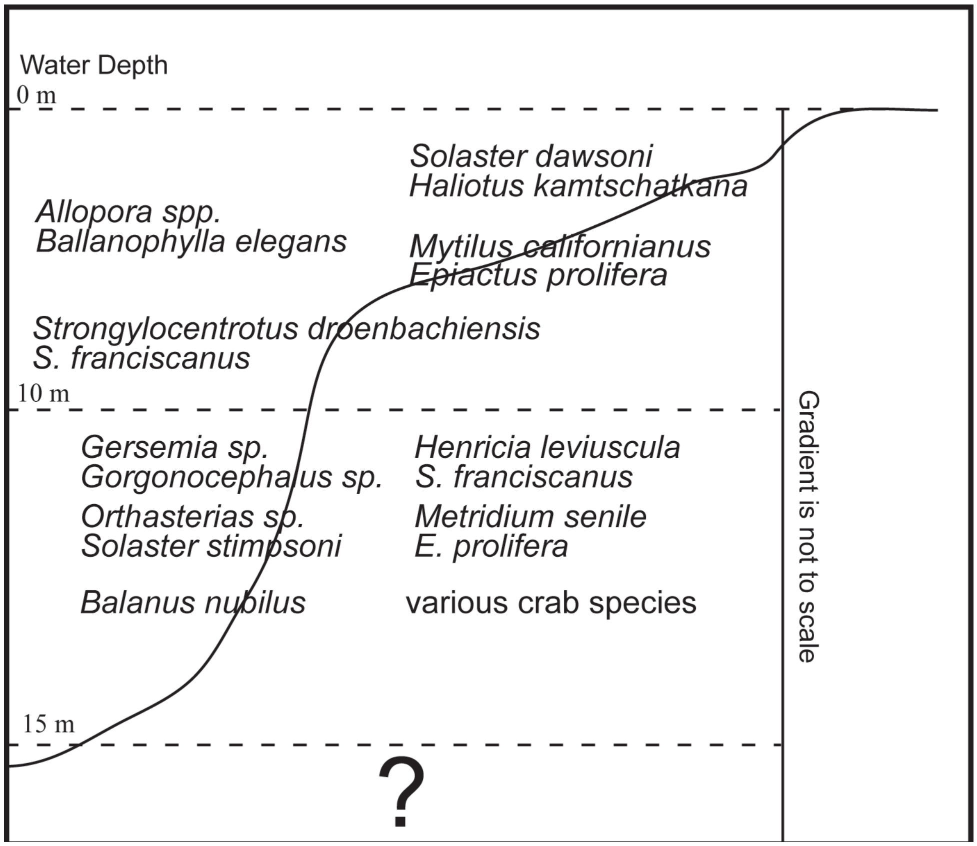

Figure 23. Basic distribution pattern of the dominant subtidal macroinvertebrates at Race Rocks Pilot MPA, Great Race as recorded by Goddard (1975).

were mostly the seastars *Pycnopodia helianthoides*, *Pisaster orchraeus*, and *P. brevispinus*. They also noted large numbers of the anemones *M. senile* and *E. prolifera*. The subtidal community cited is the same as that in Goddard (1975).

Nyblade (1978, 1979) studied the benthic communities in the Washington State waters of the SJF as part of the MESA study. Intertidal and subtidal benthic analyses were performed at two rocky sites, Pillar Point and Tongue Point, both of which are rocky intertidal but Pillar differs by having a sandy subtidal habitat. Intertidally, both sites are structurally dominated by macroalgae and its associated invertebrate fauna. High in the intertidal zone, brown and red algae provided food and protection for herbivorous gastropods (*Littorina spp.*) and also planktivorous barnacles and mussels. Associated with this community are various small crustaceans. The authors noted that the spring samples were dominated by large numbers of barnacle larvae and the larvae of the bivalve *Musculus*.

In the mid-intertidal, macroalgae species of *Alaria* , *Bossiella*, and *Corallina* were associated with herbivores such as the chiton *Cyanoplax sp.* (*Lepidochitona*), species of the gastropods *Collisella* (*Lottia*), *Notoacmaea* (*Tectura*), and *Onchidella*. These in turn are prey for the carnivorous gastropods *Thais* and *Leptasteria*. Smaller associated fauna that inhabit free space included nematodes, polychaetes, oligochaetes, tanaids, isopods, amphipods, insect larvae, and small sea cucumbers, *Cucumaria spp*.

At the 0 m depth (i.e. their low tide mark) *Alaria spp.* is still present with the addition of *Hedopyllum* and *Phyllospadix*. The barnacles *B. cariosus* and *B. nubilus* were prominent as were the herbivores *Lacuna spp.* and *Pugettia gracilis*. Predators included *Cancer oregonensis* and *Leptasteria spp.* Pillar Point had a similar intertidal community structure.

Subtidally, Tongue Point was dominated by large foliose bladed kelps. Associated with this vegetation were the grazers *S. droenbachiensis*, chitons, gastropods, and herbivorous crabs such as *Pugettia spp*. At deeper depths, 5-10 m, these herbivores continued to be numerous but added to the community were the suspension feeders *Spirobis* (polychaete worm) and *Calytraea* (filter-feeding gastropods).

Nyblade (1978, 1979) found that of all the representative habitats studied, rocky intertidal and rocky subtidal were the richest with respect to the number of species, density, and standing crop biomass (due to the influence of the macroalgae). Summer showed peak abundance, biomass, and species richness while winter showed the lowest values.

Intertidal and subtidal transects have been done by students at Pearson College. The data is primarily concerned with tracking 5 or 6 of the macrofaunal species (e.g. red sea urchins). Pearson College has 15 pegs around the perimeter of Great Race for students to use as "monitoring" stations. Lead lines run down the intertidal-subtidal zone and students perform quadrat surveys on the left and right hand sides of the line. This series of stations appears to provide a representation of the exposure variation and the different habitats available around Great Race. Station 6 is westerly facing and is exposed to currents and waves. At the high-mid intertidal zone, the substrate is dominated by several species of red and brown algae including those of *Endocladia*, *Fucus*, *Porphyra*, *Halosaccion*, *Alaria*, and coralline species. The dominant invertebrates are *Littorina spp.*, *B. glandula*, *B. cariosus*, and *Anthopleura spp.* (Pearson College, unpublished data).

Station 12, directly across from Station 6, is east facing and similarily is exposed to currents. The slope at this site is steep from the station peg to the water line. There is a similar association of macroalgae and invertebrates but the slope truncates the zonation and the majority of all the species occurs in the 1-2 m above the watersedge (Pearson College, unpublished data).

Tidepools are numerous throughout the reserve. Tidepool organisms are often exposed to air as the tide recedes. This exposure causes rapid physical and chemical changes in the water quality of the tidepool such that the organism must quickly adapt. In the tidepool at Station 6, the species recorded were *Searlesia sp. Calliostoma spp.*, *S. purpuratus*, *S. droenbachiensis*, *C. miniata*, *M. californianus*, *Acmaea mitra*, *Mopalia spp. Katharina sp.* and an unidentified tunicate (Pearson College, unpublished data).

SIMS Results

As part of the seabed classification studies, the SIMS survey performed by CORI, classified the seabed biota (Harper et al. 1999). Faunal classifications are all based on invertebrate "types." Six types were found to exist in the area surveyed: red sea urchins, bryozoan assemblages, clusters of *B. nubilus*, tube worm aggregations, anemone aggregations, and "no-observed fauna." The bryozoan class included ascideans and sponges. The greatest percentages of occurrences were the types red sea urchin (58%), anemones (20%), and no-observed (19%). The polygon plots from the study (Figure 24) shows the relative occurrence of these types. It is important to note that these plots illustrate relative abundances based on interpolation of trackline data.

Spatially, there appears to be no distinct trend in the distribution of *S. fransicanus*. They are distributed in both shallow and deeper waters and on all faces of the outcrops. At the time of the survey (March) there does not seem to be a co-occurrence with macroalgae since urchins are in areas both with and without macroalgae. *Metridium* seem to have the highest occurrence in areas directly around Great Race, particularly on the southeast corner.

Recent Ecological Studies

Aside from benthic community analysis, there have been studies that focused on specific organisms at Race Rocks. Anita Brinckmann-Voss, with others, has published on the hydroids from area (Brinckmann-Voss 1996; Aria and Brinckmann-Voss 1980; Brinckmann-Voss et al. 1993). There is even a new species described from Race Rocks, *Rhysia fletcheri*.

In 1995-1996, Pearson College collaborated on abalone (*H. kamtschtkana*) tagging studies with the University of British Columbia. This tagging program continues with the emphasis on abalone growth and movement.

There are many other student studies, most looking at some form of faunal association or an ecological question (Fletcher 1999). One of the interesting studies done by Rosemary Macintosh (Pearson College student in 1991) involved accessing the level of imposex (male sexual characteristics imposed on females) of the neogastropods *Nucella lamellosa* and *Searlesia dura*. All the female specimens examined exhibited imposex. This, no doubt, adversely impacts the reproductive success of the whelk population at Race Rocks.

Invertebrate Fisheries

Many invertebrates form the basis of commerical, recreational, and First Nations cultural and economic fisheries. Records of annual landings can be obtained from Fisheries Management Branch, Pacific Region, DFO.

The Race Rocks Pilot MPA falls within Management Areas 19-3 and 20-5, and for recreational surveys, in Statistical Area 19F-25 (Figure 25) . However, the waters of the Reserve and the area within a 0.5 km radius from shore, is closed to any form of invertebrate fishery. Beyond this boundary, the surrounding waters are recreationally and commercially utilized (see Figures 26 and 27). Octopus and crab seem to be the main recreational target (Stock Assessment Division, Pacific Region, DFO, unpublished data 1999). It is not readily apparent what kind of role Race Rocks plays in being either a source or a sink for invertebrate larvae other than rock is, for many invertebrates, a desirable substrate to settle on.

Overview

Appendix 4 lists the species collected at Race Rocks and the surrounding area. This list does not include those species collected by Nyblade (1978, 1979), but is compiled from various sources including Goddard (1975), Hardie and Mondor (1976), Pearson College transects, various ecological studies, and from the Royal British Columbia Museum collections.

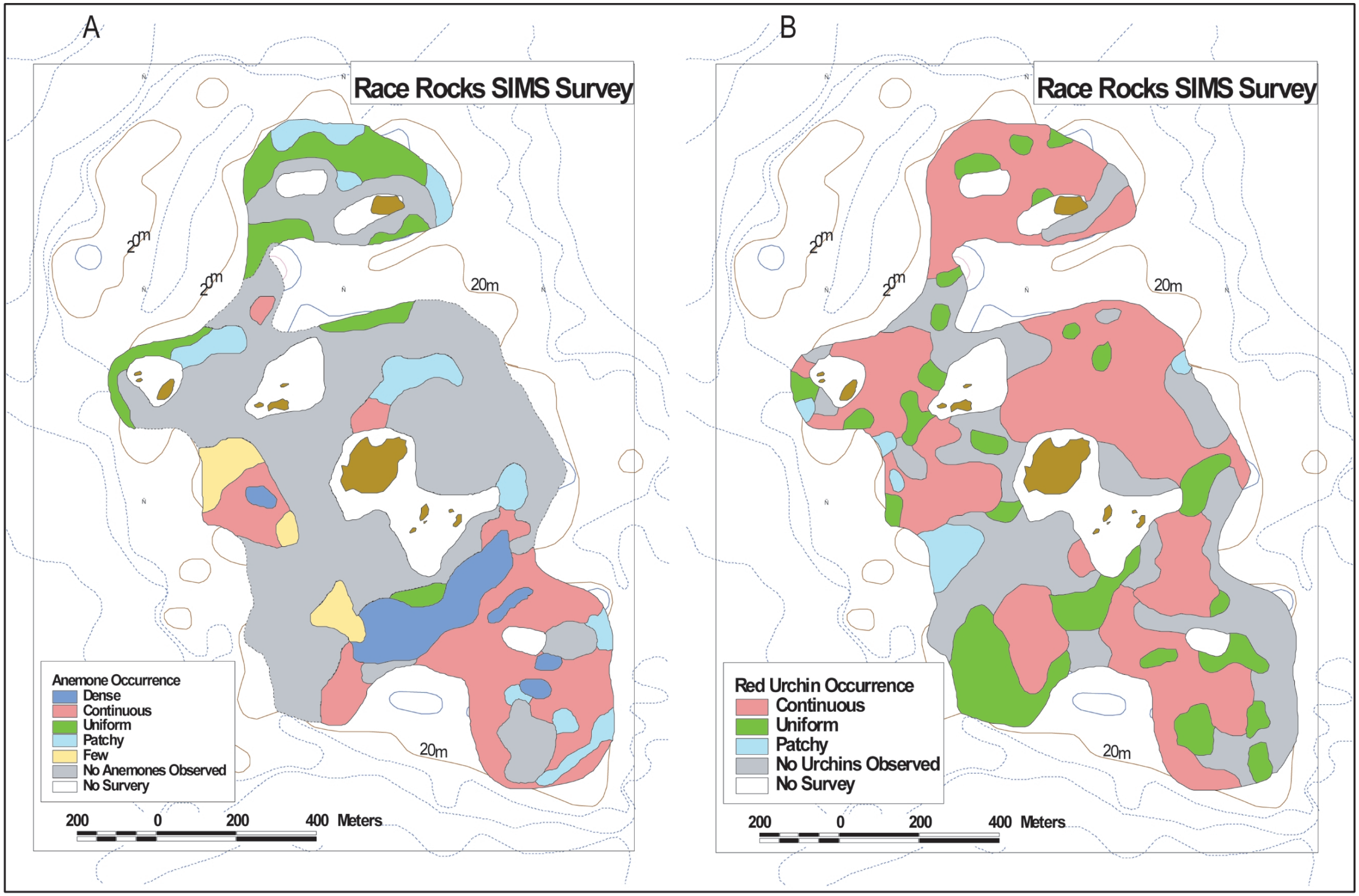

Figure 24. Polygon plots of biological types at the Race Rocks Pilot MPA from the March, 1999, SIMS Survey. Plot A illustrates the distribution of anemone (*Metridium*) occurrences. Plot B illustrates the distribution occurrence of red urchins, *S. franciscanus*. Images from Harper et al. 1999, courtesy of the Canadian Hydrographic Survey, Pacific Region.

