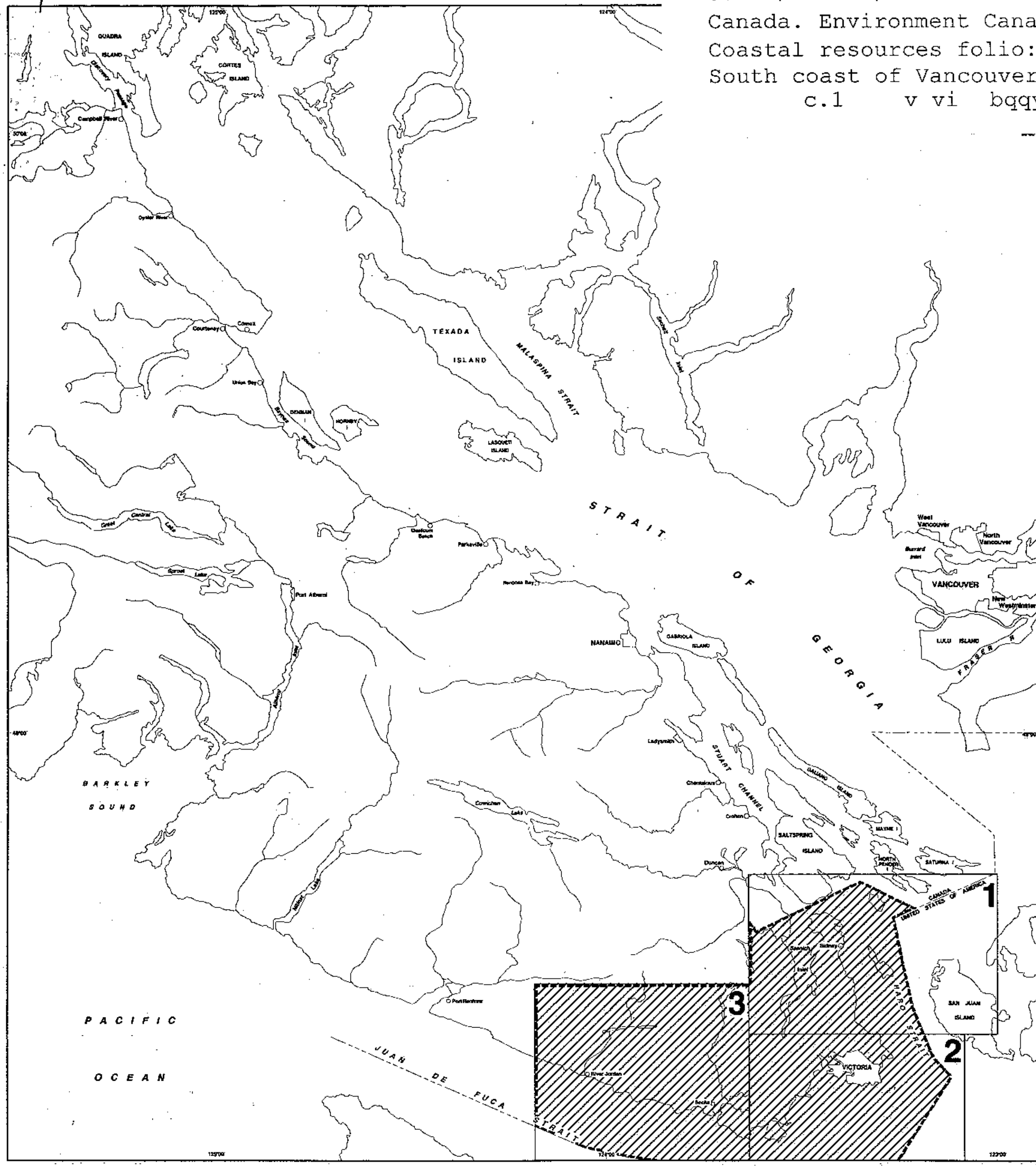


COASTAL RESOURCES FOLIO
SOUTH COAST OF VANCOUVER ISLAND

(Hatch Point to Ledingham Creek)

BRITISH COLUMBIA

VOLUME II

LANDS DIRECTORATE — DIRECTION GÉNÉRALE DES TERRES

Environment Canada — Environnement Canada

Canada

COASTAL RESOURCES FOLIO

SOUTH COAST OF VANCOUVER ISLAND
(Hatch Point to Ledingham Creek)

PREPARED BY:

M.J. ROMAINE, Project Manager.

- *Project Design*
- *Folio Layout*
- *Editorial Production*

Michael W. DUNN, Research Officer.

- *Marine Substrates*
- *Surficial Materials & Hazards*
- *Physical Shorezone*
- *Physical Processes & Energy*
- *Physiography*

Don M. MOORE, Consulting Marine Ecologist.

- *Oceanography-Salinity, Temperature, Circulation*
- *Fish & Shellfish Resources - Use, Habitat*

Trevor J. SUMMERS, Research Officer.

- *Water Resources*
- *Marine & Terrestrial Vegetation*
- *Marine Birds & Mammals*
- *Recreation*

Derek A. WOLFF, Research Officer.

- *Zoning & Administrative Boundaries*
- *Plans & Proposals*
- *Marine Facilities*
- *Land/Water Use & Status*

CARTOGRAPHY BY:

Magdalene CAWLEY
- *Recreation*

Anita L. CHARLES
- *Physical Shorezone*

Spencer W. DANE
- *Map & Narrative Editor*

Gary GILES
- *Oceanography*
- *Fish & Shellfish Resources*

Michael E. HAGEN
- *Water Resources*
- *Marine Vegetation*

Kenneth W. LONG
- *Plans & Proposals*

James D. NORTHRUP
- *Land/Water Use & Status*
- *Zoning*
- *Figures*

Tina Louise SPALDING
- *Cartographic Supervisor*
- *Land/Water Use & Status Tables*
- *Map Editor*

Jaan A. TAMM
- *Cartographic Advisor/Coordinator*
- *Administrative Boundaries*
- *Surficial Materials*
- *Marine Birds*

Greg R. THRIFT
- *Marine Substrate*

LANDS DIRECTORATE

ENVIRONMENT CANADA
Vancouver, B.C.

Cartography Section
Land Resource Research Institute
Agriculture Canada
Ottawa, Ontario

- *Folio Covers*
- *1:50,000 Base Maps*
- *Photomechanical Production of Coastal Resources Map Series*

Map Reproduction Laboratory
Surveys & Resources Mapping Branch
B.C. Ministry of Environment
Victoria, B.C.

- *Duplication of Base & Theme Maps*

TYPING & WORD PROCESSING BY:

Julia ANDERSON/Ellen NOVOSEL
Lands Directorate
Environment Canada

Pam WAKEMAN
Environment Protection Service
Environment Canada

Sharon HENDERSON
Socio-Economic Development
Indian & Northern Affairs Canada

PROVISION OF TECHNICAL SUPPORT SERVICES

Douglas GORDON/Sheldon A. McCOLLOUGH
Socio-Economic Development
Indian & Northern Affairs Canada

R.D. STEVENS
Environmental Protection Service
Environment Canada

Tom D. BIRD/Bruce McDONALD
Habitat Management Division
Fisheries & Oceans Canada

FINANCIAL SUPPORT BY:

Lands Directorate
Environment Canada
Vancouver, B.C.

Lands Directorate
Environment Canada
Ottawa, Ontario

Regional Director
General's Office
Environment Canada
Vancouver, B.C.

Habitat Protection Division
Fisheries & Oceans Canada
Vancouver, B.C.

Socio-Economic Development
Indian & Northern Affairs Canada
Vancouver, B.C.

ACKNOWLEDGEMENTS

The Coastal Resources Folio represents a cooperative effort, its contents dependent on information held by various specialists and agencies at the federal, provincial, regional and local levels of government as well as by public and private organizations. In all instances, cooperation, advice, assistance, data and, when requested, logistic and technical support, were given freely. The Sources Section (Section 5) of this Folio under "Personal Communications" identifies those individuals and agencies whose valuable contributions are gratefully acknowledged.

November, 1982

1.0 INTRODUCTION

1.1 THE COASTAL RESOURCES FOLIO PROJECT

The purpose of the Coastal Resources Folio Project is to provide an inventory and synethesis of existing biophysical and land/water use information in a format useful for environmental assessments, integrated and single purpose planning and management programs, coast-wide and regional resource allocation studies, and the identification of baseline study needs.

The Coastal Resources Folio Project was initiated by the Lands Directorate, Environment Canada in the fall of 1979. The first product - Coastal Resources Folio; East Coast of Vancouver Island (Race Point to Hatch Point and adjacent islands) was published in November 1981. The east coast of Vancouver Island study provided the opportunity to develop methods and approaches for collecting, analyzing and presenting data, as well as to obtain feedback from agencies involved in coastal research, inventory planning and management programs.

This folio - Coastal Resources Folio; South Coast of Vancouver Island - is the second of an on-going series for the British Columbia Coastal Zone.

1.2 THE STUDY AREA

The south Vancouver Island resources folio study area extends from Hatch Point, south of Duncan to Ledingham Creek, west of San Simon Point. The seaward boundary in Haro and Juan de Fuca Straits is the international border between Canada and the United States of America.

The landmark boundary extends to approximately the 150 metre (500 foot) elevation.

1.3 METHODOLOGY

The following steps are used to develop the Coastal Resources Folio:

- Overall purpose, approach and content of folio developed;

- Meetings held with selected federal, provincial and local agencies to seek advise on priorities and to locate sources of baseline information;

- Initial selection of criteria for each theme made and the collection of baseline information begun;
- Contacts with agency personnel made to obtain baseline data and advice on the type of information that should be presented in the Folio;
- Information transferred to working maps, tables and reports;
- Limited field work supported by air photo and video tape interpretation undertaken to fill some data gaps in shore process information, marine vegetation and land/water uses;
- Documents edited, finalized and published.

1.4 USE AND LIMITATIONS

1.4.1 Potential Use

A concerted effort has been made to ensure that the data presented in the Folio are technically correct and a true reflection of the original collected information. An effort has also been made to portray information in its primary - baseline form. The transformation of the baseline data into such interpretations as erosion hazards, environmental sensitivities, urban suitability, biological productivity and potential uses or conflicts, are left to the user who will have his/her own specific management responsibilities, criteria and information needs.

1.4.2 Limitations

The following limitations are inherent in the Folio:

1. The Folio is only as complete and accurate as the information upon which it is based. Primary data sources are frequently not consistent in format, quality, level of detail, or date of collection. In other instances baseline data may be absent or not readily available.

2. The Land/Water Use and Status them maps and tables, because of the nature of the information base, become quickly outdated. This is particularly true of foreshore lease information.

3. The scale of presentation at 1:50,000 is not suited for site-specific investigations. Pockets of marine vegetation, small parks or minor land use zones areas, for example, cannot be depicted at this scale. Further, in the transferring of information from one scale to another, errors in the placement of boundaries can result. For detailed analysis, the original source documents should always be consulted.

4. The marine substrates, physical shore zone, seaweeds and saltmarshes data were supplemented by aerial photo and video tape interpretations. Verification by field checks was limited.

The Lands Directorate, Department of the Environment, welcomes comments on the use and limitations of the Folio in order that improvements can be made to subsequent Coastal Resources Folio documents.

1.5 FOLIO CONTENT AND FORMAT

1.5.1 Folio Content

The Coastal Resources Folio contains the following six separate sections.

Section	1.0	INTRODUCTION
	.1	The Coastal Resources Folio Project
	.2	The Study Area
	.3	Methodology
	.4	Use and Limitations
	.5	Folio Content and Format
	.6	Availability and Coverage
Section	2.0	COASTAL RESOURCES MAP SERIES (1:50,000)
	.1	Marine Sediments
	.2	Physical Shorezone
	.2	Physical Shorezone Units Table
	.3	Generalized Terrain Limitations
	.4	Oceanography - Temperature and Salinity
	.5	Water Resources: Discharge, Use and Contamination
	.6	Seaweeds, Saltmarshes and Marine Mammals
	.7	Marine Bird Surveys
	.8	Fish and Shellfish Resources

	.9	Generalized Zoning and Marine Facilities
	.10	Land/Water Use Plans and Proposals
	.11	Selected Administrative Boundaries
	.12	Land/Water Status
	.13	Recreational Areas, Special Features and Access
Section 3.0		LAND/WATER USE AND STATUS TABLES
	.1	Regional and Local Zoning
	.2	Marinas, Bulk Oil Storage Facilities and Sewage Systems and Treatment
	.3	Land Use Plans and Proposals
	.4	Heavy Industrial Zones
	.5	Land Water Status
Section 4.0		COMPANION REPORT
	.1	Introduction
	.2	The Southeast Coast Economy
	.2.1	General Setting
	.2.2	Tourism
	.2.3	Agriculture
	.2.4	The Forest Industry
	.2.5	The Fishing Industry
	.3	General Physical Features
	.3.1	Physiography
	.3.2	Geology
	.3.3	Soils
	.3.4	Climate
	.3.5	Physical Oceanography
	.3.6	Water Resources
	.4	Biological Resources
	.4.1	Terrestrial Vegetation
	.4.2	Seaweeds and Saltmarshes
	.4.3	Marine Mammals
	.4.4	Marine Birds
	.4.5	Fish and Shellfish Resources
	.5	Recreational Resources
	.5.1	Competition for Space and Resources
	.5.2	Access
	.5.3	Pollution
	.6	Physical Process and Energy
	.6.1	Regional Wave Climate
	.6.2	Circulation
	.6.3	Sedimentation

.6.4 Atmospheric Mixing
.6.5 Seismicity
.7 Factors of Biological Productivity
.7.1 The Area
.7.2 The Physical/Chemical Environment
.7.3 Primary Production - Phytoplankton
.7.4 Primary Production - Seaweeds and Saltmarshes
.8 The Administration and Management of Coastal Resources
.8.1 Introduction
.8.2 The Administration of Coastal Land
.8.3 Water Management
.8.4 Local Planning

Section 5.0 SOURCES
.1 Introduction
.2 Coastal Resources Map Series (1:50,000)
.3 Land/Water Use Tables
.4 Companion Report

1.5.2 Intent of Folio Sections

1.0 INTRODUCTION

The introductory section is designed to inform the reader as to the purpose, content and availability of the folio.

2.0 COASTAL RESOURCES MAP SERIES (1:50,000)

The intent of this section is to portray in a standardized form, all available and relevant (spatial and/or point source) information for each of the 13 themes. The maps are designed to permit the overlay of any combination of two or more theme maps. Such an approach was developed in recognition of the value and use of overlay analysis techniques to regional planning, in initial assessments of project proposals, and in the derivation of secondary information based upon the comparison and/or combination of different data sets.

3.0 LAND/WATER USE AND STATUS TABLES

This tabular information along with descriptive highlights, provides quantitative and detailed data on such subjects as areas of foreshore leases, the present use and

and ownership of industrial zones and the services provided at marinas.

4.0 COMPANION REPORT

The purpose of the Companion Report is to provide a summary of existing and selected information on coastal resource values, uses, and processes. The Companion Report is a compilation of information on many topics and is designed to complement those themes and subjects portrayed in the Coastal Resources Map Series.

5.0 SOURCES

The Sources Section provides a list of information sources pertinent to the study area. Sources are organized under the same headings as the previous sections. In addition to a bibliography, the Sources Section includes other primary data sources such as aerial photographs, field surveys, computer print-outs, zoning by-laws, and personal communications.

1.5.1 Folio Format

The Coastal Resources Folio consists of two documents:

Volume I is an Atlas containing Section 1.0 Introduction, Section 2.0 Coastal Resources Map Series (1:50,000) and Section 3.0 Land/Water Use and Status Tables. Volume I consists of three separate folios - one for each of the three base maps areas.

Volume II, which applies to the entire study area is a report containing Section 1.0 Introduction, Section 4.0 Companion Report and Section 5.0 Sources.

1.6 AVAILABILITY AND COVERAGE

1.6.1 Availability

The Coastal Resources Folio is available either from:

Lands Directorate
Environment Canada
#904 - 1001 West Pender St.
Vancouver, B.C.
V6E 2M7

Phone: (604) 666-3162

OR

Maps Library
Surveys & Resources
Mapping Branch
B.C. Ministry of Environment
765 Broughton Street
Victoria, B.C.
V8W 1EZ

Phone: (604) 387-4441

1.6.2 Orders and Cost

Requests should be placed by mail. The Folio can be ordered by base map, resource theme, or by section. Further, Sections 2.0 Coastal Resources Map Series (1: 50,000) Manuscripts can be ordered as either ozalids (paper prints) or as films (diazo, auto-positive or coloured mylars).

The cost of your order will be in accordance with the following arrangement.

Document	Request: Number of Copies	Request: Type of Product	Cost
Volume I - Atlas	Limited number of single copy theme maps or tables	Ozalid (paper print)	No Charge
		films (diazo or auto-positives)	At current rates established by local printing firms or by the Provincial Map Reproduction Laboratory. Direct billing to apply.
		film (colour-keyed mylars by map theme)	At cost by special arrangement through Lands Directorate
	Multiple (duplicate) copoies of theme maps or tables	Ozalids (paper prints)	At current rates established by local printing firms or by the Provincial Map Reproduction Laboratory. Direct billing to apply. Estimated Cost (1982 quotations) \$1.05 - \$2.00 per print*
Volume II Report	Limited number of copies available free of charge.		

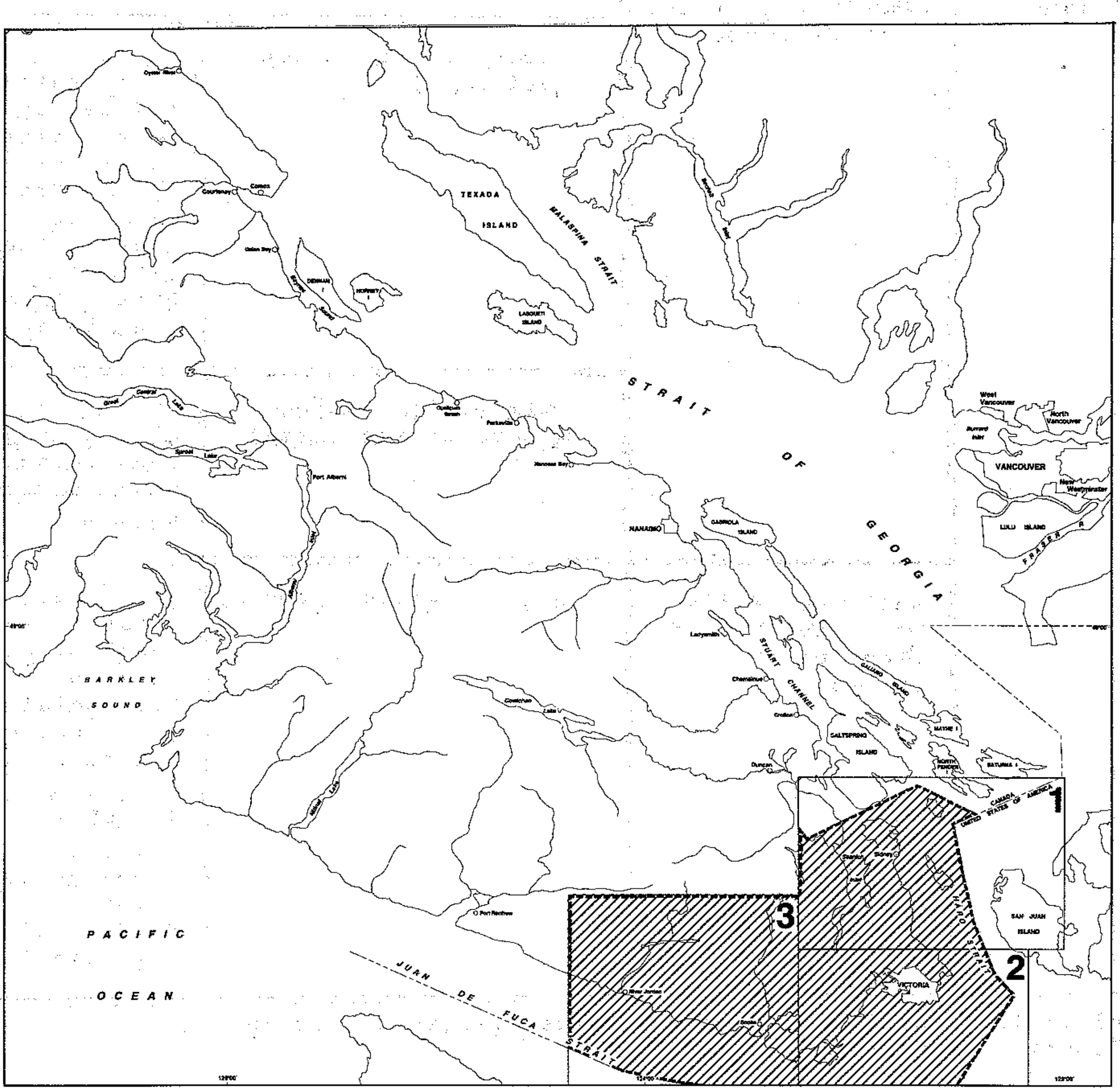
* Prices subject to change.

1.6.2 Coverage

The following charts will be of assistance in ordering the Coastal Resources Folio.

1.6.2.1 Area Coverage

Location and boundaries of study area and three base maps.



1.6.2.2 Theme Maps (Coastal Resources Map Series)

When ordering 1 : 50,000 theme maps, please quote year of publication; base maps and theme number, in accordance with the following chart.

Year	Base Maps 1	2	3	Theme Map No. & Title
81	0	0	0	.1 Marine Sediments
81	0	0	0	.2 Physical Shorezone
81	0	0	0	.2 Physical Shorezone Units Table
81	0	0	0	.3 Generalized Terrain Limitations
81	0	0	0	.4 Oceanography - Temperature and Salinity
81	0	0	X	.5 Water Resources - Discharge, Use and Contamination
81	0	0	0	.6 Seaweeds, Saltmarshes and Marine Mammals
81	0	0	0	.7 Marine Bird Surveys
81	0	0	0	.8 Fish and Shellfish Resources
81	0	0	0	.9 Generalized Zoning and Marine Facilities
81	0	0	X	.10 Land/Water Use Plans and Proposals
81	0	0	X	.11 Selected Administrative Boundaries
81	0	0	0	.12 Land/Water Status
81	0	0	0	.13 Recreational Areas, Special Features and Access

Coverage: 0 - available
X - not available

For example 81.3.1 refers to base map number 3, Marine Sediments published in 1981.

1.6.2.3 <u>Tables (Land/Water Use and Status)</u>

Table and Topic Coverage by Base Map

Table	Topic	Base Map Coverage		
		1	2	3
1	Regional and Local Zoning	0	0	0
2	Marinas, Bulk Oil Storage Facilities and Sewage Systems and Treatment	0	0	0
3	Land Use Plans and Proposals	0	0	X
4	Heavy Industrial Zones	0	0	0
5	Land and Water Status	0	0	0

When ordering, please quote required table number and topic in accordance with the following chart.

SECTION 4: COMPANION REPORT

PREPARED BY

M.W. Dunn
D.M. Moore
D.A. Wolff
T.J. Summers

WITH CONTRIBUTIONS FROM

D.G. Schaefer
M. Lashmar

COMPILED AND EDITED BY

M.J. Romaine

LANDS DIRECTORATE
ENVIRONMENT CANADA
VANCOUVER, B.C.

December, 1982

TABLE OF CONTENTS

		Page
	LIST OF FIGURES	iv
	LIST OF TABLES	v
4.1	INTRODUCTION	1
.1.1	Purpose	1
.1.2	The Study Area	1
4.2	THE SOUTH COAST ECONOMY	1
.2.1	General Setting	1
.2.2	Tourism	4
.2.3	Agriculture	4
.2.4	Forestry	4
.2.4.1	Capital Regional District	4
.2.4.2	Sooke-Port Renfrew Area	7
.2.5	The Fishing Industry	7
4.3	GENERAL PHYSICAL FEATURES	7
.3.1	Physiography	7
.3.1.1	The Nanaimo Lowland	8
.3.1.2	Haro Strait	8
.3.1.3	Juan de Fuca Strait	8
.3.2	Geology	8
.3.2.1	Bedrock	9
.3.2.2	Surficial	9
.3.3	Soils	10
.3.4	Climate	10
.3.4.1	Temperature and Precipitation	10
.3.4.2	Wind Patterns	10
.3.5	Physical Oceanography	10
.3.5.1	Tides	10
.3.5.2	Currents	11
.3.5.2.1	Tidal Currents	11
.3.5.2.2	Non-Tidal Currents	12
.3.5.3	Waves	12
.3.6	Water Resources	12
.3.6.1	Hydrology	12
.3.6.2	Water Quality	12
4.4	BIOLOGICAL RESOURCES	16
.4.1	Terrestrial Vegetation	16
.4.2	Seaweeds and Saltmarshes	16
.4.3	Marine Mammals	17
.4.4	Marine Birds	19

		Page
.4.5	Fish and Shellfish Resources	25
.4.5.1	Introduction	25
.4.5.1.1	The Nature of Marine Resources	25
.4.5.1.2	Importance of the Study Area	26
.4.5.2	Fisheries (fin fish)	27
.4.5.2.1	Salmonids	27
.4.5.2.1.1	Resource	27
.4.5.2.1.2	Habitat Requirements	31
.4.5.2.1.3	Salmonid Enhancement Peogram	37
.4.5.2.2	Groundfish	37
.4.5.2.2.1	Resource	37
.4.5.2.2.2	Habitat Requirements	38
.4.5.2.3	Other Finfish	42
.4.5.2.3.1	Herring	42
.4.5.2.3.2	Habitat Requirements	42
.4.5.3	Shellfish	44
.4.5.3.1	Resource and Habitat Requirements	44
.4.5.3.1.1	Crab	44
.4.5.3.1.2	Clams	44
.4.5.3.1.3	Shrimp	46
.4.5.3.1.4	Prawns	46
.4.5.3.1.5	Sea Urchin	46
.4.5.4	Species Names	46
4.5	RECREATIONAL RESOURCES	48
.5.1	Competition for Space and Resources	48
.5.2	Access	48
.5.3	Pollution	49
4.6	PHYSICAL PROCESSES AND ENERGY	49
.6.1	Regional Wave Climate	49
.6.1.1	Wave Heights	49
.6.1.1.1	Wind Strength	50
.6.1.1.2	Wind Duration	50
.6.1.1.3	Fetch	50
.6.1.1.4	Swell Waves	52
.6.1.1.5	Synthesis	52
.6.1.2	Wave Energy	53
.6.1.2.1	Whiffin Spit	55
.6.1.2.2	Victoria Waterfront	55
.6.1.2.3	Saanich Peninsula	55
.6.1.3	Littoral Currents	57
.6.2	Circulation	60
.6.2.1	Overall Patterns	60
.6.2.2	Factor Influencing the Movement of Oil Spills	60
.6.3	Sedimentation	61

		Page
4.6.4	Atmospheric Mixing	61
.6.5	Seismicity	62
.6.5.1	Magnitude	62
.6.5.2	Depth of Focus and Mechanism	67
.6.5.3	Soil Type	67
.6.5.4	Distance	68
.6.5.5	Quality of Building Construction	69
.6.5.6	Secondary Effects	69
4.7	FACTORS OF BIOLOGICAL PRODUCTIVITY	69
.7.1	The Area	69
.7.2	The Physical/Chemical Environment	69
.7.3	Primary Production - Phytoplankton	70
.7.4	Primary Production - Seaweeds and Saltmarshes	72
4.8	THE ADMINISTRATION AND MANAGEMENT OF COASTAL RESOURCES	76
.8.1	Introduction	76
.8.2	The Administration of Coastal Land	76
.8.2.1	Crown Land - Provincial	76
.8.2.2	Crown Lands - Federal	77
.8.2.3	Private and Other Public Lands	77
.8.3	Water Management	78
.8.3.1	Water Supply and Licencing	78
.8.3.1.1	Federal Responsibilities	78
.8.3.1.2	Provincial Responsibilities	78
.8.3.2	Water Quality and Waste Management	79
.8.3.2.1	Federal Legislation	79
.8.3.2.2	Provincial Legislation	79
.8.4	Local Planning	79
.8.4.1	Capital Regional District	80
.8.4.1.1	The Western Community	80
.8.4.1.2	Metchosin	81
.8.4.2	Saanich	81

LIST OF FIGURES

Figure		Page
1	Change in Type of Tides Along Juan de Fuca Strait	11
2	Hydrograph for the Sooke River Near Sooke Lake - Stn.08HA005 .	13
3	Hydrograph for the Colquitz River at Hyacinth Road - Stn.08HA037	14
4	Moisture Balance for Three Stations Within the Study Area	15
5	Fisheries Statistical Areas for the South Coast of Vancouver Island	27
6	Percentage Frequency of Hours with Wind Speeds 30 Km/Hour or Greater for Race Rocks (1970-80)	51
7	Power Spectrum of Relative Amount of Energy Contained by Waves over a Range of Wave Periods	53
8	Whiffin Spit Wave Refraction (Wave Period 10 Seconds from the Southwest)	56
9	Location of Sample Stations	58
10	Annual Percent Frequency of Bottom Sediment Disturbance	59
11	Frequencies of Episodes of Persistent Light Surface Winds (speeds less than 12 km/hour) by Season	63
12	Percentage Frequencies of Ground-Based Inversions by Season ..	63
13	Strain Release as a Function of Time	65
14	'Continental' Area Regional Distribution of Strain Release Since 1951	68
15	Generalized Pattern of Primary (Phytoplankton) Production in the Strait of Georgia	71
16	Schematic of Energy Transfer Between Trophic Levels in Unlimited (A) and Limited (B) Ecosystems	73
17	Average Annual Rate of Net Plant Production for Selected Ecosystems	74
18	Number of Species in Relation to Salinity Level (^{o}/oo)	75

LIST OF TABLES

Table		Page
1	Composition of Employment within Metropolitan Victoria (1976)	2
2	Experienced Labour Force for Sooke-Port Renfrew Area (1971).	3
3	Value of Agricultural Production in Percentage	5
4	Capital Regional District Farm Capital and Value of Products (1971 and 1976)	6
5	Cetaceans Occurring in Washington State and British Columbia	18
6	Functional Feeding Groups and Representative Prey Taxa of Marine Mammals known or Suspected to Occur in North Puget Sound and the Strait of Juan de Fuca	20
7	Functional Feeding Groups and Representative Prey Taxa of Marine and Shore Birds Common to Northern Puget Sound and the Strait of Juan de Fuca	21
8	Percentage of Fish and Shellfish Resources of South Vancouver Island (Fisheries Statistical Areas 19, 20) Relative to the Total Fisheries Yield of the Juan de Fuca-Strait of Georgia Systems (Areas 13-20, 28, 29)	29
9	Economic Impact of Greater Victoria's Commercial Fishery (1977 figures)	30
10	Economic Impact of Greater Victoria's Sport Fishery (1978 figures)	30
11	Salmon Fishery of Southwest Vancouver Island. Regional Perspective of Average Annual Salmon Catch (Tonnes) in 1975-1980	31
12	Regional Perspective of Average Annual Sport Salmon Catch (Number of Fish) in the Strait of Georgia plus Northern (Area 13) and Southern (Areas 19B, 20) Approaches in the Period 1972-75	32
13	A Comparison of Sports Versus Commercial Catch (x1000 fish) in the Strait of Georgia Region for the Period 1972-1975 ..	32
14	Average Salmon Spawn Escapement to South Coast Vancouver Island Rivers and Creeks in the Periods 1967-76 and 1977-81	33
15	Field Notes of Salmon Spawning Streams (Areas 19 and 20) - Brief Summaries of Stream Characteristics and Certain Historical Features	35

Table		Page
16	Groundfish Fishery of South Vancouver Island. A Regional Perspective of Average Annual Catches (nearest tonne) Relative to the Juan de Fuca-Strait of Georgia System in 1960-77 and 1979-80	39
17	Shellfish Fishery of South Vancouver Island. Regional Perspective of Average Annual Catches of Major Species in 1975-80 (Nearest Tonne)	45
18	Minimum Fetch and Duration to Produce Fully Developed Seas of Various Wind Speeds	54
19	Maximum Depth of Sediment (Sand-Sized) Disturbance due to Waves	58
20	Modified Mercalli Scale of Earthquake Intensitive with Corresponding Richter Magnitudes	64
21	Zones in Victoria Microzonation	66
22	Seismic Amplification Factors for Different Geological Materials	67

4.1 INTRODUCTION

4.1.1 PURPOSE

The purpose of this report is to provide complementary information to the maps and tables of the Coastal Resources Folio.

4.1.2 THE STUDY AREA

The South Vancouver Island Resources Folio study area extends from Hatch Point, south of Duncan to Ledingham Creek, west of San Simon Point. The seaward boundary in Haro and Juan de Fuca Straits is the international border between Canada and the United States of America.

The landward boundary extends to approximately the 150 metre (500 foot) elevation.

4.2 THE SOUTH COAST ECONOMY

4.2.1 GENERAL SETTING

Vancouver Island's south coast provides a variety of shore environments - from inlets (Saanich, Gorge); harbours (Victoria, Esquimalt, Sooke); and lagoons (Esquimalt, Witty's) - to exposed coastal areas within the Juan de Fuca Strait.

The population of the study area is about 240,000 (Ministry of Economic Development, 1978). The majority (231,000) lives within the Capital Regional District, an area which can be further divided into the western community (Colwood, Langford and Metchosin); the urban core (Victoria, Saanich, Oak Bay, Esquimalt and View Royal); and the peninsula (Sidney, North Saanich and Central Saanich). It is predicted that the population of the Capital Regional District will reach 360,000 by the turn of the century (Capital Regional District, undated). The remaining population, 99,000, lives within the Sooke-Port Renfrew area.

The major sources of employment and income in the Capital Region are derived from tourism, government and industry (Capital Regional District, 1977). Table 1 provides the composition of employment and income for the metropolitan Victoria area during 1976.

The Sooke-Port Renfrew area is primarily a residential suburb of Victoria. The forest industry provides the major source of local employment (Ministry of Economic Development 1978). Table 1 identifies the experienced labour force by sector.

TABLE 1 COMPOSITION OF EMPLOYMENT WITHIN METROPOLITAN VICTORIA

(1976)

Sector of Economy	Total Employment	Employment Supporting Sales to Local Residents	Employment Supporting Sales to Other Regions
Government			
Federal	8,970	2,050	6,920
Provincial	9,890	5,436	4,454
Local	2,550	2,550	-
Manufacturing	7,236	1,881	5,355
Construction	5,278	1,726	3,552
Transportation	5,902	2,485	3,417
Wholesale Trade	2,514	1,430	1,084
Retail Trade	11,100	7,315	3,785
Finance, Insurance and Real Estate	4,216	3,364	852
Community, Business and Personal Service	24,363	9,940	14,423
Total	82,019	38,177	43,842

Notes: 1. Base Multiplier $= \frac{82,019}{43,842} = 1.87$

(Total Employment/Base Employment)

For every job created in our economy to support sales of goods and services to other regions, 1.87 net total jobs will be created in the total economy.

2. Response rate in the Business Survey was too low from the primary sector to permit estimation of employment supporting sales to other regions, as well as sales to local residents.

Source: Capital Regional District, Economic Advisory Committee, 1977. The Challenge...Managing the Capital Region's Economy. Victoria, B.C.

TABLE 2 EXPERIENCED LABOUR FORCE FOR SOOKE-PORT RENFREW AREA (1971)

Sector	Labour Force
Agriculture	45
Forestry	405
Fishing and Trapping	65
Mines and Quarries	25
Manufacturing	245
Construction	125
Transportation, Communication and other Utilities	110
Trade	130
Finance, Insurance and Real Estate	55
Community, Business and Personal Service	305
Public Administration and Defence	120
Unspecified or Undefined	145
Total Experienced Labour Force	1,665

Source: Adapted from Ministry of Economic Development. 1978. British Columbia Regional Index. Province of British Columbia. Page 430.

4.2.2 TOURISM

The Victoria Metropolitan Area attracts more than two million visitors each year (Nixon, 1982 pers. comm.).

In 1981, tourism generated $230 million dollars in revenue (Nixon, 1982 pers. comm.). The tourist industry is seasonal, but is a major employer during the summer months when in an average year more than 2,000 workers can be employed in the accommodation sector alone (Ministry of Economic Development, 1978).

4.2.3 AGRICULTURE

The Saanich Peninsula is the prime agricultural area within the study area, producing such diversified crops as tree fruits, berries, vegetables and specialty crops - i.e. holly, flowers, seeds, and bulbs. (Ministry of Economic Development, 1978).

Beef and dairy operations contribute 45 percent of the total value of agricultural production within the Capital Region Census Division (Wood, 1979). Table 3 provides a breakdown of agricultural production by type and census division.

