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INITIAL ENVIRONMENTAL ASSESSMENT PROFILE OF VANCOUVER HARBOUR

By

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March 1985

An Annotated Bibliography on some Aspects of the Environment of Vancouver Harbour Burrard Inlet/Indian Arm

Report to

Environment Canada
Environmental Protection Service
Pacific Region
West Vancouver, B.C.

By

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Abstract

An annotated bibliography on the marine environment of Vancouver Harbour including Burrard Inlet and Indian Arm with emphasis on habitat, ecology, biota and urban effects is presented. Each bibliographic reference has a brief outline of its contents and where possible specific comments on concluding remarks or findings. This document represents the initial work on the examination of the status of the Vancouver Harbour environment.

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Introduction:

This report presents a compilation of existing environmental data, reports, papers and research conducted in and around Burrard Inlet and Indian Arm and forms the initial part of an environmental evaluation of the harbour. As a compilation the information has been collected from government and institutional sources and reflects an emphasis on the marine environment.

The information has been summarized and is presented in the form of an annotated bibliography in an alphabetic listing. In awareness of increasing scope and content, each reference is on one or more separate pages in order to ease additions to this initial document and should be given key words to add in total to the EPS computerized data base (MEQ).

In general, most of the materials reviewed presented research on the biota of the region, their habitat and ecology with a heavy emphasis on fishery resources in the broadest sense.

The oceanography of these waters is well studied and much is known and understood of local coastal processes and their effect on marine flora and fauna. The water quality and sediment conditions in the area have been studied to a limited extent in the harbour proper and only then in a variety of locales examining a range of parameters generally a function of adjacent industry and compliance monitoring requirements.

References on upland features, drainage and stormwater runoff studies and effluent have been included along with general environmental studies, municipal reports, wildlife materials, and physiological studies of fauna and flora.

This document is by no means complete and it is expected that on circulation more information may be brought to light.

Future users are requested to forward references not included in this document to:

Environment Protection Service
Kapilano 100, West Vancouver, B.C.
Attention: Librarian
or call 666-6711.

VANCOUVER HARBOUR

BURRARD INLET/INDIAN ARM

ANNOTATED BIBLIOGRAPHY

Anderson, B.C. Toxicity of Urban Stormwater Runoff. M.Sc. Thesis. UBC, Vancouver, B.C. 1982.

A study of the effects of land use (Brunette Drainage Basin) composition of urban stormwater runoff and its acute toxicity to Daphnia pulex(commercial, industrial, residential and greenspace). Parameters measured included COD, alkalinity, hardness, hydrocarbon and trace metals. Toxicity was found to be influenced by land use and rainfall event interval. Land use toxicity followed the sequence C>I>R>>O. Bioassays in synthetic stormwater demonstrated pH and SS as trace metal toxicity regulators. A detailed first flush assessment showed that while there is toxicity through the physical scouring of insoluble pollutants the soluble pollutants proved more toxic and more washed out over the rainfall event. Proposes the complete treatment of all stormwater runoff.

Trace organics - hydro-C (as isaoctaine) related to time (buildup) and land use (longer buildup in C & I). Trace metals. Cr, Fe and Hi linearly related to TSS. Ca, Cu, Pb, Zn linearly related to buildup time before sampling. Cd, Mg and Mu showed no relationship to either TSS or time.

Cr, Fe and Hi controlled by non "class-dependent" activities. Ca, Cu, Pb, Zn were "class dependent" (land use).

Toxicity - mean runoff sequence shown C>I>R>>O however on a daily basis the sequence was R>I=C>O

-trace metal control was as the mean.

Greenspace runoff was non-toxic

Anderson, M.E. Partitioning of Energy for Growth in the Nudibranch Onchidonbilamellata B.Sc. Thesis, UBC Department of Zoology, Vancouver, B.C. 1974.

Effects of food rationing and submersion periods were studied. Maximum consumption was observed at 66% submersion with 33 and 100% exhibiting less. Similar observations were made of spawn production. Field animals are exposed to 92% submersion, graving 12 mm (mean) in 6 months. Spawn production began in mid-December, peaking in February. Hatching began in March and growth to reproductive size was achieved in winter over 4 months and therefore may have two generations per year.

Anonymous, A Compilation of Coho Escapements to Burrard Inlet/Indian Arm Streams 1951-1983. Fisheries and Oceans, Vancouver, B.C. 1984.

REPORT TO COME

Anonymous. A List of Contingency Plans Held in the Environmental Emergency Branch. Environment Canada, Environmental Protection Service, West Vancouver, B.C. 1984.

A publication identifying the various plans prepared to meet a variety of coastal emergencies from spills, accidents and hazardous materials.

Anonymous. A List of Theses (B.Sc., M.Sc., and Ph.D.). UBC, Department of Zoology, Vancouver, B.C. 1985.

A list of theses selected from the Department of Zoology files having a marine orientation. Further culling is required to select those on Burrard Inlet and area.

Anonymous. Air photograph of Burnaby - an orthophoto of the Corporation of the Municipality of Burnaby (1:20,000)

Corporation of the Municipality of Burnaby, 1982.

Anonymous. Bibliography of Material Published by the Institute of Oceanography, University of British Columbia. Unpublished Bibliography, UBC. Vancouver, B.C. 1984.

A listing of published and unpublished papers, theses and data reports prepared at the Institute of Oceanography 1951-1984.

British Columbia Inlet Study. Cruises and Surveys of Columbia Inlets including Burrard Inlet and Indian Arm. of Oceanography, University of British Columbia Annual 52, 1951 to 1983.

conducted at consistent stations since 1951 in Indian s) and Burrard Inlet (5 stations) interspersed at times ary stations. Oceanographic features examined include nductivity, salinity, sigma-T,oxygen and Secchi Disc. lected using standard oceanographic procedures.

Anonymous. Burrard Inlet Biological Studies. A List of Student Reports to 1984. University of British Columbia, Department of Zoology, Vancouver, B.C. 1985.

A list of UBC's biology 405 student reports identifying author, organism, title and collection sites.

Anonymous. Canadian Tide and Current Tables, Vol. 5. Juan de Fuca and Georgia Straits, Fisheries and Oceans; Canadian Hydrographic Science. 1985.

An annual publication providing tide and current predictions at Vancouver, Point Atkinson and First and Second Narrows respectively. Prediction calculation methods for secondary ports and stations included and identified as False Creek, Port Moody, Deep Cove, Buntzen Lake for Burrard Inlet.

Anonymous. City of Vancouver Sewer Outfalls and Overflows Updated 1984. City of Vancouver, Vancouver, B.C. 1984.

These data include a tabulation of sewer outfalls and overflows for Burrard Inlet receiving waters and a plan (1:20,000) of sewer outfalls and their classification.

Twenty-four outfalls are given along with location, length,invert elevation and slope in the tabulation which excludes False Creek discharges.

In plan,17 storm discharges and 14 combined outfalls are under City jurisdiction and 1 comb. outfall and 9 comb. overflow under the GVRD's jurisdiction.

Anonymous. Combined Sewer Overflow Abatement Study - Summary Report. City Engineering Department, Vancouver, B.C. and Greater Vancouver Sewerage and Drainage District. 1980.

This study was carried out on a 6,400-acre area of Vancouver to determine the quantity and quality of combined sewer overflows which discharge into the waters of English Bay and False Creek. The QQS computer simulation model was adopted for the analysis.

The performance of existing combined sewerage facilities was simulated under single event and continuous (multi storm) rainfall conditions, and problem areas were identified. A number of system improvement alternatives were tested, and the most effective were selected for incorporation in the "future" network. The long-term behaviour of this latter proposed system was then assessed to provide a statistical comparison between "existing" and "future" overflow characteristics.

The study concluded that the capacity of the sewer system could be utilized more effectively by making relatively minor modifications to the existing facilities and by amending their current mode of operation. It also concluded that "off-line" storage of combined sewage would be an effective method for abating pollution from sewer overflows.

Anonymous. Commercial and Tidal Sport Fishing Statistical Summaries for Area 28. Fisheries and Oceans, Vancouver, B.C. 1984.

Statistics are for Area 28 which includes Howe Sound. Before these data will be of value they will have to be segregated into the specific areas (Burrard Inlet, English Bay, Port Moody, and Indian Arm). Sports Catch data include Chinook, Coho and other salmon, Lingcod, Rockfish and Crab.

Commercial catch data include annual summaries from 1951 to 1984 for Chinook, Sockeye, Coho, Pink, Chum, Steelhead and all species.

Annual summary for all species shows a distinct decline from 1951 to 1968 when the fishery was closed. Reopenings showed modest catches.

Data is also included for shellfish including octopus, prawns, shrimp, clams, crab and ground fish including mixed sole, bass, lingcod, sablefish and other rockfish, smelts and dogfish 1951 to 1985 by year.

Anonymous. Comprehensive Analyses Data for Lions Gate Sewage Treatment Plant: Influent/Effluent. Monthly summary for 1983. Greater Vancouver Regional District, Pollution Control Group Analytical Data, Burnaby, B.C. 1985.

Data reports as required under the PCB per unit (PE 30) monitoring requirements for specified parameters including nutrients, pH, suspended solids, BOD, COD, metals and toxicity measurements. Information is in a monthly summary of daily data collected at the Lions Gate treatment plant. Analytical procedures are outlined in the Ministry of Environment Handbook.

Anonymous. Contingency Plan for the Transportation and Storage of Chemicals to and from the West Coast Distribution Centre of Dow Chemical in North Vancouver.
Prepared for:Dow Chemical Ltd.,North Vancouver, B.C. 1980.
By: Beak Consultants, Vancouver,B.C.

The report reviews the process and statement of procedures for a spill contingency plan for a number of hazardous materials shipped to Dow Chemical on Burrard Inlet. It outlines the planning steps required from detection through countermeasures, history, reporting requirements and legal consequences. The plan provides background data on handling of the products (caustic soda, ethylene glycol. and ethylene dichloride) and risks of their transportation in the province. A simulated ship accident in Burrard Inlet is given along with specific action requirements. Caustic soda effects are considered to be local. EDC would significantly effect the benthos at the spill site and EG is considered to have little effect on aquatic life in the area.

Anonymous. Current Nutrient Data and Summary Statistics (1975-1979) for Lions Gate Sewage Treatment Plant. Ministry of Environment, Victoria, B.C. Equis/GVRD, Burnaby, B.C.

Daily/monthly data summaries required under PE-30 monitoring is available on the Ministry of Environment computer data base (EQUIS) for the period 1975-1979. The data include standard monitoring parameters including nutrients, metals, BOD, COD, SS, pH and toxicity.

Anonymous (unpublished). Distribution of Selected Trace Metals in Fish Tissue from False Creek.
B.C. Place Ltd.,B.C.I.T.,and Fisheries and Oceans, Vancouver, B.C. 1983.

Fish collected by net, long line and angling in False Creek were dissected and the respective tissues analyzed for trace metals by ICAP at the Fisheries Laboratory in West Vancouver. The data showed the more pelagic species to have lower metal levels in comparison to ground or bottom fish in the area. Further review of this and associated data compiled at the time is required.

Anonymous. Drainage Plans for the City of North Vancouver. City of North Vancouver, B.C. 1984.

Anonymous. Eighth Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and otner Matter 20-24, Feb/84. Agenda Item 10.

International Maritime Organization,1984.

For general reference use.

Anonymous. Environmental Baseline Survey, Northeastern Burrard Inlet.
Report for: Dow Chemical of Canada Ltd., Delta, B.C. 1979
By: Beak Consultants Ltd., Vancouver, B.C.

This report contains a historic environmental review of the Dow Chemical of Canada Lynnterm site on the northeastern shore of Burrard Inlet. Field studies to provide baseline data were taken in five areas: air, noise, water, sediments and benthos. Ethylene dichloride was not detected in either the air or sediment studies. The other surveys will serve as background from which to compare future conditions.

Detailed methodologies are given.

Anonymous. Greater Vancouver Sewerage and Drainage District Influent and Effluent Analyses for Lions Gate Sewage Treatment Plant. Extracts from Compliance Monitoring Report by the GVS&DD Laboratory. 1983.