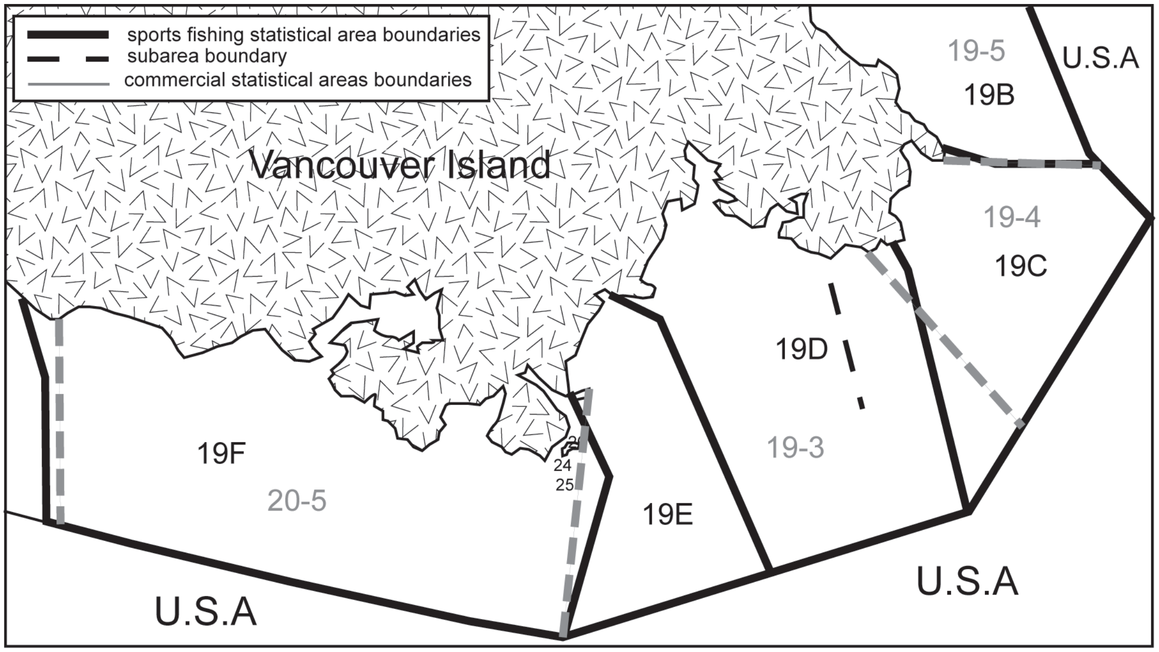

Figure 25. Eastern Strait of Juan de Fuca sports fishing statistical area boundaries. Last revised January 26, 1994. For detailed information and georeferenced points contact Stock Assessment Division, Science Branch, Pacific Biological Station, Pacific Region, DFO.

Since all studies at Race Rocks have been non-destructive, there is know way of knowing seasonal trends, abundances, or the standing biomass. However, seasonal trends in abundance and biomass may be similar to that of Nyblade (1978, 1979). Also, there is no information on benthic invertebrates deeper than 20 m. Although benthic grabs were taken by CHS, no analysis for biological components were made on these samples.

MARINE AND ANADROMOUS FISH

Qualitative or quantitative surveys of fish species at Race Rocks were not found. Most information comes as incidental sightings during subtidal transects, swim lines, and tidepool surveys by students and some professionals. In the late 1970s, in the Washington waters of the SJF the MESA study involved a survey of nearshore fish species (Miller et al. 1980). This study found approximately 94 species of nearshore fish from a variety of habitats; rocky subtidal, beach, intertidal, and tidepool. Two study sites appear most similar to Race Rocks, Pillar Point and Observatory Point. Both are rocky substrate habitats with abundant algae and a range of shore gradients and wave exposure. Pillar Point was noted as being moderately exposed with moderate energy. This may not be entirely similar to the exposure and gradients at Race Rocks, however, it was the only site that was sampled with a tow net. Observatory Point is a high energy, high gradient, high exposure area, where only tidepools were sampled.

At Pillar Point, two species dominated the tows; Pacific herring (spring/summer) and Longfin smelt (summer/fall). Other fish included salmonids (Chinook, Pink, Coho, and Chum) and surfsmelts. Density of fish was higher in the spring/summer than fall/winter, and included larval and juvenile stages of neretic species. The rocky tidepools at Observatory

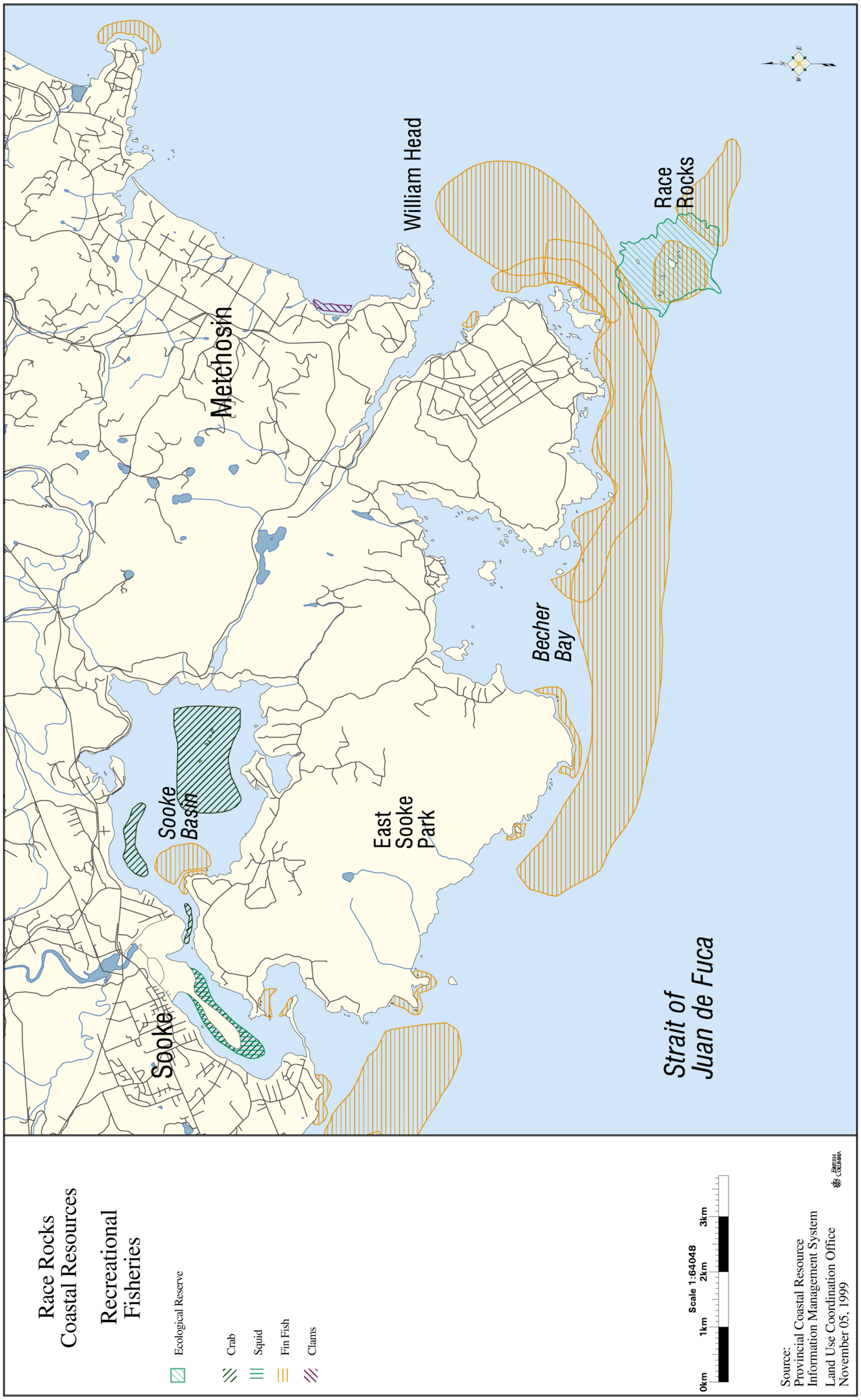

Figure 26. Recreational fisheries resources in the Race Rocks Pilot MPA and surrounding area. Map courtesy of the Land Use Coordination Office (LUCO), BC Provincial Government.

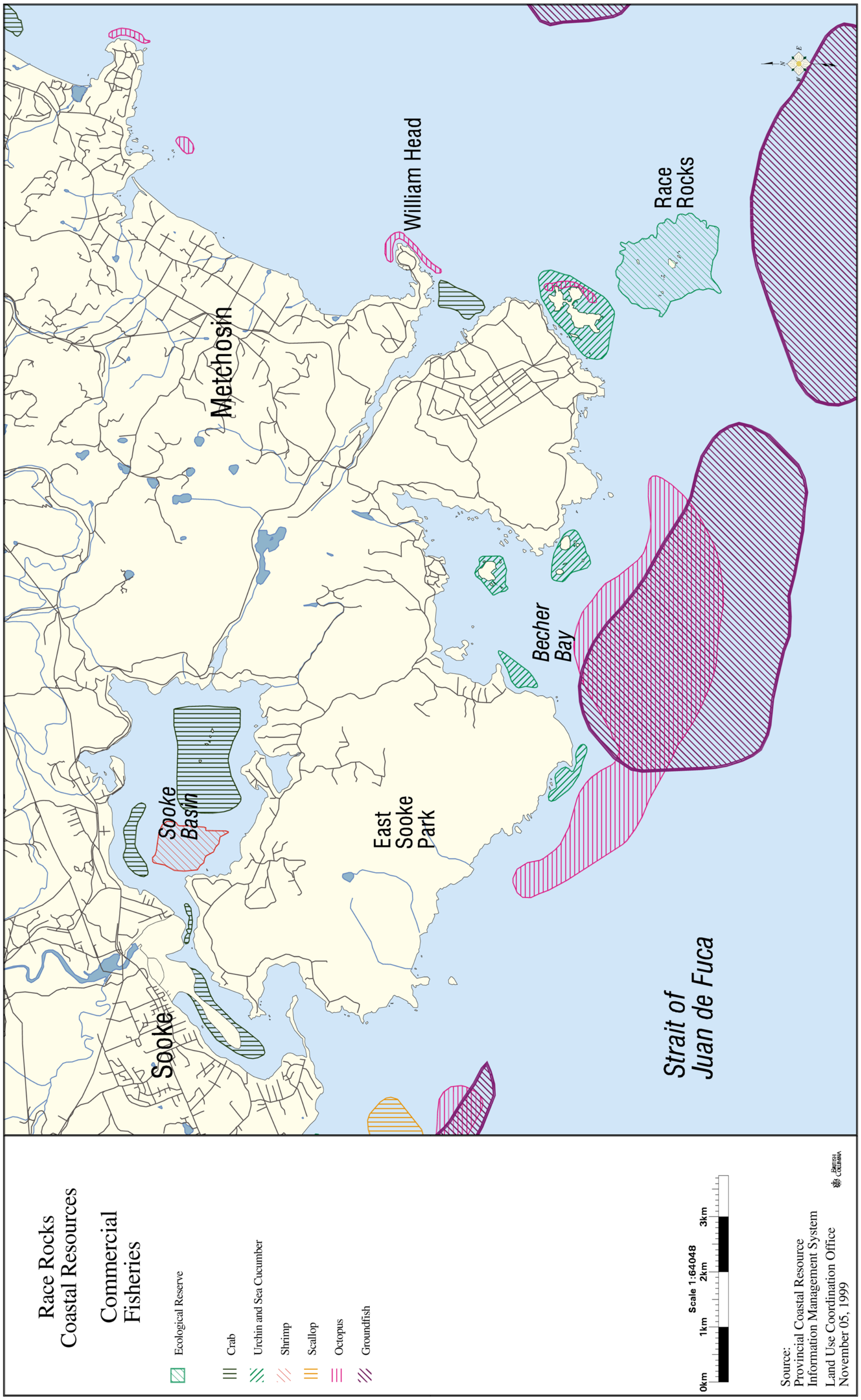

Figure 27. Commercial fisheries resources in the Race Rocks Pilot MPA and surrounding area.
Map courtesy of the Land Use Coordination Office (LUCO), BC Provincial Government.

Point were dominated by tidepool sculpins and clingfish, with the adjacent cobble or sandflat areas dominated by juvenile flatfish, and schooling species such as herring and sand lance.

Appendix 5 lists the species seen at Race Rocks and some sightings from surrounding areas. These data were taken primarily from subtidal transects, swim lines, Royal British Columbia Museum collections, and other studies that may have recorded a sighting.

