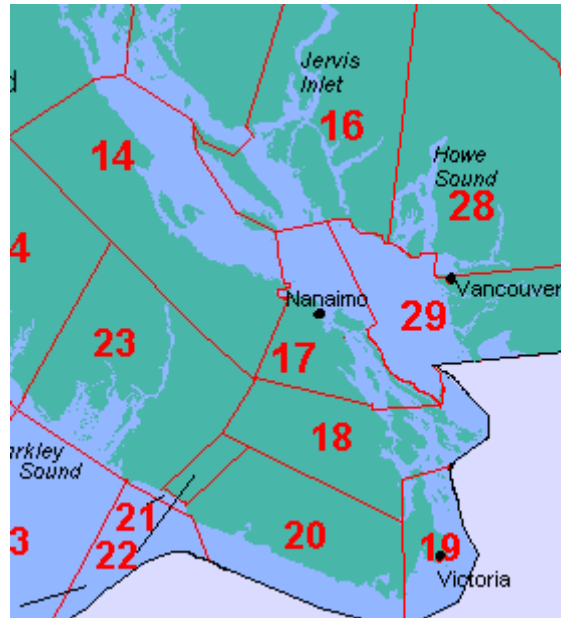


Catalogue of Indicators of Marine Ecosystem Health in the Strait of Georgia Area



Prepared for the Department of Fisheries and Oceans, Pacific Region

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Summary

2WE Associates Consulting Ltd. was engaged to compile and describe existing pressure-condition-response measurements and their potential to support indicators for the marine environment of the Georgia Basin. The identification of measurements to support indicator development is based largely on ongoing monitoring and research projects. Discontinued data collections have been identified in a few cases where future monitoring might support useful indicators.

The project work combined a metadata approach to the catalogue, at somewhere between the inventory and directory level, with evaluation of the suitability of datasets to support indicators of Marine Ecosystem Health (MEH).

The geographic scope of this report is marine waters in the Georgia Basin:

- as far north as Campbell River,
- as far south as the international boundary,
- as far west as the mouth of Juan de Fuca Strait, and
- as far east as Boundary Bay.

Potential indicators reported are only those for the marine environment.

Both scientific datasets and traditional knowledge were considered. A list of potential indicators was created from time-series datasets having at least partial coverage of the Georgia Basin. Project managers and data distributors were contacted by phone to obtain a current description of their projects. The description that was sought focused on measurements being taken, the time period covered by the records, geographic information, and information about the source, availability and repository of the data.

The catalogue includes both scientific datasets and traditional knowledge, allowing integration of these two forms of knowledge when indicators are selected. Most of the entries come from conventional scientific investigations. The originator is typically a federal or provincial agency, but other institutions and groups are also represented.

Contact was made with several of the First Nations participating in Traditional Use Studies. Much of the information gathered in these studies, which are funded through the BC Ministry of Forestry, is related to resource harvesting, the associated travel routes, and temporary residences. Hunting, fishing, and gathering played a central role in the life of aboriginal communities. First Nations harvesters had to be adaptable, shifting effort and targets with the seasons and with natural population cycles. This adaptive approach, with its basis in catch per effort judgments, implies that success in harvesting required a good knowledge of

the ecology and status of the underlying stocks. In addition, harvesters traditionally monitored the health of the animals they butchered, with fat content being an indicator of both food quality and availability.

The indicator framework used in this project was adapted from previous work by DFO and DOE, aimed at developing a methodology to select indicators of marine ecosystem health. Three core levels (stress agent, condition, effect) of a five-level hierarchy were selected for inclusion in the catalogue. The catalogue includes a preliminary evaluation of the suitability of the datasets to support indicator development.

A metadata catalogue was developed to describe the potential indicators. It uses MetaMaker, software that was developed to support the US National Biological Information Infrastructure (NBII). It is a Microsoft Access v2 application. The electronic catalogue provided with this report contains a run-time copy of Access, and can be used on its own or within Access 2.0. The electronic catalogue allows editing of the existing dataset descriptions and the addition of new indicators. It contains a query screen permitting selection by potential indicator name, stress keyword, place keyword, condition keyword, effect keyword, and decade of coverage.

A printed version of the electronic catalogue is also provided, together with station descriptions and maps illustrating the spatial coverage of the datasets underlying the potential indicators.

Acknowledgements

The catalogue was prepared by Bob Wilson and Jane Calvert, who wish to thank the many people contacted for generously providing their time and information. We also thank John Munro for providing the base map and additional information about First Nations. Brian Smiley was the Scientific Authority for this work, providing helpful advice and comments.