A comprehensive analytical summary of data required under PE-30 including nutrient analysis, alkalinity, sulphate, oil and grease, phenol and total and dissolved metals (Al-Zn) and bacteria. Annual reports to 1956 have data summaries describing a variety or parameters which have been modified ofer the years. In the full report detailed methodologies are presented.

Anonymous. Hydrology in the Maplewood Planning Area of the District of North Vancouver.
Report to: District of North Vancouver, North Vancouver, B.C. 1980
By: Tera Consultants Ltd., Vancouver, B.C.

A hydrologic and water quality study was carried out in the Seymour Heights/Maplewood flats. Chemex Laboratories undertook the testing. No methodology is given. Four locations were sampled and anlyzed for 30 metals including As, Cd, Cr, Cu, and Pb, Zn, as well as pH, SS, DS, PO4, HO2/3 and O3G. The results generally fell within or below the recommended water quality levels. However, phosphate levels were quite high as were lead levels at sample location 4a: north of Canadian Oxy. In connection with this and hydrologic work important ecological areas were identified and mapped relative to the Maplewood flats. It was identified that foreshore water inflow and swamp areas were replenished by ground water flow, which is recharged in the uplands. The report develops water management guidelines and suggests retention of natural corridors.

E

Anonymous. Independent Review of Permit PE-30 concerning the Impact of Lions Gate Sewage Treatment Plant on the Receiving Environment. Report to: Greater Vancouver Sewerage and Drainage District, Burnaby, B.C. 1981.
By: B.C. Research, Division of Applied Biology, Vancouver, Project No. 1-05-312.

A study of the receiving water at First Narrows (Lions Gate STP) included the measurement of currents, and physical, chemical and biological monitoring to determine:

1) effluent dilution, its rate and dispersal pattern,
2) concentration of known toxicants,
3) distribution of E.coli.

Methodologies are briefly outlined. Six of 15 toxicity tests failed, Iona STP metals data were used in dispersion evaluation. Report concludes that little impact occurs on public health or fisheries resources at current effluent concentrations.

Anonymous. Industry in Vancouver - A Preliminary Report for Discussion.
City of Vancouver, Planning Department. 1977.

A report profiling the industrial base of Vancouver based on a 1971 listing by industry including a brief summary of transportation, utilities, construction. Maps of area show types industrial zoning and discussion considers positive and negative aspects including impacts on the environment.

Trends concerning the shifting of industry away from the city are reviewed including sound, environment and land use implications. Criteria are developed to evaluate the alternatives.

Anonymous. Interim Standards Governing Marinas and Waste Disposal from Watercraft, City of Vancouver, City Health Department, 1975.

Regulations adopted by City of Vancouver Council, March 5, 1974 outline the requirements for marina and boat waste disposal. Provides a glossary of terms, general requirements and jurisdiction, water supply, sewage disposal, washroom, laundry room wastes and finishing and solid waste disposal and collection.

Rodent and insect control and general safety are also discussed briefly.

Anonymous, 1979. Inventory of PCB Permits for Marine Discharges. Microbiology Laboratory, Marine Programs,Environmental Protection Service Pacific Region (PCB Permits).

Information coded and included in Anon (1981)Marine Discharge Inventory. EPS.

Includes coastal maps and discharge locations by number sequence in text along with company name, location, discharge type, quantity (IGPD), quality, receiving waters, Application Date, Permit Issue date and File No.

This document has since been updated at EPS using Data Point computer base (1985) and all Permits are on this system and can be retrieved on the basis of latitude and longitude, name, waterway, etc.

Anonymous. Lower Mainland Port Economic Study - Executive Summary.
Report to: Public Works Canada, Vancouver, B.C. 1980
By: Acres Consulting Services, Vancouver, B.C.

A review of the study's significant components including major findings, historical aspects, employment impacts, geographic and jurisdictional aspects. Assessment methodologies were outlined for terminal capacity, forecasting trade opportunities and supply/demand aspect. A strategy for future requirements is outlined.

Anonymous. Lower Mainland Port Economic Study - Regional Study Phase I.
Report for: Public Works Canada, Vancouver, B.C. 1980
By: Acres Consulting Services Ltd., Vancouver, B.C.

The port economic study is a major work providing an overview of the multifaceted port operations on the lower mainland including the Port of Vancouver and therefore Burrard Inlet. The ports' setting, profile, capacity, trade flows, future are assessed. The report documents the primary components of the physical and biological environment including oceanography, surficial geology, climate air quality and water quality and pollution potential. Present water quality is addressed along with fisheries resource (marine and fresh water), avifauna, invertebrates, mammals, amphibians and reptiles and aquatic vegetation. No original work was done on environmental aspects due to the preliminary and planning nature of the study. References are given.

Anonymous. Marine Discharge Inventory. Environmental Protection Service Pollution Control Group, Municipal Program 1981.

Identifies discharges on the coast (permitted/EPS file no.) noting name, types, quality, location, company, latitude/longitude, flow, receiving water and date.

This work, like that published in 1979 by EPS is now on a system data base (Data point) at EPS (1985).

Anonymous. Marine Pollution Implications of Coastal Area Development Reports and Studies No. 11. United Nations, GESAMP, 1980.

For general reference use.

Anonymous. North Shore Ravine Study - Noons, Hutchison, Turners, Wilks and Hett Creeks. A Study for the City of Port Moody, May 1982 by McElhanney Engineering Ltd., Vancouver, B.C.

This study analyzes the water sheds in order to determine the most desirable system of conveying runoff generated by development plans. Alternatives of discharging to Burrard Inlet via trunklines or into creeks were developed. The report suggests environmental effects on the ravines would be minimal under the first alternative and extreme under the second largely due to extreme flows which would have to be carried in the streams. The latter was chosen, with some modification, based on capital cost. The study identifies current flooding potential and remedial actives proposed. Watersheds and landuse are also described along with hydrologic features of rainfall and stream discharges (predicted and instantaneous). Predevelopment and post development flows are analyzed and conveyancing systems presented. The report outlines the geotechnical aspects of ravines and environmental reserves, buffer strips and set backs.

Anonymous. Policy Statement for Operational Contingency Plan for Handling Oil and Hazardous Materials.
Report to: Department of Industry, Trade and Commerce, Burrard Ship Repair Facility. 1980.
By: Swan Wooster Engineering Co. Ltd., Vancouver, B.C.

This report on the equipment and contingency plan covers the considerations of environmental design, dealing with the drydock operations, as specified by the Federal Department of Fisheries and the Environment.

It includes the components of the drydock for pollution prevention arising from the environmental design:

1. An oil boom.
2. Oil traps and pontoon gap plates.
3. Oil absorbents.
4. Collection tanks for oily water and sewage.
5. Cleaning and painting equipment.

Systems are outlined for the normal operational collection and disposal of sewage and oily wastes,and the normal cleaning,painting and disposal of scrapings.

A contingency plan is outlined for docking a damaged vessel which is spilling oil, and for treating accidental oil spills. Spills of other hazardous materials will be cleaned up or neutralized in consultation with chemical engineers.

The environmental design and contingency plan use readily available equipment and contractors, and conform to the objective of "best practicable technology".

Anonymous. Premier St. Landfill Leachate Monitoring Test Results, August 1982 - October, 1983.
Report for: District of North Vancouver, North Vancouver, B.C. 1983.
By: Chemex Labs. Ltd., North Vancouver, B.C.

Data reported as required under Permit PR-4231 including mean values and standard deviation for data with temporal variation. Analysis included T C, pH, total and dissolved metals (Fe, Mn, Cu, Cd, Pb, Cr, Zn), COD, TOC, Ammonia, Na, BOD, surfactants, Phenols, SVS, DVS, SS and DS (Fixed).

Anonymous. Review of Encroachment Design for the Seymour River, C.N. Rail Facility Expansion.
Report to: CN Rail, Surrey, B.C. 1982
By: Reid, Crowther and Partners Ltd.

Assesses the impact of proposed CN double tracking on the north shore of Burrard Inlet at the confluence of the Seymour River. Hydrology of the drainage area is studied and evaluated in terms of proposal along with an overview of the biological setting including salmonid resources, intertidal habitat and estuarine environs. Habitat value are discussed in this and adjacent Maplewood mudflats area. A design review is made on hydraulic performance and implications to the environment discussed and compensation options suggested. This document based primarily on existing data and minimal field reconnaissance.

Anonymous. Review of Harmful Substances. Joint Group of Experts on the Scientific Aspect of Marine Pollution (GESAMP), IMCO, FOA, UNESCO, WHO, IAEA, UN. Reports and Studies No. 2. 76-98245. New York. 1976.

Report identifies some widely known substances which are harmful. Categorizes marine pollution - domestic, pesticides, inorganics, radioactive, oil and dispersants, organic industrial wastes, military, heat, detergents, solid objects, dredge spill and inert wastes. Discusses importance in general and effects of water body noting specific examples of occurrance or concern. CN, Sb, As, Be, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, P, Sc, Ag, S, Ti, Va, Zn. Annotated bibliography of source materials and a list of experts - Canada-Sprague and Waldichuk, Report Partial in this copy covering pages 1-38, 39-70 missing.

Anonymous. Summary Report on Creek Systems and Stormwater Control.
Report for: The District of North Vancouver. 1982
By: Kerr Wood Leidal Associates Ltd., North Vancouver, B.C.

An engineering study of seven (7) major drainage systems in North Vancouver was made to prepare a master plan to mitigate problem conditions of stabilization and slope and improve stormwater control. Criteria are established for peak discharge estimation on creek systems, drainage facility design. Comparative analysis of hydraulic capacities of natural and existing facilities are made to provide a basis for improving the channels and facilities. Design criteria for off-stream storm drain systems is also given. The summary is supplemented by a set of 13 working papers, one for each drainage area, reports on specific problems and for design criteria. Data was brought from existing sources and field reconnaissance/stream walks.

Anonymous. Summary Report of the Water Quality Work Group. Fraser River Estuary Study Water Quality. Government of Canada and Province of British Columbia. 1979.

The report is part of the Fraser River Estuary Study, which was set up to develop a management plan for the estuary. The report summarizes a number of detailed technical reports which describe effluents discharged, water quality and aquatic biology.

Most water quality parameters in the river are not measurably changed by the major discharges to the river, except near effluent plumes. There is some accumulation of heavy metals and toxic organic contaminants in aquatic biota, including fish. The levels of these toxicants in fish from the river are usually within accepted food criteria, although mercury occasionally exceeds the criteria in some resident species.

Fecal coliform data show summer contact use is acceptable but shell fishing is closed and will be for forseeable future. Total volume of all discharges is nearly 2x10 (6) m(3)/day. Effluent from Iona STP accounts for 65% of all municipal effluents and has degraded an area of Sturgeon Bank. Stormwater in discharged 200 locations and loading is considered to be 1/2 to twice the Annicis plant loading. Recommendations include:

1. STP upgrading
2. better waste control and disposal
3. monitoring of waste/storm water effects to determine action needed.

Anonymous. Terrain Reconnaissance in the Maplewood Planning Area of the District of North Vancouver.
Report to: District of North Vancouver, 1980.
By: Tera Environmental Consultants Ltd.

A study of a 24 ha. upland area adjacent to the Maplewood mudflat assessing the site suitability for development in consideration of natural environment values. Analysis is based on an integration of the identified climatic geologic, hydrologic, vegetation and wildlife constraints. Field work and analyses were conducted from December 1979 - March 1980 and is incorporated with the base of available data to provide an environmental overview.

Anonymous. The Burrard Inlet-Howe Sound Area: Preliminary Description of Existing Environmental Conditions (Draft Report). Draft Report - Canada Department of the Environment. 1971.

A report on selected environmental resource factors, land and water use and land status in the Burrard Inlet-Howe Sound Area to be used as an aid in interpreting resource capability. Factors described include climate, geology and soils, vegetation and forestry capability, wildlife and avian elements, fresh water resources and marine resources. The marine environment of Burrard Inlet is described including oceanography and fisheries resources (spawning data, fresh water requirements, area biological habitat usage, importance and exploitation of fish stocks). Recreation resources, land use, zoning, public utilities and travel and traffic characteristics.

It is noted that Burrard Inlet is well utilized as a rearing area for local and non-local fish stocks. The harbour entrance has been less subject to modification than inner areas such as Coal Harbour where water is poorly flushed. Summarizes four (4) problem areas as affecting fisheries resources (p.52) which are storm/waste water, spills, wharf fishermen, harbour construction and operation. Several appendices list species, spawning data, oceanography, discharges to Coal Harbour, plankton data, and notes on streams.