In an attempt to put these fish species into an ecosystem context, prey items have been listed and a comment section attempts to provide important life-history information. It should be noted, however, that the level of information on the life-history of some of these species, particularly in BC waters, is variable.

Fish are a critical link in the marine food web. Certain seabirds rely on fish for food, especially when nesting; fledgling success is often hinged to fish supply. Certain marine mammals also rely heavily on fish for food and, as seen from the listing, there are several species of fish that are piscivorous. Fish are providers of organic debris to the sea floor and many play a role in plankton dynamics, either as being members of the plankton during larval/juveniles stages, and/or as predators of plankton.

Some of the more commonly known species at Race Rocks include lingcod, rockfish, halibut, kelp greenling, and Pacific herring. Pacific herring move onshore to spawn on red algae, sea grass, and kelp which are in abundance at Race Rocks. Rockfish, in general, show a preference for rocky intertidal/subtidal habitats where there are an abundance of rocky crevices. Some species like Black rockfish and Kelp greenling also prefer rocky areas with kelp beds. Lingcod show a high preference for rocky subtidal areas where there are swift currents, rocky crevices where they can lay eggs, and kelp beds where juveniles can congregate.

However, these species are also commercially and recreationally fished. The commercial and recreational/sport fishery is a critical resource for BC coastal communities. At Race Rocks (Statistical Sub-areas 19-3/20-5 and 19F-25) (Figure 25), the Reserve is a "no-take" area at depths less than 36.6 m (some fisheries documents have listed it as 40 m), except for salmon and halibut which are considered migratory species. The 1990's recreational fisheries census reports that for Area 19F-25, approximately 75-100 rockfish of various species were taken per year, along with up to a couple of thousand salmonids, 11-40 halibut, and up to 300 other species of fish. These totals include released fish. It is not known what percentage of the salmon and halibut were caught within the presently existing Reserve boundaries. In 1998, catches of all fish in Area 19F-25 were down (Stock Assessment, unpublished data 1999). The reasons are not known.

The recreational/sports fishery catch is controlled by daily catch and possession limits. There is considerable concern about rockfish and lingcod stocks in BC waters and as a result, there are somewhat tighter restrictions regarding their take. The provisions put on daily possession limits as well as areas of fisheries closures have the potential to change on a yearly basis and these regulations are summarized in the British Columbia Tidal Waters Sport Fishing Guide, released by the Stock Assessment Division of Fisheries and Oceans Canada.

MARINE MAMMALS

Pinnipeds (Seals and Sea Lions)

There are five known species of pinnipeds in BC waters, all of which can be found in the SJF. Two, northern elephant seal and the harbour seal, belong to the true seals (Phocidae), while the other three belong to eared seals (Otarridae); northern fur seal, stellar sea lion, and California sea lion. All species are protected under the 1993 Marine Mammal Regulations of the Fisheries Act.

Below is a short account of each species, their status in BC, and their presence in SJF and Race Rocks.

Northern Elephant Seal (***Mirounga angustirostra***) **:** Females are approximately 3 m long and weigh up to 1,000 kg while the males are approximately 5 m and weigh up to 2,000 kg. These seals are migratory and use California and Mexico waters for breeding (Olesiuk and Bigg 1988). After leaving their southern rookeries in March, they disperse with a few individuals appearing in BC waters (Olesiuk and Bigg 1988). Elephant seals moult and during these periods haul out at sites like Race Rocks. In the last few years, male and female elephant seals have been sighted moulting at Race Rocks (Warden's Log 1998). Elephant seals main prey items are ratfish, sharks, eels, and squid (Olesiuk and Bigg 1988). Elephant seals are known to be deeper water foragers (Olesiuk and Bigg 1988), but in BC waters, their diet is largely unknown.

Harbour Seal (***Phoca vitulina richardsi***)**:** This is the most abundant of all pinniped species in BC waters (Calambokidis and Baird 1994) and is seen in coastal areas, inlets, and estuaries (Reeves et al. 1992). Males and females range from 1.2-1.6 m long and are 60-80 kg (Olesiuk and Bigg 1988). They breed throughout their range and are non-migratory though they travel considerable distances. On southern Vancouver Island, the birthing of pups takes place in July-late August (Olesiuk et al. 1990). Their primary prey are fish including sculpins, flatfish, rockfish, greenling, smelts, and perches (Olesiuk and Bigg 1988). Their numbers in the SJF and Puget Sound are greatest in the spring (Everitt et al. 1979). Harbour seals themselves are prey for transient killer whales (Baird 1994).

After near decimation from commercial harvesting in the 1960s, the harbour seal population in BC has increased at an annual rate of 11-12 % (Olesiuk et al. 1990; Olesiuk, pers. comm. 1999). It is thought that the population in BC may now be at carrying capacity with an annual mortality of 10% (Olesiuk et al. 1990), approaching historic levels (Olesiuk, pers. comm. 1999). Race Rocks has the highest concentrations of harbour seals on the Canadian side of the SJF and the second highest in the South Gulf Island region and Strait of Georgia (Olesiuk, pers. comm. 1999). Since the 1960s the number of seals using Race Rocks has increased. A recent aerial survey taken in July, 1996, counted 858 seals and this number may not be capturing peak abundances. Numbers in 1998 were down, although this was also seen in many localities in BC and Washington. The reason for the low numbers during this survey are not known (Olesiuk, pers. comm. 1999). At Race Rocks, seals begin congregating in the "nursery area" to give birth in July (Wardens' Logs 1997).

Northern Fur Seal (***Callorhinus ursinus***)**:** This is the only species of fur seal in North Pacific waters (Calambokidis and Baird 1994). Females attain a length of 1.3 m and weigh approximate 35 kg, while the males are up to 1.9 m and weigh 200 kg. The females and males live an average of 25 years and 15 years, respectively. The Pacific stock was estimated at 900,000 but has recently declined. The dynamics of this population are complex, but high juvenile mortality is suspected (Olesiuk and Bigg 1988). Its main prey item is small schooling fish such as herring (up to 84% of the stomach contents) (Spalding 1964). They also consume salmon, sablefish, and rockfish (Perez and Bigg 1986). This species migrates south from its rookeries on the Pribilof Islands in the Bering Sea. It is primarily females and subadult juveniles that show up off the BC coast in November (Bigg 1985). This species tends to stay offshore, however, the occasional animal hauls out at Race Rocks (Bigg 1985). Evidence of sightings by lighthouse staff reported that between 1974 and 1982 there was a single *C. ursinus* sighted consistently at Race Rocks each winter. Northern fur seals are presently listed as "Depleted" (falling below optimum sustainable population) by the National Marine Fisheries Service of the US.

Stellar Sea Lion (*Eumetopias jubatus*): The average length for adult females is 2.4 m and they weigh from 180-230 kg, while males average 3 m in length and weigh between 450-1000 kg. This species breeds in June/July in rookeries that are usually isolated sites that are far from major landmasses and are exposed to oceanic swells (Bigg 1985). They consume fish (rockfish, herring, hake, pollock, dogfish, salmon) as their main prey, but also eat octopus (Olesiuk and Bigg 1988). Prior to 1972, their numbers were low but they have since increased and are presently stable and at historic levels (Olesiuk and Bigg 1988; Olesiuk, pers. comm. 1999). The low numbers before 1972 were due to bounty hunting that was banned in 1972. This sea lion is also listed as "Threatened" (the population east of 144°W) by the US Marine Mammal Commission and the Washington Department of Fish and Wildlife.

Race Rocks is currently one of the areas used as a winter haulout site for non-breeding adult and subadult males (Bigg 1985). Haulout sites are critical to their life history and are generally situated on rocky islets. Individuals start to arrive at Race Rocks in September, numbers peak from January to March, and they begin to leave in May but a few are still around in June. Numbers will vary depending on the availability of herring and also competition from California sea lions (Bigg 1985).

Winter aerial censuses consistently report >50 individuals at Race Rocks (Bigg 1985). Surveys from 1985 to 1995 show numbers ranging from lows of 6 to highs of 83 (Olesiuk, unpublished data). Recent aerial surveys from 1997 to 1999 are not available (Olesiuk, pers. comm. 1999). Aside from aerial surveys, a maximum number of 300 Stellar sea lions have been recorded at Race Rocks (Olesiuk, pers. comm. 1999). California and Stellar sea lion aerial surveys are performed in February to coincided with peak abundance of local herring. However, in recent years, herring have moved northward. As a result, the timing has changed, and February surveys no longer capture peak abundance. Race Rocks is now primarily a stopover site (Olesiuk, pers. comm. 1999).

California Sea Lion (*Zalophus californianus*): The California sea lion is the most common sea lion in BC waters, with numbers greater than those of the stellar (Olesiuk, unpublished data). Adult females weigh 70-110 kg and have an average length of 1.4-1.7 m, while adult males weigh from 200-400 kg and are 2-2.5 m in length. This species of sea lion breeds during May-August in California and Mexico. There is no breeding in BC waters and only adult and subadult males travel northward. They arrive in BC in September/October and head south in April/May to return to their breeding grounds. Their prey is primarily schooling fish such as herring (largest percentage of their diet), hake, and pollock. Race Rocks is one of the areas with the highest concentration of individuals. The wintering population of males off southern Vancouver Island is stable at about ~3000 animals (Olesiuk and Bigg 1988).

In the early 1900s numbers were low, but by 1960 a small colony had formed on Race Rocks, and presently, it is a primary winter haulout site (Bigg 1985). The breeding recovery program in California is likely responsible for bringing the populations back to their historic ranges (Olesiuk, pers. comm. 1999). By September's end, the number of California sea lions shows an increase in numbers with up to over 700 individuals sighted (Wardens' Log 1997). The highest number of individuals recorded was in October, 1984, with 1,233 individuals (Olesiuk, pers. comm. 1999). Surveys in February show lower numbers, but this is due to changes in the timing of peak abundances of herring stocks.

Cetaceans

Five species of cetaceans are listed as being common in BC waters. There are other species sighted, but these are mainly from incidental/accidental sightings, strandings, or dead carcasses. Because of the mobility and/or migratory nature of cetaceans, it is unlikely that any one species uses Race Rocks as any sort of "home base". The following account of species describes those cetaceans that are the most frequently seen in the SJF and and those that have been seen in the vicinity of Race Rocks. Following this is an account of the cetacean species that are less common in these waters.

Killer Whales (*Orcinus orca*): In the eastern SJF there are two genetically distinct "types" of killer whales, residents and transients (Hoelzel 1991; Ford and Ellis 1999). Both are highly mobile throughout the Strait. Resident killer whales live in family units (pods and subpods) and travel in numbers (pod numbers ranges from minimums as low as 3 and some are as high as 59) (Ford et al. 1994).The Southern Resident Stock is listed as having 80+ individuals (Forney et al 1999) in three pods, J, K, and L. They are well catalogued on the southern BC coast via photographs of their markings. They consume salmon as their main prey and other schooling fish. Males are generally 6-7 m long while females are <6 m (Nishiwaki 1972). Breeding occurs year round with peak birthing in the spring/summer (Everitt et al. 1979). Transient killer whales generally travel in smaller numbers and do not form stable family associations (Ford and Ellis 1999). They hunt seals, sea lions, small porpoises, and whales. There are approximately 336 individuals in the Eastern Pacific Transient Stock (Forney et al. 1999) and approximately 213 have been catalogued (Ford and Ellis 1999). Transients and residents do not travel together, and in fact, go to some length to avoid each other (Baird and Dill 1995).

Both populations have been seen in the Race Rocks region and Howes et al. (1993) lists this area as being of "high" importance to both groups. Due to the high number of pinnipeds that use Race Rocks, transients do forage at Race Rocks for harbour seals, stellar and California sea lions. Baird (1994) noted that there is generally an increase in transient sightings associated with harbour seal pupping/weaning/ post-weaning stages. Recordings from 1990 show over 100 sitings of killer whales at Race Rocks (Baird 1991). The Wardens' logs (1997-1999) show pods moving in and around the area year round. At times up to 25-30 animals per day are seen.

Under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), residents are considered "Threatened" and the transients are listed as "Vulnerable."

Harbour Porpoise (*Phocoena phocoena*): This is one of the smallest porpoises at 1.8 m in length and weighing up to 54 kg (Nishiwaki 1972). They generally move in small groups of 1-3. Breeding/calving takes place in the spring and summer (Everitt et al. 1979). Prey items include small schooling fish and squid (Scheffer and Slipp 1948), and they themselves are prey for transient killer whales (Baird 1994; Everitt et al. 1979). Aerial surveys in the SJF from 1996 show 66% percent of the sightings were single individuals. Estimated abundance in the Canadian waters of the SJF was approximately 1,616 individuals and the inland Washington stock was estimated at 3,509 animals (Calambokidis et al. 1997). Harbour porpoises are elusive and avoid boat traffic. The aerial survey tracklines include Race Rocks, however, harbour porpoise sightings have not been recorded in the Wardens' Logs. Harbour porpoise sightings that include the area around Race Rocks show there are approximately 6-7 groups per 100 km of surveyed area (Calambokidis et al. 1997).

Dall's Porpoise (*Phocoenoides dalli*): Similar in size to harbour porpoises, Dall's porpoises generally move in groups of 1-5 with 87% of sightings being 1-2 individuals (Calambokidis et al. 1997). They are approximately 2.2 m in length and weigh 150 kg (Pike and MacAskie 1969). Unlike Harbour porpoises they are associated with deeper water (Everitt et al. 1979) where their main prey is small fish and squid (Pike and MacAskie 1969). Aerial census show estimated abundance of 451 in the Canadian waters of SJF (Calamobokidis et al. 1997). Dall's porpoises have been seen off Rocky Point in the deeper waters of SJF (Calambokidis et al. 1997).