Methodology

Scope

2WE Associates Consulting Ltd. was engaged to compile and describe existing pressure-condition-response measurements and potential indicators for the marine environment of the Georgia Basin. Two considerations governed the approach to the project:

1. the need for an intermediate product that will allow DFO and its partners to focus on a more limited number of datasets that can be used, in future, to support indicators of marine ecosystem health;
2. the identification of datasets that could be useful in ecosystem delineation work for Marine Protected Areas.

The identification of measurements to support indicator development is based largely on ongoing monitoring and research projects. Discontinued data collections have been identified in a few cases, where future monitoring might support useful indicators. Government restraint in the last five years has reduced the amount of work undertaken, and selected projects have been identified in cases where resumption of the work could be a useful element of the Georgia Basin Ecosystem Initiative.

The geographic scope of this report is the shoreline and marine waters in the Georgia Basin:

- as far north as Campbell River,
- as far south as the international boundary,
- as far west as the mouth of Juan de Fuca Strait, and
- as far east as Boundary Bay.

The potential indicators reported here are only those which can represent the coastal and marine environments. Where datasets also incorporate measurements in terrestrial or freshwater ecosystems, only the components dealing with the marine environment have been described.

Datasets

A listing of projects thought to be time-series datasets was the starting point for investigating potential indicators. The initial list came from three main sources. Environment Canada has previously prepared a catalogue of ecosystem science and indicators work for a portion of the Georgia Basin (2WE Associates, 1998)ⁱ. Several of the datasets catalogued for this region were marine, and so fell within the ambit of the present project. Workshops held in 1994 (Harding et al., 1994)ⁱⁱ,

and 1995 (Hay *et al.*, 1996)ⁱⁱⁱ to present and discuss time series monitoring projects were a second source of information. Finally, discussion and the personal knowledge of project participants contributed further to the list.

A decision was made not to list stock assessment databases for exploited stocks of fish and invertebrates. These datasets are generally well known to DFO staff. The one or more databases typically available for each exploited species are a cornerstone of DFO's fisheries management practices. In general terms, changes in stock levels reflect three stresses: instability in the natural environment, the influences of harvesting activities, and the influence of habitat alteration and destruction. Information is available to support several ecological indicators of effect.

After the initial list of datasets was assembled, project managers and data distributors were contacted by phone to obtain a current description of activities. The description sought focused on measurements being taken, the time period covered by the records, geographic information, and information about the formats, availability and location of the data.

Since indicators of marine ecosystem health must be founded on descriptions of environmental change, only time series datasets were considered for inclusion in the catalogue. Project managers in a number of cases stated that their data did not meet this criterion. In such cases, and for a number of other reasons, datasets identified were not included in the catalogue.

Indicators

Work began with the identification of an indicator framework. After discussion with Brian Smiley and others, the core of a framework developed specifically for the marine environment (Smiley *et al.*, 1998)^{iv} was adopted. This core is based on a multilevel ecosystem approach to:

- stress activities - human activities (e.g. urban development, mining) that have an environmental impact;
- stress agents - the source of change in marine ecosystems, generally a product of human activity;
- effect - an intermediate result of stress, best characterised as a response of biota to source(s) of change;
- condition - the measured state of marine ecosystems resulting from the interaction of stresses and effects; and
- societal responses - what people and institutions do in response to the perceived changes.

The first and last levels of the framework were not implemented in this project due to a restriction in the database structure. Chemical components at the stress

agent level were modified to reflect the top grouping of contaminants in the National Contaminants Information System (NCIS). The framework used is listed in [Table 1](#).

A rigorous selection of environmental indicators requires five steps ([Smiley et al., 1998](#))^{iv}:

- generation of an issue statement;
- understanding and refinement of the framework;
- identification and validation of linkages between stress, effect, condition and response;
- definition of an indicator; and
- preparation of a written summary of the steps.

The focus in this project was on the identification and description of marine datasets that could be used, later, to support indicator development. Although actual selection of the indicators is left to the future, preliminary linkages have been drawn between the datasets identified and the elements in [Table 1](#). These linkages represent only an initial opinion of 2WE Associates, unsupported by an audit trail, and will need further work to produce an indicator set.

Catalogue and Database

The heart of this project is an electronic database holding metadata about potential indicators. The database used is MetaMaker (v2.22), a product developed to support the US National Biological Information Infrastructure (NBII). The NBII program is co-ordinated by the US Geological Survey, who offer a central exchange platform and query engine for MetaMaker datasets in addition to the database structure. MetaMaker was designed to describe biological datasets in a fully georeferenced format, and is available over a [USGS website](#)^v. The data model for MetaMaker is illustrated in [Appendix 1](#).

MetaMaker is a Microsoft Access v2 application. The electronic catalogue provided with this report contains a run-time copy of Access, and can be started up on its own or from within Access 2.0. The macros in it do not convert cleanly to Access 97. An important feature is an intuitive interface that saves users from the complexities of working in Access.