Anonymous. The Review of the Health of the Oceans. Report and Studies No. 95. UNESCO, 1982. IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution. (GESAMP).

For general reference use.

Anonymous. Thermal Profiling in the Vicinity of Burrard Thermal X
Generating Plant, April 1980.
Report for: B.C. Hydro and Power Authority, Vancouver, B.C. 1980.
By: Beak Consultants Ltd., Vancouver, B.C.

A report on the distribution of heat in Burrard Inlet generated by the Burrard Thermal Generating Plant. The isotherm 1 degree C above ambient temperature was mapped using a Lowrance CTT-100 telethermometer at three depths over 4 tidal stages in April 1980. The study indicated physiography, climatic conditions, low delta T's and water conditions to interfere in the determination of the 1 degree C isotherm (+ ambient). Charts show temperature distribution and study transects.

Anonymous. Vancouver Christmas Bird Count Survey Areas, Vancouver Natural History Society, Vancouver, B.C. 1974.

A listing of survey areas and observers for the Christmas bird count provided by CWS along with notes on tabulations available at CWS offices for 1968-1974.

Anonymous. Waste Management Branch File on 1)Discharges to Burrard Inlet (1982) 2)Fish and Wildlife Strategy for Steelhead and Cutthroat Trout and 3) L & K Lumber, 1983-4. Waste Management Branch, Surrey, B.C., 1985.

File includes the following:

1. a photograph legend of outfalls into Burrard Inlet.
2. a map showing discharges of 8" dia. or greater.
3. Howe Sound, Burrard Inlet/Indian Arm Management and Enhancement Strategy for Steelhead and Anadromous Cutthroat Trout including summary data on present stocks and future plans.
4. A listing of North Burrard Inlet Discharges - Lynnwood marina to BCR discharge including summary and recommendations for action according to level of concern with the discharge; observed effluent discharge from BCR; report on L & K Lumber with photo essay re Dip Tank and analytical data for PCB's (92-240 ppm).

Anonymous (unpublished). Water Sampling Record - Survey for GVRD - Port Moody/Bedwell Bay. Simon Fraser Health Unit, Port Moody, B.C. 1982.

Data sheets for 1982 on local beaches assessed for coliform for health purposes. Data show low Fecal coliform levels within criteria for primary contact with occassional exceptions, particularly in Port Moody Bay near a discharge on the south shore.

Atwater,J. Impacts of Landfills-Fraser River Estuary Study Water Quality Quality. Environmental Protection Service, Environment Canada. 1980. Background report to the FRES Steering Committee.

This report is a summary of available information on landfills located within the area contiguous to the Fraser River Estuary.

The information is reviewed within the context of leachate generation and pollutant loads associated with the leachate, present and future, and the potential impact of the pollutants on the Fraser River Estuary including fish toxicity.

Four classes of landfills are dealt with: large active municipal landfills, large closed municipal landfills, wood waste landfills, and small unicipal and miscellaneous landfills.

Landfilling was found to be the prime method of solid waste disposal, with only about 10% of the wood waste currently going to incineration. Estimates of pollutant loads resulting from the first three landfill classes are made and presented in the report.

The landfills were seen to be significant sources of organic material, ammonia, and total solids, although not major sources of trace metals. Leachate from wood waste landfills was seen to cause significant degredation of water quality where directed into small tributaries and drainage ditches flowing into the Fraser River.

Atwater, J.W. City of Vancouver, Industrial Waste Inventory, 1977. Regional Program Report: 79-20, 1979. Environmental Protection Service Pacific Region.

This report presents an inventory of the industrial waste generated during 1977 by the manufacturing, commercial and institutional establishments located in Vancouver, British Columbia, a port city of approximately 415,000 people. In addition to the waste generation data, brief descriptions of the firms generating the waste are provided as is information concerning the disposal of those wastes. The tabled quantities are based on personal interviews undertaken at 727 of the 1785 firms in the City of Vancouver.

Some 1,024,783 Imperial gallons (4,658,752 litres) of mixed aqueous liquids, 789,483 Imperial gallons (3,589,145 litres) of mixed sludge, plus 80,968 short tons (73,400 tonnes) of solid waste were reported to be generated annually by the 1785 firms.

The data and summary tables for each principal industrial group follow the text description of the industrial group. Thus each industrial group is presented as complete, unified segment of information.

Barreca, Jeannette. Intertidal Baseline Study of Figurehead Point, Vancouver, B.C. Vancouver Natural History Society, Environment 2000, Environment Canada. 1984.

The data report includes a detailed methodology on quantitative intertidal surveying for work carried out on the Figurehead Pt. intertidal area, May 15, 1984 identifying the vertical distribution of macro invertebrate fauna and algae that can be used in the future along with supplementary studies of the same site. Samples were identified to species where time permitted and are in the UBC Invertebrate Museum. Sediments are described with boulders through the transect at 3.2/m2 along with silts to pebble size fractions. Epi Fauna were assessed by no./m2 and wet weight (gms)/m2. Infauna were similarly treated.

A list of UBC student reports is appended (Bi 405).

Beech, F. 1984. Shoreline Protection and Cleanup Manual, Port of Vancouver. Regional Program Report 84-02. Environmental Protection Service, Pacific and Yukon Region.

Report relates the experience gained in control and clean up of spills in the harbour. Identifies shoreline resources by classification, assess, resource material and countermeasures on operational maps. Includes a selected bibliography and review of existing biological resources.

Bell, D. Summary and Recommendations for Floating Committees, Greater Vancouver Regional District, Sub-Committee on Float Homes, December, 1978.

Established by the GVRD Planning Committee in 1977 to review the overlapping jurisdiction in connection with float homes the sub-committee generated an integrated document setting out: role clarification, legislative requirements, standards and approvals procedures, and to reach technical agreement on locating float homes. The report outlines the parties involved and presents the committee's recommendations.

Bell, D.H. Jurisdictional Issues Related to Floating Committees Background Paper. Greater Vancouver Regional District Planning Department, 1978.

Presents the results of extensive interagency discussions at the Federal, Provincial and municipal levels along with a review of prior research. It is the basis of legal retionale for many of the sub-committee's recommendations made in their report "Summary and Recommendations" for float homes and committees.

Bell, G.R. and G. E. Hoskins (Unpublished). Apparent Absence of the Lobster pathogen Aerococcus viridans in Dungeness crabs (Cancer magister) in the waters off Vancouver. Department of Fisheries and Oceans. Fisheries Research Branch, Nanaimo, B.C. March 1985.

A population study of Cancer magister in and around Vancouver Harbour in 1967 was carried out to determine if a pathogen (Aerococcus veridans) common to lobster may be common to this local decapod of commercial and recreational importance. At this time the area sampled is considered as having poor water quality. Sampling and determination methodologies are briefly noted and referenced. Some 522 adult crabs, including 300 females, 155 males and 67 unsexed were collected by bottom trawl and with little variation no A. viridans could be confirmed suggesting that the Dungeness Crab in local B.C. waters does not carry the lobster pathogen. Further study determined that a pathogenic effect could be obtained in C.magister by injection only.

Benn, D.R. and A. McLean. Lower Mainland Natural Areas Inventory. The Nature Conservancy of Canada Canada. Sponsored by: National Second Century Fund GVRD and the Koerner Foundation, 1977.

Publication to be forwarded.

Billings, S.J. Steelhead Harvest Analysis, 1983-84. Fisheries Technical Circular No. 64, 1984. Ministry of Environment, Fisheries and Wildlife Branches, Victoria, B.C.

This harves analysis provides catch statistics for steelhead on a province wide basis for all anglers, identifying numbers, angler days, kept, release, kept and catch/day. In the Burrard Inlet area the Capilano and Seymour Rivers are among those having the highest total catch in 1983-84, in fact ranked 3-4th in the Lower Mainland area (2).

Birtwell, I.K., I. McDonald, E. McGreer. Intertidal Ecology in Burrard Inlet.
A Project Report to N. D. Lee and Associates Ltd.1970.
By: B. C. Research Ltd., Vancouver, B.C.

A preliminary report on the intertidal ecology of an area on the south side of Burrard Inlet for which recreational developments were proposed was carried out in 1970 . Physical and biological features of three areas are assessed by the standard marine biological procedures outlined.

Three beach types were found in the study area - gravel, sand and rock. Each supporting a different animal and plant community. Algae were sparse, and frequently associated with freshwater seepage areas. On the sand beach at the west of the study area Zostera sp. (eelgrass) was found. Clams were the dominant macrofauna element on this beach, especially at the lower shore level. On the gravelbeaches, mussels, barnacles and gastropods were found above the sediment, while clams predominated the fauna within the sediment. Rock beaches supported an abundance of barnacles, mussels and gastropods.

The report suggests the industrial development of the area appears to have an effect on the intertidal community.

The report identifies that beach development for swimming and sunbathing would be preferable at Site 1 where the ecological effect would be minimal. Marina developments should take place off rock beaches for the same reasons.

Recommendations for future work are made before a more precise preduction of the ecological effects of the proposed developments can be made.

Blunden, R. H. Vancouver's Downtown (Coal) Peninsula Urban Geology. Univerisity of British Columbia, Vancouver, B.C. 1971.

A synopsis of geological findings arising from studies on the proposed third crossing of Burrard Inlet and on foundation investigations for buildings, tunnels and bridges in and around downtown Vancouver.

Upper Cretaceous sandstones (Brothers Creek formation) are mapped on the northern and western shores of Stanley Park. These are overlain disconformably by sandy and shaly beds (Ferguson Point formation) of Paleocene and Eocene age, and these in turn in a sandy to shaly, and locally conglomeratic unit (Kitsilano formation of Johnston revised) of late Eocene age. These have been intruded by basaltic and doleritic rocks (Prospect Point eruptives).

Quaternary beds, locally greater than 100' thick, but generally less than 20 feet thick in the business area of Vancouver, incluces a complex succession of late Pleistocene diamictons and turbidites (Gumboot group), some of which are interpreted as solifluction deposits. A bouldery surface mantle (Bose group) is attributed to ice-rafting at a time of high relative sea level. Marine silts, sands, gravels and shell deposits of postglacial age are referred to as the Burrard Inlet group.

Several faults are identified, as cutting Eocene beds, particularly under Coal Harbour.Some evidence of recent movement is available for five of these faults.

Areas experiencing significant ground motion in historic earthquakes have been mapped.

Bonham, N. & N. McFadden. Port of Vancouver Review of Oil Spills and Slicks, 1980-1983. Environment Canada, Environment Protection Service, West Vancouver, B.C.

The review identifies the main sources of oil which may spill in the Port of Vancouver and examines the records of spill reports from 1980-83 and segregates the spills geographically in 14 regions from Pt. Atkinson to Port Moody to Pt. Grey. The area with the greatest number of spills reported is Vancouver Wharves to Pioneer Grain and CPR/A to Second Narrows and no significant changes are reported from year to year. 50% of reported incidents are from unknown sources and in discussion the need to reduce this percentage is recommended to reduce the occurrance.

Bourne, D.R. 1974. Trace Element Distribution in Bottom Sediments of Port Moody Inlet, Port Moody, B.C. B.Sc. Thesis. UBC Geological Science Library.

Seventy samples of bottom sediment from Port Moody Inlet were analyzed for Cu, Pb, Zn, Fe, Ni, Mn, Cd, Ag , Co,S, organic matter,and sand. The highest concentration of trace metals characterize finer sediments away from sandy tidal flats and creek mouths. Multivariate Analyses indicated that Mn and S are two other important variables controlling trace metal distribution.

High lead, ranging from 1-260 ppm with a mean of 70 ppm, and zinc, ranging from 44-663 ppm, with a mean of 136 ppm.Values possibly result from automobile exhaust, a drum reconditioning plant, oil refining and residential wastes.

Bowman, S. Valuation of Lynn Creek Fish Resources.
Report for: District of North Vancouver, North Vancouver, B.C.1984
By: Envirocon Ltd., Vancouver, B.C.