Minke Whale (*Balaenoptera acutorostrata*): These whales are generally <10 m and can weight over 10 tonnes. They breed from February to April and calf in January to May, with a gestation period of 10-11 months (Everitt et al. 1979). Minke whales are reported in the SJF year round, but most sightings occur from March to November. They primarily use the region for feeding (Calambokidis and Baird 1994); their main diet consisting of euphasiids, copepods, and small fish (see Everitt et al. 1979). There are no recent reliable census numbers for this whale in BC waters (Calambokidis and Baird 1994).

Grey Whale (*Eschrichtius robustus*): Grey whales migrate up and down the Pacific North American coast between their southern birthing grounds of Mexico in the winter and their northern summer feeding grounds in the Chukchi and Bering sea. Their primary food source is shallow-water amphipods and crustaceans. There have been sightings in the SJF and off Race Rocks. Although most are sighted in spring/summer, there have been sightings at other times of the year (Calambokidis and Baird 1994). The Washington Department of Fish and Wildlife lists this species as "Sensitive."

Other Whales

Humpback whales (*Megaptera novaeangliae*) also calf in the winter off Baja and move north to feeding grounds, reaching Vancouver Island in May-June. Based upon the numbers, humpback sightings in the SJF are considered rare (Everitt et al. 1979).

Fin whales (*Balaenoptera physalus*) are also rare in the SJF since they inhabit primarily oceanic offshore waters. There have been a few sightings and these have been lone individuals and one stranding (Everitt et al. 1979).

Risso's dolphin (*Grampus griseus*) sightings are considered as accidentals (i.e. a sighting in a location where they are not naturally present) since they are predominantly a warm water species. Sightings in BC waters are restricted to mostly stranded individuals (Baird and Stacey 1991; Everitt et al. 1979)

The Short-finned pilot whale (*Globicephala macrorhynchus*) is a gregarious species (Leatherwood et al. 1988) and the sightings in the SJF of small groupings leads to the assessment that their presence is accidental (Stacey and Baird, 1993). Two records of sightings close to Race Rocks (between 48°21'-48°18' and 123°50'-123°39') showed a single individual and a group of 30 (Baird and Stacey 1993).

Other Mammals

Another aquatic mammal known from Race Rocks is the river otter, *Lutra canadensis*. Although they are common in SJF (Everitt et al. 1980), they are a recent arrival to Race Rocks. They nest in the softer topsoil banks on Great Race. *L. canadensis* preys on marine birds. They have been observed actively raiding nests. Efforts have been made to reduce the number of otter nesting sites associated with human-made structures at Race Rocks.

BIRDS

There are approximately 116 species of marine birds* in the SJF (Wahl et al. 1981). The species composition and total numbers vary inter- and intra-annually. The highest total number occur during the migration period, late June through November. Winter numbers are also generally higher than summer due to the population of birds that winter in coastal BC. Marine birds, particularly nesting species, are vulnerable to several types of threats. Disturbances from humans, boats, domestic animals, commercial fishing, and military activities can disrupt courtship and foraging activities, nesting behaviour, and in some cases cause direct mortality. Oil pollution and toxins in the food web can cause direct mortality, or decreased fitness, both physical and reproductive.

Undisturbed sites are critical for the establishment of roosting and nesting sites. Rocks and islands provide ideal habitat, thus Race Rocks is often cited in census reports as being a important area for nesting seabirds. The majority of seabirds depend on fish as their primary food resource, and others utilize benthic invertebrates, plankton, and other bird species. Simenstad et. al. (1979) provides a good review on the diets of various marine birds that are found in the SJF.

Information pertaining to birds at Race Rocks is limited to the Wardens' logs, student and instructor transects from Pearson College, and some census reports taken in the 1970s and 1980s. The Wardens' logs (1997-1999) record presence/absence, and relative numbers of

* Wahl et. al. (1981) includes the following: loons, grebes, cormorants, herons, swans, geese, ducks, hawks, eagles, falcons, ospreys, rails, oystercatchers, plovers, sandpipers, shorebirds, phalaropes, jaegers, skuas, gulls, terns, alcids, shearwaters, and storm petrals.

nesting pairs, nest numbers, clutch size, and fledgling success. However, this information is patchy and not inclusive for all nesting species. Although the transect data of Pearson College is somewhat variable with respect to the observer (i.e. individuals abilities to identify species) and also with weather conditions, it does provide some level of baseline information such as presence/absence, relative timing with respect to winter arrivals/departures, and limited breeding information. However, a more rigorous and systematic approach is required for monitoring birds at Race Rocks. Presently, CWS, in coordination with the Oceans Directorate and Pearson College, is developing a long-term monitoring strategy for Race Rocks. Preliminary plans are to include direct census of species and breeding success by taking records at regular intervals and performing annual nest surveys (Smith 2000).

At Race Rocks four species numerically dominate the composition of nesting marine birds, Glaucous-winged gulls, Pelagic cormorants, Pigeon guillemots, and Black oystercatchers. In southwestern BC coastal waters, from censuses taken in 1974/1975 and again in 1989, Pelagic cormorants decreased by 70% and Glaucous-winged gulls by 13%. However, it appears the Pelagic cormorant colony at Race Rocks is stable (152 nests in 1989) and the Glaucous-winged gulls increased substantially between census periods (Vermeer et al. 1992a). The decreases in other coastal sites is thought to be associated with the 1988 Nestucca oil spill and/or limited food resources that year (Vermeer et al. 1992a). The Race Rocks site was not affected by the oil spill.

Speich and Wahl (1989) completed a major cataloguing study of nesting birds in the marine waters of Washington State. Most of the information cited below comes from this study and references cited therein.

Pelagic Cormorants (*Phalacrocorax pelagicus*): This cormorant nests on rocky shorelines around kelp beds and tidal channels where they have access to their main prey items, fish and shrimp species. They typically nest within the spray zone. They are easily flushed off their nests, leaving eggs and young vulnerable to exposure and predation. Their main egg laying period is May to July, hatching occurs July through August, and fledging occurs July through September. Typically 4-6 eggs are laid and incubation lasts 28-32 days. Thereafter, the nestling period is 42-51 days. Wahl et al. (1981) cited that 23% of all known nestings of Pelagic cormorants in the eastern SJF takes place at Race Rocks.

Glaucous-winged gulls (*Larus glaucescens*): Nesting occurs in a variety of areas including rocky shorelines. They are omnivorous and have adapted well to human encroachment. They lay 1-3 eggs from May to July. The eggs hatch from June to August, and the young fledge between June and September. The incubation period is 26-29 days and nestling period is 31-52 days.

Pigeon Guillemots (*Cepphus columba*): They preferentially nest in cavities and crevices that are available on rocky shores and islands, although they will nest in a wide variety of cavities. Their main prey is fish. This species of seabird is generally site fidelic, meaning they will nest at the same site for life. A clutch of 1-2 eggs is laid in May to late July, hatching occurs from June to August, and fledging of their young from July to September. The incubation period is 28-32 days and the nestling period is 29-39 days. The local Pigeon guillemot population appeared stable between 1976 and 1987 (Emms and Morgan 1989). Mahaffy et al. (1994) cites the Washington population as stable.

Black Oystercatcher (***Haematopus bachmani***)**:** This species favours rocky islands with adjacent rocky intertidal areas for foraging. Their main prey is intertidal invertebrates including mussels, chitons, and crabs (Groves 1982). The laying period is May-June with a clutch of 1-4 eggs. The incubation period is 26-27 days with fledging occuring between mid-July and mid-September, and a nestling period of 40-75 days. There seems an affinity between this species' nest areas and that of the Glaucous-winged gulls (Vermeer et al. 1992b). *H. bachmani* is vulnerable to human and small boat traffic and are easily flushed off their nests. Nests are also well camouflaged, thereby increasing the potential of being stepped on. Some pairs suffer low breeding success by nesting close to the high tidal mark, thereby increasing the risk of the nest being washed out by surges. For the eastern portion of SJF (and Race Rocks) there are little data available on total birds, total nesting pairs, or breeding success. Mahaffy et al. (1994) cites the Washington population as stable.

Brandt's cormorants (***Phalacrocorax penicillatus***)**:** These birds lay their eggs from early May to mid-June with a clutch of 2-6 eggs. The incubation period lasts between 28 and 32 days and chicks fledge from early July to mid-September, a nestling period of 40 and 42 days. *P. penicillatus* also nests at Race Rocks (e.g. three nests in 1987) (Campbell et al. 1990). There are no listed recordings since that time.

Appendix 6 lists the species of birds (marine and non-marine) seen feeding, nesting, and/or resting at Race Rocks This information was gathered from the Wardens' Logs (1997-1999), the transect information of Pearson College (unpublished data), and from the 1997 Christmas Bird Count conducted by the Victoria Natural History Society.

The Victoria Natural History Society, in cooperation with the Canadian Wildlife Service, monitors a station at Rocky Point, one of the closest Vancouver Island points to Race Rocks. This region is a critical habitat for migrating songbirds and also birds of prey. Lashmar (1994) cites listings for 162 species, 59 of which likely breed at Rocky Point. Information gathered from surveys at Rocky Point have been used to establish bird checklists that are applicable also to the SJF (e.g. Gates and Taylor 1994). Though Rocky Point will likely not be included in the Pilot MPA, it is important to note species in surrounding habitats

CONCLUSIONS AND RECOMMENDATIONS

The word "unique" has often been used when describing Race Rocks. This statement is often from personal observations and seldom backed up with "hard data." One of the objectives of this report was to attempt to quantify this statement using the available scientific and traditional ecological knowledge. Having "quantifiables" is important when making decisions regarding monitoring efforts and for decerning the boundary of the MPA. It is apparent from this report that there are gaps in the scientific knowledge and natural history knowledge of Race Rocks and the surrounding area. Some of these gaps have lower priorities than others, but nonetheless, they all contribute to our inability to clearly understand the facets of the Race Rocks ecosystem, an integral part of the larger ecosystem that is the Strait of Juan de Fuca.

TRADITIONAL ECOLOGICAL KNOWLEDGE

The Race Rocks area is traditional territory for four Coast Salish Nations. Pearson College continues to work with local bands and others to foster a shared commitment to the area and to gather traditional information. It is believed that Race Rocks and the surrounding area were vitally important traditional areas with varying levels of use depending on the season. As information is provided, it can be incorporated into environmental overview updates.

PHYSIOCHEMICAL ENVIRONMENT

Race Rocks is fairly representative of the SJF with respect to its substrate; rock. Most of the SJF littoral and sublittoral regions are rocky, but Race Rocks creates a shallow area constriction in a deeper water setting, and it is juxtaposed to a headland. This has several consequences, but physically, the most overwhelming consequence is the high velocity currents, up to 6 knots, which are the fastest in the SJF. These currents create an area of water mixing that brings nutrients, dissolved and particulate, up from depth and supports a complex localized food web. Also, there are few areas in SJF that do not exhibit some degree of seasonal stratification, but Race Rocks appears well mixed year round. This mixing may result in higher DO values at depth than at other areas in SJF. This has important consequences for biological the communities.

It is reasonable to make assumptions about the physical and chemical state of the waters at Race Rocks based on both the physical oceanography and nutrient concentrations elsewhere in the SJF. Many of these assumptions are made in the previous sections. However, it would be valuable to sample for 1 year to assess nutrients, DO and CTD (conductivity-temperature-depth) to verify these assumptions. The measurements ideally, would take place at three stations, one east of Race Rocks, one within the Pilot MPA area, and one west of Race Rocks. Sampling design should consider seasonal changes and the range of water depths. Strategically placed, the stations may give some indication of the stability of the boundary layers in the water column.

Currents, tidal action, and surficial geology all inhibit the SJF from being either a source or a sink for sediments. However, there are sedimentry deposits in the Race Rocks area. Thus, sampling sediments, water, and biological tissue for contaminants would be useful at Race Rocks. It may provide information about the general health of this area of the SJF.

Also, the SJF is at a moderate risk to an oil spill. Modelling spills is useful, but the factors affecting spills are varied and complex. A contingency plan for Race Rocks is required.

BIOLOGICAL COMPONENTS

In terms of the biological components of the Race Rocks ecosystem; the physical position of the islets in relation to deep waters, the presence of a rocky substrate, high velocity currents that bring a continual supply of nutrients and DO, makes Race Rocks attractive habitat.

Algae

Approximately 41 taxa (i.e. genus, species, or higher taxonomic level) of macroalgae algae listed from Race Rocks are representative of the SJF, but the potential biomass may be significantly higher than in surrounding areas. From many peoples personal observations, Race Rocks is "blanketed" with macroalgae in the spring and summer. The present Reserve is 220 ha. If a very conservative estimate of 50% of that area was multiplied by Sutherland (1989) estimate of 67 metric tonnes/ha, the total biomass would be 7,370 metric tonnes. This is greater than all of the survey block A of the Sutherland study and would be approximately 15% of the total biomass for the entire Sutherland survey are which included 105 km of coastline.