Starting MetaMaker opens the main menu, with buttons for seven activities:

- add new metadata dataset,
- edit metadata dataset,
- query menu,
- import/export metadata,
- report menu,
- edit or add new template menu,

- system menu,
- exit.

These features are described briefly in the following paragraphs and more completely in the help screens available from within the program.

Add New Metadata Dataset

The first step in entering a dataset into MetaMaker is to enter its title and save it to the database. Dataset names must be unique. The “Add” button can only be used to increase the size of the database; deletions must be made from the “Edit” menu.

Edit Metadata Dataset

This button provides access to most of the application's functionality. Once a dataset name has been entered, the metadata can be added using a sequence of data entry screens. Field definitions can be obtained from a manual that accompanies the database. Many of the fields can be completed from keyword drop boxes, whose use enables a controlled vocabulary for query fields, and for other fields where consistent naming is important.

The edit function incorporates options for deleting and duplicating datasets, the latter feature being useful for reproducing datasets having much of the information in common.

Query Menu

The query menu provides a useful entry point for users with questions about the ability of the catalogue to support indicator development. The queries have been customised for this catalogue, although the underlying data structure of MetaMaker has been left intact. Six query types are possible:

- by dataset name;
- by stress keyword. The stress keywords have been taken from Table 1;
- by place keyword. The place keywords have been taken from CHS chart 3001 and from the Sailing Directions for the South Coast;
- by condition keyword. The condition keywords have been taken from Table 1;
- by temporal keyword. The temporal keywords allow identification of datasets by decade, for each decade of the 20th century; and
- by effect keyword. The effect keywords have been taken from Table 1.

Initiating a successful query will result in a preview of an abbreviated dataset report, including the most important field contents. Multiple retrievals can be viewed one screen at a time.

A limitation of this (the latest) version of MetaMaker is that queries are possible on only one keyword at a time. More complex questions cannot be built in MetaMaker, although they are relatively easy to construct by running the database within Access.

Import/Export Metadata

The import and export button is self-explanatory. Microsoft Access is the only format supported, but the function allows importing and exporting all or part of a database.

Report Menu

The report menu allows a user to produce reports one at a time, by first building them (using the NBII build option), then previewing them, then routing them to a printer or to a file. The latter procedure enables subsequent editing with a word processor.

Edit or Add New Template Menu

The keywords used to control vocabulary must first be entered into the drop-box templates, using the edit feature. In addition, some elements of the database are input from templates, including contacts, citation information, and the time periods covered.

System Menu

The system menu provides the capability to change the DOS directory name in which the database is held. Earlier versions of MetaMaker required the database to be installed in a directory called METANBII, which is still the default for the current version.

Exit

The exit button closes the application.

Discussion of the Potential Indicators

Dataset Summary

A total of 61 datasets were listed during the project for consideration of their indicator potential. The 45 identified as candidates for indicator development are shown in **Table 2**. Towards the end of the project it was learned that Environment Canada was assembling an inventory of indicators for the aquatic, terrestrial, and atmospheric environments of the Georgia Basin, based on data holdings of federal

and provincial agencies. Information was exchanged between the two projects, and the format of [Table 2](#) has been adapted from Environment Canada's requirements.

Sixteen datasets listed during the project but not identified as potential indicators are shown in [Table 3](#). Entries in the table also contain a brief statement to explain their omission from [Table 2](#). Four reasons predominate:

- In several cases, datasets were described by their originators as not representing time-series or monitoring information.
- The contacts for some entries did not wish to be listed in the catalogue.
- Some datasets listed were outside the project's geographic scope.
- Some contacts were not completed.

The listings in [Table 3](#) may be useful when further work is undertaken to develop an indicator set.

Scientific Data

Most catalogue entries come from conventional scientific investigations. Their important characteristics are listed below, and further elaboration can be found in the catalogue:

- **Originator:** The originator is typically a federal or provincial agency, but many of the more interesting potential indicators were collected by other institutions and volunteers.
- **Purpose:** Many of the agency datasets support research objectives as their primary goal, but in doing so they provide time-series data.
- **Time period:** A few datasets cover the complete 20th century, but most were begun in the 1970s or later. Datasets covering only the 1990s may be of limited value to support indicators. This decision has been left till a later time, unless the originator of the dataset specifically mentioned that the period of record was too short to support indicator development.
- **Geographic extent:** Just under half the datasets represent the Georgia Basin as a whole, with the balance representing areas ranging from a large part of the Basin down to an individual site.
- **Ease of access and use:** Few datasets, especially those beginning in the 1970s and earlier, are available in electronic form throughout their period of record. A few require extensive manual tabulation to produce time-series statistics. Other datasets, available only in hard copy, will require significant effort to prepare them for indicator use.