The study investigated the effect of leachate discharge from Premier St. Landfill on fish resources in Lynn Creek including fish habitat, fish resource valuation, mitigation measures and associated costs. Estimates of losses were 17-34% for Steelhead Trout, 20-40% for Coho Solmon and 10-20% for Chum and Pink Salmon. Water quality data show high levels of ammonia and some dissolved metals downstream of the landfill. However all levels were lower than lowest safe upper limits identified in the literature. Frequency of increases were greater downstream of the landfill than upstream. Water quality analyses were conducted in 1982-83 by Chemex Labs. and bioassays were conducted by EPS in 1980 and 1981. Methodology not described. Work was carried out under Permit No. PR-4231 monitoring requirements.

Brouwer, K.J. Port Moody Mudflats: Environmental and Geotechnical Sampling Programs.
Report for: City of Port Moody, Parks and Recreation, 1984.

An environmental and geotechnical sampling program provided information on the amount and distribution of loose surface materials on the mudflat in the eastern extremity ofBurrard Inlet. Surficial fines have been observed to result from a combination of industrial and residential effluents and from normal peritidal processes. Underlying materials included clays, silts and sands. Recommendations for beach development are made along with other studies to make the best development decisions and minimize environmental impact. (Environmental evaluation of muds and fishery use is required.)

Brown, D.A. Toxicology of Trace Metals: Metallothionein Production and Carcinogenesis. PhD. Thesis, UBC, Vancouver, B.C. 1978.

This study reports a biochemically meaningful assay based upon the actual toxicology of the trace metals: it measures the levels of those metals that are bound by the trace metal detoxifying protein, metallothionein, and those which are free to exert toxic effects by binding enzymes in the high molecular weight protein pool. Further, a study was made of trace metal changes in carcinogenesis in order to elucidate the role of trace mentals in the etiology of cancer.

Organisms were sampled from an area known to be polluted with trace metals. Reduced survival did not occur in mussels exposed to Cd, Cu and Zn until metallothionein was apparently metal saturated, and there was a rapid increase of metals in the high molecular weight protein pool.

Phytoplankton, zooplankton and fish were exposed to mercury. Growth rates were reduced in those exposures where Hg was detectable in the high molecular weight protein pool.

Toxic effects of trace metals are attributed to the interference of nonessential metals with essential metals in metalloenzymes.

Both cancerous fish and humans had increases of Cd and the Cd:Zn ration in the high molecular weight protein pool. It is suggested that Cd, in cancerous organisms, might be interferring with the Zn-containing enzymes involved in cell division processes. Very high Cd doses increased levels of Cu and Zn in the high molecular weight protein pool over control values, and greatly increased time to death due to tumors.

Buchanan, R. J. S Study of the Species Composition and Ecology of the Protoplankton of a British Columbia Inlet. PhD Thesis. UBC Department of Botany, Vancouver, B.C. 1966.

Protoplankton and phyico-chemical aspects of Indian Arm were studied monthly over a year to determine species and distributional patterns. Environmental parameters studied at 7 stations included temperature, salinity, oxygen, Secchi Disc depth and light attenuation and supplemented by earlier works on insolation, light penetration, nutrients and runoff. Physical characteristics of mixing, light, TSP and stratification are discussed along with chemical data as they effect plankton ecology, growth and species composition. Protoplankton from 5 stations were assessed monthly including a total of 180 water samples and 60 net samples. The greatest numer of taxa were in the pycnocline to 15 m. with the surface layer selective for eurythermal and euryhaline organisms. Predominance in the pychocline was by hetertrophs September - February, photoautotrophs March - May and all June-August. The taxa encountered by rank were: Bacillariopnyceace (121 taxa), Dinophyceae (91), Citiatea (44) and Chrysophyceae (15), half of which were 60u or less in size. A probably energy cycle in Indian Arm ecosystem was developed. Significant quantities of plankton were noted as being carried into the Arm from outer areas. In Indian Arm, the two main factors regulating protoplankton were runoff induced surface flow and insolation. Photoautotrophs predominated over hetero- and myxotrophs.

Butler, T.H. The Serological Relationships of Some Pacific Coast Decapoda Crustacea. MA. UBC, Vancouver, B.C. 1953.

The serological relationships of Pacific coast decapod Crustacea were investigated by use of blood sera and protein extracts. Blood sera were obtained from eight species reprsenting six families; the protein extracts were produced from fifteen species as representatives of ten families. Protein extracts gave negative results. Testing with blood sera demonstrated no relationship between anomuran and brachyuran crustaceans. Within the Anomura a close relationship was found between the Lithodidae and Paguridae. In the Brachyura the relationships amond the families Cancridae, Atelecyclidae, Grapsidae and Maiidae were found to be generally in accord with those established by morphological studies. Testing of three species of Cancer demonstrated that they are closely related, yet distinct species.

Localities included Burrard Inlet and English Bay for which a list of species encountered is provided.

Cameron, J.L. and P.V. Fankboner. Tentacle Structure and Feeding Process in the Life Stages of the Commericial Sea Cucumber Parastichopus californicus (Stimpson). J.Exp. Mar. Biol.Ecol., Vol. 81, 193-201, 1984.

Samples collected subtidally at Woodlands, Indian Arm and in the U.S. By SCUBA. Juveniles (.5-2cm, approximately 1 yr old) from Lions Bay. Larvae culture in vitro. Feeding and tentacle observations and a study of skeletal elements by ETEC Autoscan Electron Microscopy were made. Light and electron scanning microscopy also conducted.Marphology and function of tentacles discussed.Food is collected from the substrate by repeated extension and with the aid of an adhesive mucous.

Campbell, N.J. A Study of Lateral Circulation in an Inlet. PhD Thesis UBC,Vancouver B.C.,1954.

A mathematical model for Burrard Inlet was developed for circulation including Coriolian frictional and mass field forces and tested by means of available data showing two net circulations (at surface from Fraser River brackish water and 50' attributed to tides). The actual circulation satisfied the model within the limit of observational error suggesting through relaxation methods that lateral stresses play an important role in inlet circulation. Suggests where oceanographic observations should be taken for studies of lateral circulation. Noted the need to establish a coarse gird to identify key areas for detailed study.

Chapman, P.M. and C.T. Barlow. Sediment Bioassays in Various B.C. Coastal Areas. Environmental Protection Service, West Vancouver, B.C. by E.V.S. Consultants, 1984.
Project 4711

A report on sediment bioassays using amphipod Rhepoxynius abronius to test the toxicity of composite sediment samples collected from 12 marine sites in B.C. Nine of the 12 sites were significantly ($p=0.01$) toxic compared to controls. The three most toxic sites were located in the area of Vancouver Harbour: Vancouver Wharves, Neptune Terminals and the East Basin of False Creek. Bioassay results were compared with the results of chemical analysis of the sediments for metals (including nine Priority Pollutants) and other inorganic elements. The single composite sediment sample with the highest levels of Priority Pollutant metals (including Cd and Hg) had 0% amphipod survival, but low survivals were also recorded in samples with lower measured sediment contaminant levels. The results indicated that the sediment bioassay measures a biological response to combinations of chemicals, and toxicity was not related to present ODCA criteria for Hg and Cd. These data indicated a potentially serious sediment toxicity problem in the Vancouver Harbour area, which should be addressed.

Methodologies for field collection, chemical analyses (by EPS) and bioassays are outlined.

Chocair, J.A. 1978. Microbial Biomasses and Heterotrophic Activities in Surface Sediments and Overlying Waters of Several Coastal Areas in British Columbia. M.Sc. Thesis. Simon Fraser University, Burnaby, B.C.

Comparisons made of colony forming units, ATP Levels, nos. of active bacteria, glucose, alanine heterotrophic activities and dissolved and particulate organic carbon (DOC/POC). DOC was 10x greater in sediments than water. Biomass, heterotrophic potential and turnover time values were greater in sediments. Heterotrophic potential per unit biomass however was greater in overlying water than sediments. Overlying water was metabolically more active than sediment biomass. Samples of sediments taken in Indian Arm and Port Moody among other locations. Material and methods detailed. Collection by Phleger corer. Upper centimeter used.Water sampled by Van Dorn sampler. T./S% by thermometer and YSI 33 SCT Meter within 30 min. Heterotrophic activities by radiolabel and scintillation spectrometer (Beckman). Glucose/Alanine uptake using Ameisham/Seacle Corp. products over incubation period of less than 60 min. DOC/POC by Beckman IR/CHN analysers respectively.

Microbial populations estimated on Difco Marine Agar (15 degree C for 14d)ATP determination by Bancroft technique. Numbers of active bacteria by Hoppe technique, radiotracer. Discusses ratios of bacterial populations (> in sediments, Iona Is.), Coastal/Iona Is.ATP (and other parameter levels. Wide variations suggested as due to location, time, FC and depth of cells related to amount of organic matter. The study makes general comparison of Iona and other Coastal areas. Analysis of Burrard/Indian Arm data is required.The comparison also emphasizes sediment/overlying water bacterial population information.

Chu, L.S. and R. Walker. Port Moody South Shore Drainage Study.
Report for: City of Port Moody, 1983.
By: Willis Cunliffe Tait/DelCan, New Westminster, B.C.

The report summarizes the drainage analysis and the estimated trunk storm sewer improvement costs for the south shore study area. Results of the drainage analysis, including catchment boundaries, design peak flows, existing 3 proposed pipe sizes. A computer program VSWQM was used to analyze and compute design flows. The study area includes the south shore area from Burnaby to Coquitlam which has seven drainage basins. Schoolhouse Cr. passes from the environmentally sensitive upland areas to Burrard Inlet. Large diameter sewers form the existing GVS and DD storm system including Stoney Cr., Schoolhouse Cr., Kyle St., and Williams St. which pickup runoff from the immediate area and upland Coquitlam. Two other creeks in the Area, Slaughterhouse and Moons Cr. are significant elements in the drainage plan.

Improvement works are identified to alleviate flooding problems and system deficiencies.

Clark, B. Anadronous Trout Production of Brothers Cr., Fish and Wildlife Branch. 1980. Ministry of Environment, Surrey, B.C.

A study of Brothers Cr., tributary of the Capilano R.,was conducted October 9-28, 1980, estimating populations, adult returns, passage, survival rates and enhancement opportunities to determine if angling closure was needed for protection. It was determined through standard field sampling methods that the creek biomass was 7.8 gm/m2 ,above the target level set for other areas. Rainbow make up 5.28 gm/m2 of the biomass. Cutthroat and coho levels were low.

Clark, B. and P. Bech. A Discussion of Capilano Hatchery Steelhead Production. 1972-1979. Fish and Wildlife Branch, 1980. Ministry of Environment, Surrey, B.C.

The hatchery has been producing steelhead since 1972 and the report assimilates all available data to determine:

1. size at smolting in comparison to average size for all hatchery releases,
2. age class structures,
3. amount of fresh water growth after release,
4. angling trends,
5. other char/trout production.

Results showed the wild steelhead smolt is slightly larger than successful hatching smolt but both were larger than the average hatchery release. Twenty percent of adult hatchery returns displayed extra fresh water growth and only 3% of wild returns displayed the same.

Clark, B. and J. den Breejen. Freshwater Fisheries Habitat of Indian Arm, Burrard Inlet. Fish and Wildlife Branch, Ministry of Environment, Surrey, B.C. 1980.

The study investigated fish habitat in Gardner, Shone, Holmden Bishop, Farrer, Buntzen, Unnamed and Myrtle Creeks in Indian Arm. It showed that Indian Arm creeks have very limited freshwater fisheries habitat accessible to anadromous species. Steep gradients and underground flows make enhancement work difficult. This makes the protection and improvement of present habitat, specifically Myrtle and Buntzen Creeks, a prime concern. Of equal importance is the protection of the few beaches and estuaries where adult sea-run cutthroat trout can be found.

It is acknowledged that this was a very cursory assessment and was not meant as a final report, noting that no study of Indian Arm would be complete without a biophysical survey of the Indian River itself. Such a survey would require substantial equipment and time and deserves consideration as a major project in future budget plans.

Clark, E.A.C. Colonozation of Mussel Beds: Succession vs. Seasonal Development. B.Sc. Thesis, UBC. Department of Zoology, Vancouver, B.C. 1976.

Process of mussel colonization studied at several locations including Brockton Pt. using slate plates and cleared areas in the intertidal zone and observed over 15 months. On a monthly basis a seasonality of colonization was identified. However, cumulative data suggested it was apparent succession. After 15 months the areas previously cleared had returned to their original community structure. It was observed that recruitment of algae and barnacles was a seasonal process whereas that of M. edulis and M. californicus was a successional process.