Sutherland (1989) excluded Race Rocks from his aerial survey and Harper et al. (1999) were unable to survey the shallow intertidal/subtidal areas. This represents a major gap in our knowledge about the distribution, biomass, and potential production values for algae at this site. Macroalgae play a pivotal role in the distribution of intertidal and subtidal fauna. It would be useful to our understanding of this ecosystem if there were a more quantitative survey and mapping of the dominant species of algae on a seasonal basis. It may assist in our understanding of the dynamic interactions between algal biomass/distribution and the species of fish, birds, and marine mammals that frequent the Pilot MPA. It may also provide insight into the distribution of grazing invertebrates species such as the red sea urchin and abalone, both of which are under pressure from fisheries. Kelp beds are also potential indicators of climate change and marine environmental health. Monitoring of their growth rates and production in response to changes in the environment may provide a window into the effects of changing environmental conditions such as increased sea surface temperatures, sea level rise, and decreasing salinities.

Phytoplankton and Zooplankton

Approximately 130 taxa of phytoplankton and 100 zooplankton taxa are recorded from neighboring Station JDF that lies mid-strait. The species composition is likely representative of the SJF on a year-round basis. Neighboring embayments (e.g. Pedder Bay) likely show different phytoplankton dynamics compared to Race Rocks or the SJF. Also, due to the physical presence of a sublittoral rocky community, the dynamics of the zooplankton, may be different then in other regions of the SJF. Race Rocks may be an excellent site for the monitoring of exotic species of phytoplankton and zooplankton, that originate from human activities such as ballast water dumping.

Invertebrates

In the SJF, rocky intertidal and subtidal sites are the richest in terms of the number of species, diversity, and biomass. Race Rocks is likely even higher compared to other nearby rocky sites. Invertebrate species have long been the “calling card” of Race Rocks. The physical substrate and high currents all make larval settlement attractive. Race Rocks supports a population of large-sized abalone, a species that is considered “Threatened” by COSEWIC and is a “Species of Concern” by the Washington Department of Fish and Game. It has an unusually high number of the anemones *Epiactis prolifera* and *Metridium senile*. Also present here, and only in a few other localities, are the soft coral *Germesia* and the brittle star *Gorgonocephalus*. There are several species of hydroids that are unique to areas of high current flow and a new species described from Race Rocks, *Rhysia fletcheri*.

There are over 200 taxa listed from Race Rocks, but this list is incomplete. The data from the student transects is useful for considering basic gross community structure and zonation. However, there is little mention of the smaller-sized invertebrates (e.g. crustaceans, worms) one would expect to find in such a habitat. Without this information, species richness, diversity, and abundance can not be determined with any degree of confidence or accuracy.

These gaps in our knowledge prevent us from fully characterizing the intertidal and subtidal invertebrate communities at Race Rocks. It would be valuable to have a more rigorous and quantitative study on the intertidal and subtidal communities as it would provide managers and scientists with a benchmark for monitoring changes in the Pilot MPA due to natural or human-induced perturbations.

Marine and Anadromous Fish

Approximately 35 species of fish are recorded from Race Rocks and this list is representative of the SJF. Race Rocks attracts and supports various species of rockfish, many of which are under pressure from fisheries. It is especially critical habitat for Copper Rockfish. All rockfish species are listed as a “Species of Concern” by Washington State and are under a strict quota system in BC. Race Rocks provides critical habitat for other species of fish including lingcod, kelp greenling, and sculpins, all of which prefer rocky areas with kelp beds and currents. More knowledge is required about the fish at Race Rocks, including larval dynamics. The taxa list is likely incomplete since there are approximately 95 known nearshore species in the SJF.

There has been much discussion on the designation of MPAs as refugia/nursery areas to either sustain or rebuild recreational and commercially important fish species. The lack of quantitative and qualitative fish data are a gap in understanding the dynamics of Race Rocks. The present or potential use of Race Rocks as a fish refugia/nursery needs to be quantified by performing a proper survey of fish species on both a temporal and spatial scale. It is important to understand the life-history strategies of the fish species present and how they interact within Race Rocks ecosystem.

Finally, the Wardens’ log suggests poaching occurs at Race Rocks. The Wardens will inform the suspects that the Reserve is a “no-take” area and provide them with a pamphlet outlining the conditions of the Reserve. There needs to be a greater promotion and recogniation of the Pilot MPA and it’s role in protecting biodiversity, including fish species. This needs to be done at the local level and rental/charter organizations need to be encouraged to take a pro-active stance with their clients on this issue.

Marine Mammals

Pinnipeds

There are five species of pinnipeds, three of which are primary users. The rocky outcrop and possibly the abundant food resources attract seals and sea lions who use Race Rocks as a haulout and a stopover area. Haulouts are critical to the life strategy of pinnipeds. Sea lions use Race Rocks primarily in the winter for stopover, and to some extent for haulouts and rafting. California sea lions are the dominant users in terms of total numbers, but the use by a smaller numbers of Stellars is also important since this species is considered “Threatened” by the US.

Seals are the primary users of Race Rocks, using it for hauling-out and as an area forbirthing/pupping/weaning of young. Race Rocks is the largest (in terms of total number of seals) haulout in the Canadian waters of SJF. It is the second largest in the South Gulf survey area (see Olesiuk 1999) and the second largest in the entire Canadian portion of the Georgia Basin (Olesiuk, pers. comm. 1999). Depending on the period of peak abundances, Race Rocks can represent up to 20% of the population of the South Gulf (Olesiuk 1999).

Cetaceans

In the SJF there are five commonly sighted cetaceans. The use of Race Rocks by cetaceans is less critical than for pinnipeds. These highly mobile animals use Race primarily as a pass-though area but LUCO has listed this area of SJF as being of "high" importance to both transients and resident orcas. Race Rocks is also a hunting ground for transients due to the large numbers of pinnipeds that use the area.

Birds

There are 45 known bird species, both marine, and non-marine, that use Race Rocks for feeding, roosting, nesting, or as a stop-over site. The rocky outcrop and abundant food resources attract shorebirds and seabirds for nesting, feeding, and stopovers. Race Rocks provides a reasonably undisturbed area for seabirds to nest and roost. This is important when one considers that most of this region of the SJF is urbanized. It was estimated that 23% of the Pelagic cormorant population in eastern SJF nests at Race Rocks. It also provides critical nesting habitat for Black oystercatchers, Pigeon guillemots, and Glaucous-winged gulls. It also provides potential nesting for Brandt's cormorant, a provincially threatened (Red-listed) species. The nesting bird survey and seabird census being developed by CWS in cooperation with Fisheries and Oceans Canada and Pearson College (Smith 2000) will go a long way in determining the importance of Race Rocks for the shore/seabird populations.

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Canadian Hydrographic Service, Science Branch, Pacific Region, DFO

James Galloway
William Crawford
Bodo de Lange Boom
Brian Watt

Ocean Sciences and Productivity Division, Science Branch, Pacific Region, DFO

Rick Thomson
Jim Gower
Doug Yelland
Stephen Romaine
Frank Whitney
Dave Mackas

Stock Assessment Division, Science Branch, Pacific Region, DFO

Peter Olesiuk
Dick Nagtegaal

Laurie Nagy
Duane Hardie

Canadian Wildlife Service, Environment Canada

Ken Morgan
Michael Dunn

Land Use Coordination Office, BC Ministry of Environment, Lands and Parks

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*Contact Fisheries and Oceans Canada, Marine Environment Habitat Science Division, Institute of Ocean Sciences, 9860 West Saanich Road, Sidney, British Columbia, V8L 4B2, for the availability of unpublished reports listed here.

APPENDICES: SPECIES LISTS

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Appendix 1. Algal species identified from the Race Rocks Pilot MPA. Data compiled from Pearson College records (unpublished data), swim lines, and the Pearson College Herbarium database.

Division	Genus/Species (if available)	Common Name	Habitat
Phaeophyta	*Alaria marginata*	Winged or Ribbon kelp	intertidal-shallow subtidal
	Analipus japonicus		intertidal
	Costaria costata	Ribbed kelp	low intertidal-shallow subtidal
	Desmarestia herbacea	Acid kelp	low intertidal-shallow subtidal
	Desmarestia intermedia	Acid kelp	shallow subtidal
	Desmarestia ligulata	Acid kelp	low intertidal-shallow subtidal
	Eisenia sp.		low intertidal-shallow subtidal
	Hedophyllum sessile	Sea cabbage	intertidal-shallow subtidal
	Heterochordaria abietina		mid-low intertidal
	Laminaria spp.	Spit kelp/Kombu	low intertidal-shallow subtidal/exposed
	Lessoniopsis sp.		low intertidal-surf zone
	Macrocystis sp.	Giant kelp	low intertidal-shallow subtidal (up to 10 m)
	Nereocystis luetkeana	Bull whip kelp	low intertidal-shallow subtidal (up to 20 m)
	Pterygophora californica		shallow subtidal
	Sargassum muticum	Sargassum/Wire weed	low intertidal
Rhodophyta	*Antithamnion sp.*		epiphytic on Nereocystis
	Bossiella californica	Coralline/Coral leaf	mid-low intertidal
	Calliarthron sp.	Bead coralline	low intertidal-shallow subtidal
	Ceramium spp.		epiphytic on other low intertidal algae
	Corallina vancouveriensis	Tidepool coralline	low intertidal-shallow subtidal/tidepools
	Delesseria dicipiens		shallow subtidal
	Endocladia sp.	Sea moss	upper-mid intertidal/tidepool
	Gigartina/Mastocarpus spp.	Tar spot	high-mid intertial/tidepool
	Halosaccion glandiforme	Sea sack	mid-intertidal/tidepool
	Hymenena flabelligera		shallow subtidal
	Iridaea (Mazzaella) cordata	Iridescent seaweed	mid intertidal-shallow subtidal
	Lithothamnion spp.	Pink rock crust	high intertidal-shallow subtidal
	Microcladia spp.		upper intertidal-shallow subtidal
	Odonthalia floccosa		intertidal
	Plocamium coccineum	Sea braid	low intertidal-shallow subtidal
	Polysiphonia spp.		mid-intertidal-epiphytic on coralline algae
	Porphyra spp.	Purple laver	upper-mid intertidal/tidepool
	Pterosiphonia spp.		low intertidal-shallow subtidal
	Rhodymenia palmata		low subtidal
	Smithora sp.		epiphytic on Phyllospadix
Chlorophyta	*Acrosiphonia sp.*	Tangle weed/Green rope	low intertidal
	Cladophora flexuosa	Sea moss	high-low intertidal
	Codium fragile	Sea fingers/Sea staghorn	low intertidal-shallow subtidal
	Ulva fenestrata	Sea lettuce	mid-low intertidal-shallow subtidal
	Ulva lactuca	Sea lettuce	mid-low intertidal-shallow subtidal
Anthophyta	(Flowering Vascular Plants)		
	Phyllospadix sp.	Surf grass	low intertidal-shallow subtidal/exposed

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Appendix 2. Phytoplankton species identified from the Strait of Juan de Fuca. List includes species from Chester et al., (1980) and species from IOS/DFO cruises at Station JDF.

Division/Class	Genus/Species
Chromophyta (Chrysophyta) Bachillariophyceae (Diatoms)	*Actinoptychus splendens*
	Actinoptychus undulatus
	Amphiprora gigantea v. sulcata
	Asterionella spp.
	Asterionella gracialis
	Asterionella japonica
	Bacteriastrum delicatulum
	Biddulphia aurita
	Biddulphia longicruris
	Biddulphia longicruis v. hyalina
	Ceratulina bergonii
	Chaetoceros affinis
	Chaetoceros approximatus
	Chaetoceros compressus
	Chaetoceros concavicornis
	Chaetoceros constrictus
	Chaetoceros danicus
	Chaetoceros debilis
	Chaetoceros decipiens
	Chaetoceros diadema
	Chaetoceros didymus
	Chaetoceros gracilis
	Chaetoceros laciniosus
	Chaetoceros pseudocrinitum
	Chaetoceros radicans
	Chaetoceros secundus
	Chaetoceros subsecundus
	Chaetoceros similis
	Chaetoceros socialis
	Cocconeis spp.
	Cocconeis scutellum
	Corethron hystrix
	Coscinodiscus spp.
	Coscinodiscus angstii
	Coscinodiscus astermophalus
	Coscinodiscus centralis v. pacificus
	Coscinodiscus curvatulus
	Coscinodiscus excentricus
	Coscinodiscus granii
	Coscinodiscus lineatus
	Coscinodiscus marginatus
	Coscinodiscus nitidis
	Coscinodiscus oculus-iridis
	Coscinodiscus radiatus
	Coscinodiscus stellaris
	Coscinodiscus wailesii
	Cylindrotheca closterium
	Diploneis spp.
	Ditylum brightwellii

Appendix 2. continued.

Division/Class	Genus/Species
Chromophyta (cont.) Bachillariophyceae (Diatoms)	*Eucampia zoodiacus*
	Fragilariopsis spp.
	Grammatophora marina
	Leptocylindrus danicus
	Leptocylindricus minimus
	Licmorphora spp.
	Licmorphora abbreviata
	Melosira sulcata
	Navicula directa
	Navicula distans
	Nitzschia spp.
	Nitzschia americana
	Nitzschia delicatissima
	Nitzschia lineola
	Nitzschia longissima
	Nitzschia pungens
	Nitzschia seriata
	Pleurosigma spp.
	Pleurosigma formosum
	Rhizosolenia alata
	Rhizosolenia alata v. gracillima
	Rhizosolenia delicatula
	Rhizosolenia fragilissima
	Rhizosolenia hebetata F. simispina
	Rhizosolenia setigera
	Rhizosolenia simplex
	Rhizosolenia stolterfothii
	Rhoicosphenia curvata
	Skeletonema costatum
	Stephanopyxis nipponica
	Synedra spp.
	Thalassionema nitzschiodes
	Thalassiosira spp.
	Thalassiosira aestivalis
	Thalassiosira bioculata
	Thalassiosira condensata
	Thalassiosira decipiens
	Thalassiosira excentrica
	Thalassiosira nordenskioldii
	Thalassiosira pacifica
	Thalassiosira polychorda
	Thalassiosira rotula
	Thalassiothrix frauenfeldii
	Thlalassiothrix longissima
	Tropidoneis antarctica

Appendix 2. continued.