In recent years urban pressures have forced a number of farms out of operation (Ministry of Economic Development, 1978). Table 4 shows the change of farm size and value over a five-year period, 1971-1976.

Within the Sooke-Port Renfrew area, agriculture is primarily oriented towards beef and poultry production. In 1976, there were 24 farms (.4 hectares (1 acre) more in size with sales exceeding $1,200.) in operation, covering a total area of 1 253 hectares (3,904 acres) (Ministry of Economic Development, 1978).

4.2.4 FORESTRY

4.2.4.1 Capital Regional District

The manufacturing of forest products - lumber, shakes, shingles and plywood - employed 1,600 persons in 1976 (Ministry of Economic Development, 1978).

There are two major sawmills in the area; Plumper Bay Sawmill, located in Esquimalt, and British Columbia Forest Products (B.C.F.P.) in Victoria.

The B.C.F.P. mill produces an estimated 141,000 board feet (Mfbm) of lumber in an average year, while Plumper Bay Sawmill (until it went into receivership) produced 40,000 Mfbm of lumber per year (Whybrow, 1982 pers. comm.).

TABLE 3 VALUE OF AGRICULTURAL PRODUCTION IN PERCENTAGE

Type	Census Division					Vancouver Island	British Columbia
	Alberni	Capital[1]	Courtenay	Cowichan	Nanaimo		
Livestock	35	34	48	44	44	41	55
Dairy	55	11	41	41	35	37	18
Eggs	4	13	3	10	6	7	7
Greenhouses and Nurseries	2	24	2	1	10	8	4
Potatoes and Vegetables	2	12	5	3	3	5	5
Tree Fruits	1	5	0	0	0	1	8
Forage	1	1	1	1	1	1	1
Grain	0	0	0	0	0	0	2
Totals	100	100	100	100	100	100	100

1/ The Capital Region Census Division encompasses an area larger than the Coastal Resources Folio study area.

Source: C.J.B. Wood. 1979. Agriculture in Vancouver Island Land of Contrast, Western Geographical Series, Volume 17, page 168.

TABLE 4 CAPITAL REGIONAL DISTRICT

Farm Capital and Value of Products

(1971 and 1976)[1]

	1971	1976
Total Number of Farms	683	358
Economic Class (number of farms):		
Value of Products Sold:		
Under $2,500	431	114
$ 2,500 - $4,999	69	80
$ 5,000 - $24,999	103	78
$25,000 - $39,999	36	23
$50,000 and over	39	62
Capital:		
Total Capital Value	$ 63,542,000	$ 90,157,779
Value of Land and Buildings	56,686,800	81,642,678
Value of Machinery & Equipment	4,283,500	6,625,359
Value of Livestock and Poultry	2,566,690	1,889,742

[1] It should be noted that this information is for the entire Capital Regional District rather than the Victoria Metropolitan Area.

Source: Regional Economic Expansion and Ministry of Agriculture and Food, 1980. Agriculture Region Report - South Coast Agricultural Region. Canada B.C. Subsidiary Agreement on Agriculture and Rural Development. Victoria. Page 51.

Logs for the mills come primarily from other parts of the province, due to the fact that local forest stands are owned by companies with processing facilities located outside of the Capital Region (Ministry of Economic Development, 1978).

4.2.4.2 Sooke-Port Renfrew Area

Timber is harvested from Tree Farm Licence Number 22 which is held by B.C. Forest Products Ltd., and from Tree Farm Licence Number 25 which is held by Rayonnier Canada (B.C.) Ltd. There are also some private holdings. Sooke Forest Products Ltd. is the major mill in the area, producing an annual average of 54,000 M fbm of lumber (Whybrow, 1982 pers. comm.).

In 1976, 557 people were employed in the forest industry (Ministry of Economic Development, 1978).

4.2.5 THE FISHING INDUSTRY

Within the Greater Victoria area, the commercial fishing industry generated over 21 million of net income in 1977 and provided employment for 2,287 people. Fishing accounted for approximately eighty percent of this income, while fish processing provided the balance.

The sport fishing industry generates an estimated net income of $18 million (Van Westen and Associates, 1979).

In 1977, the commercial fishery in the Sooke-Port Renfrew area involved 95 commercial fishing vessels and employed 148 people (Ministry of Economic Development, 1978).

In terms of catch, well over half of the commercial pink and coho salmon and flatfish of the entire Juan de Fuca-Strait of Georgia system (Fisheries Statistical Areas 13-20, 22, 29) are caught in the study area (Moore, 1982 pers. comm.). A complete summary of fish catch statistics is provided in the report section - Fish and Shellfish Resources.

4.3 GENERAL PHYSICAL FEATURES

4.3.1 PHYSIOGRAPHY

The study area falls partly within the Georgia Depression which is a section of the northwest-southeast trough stretching from Alaska to the Gulf of California (Barker, 1974). More specifically, on the marine side, the eastern section of the study area lies within Haro Strait, while the southern and western sections are within the Juan de Fuca Strait. The upland lies within the Nanaimo Lowland region.

4.3.1.1. The Nanaimo Lowland

The Lowland is a relatively narrow (30 kilometre (km) strip of land, below 600 metres (m) elevation, extending from Johnstone Strait to approximately Sheringham Point.

The section within the study area is characterized by frequent bedrock outcrops interspersed with pockets of unconsolidated materials of glacial and marine origin. Locally, the differential erosion of bedrock has produced a highly indented coastline.

4.3.1.2 Haro Strait

The Strait is a deep channel leading from the eastern boundary of Juan de Fuca Strait. Maximum depths are greater than 300 m. Physically, the Strait is bounded on the west by a shallow shelf of up to 12 km in width. The eastern bounds are much steeper, reaching 100 m in less than 1 km.

4.3.1.3 Juan de Fuca Strait

The Strait is a long, narrow submarine valley whose alignment is thought to be closely associated with a number of large geologic structures (Mayers and Bennett, 1973).

Repeated glaciations have given the Strait its present bottom characteristics. East of a line between Jordan River and Pillar Point, Washington, the Strait exhibits the U-shaped profile of glaciated valleys (Thomson, 1981). A suspected terminal moraine has been identified in an area lying between Victoria and Green Point, Washington (Anderson, 1967). The extreme eastern extent of the Strait is characterized by relatively shallow banks cut by several channels.

West of the Jordan River-Pillar Point line, the Strait resembles a mature river valley with its V-shaped profile (Thomson, 1981, Mayers and Bennett, 1973 and Anderson, 1967). The Juan de Fuca Strait ranges in width from 18 km to 40 km and depths vary from about 250 m at its entrance to about 55 m over the sill (Thomson, 1981). Mayers and Bennett (1973) interpreted mound-like profiles of .5 to 1 km in width and 50-100 m long as possible drumlins or moraines. They appear to be concentrated between 124^{o} 40'w and 123^{o} 40'w.

4.3.2 GEOLOGY

The area has been subjected to downfolding, subsidence, uplift, glacial scouring and erosion. These processes have continued to modify the area from Mesozoic times ($> 150 \times 10^{6}$ years B.P.). The most extensive period of mass erosion occurred during repeated glaciations and the interglacial periods of the Pleistocene era (Armstrong, 1975).

4.3.2.1 Bedrock

The bedrock of the area is a complex of volcanic rocks (basalts, dacite, breccia), sedimentary rocks (sandstone, shale, conglomerate) and plutonic rocks (granodiorite, gneiss diorite, amphibolite). The ages of these rocks vary from the late Paleozoic Period ($>300 \times 10^6$ years to the late Tertiary Period ($>7 \times 10^6$ years B.P.). Mayers and Bennett (1973) provide a summary of the geological history of the study area. A map of the region by Muller (1971) has been updated by Roddick et al (1979).

4.3.2.2 Surficial

The unconsolidated surficial materials are glacial in origin, but have also been modified by marine and fluvial processes as a result of sea-level changes and the retreat of the glaciers. Modern sediments (Holocene) are represented by channel, floodplain, alluvial fan, deltaic, and beach (marine and lacustrine) deposits. The Nanaimo Lowland is extensively overlain by glacial tills of various textures, depths and surface expressions. They tend to be compact mixtures of stones, sand, silt and clay and locally may exceed tens of metres in thickness. The deposits tend to be shallower in the more hilly areas of the study area (Fyles, 1963).

Glacio-fluvial land forms (i.e. terraces, abandoned channels and ice-contact alluvial fans) are also present (Fyles, 1963).

Much of the surface of the study area below 100 m elevation is composed of marine sediments which vary in texture from gravels to clay, and in thickness from less than 1 m to several metres in depth. The veneers tend to be on slopes and represent coarser deposits. The deepest and finest deposits are found in depressions and low-lying areas.

Colluvial deposits of post-glacial origin are common where the bedrock is at or near the surface. Colluvial deposits vary in thickness from centimetres to metres, the deeper deposits found as talus cones at cliff bases.

Organic deposits occupy poorly drained depressional areas overlying impermeable tills, bedrock, or fine textured marine deposits.

Accounts of the glacial history of the study area and resulting deposition of sediments can be found in Fyles, 1963; Mayers and Bennett, 1973; Foster, 1976; and Greer, 1979. Mapped surficial geology or stratigraphy can be found in Stanley-Jones and Benson (1973); Eis et al (1976); Foster (1976); Greer (1979); Eis and Craigdallie (1980); and Howes (n.d.). Terrain inventory maps have been done for the study area (excluding the Saanich Peninsula-Victoria area) by the British Columbia Ministry of Environment. Engineering suitability and erosion hazards for the Saanich Pendinsula-Victoria area can be found in Stanley-Jones and Benson (1973).

4.3.3 SOILS

Steep slopes tend to have shallow, coarse textured and rapidly drained soils; bedrock outcrops are common. Less steep terrain has sandy to gravelly soils with rapid to imperfect drainage. Gently sloping low-lying positions have medium to fine textured soils subject to water table fluctuations. Depressional or level areas generally have organic deposits. Glacio-marine and glacio-fluvial deposits (especially terraces) have coarse textured, and very rapidly drained soils on moderate slopes.

The soils of the study area have been mapped by Day, et al. 1959. This area is currently being remapped by the British Columbia Ministry of Environment.

4.3.4 CLIMATE

4.3.4.1 Temperature and Precipitation

A homogeneous temperature regime prevails over the lowland of the study area due to the presence of surrounding water masses. Annual mean temperatures range from about 9 to 10°C with highest values in the Victoria-Gulf Islands area. Mean annual precipitation ranges from 650 millimetres (mm) to 900 mm over much of the coastal lowlands and islands from Victoria northward. Amounts increase rapidly to the west along the Juan de Fuca shoreline. Jordan River receives almost 2,000 mm and even greater amounts occur on higher ground just to the north (Schaefer, 1982).

4.3.4.2 Wind Patterns

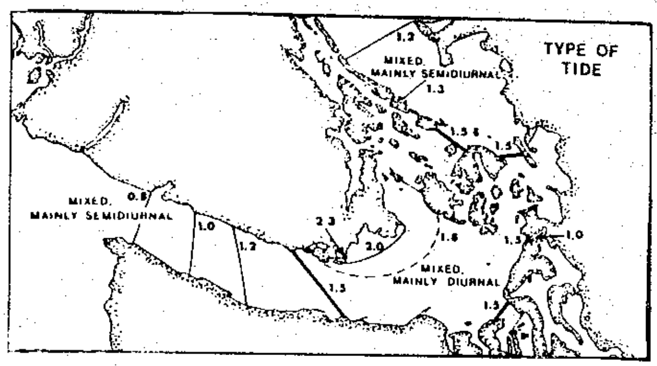
Wind patterns are strongly controlled by Juan de Fuca and Haro Straits and the topography of the surrounding land masses. Seasonally dominant pressure systems also influence wind patterns. In summer, the Pacific High produces a strong and persistent westerly inflow wind through the straits. In winter, northeasterly winds feed the outflow to offshore low pressure systems; this distribution is altered with occasional westerlies (Schaefer, 1982).

4.3.5 PHYSICAL OCEANOGRAPHY

4.3.5.1 Tides

The study area has a relatively complex tidal regime. West of Race Rocks, the tides are mixed and mainly semidiurnal. East of Race Rocks the tides are mixed and mainly diurnal (see Figure 1).

FIGURE 1   CHANGE IN TYPE OF TIDES ALONG JUAN DE FUCA STRAIT



Note: Lines give values of ratio of diurnal tides to semidiurnal tides.

Source: R.G. Thomson, 1981. Oceanography of the British Columbia Coast. Fisheries and Oceans Canada, Canadian Special Publication of Fisheries and Aquatic Sciences 56. p.192. Ottawa, Ont.

Tidal ranges also vary with a maximum range of 2.5 m in the west, 1.8 m at Victoria, and about 2.4 m at the northern end of Haro Strait (Thomson, 1981).

4.3.5.2 Currents

4.3.5.2.1 Tidal Currents

Due to the Juan de Fuca Strait's general uniform morphology (i.e. basin configuration), regular shoreline, and relative absence of freshwater discharges, tidal currents are fairly uncomplicated compared to Georgia Strait. Nonetheless the currents are modified both by the oceanic influences to the west, and the strong tidal streams originating from the narrow channels to the east.

At the western end of the Juan de Fuca Strait the maximum tidal currents (ebb and flood) tend to lag behind the actual tide by 1 to 1½ hours. At Race Rocks there is only a small lag, while east of this point the tide lags behind the current by as much as three hours (Thomson, 1981).

Maximum flood tidal currents of 1.4 to 2.5 knots (kn) are possible on large spring tides. Speeds of 3.5 kn can occur at approaches to channels (Haro Strait, for instance). In areas where tidal streams are constricted, such as at Race Rocks, currents reach extremes of 5 kn. Haro Strait receives the largest volume of tidal flood water - that is 50% of the inflow of Juan de Fuca Strait water, while Rosario Strait and Middle Channel receive 5% and 20% respectively. Admiralty Inlet directs the remaining 25% of tidal flood water into Puget Sound (Thomson, 1981).

Maximum ebb currents, in most cases, flow in the opposite direction to the flood currents. Within the top 100m, ebb currents are significantly stronger and longer-lasting than flood currents. Conversely, below 100m, currents are dominated by the flood. This phenomenon is evidently caused by the seaward flow of salt water entrained by surface freshwater coupled with the inward drift of sea water at depth to replace the water carried to the Pacific Ocean within the surface layer (Thompson, 1981).

4.3.5.2.2 Non-Tidal Currents

Non-tidal surface currents appear to flow seaward or westerly in the Juan de Fuca Strait. In the northern channels of the eastern portion of the study area, currents move southerly at speeds ranging from .2 to .4 kn (Thomson, 1981). Non-tidal currents are highly variable, and subject to freshwater run-off and weather conditions.

4.3.5.3 Waves

The eastern and southern sections of the study area are influenced by locally generated wind waves, whereas the western area is influenced both by locally generated wind and ocean swell waves.

Average wave heights range from about 2 m in the west (Thomson, 1981) to .5 m in sheltered eastern areas (Owens, 1977 and Holden, 1979).

4.3.6 WATER RESOURCES

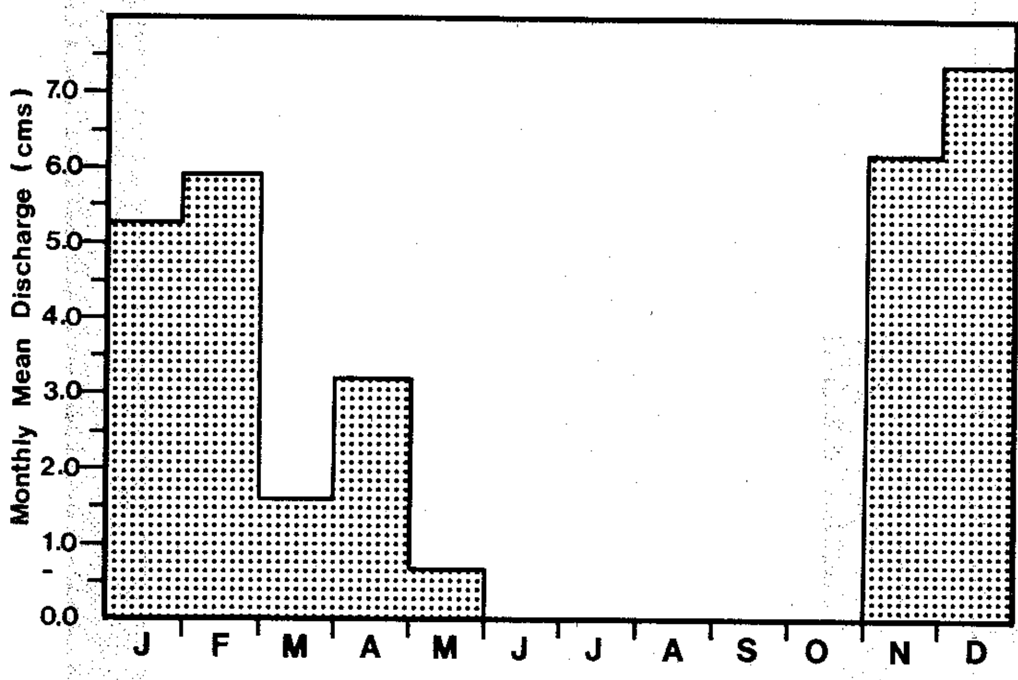
4.3.6.1 Hydrology

The study area has a number of freshwater rivers, lakes, and wetlands. Most, however, are small. Precipitation in the region falls mainly as rain. Consequently, freshet generally occurs in mid-winter (December to March) - the period of maximum rainfall. Hydrographs for the Sooke and Colquitz rivers exhibit this trend (figures 2 and 3). It is possible that rivers have a second peak discharge in late spring similar to other rivers of Vancouver Island's east coast; however, there are no data to substantiate this. The low-flow period is in late August and September when some streams are dry or are limited to subsurface or base flows. Annual precipitation, moisture deficit and moisture surplus vary considerably throughout the study area as evidenced by Figure 4.

4.3.6.2 Water Quality

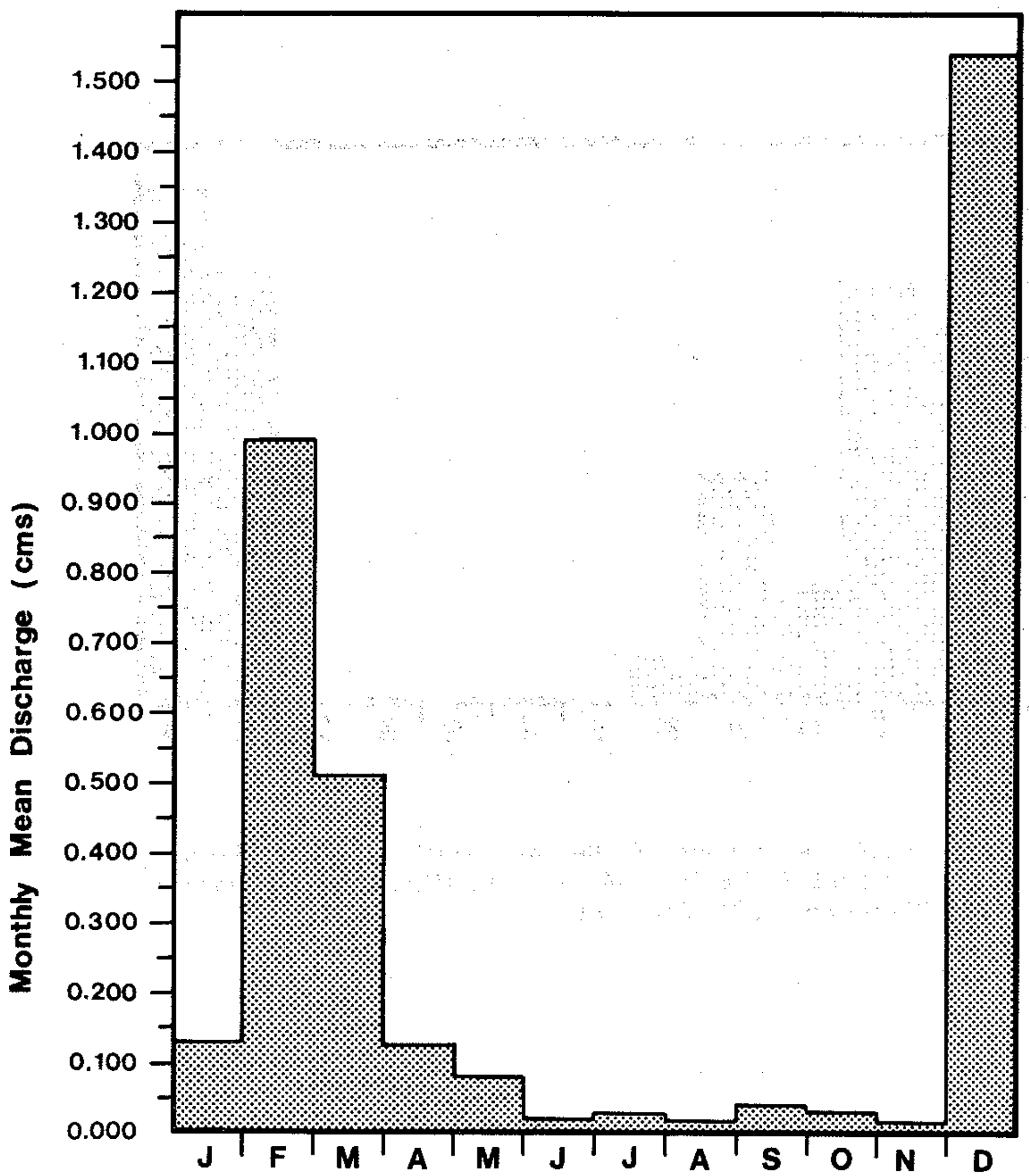
Domestic sewage and industrial effluents are the major contributors of marine and fresh waters contaminants. River and marine outfalls, septic tanks, and wastes from vessels contribute nutrients and coliform bacteria, while industrial and commercial outfalls add poisons, metals, and heat. Although the marine waters are relatively well flushed by tidal and wind-driven currents, water quality in many areas is, or is suspected to be, below the standards set for shellfish harvesting and water contact recreation.

FIGURE 2 HYDROGRAPH FOR THE SOOKE RIVER NEAR SOOKE LAKE - STN.08HA005



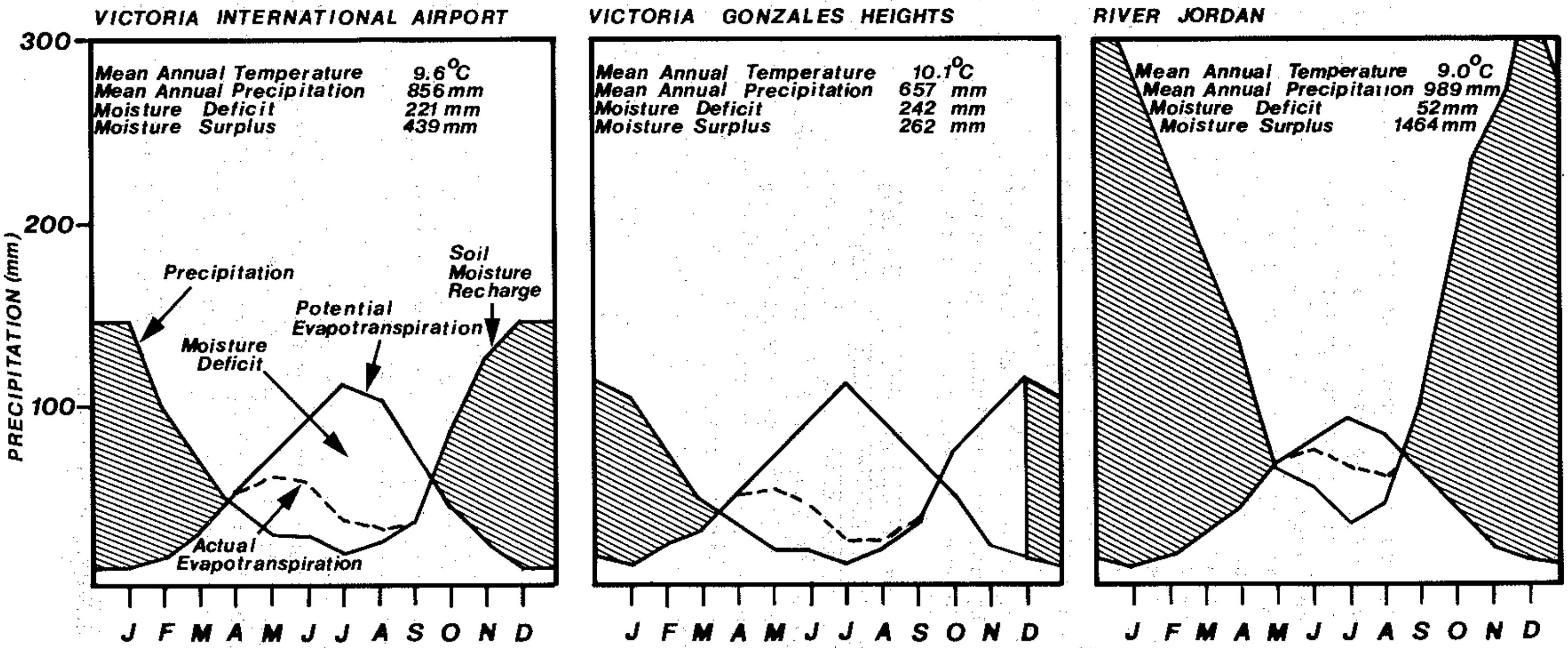
Source: Canada Department of the Environment, 1970. Historical Streamflow Summary - British Columbia, Inland Waters Directorate, Ottawa, Ont.

FIGURE 3 HYDROGRAPH FOR THE COLQUITZ RIVER AT HYACINTH ROAD - STN.08HA037



Source: Canada Department of the Environment. 1980. Historical Streamflow Summary - British Columbia, Inland Waters Directorate, Ottawa, Ont.

FIGURE 4 MOISTURE BALANCE FOR THREE STATIONS WITHIN THE STUDY AREA



Source: D.G. Schaefer, 1982, Unpublished Data, Environment Canada, Atmospheric Environment Service, Vancouver, B.C.

4.4 BIOLOGICAL RESOURCES

4.4.1 TERRESTRIAL VEGETATION

According to the data of Jones and Annas (1978), the study area lies predominantly within the Coastal Douglas Fir biogeoclimatic zone. This zone is comprised of wet and dry subzones. In drier areas Garry oak and arbutus are common while assorted coniferous species accompany Douglas fir in the wet subzone. Douglas fir is the primary climatic climax species on mesic sites.

West of the Sooke Basin the area lies within the Coastal Western Hemlock zone, which is the wettest and most productive forest zone in British Columbia (Jones and Annas, 1978). It is also comprised of a wet and dry subzone where amabilis fir and Douglas fir may accompany western hemlock respectively.

4.4.2 SEAWEEDS AND SALTMARSHES

There are in excess of 500 species of attached marine algae in British Columbia (Scagel, 1978). The classification of algae is based partly on pigmentation; hence the algal groups are Chlorophyceae (green algae), Phaeophyceae (brown algae), and Rhodophyceae (red algae). A fourth group of plants, the seagrasses, have two genera occurring in British Columbia - Zostera and Phyllospadix. Saltmarsh species include the genera Salicornia, Distichlis, and Triglochin. Several genera (i.e. Scirpus, Typha, Carex) are better adapted to brackish waters, while others (i.e. Festuca, Juncus, Hordeum) inhabit coastal (freshwater) wetlands.

A conspicuous feature of most coastlines is the zonation of seaweeds. Seaweeds occur as horizontal bands, theoretically at least, as a function of their receptivity to different wavelengths of the light spectrum, and the differential attenuation of wavelengths with increasing water depth. Consequently, green algae, brown algae, and red algae should inhabit the upper, middle, and lowermost zones respectively. But other biological and physical factors play a large part in the distribution of seaweeds. A species' tolerance to the factors of dessication (temperature, wind, and humidity) and to ultraviolet light are important in setting the upper limits of growth while the lower limits are determined by the competition between species, or herbivary. Further, preferences for a particular substrate, the wave energy environment and seawater temperatures are important in defining the vertical and horizontal limits of species. Druehl (1967), for instance, found that the horizontal distributions of two forms of Laminaria groenlandica could be explained on the basis of temperature, salinity gradients, and tolerance to wave shock. De Wreede (1978) speculates that Sargassum muticum and Zostera marina L. will not compete due to different preferences of substrate.

Vadas (1972) indicates that the upper limits for Nereoscystis Leutkeana are determined by the competition for light, while the lower limits are set by light attenuation. Both Foreman (1977) and Mann (1977) have documented a reduction of algal populations at their lower limits and a succession of species resulting from herbivore grazing.

The intertidal zonation of species on seacoasts has been documented by numerous researchers (Kozloff, 1973; Ricketts and Calvin, 1968; Carefoot, 1977; Stephenson and Stephenson, 1972). On rocky coasts, the uppermost zone - the supralittoral fringe - is affected only by the higher tides and wave splash. This band may contain lichens (g. Verrucaria), and where fresh water seepage occurs the green algae g. Enteromorpha is often found. The upper mid-littoral zone usually harbours the brown algae Fucus distichus, (with which the barnacles are closely associated), the red Endocladia muricata, Cumagloia andersonii, Bangia furcopurpurea, and Porphyra spp. and the green algae Ulva as the major seaweeds. The lower mid-littoral and sub-tidal zones contain numerous genera, but the most common are Ulva, Spongomorpha coalita (green algae); Hedophyllum sessile, Fucus and Leathesia difformis, (brown algae); and Halosaccion glandiforme (red algae). In the infralittoral region are found the surfgrass Phyllospadix, many Laminarians (e.g. Laminaria setchellii), Egregia menziesii, Pterygophora californica, Alaria marginata, Nerocystis luetkeana, Sargassum muticum; the green algae Codium fragile; the red algae Gigartina exasperata and Iridaea cordata.

Estuarine areas and quiescent mud/sand shores characteristically exhibit Enteromorpha in the upper zone where freshwater seepage is prevalent, scattered Ulva in the lower intertidal where substrate for holdfasts are available, and, subtidal beds of Zostera marina (eelgrass). With the growth of eelgrass in the summer months, numerous algal species (such as the red algae Smithora naiadum) colonize the leaves while others inhabit the surface muds around the base. The generation of detritus from numerous plant species within eelgrass beds, and its subsequent invasion by bacteria, forms one of the most productive ecosystems known.

Saltmarshes exhibit zonation from the sea landward although the critical factor that determines band width is the tolerance of species to saltwater. Closest to saline conditions in a primarily mud substrate are found Salicornia virginica and S. europaea commonly known as saltwort. Parasitizing Salicornia is the flowering plant Cuscuta salina and growing beneath it on the substrate are diatoms, blue, and blue-green algal mats. The saltgrass Districhlis spicata and arrowgrass Triglochin maritimum are commonly associated with Salicornia spp. Moving progressively inland towards a freshwater influence, one encounters Scirpus, Typya, Carex, and Juncus communities.

4.4.3 MARINE MAMMALS

The marine mammals of the Strait of Georgia and Juan de Fuca include sixteen genera of the order Cetacean (whales and dolphins) and two families of pinnipeds - Otariidae (the eared seals) and Phocidae (the earless seals - Table 5). Within the study area Orcinus orca (killer whale) is the largest resident species.

TABLE 5 - CETACEANS OCCURRING IN WASHINGTON STATE AND BRITISH COLUMBIA

Order Cetacean--whales and dolphins	Occurrence
Suborder Mysticeti--whalebone whales	
Family Eschrichtiidae--gray whales	
Eschrichtius robustus Lilljeborg, gray whale	C
Family Balaenopteridae--furrow-throated whales	
Balaenoptera physalus Linnaeus, fin or finback whale	C
B. borealis lesson, peri whale	C
B. acutorostrata lacepede little piked whale, minke whale	NC
B. musculus Linnaeus, blue whale	NC
Megaptera novaeangliae Borowski, humpback whale	NC
Family Balenidae--smooth-throated whales	
Balena glacialis Muller, northern or black right whale	R
Suborder Odontoceti--toothed whales and dolphins	
Family Ziphiidae--beaked whales	
Berardius bairdii Stejneger, Baird's beaker whale	C
Mesoplodon stejnegeri True Stejneger beaked whale	R
M. carlhubbsi Moore, Hubbs' beaked whale	R
Ziphius cavirostris Cuvier, Cuvier's beaked whale	R
Family Physeteridae--sperm whales	
Physeter catodon Linnaeus, sperm whale	C
Kogia breviceps Blainville, pygmy sperm whale	NC
Family Delphinidae--ocean dolphins	
Stenella sp., spotted dolphin	R
Delphinus delphis Linnaeus, Pacific common dolphin	R
Lissodelphis borealis Peale, northern right-whale dolphin	R
Lagenorhynchus obliguidens Gill, Pacific white-sided dolphin	C
Orcinus orca Linnaeus, killer whale or orca	A
Grampus griseus Cuvier, gray grampus or Risso's dolphin	R
Globicephala macrorhyncha, shortfin pilot whale	NC
Phocoena phocoena Linnaeus, Pacific harbour porpoise	A
Phocoenoides dalli True, Dall porpoise	C

Note: A= abundant, C= common, NC= not common, R= rare.

Source: Adapted from G.C. Pike and I.A. MacAskie 1969, cited in C.A. Simenstad, B.S. Miller, C.F. Nyblade, K. Thronburgh, and L.J. Bledsoe, 1979. Food web relationships of northern Puget Sound and the Strait of Juan de Fuca. U.S. Environmental Protection Agency, Washington. p. 260.

Killer whales are nomadic, cruising at 3-4 kn. Their migratory routes are commonly between one and three miles offshore where they are thought to prey primarily on salmon and other fish. Published data for northern Puget Sound and the Strait of Juan de Fuca (Simenstad et al, 1979) suggest, however, that prey from several trophic levels are taken (Table 6).

The harbour seal populations of the study area are permanent residents although they are nomadic between haulouts. They frequent estuaries, river deltas, tidal rocks and shallow sublittoral waters within the region. Their daily movements include hauling out during low tides while during high tides they disperse over several miles to feed. Harbour seals generally use haulouts that are not easily approached by predators. Seals prey mainly on littoral fish, although a number of other species are taken. (Table 6).

Sea lions, Stellar and California, are resident in the study area during the winter months from November to March. During the summer, California sea lions migrate south while the Stellar sea lions move to rookeries on north Vancouver Island and the Queen Charlotte Islands. In the study area the two species intermix on tidal rocks. These sites are often chosen in good feeding areas near deep water isolated from terrestrial predators. Sea lions are nocturnal feeders, leaving the water during the daytime. They prey primarily on fish, although, as documented, in the Puget Sound area many other species are eaten (Table 6).

4.4.4 MARINE BIRDS

The estuaries and coastal waters of the region are major resting sites for migrating birds on the Pacific flyway, and overwintering areas for a large population of marine birds. The environmental advantages of this region during the winter months include a relatively mild winter climate, abundant food, and a relatively sheltered coastline. During the summer months the marine bird population is low. The paucity of breeding species at this time is thought to be a response to the general variability of environmental factors such as ocean currents and meteorology (Myres, 1979) in spite of the success that wintering populations have found. The Canada Land Inventory rates the study area, except for developed areas, as important for wintering migratory birds. It is considered less important for waterfowl production.

Seabirds are at the top of marine food webs. They eat a variety of organisms and feed in a range of environments. Table 7 presents seabird prey taxa for major species sampled in northern Puget Sound and the Strait of Juan de Fuca. It is evident that saltmarsh and marine plants play an important role in providing food for marine birds. Indeed, many of their prey spend some, if not all, of their life cycle within the protection of algal communities.

TABLE 6 - FUNCTIONAL FEEDING GROUPS AND REPRESENTATIVE PREY TAXA OF MARINE MAMMALS KNOWN OR SUSPECTED TO OCCUR IN NORTH PUGET SOUND AND THE STRAIT OF JUAN DE FUCA

Habitat	Feeding Group	Predator Species	Representative Prey Taxa
Nearshore	Obligate piscivore	Northern sea lion	Pacific Herring (C. harengus pallasi)
		California sea lion	Pacific sand lance (A. hexapterus)
		Pacific harbour seal	Walleye pollock (T. chalcogramma)
		Harbour porpoise	Salmon (Oncorhynchus sp.)
			Starry flounder (Platichthys stellatus)
			Pacific tomcod (Microgadus pacificus)
			Rockfish (Sebastes sp.)
			Skate (Rajiidae)
			Pacific cod (Gadus macrocephalus)
			Pacific hake (M. productus)
			Spiny dogfish (Squalus acanthias)
			Plainfin midshipman (Porichthys notatus)
			Greenling (Hexagrammidae)
			Shiner perch (Cymatogaster aggregata)
			Shrimp
			Crab (Cancer Sp.)
			Octopus (Octopus Sp.)
	Facultative carnivore	Orca (killer whale)	California sea lion (Zalophus californianus)
			Northern sea lion (Eumetopias jubatus)
			Harbour seal (phoca vitulina)
			Elephant seal (Mirounga californianus)
			Harbor porpoise (Phocoena phocoena)
			Dall porpoise (Phoecoenoides dalli)
			Minke whale (Balaenoptera acutorostrata)
			Nursing calves of humpback (Megaptera novaengliae), finback (Balaenoptera physalus), and gray whale (Eschrichtius robustus)
			Lingcod (O. elongatus)
			Salmon (Oncorhunchus sp.)
			Steelhead trout (Salmo gairdneri)
			Pacific halibut (Hippoglossus stenolepis)
			Pacific herring (C. harengus pallasi)?