Conlin, K. Distribution of Capilano Hatchery Chinook in tne Capilano Estuary and Burrard Inlet. Fisheries and Oceans, New Westminster, B.C. 1979.

The study assesses the 1979 Capilano Hatchery chinook at 23 locations in the Capilano estuary and Burrard Inlet. Predetermined release of smolt offered a unique opportunity to monitor their use of and distribution in the area including a mark/recapture program involving Coho and Steelhead as well. Sampling methods are outlined and sites described. Lengths of marked and unmarked fry populations were sampled weekly to monitor growth. Scales were collected after 1 month of release. The data showed that Capilano Chinook and Coho make extensive use of the North Shore Burrard Inlet as rearing habitat and not English Bay or Spanish Banks. (Tidal effect is suggested.) Foreign stocks were noted possibly from other North Shore streams and the Shuswap (via Fraser R.). Capilano estuary use by chinook is over about 70 days (June-August) with graphs showing rate of departure. Data on growth is given along with scale analysis of smolts and returning adults showing estuary growth rings. Coho and steelhead distribution was not determined from the catch statistics. Suggests purse seining should have been done as well.

Davidson, L.W. On the Physical Oceanography of Burrard Inlet and Indian Arm. M.Sc. Thesis, UBC. Department of Physics and Institute of Oceanography. Vancouver, B.C. 1979.

Measurements of the distributions of temperature, salinity and oxygen in Burrard Inlet and Indian Arm, B.C. from May 1974 to October 1975 were analysed to determine features of the large scale circulation in this system. Observations at roughly four-week intervals were supplemented by serial CSTD casts taken over intervals of a few hours, and by 93-day records of near-bottom currents, temperature, and salinity on the Indian Arm sill.

Short-term tidal fluctations in property distributions have been shown to be small compared to seasonal changes.

Circulation in the Burrard Inlet - Indian Arm system is basically estuarine: relatively fresh surface waters normally flow down the inlet overlying more saline waters which enter fromthe Strait of Georgia. Turbulent mixing associated with estuarine and tidal flow through the shallow constrictions at both First and Second Narrows yields surface waters between the narrows which are more saline and cooler than those which would be found in a simpler estuarine environment. In a complementary sense, bottom waters are fresher and warmer.

Significant exchange and overturn of deep water in Indian Arm was recorded between October 1974 and April 1975. Intruding waters were shown to have originated west of First Narrows. In one instance exchange of at least 80% of the volume of the Arm, over an interval of 33 days, was inferred from property distributions,compared to exchange estimates of 111% and 74% deduced fromthe current meter record for the same event. Exchange was shown to be intermittent, with fresh water runoff volume into Indian Arm, tidal mixing (particularly at Second Narrows) and density of Georgia Strait water being identified as some of the controlling factors. Potential investigations are outlined.

Dayton, M.J.J. West Vancouver Drainage Survey.
Report for: District of West Vancouver, West Vancouver, B.C. 1973
By: Dayton & Knight Ltd., West Vancouver, B.C.

The survey reviews:
1. the design criteria for rainfall intensity, runoff coefficients and design period;
2. highway drainage;
3. effects on municipal facilities;
4. cause of drainage problems and
5. legal position with respect to natural water courses.

Area characteristics including climate, soil permiability, drainage areas, existing facilities and creeks are discussed as well as hydrology, rainfall data and stream flow data. Detailed culvert analyses on each creek are given including storm water quantities. Watershed areas are also given with estimates of flows.

Dayton, M.J.J. Major Drainage System Relief and Flood Control (Part 2 of a Drainage Survey and Report)
Report for: The City of North Vancouver, 1975.
By: Dayton & Knight Ltd., West Vancouver, B.C.

This report applies the background material and proposed design criteria to the major city storm sewers and the drainage facilities on Mission, Wagg and Mackay Creeks. It concludes with the identification of the problem areas and presents one proposed 5 year and a long term plan. Existing drainageis described and its adequacy discussed and solutions to problems presented. Discharges to Burrard Inlet are shown in plan and flow and drainage data tabulated and capacities rated.

Dayton, M.J. City of North Vancouver Drainage Survey.
Report for: City of North Vancouver, North Vancouver, B.C.
By: Dayton & Knight Ltd. 1973.

The report outlines the area characteristics, the existing drainage system(s)(1973) and developes design criteria and discusses the area conditions. Major water courses are identified as is areal permeability. Creeks are well confined and there have been few flooding problems. Rainfall intensity curve presented. The Rational Method is the basis for design along with runoff coefficients. Area rainfall curves presented.

Stream flow records for Mackay, Montroyal Mosquito, and McCartney Creeks are continuous. Various data exists on Capilano and Seymour Rivers.. Mosquito Cr. had the largest flow at 540 cfs (1968).

A breakdown of storm water quantities estimated for 50 and 100 year floods is provided along with critical time in minutes.

	50		100	
Creek	CFS	Time	CFS	Time
Mackay	2100	70	2350	70
Mosquito	3100	60	3500	60
Mission/Wagg	1030	50	1160	50

Study notes erosional factors, hazards, and pollution including atmospheric, road, garden and domestic animal wastes.

Plans at 1:5000 show discharges and drainage system.

DeJong, M.M. Substrate and Feeding Preference of the Isopod Idotea wosnesenski B.Sc. Thesis, UBC. Department of Zoology, Vancouver, B.C. 1975.

Study describes Brockton Point area intertidal physical characteristics and floral and faunal zonation including the sublittoral area.Idotea biology is discussed and feeding habit observations and sediment preferences detailed.

Dehnel, P.A. (Unpublished). Analysis of Shell Variation in Limpets of the Genus Collisella (1976-1977). University of British Columbia, Zoology Department, Vancouver, B.C. 1977. NRCC Project.

This study is designed to determine whether intraspecific variation in shell morphology in four species of Collisella is related to intertidal vertical distribution and also whether interspecific variation in shell morphology is a function of the environment. Various shell measurements, including shell volumes and anterior and posterior angles, are being considered, as well as wet weights and dry weights of soft parts.

Derksen, G. Water Quality and Periphytic Algal Standing Crop of Lynn Creek, North Vancouver: A Coastal Stream Adjacent to a Sanitary Landfill. Environmental Protection Service, Regional Program Report No. 80-6, 1980.

Sampling analytical methods were conducted as shown in the Pollution Sampling Handbook at the EPS West Vancouver Laboratory.

Significant increases in total ammonia, nitrate and total organic carbon were found in Lynn Creek downstream of the Premier Street landfill in North Vancouver. The higher levels of total ammonia downstream of the landfill were not restricted to any particular season of the year.

The standing crop of attached algae, measured as ug chlorophyll-a/cm2, at the sample site downstream of the landfill was generally higher than that of the control stations. Levels at the control stations were similar to those reported for two other North Shore Vancouver streams.

Derksen, G. Water Quality and Periphytic Algal Standing Crop of the Capilano and Seymour Rivers, North Vancouver, B.C. Environmental Protection Service, Regional Program Report No. 81-21, 1981.

Water quality and algal collection and analysis were conducted by means of methods outlined in Environment Canada, Pollution Sampling Handbook and conducted at the EPS, West Vancouver Lab.

The Capilano salmonid hatchery did not appear to have an appreciable effect on the dissolved oxygen, pH, temperature, or total organic carbon content of the Capilano River. Elevated levels of nitrate and ammonia were found to be significantly greater downstream of the hatchery during certain times of the year. The high detection limit for phosphorus was not adequate to monitor the influence of the hatchery on that component.

The standing crop of attached algae, measured as ug chlorophyll-a/ cm2, was greater downstream of the hatchery. The highest standing crop values on the Capilano River were found immediately downstream of the hatchery through the spring to early summer. However, during the late summer and early fall, the standing crop at the more downstream station increased above that of other stations on the Capilano River and those on the Seymour River.

The water quality of the Seymour River was found to be similar to that of the Capilano River control station.

Dobell, P.E.R. A Study of Dinoflagellate Cysts from Recent Marine Sediments of British Columbia. M.Sc. Thesis, UBC. Department of Biology, Vancouver, B.C. 1978.

The report includes sediment samples from coastal areas including Indian Arm which were analyzed for cysts. Cyst-theca relationships were confirmed and outlined for each grouping and two new cyst based taxa are described. Assemblages in recent sediments were similar to many temperate estuarine and neritic areas. The dominance of Operculodinium centrocarpum in Indian Arm is a pattern typical of temperate estuarine conditions. Other species were typical of fjord environments.

Druehl, L.D. Distribution of Two Species of Laminaria as related to some Environmental Factors. J.Phycol. 3, 103-108 1967.

The study examines the distributions of Laminaria saccharine and the long and short stipe forms of L. groenlandica about Vancouver Island and Deep Cove correlating them with temperature, salinity, and water motion. The 2 forms of L. groenlandica were absent from areas of high temperature and low salinity. The long stipe form was restricted to area of heavy surf and the short stipe form to areas of moderate surf. L. saccharina was absent from areas subjected to surf. These observations were subjected to laboratory and field tests involing gametophytes and sporophytes of both species. The distribution of the 2 forms of L. groenlandica can be explained on the basis of temperature and salinity distributions: both forms require low temperature and high salinity for survival. L. saccharina has a wide range of tolerance to temperature and salinity; surf appears to be the controlling agent.

Druehl, L.D. Vertical Distributions of some Benthic Algae in a British Columbia Inlet, as Related to Some Environmental Factors. J. Fish. Res. Bd. Canada, V.24(1), 1967.

The vertical distribution of 12 benthic marine algae and one animal are described for Indian Arm, an inlet in British Columbia. In general, the vertical distributions had distinct limits and relative vertical positions of the species were constant throughout the inlet. The relative vertical distributions of the biota within the inlet are essentially the same as described for the northeast Pacific by other authors concerned with the same biotic elements.However, the upper limits of Laminaria saccharina (L.) Lamouroux, Costaria costata (Turn.) Saunders, and Constantinea subulifera Setchell are from 1 to 3 m lower within the inlet than elsewhere, whereas those of Agarum cribosum Bory, Fucus evanescens C. Agardh, and Sargassum medicum (Yendo) Fensholt are essentially the same within and outside of the inlet. For the remaining species studied (Enteromorpha compressa (L.) Greville, E. linza (L.) J. Agardh, E. intestinalis (L.) Link, Monostroma fuscum (Postels & Ruprecht) Wittrock, Ulva lactuca Linnaeus, Navicula grevillei (C.Ag.) Cleve, and Balanus glandulus (Darwin)) there were no comparable distribution data outside of the inlet.

Available data suggest the deepening of the upper limits of some algae in Indian Arm reflects their intolerance to the high temperature and low salinity of the surface waters of the inlet.

Druehl, L.D. and S. I.Hsiao. Intertidal kelp response to seasonal environmental changes in a British Columbia Inlet. J. Fish. Res. Board Can. 34:1027-1211, 1977.

Costaria costata, Laminaria saccharina and Alaria fenuolia were studied. Sporophyte response in the intertidal zone of Burrard Inlet at Lumbermans Arch and Brockton Point was correlated primarily with tidal and atmospheric conditions and not salinity or nutrients. Nutrients (NO3, NO2, PO, I), salinity and air and seawater temperatures were monitored weekly from July 1968-June 1971. The beaches had 1:7 and 1:15 slope respectively with mud, shells and rock substrates and the latter had a sewer outfall discharging 0.26-0.60 m3/s. Chemical analyses were after Strickland and Parsons (1968). Physical and chemical data are summarized (T degress C, 4.5-16; 5%, 20-28). Nitrate and phosphate were irregular, organic iodine showed no seasonality ranging 1-30 ugI/l. Nitrite ranged from 0.14 to 0.65 ug-at NO2-M/l. Nitrite max 27.3 ug-at NO3-M/l. Phosphate ranged from 1 - 3.9 ug-at PO4-P/l. Nutrient Levels were higher at Lumbermans Arch. Sporophytes (young) first occurred February-March when insolation increased and tidal cycle shifted to low in the day (<0 to +1.3m). By April plants above 0.7 m (chart datum) died and remainder achieved max. biomass in May, decreasing thereafter due to increased exposure to air. C. costata produced meiospores in July the others persisting to Autumn before production.