Division/Class	Genus/Species
Chromophyta (cont.)	
Dictyochophyceae	*Dicthyocha fibula*
Prymnesiophyceae	*Imantonia rotunda*
	Coccolithus pelagicus
	Coccolithoporid spp.
Pyrrhophyta (Dinoflagellates)	*Amphidinium spp.*
	Ceratium fusus
	Dinophysis spp.
	Dinopysis acuta
	Exuviaella spp.
	Glenodinium spp.
	Glenodinium danicum
	Gonyaulax spp. (Alexandrium)
	Gymnodinium spp.
	Gyrodinium spp.
	Oxytoxum spp.
	Peridinium spp.
	Peridinium cerasus
	Peridinium conicum
	Peridinium depressum
	Peridinium discoides
	Peridinium granii
	Peridinium pellucidum
	Peridinium micrapium
	Peridinium minisculum
	Prorocentrum gracile
	Prorocentrum micans
Sarcomastigophora	
Ebriideae	*Ebria tripartita*
Chlorophyta	
Prasinophyceae	*Pterosperma spp.*
	Miscellaneous euglenoids
Cyanophyta	Unidentified spp.
Cryptophyta	*Cryptomonad spp.*

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Appendix 3. Zooplankton taxa collected at Station JDF, April, 1996-February, 1997, by the Institute of Ocean Sciences. Data courtesy of Ocean Sciences and Productivity Division, IOS, Pacific Region, DFO.

Phylum/Class	Genus/Species or Higher Taxa
Annelida Polychaeta	Polynoidae (larvae) Spionidae (larvae) Tomopteridae Typhloscolecidae
Crustacea Cirripedia	Cirripedia cyprids Cirripedia nauplii
Branchiopoda	*Evadne spp.* *Podon spp.*
Copepoda Calanoida	*Acartia spp.* *Acartia californiensis* *Acartia californiensis* *Acartia clausi* *Acartia longiremis* *Calanoida spp.* *Calanus spp.* *Calanus marshallae* *Calanus pacificus* *Candacia bipinnata* *Centropages abdominalis* *Clausocalanus parapergens* *Clausocalanus pergens* *Ctenocalanus vanus* *Epilabidocera spp.* *Epilabidocera longipedata* *Eucalanus bungii* *Eucalanus californicus* *Euchaeta spp.* *Euchaeta elongata* *Euchirella spp.* *Heterorhabdus spp.* *Lucicutia spp.* *Metridia spp.* *Metridia pacifica* *Metridia pseudopacifica* *Microcalanus pygmaeus pusillus* *Neocalanus cristatus* *Paracalanus parvus* *Pseudocalanus spp.* *Pseudocalanus mimus* *Racovitzanus antarcticus* *Scolecithricella minor* *Scolecithricella ovata* *Spinocalanus longicornis* *Tortanus discaudatus*
Cyclopoida	*Corycaeus anglicus* *Oithona atlantica* *Oithona similis* *Oncaea conifera* *Oncaea prolata*
Ostracoda	*Conchoecia spp.* *Conchoecia elegans* *Conchoecia spinirostris*

Appendix 3. continued.

Phylum/Class	Genus/Species or Higher taxa
Crustacea (cont.) Amphipoda	*Cyphocaris challengeri* Gammaridea *Themisto spp.* *Themisto pacifica*
Malacostraca Mysidacea	*Meterythrops robusta* Mysidacea
Euphasidacea	Euphausia pacifica Euphausiia (nauplii, protozoae,zoea) *Nematoscelis difficilis* *Thysanoessa raschi* *Thysanoessa spinifera*
Malacostraca Anomura	Axiidae Pagurid (zoea) Porcellidiidae (zoea)
Brachyura	Brachyuran (megalops) Brachyuran (zoea)
Caridea	Caridean mysis Crangonidae Pandalidae mysis *Pandalus jordani*
Bryozoa	*Cyphonautes spp.*
Chaetognatha	Chaetognath juvenile *Eukrohnia hamata* *Sagitta elegans* *Sagitta scrippsae*
Cnidaria Hydrozoa	*Aglantha sp.* *Aglantha digitale* *Bougainvillia spp.* *Eutonina spp.* *Mitrocoma spp.* *Obelia spp.* *Phialidium spp.* *Sarsia spp.* *Solmissus spp.* *Lensia spp.*
Ctenophora	*Pleurobrachia spp.*
Mollusca	Bivalvia (veligers) Gastropoda (veligers) *Limacina helicina* Echinospira larvae
Echinodermata	Echinoderm pluteus Ophiuroid pluteus
Protists: Sarcodina	Foraminifera Radiolaria
Urochordata	*Fritillaria spp.* *Oikopleura spp.*
Vertebrata	Fish larvae

Appendix 4. Species list of benthic invertebrates from Race Rocks Pilot MPA and surrounding area. Comment category pertains to legend at the bottom of the appendix and outlines collection information.

Phylum/Class	Genus/Species	Common Name	Comments*
Porifera Demospongiae	*Anthoarcuata graceae*	---	5 (973-249)
	Cliona celata	Yellow boring sponge	1
	Halichondria spp.	Crumb-of-bread sponge	1
	Haliclona spp.	Encrusting sponge	1, 6
	Haliclona gracilus	---	5 (973-251)
	Isodictya quatsinoensis	Tan finger sponge	1
	Neoesperiopsis rigida (Isodictya)	---	5 (973-249)
	Jones amaknakensis	---	5 (974-622)
	Mycale adhaerens	Smooth scallop sponge	1
	Myxilla lacunosa	Sulphur sponge	1
	Ophlitaspongia pennata	Velvety red sponge	1
	Neoesperiopsis rigida (Isodictya)	---	5 (973-249)
	Plocamia karykina	Red encrusting sponge	1
	Podotuberculum hoffmanni	---	5 (973-251)
	Suberites montiniger	Orange puffball sponge	1
	Suberites suberea	Hermit crab sponge	1
	Syringella amphispicula	---	4
	Xestospongia trindanea	---	5 (973-249)
Calcarea	*Scypha spp.*	---	
Cnidaria Anthozoa	*Anthopleura elegantissima*	Aggregate green anemone	1, 4, 5 (973-251)
	Anthopleura xanthogrammica	Giant green anemone	4
	Balanophyllia elegans	Orange cup coral	1, 2, 5 (973-251)
	Cribrinopsis spp.	---	5 (974-622)
	Cribrinopsis fernaldi	Crimson anemone	1, 5 (974-622/973-249/973-251)
	Epiactis prolifera	Brooding anemone	1, 2, 3, 4, 5 (974-622/973-250/973-251)
	Gersemia rubiformis	Soft coral	1, 2, 5 (974-622/973-249)
	Metridium spp.	---	5 (973-251)
	Metridum giganteum	Plumose anemone	1
	Metridium senile	Short plumose anemone	1, 2, 3, 5 (273-249/973-251)
	Urticina spp. (Tealia)	---	5 (973-249)
	Urticina crassicornis	Christmas anemone	1, 5 (988-00211-011/973-249/973-251)
	Urticina lofotensis	White-spotted anemone	1
	Urticina piscivora	Fish-eating anemone	1
	Epizoanthus scotinus	Zoanthid	1
Hydrozoa hydroid polyps	*Abietinaria abientina*	Sea fir hydroid	1, 6
	Abietinaria greeni	Silver-tip hydroid	1, 6
	Aglaophenia latirostris	---	1, 6
	Aglaophenia struthionides	Ostrich-plume hydroid	1
	Campanularia spp.	---	6

Appendix 4. continued

Phylum/Class	Genus/Species	Common Name	Comments*
Cnidaria (cont.) Hydrozoa hydroid polyps	*Garveia annulata*	Orange hydroid	1, 2, 3, 5 (973-249), 6
	Hydractinia spp.	Snail-fur hydroid	1
	Hydractinia milleri	Hedgehog hydroid	5 (973-249)
	Orthopyxis spp.	Network hydroid	1
	Plumularia spp.	Glassy plume hydroid	1
	Plumularia lagenifers	---	6
	Rhysia fletcheri	---	5 (992-001), 6
	Sertularia spp.	---	1
	Symplectoscypus turgidus	---	4
	Thuiaria spp.	---	1
	Tubularia marina	Pink-mouthed soliary hydroid	1
hydromedusae	*Aequorea victoria (aequorca)*	Water jellyfish	1, 5 (973-250)
	Phialidium gregarium	Star jellyfish	1
hydrocorals	*Allopora californica*	---	5 (973-249)
	Allopora petrograpta	Encrusting hydrocoral	1, 2, 5 (973-249)
	Stylaster venusta (Allopora)	Pink branching hydrocoral	1
Scyphozoa	*Cyanea capillata*	Lion's mane	4
Ctenophora	*Pleurobrachia bachei*	Sea gooseberry	4
Nemertea	*Tubulanus polymorphus*	Orange ribbon worm	1
Annelida Polychaeta sedentary	*Dodecaceria fewkesi*	Fringed tube worm	1
	Eudistylia vancouveri	Northern feather-duster worm	1
	Myxicolla infundibulum	Slime tube worm	1
	Owenia fusiformis	---	5 (973-250)
	Pectinaria granulata (Cisterides)	---	5 (973-250)
	Sabella spp.	Feather-duster worm	1
	Sabellaria cementarium	Feather-duster worm	1
	Serpula vermicularis	Multicolour calcareous tube worm	1
	Sternapsis scutata	---	5 (973-250)
	Thelepus crispus	Spagetti worm	1
scale worms	*Halosydna brevisetosa*	Scale worm	1, 5 (974-622/973-249)
	Harmothoe spp.	Scale worm	1
	Harmothoe extenuata	Scale worm	5 (973-251)
errant	*Ampharete acutifrons*	---	5 (973-250)
	Cirratulus cirratus	---	5 (973-250)
	Glycinde picta	---	5 (973-250)
	Lumbrineris californiensis	---	5 (973-250)
	Lumbrineris inflata	---	5 (973-249)
	Nereis pelagica	---	5 (973-249)
	Onuphis iridescens	---	5 (973-250)

Appendix 4. continued

Phylum/Class	Genus/Species	Common Name	Comments*
Annelida (cont.) Polychaeta errant	*Platyneris bicanaliculata*	---	5 (973-250)
	Scoloplos armiger	---	5 (973-250)
	Tharyx multifilis	---	5 (973-250)
Mollusca	*Cryptochiton stelleri*	Gumboot chiton	4
Polyplacophora	*Katharina tunicata*	---	1
	Lepidozona mertensii	Merten's chiton	5 (973-249/ 973-251)
	Mopalia spp.	---	1, 4, 5 (973-249)
	Tonicella insignis	White-line chiton	1
	Tonicella lineata	Lined chiton	4, 5 (973-250)
	Trichotropsis cancellata	Dwarf hairy chiton	1, 5 (973-251)
Gastropoda	*Haliotis kamtschatkana*	Northern abalone	1, 2, 3 /**/***
	Puncturella cucullata	Hooded puncturella	1
	Acmaea mitra	White-cap limpet	2, 3, 4, 5 (974-622), 6
	Collisella digitalis (Lottia)	Ribbed limpet	6
	Diordora aspera	Keyhole limpet	2, 6
	Notoacmaea scutum (Tectura)	Plate limpet	6
	Calliostoma annulatum	Ringed top snail	1
	Calliostoma ligatum	Blue top snail	2, 4
	Crepidula adunca	Hooked slipper snail	1
	Ceratostoma foliatum	Leafy hornmouth shell	2
	Fusitriton oregonensis	Oregon or Hairy triton	1
	Margarites pupillus	Puppet margarite	4
	Ocenebra interfossa (Ocinebrina)	Carpenter's dwarf triton	5 (973-249)
	Ocenebra lurida (Ocinebrina)	Dwarf lurid triton	1, 5 (973-249)
	Lacuna variegata	Variable lacuna	1
	Littorina sitkana	Sitkana periwinkle	4
	Opalia borealis	Smooth-edged wentletrap	1
	Amphissa columbiana	Wrinkled amphissa	2
	Nucella lamellosa (Thais)	Frilled dogwhelk	4
	Searlesia dira	Dire whelk	2, 4
	Thais emarginata (Nucella)	Striped dogwinkle	4
	Acanthodoris nanaimoensis	Nanaimo dorid	1
	Archidoris montereyensis	Moneteray sea lemon	1, 5 (973-251)
	Archidoris odhneri	White dorid	1, 5 (973-251)
	Dendronotus spp.	---	5 (973-250)
	Dendronotus diversicolour	Variable dendronotid	1
	Dendronotus subramosus	---	6
	Diaulula sp.	---	2
	Doto spp.	---	1, 5 (973-249), 6
	Flabellina trilineata	Three-lined aeolid	1
	Flabellina verrucosa	Red-gilled aeolid	1