Source: Adapted from: C.A. Simenstad et al., 1979. Food web relationships of northern Puget Sound and the Strait of Juan de Fuca. U.S. Environmental Protection Agency, Washington. P. 262-264.

TABLE 7 - FUNCTIONAL FEEDING GROUPS AND REPRESENTATIVE PREY TAXA OF MARINE AND SHORE BIRDS COMMON TO NORTHERN PUGET SOUND AND THE STRAIT OF JUAN DE FUCA

Habitat	Trophic position	Predator species	Prey taxa
Offshore neritic	Obligate piscivore	Common murre Black-legged kittiwake Common tern Rhinoceros auklet Western grebe	Northern anchovy Eulachon Pacific herring Pacific sand lance Juv. rockfish Juv. Pacific salmon Surf smelt Night smelt Walleye pollock Threespine stickleback
	Facultative piscivore	Tufted puffin Marbled murrelet Ancient murrelet	Pacific sand lance Pacific herring Surf smelt Northern anchovy Rockfish Shiner perch Juv. rockfish Sea urchins Bivalve molluscs Euphausiids
	Obligate planktivore	Cassins auklet	Calanoid copepods Hyperiid amphipods Euphausiids
	Facultative planktivore	Mew gull Bonaparte's gull	Euphausids Hyperiid amphipods Pacific herring (larvae?) Pacific sand lance (larvae?)
	Parasite	Parasitic jaeger	Foods of gulls and terns

Nearshore kelp beds	Facultative avivore	Bald eagle	Gulls Pigeon guillemots Cormorants Puffins Pacific herring Pacific salmon Dolly Varden Cutthroat trout Flatfishes Sculpins Sea urchins Crabs
	Obligate piscivore	Brandt's cormorant	Redtail surfperch Kelp greenling Black rockfish Cabezon Pacific sand lance
	Facultative piscivore	Heermann's gull	Pacific herring Pacific sand lance
Inshore rocky littoral	Obligate benthivore	Black oystercatcher Whimbrel	Limpets Chitons Black turnstone Bivalve molluscs Barnacles Polychaete annelids
Inshore sand-gravel beaches	Obligate benthivore	Spotted sandpiper Surfbird Least sandpiper Sanderling	Polychaete annelids Amphipods Bivalve molluscs Univalve molluscs
Nearshore shallow sublittoral	Obligate piscivore	Double-crested cormorant Red-necked grebe Common merganser	Penpoint gunnel Crescent gunnel Pacific sand lance Shiner perch Snake prickleback Staghorn sculpin Pacific herring Juv. Pacific salmon Northern anchovy

	Facultative piscivore	Arctic loon Common loon Red-throated loon Pelagic cormorant Pigeon guillemot Redbreasted merganser Caspian tern	Crescent gunnel Pacific sand lance Penpoint gunnel Staghorn sculpin Northern clingfish Snake prickleback Pacific herring Surf smelt Black prickleback Threespine prickleback Juv. flatfish Snake prickleback Shrimp Crabs
	Obligate planktivore	Eared grebe	Mysids Amphipods
	Facultative benthivore	Lesser scaup Common goldeneye Bufflehead Oldsquaw Surf scoter	Bivalve molluscs Crustaceans Fish Pacific herring eggs Eelgrass
Inshore, saltmarsh and mudflats	Obligate herbivore	Canada goose Black brant Snow goose American coot	Eelgrass Saltmarsh plants
	Omnivore, Facultative herbivore	Mallard Pintail Northern shoveler American widgeon	Eelgrass Saltmarch plants, seeds Amphipods Insect larvae
	Omnivore	Dunlin Knot Western sandpiper	Saltmarsh plants, seeds Amphipods Polychaete annelids Oligochaetes Bivalve molluscs Tanaids Nematodes

	Obligate piscivore	Great blue heron	Staghorn sculpin Starry flounder Shiner perch Penpoint gunnel
	Obligate benthivore	Short-billed dowitcher Long-billed dowitcher	Polychaete annelids Univalve molluscs Bivalve molluscs Crabs Shrimp Isopods Amphipods
	Facultative benthivore	Greater yellowlegs	Molluscs Crustaceans Fish
Universal	Facultative benthivore	Glaucous-winged gull Western gull	Chitons Starfish Sea cucumbers Sea urchins Crabs Bivalve molluscs Polychaete annelids Pacific herring Northern anchovy Surf smelt Pacific herring eggs Cormorant fledglings Murre fledglings

Source: Adapted from: C.A. Simenstad, B.C. Miller, C.F. Nyblade, K. Thornburgh, and L.J. Bledsoe, 1979. Food web relationships of northern Puget Sound and the Strait of Juan de Fuca. U.S. Environmental Protection Agency, Washington. pp. 218-224.

Several major breeding colonies are found in the Gulf Islands (Rodway and Campbell, 1976) although, relative to breeding grounds north of the study area, the populations are small. Reasons why the area has not become a major breeding ground are obscure, although food availability and preferred nesting habitat may be significant limiting factors. The populations of seabird prey species are themselves subject to fluctuation and shifts in geography. Many seabirds have survived by adapting one or more of their functions (i.e. reproduction) to the behavior of a prey species (i.e. herring spawn). When the expected behavior of a prey species fails to materialize, catastrophic results may occur to the seabird population in the form of reproductive failures or adult mortality. When reproductive failures become chronic because of natural or human perturbations, the existence of a colony or population is threatened, although an adult enumeration may not reveal the seriousness of the event for some time. Complicating natural factors that play important roles in the dynamics of seabird populations may be missed, leading to erroneous conclusions about the reasons for colony extinction. Very little is known about the cyclical phenomena of seabird populations.

Stress and mortality within seabird populations result from a variety of natural and human perturbations. Increased commercial and recreational boat traffic disrupts their behavioral patterns related to feeding and seeking shelter during bad weather; shoreline developments destroy habitat or disturb breeding times leading to higher mortalities of the young; and predators introduced to isolated islands significantly reduce the reproductive success of breeding populations. Breeding colony disturbances by recreationists results in the temporary abandonment of nests and predation of the young by other birds. Seabirds are drowned as a result of entanglement in commercial fishing nets. Oil spills and chemical pollution from transportation activities pose additional threats to the integrity of seabird populations.

4.4.5 FISH AND SHELLFISH RESOURCES

4.4.5.1 Introduction

4.4.5.1.1 The Nature of Marine Resources

The geographical spread of a species is its range, but not everywhere in its range is a species evenly distributed. For the purpose of coastal resource management and the assessment of environmental impacts, the appropriate interpretation of environmental and biotic data requires a solid understanding of the local species distribution patterns.

Marine populations, except for birds, some marine mammals, and certain intertidal organisms, are basically out of sight. Almost everything known about distribution is based on some form of indirect observation or sample of sea life. Population-oriented investigations are few. It is often difficult to set distribution boundaries with the information at hand and, particularly in the case of mobile fish, the lines on the map are not representative of population limits, but rather of areas of known concentration.

Because fish are seasonal in their habits and distribution patterns in the wild are diffuse and shifting, the understanding of fish distribution is largely limited to certain times of the year when the adults of important species congregate to spawn in areas convenient to man.

In a restricted sense, the exploitation patterns of our fisheries may be taken as a rough guide to the actual distribution of the species. Exploitation patterns heavily favour areas of stock abundance - subject to other factors such as location, seasonality, and economic and recreational virtues of each fishery - but the real extent of the population may remain unclear.

Fish habits change with age, from larva to adult, and little is known about the life and distribution of the young in the wild, the mighty salmon included. The relationship between the young of resource species and the coastal system that supports them - the physical environment and the availability of larval food - largely determines the size of future resource populations.

Although our level of understanding of fish is related to their economic value, there is increasing awareness that future critical problems in the management of the sea may occur at lower levels of the food chain where at least equal effort will need to be devoted to investigating the structure and dynamics of the marine ecosystem.

4.4.5.1.2 Importance of the Study Area

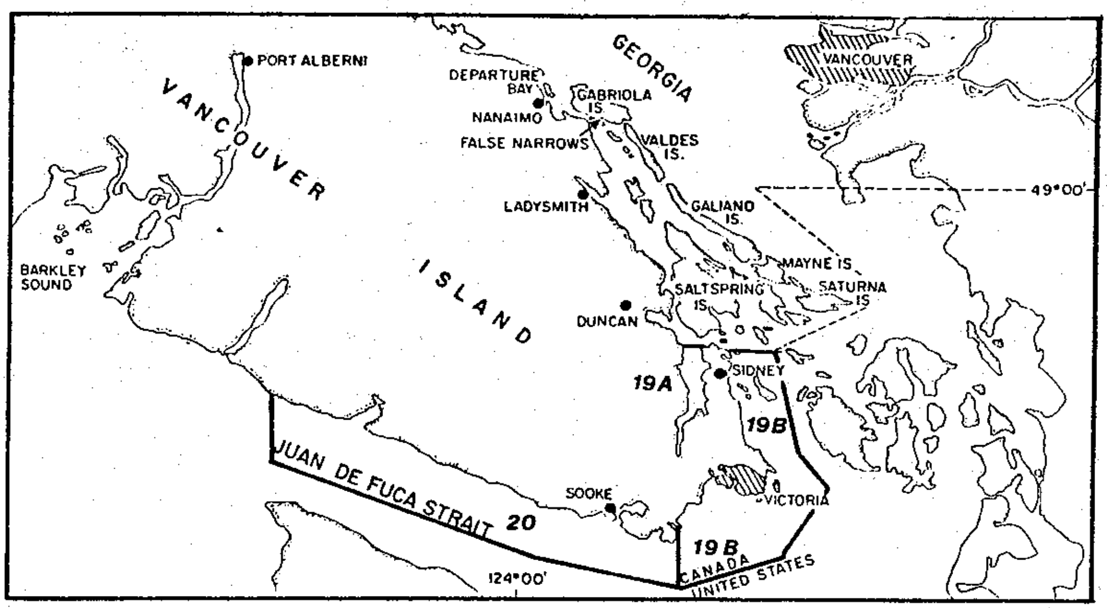
The study area includes the estuarine and coastal waters of south Vancouver Island from Saanich Inlet to Jordan River.

These waters, which form an integral part of the Juan de Fuca Strait system and the southern approaches to the Strait of Georgia, are important producers of salmon, groundfish, and shellfish which are exploited by both the commercial and recreational fishers. The study area is also an important migration route for the vast salmon and herring stocks which propagate to the north in the Strait of Georgia system.

Much of what is recorded concerning fisheries catches and other aspects of resource abundance and yield is organized by Statistical Areas (see Figure 5). The south coast study area includes Statistical Areas 19 and 20.

Saanich Inlet is sub-categorized as Area 19A, the remainder of Area 19 being referred to as Area 19B.

FIGURE 5 FISHERIES STATISTICAL AREAS FOR THE SOUTH COAST OF VANCOUVER ISLAND



Source: Adapted from Fisheries and Oceans Canada

The importance of fish and shellfish resources in the study area, relative to the entire Juan de Fuca-Strait of Georgia system (fisheries Statistical Areas 13-20, 28, 29), is summarized in Table 8.

Salmon are taken only from Area 20, Area 19 being closed to commercial salmon activities. Over twice as many flatfish are captured in Area 20 as Area 19. However, Pacific cod and dogfish catches in Area 19 greatly exceed those of Area 20.

Crabs constitute the highest proportion of shellfish taken, although the shellfish harvest in the study area as a whole is very minor relative to the rest of the inside passage. Herring catches are notably minor, being limited to food and bait use (in contrast to the huge roe fishery on spawning grounds in the Strait of Georgia).

Tables 9 and 10 illustrate the economic importance of commercial and sports fisheries within the greater Victoria area which includes most of the present study area.

4.4.5.2 Fisheries (fin fish)

4.4.5.2.1 Salmonids

4.4.5.2.1.1 Resource

A comprehensive review of the salmon fishery in British Columbia during the period 1951-63 is provided by Aro and Shepard (1967). Traditional salmon fishing areas include the whole of the present study area, although present day commercial activities tend to be concentrated in the locations depicted in the Coastal Resources Map Series (1:50,000) section, Fish and Shellfish Resources.

A regional perspective of the salmon fishery in the study area (limited to Area 20 only, by regulation) in terms of average annual catch between 1975 and 1980 is given in Table 11. The study area is a major migration route to the Strait of Georgia spawning rivers.

TABLE 8 PERCENTAGE OF FISH AND SHELLFISH RESOURCES OF SOUTH VANCOUVER ISLAND (FISHERIES STATISTICAL AREAS 19, 20) RELATIVE TO THE TOTAL FISHERIES YIELD OF THE JUAN DE FUCA STRAIT OF GEORGIA SYSTEMS (AREAS 13-20, 28-29)

	Area 19 %	Area 20 %	Total Study Area %
Salmon			
Pink	*	65	65
Coho	*	60	60
Sockeye	*	28	28
Chinook	*	9	9
Chum	*	10	10
Herring	1	*	1
Flatfish	20	50	70
Pacific cod	38	9	47
Dogfish	29	5	34
Shellfish			
Shrimp/prawn	1	1	2
Clams	1	4	5
Geoduck	12	*	12
Crabs	12	4	16
Oysters	*	24	24
Sea urchins	14	1	15

Note: Calculations are approximate and intended only as a rough guide. Asterisk (*) indicates negligible or nil.

Source: Fisheries and Oceans Canada, B.C. Catch Statistics (1975-1980). Vancouver, B.C.

TABLE 9 ECONOMIC IMPACT OF GREATER VICTORIA'S COMMERCIAL FISHERY (1977 figures)

Fishing		Fish Processing	
number of licensed fishing vessels	521	number of licensed plants	12
value of licensed fishing vessels	$25,378,000	fish products processed - weight	8,767,000 lbs.
landed catch - weight	22,057,000 lbs.	fish products processed - value	$13,443,000
landed catch - value	$12,142,000		
number of direct jobs	1107	number of direct jobs	190
number of indirect jobs	830	number of indirect jobs	160
total jobs	1937	total jobs	350
estimated net income to Greater Victoria	15,984,000	estimated net income to Greater Victoria	5,258,364

ESTIMATED TOTAL NET INCOME TO GREATER VICTORIA $21,242,364
TOTAL JOBS 2287

Source: K. van Westen and Assoc., 1979. Fisheries in Greater Victoria. B.C. Ministry of Environment, Province of British Columbia. Victoria.

TABLE 10 ECONOMIC IMPACT OF GREATER VICTORIA'S SPORT FISHERY (1978 figures)

	Resident Anglers	Visitor Anglers
Number	45,000	10,000
Estimated expenditures for direct goods and services required for sport fishing	$19,968,000	$2,230,000
Estimated expenditure for major sport fishing related purchases	$27,743,000	$1,203,000
Estimated total expenditures	$47,711,000	$3,433,000

Estimated portion of total expenditure made in Greater Victoria area (residents and visitors)	$30,726,000
Estimated total net income to Greater Victoria	$18,000,000

REGIONAL EMPLOYMENT MULTIPLIER 1.92
(For each direct job in sport fishing support services another .92 jobs are created in other sectors of the regional economy)

Source: K. van Westen and Assoc.,1979. Fisheries in Greater Victoria. B.C. Ministry of Environment, Province of British Columbia. Victoria.

TABLE 11 SALMON FISHERY OF SOUTHWEST VANCOUVER ISLAND. REGIONAL PERSPECTIVE OF AVERAGE ANNUAL SALMON CATCH (TONNES) IN 1975-1980

	Fisheries Statistical Areas				
	Strait of Georgia-Juan de Fuca Strait (a)				
Species	S.W. Coast Vancouver Is. (b)		East Coast Vancouver Is.	All Areas	Area (c)
	19	20	14, 17-18	13-20, 28, 29	13
Chinook	0	116	347	1,276	204
Coho	0	917	212	1,530	211
Chum	0	242	263	2,377	1,236
Sockeye	0	1,058	102	3,739	971
Pink	0	1,666	53	2,560	461
All species	0	3,999 (35%)	977 (8%)	11,482 (100%)	3,083 (27%)

Note: (a) includes entire Strait of Georgia system, plus (b) southern Juan de Fuca Strait and (c) northern Johnstone Strait approaches to the Strait of Georgia.

Source: Fisheries and Oceans Canada. B.C. Catch Statistics.

The Strait of Georgia Head Recovery Program (Fisheries and Oceans, Canada) had produced a revision of earlier sport catch estimates for the period 1972-76 (Table 12). The sport catch (in numbers of fish) of chinook and coho combined has been close to three times greater than the commercial troll fishery for these same species - or 75% of the total catch - and it is believed that the proportion is probably higher still (Table 13).

The sport catch is concentrated predominantly in the mid- and northern Vancouver Island coastal zone with only an overall species average of 10% being taken in the present study area. On the other hand, the commercial catch in the study area is about four times greater than that of mid- and northern Vancouver Island. Sport-commercial competition for fish stocks in Areas 19 and 20 is likely to be well below that experienced in the adjoining, more northerly areas.

4.4.5.2.1.2 Habitat Requirements

Spawning Escapement

Most salmon return to the freshwater habitat to spawn, although some chum can be found spawning in intertidal approaches to streams. The average annual escapements to regularly surveyed streams in the study area in the periods 1967-76 and 1977-81 are given in Table 14.

On a regional scale there is a lack of suitable spawning streams and as a consequence many local streams haye not been surveyed.

TABLE 12 REGIONAL PERSPECTIVE OF AVERAGE ANNUAL SPORT SALMON CATCH (Number of Fish) in the Strait of Georgia plus Northern (Area 13) and Southern (Areas 19B, 20) Approaches in the Period 1972-75

SPORT CATCH (x 1000 FISH BY AREA)

Species	13 + 14[2]	15 + 16	17	18 + 19B	28 + 29	19B + 20	Total All Areas	% Study Area
Coho	263	80	47	47	15	18	470	4%
Chinook	84	44	45	76	38	55	342	16%
Pink[1]	6	1	1	2	1	9	20	45%
Total	353	125	93	125	54	82	832	10%

Note: 1 Sport Salmon Fishing in Area 13, covering the northern approach to the Strait of Georgia, is predominantly within the Campbell River region.

2 Includes minor catches of sockeye and chum.

TABLE 13 A COMPARISON OF SPORT VERSUS COMMERCIAL CATCH (x 1000 FISH) IN THE STRAIT OF GEORGIA REGION FOR THE PERIOD 1972-1975

Species	Commercial (troll)	Sport	Total	% Sport
Coho	98	470	568	83%
Chinook	183	343	526	65%
Total	281	813	1094	74%

Source: A.W. Argue, J. Coursley and G.D. Harris. 1977. Preliminary revision of Georgia Strait and Juan de Fuca Strait tidal salmon sport catch statistics, 1972 to 1976. Fisheries and Environment Canada.

TABLE 14 AVERAGE SALMON SPAWNING ESCAPEMENT TO SOUTH COAST VANCOUVER ISLAND RIVERS AND CREEKS IN THE PERIODS 1967-76 AND 1977-81

Stream	1967 - 1976			1977 - 1981		
Area 19	Chinook	Coho	Chum	Chinook	Coho	Chum
Ayum Cr.	-	-	2,130	-	24	2,400
Colquitz R.	-	49	-	-	54	*
Craigflower Cr.	-	125	-	-	89	-
Goldstream R.	29	556	6,000	25	350	20,000
Sandhill Cr.	-	*	-	-	*	-
Shawinigan Cr.	-	n/o	n/o	-	n/o	n/o
Area 20						
De Mamiel Cr.	-	2,255	13,900	10	1,100	5,620
Jordan R.+	-	-	-	-	-	-
Kirby Cr.	-	-	110	-	80	76
Muir Cr.	-	28	395	-	44	532
Sooke R.	1,369	110	18,700	20	43	6,500
Tugwell Cr.	-	40	31	-	73	69

Notes: Asterisk (*) denotes rare and/or sporadic occurrence;
n/o denotes present but not inventories.
\+ see text.

Source: D.E. Marshall, R.F. Brown, V.D. Chahley and D.G. Demontier, 1975. Preliminary Catalogue of salmon streams and spawning escapements of Statistical Areas 19 and 20 (Sidney-Sooke). Environment Canada, Vancouver.

D.M. Moore, 1982. Updates from Operations Branch files 1978-1981, Fisheries and Oceans Canada, Vancouver, B.C.

With one exception, coho and chum are the predominant spawners in local streams throughout the study area. A total of eleven rivers and creeks are known to support salmon spawning populations and these are surveyed annually by district fisheries officers. Jordan River has been rendered sterile by decades of hydro-electric developments, logging, and mining, therefore it is no longer surveyed (Marshall et al, 1975).

Schmidt et al (1979), in an annotated bibliography os salmon stream environments in British Columbia, specified the following four primary determinants of spawning stream productivity.

(a) water temperature - the key factor in regulation of biological activity, stress and mortality;

(b) stream hydraulics - water depth, velocity, width, channel shape, gradient and bed roughness;

(c) spawning gravel - determining success of egg and alevin subgravel development; and

(d) downstream migration - interference due to water use conflicts.

Table 15 summarizes field notes of the major physical stream characteristics and historical features of salmon spawning streams in the study area.

Stream, Estuarine and Nearshore Rearing

Chinook, sockeye, coho sea-run cutthroat and steelhead all utilize streams or lakes for rearing. Pink and chum hatchlings arrive in the estuary shortly after emergence from stream spawning gravel. Chinook delay their descent to the estuary for three months or a year, while coho and sockeye remain in fresh water from one to several years before migrating to sea.

Although chinook and chum are the main users of estuaries, some stocks of coho, pink, and sockeye salmon are also known to depend on estuaries in their early feeding life. Extensive nearshore waters of the study area support the developing young of all five salmon species.

TABLE 15 FIELD NOTES OF SALMON SPAWNING STREAMS (AREAS 19 AND 20) - BRIEF SUMMARIES OF STREAM CHARACTERISTICS AND CERTAIN HISTORICAL FEATURES

Area 19

1. Ayum Creek
   - impassable falls at three-quarters mile upstream
   - winter flows have been low (1976) and high (1977)
   - years of excess flow caused siltation and damage to spawning beds
   - summer flows partially regulated by makeshift dam
   - coho and chum spawn mostly below railway bridge
   - coho escapement low and sporadic
   - some reports of over-spawning in lower reaches
   - native harvest about 15% of escapement.

2. Colquitz River
   - extensive potential spawn habitat above falls to Beaver Lake; falls too costly to remove or bypass
   - low flows in summer, early fall due to many water licences
   - suffers from siltation caused by recent land development, agriculture; also sewage disposal
   - coho spawn in low numbers throughout lower reaches to falls; chum rare, sporadic.

3. Craigflower Creek
   - falls at 2½ miles upstream passable at high water
   - suffers siltation due to land development, floods
   - poor coho escapement in recent years believed due to siltation and heavy incidental commercial seine fishery offshore in Juan de Fuca Strait.

4. Goldstream River
   - falls impassable at 2½ miles upstream; passable falls occurring at 1½ miles
   - flow controlled by dam
   - coho to falls at 2½ miles; 90% chum spawn below highway bridge
   - circulation box enhancement facilities
   - some stream clearing (1981).

5. Sandhill Creek
   - impassable dam at 2 miles upstream
   - coho escapement very low, but spawning may occur throughout up to dam
   - stream clearing by National Parks Board (1975).

---

6. Shawinigan Creek - impassable rockfalls ½ mile upstream
- very limited spawning area; incomplete field records
- coho, chum spawning in tidal section
- predation pressure by numerous seals in estuary
- incubation box enhancement facility

Area 20

7. De Mamiel Creek - passable falls at 3½ and 6 miles upstream
- problematic flows excessively high or low some years but some regulation provided by dam during spawning migration
- coho spawn throughout, but mostly between Robinson Road and Young Lake.
- chum spawn in lower ½ mile
- incubation box enhancement facilities at upper falls, Mary Vine Creek and Rocky Creek
- habitat has potential to double salmon production

8. Jordan River - rendered sterile by decades of hydro-electric developments, logging and mining
- no longer surveyed.

9. Kirby Creek - impassable rock falls at 4 miles upstream
- partial log jams 1½ miles, some periodic cleaning
- stable flows
- chum spawn in lower ½ mile
- coho spawn mostly between highway bridge and logging road bridge
- incubation for enhancement facility on west fork (1977); eggs obtained from De Mamiel Creek.

10. Muir Creek - very rocky, large boulders; falls impassable at 5 miles upstream
- erratic flows; siltation problem due to logging
- chum, coho spawn in lower 3 miles
- escapement reduced in 1960's due to heavy net fishery offshore in Strait of Juan de Fuca
- extremely poor escapement late 1970's early 1980's despite ideal spawning grounds and flows
- excellent enhancement opportunities

11. Sooke River - impassable falls at 4 miles; rock canyon
- dam-controlled flow
- chinook spawn throughout upstream to pot holes (below falls)
- coho spawn throughout to falls
- chum spawn from 3/4 miles upstream to falls
- estimated 25 miles of valuable coho spawning and rearing grounds beyond Sooke falls, in main Leech and West Leech rivers
- escapement in 1977 worst since 1956, believed due to intensive net fishery offshore in Juan de Fuca Strait

12. Tugwell Creek - impassable rock canyon cascades at 2 miles upstream, falls at 5 miles
- coho spawn to 3 miles upstream
- chum spawn lower 500 yards
- escapement in late 1960's affected by heavy net fishery offshore in Juan de Fuca Strait
- incubation box enhancement facility
- capacity for supporting much larger escapement

Source : D.E. Marshall, R.F. Brown, V.D. Chahley and D.G. Demontier. 1977. Preliminary catalogue of salmon stream and spawning escapements Statistical Area 19 and 20 (Victoria-Sooke). Fisheries and Environment Canada, Vancouver.

4.4.5.2.1.3 Salmonid Enhancement Program

A number of minor projects under the auspices of the joint federal-provincial Salmonid Enhancement Program are located on several streams. Most facilities are egg incubation boxes plus some stream clearing and spawning channel improvement. Selected lake trout stocking (see Coastal Resources Map Series (1:50,000) section, Fish and Shellfish Resources) is undertaken by provincial authorities. Details concerning the nature and locations of these and other local projects are available from the Salmonid Enhancement Program, Fisheries and Oceans Canada, Vancouver and from the Ministry of Environment, Fish and Wildlife Branch, Province of British Columbia, Victoria.

4.4.5.2.2 Groundfish

4.4.5.2.2.1 Resource

Several past trend studies of the groundfish trawl fishery in the study area and throughout the Juan de Fuca-Strait of Georgia system are available elsewhere (Forrester and Ketchen, 1963; Ketchen 1979; Westrheim, 1974, 1977, 1980).

Fisheries statistical area 19, extending from about Sidney to Beacher Head near Sooke, has its principal trawling grounds off Victoria. The areas between Albert and William Head, and Victoria and Esquimalt Harbours are closed to trawling. Average annual landings of food groundfish from Area 19 were 137 metric tonnes for 1960-77, 75% of which was taken in the winter fishery between October-March. Principal species were Pacific cod (73%), Ling cod (17%) and English sole (3%). The Pacific cod fishery is thought to exploit a migrating stock.

Fisheries statistical area 20, extending from Sooke to Bonilla Point, has its principal trawling grounds off Port San Juan. The western half of Area 20, including that around Port San Juan, is not part of the current study area. Average annual landings of food groundfish from Area 20 were 184 tonnes for 1960-77, 69% of which was taken in the summer fishery between April-September. Principal species taken were Dover sole (36%), Pacific cod (33%), English sole (10%) and Ling cod (7%). This is the only area in the Juan de Fuca-Strait of Georgia system where the trawl fishery operates principally in the summer months.

A small additional fishery captures halibut from the shelf south of Victoria. Catches have been minimal (1-3 tonnes) and sporadic in recent years (1976 only in Area 20; 1977-80 in Area 19).

A regional perspective of the trawl fishery of south Vancouver Island as compared to the remainder of the Juan de Fuca-Strait of Georgia system and the northern counterpart of approach to the Strait of Georgia (Area 13) is given in Table 16. Principal species include flatfish, Pacific cod, Ling cod and dogfish. Secondary species include rockfish and pollock.

4.4.5.2.2.2 Habitat Requirements

Flatfishes

Included in the flatfish group are rock sole, English sole, petrale sole, Dover sole and turbot. Halibut, a minor species in this study area, is researched and managed by the International Halibut Commission. They are all bottom dwelling species found in wide depth ranges from shallow (18 m; 10 (fm)) to very deep (366 m; 200 fm) water - halibut being the largest and the deepest dwelling species. All spawn during mid-to-late winter months, and, with the exception of rock sole, produce free-floating eggs. The planktonic larvae of these flatfishes undergo metamorphosis, wherein the left eye migrates to the right side of the body before settling to the bottom, blind side down. In early life flatfish species are found in the intertidal zone and quite shallow water, moving into deeper water as they grow. The fish move into shallow water in spring and deeper water in winter.

As a group, flatfishes are characterized by moderate growth rates: age at first capture is generally 2-3 years; age at first maturity is 3-7 years; natural mortality rate is relatively low and life span is 15-40 years. Several to many age groups contribute to the catch each year. Thus abundance does not fluctuate as wildly as that of such species as cod and pollock, although fluctuations in individual year-classes are known to occur.

TABLE 16 GROUNDFISH FISHERY OF SOUTH VANCOUVER ISLAND. A REGIONAL PERSPECTIVE OF AVERAGE ANNUAL CATCHES (NEAREST TONNE) RELATIVE TO THE JUAN DE FUCA-STRAIT OF GEORGIA SYSTEM IN 1960-77 AND 1979-80

	Area 19 (Sidney-Sooke)		Area 20 (Sooke-Bonilla Pt.)		Strait of Georgia[a]
	1960-77[2]	1979-80[1]	1960-77[2]	1979-80[1]	1960-77[2]
Pacific cod	101	708	61	219	578
dogfish	6	343	6	92	198
Flatfish[b]	4[c]	56	85[d]	104	201[c]
Rockfish[e]		12		52	
Pollock		14		12	
Ling cod[f]	55	17	24	6	832

Notes:
a) Includes Strait of Juan de Fuca and northern approaches.
b) Mostly Dover sole, English sole plus six or more species.
c) Data for English sole only.
d) Dover sole and English sole only.
e) Two or more species.
f) Includes line and trawl fisheries.

Sources:
1. J.E. Smith. 1980. Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1979. Canadian Technical Report of Fisheries and Aquatic Sciences No. 961.

2. S.J. Westrheim. 1980. The total fishery in the Strait of Georgia and vicinity, 1945-77. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1563.

Flatfishes feed primarily on clams and other molluscs, marine worms, small crabs, shrimps, and brittle stars.

Pacific cod

Pacific cod, the long-time mainstay of the domestic trawl fishery is the only true cod in the North Pacific and is similar in appearance to its more famous cousin in the North Atlantic. In Canadian waters it is close to the southern limit of its range and occupies intermediate depths along the continental shelf. It is fast-growing and short-lived. Pacific cod reach commercial size as 2-3 year-olds and mature at about the same age. Few cod live beyond 5 or 6 years of age as the natural mortality rate is relatively high (possibly as much as 50% per year). With few age groups, cod populations exhibit considerable instability. Large and almost cyclical fluctuations in abundance have a profound effect on the annual success of fishing. As yet these fluctuations cannot be reliably predicted.

Pacific cod spawn in February and March, the eggs being fertilized in the water column. To date no fertilized eggs have been observed or collected in the sea but laboratory evidence suggests that cod eggs incubate on the bottom. Bottom temperatures on spawning grounds in British Columbia are usually 7-8°C.

In general, small cod eat plankton (euphausids and shrimp) and larger fish eat crabs, shrimp and other fish (mainly herring and sandlance). Cod tend to disperse for feeding and to congregate for spawning. Similarly, they move into deeper water in autumn and return to shallow water in spring.

Ling cod

The ling cod is widely distributed along the continental shelf from Mexico to the western Gulf of Alaska, but the centre of abundance appears to be off British Columbia. It occurs from the inter-tidal zone to depths of 366 m (200 fm).

Ling cod spawn in rocky, current-swept areas,
masses in crevices. These egg clusters are defended by the male. After a 2-3 month pelagic stage, larval ling cod assume a bottom-dwelling life. Growth rate is relatively rapid in the early years of life and entry into the commercial fishery occurs at 3-5 years of age. The majority of ling cod mature at 4-5 years of age, or a length of 65-76 cm. They cease to be of significance in commercial landings beyond the age of 10-12 years, but may live as long as 18 years.

Tagging results of adults suggest that the species is relatively non-migratory, thus it is likely that the resource consists of numerous local stocks.

Ling cod are fished commercially in Canadian waters primarily by bottom trawl and handline or troll methods. During 1968-79 ling cod comprised an average of 11% of the total groundfish landings, excluding halibut. As well as being of commercial interest, ling cod are also landed by recreational fishermen using jig, troll and spear fishing gear.

Spiny dogfish

The spiny dogfish range is from southern California to the Gulf of Alaska; it is most abundant from southern Oregon to Dixon Entrance.

Dogfish have been fished commercially for over 100 years, beginning in the 1870's when the liver and body oils were used as a lubricant and fuel for lamps. The major fishery occurred between 1937 and 1949 as a result of a strong market for dogfish livers as a source of Vitamin A. From 1950 to about 1975 the resource remained virtually unexploited. With the development of foodfish markets abroad, dogfish landings increased from 1976 to 1979, but decreased in 1980 as a result of a decline in market conditions.

Dogfish are characterized by slow growth, a low birth rate and a long life-span. The young are born after a uniquely long gestation period of nearly 2 years. Males mature at a length of 62 cm (16 years) while females mature at 90 cm or in their 25th year. During the 1979 fishery in the Strait of Georgia, the average size was 84 cm and 102 cm for males and females respectively. Elsewhere along the coast, especially in Hecate Strait, the species remains unexploited and interferes with the pursuits of other commercial fisheries. The impact of dogfish as a predator on other groundfish and herring is not fully understood.

As the dogfish has a low rate of reproduction, it is extremely sensitive to overfishing and a rational approach to exploitation requires careful monitoring of the harvest.

The young dogfish diet begins with planktonic organisms, yet adults too have been observed eating planktonic euphausids. Principal foods include herring, hake, sandlance, and a wide variety of invertebrates such as crabs, shrimp and octopus. Little evidence exists to indicate that dogfish are serious predators of salmon.

Rockfish

Rockfish constitute a large and complex portion of west coast bottom-fish resources. There are more than 30 species of which at least seven are of importance to the domestic trawl fishery. As a group they are characterized by slow growth; a prolonged period of immaturity (11-13 years); an even longer time to become fully recruited to the fishery (13-15 years); an extended life span in which, depending on species, an age of 50-60 years is not uncommon, and by a natural mortality rate which in most species is probably less than 5% per annum.

Although composed of many age groups, rockfish stocks are highly vulnerable to over-exploitation. Indeed, many were decimated during the years when uncontrolled foreign fleets were present off British Columbia (1965-76). Particularly hard hit were the stocks of Pacific ocean perch located off Dixon Entrance, off the west coast of Vancouver Island and in Queen Charlotte Sound.

Rockfishes as a group occupy a wide range of depths, but as individual species occupy more restricted ranges from intermediate depths on the continental shelf (73-110 m; 40-60 fm) to the upper continental slope (183-457 m; 100-250 fm). They overlap in their distributions with each other, but more importantly with other species requiring quite different (conflicting) management policies.

For most rockfish species the basic biological parameters are not well known (particularly the relationship between spawning stock and recruitment) because it was not until recent years that rockfishes other than Pacific ocean perch became of economic importance to Canadian fishermen and hence warranted priority for investigation. Such information as recruiting rates is needed to determine the level of fishing which can be tolerated while still allowing for a practical rehabilitation schedule.