Dunbar, D.S. A Numerical Model of Indian Arm. PhD Thesis UBC, Vancouver, B.C. 1985.

A numerical model was applied to study the stratified tidal circulation in Indian Arm including horizontal velocity, salt conservation,continuity, density and hydrostatic approximal in equations. The model is time dependent and includes a number of variable terms. Initial and boundary conditions based on 1974-5 data were used to study tidal forcing and simulate deep water remewal. Good agreement was found between observed and calculated barotropic tide through application of coefficients for horizontal, turbulent diffusion of momentum and salt. Assessment showed a standing wave pattern for K1 and M2 internal tides in Indian Arm. Cyclesonde analysis in time xxxx were consistent with calculated vertical ampletide and phase profiles. Most energy was found to be in the barotropic and first baroclinic modes, the latter dominating the deep basin. Indications show energy from the former is being radiated via the internal tide. Simulations of dense water influx yielded rates of exchange consistent with observed values and suggest the possibility for use as a predictive model.

Dunn, B.P. Benzo (a) pyrene in the Marine Environment: Analytical Techniques and Results.
From: Hydrocarbons and Halogenated Hydrocarbons in the Aquatic Environment. BK Afghan & D. Mackay Eds. 1980.

An evaluation of different techniques for determining B(a)P in tissues and sediments from the marine environment and notes that while all methods are sensitive suggests high pressure liquid chromatography coupled with the extraction and clean up steps described as a more suitable procedure. In conducting this work marine sediment from B.C. waters and others were used from harbour and non-harbour areas and it was evident there was a general trend for higher B(a)P levels in harbour areas. Median level of B(a)P in 22 samples was 105 ug/kg in harbour areas and 0.4 ugkg in non harbour areas (none named). In finding these differences the research examines tiddues for biological differences, specifically a B(a)P induced product Aryl Hydrocarbon Hydroxylase in the livers of juvenile Lemon sole. Using radiometric methods a trend to higher levels of AHH's was determined in soles from areas substantially contaminated by B(a)P. It is noted that one incidence of high AHH occurred in the vicinity of a pulp mill where B(a)P was low suggesting there are non-PAH enzyme inducers in the effluent.

Dunn, B.P. Polycyclic Aromatic Hydrocarbons in Marine Sediments, Bivalues and Seaweeds: Analysis by High-Pressure Liquid Chromatography.
Reprint: Fourth International Symposium on Analysis, Chemistry and Biology of Polynuclear Aromatic Hydrocarbons. Columbus, Ohio 1980.

The report considers the development of criteria for the suitability of coastal areas for commercial seafood production with respect to carcinogen contamination and address the problem of what type of environmental sample to measure and which PAH compounds to quantitate. The relationship between levels of a range of PAH isomers in three types of marine samples is examined. Samples were collected from inner and outer harbour areas of Vancouver, B.C. (3 sites). Analysis for B(a)P were high correlated with high molecular weight. PAH is therefore used as an indicator of PAH contamination. PAH data varied as much as 100 fold in sediments and 40 fold in Fucus sp. and mussel samples. Coal Harbour data show relatively low sediment contamination but high Fucus sp. contamination suggesting effects from marina area identifies the need for direct tissue analysis. Discussion of the results examines uptake mechanisms and patterns of PAH enrichment.

Dunn, B.P. Techniques for Determination of Benzo(a) pyrene in Marine Organisms and Sediments.
Environmental Services and Technology, V.100, p.1018. 1976.

Rapid, economical, and reliable procedures are developed for the measurement of the carcinogen benzo(a)pyrene in small marine tissue and sediment samples. These involve alkaline digestion of samples,column chromatography on Florisil, DMSO extraction, separation of polycyclic aromatic hydrocarbons by thin-layer chromatography, and measurement of benzo(a)pyrene by fluorimetry. Recoveries of compound are measured for each sample by the use of radioactive benzo(a)pyrene as an internal standard. The procedures, which have a sensitivity of 0.1 ug/kg and a precision of 6%, appear more than adequate for application in routine monitoring programs for polycyclic aromatic hydrocarbon carcinogens in the marine environment.

Dunn, B.P. and J. Fee. Polycyclic Aromatic Hydrocarbon Carcinogens in Commerical Seafoods.
Jour. Fish. Res. Bd. Canada 36(12):1469-1476. 1979.

Fresh and processed commercial seafoods were analyzed for the polycyclic aromatic hydrocarbon carcinogen benzo(a)pyrene using a thin-layer chromotographic separation technique and quantitation by fluorescence. Commerical samples of vertebrate fish did not contain detectable levels, except where fish were packed with vegetable oil, an exogenous source of carcinogens. Levels in most shellfish samples were generally less than 10 ng/g wet weight, but occasional samples contained up to 36 ng/g. Crab and shrimp samples contained little or no benzo(a)pyrene (ND to 0.5 ng/g). Commercial lobsters contained 0.8 to 7.9 ng/g. The source of contamination of lobster was further investigated, utilizing high pressure liquid chromatography to measure 13 polycyclic aromatic hydrocarbon isomers. Freshly caught lobsters had less than 1 ng/g benzo(a)pyrene. Lobster which had been kept in a commercial tidal pond constructed of creosoted timber contained highly elevated levels of benzo(a)pyrene and other carcinogenic hydrocarbons, including chrysene, benzo(a)anthracene, benzo(b)fluoranthene, dibenz (a,h)anthracene, and indeno (1,2,3-cd)pyrene.The maximum level of benzo(a)pyrene yrene was 2300 ng/g wet weight in digestive gland, and 281 ngg in edible tail meat. These levels are substantially higher than previously reported for any foodstuff, and are most probably attributable to creosote contamination during impoundment.

Dunn, B.P. and H.F. Stich. Monitoring Procedures for Chemical Carcinogens in Coastal Waters. J. Fish. Res. Board of Canada 33(9) 2040-2046. 1976.

Sampling procedures and analytical techniques have been developed for evaluating the contamination of coastal waters by polycyclic aromatic hydrocarbon carcinogens. The procedures involve extraction and purification of hydrocarbon fractions from marine sediments or organisms, and determination of compounds by thin-layer chromatography and fluorimetry, or gas chromatography.

Sediment samples in the vicinity of a sewage outfall showed elevated levels of benzo[a]pyrene (B[a]P). Mussels (Mytilus edulis) taken from the outer Vancouver harbor showed lower B[a]P levels in the summer than in the winter, perhaps a result of seasonal discharges of sewage and storm drain water into the harbor. Elevated levels of B[a]P in mussels growing near creosoted timbers or pilings suggested that creosote may be a significant source of B[a]P in the marine environment. Direct evidence for this suggestion was obtained by comparison of gas chromatographic profiles of polycyclic aromatic hydrocarbons isolated from mussels and from creosoted wood.

The procedures developed are rapid, sensitive, and reproducible. They appear to be suitable for application in large-scale monitoring systems for carcinogenic hydrocarbons in coastal waters.

Dunn, B.P. and H.F. Stich. Release of the Carcinogen Benzo[a]pyrene from Environmentally Contaminated Mussels. Environmental Contamination and Toxicology, Vol. 15(4) 1976.

The study examines 600 mussels from Burrard Inlet to examine the release of B[a]P from contaminated organisms. Methods of collection, cleaning and analysis are detailed. B[a]P measured by fluorescence emission spectroscopy. The data showed that the PAH's were only slowly released making the mussels attractive as bioaccumulators in monitoring programs. Mussels maintained several days out of water showed no change in B[a]P contact again indicating their value as a monitoring organism. The short depuration period for bacteria is not suitable for B[a]P and has public health implications for some areas of the world where mussels are cultured in polluted areas.

Dunn, B.P. and H.F. Stoch. The Use of Mussels in Estimating Benzo[a]Pyrene Contamination of the Marine Environment (38971). Proceedings of the Society for Experimental Biology and Medicine 150, 49-51. 1975.

The paper examines chemical carcinogens and nutagens in the marine environment at several locations in Burrard Inlet using mussels (mytilus edulis) to estimate levels of benzo[a]pyrene. PAH`s in the environment, flora and fauna are briefly discussed and sampling and analytical methodologies outlined and referenced. Mussels from English Bay (sic) contained substantial B[a]P (2mg/kg), and Vancouver Harbor still higher levels (18 mg/kg). A poorly flushed harbor inlet (False Creek?) showed the highest levels (x 42 mg/kg). Examination of mussels associated with PAH point sources at a powerboat marina showed mussels from the creosoted piles exhibited highest B[a]P levels (68-133 mg/kg) which varied by season. The results show a correlation between B[a]P levels in mussels and their proximity to industrial, urban or recreational areas and activity. The results do not suggest large PAH amounts originate by endogenous synthesis by marine flora. The data indicate mussels to be a simple indicator for the degree of PAH contamination of the marine environment.

Duval, W.S. A Review of the Impacts of Log Handling on Coastal Marine Environments and Resources. Council of Forest Industries and Government (ERP) Estuary Foreshore and Water Log Handling and Transportation Study. Vancouver, B.C. ,1980.

Describes the principal phases of log handling, its physical and chemical, plant community, benthic and intertidal, fish, marine mammal, aquatic birds, other environment use impacts in detail and summary. Refers to the generic/regional effects rather than site specific although specific references are made. Summary includes a matrix of activities versus impacts to major biological environmental components, a table of regional differences of log handling activities including the Fraser North Arm and Vancouver Harbor (Table 10.8-1) identifying volume of logs, lease area and number, storage and dumping areas and mode, predominant substrate, depth, habitat. Provides recommendations for mitigation of adverse impacts and future investigations. Lists species of plants, invertebrate, fish, mammals and birds and reference materials. Provides an overview of locations including Barrard Inlet and Indian Arm.

Dwernychuk, L.W. and J. Millar. Select Physical and Chemical Properties of Sediment and Water Adjacent to Pacific Coast Terminals, Port Moody Arm, B.C.
Report for: Pacific Coast Terminals, New Westminster, B.C. 1981.
By: Beak Consultants Ltd., Richmond, B.C.

This study examined the sulphur and its distribution in the marine environment adjacent to Pacific Coast Terminal in the surficial bottom sediments of the Inlet. Parameters included sulphides, sulphur, DO, pH, T C. Sulphide levels were found to be low and exhibited no trends. Sulphur was encountered in high levels nearest the PCT dock bulk loading facility. DO levels were consistantly high (10.1-11.1 mg/l), pH were consistant (6.1-6.45) and temperatures were warmer on the bottom than the surface. Sampling was conducted October 27, 1981. Analytical procedures followed the Department of Environment Laboratory Manual 1976. Insitu analysis were by YSI meter.

Evans, M.S. The Distributional Ecology of the Calanoid Copepod Paraeuchaeta elongata Esterly. Ph.D Thesis UBC. Department of Zoology and Institute of Oceanography, Vancouver, B.C. 1973.

Three survey cruises over 2 years of coastal inlets including Indian Arm were conducted examining a wide range of temperature - salinity characteristics which could be segregated into six station groups. The study observed the transfer of subsurface Pacific Ocean water inshore and showed distributional features of P.elongata noting it is capable of breeding in all areas suggesting that species abundance was unrelated to water quality (directly) rather associated with primary production and the origin and residence time of the water. Field and laboratory comparisons of Indian Arm organisms were included in the study. Mortality from nauplius to adult was detrmined at 97% and that mortality of the egg had a small role in determining population size.

Detailed field and laboratory methodologies are given.

Fankboner, P.V. Growth, Recruitment and Development in the Commercial Sea Cucumber Parastichopus californicus.
Report to: B.C. Science Council. 1984.

The study was undertaken 1982 to 1983 after 14 months at Croker Island , Indian Arm. Density/m2 was 0.3-0.6. Spawning may begin in early June and through the summer and developes into a planktonic form in 10-12 days, remaining in the water up to 60 days then settle out. Noted asynchronization in development and metamorphosis may be delayed an additional 60 days. Sexual maturity occurs after 4 years when they weigh > 0.5 kg. Seasonal visceral atrophication was noted during autumn. Harvesting revealed insufficient recovery to permit an annual fishery (Annual recovery rate at 40%) but rather 2-3 years under proper planning. Includes tables of visceral atrophication, gonadal index, growth index, body weight, density at the North end of Indian Arm, Mussle to body wall weight ratio.