Traditional Knowledge

Both federal and provincial levels of government have fiduciary responsibilities to protect aboriginal access to resources. Decisions in the Supreme Court ([Sparrow](#),

1990; Delgamuukw, 1997)^{vi,vii} have confirmed the constitutional rights of First Nations to harvest traditional resources, subject to the primacy of conservation. To meet the government's need for a body of information about the culture and land use of First Nations, a requirement for ensuring aboriginal access, the BC government began a program to fund Traditional Use Studies (TUS) in 1996.

Much of the information gathered in TUS is related to resource harvesting, and to the associated travel routes and temporary residences. Hunting, fishing, and gathering played a central role in the life of aboriginal communities (Weinstein, 1997)^{viii}. Harvesters had to be adaptable, shifting effort and targets with the seasons and with natural population cycles. This adaptive approach, with its basis in catch per effort judgments, implies that success in harvesting required a good knowledge of the ecology and status of the underlying stocks. In addition, First Nations harvesters traditionally monitored the health of the animals they butchered, with fat content being an indicator of both food quality and availability^{viii}.

Long term reductions in the abundance of resource species are likely to affect the transmission of traditional knowledge. If species are insufficiently abundant to justify an investment of effort in harvesting, there is little incentive for resource users to pass on their knowledge and training. Long term restrictions in access, for example those due to pollution, are likely to produce a similar effect^x.

It is critical to note that First Nations peoples were literally decimated in two sequential smallpox epidemics following contact, with mortality rates in each epidemic approaching 90-95% in those villages that survived. In a society dependent on oral tradition and life-long learning for the transmission of ecological knowledge, the effect of the epidemics on the information now available must have been devastating.

First Nations are vitally concerned with the effects of government decisions in three broad areas: habitat and landscape change, resource allocation, and the establishment of access by competitors to common resources (Weinstein, 1998)^x. Today, land and resources are common property over much of the traditional territories. Although this has always been the case in many First Nations, access was more limited than it is today and the nature of resource use has been changed forever.

Limiting access to common property resources is the central issue in managing those resources. Limiting the transmission of knowledge is the simplest way of managing common property, and has long been a practice in First Nations. Knowledge of resources was transmitted, often within kin groups, only to those who needed it to ensure their success as hunters and harvesters.

"As people are brought into the system, they are provided with geographic knowledge. They are taught about the location of travel routes and how to use them strategically for harvesting. They are taught about details of locating resources, including how the more predictable behaviours of mobile resources work out on the local land and seascape. Along with the geographic details, they are taught the (common property resources) rules and environmental values. Among these are rules including appropriate behaviour toward the resources and toward other humans. The rules include a definition of people within the shared knowledge pools and those outside of it."^x

Access by government to information held by First Nations is thus a difficult area, compounded by suspicion and mistrust, and intensified by political and cultural differences in the way knowledge is shared and decisions are made.

One effect of the Provincial government 's TUS program is to formalize the oral and cultural traditions of aboriginal peoples by creating georeferenced, written records. The program operates with standards for information gathering, recording and mapping (Ministry of Forests, 1996)^x. Historical documentation is searched, including: ethnographic summaries and field notes; maps of traditional territories (available from the office of the B.C. Treaty Commission); linguistic studies of aboriginal place names, government records such as Indian Affairs files and provincial trapline records; local and regional histories; available archaeological reports and field notes; and historical maps and photographs. Interviews are held with elders, resource users, and others in First Nations. To resolve conflicts in the interview information, interviewers are trained in the analysis of ethnographic data. Information is assembled in an electronic database or in hard copy. Maps are created in a GIS application or on sheets, at a scale of 1:50,000 or larger. As each study draws to a close, a copy of the information is provided to the funding agency (Ministry of Forests), who transmit a copy to the Provincial Heritage Registry Database (PHRD) of the Ministry of Small Business and Culture. Data that First Nations decide are confidential may be retained within the community (i.e. not transmitted to the Province), as long as certain minimum requirements for data transmission are met. There are no plans to release the information received to parties outside the Provincial government (Gelean, pers. comm)^{xi}.

The harvest data in TUS are site-oriented but do not describe the abundance of natural resources. It can be inferred from the data that resources were abundant enough to harvest in the past and, for species where such is not the case today, the TUS data could be used to support an indicator of change. Accessing First Nations information in this way would, however, ignore the insight to be gained from further ethnographic work. Better information about changes in resource

status could be one product of special studies, in which this information is specifically sought from elders and others (Quinn, pers. comm.)^{xii}.