Walleye pollock

Like the hake, the walleye pollock is a newcomer to the trawl fishery for foodfish. It occurs in both midwater and on the bottom at intermediate depths. There appear to be several stocks in the Canadian zone, but as yet their interrelationships are not fully understood. For example, it is possible that one or both of the stocks or populations of adults which spawn (in midwater) in the Strait of Georgia may make their way out of the strait to the west coast of Vancouver Island in spring and summer.

Like Pacific cod, pollock off British Columbia are near the southern limit of their range. Their life span is relatively short; maturity is reached in 2-4 years; there are as few as 3-5-year classes in unexploited stocks; natural mortality rate is relatively high (45%) and there are substantial variations in recruitment. These factors produce much instability in the populations and thus make difficult the prediction of abundance.

4.4.5.2.3 Other Finfish

4.4.5.2.3.1 Herring

In comparison to the Strait of Georgia roe fishery, the herring fishery for food and bait in the present study area is negligible (about 1%). Herring are taken during their migration into the Strait of Georgia.

Herring spawning and rearing is limited to a few of the limited number of inlets in the study area, where anchovy also enter from offshore spawning areas to rear (see Coastal Resources Map Series (1 50,000) section, Fish and Shellfish Resources). Small as it is, the local herring population is nevertheless exploited by both commercial and recreational fisheries.

4.4.5.2.3.2 Habitat Requirements

A biological phenomenon is the annual convergence of huge schools of he herring on a limited number of intertidal and shallow subtidal spawning grounds which are generally scattered throughout the Pacific coast. Few areas throughout the West Coast appear to offer a suitable spawning habitat, but where these occur, (such as in the present study area), they are heavily utilized.

Herring spawn in winter and early spring when salinity and temperature are reduced. Adhesive eggs are deposited onto seaweeds, primarily rockweed (Fucua), Japweed (Sarg-ssum), and eelgrass (Zostera). The deposition of eggs can range from above low water to 10-15 m below. Egg survival during the incubation period of two to three weeks does not exceed 30% due to predation by marine birds, intertidal fish, and exposure to storms which dislodge egg-laden seaweed.

Herring mortality is estimated to reach 99% during the larval phase and evidence suggests this is chiefly due to larvae being carried offshore by wind-driven surface currents as well as by lack of larval food (plankton) and predation. By summer, juveniles school in shallow bays and inlets, typically near kelp beds, feeding in surface waters at dawn and dusk on small zooplankton (copepods, euphausids and amphipods).

Near the end of their first summer, herring migrate from the Strait of Georgia by way of the present study area to offshore feeding grounds, mainly off the lower west coast of Vancouver Island. A small number of herring remain behind to form minor resident populations. The fall return migration begins in their third or fourth year. Strait of Georgia herring remain separate from stocks elsewhere on the coast during their spawning migrations, so that all production and recruitment of the fishery stock must come from within the Strait of Georgia system, particularly the present study area.

A list of the localities within the study area where herring spawning has been recorded up to the present is available elsewhere (Hourston and Hamer, 1979). Historical data of spawning intensity, timing, and local habitat characteristics are currently being analyzed by researchers of the Pacific Biological Station (Fisheries and Oceans, Canada).

On individual herring spawning grounds, no clear relationship exists between spawning intensity and the number of spawning days. This is reflected in the unpredictable nature of local spawning and hence the difficulty in predicting the timing and abundance of individual roe herring fisheries at the local level.

Evidence suggests that changes in preferred spawning grounds are related to broad-scale variation in environmental conditions but it is not known whether such shifts are the result of changes in herring migratory patterns or in variable survival rates for different herring spawning grounds. The variability in actual timing of spawning from year to year in any locality appears to be related to local vagaries of the environment rather than to oceanographic and climatic patterns.

4.4.5.3 Shellfish

Table 17 provides a brief regional perspective of the south Vancouver Island shellfish fishery in terms of average annual commercial catch (1975-80) in the study area, east Vancouver Island and Juan de Fuca-Strait of Georgia system as a whole. Overall, the commercial shellfish resource of south Vancouver Island is minor. The principal species are crabs and geoduck clams.

4.4.5.3.1 Resource and Habitat Requirements

4.4.5.3.1.1 Crab

The Pacific, edible or Dungeness crab is generally trapped on firm sand bottoms in less than 38 m (20 fm) of water. Highest landings are reported from the southern Gulf Islands (Area 18) where the crab catch is over three times that of adjoining Area 17. However, as shown in Table 17, south coast catches (Area 19, 20) are comparable to all of the east coast Vancouver Island catch.

The edible crab lives mainly on firm sand from the low tide mark to as deep as 190 m (100 fm). Spawning occurs in late fall or early winter with eggs being carried by the female until hatching in the spring. Crab larvae swim freely among plankton for three or more months before settling to the bottom. The adult diet includes clams, marine worms and small fish.

4.4.5.3.1.2 Clams

Traditionally, the clam fishery in the Juan de Fuca-Strait of Georgia system has been based on three species: Butter clam, Japanese Littleneck or Manila clam, and Native Littleneck clam. Landings of Geoduck clam first reported in 1977 exceed the average annual landings of the traditional species in the study area overall. Horse clams were first reported in the commercial fishery in 1979.

Landings in Areas 19 and 20 are a small fraction of those taken from the east coast of Vancouver Island. Large tracts of coastline in the present study area are highly exposed and generally unsuitable for clam populations.

The Butter clam is found in many types of sediments but is most abundant in the lower third of the intertidal zone of beaches and bars composed of a mixture of sand, broken shell and gravel. Manila clams live on mud-gravel beaches at about the mid-tide mark while its close relative, the Native Littleneck clam, is typically found in a mixture of fine sand, shell and gravel in the lower half of the intertidal zone. The main populations of the large Geoduck clam are found in subtidal sand or mixed sand-mud, but they can also be found in the lower part of an intertidal beach.

TABLE 17 SHELLFISH FISHERY OF SOUTH VANCOUVER ISLAND. REGIONAL PERSPECTIVE OF AVERAGE ANNUAL CATCHES OF MAJOR SPECIES IN 1975-80 (NEAREST TONNE)

Species	Strait of Georgia-Juen de Fuca Strait			
	S.W. Coast Vancouver Island		East Coast Vancouver Island	All Areas
	19	20	14, 17, 18	13-20, 28, 29
Shrimp & prawns[(a)]	2	3	64	246
Butter clam	-	4	118	132
Japanese littleneck(Manila)	-	11	69	292
Native littleneck	-	10	54	138
Mixed clams	5	1	11	91
Geoduck clam (1977-1980)	97	2	349	805
Abalone	-	4	-	4
Crabs	52	16	59	422
Oysters[(b)]	-	18	50	74
Sea urchins (1979 only)	45	2	266	313

Notes: (a) mostly captured by traps
(b) nearest 1000 U.S. gallon shucked

Source: Fisheries and Oceans Canada. Annual Reports, and B.C. Catch Statistics.

4.4.5.3.1.3 Shrimp

Commercial shrimp are trawled mainly from muddy or sandy bottoms in 95-130 m (50-70 fm) of water. Shrimp are found in a wider variety of habitats (rock to mud, pelagic to demersal) than is the edible crab. A major, integral part of the marine ecosystem in pelagic and demersal waters, shrimp are of great value in the diets of commercial fish, marine mammals, and large invertebrates. In turn, shrimp prey upon other crustaceans, many pelagic and demersal invertebrates, and recycle dead or decaying organic matter. No detailed ecological studies exist because of difficulties in species identification.

4.4.5.3.1.4 Prawns

Prawns live on rocky bottoms. Catches in the study area are primarily taken by baited traps from the few large, sheltered inlets and rocky islet groups. Saanich Inlet, for example, is closed to all net fisheries; trapping is used in the rocky island areas of Discovery Island and Race Rocks; trapping and limited trawling occur in Sooke Basin.

4.4.5.3.1.5 Sea Urchin

Limited harvesting of red sea urchin in the Strait of Georgia began in 1972. In the period 1975-79 over three quarters (86%) of the sea urchin harvest from southern British Columbia came from the east coast of Vancouver Island with the only other significant landings recorded from the present study area, the southern approach to the Strait of Georgia (Area 19). Harvesting is done by divers who are limited in their operations by depth and currents. Therefore, only the densest populations can economically support the fishery.

The densest populations of red sea urchins are on rocky bottoms in or near large algae beds, generally 3-5 m below low tide. Populations below 15 m are limited to small isolated clusters.

4.4.5.4 Species Names

In this report, common names are used throughout but, in order to avoid confusion, the scientific names are given below. Common names of fish are those of Hart (1973), shrimp of Butler (1980), and clams of Quayle and Bourne (1972).

Salmon

Chum	*Oncorhynchus keta*
Chinook	*O. tshawytscha*
Coho	*O. kisutch*
Pink	*O. gorbuscha*
Sockeye	*O. nerka*
Coastal Cutthroat trout	*Salmo clarki clarki*
Steelhead	*S. gairdneri*
Pacific herring	*Clupea pallasii*

Groundfish/Midwater Fish

Pacific cod	*Gadus macrocephalus*
Walleye pollock	*Theragra chalcogramma*
Pacific hake	*Merluccius productus*
Tomcod	*Mocrogadus proximus*
Slender sole	*Lyopsetta exilis*
English (Lemon) sole	*Parophys vetulis*
Flathead sole	*Hippoglossoides elassodon*
Rex sole	*Glytocephalus zachirus*
Rock sole	*Lepidopsetta bilineata*
Dover sole	*Microstomus pacificus*
Sand sole	*Psettichthys melanostictus*
Arrowtooth flounder	*Atheresthes stomias*
Butter sole	*Isopsetta isolepis*
Starry flounder	*Platichthys stellatus*
Speckled sanddab	*Citharichthus stigmaeus*
Pacific halibut	*Hippoglossus stenolepsis*
Rockfish	*Scorpaenidae*
Spring dogfish	*Squalus ocanthias*
Ling cod	*Ophiodon elongatus*

Shellfish

Prawn	*Pandalus Platyceros*
Shrimp	*P. jordani*
	P. borealis
	P. hypsinotus
	P. danae
	Pandalopsis dispar
Edible (Dungeness) crab	*Cancer magister*
Razor clam	*Siliqua patula*
Butter clam	*Saxidomus giganteus*
Manila clam	*Venerupis japonica*
Littleneck clam	*Protothaca staminea*
Horse clam	*Tresus capax*
Geoduck clam	*Panope generosa*
Oyster	*Crassostrea gigas*
Sea Urchin	*Strongylocentrotus franciscanus*
Mussels	*Mytilus edulis*
Red squid	*Beryteuthis magister*
Opal squid	*Loligo opanescens*
Octopus	*Octopus spp.*
Abalone	*Haliotus rufescens*

4.5 RECREATIONAL RESOURCES

The southern coast provides abundant opportunities for outdoor recreation. There are bays, inlets, harbours, scenic shorelines and shore process features (e.g. spits) to attract recreationists. Small sand and shell beaches are common, although large beaches with good quality sand are few. Many low lying areas provide easy access to the shorezone for viewing, walking, nature study and boating, while the rocky coasts contain a diversity of marine life that attracts divers. The coastal uplands provide hiking trails, scenic environments and parks. The Canada Land Inventory rates much of the shorezone of the study area class 1 to class 5, signifying that the study coast has a variety of capabilities for outdoor recreation.

4.5.1 COMPETITION FOR SPACE AND RESOURCES

While many important recreational resources are currently protected from alienation within the coastal zone, some areas currently in use, as well as those with significant potential (including scuba diving sites, shore process features, beaches and backshore camping areas) remain unprotected. With the predicted population growth, competition for many of the areas will doubtless increase. For instance, expansion of current uses such as log storage, commercial fishing, shoreline residential development, and commercial and industrial construction on the foreshore or backshore zones preempts recreational use as effectively as numerous licenced water withdrawals from rivers prevent river boating or fishing. Beaches become alienated through overuse (crowding), misuse (vehicular traffic), inappropriate use (excavation), or indirectly by the interruption of longshore sediment transport that sustains them. The protection of unique, recreationally valuable sites must occur relatively soon while they still remain, and/or the costs of acquisition are not prohibitive.

4.5.2 ACCESS

One of the most pressing coastal zone problems of other jurisdictions (e.g. California, Sweden) is the lack of public access to the shoreline. A combination of private waterfront ownership, heavy forest cover and rock cliffs precludes the use of many potential recreational areas by the non-boating public. Similarly, marinas with security fences and adjacent commercial/industrial developments either physically prevent access or render the site unattractive for recreational purposes. In other coastal areas, access to the water is either unmarked or inadequate for vehicles and pedestrians. Log booming and storage on intertidal flats or rocky shorelines similarly prevents their unobstructed enjoyment while also reducing the habitat of recreational wildlife species. Backshore developments and foreshore leases destroy the wilderness and the aesthetics of many sections of scenic coast. While many miles of unobstructed shoreline remain for recreationists wishing to enjoy the scenery and biota of the coastal zone in solitude and beyond sight of human activities, the issuance of foreshore leases into new areas could, in time, eliminate all vestiges of isolation in the study area.

4.5.3 POLLUTION

Marine water quality in the study region currently restricts recreational activities in local areas. The sewage from urban outfalls is responsible for shellfish closures along the coast. Boat wastes in waters surrounding marinas and wharves contribute to local shellfish harvesting restrictions. Sewage discharged from recreational vessels in open waters is not yet identified as problematic, although several heavily used anchorages evidence poor visual and aesthetic water quality.

Water contact sports (e.g. swimming) conducted in areas of contamination pose definite health risks to recreationists. Leachates from log booming and storage, and effluent from coastal industries reduce the recreational value of adjacent coastal waters and can jeopardize the integrity of local coastal ecosystems. The consumption of marine and intertidal biota are important recreational activities in this area; water quality, therefore, is of great concern. In many instances, the costs of pollution are not borne by the originating sources; the resulting impact being borne by the recreational community and the public at large.

4.6 PHYSICAL PROCESSES AND ENERGY

4.6.1 REGIONAL WAVE CLIMATE

An understanding of the potential for a body of water to produce waves under certain conditions is important from engineering, planning, and recreational points of view. Engineers are concerned with the effect of waves on coastal structures such as breakwaters or wharves, as well as the sedimentation of harbours. Planners, on the other hand, are concerned with wave effects on coastal bluffs, the probability of inundation during storms, and the sensitivity of certain shoreforms, such as spits, to erosion. Recreationists are concerned about the stability of coastal bluffs (on recreational properties), marina protection, and the maintenance of sandy beaches.

The following discussion does not attempt to cover the current state of the art in wave theory, but reviews what is known about wave characteristics in the study area. For further general reading on the subject, Bascom (1980) provides an excellent layman's text. For works in the field relating to Canadian conditions, reports by the Associate Committee for Research on Shoreline Erosion and Sedimentation (ACROSES) (1980) , and McCann (1980) are available. Also, an excellent series of articles by Thomson (1974-1977) as well as an oceanographic text (Thomson, 1981) apply directly to the study area.

4.6.1.1 Wave Heights

In the absence of real wave measurements for the study area (except for Victoria Harbour), it is necessary to describe what is known about the components of waves.

Wave height is a function of the generating wind - its strength (speed), duration (time for which it has been blowing at a particular speed), and fetch (the unobstructed length of water over which it can blow).

4.6.1.1.1 Wind Strength

Owens (1980) states that the direction of the strongest winds is more significant to wave generation than prevailing winds. Clague and Bornhold (1980) identified west and south as directions of the strongest annual average winds for Gonzales Heights and Victoria International Airport, respectively. Seasonal annual averages (summer and winter) compiled by the Atmospheric Environment Service (1980) identified west at Race Rocks, southwest at Gonzales Heights, and southeast and northeast at Victoria International Airport as directions of the highest averages.

Hale and Greenwood (1980), in their work on storm wave climatology, selected 19 km/hour (hr) to define the lower limit of a storm. Figure 6 displays the percentage frequency of hours with wind speeds greater than 30 km/hr for a representative area: Race Rocks. It is evident that the western quadrant predominates throughout the year. There is, however, a strong easterly component in the winter; a time when overall velocities are at a maximum. Greer (1979), in his Victoria waterfront study, chose southwesterly and southeasterly directions to calculate the storm wave climate. His speed classes (with 15 km intervals) ranged from 0 km/hr to greater than 48 km/hr Holden (1979), reviewed 30 years of wind records for Whiffin Spit and identified 115 km/hr from the southwest as the extreme value for his wave calculations. In comparison, for the Sidney Spit study Holden (1980) chose 80 km/hr from the southeast. Thurber Consultants (1973) felt winds over 29 km/hr were significant for wave calculations at Gordon Head.

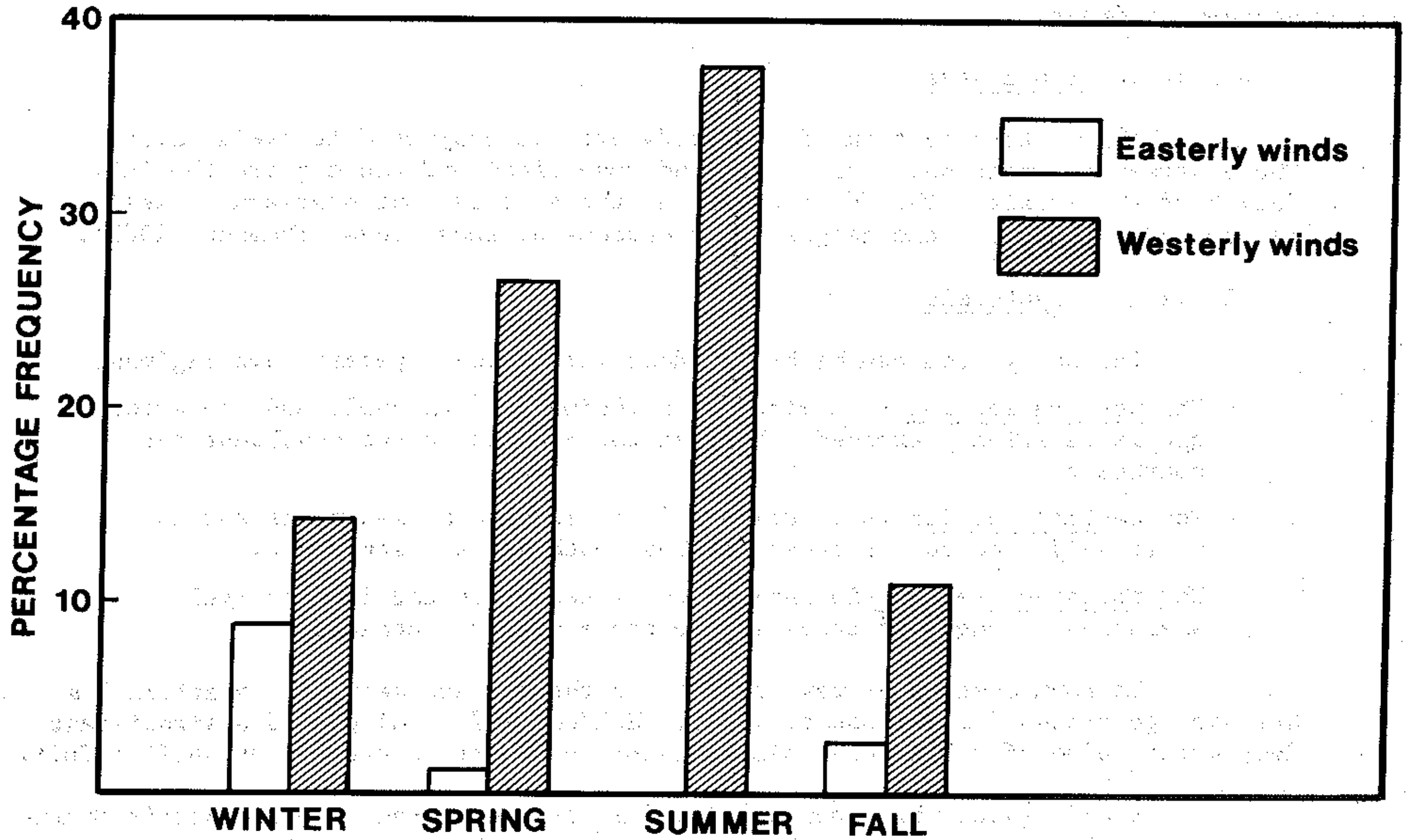
4.6.1.1.2 Wind Duration

There have been a wide range of wind duration values calculated for the study area. Hale and Greenwood (1980) chose 6 hrs as the minimum duration for a storm to fully develop. Thomson (1981) used a 10-hr duration for his calculations at the seaward end of Juan de Fuca Strait. Greer (1979) used 4 hrs for the Victoria waterfront, while Thurber Consultants (1973), Holden (1979) and Harper (1980) felt that a minimum of 1 hr duration was significant. Harper(1980, pers. comm.) specifically noted that 1 hr should produce significant waves for less exposed sites.

4.6.1.1.3 Fetch

Thomson (1981) used a maximum fetch of 140 km for Juan de Fuca Strait. Dunn (1982) measured effective fetches of up to 80 km to the southeast for the study area. For Whiffin Spit, Holden (1979) calculated just over 29 km to the

FIGURE 6 PERCENTAGE FREQUENCY OF HOURS WITH WIND SPEEDS 30 KM/HOUR OR GREATER FOR RACE ROCKS (1970-80)



Source: D.G. Schaefer, 1982. Unpublished Report. Environment Canada, Atmospheric Environment Service. Vancouver, B.C.

southwest as the effective fetch. Greer (1979) measured 50 km to the southeast for his Victoria waterfront calculations.

In more sheltered eastern locations of the study area, Holden (1980), Owens (1980) and Harper (1982) all used values of less than 15 km from the eastern quadrant.

4.6.1.1.4 Swell Waves

The western section of the study area is subjected to swell waves. These waves are independent of local wind conditions and can migrate the full length of the Strait. They decrease in height as they move eastward. Swell waves tend to increase the height and steepness of local seas (Thomson, 1981).

4.6.1.1.5 Synthesis

The study area can be broken down into three separate wave regimes.

- The western section is a mixed wave regime of both swell and sea waves and is relatively exposed. Longest fetches are to the southwest and southeast.
- The central section is predominantly influenced by sea waves and is relatively exposed. Longest fetches southeast and southwest.
- The northeast section is influenced by sea waves and is relatively sheltered. Longest fetches are to the east and southeast.

Maximum deep water wave heights in the western section can attain 3 m but average around 2 m (Thomson, 1981). Holden (1979) calculated a significant deep water value of 3.3 m while his nearshore calculation was 2 m at Whiffin Spit.

Swell waves, while approaching 6 m at the entrance to the Strait of Juan de Fu (winter value), are reduced as they move eastward. Holden (1979) estimated that in November 1978 swell waves of .4 m with 12-second periods occurred at Whiffin Spit.

Greer (1979) calculated the design waves for the exposed Victoria waterfont to be approximately 4 m. with 8-second periods. Characteristic of the sheltered locations in the study area, real waves were measured in Victoria Harbour. These are the only measurements of waves in the study area. The values are as follows:

Victoria Harbour, Station 4 at -4.6m, March 10, 1976 to March 24, 1977

Largest wave recorded: about 1 m. with a peak period between 3 and 4 seconds.

Greatest percentage wave height and period: 94% less than .3 m. with 2-4 second periods.

Exceedance: 10% probable maximum exceedance of .4 m.

Victoria Harbour, Station 95, at -3.7 m, December 3, 1975 to July 28, 1976

Largest wave recorded: .75 m with peak period of 4 seconds.

Greatest percentage wave height and period: 94% less than .3m with 2-4 second periods.

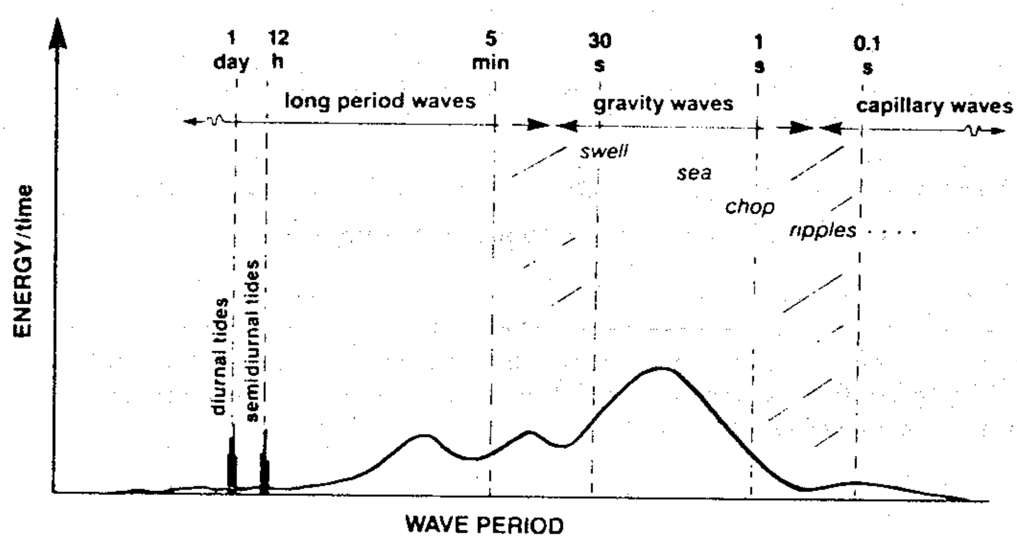
Exceedance: 10% probable maximum exceedance of .4m.

Significant wave heights identified for the northeast coast of the study area showed great variability. Harper (1982) calculated maximums of about 2 m with 4.5 to 5.5 second periods from the east for Saani h Peninsula. Holden (1980), calculated a maximum value of 1.5 m with 5-second periods from the southeast for Sidney Spit. Owens (1979, 1980) noted that wave heights greater than 1 m would be rare in channels adjacent to Saltspring Island, while in sheltered locations values would not exceed .5 m.

4.6.1.2 Wave Energy

Wave energy is a function of wave height, wave period and nearshore slope. An important end product on the shore is the generation of a littoral current. Table 17, developed by Thomson (1981) shows the relationship between factors which determine waves and their energy. Thomson (1981) also provides a graphic illustration of the relationship between wave periods and wave energy (see Figure 7).

FIGURE 7 POWER SPECTRUM OF RELATIVE AMOUNT OF ENERGY CONTAINED BY WAVES OVER A RANGE OF WAVE PERIODS



Note: Broken lines show overlap of wave types.
Tidal energy is concentrated within a narrow band of periods near diurnal and semi-diurnal periods. (After Kinsman, 1965).

Source: R.E. Thomson, 1981. Oceanography of the British Columbia Coast. Canadian Special Publication of Fisheries and Aquatic Sciences 56. Fisheries and Oceans Canada. Ottawa. p.89.

TABLE 18 MINIMUM FETCH AND DURATION TO PRODUCE FULLY DEVELOPED SEAS OF VARIOUS WIND SPEEDS

Wind Speed (knots)	10	15	20	25	30	40	50
Fetch (kilometres)	19	63	139	296	518	1315	2630
Duration (hours)	24	6	10	16	23	42	69
Average Height (metres)	0.3	.8	1.5	2.7	4.3	8.5	14.6
Significant Height[1] (metres)	.4	1.1	2.4	4.3	6.7	13.4	23.8
Average of the highest 10% (metres)	.6	1.5	3.1	5.5	8.4	17.4	30.2
Period having the greatest concentration of energy (seconds)	4	6	8	10	12	16	20

[1] The Significant Height is the average height of the highest 1/3 of the existing waves. The maximum wave height is about 1.8 times the significant height.

Source: R.E. Thomson, 1981. Oceanography of the British Columbia Coast. Canadian Special Publication of Fisheries and Aquatic Sciences 56, Fisheries and Oceans Canada. Ottawa.

Bornhold and Clague (1980) note that for Juan de Fuca Strait and the Strait of Georgia wave energy is fetch-dependent. Owens (1980) states that wave energies generally correspond to the seasonal variation in wind velocities and wave heights. The winter months (October to April) produce the higher values.

Wave energy studies have been done for three sites within the study area.

4.6.1.2.1 Whiffin Spit

Holden (1979), using wave refraction diagrams, found that wave energy is generally reduced along the spit. He did note, however, that waves from the southwest and west were not reduced by refraction and therefore had more available energy. This concentration of energy was at the migrating zone of the spit neck (see Figure 8). Areas of concentrated wave energy due to refraction are indicated by the more closely spaced orthogonals.

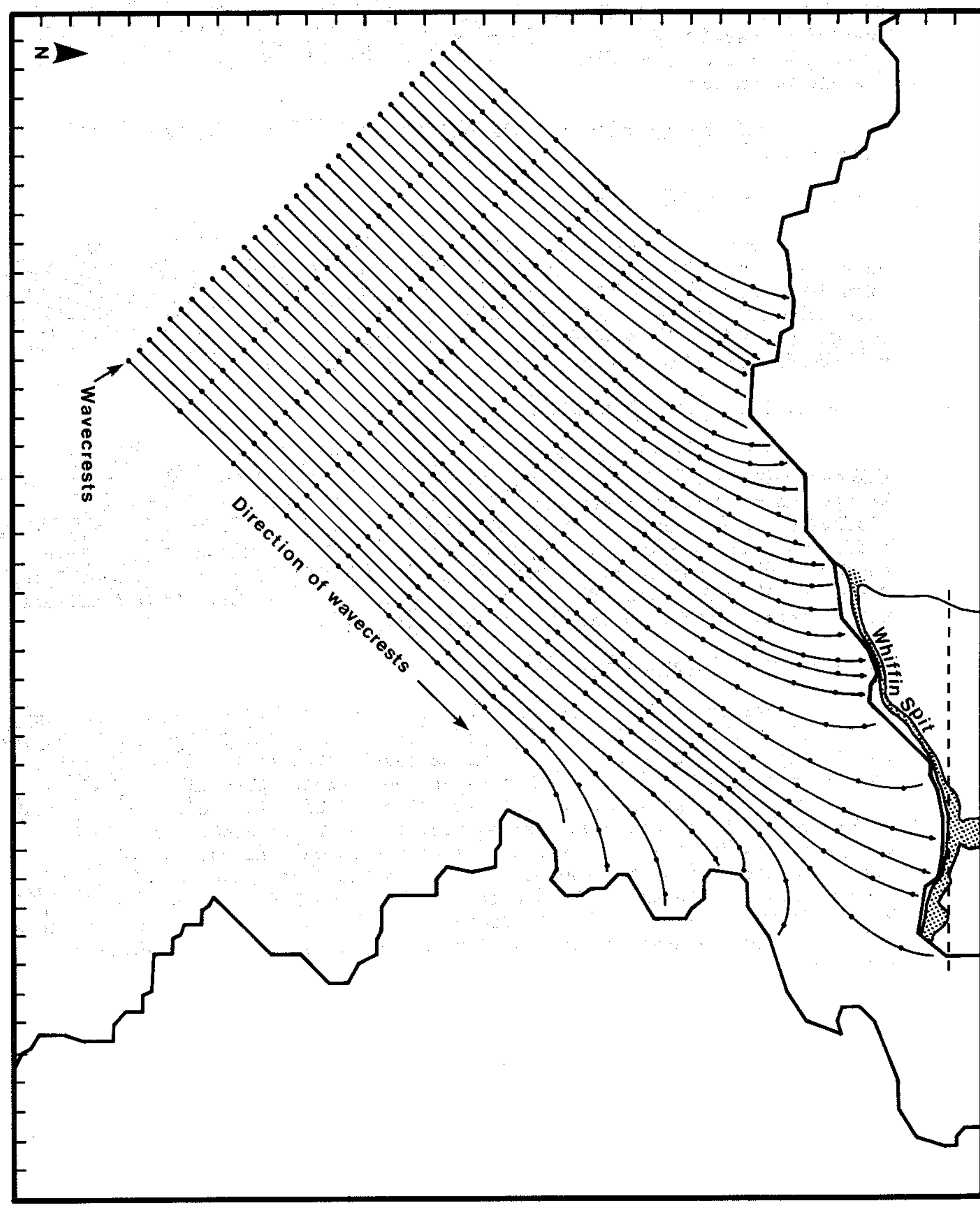
4.6.1.2.2 Victoria Waterfront

Greer (1979) used the same type of analysis and found that the highest wave energy levels on the shoreline varied with wind direction. Wave energy was concentrated between Finlayson and Clover points during west-southwest winds. Brotchie Ledge was found to focus energy on the shore between Ogden and Holland points during southwest and south-southwest winds. East-southeast winds concentrated wave energy on the eastern side of Clover Point. Greer (1979) noted, with interest, that waves from this direction dissipated their energy further to the west in the study area.

4.6.1.2.3 Saanich Peninsula

Harper (1982), using a wave climate model, calculated wave energy levels for fifteen stations. He found that total annual energy levels appeared to be higher on the west coast of the peninsula than on the more exposed east coast; this is attributed to the moderate persistent westerlies. Seasonal variations of energy showed some interesting values. East coast values peak in December, while west coast values peak in March and June. The winter wave energy levels for the east coast of the peninsula were almost an order of magnitude larger than the summer values. On the west coast, energy levels remain high through the seasons with the summer peak only twice the minimum. Harper (1982) qualifies these findings by noting that equations used in this model are uncalibrated for the Saanich Peninsula and some uncertainty in predictions exists.

FIGURE 8 WHIFFIN SPIT WAVE REFRACTION (WAVE PERIOD 10 SECONDS FROM THE SOUTHWEST)



Source: B.J. Holden, 1979. Whiffin Spit. B.C. Ministry of Lands, Parks and Housing. Province of British Columbia. Victoria.

Another factor which contributes to the amount of wave energy available is water level. Owens (1980) notes that as tidal range increases, available wave energy dissipates over a larger vertical area. This agrees with Greer (1979) and Holden (1979). Maximum tidal ranges in the study area vary from 2.5 m in the west, 1.8 m at Victoria and 2.4 m in Haro Strait. The most energy affecting the backshore would be when strong winds occur with a high tide. Greer (1979) calculated that this event could happen for about 34 hrs per year for winds in the southern quadrant.

A combination of strong winds and high tides can cause storm surges which can exceed high tide levels by as much as 0.5 m (Holden, 1979, Owens, 1980). Storm surges of this magnitude have a 50 to 100-yr return probability (Holden, 1979).

4.6.1.3 Littoral Currents

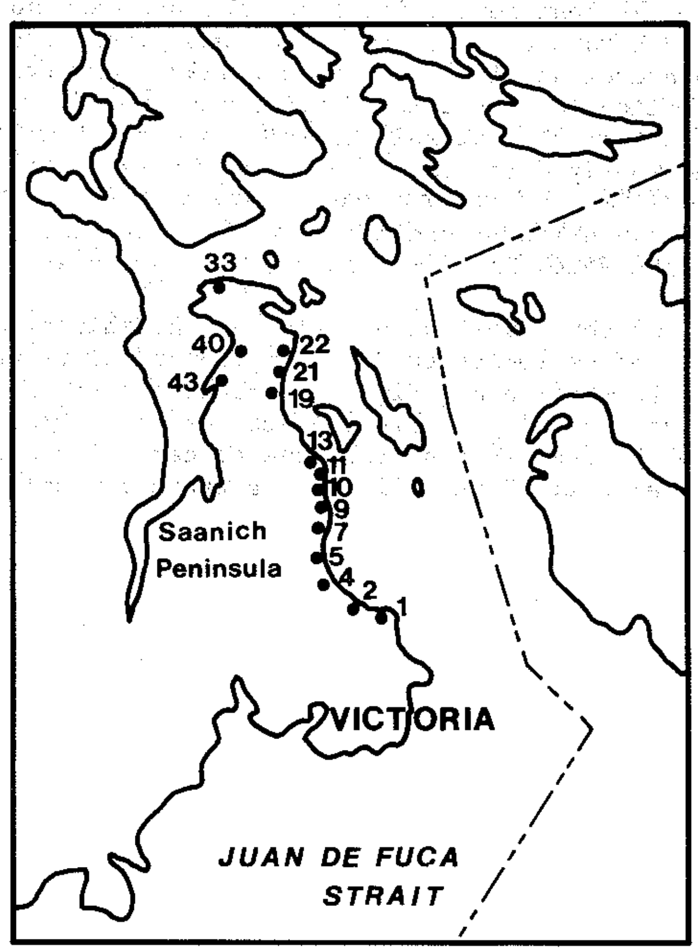
Littoral currents are generated by waves striking the shoreline at an angle. Thomson (1977) states that short period waves produce stronger currents than long period waves as they are less susceptible to refraction. Clague and Bornhold (1980) note the consistent northward trend of the spits on James and Sidney islands. Harper (1980) observed that seasonal changes of wind direction in restricted fetches may produce seasonal reversals of littoral drift. On Saanich Peninsula he found a small southerly drift in summer and a larger northerly drift in winter: in general, there was an accretional phase in summer and an erosional phase in winter; also there was a net northerly drift of sediments on the east coast of the peninsula ending at Cordova Spit which is accreting at .2 m per year.