Fankboner, P.V. Suspension-Feeding Mechanisms of the Armoured Sea Cucumber Psolus Chitinoides Clark. J. Exp. Mar. Biol. Ecol. Vol.31 11-25, 1978.

Samples collected by rock dredge or SCUBA between 3 and 8 inches in Indian Arm, Barkley Sound and Rosario Strait. Field observations on feeding including capture and detailed examinations were made. (Phillips EM 300 electron microscope) The crown may be retracted for several days and may be independent of ambient sea-water quality. Details of feeding tentacles are presented and discussed along with comparative comments with other fauna.

Fankboner, P.V. and R.G.B. Reid. Protein Digestion in the sea gooseberry Pleurobranchia bachei A. Agassiz (Ctenophora: Tentaculata). Experientia 34, 728. 1978.

Assessed proteolytic activity of pharyngeal juice which peaked at pH 5.75 and 7.5. Digestive proteases included tryptic alkaline and a thiol-activated acid (prob. cathespin B). Proteolytic activity parallels those of other zooplankton carnivors. Several hundred P. bachei were collected by plankton net at 1-20 m. in Indian Arm. Juices extracted and frozen. Activity determined with serum albumin substrate and digests of amino acid measured with a Hitachi-Perkin Elmer spectrophotometer with and without activators and inhibitors. Feeding mechanism is outlined.

Fedorenko, A.V. and B.G. Shepherd. Review of Salmonid Resource Studies in Indian River and Indian Arm, and Enhancement Proposals for the area. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1769. 1984. Fisheries and Oceans, Vancouver, B.C.

The Indian River solmon stocks, particularly pink (Oncorhynchus gorbuscha) and coho (O. kisutch) have declined considerably since the 1970's, probably mainly due to overfishing and habitat degradation. This report reviews the status of the Indian River salmonid resource, describes local fisheries and other human activities in the area, and summarizes Department of Fisheries and Oceans studies and enhancement proposals.

Ferguson, K.D. and K.J. Hall. Stormwater Discharges - Fraser River Estuary Study Water Quality. Background report to FRES Steering Committee. Government of Canada and Province of B.C. 1979.

An assessment was made of the pollutant load from stormwater discharges in the Greater Vancovuer Regional District (GVRD) to the lower Fraser River/Estuary, aspects of the stormwater collection, treatment, and disposal practices in the region which require further research and stormwater management policy questions which must be addressed by local municipal, regional district and pollution control regulatory agencies. Stormwater pollutant loadings were based on literature-reported average pollutant concentrations since very few monitoring programs have been conducted in the region. A stormwater monitoring program should be implemented to obtain data that may be used to calculate representative stormwater pollutant loadings. These measurements would provide information in support of developing the most appropriate overall strategy for stormwater management and the level of protection from pollution from this source that can be effectively provided to the Fraser River/Estuary.

Gardner, G.A. Ecological Separation of Two Calanus Species: Filtering ability as a means of ecological separation between Calanus plumchrus Marukawa and C. marshallae. Frost in the Strait of Georgia, B.C. National Research Council Grant A-2067 by Institute of Ocean Sciences and UBC. 1976.

Morphologically similar species co-occur in the Strait of Georgia. C. plumchrus filtering particles to 2.0 um in diameter whereas C. marshallae filtered particles to 4.5 um and was less efficient than the former with particles between 4.5 and 12 um. C. plumchrus can exploit a large biomass about which little is known. The filtering difference may facilitate co-occurrance and may also ameliorate effect of recent hydrographic changes in favor of C. marshallae.

Gardner, G.A. The Analysis of Zooplankton Population Fluctuations in the Strait of Georgia, with emphasis on the relationships between Calanus plumchrus Marukawa and Calanus marshallae Frost. PhD. Thesis, UBC. 1976.

The study indicated subtle hydrographic shifts in the Strait of Georgia (salinity and temperature in deep water) appeared to have effected the zooplankton community. Data indicated the most important factor to be the structure of the water column (surface, intermediate and deep water). A temporal trend was noted in the deep water. The data indicated that the feeding differences of the species may be in favour of C. plumchrus although hydrographic effects may not be. If C. plumchrus populations continue to drop it is speculated that it could effect economically important species which use them as food.

Garrett, C.L. Toxic Organic Contaminants - Fraser River Estuary Study Water Quality.
Report to the FRES Steering Committee
Government of Canada and Provicne of B.C., Vancouver, B.C. 1980.

This report is a compilation of available data pertaining to the contamination of the Fraser River and its estuary by toxic organic contaminants. The main objectives were to: document localized areas of high contamination; identify known and potential sources of release to the environment; and make recommendations with regard to the need for further investigation.

Existing data relating to use patterns,sources and release and environmental levels of these compounds in the Fraser River system are confined primarily to PCBs and the organochlorine pesticides. Much of this information was collected in the early 1970`s and information on current levels of contamination is limited.

Levels of organochlorine pesticides are generally low and are thought to reflect background concentrations. It is apparent, however, that industrial and sewage treatment plant discharges into the Fraser River system have contributed to localized elevated PCB levels in sediments and biota. Despite recent restrictions on industrial uses of these compounds, certain facilities continue to discharge significant quantities. Limited monitoring within the past two years has also indicated the presence of such compounds as chlorinated phenols, phthalate esters, hexachlorobenzene and polycyclic aromatic hydrocarbons in the effluents and/or receiving environments of certain industrial and sewage treatment facilities.

Garrett, C. (Unpublished). A summary of major pollutant concentrations in Vancouver Harbor Area - Part of Vancouver Harbor Assessment Profile. Environment Canada, Environmental Protection Service,1984

A data summary of measurements of some 26 locations in Burrard Inlet examining organics and metals in sediments and biota. The summary notes station number, year sampled and analyzed, location, parameter sampled and pollutant levels. Included is a listing of compounds and their toxicities to marine organisms.

Garrett, C.L. An Overview of PCB's and their Current Status in British Columbia. Regional Program Report: 83-16. 1983. Environment Canada, Environmental Protection Service, West Vancouver, B.C.

This report has been prepared to provide a summary of the current status of PCBs in British Columbia. A general overview of PCBs is provided in order to allow the reader to put the British Columbia data into the proper perspective. The main objectives of this report were to: identify current uses of PCBs in British Columbia and potential sources of release to the environment; assess the potential for environmental impacts as a result of these releases; document available information on PCB levels in the British Columbia environment and compare these levels to those reported for other areas of the world; and, identify localized areas of particularly high concentrations (eg. Vancouver Harbor).

Much of the data included were obtained through Environmental Protection Service monitoring and industrial surveys. Published and unpublished data were also obtained from other federal and provincial government agencies, environmental consultants and research organizations

Garrett, C.L., L.A. MacLeod, M.J. Sneddon. Mercury in the British Columbia and Yukon Environments - Summary of Data to January 1, 1979. Regional Program Report 80-4. Environment Canada, Environment Canada, Environmental Protection Service, West Vancouver, B.C. 1980.

This report was prepared to provide an overview of the uses and environmental levels of mercury in British Columbia and the Yukon Territory. The main objectives of this report were to: identify current uses of mercury in the Pacific Region and potential sources of release to the environment; assess the potential for environmental impacts as a result of these releases; document all existing information on mercury levels in the British Columbia and Yukon environments and compare these levels to those reported for other areas of the world; and, identify localized areas of particularly high concentration. Data was obtained from provincial and federal government agencies, universities, and research organizations and was compiled, interpreted, and plotted on a series of regional maps to permit geographicalanalysis.

Elevated mercury levels occurred most frequently in aquatic organisms, fish-eating birds, and sediments from the more heavily urbanized areas around Vancouver and Victoria and from regions of extensive natural mineralization, such as Pinchi Lake. Localized incidents of mercury contamination have also been demonstrated in the receiving environments of industrial operations such as mines, smelters, pulp mills, and a mercury cell chlor-alkali plant. In most instances, the occurrence of high levels of environmental contamination has been attributed to industrial mercury releases prior to recently implemented government regulations and pollution control measures; however, some industrial facilities in B.C. continue to discharge significant amounts of mercury to the atmosphere and receiving waters.

No major areas of mercury contamination have been identified in the Yukon Territory. Preliminary sampling programs, however, have indicated the presence of elevated concentrations in surface waters, sediments, and fish from various Yukon water systems. While the presence of mercury in the Yukon environment has not been attributed to industrial releases, it is likely that past placer and base metal mining combined with natural releases fromheavily mineralized areas have contributed to elevated levels in some squatic systems.

Gerrath, J. F. The Monthly Abundance of Larvae of Bottom Invertebrates in Indian Arm, British Columbia. B.Sc. Thesis, UBC. Vancouver, B.C. 1963.

This investigation showed there were definite periods of larval abundance at Station 15 near Deep Cove, Indian Arm. Abundance and composition showed considerable variation in the year with a peak of numbers in the early spring and a lesser peak in summer similar to data from Friday Harbour, Washington. Barnacle larvae and brachyuran zoea were most abundant during the early spring (March) and Molluscan larvae were most common in June. Oceanographic factors may have been responsible for the large numbers present in the spring. Benthic larvae may make up an important food component of other plankton. Cirripede nauplius which had typical planktonic behavior were generally confined to surface and 30m samples. Cypris larvae on the other hand responded positively to light, opposite to many other planktonic organisms.

While daily vertical migration may occur for Cirripede nauplius and cypris stages it was not evident for the brachyuron larvae. The author points out the lack of basic information on the benthic fauna in this area.

Gibson, E.M. The Urbanization of the Strait of Georgia Region. A study of the impact of urbanization on the natural resources of B.C. Geographical Paper No. 57. Lands Directorate, Environment Canada. Ottawa. 1976.

Examines the human use and development of the region in terms of settlement, population, city centre land use, urban fringe areas and transportation. A discussion of social and cultural changes. Includes Georgia Straite Urgan Region Map by L.Skoda.

Gilbertson, M. 1984. Need for Development of Epidemiology for Chemically Induced Disease in Fish in Canada. Can. J.Fish. Aquat. Sci. Vol. 41.

Questions the adequacy of approaching aquatic toxicology mainly by laboratory experiments. Field observations of anomalous phenomena required first.

Gilfillan, E.S. The Effects of Changes in Temperature, Salinity and Undefined Properties of Sea Water on the Respiration of Euphausia pacifica Hansen (Crustacae) in Relation to Species Ecology. PhD. Thesis. UBC. 1970.

E. pacifica (adult) were collected in Strait of Georgia and Indian Arm at surface at night (lab animals) and in day by Clarke-Bumpus and conical samplers at 25m intervals along with T C and So/oo at 10-25m intervals by Van Dorn sampler. Indian Arm was sampled at I.A. - 9 off Orhlomah Beach. Ave. size E. pacifica used as lab animals. Lab procedures outlined and GME Oxygraph (KM) recorded electrode feed to determine respiration rates as Q/mg dry wt/hr. T C and So/oo manipulated in the laboratory showed large and consistent differences occur in their tolerances of changes. Coastal specifics showed greater tolerance, oceanic the least, and coastal/oceanic intermediate identifying separate physiological races. Noted that a sharp reduction in respiration rate could be indicative of stress, however, as limits of tolerance were approached T C and So/oo effects interact. Identified effects of "other" properties of sea water in specimens from two depths over 14 months. Noting observed changes may relate to trace element content and that Indian Arm was inferred to have a lower concentration of trace elements (E. pacifica is adapted to lower concentration in Indian Arm). Data did not show "other" properties effect E. pacifica distribution between sample points but notes that it does not rule out that "other" properties may not effect E. pacifica passage from Georgia Strait to Indian Arm (Plan shows locations).

Gilmartin, M. The Primary Production for a British Columbia Fjord. J. Fish. Res. Bd. Canada, 21(3) 1964

An annual cycle of primary production was established for a British Columbia fjord (Indian Arm). Detailed oceanographic analyses of the total oxygen budget of the fjord provided a biological oxygen budget that was further apportioned into estimations of the gross primary production (24), net primary production (24), and subeuphotic utilization of organic material. The values for 1958-59 were 671,381, and 290 g C/m2/yr, respectively. Using C14 data, corrected for observed respiration and variations in insolation, 24-hr gross and net primary production estimations of 609 and 455 g C/m2/yr were derived. Over 90% of the year's primary production was attributed to the nannoplankton. The relation between the physical environmental factors of the fjord and primary production is discussed.