Appendix 4. continued

Phylum/Class	Genus/Species	Common Name	Comments*
Mollusca (cont.) Gastropoda	*Geitodoris heathi*	Heath's dorid	1
	Hermissenda crassicornis	Opalescent aeolid	1, 5 (974-622)
	Laila cockerelli	Cockerel's dorid	1, 5 (973-251)
Bivalvia	*Mytilus californianus*	California Mussel	2, 3, 4
	Crassadoma gigantea	Rock scallop	1
	Chlamys spp.	Swimming scallop	1
	Entodesma saxicola	Northwest ugly clam	1
	Mytilimeria nuttallii	Sea bottle clam	1
	Nucula tenuis	---	5 (973-250)
	Pododesmus cepio	Jingle shell	1
	Psephidia lordi (Nutricola)	Lord dwarf venus	5 (973-250)
Cephalopoda	*Octopus dolfeini*	Giant Pacific octopus	5 (982-00060-001)
Arthropoda Crustacea Cirripedia	*Balanus cariosus (Semibalanus)*	Thatched barnacle	3, 4
	Balanus glandula	Acorn barnacle	3, 4
	Balanus nubilus	Giant acorn barnacle	1, 2
	Pollicipes polymerus	Gooseneck barnacle	4
Malacostraca crabs	*Crytolithodes spp.*	---	2
	Cryptolithods sitchensis	Umbrella crab	5 (973-251)
	Cryptolithodes typicus	Turtle or Butterfly crab	1
	Hapalogaster mertensii	Hairy lithod crab	1
	Petrolisthes cinctipes	Flat porcelain crab	1
	Pugettia gracilis	Slender kelp crab	1
	Scyra acutifrons	Sharp-nose crab	1, 2, 5 (973-249/973-251)
	Cancer oregonensis	Oregon crab	1
	Hemigrapsus nudus	"Purple" shore crab	4
	Placetron wosnessenskii	Scaled crab	1
	Elassochirus gilli	Orange hermit crab	1, 5 (973-251)
	Elassochirus tenuimanus	Wide hand hermit crab	1, 5 (973-250)
	Pagurus armatus	Blackeyed hermit crab	5 (973-250)
	Pagurus hirsutiusculus	Hairy hermit crab	4
	Pagurus stevensae	Sponge hermit crab	1
shrimps	*Heptacarpus kincaidi*	Kincaid's shrimp	1
	Lebbeus grandimanus	Candycane shrimp	1
	Pandalus danae	Coon-striped shrimp	1
amphipods	*Anisogammarus spp.*	Sand flea	1
	Caprella sp.	---	5 (973-249)
	Ischyrocerus sp.	---	5 (973-249)
	Jassa staudei	---	5 (973-249)
	Orchestia spp. (Traskorchestia)	Beach hoppers	5 (973-250)
	Photis brevipes		1

Appendix 4. continued

Phylum/Class	Genus/Species	Common Name	Comments*
Malacostraca (cont.) isopods	*Un-named species*	---	5 (973-249)
Pycnogonida	*Tanystylum sp.*	---	5 (973-249)
Phorinida	*miscellaneous unidentified species*	---	5 (973-250)
Brachiopoda/Articulata	*Laqueus californianus (?)*	Lamp shell	1
Bryozoa Gymnolaemata	*Bugula californica*	Spiral bryozoan	1
	Eurystomella spp.	---	1
	Hippodiplosia insculpta	Fluted bryzoan	1
	Membranipora membrancea	Kelp lace bryozoan	1
	Microporella spp.	Kelp encrusting bryozoan	1
	Microporella californica	---	5 (975-00295-006)
	Schizoporella spp.	---	1
Stenolaemata	*Diaperoecia californica*	Southern staghorn	1
	Heteropora pacifica	Northern staghorn	1
Echinodermata Echinodea	*Strongylocentrotus droebachiensis*	Green sea urchin	2, 4
	S. franciscanus	Red sea urchin	2
	S. pallidus	White sea urchin	2, 4
	S. purpuratus	Purple sea urchin	5 (973-251)
Asteroidea	*Ceramaster articus*	Arctic cookie star	3, 5 (973-251)
	Dermasteria imbricata	Leather star	2
	Henricia leviuscula	Blood star	1, 2, 5 (974-622)
	Leptasterias hexactis	Six-rayed star	5 (995-00134-003/974-622)
	Orthasterias koehleri	Rainbow star	2, 6
	Pisaster brevispinus	Spiny pink star	3
	Pisaster orchraeus	Orchre star	3
	Pycnopodia helianthoids	Sunflower star	2, 3, 6
	Solaster dawsoni	Morning sun star	2
	Solaster stimpsoni	Sun star	1
	Stylasterias forreri	Velcro star	1, 2, 5 (973-251)
Ophiuroidea	*Gorgonocephalus eucnemis*	Basket star	2, 3, 5 (974-622/973-249)
	Gorgonocephalus caryi	---	5 (973-249)
	Ophiopholis aculeata	Daisy brittle star	1
	Ophiura lütkeni	Grey brittle star	5 (973-250)
Holothuroidea	*Eupentacta sp.*	---	2
	Psolus chitinoides	Armoured sea cucumber	2
	Cucumaria curatus (Pseudocnus)	Black sea cucumber	5 (995-00134-003)
	Cucumaria lubrica	Black sea cucumber	1, 5 (995-00134-003/973-251)
	Cucumaria miniata	Orange sea cucumber	4

Appendix 4. continued

Phylum/Class	Genus/Species	Common Name	Comments*
Echinodermata (cont.) Holothuroidea	*Parastichopus californicus*	California sea cucumber	1
Sipuncula	*Phascolosoma agassizii*	Agassiz's peanut worm	1
Urochordata	*Clavelina huntsmani*	Light-bulb sea squirt	1
Ascidiacea	*Chelysoma productum*	Horse-shoe ascidian	1
	Cnemidocarpa finmarkiensis	Shiney orange sea squirt	1
	Cystodytes lobatus	Lobed ascidian	1
	Distaplia smithi	Stalked compound sea squirt	1, 5 (974-622/973-249/973-251)
	Didemnum albidum	White leather glove sea squirt	1
	Metandrocarpa taylori	Orange social sea squirt	1
	Pycnoclavella stanleyi	Yellow social sea squirt	1
	Styela montereyensis	Monterey stalked sea squirt	5 (973-249)

* Legend for Source Information
1 Donna Gibbs Swim Line (www.racerocks.com/pearson/racerock/INVERTS/dgibbs.htm)
2 Goddard (1975)
3 Hardie and Mondor (1976)
4 Pearson College reports
5 Royal B.C. Museum (catalogue number)
6 Brinkmann-Voss permit reports (with Pearson College)
** Listed as a Candidate for Species of Concern by the Washington Department of Fish and Wildlife
***COSEWIC Listed as Threatened

Appendix 5. Fish species identified from Race Rocks and surrounding area. Information compiled using swim lines, Pearson College student records and Royal British Columbia Museum collections.

Family: SQUALIDAE (Dogfish Sharks)

Genus/Species: *Squalus acanthias*
Common Name: Spiny dogfish
Habitat: Subtidal
Prey/Food: Crustaceans (amphipods, crabs, crab larvae + others), ctenophores, polychaetes, green algae, fish (Miller et al. 1980).
Comments: Listed by Hardie and Mondor (1976); will often migrate between feeding areas.

Family: CLUPEIDAE (Herrings)

Genus/Species: *Clupea harengus pallasi*
Common Name: Pacific herring
Habitat: Adults primarily live offshore; juveniles and larvae inshore waters (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).
Prey/Food: Juveniles: calanoid copepods, ostracods, other crustaceans (Miller et al. 1980)
Comments: Listed in Donna Gibbs' Swimline Log (1997) off William Head; breed inshore in March with larvae and juveniles in nearshore surface waters. Lay eggs on red algae, kelp, and seagrasses. (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm); important commercial and recreational fishery.

Listed as a Candidate for "Species of Concern" by the Washington Department of Fish and Wildlife.

Family: ENGRAULIDIDAE (Anchovies)

Genus/Species: *Engraulis mordax*
Common Name: Northern Anchovy
Habitat: Pelagic; spring/summer move inshore; winter, move offshore (Hart 1973)
Prey/Food: Euphasiids, copepods, decapod larvae (Hart 1973).
Comments: Sample from Pedder Bay, listed as RCBM catalogue number 982-00151-001; spawning appears to be temperature dependent (Hart 1973).

Family: OSMERIDAE (Smelts)

Genus/Species: *Thaleichthys pacificus* (adult & larval)
Common Name: Eulachon
Habitat: Anadromous in rivers
Prey/Food: Zooplankton such as copepods, mysids, ostracods invertebrate larvae, small fish (Hart 1973)
Comments: Sample from Race Rocks, listed as RCBM catalogue number 975-00461001, 975-00529-001, 975-00531-001, 975-00531-001 are all larval; the catalogue number 982-00267-003 and 982-00268-002 are

not listed as larvae (assume adult); spawn Mar.-May in rivers (e.g. Fraser) and in spring/summer larvae carried to marine waters.

Listed as a Candidate for "Species of Concern" by the Washington Department of Fish and Wildlife.

Family: SALMONIDAE (Salmons and Trouts)

Genus/Species: *Oncorhynchus kisutch*
Common Name: Coho salmon
Habitat: Inshore subtidal and offshore waters; anadromous in rivers (Hart 1973).
Prey/Food: Juveniles: polychaetes, green algae (Miller et al. 1980). Adults: small schooling fish and invertebrates (Hart 1973).
Comments: Listed by Hardie and Mondor (1976); transient in the Reserve.

Genus/Species: *Oncorhynchus tshawytscha*
Common Name: Chinook salmon
Habitat: Inshore and offshore waters; some anadromous in larger rivers (Hart 1973).
Prey/Food: Crustaceans, small schooling fish (Hart 1973).
Comments: Listed by Hardie and Mondor (1976); transient in the Reserve.

Family: STERNOPTYCHIDAE (Hatchetfishes)

Genus/Species: *Argyropelecus sladeni* (also known as *A. lychnus lychnus*)
Common Name: Silvery hatchetfish
Habitat: Bathypelagic from 55 m to 4066 m (Hart 1973).
Prey/Food: Copepods (Hart 1973)
Comments: Sample from Pedder Bay, listed as RCBM catalogue number 959-00002-001and 980-00650-001; life history in BC does not appear to be well documented.

Family: ALEPISAURIDAE (Lancetfishes)

Genus/Species: *Alepisaurus ferox*
Common Name: Longnose lancefish
Habitat: Pelagic, deep water (Hart 1973).
Prey/Food: Marine worms, molluscs, salps, squid, octopus, crustaceans, other pelagic fish (Hart 1973).
Comments: Specimen washed up at William Head, listed by the RCBM catalogue number 996-00156-001; not likely residential in this area.

Family: MYCTOPHIDAE (Lanternfishes)

Genus/Species: *Diaphus theta*
Common Name: California headlightfish
Habitat: Semi-bathypelagic from 46-1070 m (Hart 1973).
Prey/Food: Euphasiids, copepods, amphipods (Hart 1973).
Comments: Specimenfrom Race Rocks, listed as RCBM catalogue number 982-00267-003, and 982-00268-002.

Genus/Species: *Stenobrachius sp.*
Common Name: Lampfish
Habitat: Bathypelagic up to 750 m (Hart 1973).
Prey/Food: Amphipods, euphasiids (Hart 1973).
Comments: Sample from Race Rocks, listed as RCBM catalogue number 982-00267-003; spawning from Dec.-Mar. Reach maturity at 4 years (Hart 1973).

Family: GADIDAE (Cods)

Genus/Species: T*heragra chalcogramma* (larval)
Common Name: Walleye pollock
Habitat: Bathypelagic at approximately 200 m (Hart 1973).
Prey/Food: Shrimp, small schooling fish, mysids (Hart 1973).
Comments: Sample from Race Rocks, listed as RCBM catalogue number 975-00461-001.

Listed as a Candidate for "Species of Concern" by the Washington Department of Fish and Wildlife.

Family: TRACHIPTERIDAE (Ribbonfishes)

Genus/Species: *Trachipterus silenus* (but may be *altivelis*)
Common Name: "King-of-the-Salmon"
Habitat: Appears to be mostly deep water (up to 500 m) (Hart, 1973).
Prey/Food: Copepods, euphasiids, pelagic fish, worms, squid (Hart, 1973).
Comments: Specimen from Sheringham Point, listed by the RCBM catalogue number 908-00006-001; life history does not appear to be well documented; is listed as being found from inshore waters of SJF (listed by Hart 1973).

Family: SCORPAENIDAE (Scorpionfish and Rockfish)

Genus/Species: *Sebastes caurinus*
Common Name: Copper rockfish
Habitat: Rocky reefs where there is high current (Hart 1973; www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).
Prey/Food: Juveniles: polychaetes, amphipods. Adults: fish, euphasiids, crabs (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).
Comments: Listed in Donna Gibbs's Swim Line Log (1997) and a larval specimen is catalogued by the RBCM number 975-00531-001. Internal fertilization with the larvae being released from the female in March. Seagrass and kelp beds are critical habitat for schooling juveniles; adults solitary or loosely aggregated; growth slow. Minor commercial and sport fisheries (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).

Listed as a Candidate for "Species of Concern" with the Washington Department of Fish and Wildlife.

Genus/Species: *Sebastes emphaeus*
Common Name: Puget Sound rockfish
Habitat: Rocky reefs up to 18 m (Harbo 1999).
Prey/Food: Like other rockfish, likely eats small crustaceans and other fish.
Comments: Listed Donna Gibbs' Swim Line Log (1997) off William Head.