Harper (1982) also estimated the maximum depth of bottom disturbance of sand-sized sediments due to wave-induced currents. Table 19 provides these estimates by station and Figure 9 identifies the location of these stations. In terms of frequency of disturbance, Harper (1982) cautions that the maximum values may be reached less than one percent of the time. A smaller value may be more frequent. Figure 11 shows a typical sample profile.

TABLE 19 MAXIMUM DEPTH OF SEDIMENT (SAND-SIZED) DISTURBANCE DUE TO WAVES

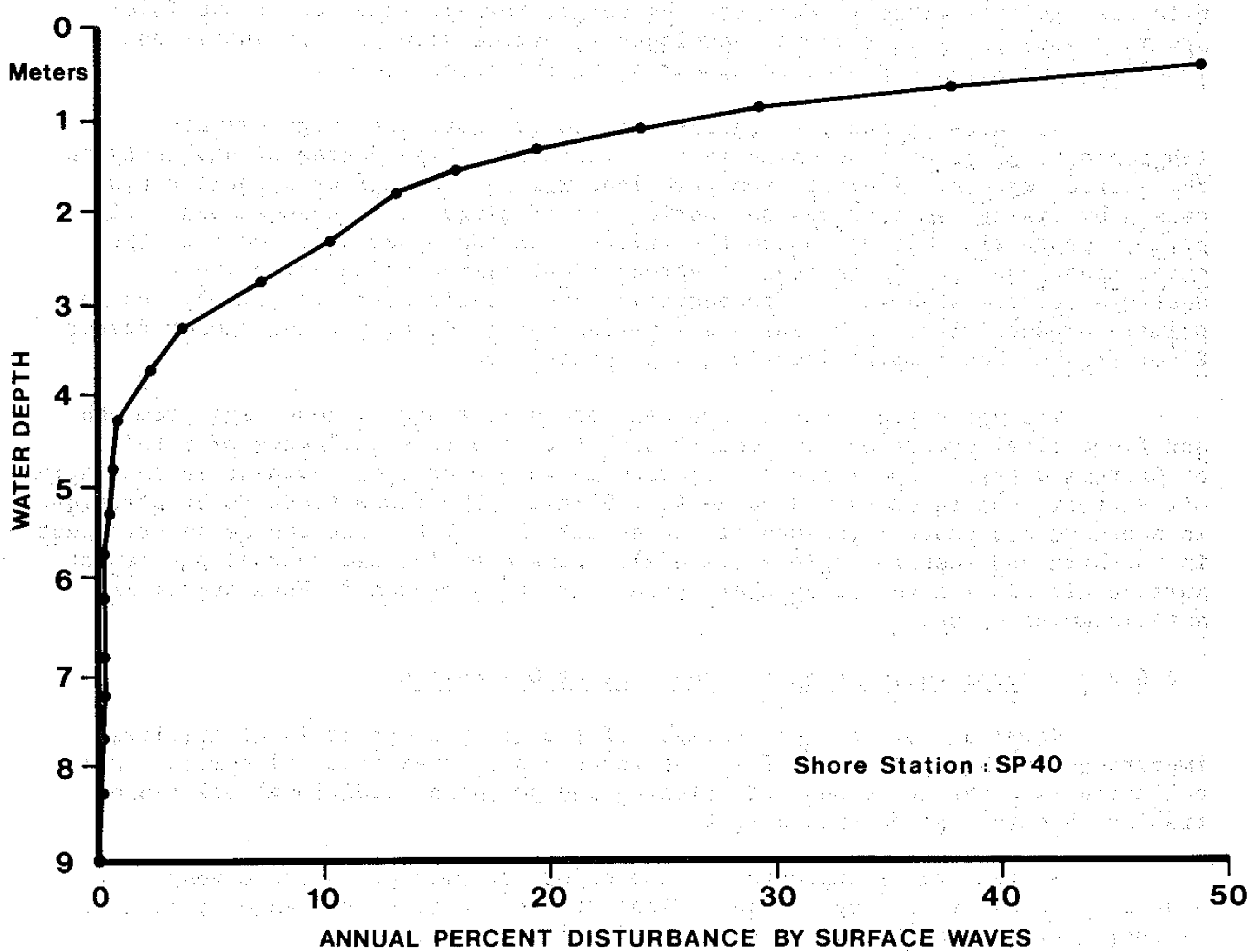
Station	SP01	SP02	SP04	SP05	SP07	SP09	SP10	SP11	SP13
Maximum Depth of Disturbance (m)	12.3	13.2	12.2	17.5	21.7	22.5	21.4	22.7	20.9
	SP19	SP21	SP22	SP33	SP40	SP43			
	7.6	7.8	8.6	8.1	8.1	7.6			

FIGURE 9 LOCATION OF SAMPLE STATIONS



Source: J.R. Harper, 1982. Geologic Applications of a Wave Climate Model with Examples from the Saanich Peninsula. Paper presented at Western Region Workshop, Associate Committee for Research on Shoreline Erosion and Sedimentation, Simon Fraser University.

FIGURE 10 ANNUAL PERCENT FREQUENCY OF BOTTOM SEDIMENT DISTURBANCE



Source: J.R. Harper, 1982. Geologic Applications of a Wave Climate Model with Examples from the Saanich Peninsula. Paper presented at Western Region Workshop, Associate Committee for Research on Shoreline Erosion and Sedimentation. Simon Fraser University.

4.6.2 CIRCULATION

4.6.2.1 Overall Patterns

The south coast is exposed to generally turbulent open coastal waters, having a small number of major inlets of fjord-like origins with relatively small river discharges at their heads. In one notable case, namely Saanich Inlet, the primary source of the estuarine structure of the surface waters is through the influx of brackish waters arriving from elsewhere (Cowichan and Fraser Rivers) - a so-called "negative" estuary. The remaining principal inlets; Victoria Harbour, the Gorge, Portage Inlet and Sooke Inlet are much smaller, with a poorly developed estuarine structure in summer and localized estuarine circulation appearing in the rainy season.

Resource productive regions tend to be those with high primary (phytoplankton) production which in turn requires a high degree of stability in the surface waters. Shelter from turbulent mixing and surface stratification caused by rising temperatures and spring runoff signal the seasonal onset of primary production blooms inside the inlets. On the other hand, most of the outer coastline lies in regions of strong tidal mixing which effectively destroys surface stability. Consequently, these regions are relatively low in primary productivity. Some surface layering may occur during the summer Fraser River freshet but remains localized and short-lived.

The net circulation of coastal waters is seaward, resulting from ebb and flood tidal excursions in concert with the estuarine influence of Strait of Georgia waters. Localized circulation gyres are at times evident in the region off Victoria and in eastern Juan de Fuca Strait. The flood tends to be strongest in southern and eastern regions of the strait (U.S.A.), the ebb being strongest in northern and western regions (Canada). Consequently, the overall pattern of surface circulation in the southern Strait of Georgia-Juan de Fuca system is anticlockwise or seaward.

4.6.2.2 Factor Influencing the Movement of Oil Spills

Knowledge of the oceanography of the coastal waters is of critical importance in the evaluation of marine resources at risk from oil spills. Oil pollution is a threat because of existing and potential additional oil tanker traffic through Juan de Fuca Strait.

Surface water currents are the major determinant in the movement of a spill when winds are negligible. Tidal currents affect the range of impact, depending at what state of the tide the spill occurred.

Wind-generated surface currents as well as direct effects of wind friction can also be critical factors in the movement of a spill. However, waves created by wind can also contribute to a lessening of impacts of the spill by increasing the attrition of oil by weathering processes - evaporation, emulsification or sinking.

Most probable impact zones following an oil spill in the Juan de Fuca Strait-Puget Sound system are provided by a recent report (Wolferstan, 1981). All or parts of the study area are likely to be impacted, depending on the location of the spill.

The most vulnerable habitats are those which occur in the most protected waters of estuaries and inlets where finer sediments and shallow waters support a wide variety of saltmarsh and estuarine marine life.

4.6.3 SEDIMENTATION

There is general agreement that nearshore sediments originate primarily from unconsolidated coastal bluffs within the study area. (Foster, 1976; Holden, 1979, 1980; Greer, 1979; and Clague and Bornhold, 1980).

Rates of sedimentation are unknown although Foster (1976) did an extensive survey of coastal recession. The rate of sediments available to littoral currents is influenced by such factors as wave action and texture of materials. Owens (1980) states that the presence of log debris in the upper tidal area stabilized underlying sediments.

Harper (1980) measured the seasonal volumes of materials removed and added within the sweep zone of waves for two areas - Juan de Fuca Strait from Whiffin Spit west to San Simon Point - and the Saanich Peninsula from Cordova Bay to Patricia Bay. For the Juan de Fuca study, net volumetric changes ranged from $-2.2\ m^3$ to $+13.2\ m^3$, while for the Saanich Peninsula area values ranged from $-20.2\ m^3$ to $+ 4.8\ m^3$.

4.6.4 ATMOSPHERIC MIXING

The following information is provided by Schaefer (1981). The capacity of the atmosphere to disperse airborne pollutants is determined by the combined effect of horizontal transport and vertical mixing. Horizontal transport is a function of wind speed and direction; vertical mixing is a function of the stability of the lower atmosphere. Conditions which inhibit vertical mixing and/or horizontal transport are ground based inversions and light surface winds.

An estimate of the seasonal frequency of persistent light winds (speeds less than 12 km/hour, is presented in Figure 11. These values are based on a Canadian study by Shaw, Hirt and Tilley (1972).

During fall and winter, stationary or slow moving high pressure centres produce significant light wind episodes with those persisting 48 hrs or more less common than those persisting only 24-47 hrs. Calms are most frequent in the hours around sunrise and sunset, when reversals in the land and sea breeze circulations take place. Persistent westerly inflow in Juan de Fuca Strait reduces the frequency of calm or persistent light winds during summer months.

Inversions prevent convective mixing and limit the vertical dispersal of pollutants. Inversions are most commonly caused by nocturnal cooling of the earth's surface. In such cases, afternoon heating normally restores convective mixing. In the study area, however, several factors lead to more persistent inversions which may last throughout the day. These include: overrunning warm air from more southerly parts of the Pacific Ocean, particularly in fall and winter; cooling effects of the sea breeze in late spring and summer; and the occasional presence of cold Arctic air from the mainland during winter months.

Estimates of the diurnal and seasonal percentage frequencies of ground-based inversions for the study are provided in Figure 12. Values are based on a national study by Munn, Tomlain, and Titus (1970), a regional study by Emslie (1979) and considerations of local factors. Considerable variation from the indicated values can be expected due to the local influences of water bodies and topography.

A measure of the dispersive capability of the lower atmosphere termed the ventilation coefficient can be calculated as the product of the height of the convectively mixed layer and the mean horizontal wind speed in that layer. Portelli's (1977) study of these factors indicates that, for the British Columbia coast, mean afternoon values of the ventilation coefficient peak sharply in spring (April), decline throughout the summer and persist at low levels during fall and winter. Problems of pollutant buildup are generally limited to periods of calm or light winds which coincide with persistent ground-based inversions. During the wet season, pollutants are partially removed from the lower atmosphere by rain.

4.6.5 SEISMICITY

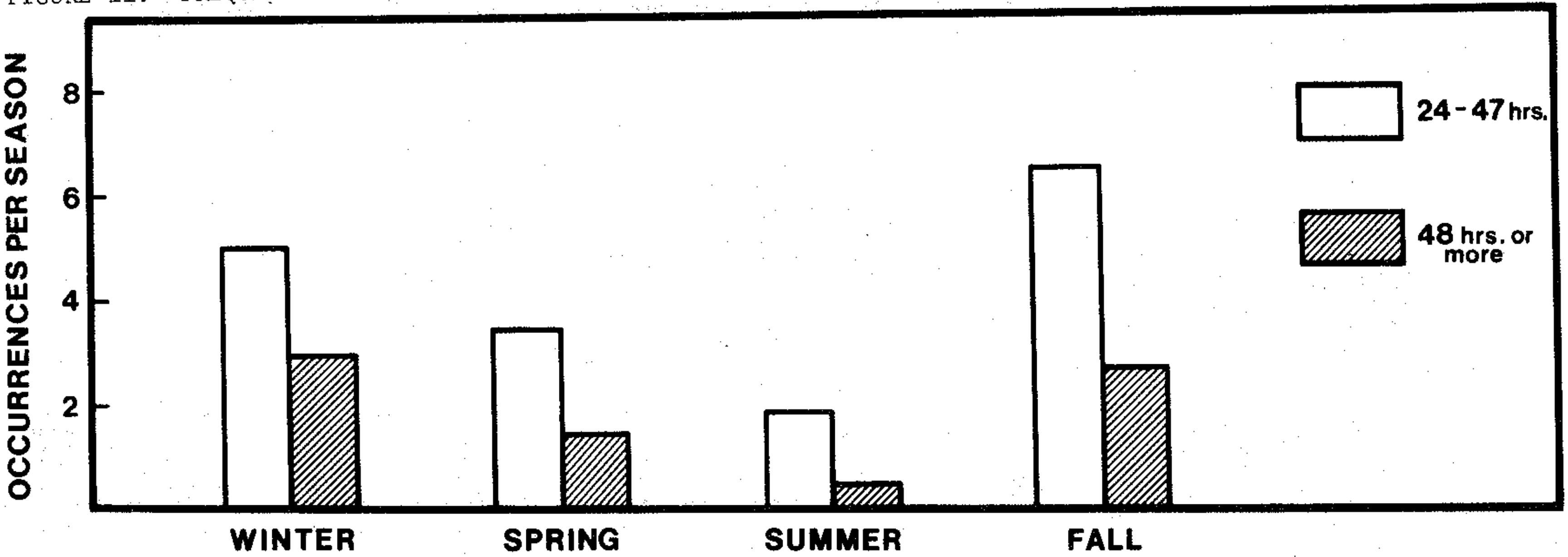
The B.C. coast has a 1 in 100 probability of an earthquake exceeding a horizontal acceleration of 6% of gravity. Horizontal acceleration is an accepted index of ground motion for engineering purposes. Witham and Milne (1972) note that earthquake damage is a function of earthquake magnitude, its depth of focus and mechanism, soil type, distance, and the quality of building construction.

4.6.5.1 Magnitude

A common measure of earthquake magnitude is the Richter system; earthquake intensities are also described by the Modified Mercalli scale. Table 20 provides a comparison of the two methods of measurement.

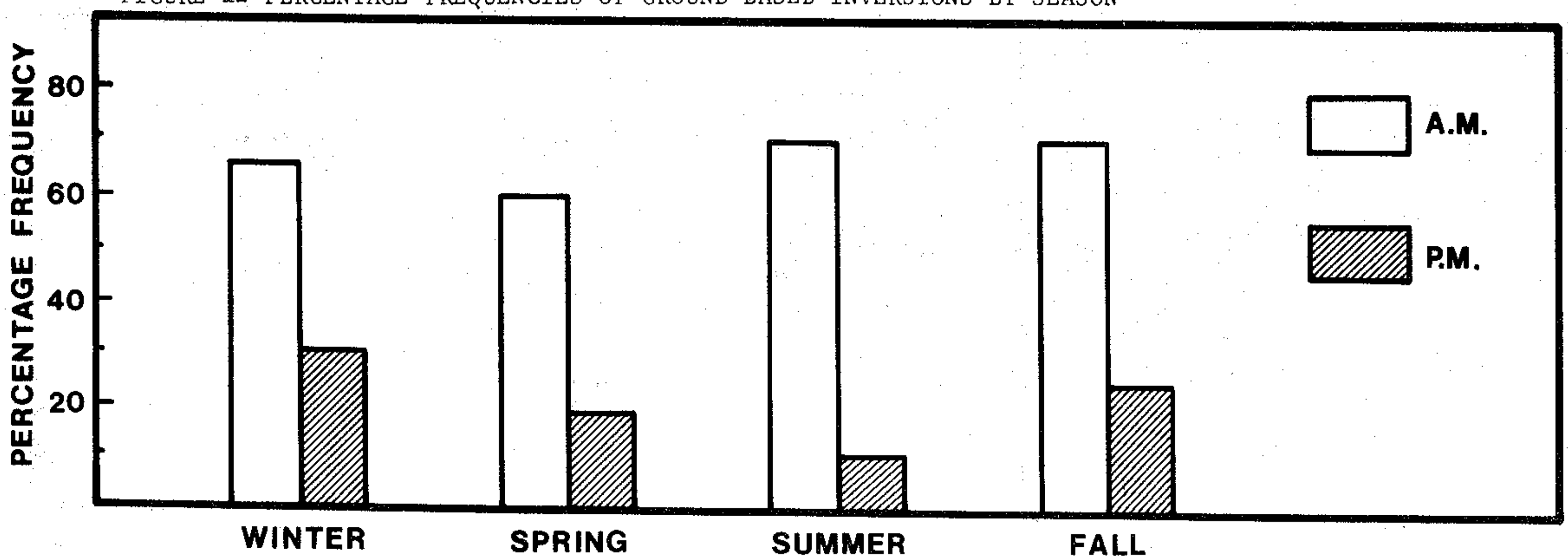
The threshold for significant damage during earthquakes is set at magnitude 5 on the Richter scale. Milne, Rigers, Riddihough, McMechan and Hyndman (1978) calculated a frequency of one in ten years for potentially damaging earthquakes. Figure 13 provides a comparison between the continental and

FIGURE 11. FREQUENCIES OF EPISODES OF PERSISTENT LIGHT SURFACE WINDS (SPEEDS LESS THAN 12KM/HOUR) BY SEASON



Source: R.W. Shaw, M.S. Hirt and M.A. Rilley, 1972. Persistence of light surface winds in Canada. Atmosphere 10(2): 33-43.

FIGURE 12 PERCENTAGE FREQUENCIES OF GROUND-BASED INVERSIONS BY SEASON



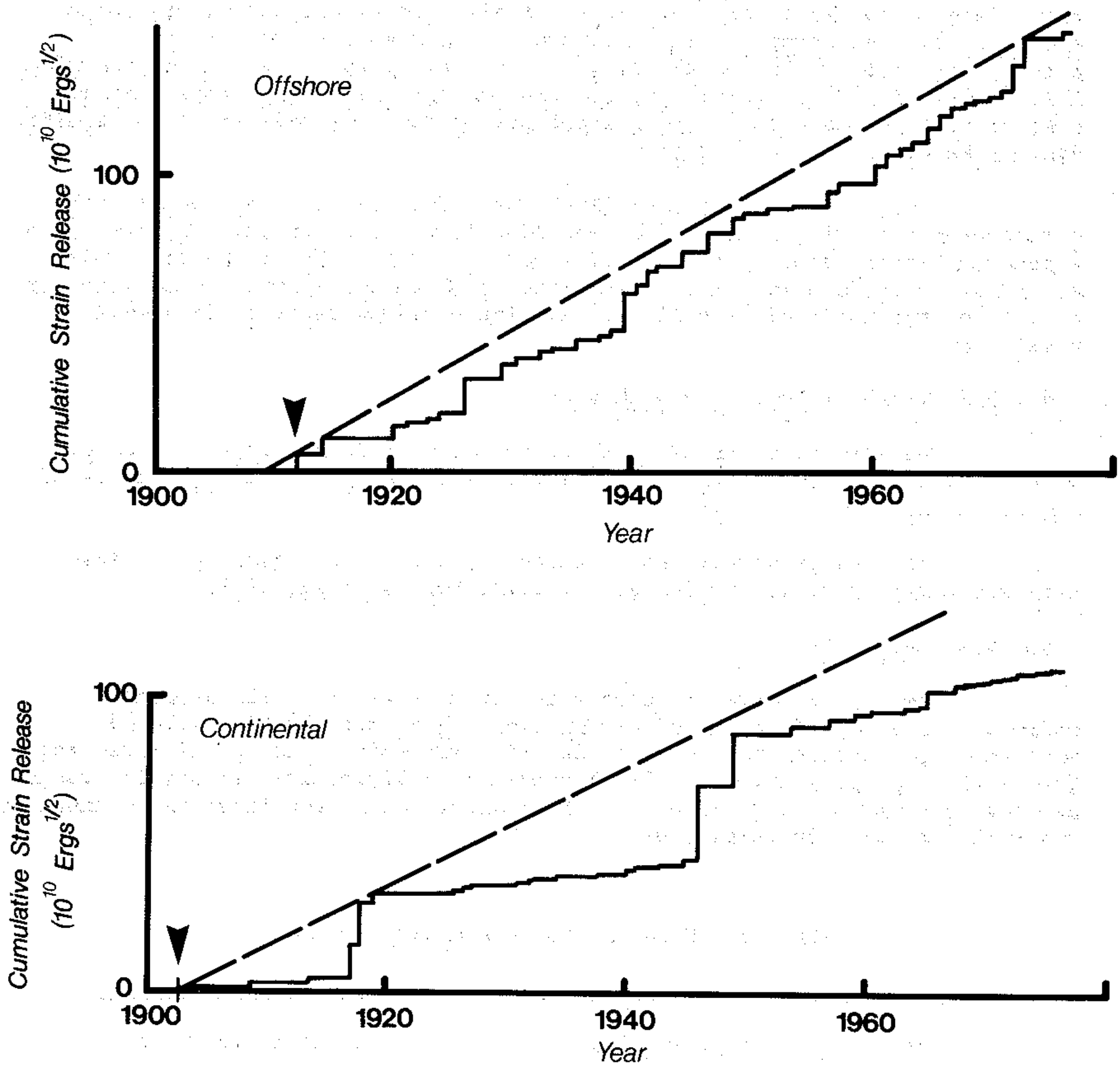
Source: R.E. Munn, J. Tomlain, and R.L. Titus, 1970. A Preliminary Climatology of ground-based Inversions in Canada. Atmosphere 8(2): 52-56.
J.H. Emslie, 1979. Ground-based inversions frequencies determined from surface climatological data. Boundary Layer Meteorology 16(4): 409-419.

TABLE 20 MODIFIED MERCALLI SCALE OF EARTHQUAKE INTENSITIES WITH CORRESPONDING RICHTER MAGNITUDES

Intensity (Modified Mercalli Scale)	Description of Characteristic Effects	Magnitude Approximately Corresponding to Highest Intensity Reached
I	Instrumental: detected only by seismography	
II	Feeble: noticed only by sensitive people	3.5 to 4.2
III	Slight: like the vibrations due to a passing heavy truck; felt by people at rest, especially on upper floors	
IV	Moderate: felt by people while walking; rocking of loose objects, including standing vehicles	4.3 to 4.8
V	Rather Strong: felt generally; most sleepers are woken and bells ring	
VI	Strong: trees sway and all suspended objects swing; damage by overturning and falling of loose objects	4.9 to 5.4
VII	Very Strong: general alarm, walls crack and plaster falls	5.5 to 6.1
VIII	Destructive: car drivers seriously disturbed; masonry fissured; chimneys fall; poorly constructed buildings damaged	6.2 to 6.9
IX	Ruinous: some houses collapse where ground begins to crack; pipes break open.	
X	Disastrous: ground cracks badly; many buildings destroyed and railway lines bent; landslides on steep slopes	7.0 to 7.3
XI	Very Disastrous: few buildings remain standing bridges destroyed; all services (railway, pipes, cables) out of action; great landslides and floods.	7.4 to 8.1
XII	Catastrophic: total destruction; objects thrown into air; ground rises and falls in waves	8.1+

Source: D. Maynard, 1979. Terrain Capability for Residential Settlements: Summary Report, Resource Analysis Branch, Victoria. 61 p.

Figure 13. STRAIN RELEASE AS A FUNCTION OF TIME



Source: Milne, W.G., G.C. Rogers, R.P. Riddihough, G.A. McMechan, and R.D. Hyndman, 1978. "Seismicity of Western Canada". Canadian Journal of Earth Sciences, vol. 15. pp.1170-1193.

offshore areas. Note that the offshore graph shows a relatively smooth slope with few large releases of strain. The continental area graph, however, shows large steps which are indicative of high strain release during large earthquakes. The straight lines represent an estimate of the strain accumulation rate (Milne et al, 1978). From this graph, the authors postulate that if the historical seismicity pattern for the continental area continues, a major part of the present accumulated strain could be released in a significant earthquake within the next decade.

A study cited in Foster (1976) by Milne and Davenport dealt with earthquakes occurring between 1899 and 1960 in western Canada. They assigned a peak horizontal acceleration of 10.7 percent gravity for Victoria. This would have a hundred-year return probability which corresponds to an intensity of VIII on the Modified Mercalli scale. These values refer to firm soil conditions.

4.6.5.2 Depth of Focus and Mechanism

The maximum recorded depth of earthquakes in the region is about 70 km. By comparison, depths of up to 700 km are common in similar areas of the world (Milne et al, 1978).

The primary mechanisms of earthquakes in this region are strike-slip and normal faulting (Milne et al, 1978; Rogers et al, 1978).

4.6.5.3 Soil Type

The type of material upon which structures are built directly influences the amplification of earthquakes. Wuorinen (1976) developed a seismic micro-zonation map for the Victoria area which consists of three zones (Table 21). By comparison, Table 22 provides amplification factors for various geological materials and represents the minimum design requirements recommended under the National Building Code.

TABLE 21 ZONES IN VICTORIA MICROZONATION

Zone	Related Ground Type	Intensity Increment
A	Bedrock within 3 metres	-1
B	Other than A or C	0
C	Fill or former swamp	+1

Source: V. Wuorinen, 1976. "Seismic microzonation of Victoria. A social response to risk. In: Victoria: Physical environment and development. Western Geographical Series, 12. University of Victoria, Victoria, B.C.

TABLE 22 SEISMIC AMPLIFICATION FACTORS FOR DIFFERENT GEOLOGICAL MATERIALS

TYPE AND DEPTH OF MATERIAL	AMPLIFICATION FACTOR
1. Rock, dense and very dense coarse-grained sediments, very stiff and hard fine-grained sediments, compact coarse-grained sediments and firm and stiff fine-grained sediments from 0 to 15 m deep	1.0
2. Compact coarse-grained sediments, firm and stiff fine-grained sediments with a depth of greater than 15 m; very loose coarse-grained sediments and very soft and soft fine-grained sediments from 0 to 15 m deep	1.3
3. Very loose and loose coarse-grained sediments and very soft and soft fine-grained sediments with depths greater than 15 m	1.5

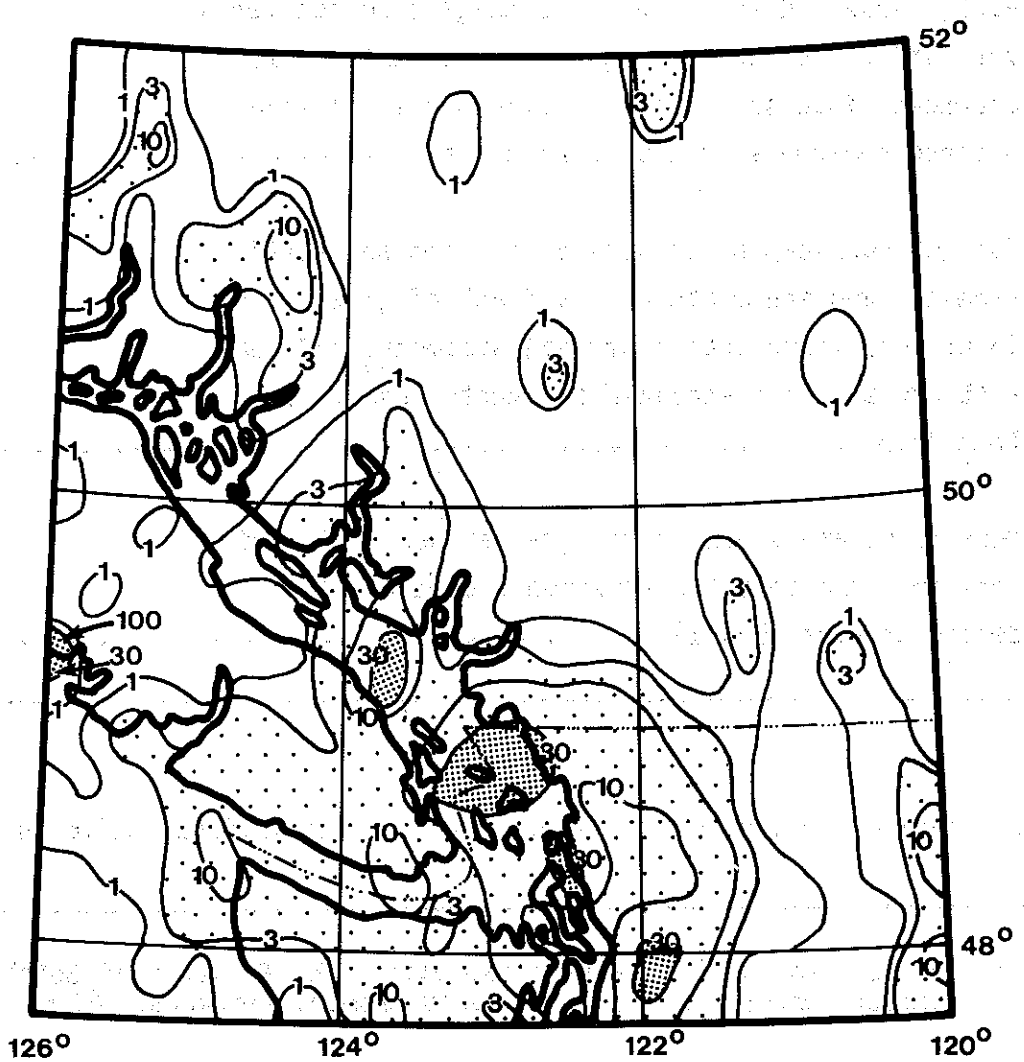
Note: Prepared by the Associate Committee of the National Building Code 1977b

Source: D. Maynard, 1979. Terrain Capability for Residential Settlements: Summary Report, Resource Analysis Branch, Victoria. 61 p.

4.6.5.4 Distance

Earthquake damage diminishes with distance from the epicentre (Whitman and Smith, 1970). Active faults in recent geological time are the San Juan and Leech River faults. Milne et al (1978) report that the more active earthquake areas correspond to the boundaries of major tectonic plates on the coast. The Strait of Georgia and Puget Sound are specifically influenced by the contact of the Juan de Fuca and America plates. Figure 14 shows the distribution of strain release for the continental area for the years 1951-1975. It shows that strain released since 1951 is concentrated in the Gulf Islands - Puget Sound area south of 49°. This led Milne et al (1970) to postulate that this is evidence of a tectonic feature in the area.

FIGURE 14 'CONTINENTAL' AREA REGIONAL DISTRIBUTION OF STRAIN RELEASE SINCE 1951



Note: Contours are equivalent number of magnitude 5 earthquakes per 100 years/100km^2.

Source: W.G. Milne, G.C. Rogers, R.P. Riddihough, G.A. McMechan and R.O. Hyndman, 1978. Seismicity of Western Canada. Canadian Journal of Earth Sciences. 15: 1170-1192.

4.6.5.5 Quality of Building Construction

Studies undertaken by Foster and Carey (1976) and Wuorinen (1976) for the Victoria area give accounts of the types of structures susceptible to earthquake damage. They also note that the severity of damage can be lessened or magnified by the type of foundation condition. Structures believed to be the most susceptible were unreinforced masonry and concrete structures, wood frame structures under four storeys with poor lateral force bracing at foundation level and most structures on poor foundation materials (Foster and Carey, 1978). In terms of Victoria, almost all of the Central Business District was considered to have the highest damage potential.

4.6.5.6 Secondary Effects

The secondary effects of earthquakes include tsunami and landslides. The probability of a damaging tsunami in the region is less than the probability of a damaging earthquake. The probability of landslides from seismic activity in the region is highest in areas of unconsolidated deposits and jointed bedrock. Steeply sloped coastal bluffs, and incised river valleys are most vulnerable to failure. Liquefaction of saturated, fine-grained sediments could also be hazardous in built-up areas.

4.7 FACTORS OF BIOLOGICAL PRODUCTIVITY

4.7.1 THE AREA

The southern shorezone of Vancouver Island offers a variety of landscapes, shore processes, and habitats. Geological processes and wave energy have modified the coastline to create a range of geomorphic forms, from low backshore with gently sloping sand beaches to vertical rock cliffs dropping deeply into the sea. Because of the size and configuration of the Straits of Georgia and Juan de Fuca, a range of energy environments exists.

A classification system that describes this environment and is complementary to that of Ricketts and Calvin (1968) would include (a) estuaries, (b) protected shorelines, (c) channels and protected inner coasts, and (d) unprotected coasts. Within these environments, differences in substrate, wave energy, and the physical/chemical environment are revealed by the differences in the indigenous biota.

4.7.2 THE PHYSICAL/CHEMICAL ENVIRONMENT

Water temperature, salinity, light penetration, and nutrient, and dissolved oxygen contents are major factors influencing primary production in the sea. Many of the physiological functions (i.e. reproduction, cell growth, respiration) of marine organisms are temperature regulated, occurring only within a narrow temperature range. Similarly, organisms that are unable to regulate their internal environment in response to changes within their external medium, must remain within a relatively narrow range of salinities for survival. Light penetration is necessary for photosynthesis by plants, and aids in determining the efficiency of "visual" predators. Nutrients are required by all marine life forms; and dissolved oxygen is, of course, necessary for respiration to occur.

Water temperatures within a column of seawater in the study area are relatively homogeneous during the winter, autumn, and spring. During the summer months, however, the upper layer of water - perhaps 30 m deep - becomes warmer as solar radiation increases. The resultant temperature gradient inhibits mixing with the deeper water by virtue of the density gradient that accompanies a temperature change. Mixing by wind action continues, however, within this upper layer, thus maintaining a relative uniform temperature within it.

The salinity of seawater varies with the quantity and rate of precipitation, evaporation, and river discharge. Precipitation and river discharge dilute marine surface waters, while evaporation increases the salinity. As fresh water is less dense than salt water, the salinity of the water column increases with depth. Also, the salinity of surface waters increases with increasing distance from river inflows.

The penetration of light into the water column is a function of turbidity. Turbidity results from suspended particulate matter and dissolved organic substances that scatter and absorb incident light. Coastal waters typically receive little light below 30 m.; the depth to which 1% light transmission occurs (which demarcates the lower limit of plant growth) is characteristically 10 m (Sumich, 1976).

The distribution of dissolved oxygen within surface waters is usually homogeneous because of wind-induced mixing. Minor variations may be evident. Dissolved oxygen concentrations in areas of good tidal exchange are normally adequate for all organisms.

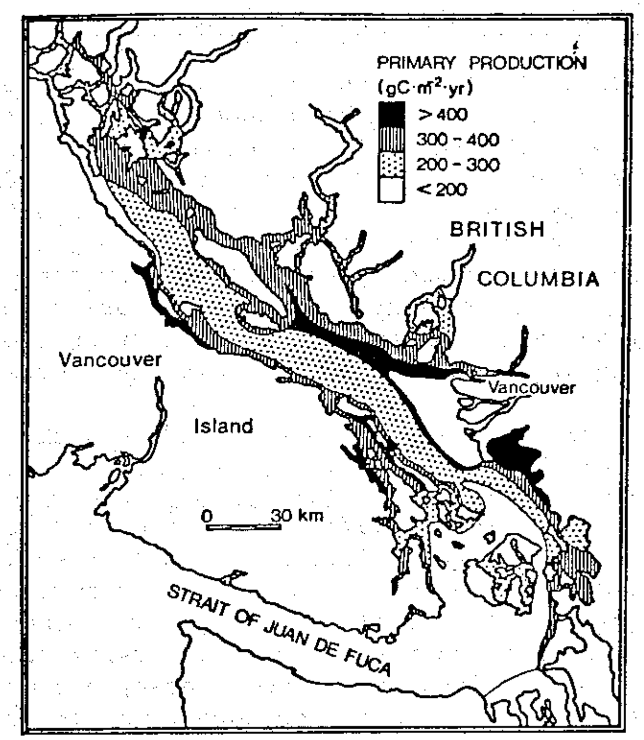
The availability of nutrients for growth within surface waters declines during the growing season as plant production increases. Regions of upwelling result in a replenishment of nutrients from the lower strata. River discharges and nutrient regeneration from shallow muds also contribute to the nutrient pool. Tidal and wind currents further redistribute nutrient rich water within the coastal zone.

4.7.3 PRIMARY PRODUCTION - PHYTOPLANKTON

Primary production is the creation of organic material from carbon dioxide, water, and nutrients at the expense of solar energy. Gross primary production refers to the total amount of organic material produced by photosynthesis; net primary production refers to the amount of organic material available to other levels of the food chain after losses to respiration, reproduction, and mortality are considered. Primary production is usually reported in grams of carbon fixed by photosynthesis within a square metre per unit of time (gC/m^2year).