Developing indicators of marine ecosystem health from traditional knowledge will require a procedure different from the one used for scientific datasets. DFO could consider an approach, respectful of the way in which traditional knowledge of resources is shared, that helps make First Nations partners in resource management, and helps restore their access to the seafoods, materials and medicines gathered from their traditional territories.

Printed Version of the Catalogue

The printed catalogue (Appendix 2) is best seen as a documentary transmission of potential indicators for browsing and verification. Some fields (e.g. the effects fields) are accompanied by one or more associated entries whose presence has been deemed essential by the NBII developers, making much of the detail tiresome to read. Appendix 2 is definitely not cover-to-cover reading. The electronic database and the query screens offer much better access to the catalogue's contents.

The reports for each potential indicator in Appendix 2 have typically been produced from three sources. A printed report from MetaMaker is usually followed by a printout of station locations associated with the dataset, and by a map of the Georgia Basin with the station information plotted. Metadata can be entered into MetaMaker only at the dataset level. In order to produce maps that would describe the geographic coverage of the datasets, station-level information was produced in Excel 97. Maps were produced in a low-end GIS application, Map Maker Basic v 3.0.

Some potential indicators are not associated with a station listing and/or were not mapped, for one or more reasons best illustrated by example.

- *Comprehensive coverage*: The entry associated with “Frequency of phytoplankton blooms” describes three types of satellite imagery held at the Institute of Ocean Sciences. Since the images completely cover the Georgia Basin (and a much broader area), no extra understanding would have been gained from viewing a map.
- *Data representation is spatially imprecise*: “Organochlorine contaminant trends in seals and killer whales” describes a program to sample seals and killer whales. The two whale populations sampled (Southern resident, and transient) range throughout the Georgia Basin and beyond. The animals' range is among the influences on the contaminant concentrations measured, making the actual location of sample points irrelevant to the data described.

- *High mapping effort.* The dataset “Health of the aquaculture industry and wild fishery” is based on time-series data collected at about 400 stations around the Georgia Basin. While station locations could have been identified, the extra information gained would not have justified the cost of producing a map.

The maps in [Appendix 1](#) are at a scale of 1:1,000,000. Because each point plotted covers several square kilometres on the ground, adjacent stations have sometimes been combined.

TABLE 1. ELEMENTS OF THE INDICATOR FRAMEWORK INCLUDED IN THE CATALOGUE (ADAPTED FROM SMILEY ET AL., 1998)

Stress:	Conditions:	Effects:
Biological Pollutants-Introduced Species	Air-Lower Atmosphere	Behavioral-Aggression
Biological Pollutants-Parasites	Air-Upper Atmosphere	Behavioral-Feeding
Biological Pollutants-Pathogens	Fauna-Amphibians	Behavioral-Locomotion
Biotic Removal	Fauna-Arthropods	Behavioral-Migration
Chemical Pollutants-C,H,O,N,P,S and X Compounds	Fauna-Bacteria	Behavioral-Orientation
Chemical Pollutants-Endocrine Disrupters	Fauna-Birds	Behavioral-Preference/Avoidance
Chemical Pollutants-Halogenated Organic Compounds	Fauna-Bony Fish	Behavioral-Reproduction
Chemical Pollutants-Hydrocarbons	Fauna-Cartilaginous Fish	Biochemical-Endocrinological
Chemical Pollutants-Inorganics	Fauna-Coelenterates	Biochemical-Enzyme Activity
Chemical Pollutants-Natural Products	Fauna-Mammals	Biochemical-Genetic Induction/Inhibition
Chemical Pollutants-Nutrients	Fauna-Molluscs	Biochemical-Genotoxicity
Chemical Pollutants-Properties	Fauna-Other Invertebrates	Biochemical-Metabolites
Habitat Impairment-Alteration	Fauna-Other Microbes	Biochemical-Protein Induction/Inhibition
Habitat Impairment-Destruction	Fauna-Placazoa	Culture and Heritage-First Nations
Human Presence	Fauna-Protozoa	Culture and Heritage-Tradition
Natural Instability	Fauna-Reptiles	Ecological-Community Dynamics
Not Known	Fauna-Sponges	Ecological-Community Function
Physical Pollutants-Heat	Fauna-Viruses	Ecological-Community Production
Physical Pollutants-Noise	Flora-Algae	Ecological-Ecosystem
Physical Pollutants-Odour	Flora-Flowering Plants	Ecological-Population Abundance
Physical Pollutants-Persistent Litter	Flora-Fungi	Ecological-Population Age Structure
	Flora-Other Vascular Plants	Ecological-Population Distribution
	Land-Aquatic Sediments	Ecological-Population Migration and Dispersal
	Land-Terrestrial Soils	Ecological-Population Recruitment