Listed as a Candidate for "Species of Concern" with the Washington Department of Fish and Wildlife.

Genus/Species: *Sebastes maliger*
Common Name: Quillback rockfish
Habitat: Unconsolidated sediment; kelp beds androcky reefs to 40-50 m in the inshore (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).
Prey/Food: Crustaceans (e.g. crabs, shrimp, copepods), adults also prey on fish (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).
Comments: Listed in Donna Gibbs' swimline log (1997); spawn Oct.-Jan. with larvae released from females in Apr.-May with juveniles schooling in small groups in inshore rocky areas; adults usually solitary; important commercially species (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).

Listed as a Candidate for "Species of Concern" with the Washington Department of Fish and Wildlife.

Genus/Species: *Sebastes melanops*
Common Name: Black rockfish
Habitat: Kelp beds and rocky reefs up to 360 m (Harbo 1999).
Prey/Food: Like other rockfish, likely eats small crustaceans and other fish.
Comments: Listed by Hardie and Mondor (1976) and Donna Gibbs Swim Line Log (1997). This is a schooling species predominately in the (Hart 1973; Harbo 1999).

Listed as a Candidate for "Species of Concern" with the Washington Department of Fish and Wildlife.

Genus/Species: *Sebastes nigrocinctus*
Common Name: Tiger rockfish
Habitat: Rocky reef crevices.
Prey/Food: Like other rockfish, likely eats small crustaceans and other fish.
Comments: Listed in Donna Gibbs' Swim Line Log (1997); this is a solitary, territorial species and juveniles or young are generally in shallower areas (Hart 1973; Harbo 1999).

Listed as a Candidate for "Species of Concern" with the Washington Department of Fish and Wildlife.

Family: HEXAGRAMMIDAE (Greenlings and Lingcods)

Genus/Species: *Hexagrammos lagochephalus*
Common Name: Rock greenling
Habitat: Adults: Kelp beds and rocky areas up to 150 m. Juveniles: sand and mud bottom (Harbo 1999).

Prey/Food: Small crustaceans (primarily amphipods and shrimps) and bivalves (Miller et al. 1981).
Comments: Listed by Donna Gibbs Swim Line Log (1997).

Genus/Species: *Ophiodon elongatus*
Common Name: Pacific lingcod
Habitat: Rocky intertidal-subtidal, generally not exceeding 200 m (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).
Prey/Food: Fish, shrimp, copepods (Miller et al. 1980).
Comments: Listed by Hardie and Mondor (1976). Spawning occurs in Jan.-Feb. with females laying eggs in rocky crevices. Larvae hatch in March and stay in surface inshore waters feeding on plankton until July when they move offshore where they stay for several years (www.pac.dfo-mpo.gc.ca/ops /fm/fishmgmt.htm).

Family: COTTIDAE (Sculpins)

Genus/Species: *Artedius harringtoni*
Common Name: Scalyhead sculpin
Habitat: Shallow rocky reefs up to 10 m (Hart 1973; Harbo 1999).
Prey/Food: Unavailable.
Comments: Listed by Donna Gibbs' Swim Line Log (1997). This is a territorial solitary species (Harbo 1999); life history appears poorly documented.

Genus/Species: *Hemilepidotus hemilepidotus*
Common Name: Red Irish Lord
Habitat: Rocky intertidal-subtidal (Harbo 1999).
Prey/Food: Juveniles: copepods; adults: crabs, barnacles, mussels (Hart 1973).
Comments: Listed in Donna Gibbs' Swim Line Log (1997). This is a territorial solitary species (Harbo 1999); females spawn in shallows in March (Hart 1973) with eggs guarded by male (Harbo 1999).

Genus/Species: *Oligocottus maculosus*
Common Name: Tidepool sculpin
Habitat: Rocky tidepools.
Prey/Food: Crustaceans, polychaete worms, fish, nudibranchs, turbellarians, limpets (Miller et al. 1980).
Comments: Listed by Hardie and Mondor (1976). External fertilization. Eggs layed in rocky reefs (Hart 1973).

Genus/Species: *Scorpaenichthyes marmoratus*
Common Name: Cabezon
Habitat: Rocky reefs; intertidal-subtidal up to 76 m (Harbo 1999).
Prey/Food: Juveniles: copepods, invertebrate larvae; adults; fish, crustaceans, molluscs (Hart 1973).
Comments: Listed in Donna Gibbs' Swim Line Log (1997); eggs are laid in shallow intertidal areas in Jan.-Mar. (Hart 1973; Harbo 1999).

Genus/Species: *Rhamphocottus richardsonii*
Common Name: Grunt sculpin
Habitat: Tidepools and shallow rocky subtidal, undercover of rocks oralgae (Hart 1973; Harbo 1999).
Prey/Food: Amphipods, invertebrate larvae, copepods, fish larvae, crustaceans (Hart 1973).
Comments: Specimen washed up at William Head; listed as RCBM catalogue number 923-00001-001.

Family: ANARHICHADIDAE

Genus/Species: *Anarrhichythys ocellatus*
Common Name: Wolf-eels.
Habitat: Rocky reefs up to 210 m (Harbo 1999).
Prey/Food: Urchins, larger crustaceans, bivalves (Hart 1973).
Comments: Listed as a species in the Permit documentation of Pearson College.

Family: PSYCHROLUTIDAE (Psychrolutids)

Genus/Species: *Psychrolutes paradoxus*
Common Name: Tadpole Sculpin
Habitat: Shallow subtidal from 33-40 m (Hart 1973)
Prey/Food: invertebraet larvae, copepods, amphipods (Hart, 1973).
Comments: Sample from Race Rocks, listed as RCBM catelouge number 92-00267-003

Family: LIPARIDIDAE (Snailfishes)

Genus/Species: *Liparis florae*
Common Name: Snailfish
Habitat: Rocky tidepools.
Prey/Food: Harpacticoid copepods, isopods (Miller et al. 1980).
Comments: Listed as clingfish by Hardie and Mondor (1976); life history information appears poorly documented.

Genus/Species: *Paraliparis cephalus* (*deani*)
Common Name: Prickly snailfish
Habitat: Subtidally from 50-500 m (Hart, 1973).
Prey/Food: Unavailable.
Comments: Specimen from Race Rocks; listed as RCBM catalogue number 965-00003-001. Life history does not appear to be well documented.

Family: STICHAEIDAE (Pricklebacks)

Genus/Species: *Chirolophis nugater*
Common Name: Mosshead Warbonnet
Habitat: Rocky tidepools and shallow subtidal (Hart 1973)
Prey/Food: Unavailable.
Comments: Listed by Donna Gibbs' Swim Line Log (1997); life history appears poorly documented.

Genus/Species: *Lumpenus maculatus*
Common Name: Daubed Shanny
Habitat: Hard sandy substrates at depths from 55-91 m (Hart 1973).
Prey/Food: Unavailable.
Comments: Specimen from Race Rocks, listed as RCBM catalogue number 982-00267-003.

Family: PHOLIDIDAE (Gunnels)

Genus/Species: *Pholis clemensi*
Common Name: Longfin gunnel.
Habitat: Rocky subtidal (Rosenblatt 1964).
Prey/Food: Unavailable.
Comments: Listed by Donna Gibbs Swim Line Log (1997) off William Head.

Family: AMMODYTIDAE (Sand Lances)

Genus/Species: *Ammodytes hexapterus*
Common Name: Pacific sand lace
Habitat: Range in habitats from large offshore schools to shallow, sandy substrates (Hart 1973).
Prey/Food: Copepod eggs and larvae (Hart 1973).
Comments: Specimen from Race Rocks, listed as RCBM catalogue number 982-00267-003.

Family: GOBIIDAE (Gobies)

Genus/Species: *Coryphopterus nicholsii*
Common Name: Blackeye gobi
Habitat: Rocky intertidal-subtidal (Ebert and Turner 1962).
Prey/Food: Copepods, amphipods, invertebrate larvae (Hart, 1973).
Comments: Listed in Donna Gibbs' Swim Line Log (1997) off William Head.

Family: PLEURONECTIDAE (Righteye Flounders)

Genus/Species: *Hippoglossus stenolepis*
Common Name: Pacific Halibut
Prey/Food: Invertebrate larvae, copepods, amphipods (Hart 1973).
Comments: Sample from Race Rocks, listed as RCBM catelog number 982-00267-003.
Habitat: Juveniles planktonic. Adults subtidal benthic.
Prey/Food: Adults are benthic feeders on crustaceans and octopus (www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm).
Comments: Not listed on any survey, but the Race Rocks area is known as a recreational Halibut fishing ground.

Genus/Species: *Lyopsetta exilis*
Common Name: Slender sole
Habitat: Coastal water up to 500 m (Hart, 1973).
Prey/Food: Euphasiids and shrimps.
Comments: Sample from Race Rocks, listed as RCBM catalog number 982-00267-003.

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Appendix 6. Bird species recorded at the Race Rocks Pilot MPA. Collected from Warden's Logs, (1997-1999) Pearson College studies (unpublished data) and the 1997 Christmas Bird Count. Rocky Point sightings not included.

Family	Common Name	Scientific Name	Provincial Status*	Other Status	Comments
Gaviidae	Red-throated loon	*Gavia stellata*			only one listed sighting
Podicipedidae	Western grebe	*Aechmophorus occidentalis*	S1B, S3N		wintering, red-listed
	Eared grebe	*Podiceps nigricollis*			wintering
Procellariidae	Sooty shearwater	*Puffinus griseus*			only one sighting
Pelecanidae	Brown pelican	*Pelecanus occidentalis*		E[1,2]	seen fall/winter of 1997 and 1999; high water temperature+low salinity
Phalacrocoracidae	Brandt's cormorant	*Phalacrocorax penicillatus*	S1B S4N	C	nesting?/red-listed
	Double-crested cormorant	*Phalacrocorax auritus*	S2S3B, SZN		blue listed
	Pelagic cormorant	*Phalacrocorax pelagicus*	S4B, SZN		
Anatidae	Harlequin duck	*Histrionicus histrionicus*	S3N, S4B	SC	wintering
	Common merganser	*Mergus merganser*			
	White-winged scoter	*Melanitta fusca*			
	Surf scoter	*Melanitta perspicillata*			blue listed
	Bufflehead	*Bucephala albeda*			wintering
	Canada goose	*Branta canadensis*			
	Brant	*Branta bernicla*	S3N		
Cathartidae	Turkey vulture	*Cathartes aura*	S3		
Accipitridae	Bald eagles (mature and immature)	*Haliaeetus leucocephalus*	S4	T[1,2]	vunerable
Haemotapodidae	Black oystercatcher	*Haematopus bachmani*			breeding
Scolopacidae	Sandpipers	-----			species note stated
	Black turnstone	*Arenaria melanocephala*			wintering
	Ruddy turnstone	*Arenaria interpres*			wintering
	Surfbird	*Aphriza virgata*			
	Longbilled sandpiper	-----			wintering
	Whimprel	*Numenius phaeopus*			
	Sanderling	*Calidris alba*			
Ardeidae	Great blue heron	*Ardea herodias*	S3S4B, SZN		blue listed
Laridae	Bonaparte's gull	*Larus philadelphia*			wintering; red listed
	Heermann's gull	*Larus heermanni*			
	Western gull	*Larus occidentalis*			
	Glaucous-winged gull	*Larus glaucescens*			
	Herring gull	*Larus argentatus*			
	Mew gull	*Larus canus*			
	Thayer's gull	*Larus thayeri*			
Alcidae	Pigeon guillemot	*Cepphus columba*			breeding

Appendix 6. continued.

Family	Common Name	Scientific Name	Provincial	Other Status	Comments
Alcidae	Marbled murrelet	*Brachyramphus marmoratus*	S2B, SZN	$T_{C;\,T}^{1,2}$	fall-spring in small numbers, many times only single sightings; red listed
	Ancient murrelet	*Synthliboramphus antiquus*	S3B, SZN	T_C	fall-spring in small numbers, only a few sightings; blue listed
	Rhinoceros auklet	*Cerorhinca monocerata*	S4B, SZN		presently usually in small numbers of <10 in the fall
	Common murre	*Uria aalge*	S2B SZN	C	
Trochilidae	Hummingbird	-----			species not stated
Hirundinidae	Swallow	-----			species not stated
Corvidae	Northwestern crow	*Corvus caurinus*			
Sittidae	Nuthatche	*Sitta sp.*			Species not stated
Sturnidae	European starling	*Sturnus vulgaris*			
Vireonidae	Hutton's vireo	*Vireo huttoni*	S3,S4		blue listed
Emberizidae	Sparrow	-----			species not stated

* Provinical Status pertains to only indigenous species
** Information taken from Simstead, 1979
The Global Rank refers to
T_C=Listed as Threated under COSEWIC
T^1=Listed as Threatened by U.S Fish and Wildlife Service or the National Marine Fisheries Service
T^2=Listed as Threated by the Washington Department of Fish and Wildlife
E^1=Endanged listing by U.S Fish and Wildlife Service or the National Marine Fisheries Service
E^2=Endanged listing by the Washington Department of Fish and Wildlife
C=Listed as a Species of Concern and candidate for listing with the Washington Department of Fish and Wildlife
SC=Listed as a species of Concern by the U.S Fish and Wildlife Service or the National Marine Fisheries Service
Red-listed=Endangered/Threatened Blue-listed=Vunerable
S1: Critical, S2: Imperial, S3: Vunerable, S4: Apparently secure, S5: Secure, N: Non-breeding, B: Breeding, Z: Moving