Data relevant to the study area (Figure 15) reveal relatively high rates of primary productivity along the sheltered coastlines, but relatively low rates in exposed areas.

FIGURE 15 GENERALIZED PATTERN OF PRIMARY (PHYTOPLANKTON) PRODUCTION IN THE STRAIT OF GEORGIA



Source: J.G. Stockner, D.D. Cliff and K.R.S. Shortread, 1979. Phytoplankton Ecology of the Strait of Georgia, British Columbia. Journal of Fisheries Research Board of Canada. 36: 657-666.

With the exception of estuaries, the areas of highest productivity occur where temperature stratification is well developed, salinity is consistently high, and other factors of the physical/chemical environment, described earlier, are in abundant supply. Where this occurs, primary production is limited primarily by the grazing activities of organisms higher on the food web. When the supply of one or more factors exceeds the tolerance limits of phytoplankton species, however, growth of the individual and the population is curtailed. Primary productivity is also limited by the factor in least supply. Figure 16 illustrates the importance of each of the factors of growth in maintaining high productivity. For example, a reduction in the "quantity" of one factor (e.g. nutrients) results in diminished primary productivity which sequentially limits the energy transmitted to, and populations sustained at, higher levels of the food web. Simply stated, a low phytoplankton crop supports a low zooplankton crop which in turn supports fewer juvenile salmon.

4.7.4 PRIMARY PRODUCTION - SEAWEEDS AND SALTMARSHES

The productivity of seaweed and saltmarsh communities is impressive (Figure 17). Seaweed studies from Nova Scotia indicate that Laminaria longieururis on a rock substrate will produce up to 20 times the initial weight of the blade over a two-year period, even though 35 to 40% of the gross production is liberated as dissolved organic matter during the same period (Carefoot, 1977). Such high rates of production result from adequate temperature and light, and the constant provision of nutrients to the leaves by currents. In estuaries, detrital based eelgrass ecosystems are also highly productive. Their productivity derives from the interaction of numerous species that have evolved complex symbiotic relationships within these communities.

Estuaries are transitional areas, and as such, contain a significantly high proportion of brackish water - water of intermediate salinity. Numerous classifications of brackish water exist although a common standard is 0.2°/oo to 30.0°/oo (Remaine and Schlieper, 1971). Brackish water originates when salt water is mixed with fresh water. Particulate matter such as plankton, detritus, or sediment uplifted from the substrate by wave or current action, or discharged by rivers, will diminish light penetration and may reduce plant growth. Normally, brackish water is poor in species diversity relative to fresh and salt waters; however the populations of species present are usually larger (Remaine and Schlieper, 1971). For instance, the lowest number of species occurs at the 5-7°/oo salinity level (Figure 18). In addition, a smaller size is attained by organisms living in brackish conditions, although species that migrate to sea water (i.e. salmonids) generally attain rapid growth thereafter. An important seagrass in the ecology of estuaries is Zostera marina. It is acclimated to brackish water conditions and survives to the 3°/oo salt concentration level. The estuarine phase is an extremely important part of the life cycle for many organisms (i.e. salmonids, shrimp) as it prepares them for survival in the open sea.

FIGURE 16 - SCHEMATIC OF ENERGY TRANSFER BETWEEN TROPHIC LEVELS IN UNLIMITED (A) AND LIMITED (B) ECOSYSTEMS

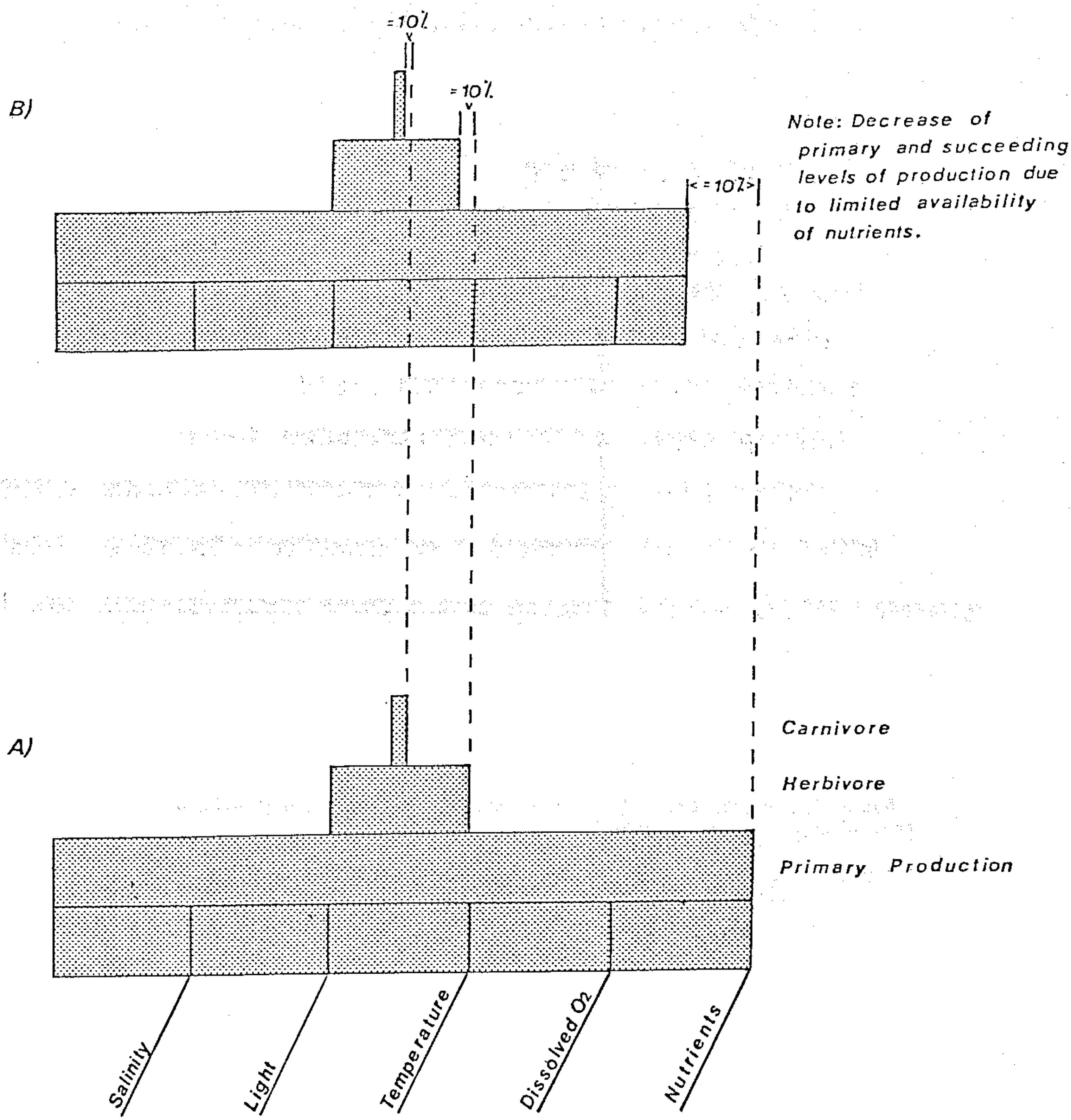
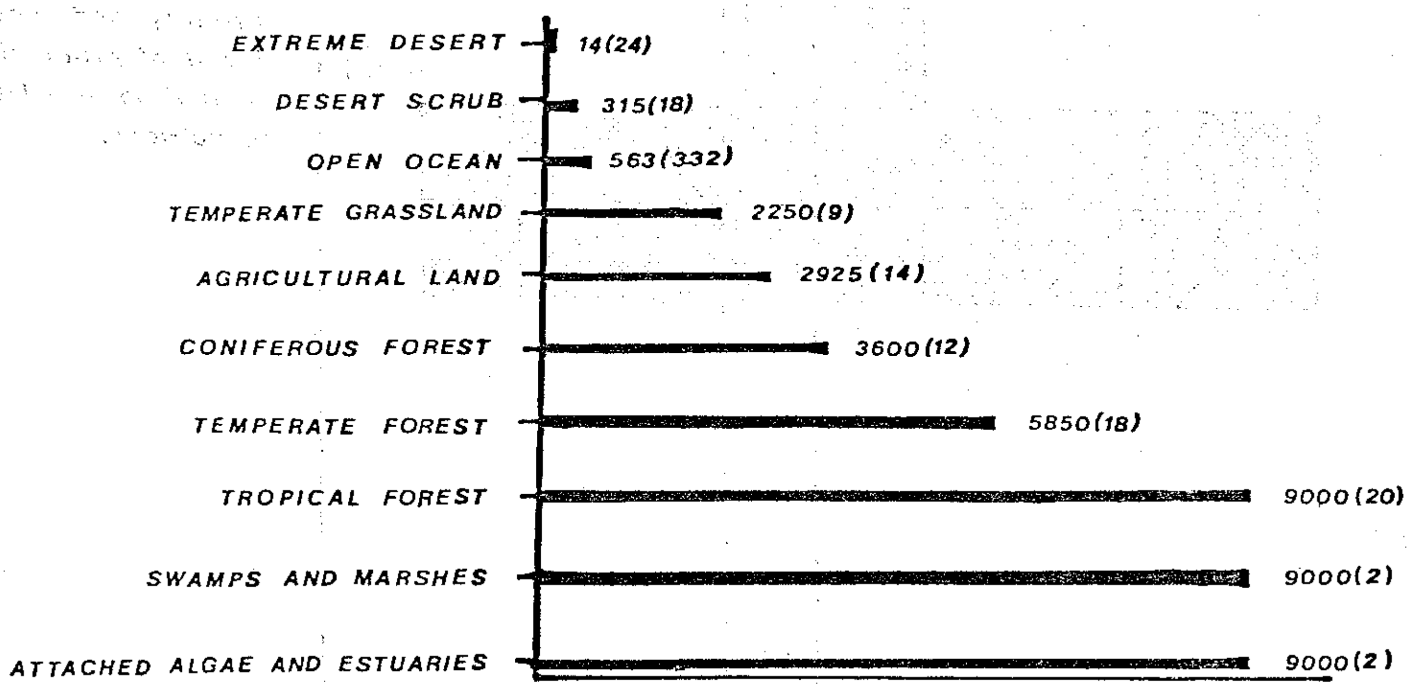


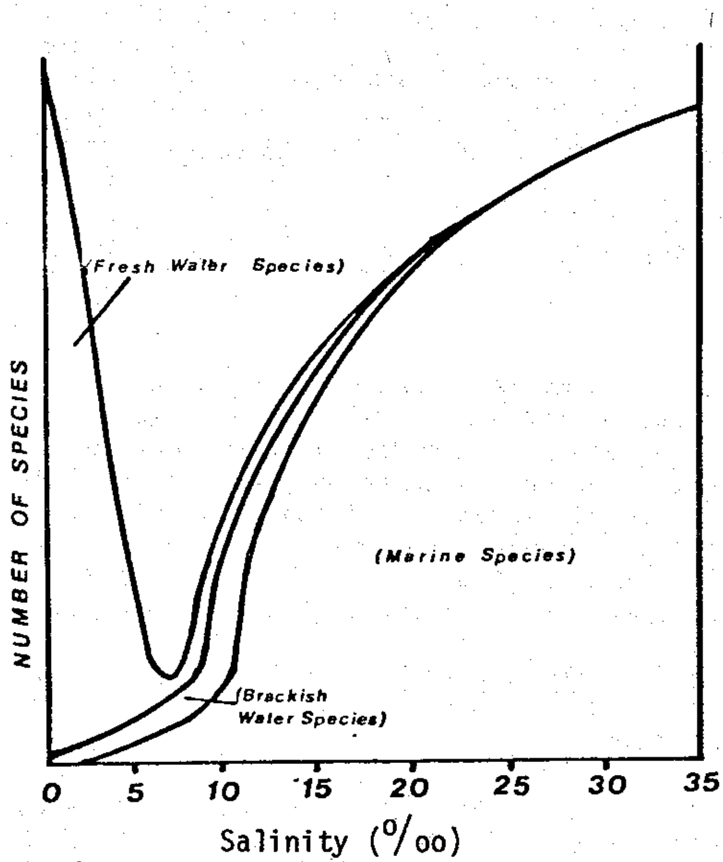
FIGURE 17 AVERAGE ANNUAL RATE OF NET PLANT PRODUCTION FOR SELECTED ECOSYSTEMS



Note: The number after the bar is Kcal/m^2/yr; the number within parenthese is area in $10^6 km^2$.

Source: Adopted from E.G. Kormandy, 1976. Concepts of Ecology, Prentice Hall Inc. New Jersey.

FIGURE 18: NUMBER OF SPECIES IN RELATION TO SALINITY LEVEL ($^{o}/oo$)



Source: A. Remaine, and C. Schlieper, 1971. Biology of Brackish Water. John Wiley and Sons, Inc.

The ecological importance of seaweeds and saltmarshes is documented in the literature (Perkins, 1974; Carefoot, 1977; Cushing and Walsh, 1976, and Harrison, 1980). Seaweeds provide food for grazers, shelter for numerous organisms including fish, and substrate for reproduction (e.g. herring spawn). Further, some seaweed and seagrass species are extremely important in nutrient cycling within coastal waters. By reducing water current velocities and wave shock, they allow nutrient-rich sediments and particulate matter to settle out, thus enriching the substrate for benthic fauna. Marshes are invaluable as nutrient reserves for estuaries, as upland mammal and reptile habitat, and as marine and shorebird habitat. Geese, widgeon, and pintails eat the saltmarsh plant Salicornia while eelgrass is an important food source for brant.

The economic importance of seaweeds are identified by Greenius (1967) and Carefoot (1977). The natural products of red and brown algae include agar, carrageen, and algin. They are used in a myriad of commercial products from food to soaps, paper products, and pharmaceuticals. The genera Gigartina, Iridaea, Nereocystis, Macroycystis, Gracilaria and Gracilariopsis are especially important for these purposes.

4.8 THE ADMINISTRATION AND MANAGEMENT OF COASTAL RESOURCES

4.8.1 INTRODUCTION

Numerous agencies administer and manage coastal resources. The Coastal Zone Resources Subcommittee publication (1978) identifies agency roles and responsibilities. In 1980 the Land Use Planning section of the Ministry of Lands, Parks and Housing prepared a discussion paper entitled "The Ministry of Lands, Parks and Housing's Role in Foreshore Administration". This document identifies agency mandates, planning programs, and responsibilities for foreshore administration. The publication "Land Use Law" by Ince (1977) provides an overview of the legislation governing land use in British Columbia.

4.8.2 THE ADMINISTRATION OF COASTAL LAND

4.8.2.1 Crown Land - Provincial

The Ministry of Lands, Parks and Housing is a key management and administrative agency in the coastal zone. The Ministry may transfer its management responsibility to other provincial agencies (i.e. Marine Resources Branch) that indicate their particular interest in an area or a resource (i.e. oyster growing areas). The Ministry remains, however, the authority for the issuance of foreshore leases.

The application process for foreshore leases varies according to the type of lease, and the area in which it is located. Log storage lease applications undergo a complex review process through various levels of government (Ministry of Lands, Parks and Housing, 1980). On the other hand, a commercial foreshore lease application may obtain approval at a regional office the same day it is submitted. In areas where management committees and a management plan exist, individual lease applications are reviewed for conformity.

In terms of foreshore regulation the Ministry of Lands, Parks and Housing monitors and enforces its own policies be it a trespass on Crown foreshore or fulfillment of terms and conditions of a foreshore lease. The Ministry is also responsible for area management plans; an example of such a plan is the Sooke Harbour and Basin Crown Foreshore Plan (Ministry of Lands, Parks and Housing, 1980).

While the Ministry of Lands, Parks, and Housing is the primary agency with responsibilities in the coastal zone, direct responsibilities are also held by the Ministries of Environment, Forests, Energy, Mines and Petroleum Resources, and Transportation and Highways.

4.8.2.2 Crown Lands - Federal

The Small Craft Harbours Branch of the Department of Fisheries and Oceans controls and administers wharves and piers constructed on federal property or with federal funds. The Canadian Wildlife Service may establish reserves for migratory birds. Transport Canada administers public harbours and navigation facilities. The Department of National Defence administers military reserves.

Under the Indian Act, the band Council, the Cabinet and the federal government (Department of Indian and Northern Affairs) are responsible for land use on Indian Reserves. While the Council may divide the reserve into zones of permitted use, the federal cabinet exercises ultimate control in major land use decisions.

4.8.2.3 Private and Other Public Lands

The Regional Parks Act of 1965 allows the regional districts to acquire, develop and manage regional parks. The Capital Regional District has acquired ten regional parks in the study area, ranging in size from Cole's Bay Park (3.7 hectares) to East Sooke Park (1 423 hectares) (Forward, 1979).

Tree farms are privately owned land. The owner agrees to follow good forest management practices, in return for which the land is valued by the B.C. Assessment Authority on the basis of the harvest yields predicted from an approved plan of forest management.

Timberland refers to those forest lands where fee-simple ownership is held by forest companies. There are no cut stipulations. Such lands were obtained through Crown grants made early in the history of the province. Ownership of this type of forest land provides greater freedom to the owner to use and develop the land and forest resources than is the case with Crown forest tenure.

A tree farm licence is an amalgamation of Crown and private lands formed under an agreement between the Crown and the owner to combine private lands with unencumbered Crown land to form self-contained sustained yield management units. This combination of lands allow for efficient forest management practices which otherwise would not be possible with divided ownership.

Private lands are recorded on the B.C. Assessment Authority's taxation assessment rolls. The lots, their area and boundaries, are recorded on cadastral maps.

4.8.3 WATER MANAGEMENT

4.8.3.1 Water Supply and Licencing

4.8.3.1.1 Federal Responsibilities

Major federal legislation dealing with water supply includes the Canada Water Act and the Fisheries Act. The Canada Water Act permits the federal government to operate a network of streamflow, water level, and sediment stations, to develop flood damage reduction programs, to undertake flood control measures, to undertake shoreline and water resource management programs, and to conduct research on surface and groundwater hydrology. The Fisheries Act allows the Department of Fisheries and Oceans to influence flow regimes of regulated rivers in order to protect the migration and spawning habitat of salmon stocks.

4.8.3.1.2 Provincial Responsibilities

The Ministry of Environment manages freshwater supplies by controlling the issuance of water licences, conducts ground and surface water research, and engages in river and flood control programs. Under the Municipal Act, local and regional administrations are responsible for water supply and distribution functions.

The right to withdraw and use surface water in the province is granted by water licence. Water licences are issued by the Ministry of Environment, Water Management Branch, for domestic, waterworks, mineral trading, irrigation, mining, industrial power generation, hydraulicking, storage, conservation, fluming, conveying and land improvement purposes. Within the study region, domestic, waterworks, irrigation, industrial power generation, and conservation purposes require major allocations of fresh water. Water licences have precedence according to the date of issuance so that in low flow situations some users may be denied their allocation. Currently, groundwater may be diverted without licence.

Studies of watershed characteristics upon which to determine optimal patterns of development and resource allocations are not yet available. Streams can be licenced for diversions in excess of the recorded minimum daily discharge. Although not all users divert the maximum licenced quantities, it is possible that under extreme conditions, shortfalls in water supplies could result for some users.

An interagency referral system currently used in British Columbia is designed to account for the stream resource flow requirements of all users in order to avoid conflicts, or situations where users are lost. For instance, for the survival, migration, and spawning of fish, a certain discharge is required. Spawning habitat increases or decreases with greater or lesser flows:

migration is restricted or blocked at extremely high or low flows; and survival is possible only at certain water temperatures which, in small streams, depends greatly on the discharge. Similarly, recreational use (e.g. canoeing) is possible only within a given range of discharges.

4.5.3.2 Water Quality and Waste Management

Water quality comes under the purview of the provincial and federal governments. While numerous acts deal with specific environmental issues, only the major legislation is reviewed here.

4.8.3.2.1 Federal Legislation

The Canada Water Act and the Fisheries Act are important federal statutes. Under the provisions of the Canada Water Act, the federal government sets national effluent standards and co-operates with the provinces in controlling pollution of specified water bodies. Part one of the Act allows the federal government (on federally owned water bodies) or the federal and provincial governments, to designate a water body as a water management area, thus bringing into force regulations against effluent discharges. Part two of the Act deals with the problem of eutrophication by regulating the concentration of nutrients in cleaning agents that are imported into Canada. The Fisheries Act prohibits the discharge of deleterious substances in any waters frequented by fish. This includes logging debris, obstacles to migration, and activities within the watershed that lead to erosion, stream siltation, or the loss of fish, fish eggs, and other marine organisms.

The Canada Shipping Act and the Ocean Dumping Control Act are important statutes, respectively regulating pollutant discharges from ships and the dumping of substances into marine waters.

4.8.3.2.2 Provincial Legislation

The Pollution Control Act prohibits the direct or indirect discharge of contaminants into any water body without a permit. A referral system requires the Comptroller of Water Righrs, the Ministry of Agriculture, and the Ministry of Health, to be notified and sent copies of applications to discharge wastes. The federal Department of Fisheries and Oceans usually co-operates in the setting of terms or permits in order to protect fishery concerns. Pollution control objectives are published for forest products, municipal discharges, food processing, mining, and chemical and petroleum products. They are used primarily as guidelines and have minimal legal force. Landfill sites are also regulated by permit.

The Health Act establishes local Boards of Health comprised of the municipal council. The boards have relatively wide powers to deal with nuisances that relate to public health. An official notice to terminate a nuisance is required before action can be taken under the Act. The discretionary power is held by the Minister and the local board. The Municipal Act deals with nuisances that may not directly involve the public health.

4.8.4 LOCAL PLANNING

Local governments, i.e. regional districts and municipalities, may regulate the use of the foreshore by designating waterfront zones. The

Corporation of the District of Central Saanich, the Cowichan Valley Regional District, the Corporation of the District of Oak Bay, the District of North Saanich and the Town of Sidney have adopted such zones.

Another means of controlling waterfront development is through the establishment of development control areas. These areas are established to ensure that special precautions and/or protection are provided. Development control areas are based upon Section 717 (Development Permits) of the Municipal Act which states in part that "Permits may require the preservation or dedication of natural water courses and the construction of works to preserve and beautify them in accordance with the terms and conditions specified in the permit and require that an area of land specified in the permit above the natural boundary of streams, rivers, lakes or the ocean remain free of development except as specified in the permit". (Province of British Columbia, 1980).

In the formulation of regional, settlement and community plans, local governments provide policies and measures to protect or conserve sensitive environmental areas. The Coastal Resources Folio Land/Water Use and Status Tables section, Plans and Proposals, provide a listing of existing land use plans for the study area. The following, however, is a brief account of selected local governments' coastal zone management efforts.

4.8.4.1 Capital Regional District

The Capital Regional District has developed management policies for the Western Community and Metchosin coastal areas. These policies will eventually be incorporated into a Regional Shoreland Management Plan (Donnelly, 1982 pers. comm.).

A Capital Regional District pilot study is currently determining the feasibility of a computerized coastal zone data base. The data base is intended to provide shore zone information in a form suitable for both short-term decision-making such as the processing of development applications, as well as for long-range planning - that is, regional settlement and community plans.

4.8.4.1.1 The Western Community

The Western Community Settlement Plan provides special protective measures for areas of inherent environmental sensitivity. These areas are designated either environmental conservation or environmental assessment areas. Conservation areas are either uplands that have poor drainage, unstable soils, steep slopes or rare biotic communities or marine shorelands (rocky shores, beaches, and lagoons). The plan permits only those uses which will not interfere with natural environmental processes. Management strategies, guidelines and protective measures are provided for each type (Capital Regional District, 1979). Environmental assessment area designations may apply to lands that have a "high capability for supporting fish or wildlife populations, rare plant communities, hillsides, high hydrological significance, archaeological sites and significant recreational value: and which " may be adversely affected by excavation, the placing or dumping of fill, the construction of buildings or structures or areas with potential air pollution problems" (Capital Retional District, 1979).

4.8.4.1.2 Metchosin

The Metchosin Settlement Plan also prescribes protective measures for such sensitive environmental areas as lakes, creeks and streams, inland wetlands, marine shorelands, wildlife habitat, unique vegetation, unstable soils, lands with erosion potential, and historic man-made environments such as archaeological sites. (Capital Regional District, 1979). Protective measures for sensitive environmental areas include the option of requesting an environmental impact assessment of proposed developments of th se areas considered "against the public interest".

4.8.4.2 Saanich

The District of Saanich has formulated shoreland conservation and recreation policy and protection recommendations. These recommendations request that provisions be established under the Municipal Act to protect coastal areas from degradation and alienation. Further, site specific protective measures for the various shorezone units are recommended, including: restoration and protection of shoreline; prevention of further disturbance to estuarine eco-systems; clearance and rehabilitation of public beach access; protection of habitat for rare and endangered bird life; prevention of cutting of timber and clearing of land; the establishment of ecological reserves, control of pollution, visual protection and the prevention of interference with the backshore. (Slater, 1978).

These recommendations are incorportated in the Saanich Community Plan which also designates all marine shoreline as conservation areas (District of Saanich, 1979).

This report is only part of the documentation available: Other sections of the Coastal Resources Folio; South Coast of Vancouver Island (Hatch Point to Ledingham Creek) British Columbia include Introduction, Coastal Resources Map Series (1:50,000), Land/Water Use and Status Tables, and Sources.

SECTION 5: SOURCES

PREPARED BY

D.A. Wolff
M.W. Dunn
D.M. Moore
T.J. Summers

COMPILED BY

M.J. Romaine
S.W. Dane

EDITED BY

M.J. Romaine
E. Novosel

LANDS DIRECTORATE
ENVIRONMENT CANADA
VANCOUVER, B.C.

December, 1982

TABLE OF CONTENTS

		Page
5.1	INTRODUCTION	1
5.2	COASTAL RESOURCES MAP SERIES (1:50,000)	1
5.2.1	Marine Sediments	1
	Reports, Maps and Surveys	1
	Personal Communications (1981)	3
5.2.2	Physical Shorezone	3
	Reports, Maps and Surveys	3
	Aerial Photographs	5
	Video Tapes (3/4")	5
5.2.3	Generalized Terrain Limitations	6
	Reports, Maps and Surveys	6
	Fault Lines	7
5.2.4	Oceanography - Temperature and Salinity	7
	Reports and Surveys	7
5.2.5	Water Resources: Discharge, Use and Contamination	9
	River Discharges	9
	Water Licences	9
	Marine/River Outfalls and Landfill Sites	9
	Shellfish Sanitary Surveys	9
	Shellfish Closure Areas	9
	Personal Communications (1981)	9
5.2.6	Seaweeds, Saltmarshes, Sand Dune Ecology and Marine Mammals	10
	Marine Vegetation	10
	Marine Mammals	10
	Saltmarshes and Sand Dune Ecology	10
	Personal Communication (1981)	10
5.2.7	Marine Bird Surveys	10
	Waterfowl Surveys	10
	Bald Eagle Survey	10
	Critical Marine Bird Rookeries	10
	Personal Communications (1981)	11

Page

5.2.8 Fish and Shellfish Resources 11

Personal Communications (1981) 11

5.2.9 Generalized Zoning and Marine Facilities 11

Zoning and Marine Facilities 11
Marine Parks 11
Ports 11

5.2.10 Land/Water Use Plans and Proposals 12

Land Use Plans 12
Agricultural Land Reserves 12
Proposals 12

5.2.11 Selected Administrative Boundaries 12

5.2.12 Land/Water Status 12

5.2.13 Recreational Areas, Special Features and Access 12

Parks and Reserves 12
Ecological Reserves 13
Wildlife Areas 13
Archaeological Sites 13
Recreational Shellfishing Areas 13
Hiking Trails 13
Anchorages 13
Scuba Diving Site 14
Shoreline Process Features 14
Recreation Areas and Activities 14
Beaches 14
Public Access 14
Related Readings 14
Personal Communication (1981) 15

5.3 LAND/WATER USE AND STATUS TABLES 15

5.3.1 Regional and Local Zoning 15

Regional Districts 15
Municipalities 15

5.3.2 Marinas, Bulk Oil Storage Facilities and Sewage Systems and Treatment 16

Marinas 16
Bulk Storage Facilities 16

		Page
5.3.3	Land Use Plans and Proposals	16
	Regional Districts	16
	Municipalities	17
5.3.4	Heavy Industrial Zones	17
5.3.5	Land and Water Status	17
	Provincial Crown Land	17
	Federal Crown Land	18
	Alienated Land	18
5.4	COMPANION REPORT	19
5.4.1	The South Coast Economy	19
	Personal Communications (1982)	20
5.4.2	General Physical Features	20
5.4.2.1	Physiography	20
5.4.2.2	Geology	21
5.4.2.3	Soils	22
5.4.2.4	Climate	22
5.4.2.5	Physical Oceanography	22
5.4.2.6	Water Resources	23
5.4.3	Biological Resources	23
5.4.3.1	Terrestrial Vegetation	23
5.4.3.2	Seaweeds and Saltmarshes	24
5.4.3.3	Marine Mammals	24
5.4.3.4	Marine Birds	24
	Personal Communication (1981)	27
5.4.3.5	Fish and Shellfish Resources	27
5.4.3.5.1	Fisheries (finfish)	27

Page

5.4.3.5.1.1 Salmonids 27

5.4.3.5.1.2 Groundfish 29

5.4.3.5.1.3 Other Finfish 30

5.4.3.5.2 Shellfish 31

5.4.3.5.3 Species Names 32

5.4.4 Recreational Resources 32

5.4.5 Physical Processes and Energy 35

5.4.5.1 Regional Wave Climate 35

5.4.5.2 Circulation 37

5.4.5.3 Sedimentation 37

5.4.5.4 Atmospheric Mixing 37

Personal Communication (1981) 38

5.4.5.5 Seismicity 38

5.4.5.6 Factors of Biological Productivity 39

Personal Communication (1981) 40

5.4.5.7 The Administration and Management of Coastal Resources 40

Personal Communication (1982) 42

5.1 INTRODUCTION

Coastal Zone Resource Subcommittee.
1978: The management of coastal resources in British Columbia. Vol. 1: State-of-the Art. Prepared for the B.C. Land Resources Steering Committee. Fisheries and Environment Canada, Lands Directorate, Vancouver, B.C. Mimeographed.

Environment Canada, Lands Directorate.
1981: Coastal Resources Folio; east coast of Vancouver Island (Race Point to Hatch Point and adjacent islands) British Columbia. 2 vols. Vancouver, B.C.

5.2 COASTAL RESOURCES MAP SERIES (1:50,000)

5.2.1 Marine Sediments

Reports, Maps and Surveys

Anderson, F.E.
1967: Stratigraphy of late Pleistocene and Holocene sediments from the Strait of Juan de Fuca. University of Washington, Seattle, Wash. Ph.D. thesis.

Bornhold, B.D.; Clague, J.J. and Bell-Irving, R.
1980: Reconnaissance coastal geology - eastern Vancouver Island. 1:50,000 maps for Sooke, Victoria and Sidney. Energy, Mines and Resources Canada, Geological Survey of Canada, Vancouver, B.C.

Canada, Department of Energy, Mines and Resources, Geological Survey of Canada, Pacific Geoscience Centre.
n.d.: Sediment sample data file. Victoria, B.C.

Cockbain, A.E.
1963: Distribution of sediments on the continental shelf off the southern British Columbia coast. Manuscript Report 15. University of British Columbia, Institute of Oceanography, Vancouver, B.C.

Environment Canada, Environmental Protection Service.
1976: Oil and chemical spill countermeasures series: Physical base, land and water use. 1:50,000 map sheets for Jordan River, San Juan, Sooke and Victoria. Vancouver, B.C.

Fisheries and Oceans Canada, Institute of Ocean Sciences, Canadian Hydrographic Services.
Hydrographic charts. Ottawa, Ont.

1973: 3310: Sheets 1 and 2 Marine Sciences Directorate

1978: 3422: Race Rocks to Discovery Island, 1:40,000
3430: Plans Juan de Fuca, various scales
3448: Juan de Fuca Strait, Eastern Portion, 1:80,000
3607: Juan de Fuca Strait, 1:58,088

Hydrographic charts. (Contd.)

1979: 3415: Victoria Harbour, 1:6,000
3417: Esquimalt Harbour, 1:8,000
3452: Haro Strait to Stuart Channel, 1:40,000
3455: Sidney to Swartz Bay, 1:12,000

1980: 3423: Trial Island to Cadboro Bay, 1:12,000

Available from: Institute of Ocean Sciences, Sidney, B.C.

Gardner, R.H.
1976: Bibliography of marine geoscience information, Pacific regions of Canada. Canada, Department of Energy, Mines and Resources, Geological Survey of Canada, Ottawa, Ont. Unpublished.

Goddard, J.M.; King, P.M. and Frewing, T.
1971: Report of the Victoria District sea-bed survey; Opportunities for Youth summer project. Secretary of State Canada, Ottawa, Ont;

Herzer, R.H. and Bornhold, B.D.
1981: Surficial sediments on the continental shelf; southwestern Vancouver Island. Open file 782. Energy, Mines and Resources Canada, Geological Survey of Canada, Pacific Geoscience Centre, Victoria, B.C.

Holden, B.J.
1979: Whiffin Spit. B.C. Ministry of Lands, Parks and Housing, Victoria, B.C.

1980: Sidney Spit: An investigation of erosion. B.C. Ministry of Lands, Parks and Housing, Victoria, B.C.

Madill, J.W.; MacFarlane, W.T. and Baudat, C.
1978: A study of sediment distribution in Esquimalt Harbour. Coastal Marine Science Laboratory Report 78-4. Royal Roads Military College, Victoria, B.C. Unpublished.

Matthews, W.H. and Murray, J.W.
1966: Recent sediments and their environment of deposition; Strait of Georgia and Fraser River Delta: A manual for field conferences. Tenneco Oil and Minerals, Ltd., Calgary, Alta.

Mayers, I.R. and Bennett, L.C., Jr.
1973: Geology of the Strait of Juan de Fuca. Marine Geology 15: 89-117.

Milliman, J.D.
1976: Sand and gravel deposits off southwestern Vancouver Island, British Columbia. In: Report of Activities, part A. Paper 76-1. Geological Survey of Canada, Ottawa, Ont. p. 23-26.

Schurer, P.J. and MacFarlane, W.T.
1980: Investigation of shallow water sediments offshore from Vancouver Island. In: Canadian Coastal Conference, 1980 Proceedings. National Research Council, Ottawa, Ont.

Schurer, P.J.; MacFarlane, W.T. and Duffus, H.J.
1979: Sub-bottom surveys of harbours near Victoria, B.C. Coastal Marine Science Laboratory Report 79-8. Royal Roads Military College, Victoria, B.C. Unpublished.

Staal, I.M.
1980: Hindsight evaluation of the Mount Douglas Park bank stabilization program. University of Waterloo, Faculty of Environmental Studies, Waterloo, Ont. B.E.S. thesis.

University of British Columbia, Institute of Oceanography.
1962: Sediment grain-size analyses, 1960/61. Data Report 20. Vancouver, B.C.

Waldichuk, M.
1953: Character of the bottom. Vol. 3: Oceanography of the Strait of Georgia. Progress Report 95. Fisheries Research Board of Canada. p. 59-63. Available for reference in Canada, Department of Fisheries and Oceans libraries.

Personal Communications (1981)

Bornhold, B.D.)
Luternauer, J.) Geological Survey of Canada, Pacific Geoscience
McLaren, P.) Centre, Victoria, B.C.
Pickrill, R.)

5.2.2 Physical Shorezone

Reports, Maps and Surveys

Bauer, W.
1976: Western Community: Marine shore resource analysis. Capital Regional District, Victoria, B.C.

Bornhold, B.D.; Clague, J.J. and Bell-Irving, R.
1980: Reconnaissance coastal geology - eastern Vancouver Island. 1:50,000 maps for Sooke, Victoria and Sidney. Energy, Mines and Resources Canada, Geological Survey of Canada, Vancouver, B.C.

Brown, D.W. and Baird, W.F.
1980: The use of wave energy to predict the effects of changes in Great Lakes water levels on shore erosion. In: Canadian Coastal Conference, 1980 Proceedings. National Research Council, Ottawa, Ont. p. 165-184.

Clague, J.J. and Bornhold, B.D.
1980: Morphology and littoral processes of the Pacific Coast of Canada. In: The Coastline of Canada: Littoral processes and shore morphology. Paper 80-10. Geological Survey of Canada, Ottawa, Ont. p. 339-380.

Eis, S. and Craigdallie, D.
1980: Shore and landscape analysis of the western section of the Capital Regional District of British Columbia. Report BC-X-208. Environment Canada, Canadian Forestry Service, Victoria, B.C.