TABLE 1. ELEMENTS OF THE INDICATOR FRAMEWORK INCLUDED IN THE CATALOGUE (ADAPTED FROM SMILEY ET AL., 1998)

Stress:	Conditions:	Effects:
	Water-Freshwater	Ecological-Population Reproductive Success
	Water-Groundwater	Ecological-Population Size Composition
	Water-Marine Water	Ecological-Population Survival
		Economic-Economic Growth
		Economic-Employment
		Economic-Income
		Morphological and Pathological-Body Indices
		Morphological and Pathological-Deformation
		Morphological and Pathological-Haematological Disorders
		Morphological and Pathological-Histological
		Morphological and Pathological-Immunological
		Morphological and Pathological-Lesions
		Morphological and Pathological-Tumours
		Physiological-Circulation
		Physiological-Digestion
		Physiological-Excretion
		Physiological-Growth
		Physiological-Haematological
		Physiological-Locomotion
		Physiological-Nervous/Sensory
		Physiological-Osmoregulation
		Physiological-Reproduction
		Physiological-Respiration

TABLE 1. ELEMENTS OF THE INDICATOR FRAMEWORK INCLUDED IN THE CATALOGUE (ADAPTED FROM SMILEY ET AL., 1998)

Stress:	Conditions:	Effects:
		Political-International Disputes Political-Jurisdictional Relations Social-Aesthetics Social-Crime Social-Demography Social-Lifestyle and Quality of Life Social-Regional Transportation Toxicological-Toxicology

TABLE 2: POTENTIAL INDICATORS INCLUDED IN THE CATALOGUE

Indicator	Condition / Stress / Effect	Data Sources	Contact	Data Collection method	Data Collection Frequency	Historic Records	Data Collection Unit	Data Coverage
#1 Abundance of zooplankton and ichthyoplankton	S,C,E	DFO	Steve Romaine	sampling	up to 7x per year	1990	Two repetitive stations	northern GB
#2 Area closed to fishing by dioxin and furan contamination	S,C,E	DFO/EC	Wayne Knapp/ Mike Hagen	Sampling	annual	1989	areas adjacent to pulp mills	Strait of Georgia
#3 Background sediment quality in Inlets	S,C,E	EC	Dixie Sullivan	sampling	irregular	1987	Selected stations	Jervis inlet, Hotham Sound
#4 Changes in benthic species composition around pulp mills	S,CE	EC	Janice Boyd	sampling	3 year cycles	1993	area around pulp mills	GB
#5 Change in sea surface temperature and salinity	S,C,E	DFO	Ron Perkin	sampling	daily	1914	Some lightstations	Southern Strait of Georgia
#6 Changes in the abundance and species composition of zooplankton	S,C,E	DFO	Steve Romaine	sampling	irregular, several times a year	1982	Standard grid	GB

TABLE 2: POTENTIAL INDICATORS INCLUDED IN THE CATALOGUE

Indicator	Condition / Stress / Effect	Data Sources	Contact	Data Collection method	Data Collection Frequency	Historic Records	Data Collection Unit	Data Coverage
#7 Changes in the area and use of Crown foreshore lands	S,E	MELP	Brendan Feary	files	weekly	1986; earlier data in hard copy	foreshore leases; Crown land	GB
#8 Changes in the marine ecosystem based on traditional knowledge: Ministry of Forests	S,C,E	MOF	Shannon Galean	historical research; interview	once	20th century	First Nations traditional territories	most of GB
#9 Changes in the marine ecosystem based on traditional knowledge: Sliammon Indian Band	S,C,E	Sliammon	Maynard Harry	traditional knowledge	interviews, historical research	approximately 1900	Traditional territory	Central part of the Strait of Georgia
#10 Changes in the marine ecosystem based on traditional Knowledge: Tsleil-Waututh (Burrard) First Nations	S,C,E	Tsleil-Waututh	Mike George	traditional knowledge	interviews, historical research	approximately 1900	Traditional territory	Howe Sound, Vancouver Harbour
#11 Contamination in sediment, benthos and fish by pesticides and heavy metals	S,C	MELP	Les Swain	Sampling	2-3 yr	1986-93	Selected stations	Boundary Bay, Fraser Estuary
#12 Ecological richness in saltmarsh ecosystems	S,C,E	UVic	Richard Hebda	sampling	annual	1997	Selected saltmarsh stations	Saanich Inlet