Environment Canada, Environmental Protection Service.
1976: Oil and chemical spill countermeasures series: Physical base, land and water use. 1:50,000 map sheets for Jordan River, San Juan, Sooke and Victoria. Vancouver, B.C.

Foster, H.D.
1976: Coastal erosion: A natural hazard of the Saanich Peninsula, Vancouver Island. In: Victoria: Physical environment and development. Western Geographical Series 12. University of Victoria, Victoria, B.C. p. 101-184.

Gillies, R.D.
n.d.: Morphodynamics and sediments of Victoria City beaches. Pacific Geoscience Centre, Marine Geology Section, Sidney, B.C. Unpublished.

Greer, M.E.
1979: Coastal erosion study along Dallas Road, Victoria, British Columbia. Queen's University, Department of Geological Sciences, Kingston, Ont. B.Sc. thesis.

Harper, J.R.
1980: Seasonal changes in beach morphology along the British Columbia coast. In: Canadian Coastal Conference, 1980 Proceedings. National Research Council, Ottawa, Ont. p. 136-150.

1981: Coastal landform inventory of the West Coast Trail, Pacific Rim National Park. Prepared for Parks Canada. Woodward-Clyde Consultants, Victoria, B.C.

1982: Geologic applications of a wave climate model with examples from the Saanich Peninsula, British Columbia. Presented at: Western Region Workshop, Associate Committee for Research on Shoreline Erosion and Sedimentation. Simon Fraser University, Burnaby, B.C.

Holden, B.J.
1979: Whiffin Spit. B.C. Ministry of Lands, Parks and Housing, Victoria, B.C.

1980: Sidney Spit: An investigation of erosion. B.C. Ministry of Lands, Parks and Housing, Victoria, B.C.

Howes, D.E.
1979: Shorezone units of Saanich Peninsula. B.C. Ministry of Environment, Terrestrial Studies Branch, Victoria, B.C. Unpublished.

Howes, D.E. and E.H. Owens
n.d.: Descriptive terminology and definitions of terms for shorezone classification. B.C. Ministry of Environment, Terrestrial Studies Branch and Woodward-Clyde Consultants, Victoria, B.C.

Muller, J.E.
1971: Geological reconnaissance map of Vancouver Island and Gulf Islands. Open file. Energy, Mines and Resources Canada, Geological Survey of Canada, Ottawa, Ont.

Owens, E.H.
1979: Physical shorezone analysis of North Saanich. Prepared for District of North Saanich. Woodward-Clyde Consultants, Victoria, B.C.

Owens, E.H. and Harper, J.R.
1981: Pacific coast spill response manual pilot study: Esquimalt to Bamfield. Prepared for Environment Canada, Environmental Protection Service. Ottawa, Ont.

Staal, I.M.
1980: Hindsight evaluation of the Mount Douglas Park bank stabilization program. University of Waterloo, Faculty of Environmental Studies, Waterloo, Ont. B.E.S. thesis.

Thurber Consultants, Ltd.
1973: A pre-design sewer study for north Gordon Head. Prepared for Municipality of Saanich. Saanich, B.C.

Aerial Photographs

Provincial

BC 80078	July 1979	1:20,000	B & W
BCC 248	July 1980	1:20,000	Colour

Federal

A31202	June 1978	1:10,000	Colour

Video Tapes (3/4 inch)

B.C. Ministry of Environment, Terrestrial Studies Branch.
June, 1979: Saanich Peninsula. Victoria, B.C.

Environment Canada, Environmental Protection Service.
June, 1980: Bamfield to Fisgard Light. Vancouver, B.C.

Environment Canada, Lands Directorate.
Oct., 1979: Parts of Victoria waterfront to Cowichan Head. Vancouver, B.C.

Aug., 1981: Part of Gulf Islands, Vancouver, B.C.

5.2.3 Generalized Terrain Limitations

Reports, Maps and Surveys

B.C. Ministry of Environment, Resource Analysis Branch.
1972: Terrain analysis maps: Shawnigan, Sooke, San Juan, Carmanah,
1975: River Jordan. 1:50,000. Kelowna, B.C.

Canada, Department of Agriculture.
1973: Surficial materials: Sidney - Victoria mapsheets. 1:50,000. Vancouver, B.C.

Day, J.H.; Farstad, L. and Laird, D.G.
1959: Soil survey of southeast Vancouver Island and Gulf Islands, British Columbia. Research Report 6. Canada, Department of Agriculture, Ottawa, Ont.

Eis, S. and Craigdallie, D.
1980: Shore and landscape analysis of the western section of the Capital Regional District of British Columbia. Report BC-X-208. Environment Canada, Canadian Forestry Service, Victoria, B.C.

Eis, S.; Craigdallie, D. and Oswald, E.T.
1976: Western Community: A landscape analysis for urban development. Report BC-X-153. Environment Canada, Canadian Forestry Service, Victoria, B.C.

Foster, H.D.
1976: Coastal erosion: A natural hazard of the Saanich Peninsula, Vancouver Island. In: Victoria: Physical environment and development. Western Geographical Series 12. University of Victoria, Victoria, B.C. p. 101-184.

Greer, M.E.
1979: Coastal erosion study along Dallas Road, Victoria, British Columbia. Queen's University, Department of Geological Sciences, Kingston, Ont. B.Sc. thesis.

Halstead, E.C.
1966: Surficial geology of Duncan and Shawnigan map areas, Vancouver Island, British Columbia. Paper 65-24. Energy, Mines and Resources Canada, Geological Survey of Canada, Ottawa, Ont.

Howes, D.E.
1981: Terrain inventory and geological hazards: Northern Vancouver Island. APD Bulletin 5. B.C. Ministry of Environment, Terrestrial Studies Branch, Victoria, B.C.

McMinn, R.G.; Eis, S.; Hirvonen, E.T.; Oswald, E.T. and Senyk, J.P.
1976: Native vegetation in British Columbia's Capital Region. Report BC-X-140. Environment Canada, Canadian Forestry Service, Victoria, B.C.

Muller, J.E.
1971: Geological reconnaissance map of Vancouver Island and Gulf Islands. Open file. Energy, Mines and Resources Canada, Geological Survey of Canada, Ottawa, Ont.

Fault Lines

B.C. Hydro and Power Authority, Gas Engineering Division.
1980: Vancouver Island natural gas system; corridor and route nomination. Atlas volume. Vancouver, B.C.

Foster, H.D. and Carey, R.F.
1976: The simulation of earthquake damage. In: Victoria: Physical environment and development. Western Geographical Series 12. University of Victoria, Victoria, B.C. p. 221-246.

Mayers, I.R. and Bennett, L.C., Jr.
1973: Geology of the Strait of Juan de Fuca. Marine Geology 15: 89-117.

Muller, J.E.
1971: Geological reconnaissance map of Vancouver Island and Gulf Islands. Open file. Energy, Mines and Resources Canada, Geological Survey of Canada, Ottawa, Ont.

Roddick, J.A.; Muller, J.E. and Okulitch, A.V.
1979: Fraser River: British Columbia - Washington. Geological Atlas, sheet 92. Map 1386A. Energy, Mines and Resources Canada, Geological Survey of Canada, Ottawa, Ont.

Wourinen, V.
1976: Seismic microzonation of Victoria: A social response to risk. In: Victoria: Physical environment and development. Western Geographical Series 12. University of Victoria, Victoria, B.C. p. 185-219.

5.2.4 Oceanography - Temperature and Salinity

Reports and Surveys

Balch, N.; Warles, E.; Ellis, D. and Littlepage, J.
1972: Macauley Point outfall monitoring program. Annual Report 1971-1972. University of Victoria, Department of Biology, Victoria, B.C.

Crean, P.B.
1978: A numerical model of baratropic mixed tides between Vancouver Island and the mainland and its relation to studies of the estuarine circulation. In: Hydrodynamics of Estuaries and Fiords. J.X.J. Nihoul, ed. Elsevier Scientific Publishing Company, Amsterdam. p. 283-313.

Elliot, J.A.
1969: A synoptic study of Sooke Basin. Manuscript Report 22. University of British Columbia, Institute of Oceanography, Vancouver, B.C.

Ellis, D.V. and Littlepage, J.L.
1972: Clover Point, 1971, an investigation of the accumulated effects of the Clover Point sewer on the local marine ecosystem; including the shoreline. Report submitted to the Minister of Lands, Forests and Water Resources of the Province of British Columbia. University of Victoria, Department of Biology, Victoria, B.C. Available for reference in B.C. Ministry of Environment, Waste Management Library, 810 Blanchard St., Victoria, B.C. and Capital Regional District, Engineering Department Library, Victoria, B.C.

Fulton, J.S.; Kennedy, O.D.; Seki, H. and Stephens, K.
1969: Biological, chemical and physical observations in Saanich Inlet, Vancouver Island, British Columbia. Manuscript Report 1018. Fisheries Research Board of Canada.*

Giovando, L.F.
1977: The coastal waters of British Columbia - some general aspects of their physical oceanography. Environment Canada, Ocean and Aquatic Sciences, Vancouver, B.C. Unpublished.

Herlinveaux, R.H.
1962: Oceanography of Saanich Inlet in Vancouver Island, British Columbia. Journal of the Fisheries Research Board of Canada 19(1): 1-37.*

1972: Oceanographic features of Saanich Inlet, 19 May - 2 July, 1968. Technical Report 300. Fisheries Research Board of Canada.*

Herlinveaux, R.H. and Giovando, L.F.
1969: Some oceanographic features of the inside passage between Vancouver Island and the mainland of British Columbia. Technical Report 142. Fisheries Research Board of Canada.*

Herlinveaux, R.H. and Tully, J.P.
1961: Some oceanographic features of Juan de Fuca Strait. Journal of the Fisheries Research Board of Canada 18: 1027-1071.*

Owens, E.H.
1977: Coastal environments of Canada: the impact and clean-up of oil spills. Economic and Technical Review Report EPS-3-EC-77-13. Fisheries and Environment Canada, Environmental Protection Service, Ottawa, Ont.

Thomson, R.E.
1974a: The tides - the physical oceanography of the British Columbia coast - part 1. Pacific Yachting 9(2): 14-18, 72-73.

1974b: Tidal currents - the physical oceanography of the British Columbia coast - part 2. Pacific Yachting 9(3): 32-37, 66-68.

1975a: Currents in the Strait of Georgia - the physical oceanography of the British Columbia coast - part 5. Pacific Yachting 9(6): 58-61, 78-80.

1975b: Surface currents in the Strait of Georgia - the physical oceanography of the British Columbia coast - part 6. Pacific Yachting 10(1): 62-67, 96-97.

Waldichuk, M.
1957: Physical oceanography of the Strait of Georgia, British Columbia. Journal of the Fisheries Research Board of Canada 4(3): 321-486.*

Waldichuk, M.; Meikle, J.H. and Hyslop, W.F.
1968: Victoria Harbour, the Gorge and Portage Inlet: Physical and Chemical oceanographic data, 1965-1966. Manuscript Report 938. Fisheries Research Board of Canada.*

Waldichuk, M.; Meikle, J.H. and Markert, J.R.
1968: Physical and chemical oceanographic data from the east coast of Vancouver Island, 1954-1966. Manuscript Report 989. Fisheries Research Board of Canada.*

Webster, J.
1977: A physical oceanographic study of Haro Strait: a data summary and preliminary analysis. Contractor Report Series 77-3. Institute of Ocean Sciences, Sidney, B.C.

Wolferstan, W.H.
1981: Oil tanker traffic: Assessing the risks for the southern coast of British Columbia. A.I.D. Bulletin 9. B.C. Ministry of Environment, Victoria, B.C.

* Available for reference in Canada Department of Fisheries and Oceans libraries.

5.2.5 Water Resources: Discharge, Use and Contamination

River Discharges

Environment Canada, Inland Waters Directorate, Water Resources Branch, Water Survey of Canada.
1979: Surface water data reference index. Ottawa, Ont.

1980: Historical streamflow summary to 1979. Ottawa, Ont.

Water Licences

B.C. Ministry of Environment, Water Management Branch.
1979: Computer printout to December, 1979. Victoria, B.C.

Marine/River Outfalls and Landfill Sites

B.C. Ministry of Environment, Waste Management Branch.
n.d.: Unpublished maps. Victoria, B.C.

Shellfish Sanitary Surveys

Arney, D.B. and Gaertner, M.K.
1975: Shellfish growing water sanitary survey of Sooke Harbour and Sooke Basin, British Columbia. Report EPS-PR-75-8. Environment Canada, Environmental Protection Service, Vancouver, B.C.

Shellfish Closure Areas

Fisheries and Oceans Canada.
varied: Departmental Acts and Regulations Manual. Section 105-1. Pacific Shellfish Regulations. Vancouver, B.C.

Personal Communications (1981)

McLaren, D.) B.C. Ministry of Environment, Waste Management Branch,
Morgan, C.) Victoria, B.C.

5.2.6 Seaweeds, Saltmarshes, Sand Dune Ecology and Marine Mammals

Marine Vegetation

Foreman, R.E. and Root, J.
1975: Macrophyte studies in the Strait of Georgia. BERP Report 75-2. University of British Columbia, Department of Botany, Vancouver, B.C.

Summers, T.J.
1980: Interpretation of colour aerial photographs (1:10,000). Environment Canada, Lands Directorate, Vancouver, B.C.

1981: Air photo interpretation and field surveys. Environment Canada, Lands Directorate, Vancouver, B.C. Unpublished.

Marine Mammals

Bigg, M.
n.d.: Unpublished data. Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, B.C.

Saltmarshes and Sand Dune Ecology

Summers, T.J.
1981: Air photo interpretation and field surveys. Environment Canada, Lands Directorate, Vancouver, B.C. Unpublished.

Personal Communication (1981)

Coon, M. B.C. Ministry of Environment, Marine Resources Branch, Victoria, B.C.

5.2.7 Marine Bird Surveys

Waterfowl Surveys

B.C. Ministry of Environment, Terrestrial Studies Branch, Victoria, B.C.

B.C. Provincial Museum, Victoria, B.C.

Ducks Unlimited, Delta, B.C.

Environment Canada, Canadian Wildlife Service, Delta, B.C.

Bald Eagle Survey

Environment Canada, Canadian Wildlife Service, Delta, B.C.

Critical Marine Bird Rookeries

Rodway, M.S. and Campbell, R.W.
1977: Natural history theme study of marine bird and mammal habitats in the Gulf Islands, British Columbia. Parks Canada, Ottawa, Ont.

Personal Communications (1981)

Campbell, W.	B.C. Provincial Museum, Victoria, B.C.
Hunter, R.	B.C. Ministry of Environment, Terrestrial Studies Branch, Victoria, B.C.
Kaiser, G.	Environment Canada, Canadian Wildlife Service, Delta, B.C.
Summers, K.	Ducks Unlimited, Delta, B.C.

5.2.8 Fish and Shellfish Resources

Note: The Coastal Resources map series (1:50,000), Fish and Shellfish Resources, are based on the pooled professional knowledge and judgment of a number of specialists in government, university and private agencies whose contributions ranged from site-specfic data and local knowledge to region-wide surveys and direction to the relevant literature.

Fisheries studies and report are provided in the Companion Report Sources. (See 4.5.4.6.4.)

Personal Communications (1981)

Bourne, N.)
Butler, T.)
Haegle, C.)
Healey, M.)
Ketchen, K.)
Westrheim, J.)
Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, B.C.

Fields, T.) Fisheries and Oceans Canada, District Fisheries Officer, Duncan, B.C.

5.2.9 Generalized Zoning and Marine Facilities

Zoning and Marine Facilities

(See 5.3.1 and 5.3.2.)

Marine Parks

B.C. Ministry of Recreation and Conservation, Provincial Parks Branch.
1975: Map of provincial parks on Vancouver Island. Victoria, B.C.

Ports

Pacific Pilotage Authority.
1975: Port traffic volume statistics. Vancouver, B.C.

5.2.10 Land/Water Use Plans and Proposals

Land Use Plans

B.C. Ministry of Lands, Parks and Housing, Lands and Housing Regional Operations, Vancouver Island Region.
1980: Sooke Harbour and basin crown foreshore plan. Victoria, B.C.

B.C. Ministry of Municipal Affairs.
1979: Technical guide for the preparation of official settlement plans. Victoria, B.C.

Province of British Columbia Municipal Act, RSBC 1979, Chapter 290.
1980: Queen's Printer, Victoria, B.C.

Agricultural Land Reserves

Capital Regional District.
1981: Agricultural land reserve plans. 1:50,000 maps. Victoria, B.C.

Cowichan Valley Regional District.
1981: Agricultural land reserve plans. 1:50,000 maps. Duncan, B.C.

Proposals

Proposed Natural Gas Pipeline

B.C. Hydro and Power Authority, Gas Engineering Division.
1980: Vancouver Island natural gas system corridor and route nomination. Part II: Route selection. Vancouver, B.C.

5.2.11 Selected Administrative Boundaries

(See 5.3.)

5.2.12 Land/Water Status

(See 5.3.)

5.2.13 Recreational Areas, Special Features and Access

Parks and Reserves

B.C. Ministry of Lands, Parks and Housing, Parks Branch.
1980: Provincial parks on Vancouver Island. Victoria, B.C.

Capital Regional District.
1980: Capital Regional District parks. Victoria, B.C.

Environment Canada, Parks Canada.
1980: National parks. Calgary, Alta.

Ecological Reserves

B.C. Ministry of Lands, Parks and Housing, Ecological Reserves Unit, Victoria, B.C.

Wildlife Areas

B.C. Ministry of Environment, Fish and Wildlife Branch, Victoria, B.C.

Environment Canada, Canadian Wildlife Service, Delta, B.C.

National Second Century Fund, Park Royal, West Vancouver, B.C.

Archaeological Sites

B.C. Ministry of Provincial Secretary and Government Services, Heritage Conservation Branch, Victoria, B.C.

Recreational Shellfishing Areas

B.C. Ministry of Environment, Marine Resources Branch, Victoria, B.C.

Hiking Trails

B.C. Ministry of Lands, Parks and Housing, Parks Branch, Victoria, B.C.

Anchorages

Fisheries and Oceans Canada, Institute of Ocean Sciences, Canadian Hydrographic Services.
Hydrographic charts. Ottawa, Ont.

1973:	3310:	Sheets 1 and 2 Marine Sciences Directorate
1978:	3422:	Race Rocks to Discovery Island, 1:40,000
	3430:	Plans Juan de Fuca, various scales
	3448:	Juan de Fuca Strait, Eastern Portion, 1:80,000
	3607:	Juan de Fuca Strait, 1:58,088
1979:	3415:	Victoria Harbour, 1:6,000
	3417:	Esquimalt Harbour, 1:8,000
	3452:	Haro Strait to Stuart Channel, 1:40,000
	3455:	Sidney to Swartz Bay, 1:12,000
1980:	3423:	Trial Island to Cadboro Bay, 1:12,000

Available from: Institute of Ocean Sciences, Sidney, B.C.

Summers, T.J.
1981: Aerial reconnaissance. Environment Canada, Lands Directorate, Vancouver, B.C.

Wolferstan, W.H.
1976: Cruising guide to the Gulf Islands. Agency Press Ltd., Vancouver, B.C.

Scuba Diving Site

Pratt-Johnson, B.
1977: 141 dives in the protected waters of Washington and British Columbia. Gordon Soules Book Publishers, Vancouver, B.C.

Shoreline Process Features

Summers, T.J.
1981: Aerial reconnaissance and air photo interpretation. Environment Canada, Lands Directorate, Vancouver, B.C. Unpublished.

Recreation Areas and Activities

Outdoor Recreation Council of British Columbia.
1977: British Columbia's trails, rivers and shorelines: A status report. A report submitted to the Minister of Recreation and Conservation. Vancouver, B.C.

Summers, T.J.
1981: Aerial reconnaissance. Environment Canada, Lands Directorate, Vancouver, B.C.

Beaches

Bauer, W.
1977: Shore resources inventory for southeast Vancouver Island. Department of Recreation and Conservation, Victoria, B.C.

Environment Canada, Lands Directorate.
1982: Physical shorezone 1:50,000 map series. In: Vol. 1: Coastal resources folio; south coast of Vancouver Island (Hatch Point to Ledingham Creek) British Columbia. Vancouver, B.C. In press.

Public Access

Canada, Department of Transport.
1978: World Aeronautical chart E-16. Ottawa, Ont.

Environment Canada, Environmental Protection Service.
1976: Oil and chemical spill countermeasures series: Access and land status. Vancouver, B.C.

Related Readings

Shaffer, M.; Hale, R. and Lyle, J.
1977: The economic impact of recreational boating in British Columbia. Fisheries and Marine Service, Small Craft Harbours Branch, Vancouver, B.C.

Task Force Technical Working Group.
n.d.: National marine parks - Straits of Georgia and Juan de Fuca. A report to The Interdepartmental Task Force on National Marine Parks. Parks Canada, Ottawa, Ont. Unpublished.

Taylor, M.C.
1978: Land capability for outdoor recreation. Summary Report. The Canada Land Inventory Report #14. Environment Canada, Lands Directorate, Ottawa, Ont.

Wise, P.L.; Kotas, G.F. and Horas, W.S.
1978: Coping with the coast. Proceedings of Fourth Annual Conference, Burlington, Ont. The Coastal Society, Arlington, Virginia.

Personal Communication (1981)

Block, J. B.C. Ministry of Lands, Parks and Housing, Parks Branch, Victoria, B.C.

5.3 LAND/WATER USE AND STATUS TABLES

5.3.1 Regional and Local Zoning

Regional Districts

Capital Regional District.
1980: Sooke electoral area. Zoning by-law no. 282.*

n.d.: Langford, Colwood and Metchosin electoral areas. Zoning regulation 20/67.*

n.d.: The Town of Sidney. Zoning by-law no. 345.*

n.d.: View Royal electoral area. Zoning by-law no. 599.*

* Available from: Capital Regional District, Victoria, B.C.

Cowichan Valley Regional District.
1974: Cowichan Valley Regional District electoral area. Zoning by-law no. 145.*

1977: Cobble Hill electoral area. Zoning by-law no. 295.*

* Available from: Cowichan Valley Regional District, Duncan, B.C.

Municipalities

City of Victoria.
1981: Zoning by-law no. 89-159.

Corporation of the District of Central Saanich.
1981: Zoning by-law no. 465.

Corporation of the District of Saanich.
1978: Zoning by-law no. 4190.

District of North Saanich.
1976: Zoning by-law no. 194.

Municipality of Esquimalt.
1977: Zoning by-law no. 1957.

Municipality of Oak Bay.
1974: Zoning by-law no. 3066.

5.3.2 Marinas, Bulk Oil Storage Facilities and Sewage Systems and Treatment

Marinas

B.C. Ministry of Environment.
n.d.: An ocean around you -how to make the most of Victoria's water environment. Victoria, B.C.

Capital Regional District.
1980: Boating facilities within the Capital Regional District. Background Report. Victoria, B.C.

Eby, P. and Associates Ltd.
1979: Recreational boating facility requirements to 1985 in British Columbia. Prepared for Fisheries and Oceans Canada, Small Craft Harbours Branch, Vancouver, B.C.

Fisheries and Environment Canada.
1978: Guide to federal fishing and recreational harbours of British Columbia. Prepared for Canadian Hydrographic Service, Small Craft Harbours Branch, Sidney, B.C.

Bulk Storage Facilities

Beach, F.G.; Betts, O.A. and Sherwood, R.L.
1979: West coast oil spill countermeasures study year 1. Regional Program Report 79-28. Environment Canada, Environmental Protection Service, Vancouver, B.C.

5.3.3 Land Use Plans and Proposals

Regional Districts

Capital Regional District.
1976: Sooke official settlement plan.*

1979: Metchosin official settlement plan. By-law no. 436.*

1979: Sooke Village plan.*

1979: Western Community official settlement plan. By-law no. 339.*

1980: Official regional plan for the Victoria Metropolitan area. By-law no. 190.*

1982: Sooke draft official settlement plan.*

* Available from: Capital Regional District, Victoria, B.C.

Cowichan Valley Regional District.
1978: Mill Bay-Malahat official settlement plan.*

1980: Shawnigan official settlement plan. By-law no. 512.*

1981: Cobble Hill official settlement plan. By-law no. 570.*

* Available from: Cowichan Valley Regional District, Duncan, B.C.

Municipalities

Corporation of the District of Central Saanich.
1979: Official community plan. By-law no. 544.

Corporation of the District of Saanich.
1977: Official community plan. By-law no. 4262.

Corporation of the Township of Esquimalt.
1977: Community plan.

Town of Sidney and District.
1980: Official community plan. By-law no. 651.

5.3.4 Heavy Industrial Zones

Capital Regional District.
1977: Industrial land inventory Victoria Metropolitan Area. Planning Department, Victoria, B.C.

1980: Industrial land inventory Victoria Metropolitan Area. Planning Department, Victoria, B.C.

5.3.5 Land and Water Status

Provincial Crown Land

Vacant Crown Land

B.C. Ministry of Environment, Surveys and Mapping Branch.
1979: British Columbia reference - crown land status. 1:100,000 map. Victoria, B.C.

Provincial Parks

B.C. Ministry of Lands, Parks and Housing, Parks Branch.
1980: Provincial parks on Vancouver Island. Victoria, B.C.

Provincial Reserves

B.C. Ministry of Environment, Surveys and Mapping Branch.
1979: British Columbia reference - crown land status. 1:100,000 map. Victoria, B.C.

B.C. Ministry of Lands, Parks and Housing, Surveys and Lands Records Branch.
1980: Computer print-outs. Victoria, B.C.

Foreshore Leases

B.C. Ministry of Lands, Parks and Housing, Surveys and Lands Records Branch.
1980: Computer print-outs. Victoria, B.C.

n.d.: Victoria Harbour - plan of subdivision of Lot 119, Esquimalt District, former Songhees Indian Reserve. Victoria, B.C.

n.d.: Victoria Land Recording District - Vancouver Island Resource Management Region Ministerial reference maps R92B/6 and R92B/11. Victoria, B.C.

Oyster Leases

B.C. Ministry of Environment, Marine Resources Branch.
1980: Oyster and culture and management areas, and oyster culture leases and licences. Victoria, B.C.

Regional Parks

Capital Regional District.
1980: Capital Regional District parks. Victoria, B.C.

Federal Crown Land

Indian Reserves

Energy, Mines and Resources Canada, Surveys and Mapping Branch.
varied: National topographic series base maps. 1:50,000. Ottawa, Ont.

Other Federal Property

Environment Canada, Lands Directorate.
1980: Federal land mapping program. 1:50,000. Vancouver, B.C.

Alienated Land

Tree Farm

B.C. Ministry of Forests, Forest Surveys and Inventory Division.
1957: Interim forest cover series and forest inventory reference system. 1:126,720 maps. Victoria, B.C.

n.d.: 1:31,680 map to accompany Maquinna Tree Farm Licence No. 22, Block 6. Victoria, B.C.

n.d.: Sooke and District, Vancouver Island. 1:48,000 map to accompany Naka Tree Farm Licence No. 15, Block 1. Victoria, B.C.

Petroleum and Natural Gas Permit

B.C. Ministry of Energy, Mines and Petroleum Resources.
n.d.: Permit map of southwestern British Columbia. Victoria, B.C.

5.4 COMPANION REPORT

5.4.1 The South Coast Economy

B.C. Agricultural Land Commission.
1980: Agricultural land reserves statistics - April 1, 1980. Victoria, B.C.

B.C. Ministry of Economic Development.
1978: British Columbia regional index. Victoria, B.C.

B.C. Ministry of Environment.
n.d.: An ocean around you -how to make the most of Victoria's water environment. Victoria, B.C.

B.C. Ministry of Industry and Small Business Development. British
1980: Columbia manual of resources and development. Victoria, B.C.

Canada, Department of Regional Economic Expansion and B.C. Ministry of Agriculture and Food.
1980: Agricultural Regional Report - south coastal agricultural region. Canada - British Columbia subsidiary agreement on agriculture and rural development. Victoria, B.C.

Capital Regional District, Economic Advisory Committee.
1977: The challenge...managing the Capital Region's economy. Victoria, B.C.

n.d.: Parks for all seasons. Victoria, B.C.

n.d.: Planning for tomorrow today - how do we grow? Victoria, B.C.

n.d.: The impact of tourism on the Capital Region Economy. Victoria, B.C.

City of Victoria.
1980: Social and economic data. Victoria, B.C.

Environment Canada, Lands Directorate.
Victoria 1966-1976 - Canada land use monitoring program; total land use change in urban centered region. Vancouver, B.C. In preparation.

McFadden, M. and Wittenberg, R.
1980: Regional development plans; profile for Duncan District office area. In: Agriculture Regional Report - south coastal agricultural region. Canada - British Columbia subsidiary agreement on agriculture and rural development. Canada, Department of Regional Economic Expansion and B.C. Ministry of Agriculture and Food, Victoria, B.C.

Stratford, K.
1981: Victoria's Capital Region. The Capital Region Economic Development Commission, Victoria, B.C.

van Westen, K. and Associates.
1979: Fisheries in Greater Victoria: A resource guide for local lakes and streams. Prepared for the B.C. Ministry of Environment. Victoria, B.C.

Wood, Colin J.B.
1979: Agriculture. Vancouver Island - land of contrasts. Western Geographical Series 17. University of Victoria, Victoria, B.C. p. 161-174.

Personal Communications (1982)

Deakin, P. Capital Regional District, Economic Development Commission, Victoria, B.C.

Duff, R. B.C. Ministry of Lands, Parks and Housing, Victoria, B.C.

Kerr, A. Environment Canada, Lands Directorate, Vancouver, B.C.

Nixon, D. Greater Victoria Visitors Information Centre, Victoria, B.C.

Whybrow, M. B.C. Ministry of Forests, Strategic Studies Branch, Victoria, B.C.

5.4.2 General Physical Features

5.4.2.1 Physiography

Anderson, F.E.
1967: Stratigraphy of late Pleistocene and Holocene sediments from the Strait of Juan de Fuca. University of Washington, Seattle, Wash. Ph.D. thesis.

Barker, M.L.
1974: Water resources and related land uses Strait of Georgia - Puget Sound basin. Geographical Paper 56. Environment Canada, Lands Directorate, Ottawa, Ont.

Clague, J.J. and Bornhold, B.D.
1980: Morphology and littoral processes of the Pacific Coast of Canada. In: The Coastline of Canada: Littoral processes and shore morphology. Paper 80-10. Geological Survey of Canada, Ottawa, Ont. p. 339-380.

Fyles, J.G.
1963: Surficial geology of the Horne Lake and Parksville map areas, Vancouver Island, British Columbia, 92F/7, 92F/8. Memoir 318. Canada, Department of Mines and Technical Surveys, Geological Survey of Canada, Ottawa, Ont.

Mayers, I.R. and Bennett, L.C., Jr.
1973: Geology of the Strait of Juan de Fuca. Marine Geology 15: 89-117.

Thomson, R.E.

1981: Oceanography of the British Columbia coast. Canadian Special Publication of Fisheries and Aquatic Sciences 56. Canada, Department of Fisheries and Oceans, Ottawa, Ont.

5.4.2.2 Geology

Alley, N.F.

1975: Surficial geology of Vancouver Island. B.C. Ministry of Environment, Resource Analysis Branch, Victoria, B.C.

n.d.: Terrain mapping and quarternary geology, southern Vancouver Island. B.C. Ministry of Environment, Resource Analysis Branch, Victoria, B.C. Unpublished.

Armstrong, J.E.

1975: Quarternary geology stratigraphic studies and re-evaluation of of terrain inventory maps, Fraser lowland, British Columbia. Report of Activities, Part A. Geological Survey of Canada, Ottawa, Ont. p. 377-380.

Eis, S. and Craigdallie, D.

1980: Shore and landscape analysis of the western section of the Capital Regional District of British Columbia. Report BC-X-208. Environment Canada, Canadian Forestry Service, Victoria, B.C.

Eis, S.; Craigdallie, D. and Oswald, E.T.

1976: Western Community: A landscape analysis for urban development. Report BC-X-153. Environment Canada, Canadian Forestry Service, Victoria, B.C.

Eis, S. and Oswald, E.T.

1976: The highland landscape. Report BC-X-119. Environment Canada, Canadian Forestry Service, Victoria, B.C.

Foster, H.D.

1976: Coastal region: A natural hazard of the Saanich Peninsula, Vancouver Island. In: Victoria: Physical environment and development. Western Geographical Series 12. University of Victoria, Victoria, B.C. p. 101-184.

Fyles, J.G.

1963: Surficial geology of the Horne Lake and Parksville map areas, Vancouver Island, British Columbia, 92F/7, 92F/8. Memoir 318. Canada, Department of Mines and Technical Surveys, Geological Survey of Canada, Ottawa, Ont.

Greer, M.E.

1979: Coastal erosion study along Dallas Road, Victoria, British Columbia. Queen's University, Department of Geological Sciences, Kingston, Ont. B.Sc. thesis.

Mayers, I.R. and Bennett, L.C., Jr.
1973: Geology of the Strait of Juan de Fuca. Marine Geology 15: 89-117.

Muller, J.E.
1971: Geological reconnaissance map of Vancouver Island and Gulf Islands. Open file. Energy, Mines and Resources Canada, Geological Survey of Canada, Ottawa, Ont.

Roddick, J.A.; Muller, J.E. and Okulitch, A.V.
1979: Fraser River: British Columbia - Washington. Geological Atlas, sheet 92. Map 1386A. Energy, Mines and Resources Canada, Geological Survey of Canada, Ottawa, Ont.

Stanley-Jones, C.V. and Benson, W.A., eds.
1973: An inventory of land resources and resource potentials in the Capital Regional District. Capital Regional District, Victoria, B.C.

5.4.2.3 Soils

Day, J.H.; Farstad, L. and Laird, D.G.
1959: Soil survey of southeast Vancouver Island and Gulf Islands, British Columbia. Research Report 6. Canada, Department of Agriculture, Ottawa, Ont.

Frank, R.J.
1980: A proposed coastal zone classification for use in British Columbia. University of British Columbia, Department of Soil Sciences, Vancouver, B.C. M.Sc. thesis.

5.4.2.4 Climate

Phillips, D.W.
1976: Monthly water balance tabulations for climatological stations in Canada, D5 #4-76. Environment Canada, Atmospheric Environment Service, Downsview, Ont.

5.4.2.5 Physical Oceanography

Clague, J.J. and Bornhold, B.D.
1980: Morphology and littoral processes of the Pacific Coast of Canada. In: The Coastline of Canada: Littoral processes and shore morphology. Paper 80-10. Geological Survey of Canada, Ottawa, Ont. p. 339-380.

Holden, B.J.
1979: Whiffen Spit: An investigation of erosion. B.C. Ministry of Lands, Parks and Housing, Victoria, B.C.

Owens, E.H.
1977: Coastal environments of Canada: The impact and clean-up of oil spills. Economic and Technical Review Report EPS-3-EC-77-13. Fisheries and Environment Canada, Environmental Protection Service, Ottawa, Ont.

Thomson, R.E.
1981: Oceanography of the British Columbia coast. Canadian Special Publication of Fisheries and Aquatic Sciences 56. Canada, Department of Fisheries and Oceans, Ottawa, Ont.

5.4.2.6 Water Resources

Barker, M.L.
1974: Water resources and related land uses, Strait of Georgia - Puget Sound basin. Geographical Paper 56. Environment Canada, Lands Directorate, Ottawa, Ont.

Brown, I.D., ed.
1967: Groundwater in Canada. Economic Geology Report 24. Canada, Department of Energy, Mines and Resources, Geological Survey of Canada, Ottawa, Ont.

5.4.3 Biological Resources

5.4.3.1 Terrestrial Vegetation

Bell, M.A.M.; Beckett, J.M. and Hubbard, W.F.
1974: Impact of harvesting on forest environments and resources. Environment Canada, Canadian Forestry Service, Ottawa, Ont.

B.C. Ministry of Environment, Resource Analysis Branch.
1979: Biophysical forest zones. 1:250,000 map. Victoria, B.C.

B.C. Ministry of Forests, Forest Surveys and Inventory Division.
1957: Interim forest cover series and forest inventory reference system. 1:126,720 maps. Victoria, B.C.

Klinka, K.; Nuszdorfer, F.C. and Skoda, F.
1979: Biogeoclimatic units of central and southern Vancouver Island. B.C. Ministry of Forests, Victoria, B.C.

Krajina, V.J.
1965: Vol. 1: Ecology of western North America. University of British Columbia, Department of Botany, Vancouver, B.C.

1969: Vol. 2(1): Ecology of western North America. University of British Columbia, Department of Botany, Vancouver, B.C.

McCormack, R.J.
1970: Land capability classification for forestry. Canada Land Inventory Report 4, 2d ed. Environment Canada, Lands Directorate, Ottawa, Ont.