TABLE 2: POTENTIAL INDICATORS INCLUDED IN THE CATALOGUE

Indicator	Condition / Stress / Effect	Data Sources	Contact	Data Collection method	Data Collection Frequency	Historic Records	Data Collection Unit	Data Coverage
#13 Effects of bacterial contamination on shellfish harvesting areas	S,C,E	EC	Hal Nelson	sampling	cyclical	1972	Selected areas	GB
#14 Effects of human activities on benthos in Porteau Cove	S,C,E	MELP	Brandin Schulz	observation	irregular	1990	Subtidal transect	Porteau Cove
#15 Effects of oil on seabirds	S,C,E	UVic	Alan Burger	Observation	seasonal	1989-95	Selected beaches	Georgia Basin (GB), focus in south
#16 Enhanced size and reproduction of ling cod in marine conservation areas	S,C,E	Vancouver Aquarium	Jeff Marliave	sampling	annual	1994	Fisheries closure areas	Howe Sound, Vancouver Harbour
#17 Faunal changes in the Race Rocks Pilot Marine Protected Area	S,C,E	Lester B Pearson College of the Pacific	Gary Fletcher	observation	variable	1980	Transects	Race Rocks MPA
#18 Fecal coliform contamination at CRD beaches	S,C	CRD	Arlene Turner	Sampling	variable, seasonal	1986	16 beaches in CRD	CRD
#19 Fecal coliform contamination at GVRD beaches	S,C,E	GVRD	Judy Smith	sampling	seasonal	1993 with earlier data	13 beaches in the GVRD	GVRD

TABLE 2: POTENTIAL INDICATORS INCLUDED IN THE CATALOGUE

Indicator	Condition / Stress / Effect	Data Sources	Contact	Data Collection method	Data Collection Frequency	Historic Records	Data Collection Unit	Data Coverage
#20 Frequency and severity of imposex in marine gastropods	S,C,E	2WE Associates	Jeff Thompson	sampling	irregular	1987-96	Selected beaches	GB
#21 Frequency of earthquakes and floods	S,C	UVic	Brian Bornhold	sampling	deep sediment core	approx 14,500 years bp	Two stations	Southeastern Vancouver Island
#22 Frequency of phytoplankton blooms	S,C,E	DFO	Jim Gower	spectral imaging	variable	1996	Swaths	GB
#23 Health of the aquaculture industry and wild fisheries	C,E	MoF	Carmen Matthews	reporting files	annual	1982	Fish farms, seafood buyers	GB
#24 Human population growth in the Georgia Basin	S	BCStats	Ruth MacDougall	census; modelling	annual	1971	Regions and sub-regions	GB
#25 Impacts of human presence in a marine park	S,C,E	Uwash	Megan Dethier	observation	semiannual	1990	quadrates	Botanical Beach
#26 Intensity of marine park use	S	MELP	Sebastien Destrooper	observation	seasonal	1958	About 30 marine parks	GB
#27 Intertidal flora and fauna on unprotected beaches	S,C,E	DFO	Glen Jamieson	observation	annual	1997	35 (1998) Selected beaches	Southwest Strait of Georgia

TABLE 2: POTENTIAL INDICATORS INCLUDED IN THE CATALOGUE

Indicator	Condition / Stress / Effect	Data Sources	Contact	Data Collection method	Data Collection Frequency	Historic Records	Data Collection Unit	Data Coverage
#28 Natural changes in temperature and salinity outside the Fraser River plume	S,C	DFO	Dick Beamish	sampling	daily to weekly	1967	Selected stations	Nanoose Bay
#29 Oil and hazardous materials spill incident frequency and amounts	S	MELP	Stafford Reid	observation	irregular	1991-95	individual spills	GB
#30 Organic and heavy metal contamination at selected ocean disposal sites	S,C	EC	Dixie Sullivan	sampling, video	irregular	1976	Selected ocean disposal sites	Strait of Georgia
#31 Organochlorine contaminant bioaccumulation and effects in cormorants and herons	S,C,E	EC	Laurie Wilson	sampling	irregular	1973	selected heron and cormorant colonies	GB
#32 Organochlorine contaminant trends in harbour seals and killer whales	S,C,E	DFO	Richard Addison	Sampling	irregular	1991	Individual animals	Whales - GB; seals - Southern GB
#33 Phytoplankton succession in Pedder Bay	S,C,E	Lester B Pearson College of the Pacific	Gary Fletcher	sampling	annual	1996	Single site	Peddar Bay