Packee, E.
1974: Biogeoclimatic zones of Vancouver Island. 1:380,000 map. Third Approximation. MacMillan Bloedel Ltd., Vancouver, B.C.

Taylor, R.L. and MacBryde, B.
1977: Vascular plants of British Columbia. University of British Columbia Press, Vancouver, B.C.

Valentine, K.W.G.; Sprout, P.N.; Baker, T.E. and Lavkulich, L.M.
1978: The soil landscapes of British Columbia. B.C. Ministry of Environment, Victoria, B.C.

5.4.3.2 Seaweeds and Saltmarshes

5.4.3.3 Marine Mammals, and

5.4.3.4 Marine Birds

Austin, A. and Adams, R.
1978: Aerial color infrared survey of marine plant resources. Photogrammetric Engineering and Remote Sensing 44(4).

Bartonek, J.C. and Nettleship, D.N., eds.
1979: Conservation of marine birds of North America. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Bigg, M.A.
1969: The harbour seal. Fisheries Research Board of Canada, Ottawa, Ont.*

Bigg, M.; MacAskie and Ellis, G.
1976: A preliminary report on abundance and movement of killer whales off eastern and southern Vancouver Island, with comments on management. Arctic Biological Station, Ste. Anne de Bellevue, P.Q. Unpublished.

Burns, T.
1978: Inventory of wetlands and other high capability biotic lands in developing zones of British Columbian south coastal regions. B.C. Ministry of Recreation and Conservation, Victoria, B.C.

Cameron, T.A.
1916: The commercial value of the kelp beds of the Pacific coast - a preliminary report and survey of the beds. Sessional Paper 38a. Vol. Ll, No. 27. Available from: B.C. Ministry of Environment, Marine Resources Branch, Victoria, B.C.

Campbell, R.W.; Carter, H.R.; Shepard, C.D. and Guiguet, C.J.
1979: Vol. 1: A bibliography of British Columbia ornithology. B.C. Provincial Museum, Victoria, B.C.

Carefoot, T.
1977: Pacific seashores: A guide to intertidal ecology. J.J. Douglas Ltd., Vancouver, B.C.

Clark, J.
1977: Coastal ecosystem management. John Wiley & Sons, New York, N.Y.

Conway, E.; Mumford, T.F. and Scagel, R.F.
1975: The genus Porphyra in British Columbia and Washington. Syesis 8.

Coon, M.
1981: Kelp inventory maps. B.C. Ministry of Environment, Marine Resources Branch, Victoria, B.C.

Cushing, D.H. and Walsh, J.J.
1976: The ecology of the seas. Blackwell Scientific Publications, London, U.K.

DeWreede, R.E.
1978: Phenology of Sargassum muticum (Phaeophyta) in the Strait of Georgia, British Columbia. Syesis 11.

Drent, R.H. and Guiguet, D.J.
1961: A catalogue of British Columbia seabird colonies. Occasional Paper 12. B.C. Provincial Museum, Victoria, B.C.

Druehl, L.D.
1967: Distribution of two species of Laminaria as related to some environmental factors. Journal of Phycology 3.

Ellis, D.V.
1970: A review of marine infaunal community studies in the Strait of Georgia and adjacent inlets. Syesis 4.

Everitt, R.D.; Fiscus, C.H. and Delong, R.L.
1979: Marine mammals of northern Puget Sound and the Strait of Juan de Fuca. NOAA, Boulder, Colorado.

Foreman, R.E.
1977: Benthic community modification and recovery following intensive grazing by Strongylocentrotus droebachiensis. Helgolander wiss: Meeresunters 30.

1979: Nearshore biophysical inventory programme. BERP Report 79-1. University of British Columbia, Department of Botany, Vancouver, B.C.

Gillett, W.H.; Hayward, J.L., Jr. and Stout, F.F.
n.d.: Effects of human activity on egg and chick mortality in a glaucous-wing gull colony.

Greenius, A.W.
1967: The general status of the seaweed industry in British Columbia. Fisheries and Environment Canada, Ottawa, Ont.

Hartwick, E.B.
1974: Breeding ecology of the black oystercatcher. Syesis 7.

Kool, R.
1980: Edges. Wildlife Review 9(6). B.C. Ministry of Environment, Fish and Wildlife Branch, Victoria, B.C.

Kormondy, E.J.
1976: Concepts of Ecology. Prentice-Hall, Inc., New Jersey.

Kozloff, E.N.
1973: Seashore life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago. J.J. Douglas Ltd., Vancouver, B.C.

Kury, C.R. and Gochfeld, M.
1975: Human interference and gull predation in cormorant colonies. Biological Conservation 8.

Levings, C.D.
1980: An account of a workshop on restoration of estuarine habitats. Manuscript Report 1571. Fisheries and Oceans Canada, Vancouver, B.C.

Mann, K.H.
1977: Destruction of kelp beds by sea urchins: A cyclical phenomenon or irreversible degradation? Helgolander wiss: Meeresunters 30.

Manuwal, D.A.; Wahl, T.R. and Speich, S.M.
1979: The seasonal distribution and abundance of marine bird populations in the Strait of Juan de Fuca and northern Puget Sound in 1978. NOAA, Boulder, Colorado.

Myres, M.T.
1979: Long term climatic and oceanographic cycles regulating seabird distributions and numbers. In: Conservation of marine birds of northern North America. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C.

Perkins, E.J.
1974: The biology of estuaries and coastal waters. Academic Press, London, U.K.

Remane, A. and Schlieper, C.
1971: Biology of brackish water. John Wiley and Sons, Inc., New York.

Ricketts, E.F. and Calvin, J.
1968. Between Pacific tides. Stanford University Press, Stanford, Calif.

Robert, H.C. and Ralph, C.J.
1975: Effects of human disturbance on the breeding success of gulls.

Robertson, I.
1977: Low seabird densities in the pelagic environment of the Strait of Georgia, British Columbia. Pacific Science 31(3).

Rodway, M.S. and Campbell, R.W.
1976: Natural history theme study of marine bird and mammal habitats in the Gulf Islands, British Columbia. Parks Canada, Ottawa, Ont.

Scagel, R.F.
1978: Guide to common seaweeds of British Columbia. B.C. Provincial Museum, Victoria, B.C.

Simenstad, C.A.; Miller, B.C.; Nyblade, C.F.; Thornburgh, K. and Bledsoe, L.J.
1979: Food web relationships of northern Puget Sound and the Strait of Juan de Fuca. U.S. Environmental Protection Agency, Washington, D.C.

Spalding, D.J.
n.d.: Comparative feeding habits of the fur seal, sea lion and harbour seal on the British Columbia coast. Fisheries Research Board of Canada, Nanaimo, B.C.*

Stephenson, T.A. and Stephenson, A.
1972: Life between the tidemarks on rocky shores. W.H. Freeman, San Francisco, Calif.

Treholme, S.N. and Campbell, R.W.
1975: Survey of bald eagle populations in the southern gulf islands, British Columbia. Syesis 8.

Trethewey, D.E.C.
1974: An assessment of the impacts of wildlife and wildlife-related recreation of four alternative development proposals for the Cowichan River estuary and flood plain. Environment Canada, Canadian Wildlife Service, Delta, B.C.

Vadas, R.L.
1972: Ecological implications of culture studies on Nereocystis leutkana. Journal of Phycology 8.

Whittaker, R.H.
1975: Communities and ecosystems. MacMillan Publishing, New York.

* Available for reference in Canada, Department of Fisheries and Oceans libraries.

Personal Communication (1981)

Coon, M. B.C. Ministry of Environment, Marine Resources Branch, Victoria, B.C.

5.4.3.5 Fish and Shellfish Resources

5.4.3.5.1 Fisheries (finfish)

5.4.3.5.1.1 Salmonids

Alderdice, D.F.; Barns, R.A. and Velsen, F.P.J.
1977: Factors affecting deposition, development and survival of salmonid eggs and alevins. A bibliography, 1965-75. Technical Report 743. Fisheries and Environment Canada, Fisheries and Marine Service, Vancouver, B.C.*

Argue, A.W. and Pitre, K.R.
1972: Distribution of commercial and sport vessels fishing Pacific salmon in southern British Columbia marine waters, based on overflights from 1965 to 1971. Technical Report 1972-3. Canada, Department of Fisheries, Fisheries and Marine Service, Vancouver, B.C.*

Argue, A.W.; Coursley, J. and Harris, G.D.
1977: Preliminary revision of Georgia Strait and Juan de Fuca Strait tidal salmon sport catch statistics, 1972 to 1976, based on Georgia Strait Head Recovery Program data. Technical Report Series PAC/T-77-16. Fisheries and Environment Canada, Fisheries and Marine Service, Vancouver, B.C.*

Aro, K.V. and Shepard, M.P.
1967: Salmon of the north Pacific Ocean - Part IV. Spawning populations of north Pacific salmon. 5. Pacific Salmon in Canada. Bulletin 23: 225-327. International North Pacific Fisheries Commission, Vancouver, B.C.

B.C. Ministry of Recreation and Conservation, Fish and Wildlife Branch.
1979: Steelhead harvest analysis. Victoria, B.C.

Burns, T.
1971: Stream summaries of Vancouver Island streams. B.C. Ministry of Recreation and Conservation, Fish and Wildlife Branch, Victoria, B.C.

Ellis, D.
1977: Pacific salmon enhancement for people. Western Geographical Series 13. University of Victoria, Victoria, B.C.

Fisheries and Oceans Canada.
1977-1979: British Columbia catch statistics (annual reports). Vancouver, B.C.

Friedlander, M.J. and Reif, G.
1979: Working paper on Indian food fisheries and salmonid enhancement. Fisheries and Oceans Canada, Vancouver, B.C.

Hart, J.L.
1973: Pacific fishes of Canada. Bulletin 180. Fisheries Research Board of Canada.*

Levy, D.
1977: Bibliography of source literature - estuary utilization by salmonids. University of British Columbia, Westwater Research Centre, Vancouver, B.C.

Marshall, D.E.; Brown, R.F.; Chahley, V.D. and Demontier, D.G.
1975: Preliminary catalogue of salmon streams and spawning escapements of Statistical Areas 19 and 20 (Sidney-Sooke). Data Report Series PAC/D-75-5. Environment Canada, Fisheries and Marine Service. *

Northern Natural Resource Services Ltd.
1978: Collection of data from marine tag-recovery programs conducted from 1925-1977 in British Columbia coastal waters. 5 vols. Fisheries and Environment Canada, Salmonid Enhancement Program, Vancouver, B.C.

Parker, R.R. and LeBrasseur, R.J.
1976: Ecology of early sea life, pink and chum juveniles. In: Proceedings of the 1974 Northeast Pacific Pink and Chum Salmon Workshop. D.R. Harding, ed. p. 161-184.*

Phillips, A.C. and Barraclough, W.E.
1978: Early marine growth of juvenile Pacific salmon in the Strait of Georgia and Saanich Inlet, British Columbia. Technical Report 830. Fisheries and Environment Canada, Fisheries and Marine Service.*

Schmidt, A.H.; Graham, C.C. and McDonald, T.E.
1979: Summary of literature on four factors associated with salmon and trout fresh water life history. Manuscript Report 1487. Fisheries and Environment Canada, Fisheries and Marine Service, Vancouver, B.C.*

van Westen, K. and Associates.
1979: Fisheries in Greater Victoria: A resource guide for local lakes and streams. Prepared for the B.C. Ministry of Environment, Victoria, B.C.

* Available for reference in Canada, Department of Fisheries and Oceans libraries.

5.4.3.5.1.2 Groundfish

Forrester, C.R. and Smith, J.E.
1974: The trawl fishery in the Strait of Georgia and vicinity 1960-72. Circular 96. Fisheries Research Board of Canada.*

Ketchen, K.S.
1961: Observations on the ecology of the Pacific cod (Gadus macrocephalus) in Canadian waters. Journal of the Fisheries Research Board of Canada 18: 513-558.*

1979: An overview of the Strait of Georgia winter trawl fishery, 1951-52 to 1977-78. Manuscript Report Series 1511. Fisheries and Oceans Canada, Fisheries and Marine Service.*

Ketchen, K.S. and Forrester, C.R.
1954: Migration of the lemon sole (Parophrys vetulus) in the Strait of Georgia. Pacific Progress Report 104. Fisheries Research Board of Canada. p. 11-15.*

Low, C.J. and Beamish, R.J.
1978: A study of the nesting behaviour of Lingcod (Uphiodon elongatus) in the Strait of Georgia, British Columbia. Technical Report 843. Fisheries and Environment Canada, Fisheries and Marine Service.*

Phillips, A.C. and Barraclough, W.E.
1977: On the early life history of the Lingcod (Uphiodon elongatus). Technical Report 756. Fisheries and Environment Canada, Fisheries and Marine Service.*

Westrheim, S.J.
1977: Production and stock assessment of principal groundfish stocks off British Columbia. Industrial Report 94. Fisheries and Environment Canada, Fisheries and Marine Service.*

1980: The trawl fishery in the Strait of Georgia and vicinity, 1945-77. Manuscript Report 1563. Fisheries and Oceans Canada, Fisheries and Aquatic Sciences.*

* Available for reference in Canada, Department of Fisheries and Oceans libraries.

5.4.3.5.1.3 Other Finfish

Alderdice, D.F. and Velsen, F.P.J.
1971: Some effects of salinity and temperature on early development of Pacific herring (Clupea pallasii). Journal of the Fisheries Research Board of Canada 28: 1545-1562.*

Hourston, A.S.
1977: Status of British Columbia herring stocks. Manuscript Report Series 1421. Fisheries and Environment Canada, Fisheries and Marine Service.*

1977: Publications and reports on Pacific herring from investigations conducted at or in co-operation with the Pacific Biological Station. Manuscript Report Series 1427. Fisheries and Environment Canada, Fisheries and Marine Service.*

1978: The decline and recovery of Canada's Pacific herring stocks. Technical Report 784. Fisheries and Environment Canada, Fisheries and Marine Service.*

Humphreys, R.D. and Hourston, A.S.
1978: British Columbia herring spawn deposition manual. Special Publication. Fisheries and Environment Canada, Fisheries and Marine Service, Vancouver, B.C.

Jones, B.C.
1972: Effect of inter-tidal exposure on survival and embryonic development of Pacific herring spawn. Journal of the Fisheries Research Board of Canada 29: 1119-1124.*

Webb, L.A.; Hourston, A.S. and Jubinville, B.C.
1980: Review of the 1977-78 British Columbia herring fishery and spawn abundance. Canadian Industry Report 112. Fisheries and Oceans Canada, Fisheries and Aquatic Sciences.*

* Available for reference in Canada, Department of Fisheries and Oceans libraries.

5.4.3.5.2 Shellfish

Brett, J.R.; Calaprice, J.R.; Ghelardi, R.J.; Kennedy, W.A.; Quayle, D.B. and C.T. Shoop.
1972: A brief on mariculture. Technical Report 301. Fisheries Research Board of Canada.*

Butler, T.H.
1964: Growth, reproduction and distribution of pandalus shrimp in British Columbia. Journal of the Fisheries Research Board of Canada 21: 1403-1452.*

1968: The shrimp fishery of British Columbia. Fisheries Report 57. United Nations, FAO.

1980: Shrimp of the Pacific coast of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 202.*

Fisheries and Oceans Canada.
1977-1979: British Columbia catch statistics (annual reports). Vancouver, B.C.

Heritage, G.D. and Bourne, N.
1979: Pacific oyster breeding in British Columbia, 1977. Technical Report 882. Fisheries and Oceans Canada, Fisheries and Marine Service.*

Heritage, G.D.; Bourne, N. and Smith, D.W.
1977: Pacific oyster breeding in British Columbia, 1976. Manuscript Report 1419. Fisheries Research Board of Canada.*

Quayle, D.B.
1969: Pacific oyster culture in British Columbia. Bulletin 169. Fisheries Research Board of Canada.*

1974: The intertidal bivalves of British Columbia. Handbook 17. B.C. Provincial Museum, Victoria, B.C.

1978: A preliminary report on the possibilities of mussel culture in British Columbia. Technical Report 815. Fisheries and Environment Canada, Fisheries and Marine Service.*

Quayle, D.B. and Bourne, N.
1972: The clam fisheries of British Columbia. Bulletin 179. Fisheries Research Board of Canada.*

Scrivener, J.C. and Butler, T.H.
1971: A bibliography of shrimps of the family Pandalidae, emphasizing economically important species of the genus Pandalus. Technical Report 241. Fisheries Research Board of Canada.*

Smith, D.W.
1975: Manual for assessment of oyster growing areas. Fisheries Management Report 5. B.C. Department of Recreation and Conservation, Marine Resources Branch, Victoria, B.C.

* Available for reference in Canada, Department of Fisheries and Oceans libraries.

5.4.3.5.3 Species Names

Butler, T.H.
1980: Shrimp of the Pacific coast of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 202.*

Hart, J.L.
1973: Pacific fishes of Canada. Bulletin 180. Fisheries Research Board of Canada.*

Quayle, D.B. and Bourne, N.
1972: The clam fisheries of British Columbia. Bulletin 179. Fisheries Research Board of Canada.*

* Available for reference in Canada, Department of Fisheries and Oceans libraries.

5.4.4 Recreational Resources

Alley, J.A. and Ferguson, A.J.
1976: Recreational boating in Howe Sound: A data base for regional planning. Islands Trust, Victoria, B.C.

American Society of Civil Engineers.
1978: Coastal Zone '78. Symposium on technical environments, socio-economic and regulatory aspects of coastal zone management. 4 vols. San Francisco, Calif.

Bauer, W.
1977: Shore resources inventory for southeast Vancouver Island. B.C. Department of Recreation and Conservation, Victoria, B.C.

Bregha, F.J.
1977: Canadian recreation development; social dimensions. Occasional Paper 15. Fisheries and Environment Canada, Lands Directorate, Ottawa, Ont.

B.C. Ministry of Environment, Resource Analysis Branch.
n.d.: Recreation capability inventory, a description for reconnaissance inventory of: I Outdoor recreation features; II Physical carrying capacity for outdoor recreation. Victoria, B.C. Mimeograph.

Bryan, R.C.
1974: The dimensions of a salt-water sport fishing trip, or what do people look for in a fishing trip besides fish? Technical Report Series PAC/T-74-1. Canada, Department of Fisheries, Fisheries and Marine Service.*

Burka, P.
1974: Shoreline erosion: Implications for public rights and private ownership. Coastal Zone Management Journal. Crane, Russak & Co. Inc., New York.

Canadian Council of Resource Ministers.
1968: The administration of outdoor recreation in Canada. Montreal, P.Q.

Clawson, M. and Kretsch, J.L.
1966: Economics of outdoor recreation. John Hopkins Press, Baltimore, Md.

Coastal Zone Resource Subcommittee.
1978: The management of coastal resources in British Columbia: A review of selected information. Prepared for the B.C. Land Resources Steering Committee. Fisheries and Environment Canada, Lands Directorate, Vancouver, B.C.

Coomber, N.H. and Biswas, A.K.
1973: Evaluation of environmental intangibles. Genera Press, Bronxville, New York.

Dickert, T. and Sorenson, J.
1974: Social equity in coastal zone planning. Coastal Zone Management Journal. Crane, Russak and Co. Inc., New York.

Ditton, R.B. and Stephens, M.
1976: Coastal recreation: A handbook for planners and managers. U.S. Department of Commerce, NOAA, Office of Coastal Zone Management, Washington, D.C.

Eby, P. and Associates Ltd.
1979: Recreational boating facility requirements to 1985 in British Columbia. Prepared for Fisheries and Oceans Canada, Small Craft Harbours Branch, Vancouver, B.C.

Environment Canada, Lands Directorate.
1970: Canada land inventory land capability for recreation. Ottawa, Ont.

Forward, C.N., ed.
1979: Vancouver Island - land of contrasts. Western Geographical Series 17. University of Victoria, Victoria, B.C.

Georgia Department of Natural Resources.
1976: Coastal resource planning notebook. Atlanta, Georgia.

Harrison, P.
1977: Recreational aspects of shorezone development: A conceptual discussion of management and provision. Occasional Paper 13. Fisheries and Environment Canada, Lands Directorate, Ottawa, Ont.

Hildreth, R.G.
1975: Coastal land use control in Sweden. Coastal Zone Management Journal 2(1). Crane, Russak & Co., Inc., New York.

Institute of Public Affairs.
1972: Shoreland: Its use, ownership, access and management. Proceedings of a Two-day Seminar Mar. 8-10, 1972. Amherst, N.S. Available from: Environment Canada, Lands Directorate, Ottawa, Ont.

Ketchum, B.H.
1972: The water's edge: Critical problems of the coastal zone. MIT Press, Cambridge, Mass.

Kozloff, E.N.
1973: Seashore life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago. J.J. Douglas Ltd., Vancouver, B.C.

Matejko, A.
1971: Culture, work, and leisure. Society and Leisure 2.

Meyer, P.A.
1978: A study of satisfaction and substitutability in recreation available to residents of urban British Columbia. Fisheries and Environment Canada, Fisheries and Marine Service, Vancouver, B.C.

Meyer, P.A. and Harrison, M.
1976: Marina policy in the tidal area of the Pacific coast, a study of recreational responsibilities of the Small Craft Harbours Branch. Environment Canada, Fisheries and Marine Service, Vancouver, B.C.

Murphy, J.F.
1973: Philosophical dimensions of leisure. Society and Leisure 3.

Outdoor Recreation Council of British Columbia.
1977: British Columbia's trails, rivers and shorelines: A status report. A report submitted to the Minister of Recreation and Conservation. Vancouver, B.C.

Ross, J.H.
1973: A measure of site attraction. Environment Canada, Lands Directorate, Ottawa, Ont.

Shaffer, M.; Hale, R. and Lyle, J.
1977: The economic impact of recreational boating in British Columbia. Fisheries and Environment Canada, Small Craft Harbours Branch, Vancouver, B.C.

Task Force Technical Working Group.
n.d.: National marine parks - Straits of Georgia and Juan de Fuca. A report to The Interdepartmental Task Force on National Marine Parks. Parks Canada, Ottawa, Ont. Unpublished.

Taylor, M.C.
1978: Lands capability for outdoor recreation. Summary Report. The Canada Land Inventory Report 14. Environment Canada, Lands Directorate, Ottawa, Ont.

Wise, P.L.; Kotas, G.F. and Horas, W.S.
1978: Coping with the coast. Proceedings of Fourth Annual Conference, Burlington, Ont. The Coastal Society, Arlington, Virginia.

5.4.5 Physical Processes and Energy

5.4.5.1 Regional Wave Climate

Associate Committee for Research on Shoreline Erosion and Sedimentation, National Research Council.

1980: Canadian Coastal Conference, 1980 Proceedings. Ottawa, Ont.

Bascom, W.

1980: Waves and beaches - the dynamics of the ocean surface. Anchor Press/Doubleday, New York.

Canada, Department of Fisheries and Oceans, Marine Environmental Data Service.

1976: Waves recorded off Victoria Harbour (Kelk), British Columbia, Station 95, December 3, 1975 to July 28, 1976. Ottawa, Ont.

1977: Waves recorded off Victoria Harbour (W.B.), British Columbia, Station 4, March 10, 1976 to March 24, 1977. Ottawa, Ont.

Clague, J.J. and Bornhold, B.D.

1980: Morphology and littoral processes of the Pacific Coast of Canada. In: The Coastline of Canada: Littoral processes and shore morphology. Paper 80-10. Geological Survey of Canada, Ottawa, Ont. p. 339-380.

Environment Canada, Lands Directorate.

1981: Physical shorezone 1:50,000 map series. In: Vol. 1: Coastal resources folio; east coast of Vancouver Island (Race Point to Hatch Point and adjacent islands) British Columbia. Vancouver, B.C.

Foster, H.D.

1976: Coastal erosion: A natural hazard of the Saanich Peninsula, Vancouver Island. In: Victoria: Physical environment and development. Western Geographical Series 12. University of Victoria, Victoria, B.C. p. 101-184.

Greer, M.E.

1979: Coastal erosion study along Dallas Road, Victoria, British Columbia. Queen's University, Department of Geological Sciences, Kingston, Ont. B.Sc. thesis.

Hale, P.B. and Greenwood, B.

1980: Storm wave climatology: A study of the magnitude and frequency of geomorphic process. In: The Coastline of Canada. Paper 80-10. Geological Survey of Canada, Ottawa, Ont. p. 73-88.

Harper, J.R.

1980: Seasonal changes in beach morphology along the British Columbia coast. In: Canadian Coastal Conference, 1980 Proceedings. National Research Council, Ottawa, Ont. p. 136-150.

Harper, J.R.

1982: Geological applications of a wave climate model: Examples from Saanich Peninsula, British Columbia. Western Region Workshop. Simon Fraser University, Associate Committee for Research on Shoreline Erosion and Sedimentation, Burnaby, B.C.

Holden, B.J.

1979: Whiffin Spit. B.C. Ministry of Lands, Parks and Housing, Victoria, B.C.

1980: Sidney Spit: An investigation of erosion. B.C. Ministry of Lands, Parks and Housing, Victoria, B.C.

McCann, S.B., ed.

1980: The Coastline of Canada: Littoral processes and shore morphology. Proceedings of a conference held in Halifax, N.S., May 1-3, 1978. Paper 80-10. Geological Survey of Canada, Ottawa, Ont.

Owens, E.H.

1977: Coastal environments of Canada: The impact and clean up of oil spills. Economic and Technical Review Report EPS-3-EC-77-13. Fisheries and Environment Canada, Environmental Protection Service, Ottawa, Ont.

1979: Physical shorezone analysis of North Saanich. Prepared for District of North Saanich. Woodward-Clyde Consultants, Victoria, B.C.

1980: Physical shorezone analysis of Saltspring Island, British Columbia. Environment Canada, Lands Directorate, Vancouver, B.C.

Thomson, R.E.

1974a: Longshore current generation by internal waves in the Strait of Georgia. Canadian Journal of Earth Sciences 12(3): 472-488.

1974b: The tides - the physical oceanography of the British Columbia coast - part 1. Pacific Yachting 9(2): 14-18, 72-73.

1974c: Tidal currents - the physical oceanography of the British Columbia coast - part 2. Pacific Yachting 9(3): 32-37, 66-68.

1975a: Waves - the physical oceanography of the British Columbia coast - part 3. Pacific Yachting 9(4): 34-37, 62-63.

1975b: The Strait of Georgia - the physical oceanography of the British Columbia coast - part 4. Pacific Yachting 9(5): 42-45, 140-145.

1975c: Currents in the Strait of Georgia - the physical oceanography of the British Columbia coast - part 5. Pacific Yachting 9(6): 58-61, 78-80.

1975d: Surface currents in the Strait of Georgia - the physical oceanography of the British Columbia coast - part 6. Pacific Yachting 10(1): 62-67, 96-97.

Thomson, R.E.

1975e: Currents in the Juan de Fuca Strait - the physical oceanography of the British Columbia coast - part 7. Pacific Yachting 10(2): 84-91.

1975f: Inlets, sills, tide lines and temperatures - the physical oceanography of the British Columbia coast - part 8. Pacific Yachting 10(5): 30-31, 67-71.

1975g: Upwelling - bringing cold water to the surface - the physical oceanography of the British Columbia coast - part 9. Pacific Yachting 2(1): 46-51.

1976a: Tidal waves (tsunamis) - the physical oceanography of the British Columbia coast - part 10. Pacific Yachting 2(4): 34-36, 44-47, 80-81.

1976b: Winds, waves, and whitecaps - the physical oceanography of the British Columbia coast - part 11. Pacific Yachting 11(6): 46-54.

1976c: Tidal currents and the '76 Swiftsure - the physical oceanography of the British Columbia coast - part 12. Pacific Yachting 12(5): 44-47, 80-81.

1977a: Waves in shallow water - the physical oceanography of the British Columbia coast - part 13. Pacific Yachting 13(4): 44-49, 73-75.

1977b: Johnstone Strait and Discovery Passage - the physical oceanography of the British Columbia coast - part 14. Pacific Yachting 14(2): 46-48, 54-61.

1977c: The oceanographic setting of the Fraser River delta front. Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, B.C. Unpublished.

1981: Oceanography of the British Columbia coast. Canadian Special Publication of Fisheries and Aquatic Sciences 56. Canada, Department of Fisheries and Oceans, Ottawa, Ont.

5.4.5.2 Circulation

(See 5.4.2.5.)

5.4.5.3 Sedimentation

(See 5.4.2.5.)

5.4.5.4 Atmospheric Mixing

Emslie, J.H.

1979: Ground-based inversion frequencies determined from surface climatological data. Boundary Layer Meteorology 16(4): 409-419.

Munn, R.E.; Tomlain, J. and Titus, R.L.
1970: A preliminary climatology of ground-based inversions in Canada. Atmosphere 8(2): 52-56.

Portelli, R.V.
1977: Mixing heights, wind speeds and ventilation coefficients for Canada. Climatological Studies 31. Environment Canada, Atmospheric Environment Service, Downsview, Ont.

Schaefer, D.G.
1981: Climatic summary for coastal resources folio; south coast of Vancouver Island study area. Environment Canada, Atmospheric Environment Service, Vancouver, B.C.

Shaw, R.W.; Hirt, M.S. and Tilley, M.A.
1972: Persistence of light surface winds in Canada. Atmosphere 10(1): 33-43.

Personal Communication (1981)

Schaefer, D.G. Environment Canada, Atmospheric Environment Service, Vancouver, B.C.

5.4.5.5 Seismicity

Foster, H.D. and Carey, R.F.
1976: The simulation of earthquake damage. In: Victoria: Physical environment and development. Western Geographical Series 12. University of Victoria, Victoria, B.C. p. 221-246.

Maynard, D.
1979: Terrain capability for residential settlements: Summary report. B.C. Ministry of Environment, Resource Analysis Branch, Victoria, B.C.

Milne, W.G.; Smith, W.E.T. and Rogers, G.C.
1970: Canadian seismicity and micoearthquake research in Canada. Canadian Journal of Earth Sciences 7: 591-601.

Milne, W.G.; Rogers, G.C.; Riddihough, R.P.; McMechan, G.A. and Hyndman, R.D.
1978: Seismicity of western Canada. Canadian Journal of Earth Sciences 15: 1170-1193.

Thomson, R.E.
1976: Tidal waves (tsunamis) - the physical oceanography of the British Columbia coast - part 10. Pacific Yachting 11(4): 34-36, 44-47 and 80-81.

Witham, K. and Milne, W.G.
1972: Protection of the public from earthquake hazards in Canada. Geophysics. Canada, Department of Energy, Mines and Resources, Earth Physics Branch, Ottawa, Ont.

Witham, K.; Milne, W.G. and Smith, W.E.T.
1970: The new seismic zoning map for Canada. Geophysics. Canada, Department of Mines, Energy and Resources, Earth Physics Branch, Ottawa, Ont.

Wourinen, V.
1976: Seismic microzonation of Victoria: A social response to risk. In: Victoria: Physical environment and development. Western Geographical Series 12. University of Victoria, Victoria, B.C. p. 185-219.

5.4.5.6 Factors of Biological Productivity

Carefoot, T.
1977: Pacific seashores: A guide to intertidal ecology. J.J. Douglas Ltd., Vancouver, B.C.

Cushing, D.H. and Walsh, J.J.
1976: The ecology of the seas. Blackwell Scientific Publications, London, U.K.

Healey, M.C.
1980: Utilization of the Nanaimo River estuary by juvenile chinook salmon (Oncorhyncus tshawytcha). Fishery Bulletin 77: 653-668.*

Healey, M.C.; LeBrasseur, R.J.; Sibert, J.R.; Barraclough, W.E. and Mason, J.C.
1978: Ecology of young salmon in Georgia Strait. In: Proceedings of the 1976 Northeast Pacific Pink and Chum Salmon workshop. p. 201-207.*

Herlinveaux, R.H. and Giovando, L.F.
1969: Some oceanographic features of the inside passage between Vancouver Island and the mainland of British Columbia. Technical Report 142. Fisheries Research Board of Canada.*

Kool, R.
1980: Edges. Wildlife Review 9(6). B.C. Ministry of Environment, Fish and Wildlife Branch, Victoria, B.C.

Kormondy, E.J.
1976: Concepts of ecology. Prentice-Hall, Inc., New Jersey.

Marles, E.W.
1973: Bibliography of oceanographic information for the inside waters of the southern British Columbia coast. 2 vols. Marine Science Report 73-1,2. Canada, Department of Fisheries, Marine Science Directorate, Vancouver, B.C.

Naiman, R.J. and Sibert, J.R.
1979: Detritus and juvenile salmon production in the Nanaimo estuary. Importance of detrital carbon to the estuarine ecosystem. Journal of the Fisheries Research Board of Canada 36: 504-520.*

Parsons, T.R.; LeBrasseur, R.J. and Barraclough, W.E.
1970: Levels of production in the pelagic environment of the Strait of Georgia, British Columbia: A review. Journal of the Fisheries Research Board of Canada 22: 1251-1264.*

Perkins, E.J.
1974: The biology of estuaries and coastal waters. Academic Press, London, U.K.

Remane, A. and Schlieper, C.
1971: Biology of brackish water. John Wiley and Sons, Inc., New York.

Ricketts, E.F. and Calvin, J.
1968: Between pacific tides. Stanford University Press, Stanford, Calif.

Stockner, J.G.; Cliff, D.D. and Shortreed, K.R.S.
1979: Phytoplankton ecology of the Strait of Georgia, British Columbia. Journal of the Fisheries Research Board of Canada 36: 657-666.*

Sumich, J.L.
1976: An introduction to the biology of marine life. W.M.C. Brown Company, Dubuque, Iowa.

Whittaker, R.H.
1975: Communities and ecosystems. MacMillan Publishing Co., Inc., New York.

* Available for reference in Canada, Department of Fisheries and Oceans libraries.

Personal Communication (1981)

Coon, M. B.C. Ministry of Environment, Marine Resources Branch, Victoria, B.C.

5.4.5.7 The Administration and Management of Coastal Resources

B.C. Assessment Authority.
1981: Explanation of the difference between tree farms and tree farm licences. Victoria, B.C. Unpublished.

B.C. Ministry of Forests.
1974: Forest tenures in British Columbia. Policy background paper prepared by the Task Force on Crown Timber Disposal. B.C. Forest Service, Victoria, B.C.

B.C. Ministry of Lands, Parks and Housing, Land Use Planning Section.
1980: Land allocation terminology. Victoria, B.C.

1980: Interim guidelines for the review and processing of coastal log-handling applications. Victoria, B.C.

1980: The Ministry of Lands, Parks and Housing's role in foreshore administration. Victoria, B.C.

B.C. Ministry of Lands, Parks and Housing, Land Use Planning Section.
n.d.: Summary table - Land Act - reserves, designations, notations of interest, and section 98 transfers. Victoria, B.C.

Capital Regional District.
1976: Marine shore resource inventory and analysis - Western Community component. Victoria, B.C.

1979: Western Community official settlement plan. Victoria, B.C.

1979: Metchosin official settlement plan. Victoria, B.C.

n.d.: Parks for all seasons. Victoria, B.C.

Coastal Zone Resource Subcommittee.
1978: The management of coastal resources in British Columbia: A review of selected information. Prepared for the B.C. Land Resources Steering Committee. Fisheries and Environment Canada, Lands Directorate, Vancouver, B.C.

Corporation of the District of Saanich, Planning Department.
1979: Official community plan. Saanich, B.C.

Environment Canada, Lands Directorate.
1976: Land use programs in Canada - British Columbia. Ottawa, Ont.

1981: Coastal Resources Folio; east coast of Vancouver Island (Race Point to Hatch Point and adjacent islands) British Columbia. 2 vols. Vancouver, B.C.

Forward, C.N., ed.
1979: Vancouver Island - land of contrasts. Western Geographical Series 17. University of Victoria, Victoria, B.C.

Ince, J.G.
1977: Land use law. A study of legislation governing land use in British Columbia. University of British Columbia, Centre for Continuing Education, Continuing Legal Education Society of B.C., Vancouver, B.C.

Pfister, R.E.
1979: Park and recreation system. In: Vancouver Island - land of contrasts. Western Geographical Series 17. University of Victoria, B.C.

Province of British Columbia Municipal Act, RSBC 1979, Chapter 290.
1980: Queen's Printer, Victoria, B.C. p. 201.

Slater, J.
1978: Shore protection analysis - an inventory of the marine shore resources of Saanich with shoreland management and protection recommendations. Corporation of the District of Saanich, Saanich, B.C.

Personal Communication (1982)

Donelly, S. Capital Regional District, Victoria, B.C.

Note: This report is one part of the documentation available. Other sections of the Coastal Resources Folio; south coast of Vancouver Island (Hatch Point to Ledingham Creek) British Columbia, include: Introduction; Coastal Resources Map Series 1:50,000; Land/Water Use and Status Tables; and Companion Report.