TABLE 2: POTENTIAL INDICATORS INCLUDED IN THE CATALOGUE

Indicator	Condition / Stress / Effect	Data Sources	Contact	Data Collection method	Data Collection Frequency	Historic Records	Data Collection Unit	Data Coverage
#34 PSP and shellfish toxin outbreak incidence and severity	S,C,E	CFIA	Klaus Schallie	sampling	weekly or bi-weekly	1982 - PSP; 1988 domoic acid	22 selected stations	GB
#35 Relative abundance of fish species at a climate scale	S,C	UVic	Brian Bornhold	sampling	sediment core	approx 14,500 bp	Selected stations	Saanich Inlet
#36 Sea level change	S,C	DFO	Fred Stephenson	observation	hourly	1949	Selected stations	GB
#37 Seasonal and extreme marine climate	S,C	DFO	Robin Brown	sensors	hourly	1988	Marine buoys	Sentry Shoal and Halibut Bank
#38 Sewage effects on water quality, benthos, sediments and fish health	S,C,E	GVRD	Stan Bertold	sampling	5-year cycle	1988	Selected stations	Point Grey to Sand Heads
#39 Sewage effects on water quality, subtidal benthos and sediments	S,C,E	CRD	Laura Taylor	sampling	annual	1992	Selected stations	CRD
#40 Sightings, strandings and incidental mortality of cetaceans	C,E	n/a	Ron Bates	observation	daily to weekly	1985	Individual whales	GB
#41 Spatial and temporal changes in the locations where herring spawn	S,C,E	DFO	Doug Hay	observation	annual	1928	Shoreline	GB

TABLE 2: POTENTIAL INDICATORS INCLUDED IN THE CATALOGUE

Indicator	Condition / Stress / Effect	Data Sources	Contact	Data Collection method	Data Collection Frequency	Historic Records	Data Collection Unit	Data Coverage
#42 Succession on an artificial reef	S,C,E	DFO	Brian Smiley	observation	bi-weekly to monthly	1996	Subtidal transect	Sidney Pier
#43 Temporal and spatial trends in the input of contaminants to sediment	S,C	DFO	Robie Macdonald	sampling	variable	20th century	About 22 cores	Southern Strait of Georgia
#44 The number of liquid effluent discharge permits, and total permitted quantities	S	MELP	Deanna Lee/ Lloyd Erickson	files, sampling	monthly	1972	final effluents	GB
#45 Trends in killer whale abundance	C,E	DFO	Graham Ellis	observation	daily to weekly	1974	Individual whales	GB

TABLE 3: DATASETS LISTED DURING THE PROJECT BUT NOT IDENTIFIED AS POTENTIAL INDICATORS

Indicator	Agency	Contact	Reason for not selecting as a potential indicator
Nutrients, chlorophyll and primary productivity in the Fraser River estuary	UBC	Paul J. Harrison	Contact not completed
Water structure and currents in Juan de Fuca Strait	DFO	Rick Thompson	Time series not long enough to use as an indicator
Traditional knowledge from two First Nations			Did not wish to be listed in the catalogue
Marine contaminants	RRU		Contact could not be located
HEAL Program (Health, Environment & Aboriginal Life) Chemainus	First Nations Health Office	Katherina Palmer	On extended leave. Replacement unfamiliar with the program, which ends in March, 1999
HEAL Program, Sooke			
Sediment contamination in Vancouver Harbour	EC	Janice Boyd	Contact not initiated
Intertidal communities in the Fraser Estuary	EC	Bob Elner	Not a time series
Intertidal communities on Vancouver Island	DFO	Glen Jamieson	Not a time series
Trends in sealion abundance	DFO	Peter Olesiuk	Did not wish to be listed in the catalogue
Trends in harbour seal abundance	DFO	Peter Olseiuk	Did not wish to be listed in the catalogue

TABLE 3: DATASETS LISTED DURING THE PROJECT BUT NOT IDENTIFIED AS POTENTIAL INDICATORS

Indicator	Agency	Contact	Reason for not selecting as a potential indicator
Seabird studies in the Strait of Georgia	EC	Gary Kaiser	Outside geographic scope (Desolation Sound)
Population trends in seabirds	EC	Ken Morgan	Outside geographic scope
Saltery Bay (Jervis Inlet) intertidal/ subtidal inventory	MELP	Brandin Schultz	Baseline dataset, not a time series
Marine parks water quality	MELP	Doug Biffer	Outside geographic scope (Desolation Sound)
Botanical Beach intertidal inventory	MELP	Chris Kissinger	Not a monitoring program (but see U WA entry in Table 1)

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- iii Hay, D.E., R.D. Waters, and T.A. Boxwell. 1996. Proceedings, Marine Ecosystem Monitoring Network Workshop, Nanaimo, B.C., March 28-30, 1995. Can. Tech. Rep. Fish.Aquat. Sci. 2108, 160 p.
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- ix Weinstein, M. 1998. Sharing information or captured heritage. 7th Conf. Intl. Assoc for the Study of Common Property, Vancouver, BC, 9-14 June 1998.
- x Traditional Use Studies program guidelines. Aboriginal Affairs Branch, Ministry of Forests, Victoria, BC. Oct. 1996, 89 p.
- xi Shannon Gelean, Ministry of Forests, personal communication, 1999.
- xii Sid Quinn, Sechelt First Nation, pers. comm. 1999.