The amount of gross primary production exported was estimated to be 25%. The primary factor controlling productions is believed to be yearly variations in the stability of the water column which influences the mean light intensity received by the phytoplankton, and effects the replenishment of nutrients in the euphotic zone.

Gilmartin, M. Annual Cyclic Changes in the Physical Oceanography of a British Columbia Fjord. Institute of Oceanography, UBC, Vancouver, B.C. Fisheries Research Board of Canada V19(5). 1962.

A report on the oceanography of Indian Arm. Indian Arm (49 degree 30'N, 122 degree 52'W), one of the characteristic fjords of the coast of British Columbia, was intensively studied during 35 approximately monthly cruises during 1956 through 1959, with the main objective of determining the annual cycle of its oceanographic features. Unique in its duration of a British Columbia fjord study, this observational time series of the distributional patterns of salinity, temperature, density, dissolved oxygen and climate is presented, and used to analyze the circulation pattern and replenishment mechanism of fjord waters.

Sediment data suggest progressive sorting along the fjord length the material originating from the Indian R. and Burrard Inlet and suggest water entering the fjord tend to flow along the east side and out along the westside. The author notes non-stagnant conditions prevail in the sediments. Very little organic material encountered. When it occurred it was as leaves, needles, twigs and chips. No H2S noted. Water characteristics exhibit circulation patterns reflecting fjord conditions. Dissolved oxygen data provides information on circulation in the previous month when below the emphatic zone and when water beyond the sill is different from Indian Arm water. Salinity temperature and related water body stability are discussed in annual terms to reflect freshwater, seawater and sill effects. Phosphate data (PO4-P) gathered in a joint study with the U. of Washington show an ave. carc. of 1.89 ug-at/l and 1.49 at the head 3 month respectively. The difference considered a function of productivity. Indian River contributions of P in March were calculated as negligible. Vertical dist. max. at 200m, 5.29 and with values at the sill at 2-3,suggest a concentrating feature in the fjord levels are approximately three times those of Georgia Strait.

Giunio-Zorkin, N.R. The Direct Examination of Biologically Active Cu in Sea Water. PhD. Thesis, UBC, Vancouver, B.C. 1983.

An analytical technique for the differentiation of biologically active copper (Cu) in seawater was developed. The procedure involves passing a seawater sample through an ion exchange resin of the sulponate type until complete breakthrough of metal ion is achieved.

The measurement of biologically active Cu by the resin technique was verified by comparing the analytical results with results from phytoplankton bioassays.

The few studies on the electrochemical nature of organic complexing agents in seawater suggests, however, that most are negatively charged. Thus the technique would be suitable for many seawater systems.

The analytical and bioassay techniques were then applied to natural seawater samples collected from five depths in a local fjord. A discrepancy was found between some of the bioassay and resin test results. However, the discrepancy was attributed to a physiological Cu-Mn interaction in the bioassay orgnism and not to a problem with the resin technique.

Goyette, D. (Unpublished). Burrard Inlet Environmental Data Feb-May, 1973. Environment Canada, Environmental Protection Service, West Vancouver, B.C.

Field sheets reporting observed dissolved oxygen,temperature and salinity for 13 stations sampled over 3 years. Observations have been charted (whereabouts?) and data available show DO to be consistantly high (6-11 ppm),vertically and horizontally.

Hagen, M.E. British Columbia Estuarine Information Catalogue: Volume II, Lower Mainland - Sunshine Coast. Environment Canada, Lands Directorate, Vancouver, B.C. 1984.

A catalogue of estuarine information emphasizing specific environmentally sensitive sites in B.C. including Indian R., Maplewood Mudflats and Port Moody Mudflats (Vol.II) relevant to Burrard Inlet environs. It provides a guide to imagery, base mapping, resource mapping, surveys, reports, assessments and related information. Baseline data stations and special land uses, administrative and jurisdiction data are included. References are indexed and reports and manuscripts are tabularized for easy reference by topic.

Hall, K.H. and Vinod K. Gujral. Determination of Selected Trace Organic Contaminants in Marine Sediments.
Report for: Environmental Protection Service, West Vancouver, B.C. 1983
By: Westwater Research Centre and Department of Civil Engineering, UBC, Vancouver, B.C.

A brief report on a preliminary investigation to determine selected trace organic contaminants present in marine sediments collected from 9 locations in False Creek and Burrard Inlet. Solvent extracts were subjected to cleaning and measurement by gas chromatography (GC/MS). No chlorinated benzenes or hexachlorobutadiene were identified ranging in concentration from 16 ug/g for fluorene to 165517 ug/g or 165 ppm for anthracene. False Creek sediments were the most contaminated containing 14 compounds, 12 of which were in concentrations greater than 1 ppm (net wt) including PAH's and phthalates.

Hall, K.J., V.K.Bujral, P. Parkinson and T. Ma. 1984. Selected Organic Contaminants in Fish and Sediment from the Fraser River Estuary. Westwater Research Center, UBC

Ten sites in the Fraser Estuary were studied. Starry Flounder had 0.19-2.52 ug/g TCP and 0.77 to 2.77 ug/g PCP wet wt. Phenol was the only acidic organic found in sediments and concentrations lower than in fish tissues. Phthalates, diethy l-, di-n-butyl and bis (2-ethylhexyl-) esters in both fish and sediments. Benzol butyl - in fish tissue. PAH's more in sediments than fish tissue. (Phenanthrene, fluoranthene and pyrene) in sediments and naphthalene, fluoranthene and benzo-a-pyrene more often in fish.

Highest levels of chlorophenols in fish from slough (adj land fill) and STP's (eg. Annacis/Iona Islands) PAH's/phthalates in sediments near Iona and N. Arm Fraser/Industrial discharges/urban runoff.

Harris, G. The Salmon and Trout Streams of Vancouver Waters, Journal of the Vancouver Aquarium V3(1) p.4-32. 1978. Vancouver Public Aquarium Association, Vancouver, B.C.

A historic review of salmon and trout streams in Vancouver area including English Bay, False Creek and Burrard Inlet prior to development. Urbanization has resulted in a loss of 120 kms in 18 streams to storm sewers. Pictures and articles outline the progress of urban development and its effects in streams and salmonid use. Quotations of pioneers as to the relative production and uses of streams are discussed.

Harrison, P.J., J. D. Fulton, G.Miller, C.D. Levings, F. Taylor, T. Parsons, P. Thompson & D. Mitchell. A Bibliography of the Biological Oceanography of the Strait of Georgia and Adjacent Inlets with Emphasis on Ecological Aspects. Department of Fisheries and Oceans. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1293. 1984.

A preliminary bibliography of published and unpublished material emphasizing ecology of benthic and pelagric fauna and flora with limited reference to taxonomic material. CEPEX studies are included. Reference by key words in a subject index by number. Introductory remarks note the area is a valuable fishery and rearing area for the young of Pacific salmon and large stocks of herring which justifies the need having a better understanding of the economically important area.A summary is given in CJFAS, Vol. 40 (7), 1983.

Harshman, G.W. Compendium of Current Marine Studies in the Pacific Northwest. Cam. McIntosh Ed. A Publication of the Oceanographic Institute of Washington. Seattle, Washington 98109. 1976. (1976-1977) issues only - now out of print)

Records a description of all current marine studies for Washington, Oregon and British Columbia including those on the basic properties of seawater, freshwater and water motion, meteorology, surveys and predictions, marine geology, fisheries and shellfish research, marine biosystems, water quality and pollution, health safety and education, and engineering and technology, coastal zone management and finally marine affairs and legal studies. Indexed by key word, geographic location and investigator.

Hendersen, M.K. Environmental Inventory and Preliminary Assessment Report on National Harbour Board, Port of Vancouver. Environmental Protection Service, Federal Activities. PAG. Pacific Region, 1976.

Reviews Federal property based discharges in Burrard Inlet, noting grain, sulphur, coal, metal concentrates and forest products and fishing, commercial and recreational vessels. Ship repair facilities, fish processing plants, oil refineries, chemical plants, log booming. Includes Plan hand based Activities/Vessel/Water based activities Vessel Pollution Control. Land Discnarges. Appendices on Harbour Activities and Discharges by Lessees.

Herunter, H.E. Surface Plankton Community Composition and Succession of Three Oceanographically Different Areas of Outer Burrard Inlet. B.Sc. Thesis, UBC, Vancouver, B.C. 1984.

Zooplankton were vertically sampled by means of a 351 um SCOR net (mouth dia. 57 cm) from a depth of 1, 5, 10 and 15m at three locations - 1) Port Atkinson, 2) PEI and 3) First Narrows from June to October 1983.

Zooplankton and phytoplankton species composition did not alter significantly over the study period. Homogeneity of phytoplankton attributed to tidal current/mixing zooplankton at First Narrows appear different on 4 of 8 occassions and was associated with mixing characteristics of the area. Phytoplankton dominance alternated between diatoms and flagellates. Zooplankton (secondary producers) had four periods of abundance; cladocerans in early summer and larvaceans in early fall. Tertiary producers were mainly C. anglicus and coelenterates (Phlidium spp. and Pleurobeachia pileus. In general community differences between locations were slight.

Himmelman, J.H. Factors Regulating the Reproductive Cycles of Two Northeast Pacific Chiton, Tonicella lineata and T. insignis. Marine Biology. 50, 215-255. 1979.

The reproductive cycles of Tonicella lineata Wood and T. insignis Reeve are examined in relation to changes in physical and biotic conditions in different locations in British Columbia, Canada, over a 3 to 4 year period. A clearly annual reproductive cycle is displayed by both species, and in any one location and year reproductive events in the two species are similar. There is a progressive increase in the size of the gonads starting in the summer and continuing to mid-winter. Although no one environmental factor is likely to be correlated with this prolonged period of gonadal development, various phases of the annual temperature and photoperiod cycles do appear to coicide with particular phases of gametogenesis (such as gonial proliferation, vitellogenesis and gonadal maturation), and thuse could act as external cues. There is a synchronous drop in gonadal size in T. lineata and T. insignis in the spring, as a result of spawning. The exact timing and abruptness of this event in different years cannot be accounted for on the basis of temperature. However, new correlative data are presented to add further support to the hypothesis previously presented that the spring phytoplankton is the cue for natural spawning (Himmelman, 1975). Temperature may inhigit spawning in T. lineata if conditions are unseasonably cold.

Hsiao, S.I. Nutritional Requirements for Gametogenesis in Laminaria saccharina (L) Lamouroux. PhD Thesis. Simon Fraser University, Burnaby, B.C. 1972.

Gametophyte development of L. saccharina relative to nutrients, nitrates, phosphate, iodide, iodate and chloride/iodide ratios in axenic culture. Nitrate and Phosphate required and optimized concentrations maximized DNA, RNA, protein, carbohydrate and chlorophylls production. High fertility corresponded with high RNA/DNA and Protein/RNA ratios. Iodide and iodate not essential, however high concentrations of iodine had an inhibitory effect. Phenology of insitu gametogenesis, surfce water temperature, salinity, pH, nitrate, phosphate and total orgnic iodine monitored weekly for 3 years in Burrard Inlet. Diurnal and seasonal variations observed. Autumn-early winter gametogenesis took longer likely due to temperature and light conditions and not nutrients etc. Gametogenesis not limiting macroscopic sporophyte generations but the limiting action was the response of microscopic sporophytes to their environment.

Jordon, A.J., J. Stronach and E. Hagmeir. Burrard Thermal Generating Plant Liquid Effluents - Environmental Impact Assessment. A Report for: B.C. Hydro and Power Authority, Vancouver, B.C.1980 By:Beak Consultants, Vancouver, B.C.

Beak Consultants Limited conducted a physical and biological study of B.C. Hydro and Power Authority in the vicinity of the Burrard Thermal Generating Plant. The physical study was a mathematical exercise in which the flushing rates of Port Moody Arm near the facility was calculated at 33% of the volume of the arm per tidal exchange. This provides a very effective advective heat (and dissolved materials) dispersion mechanism. The first component for biological study was a re-occupation of benthic stations. Results showed a continuance of the improving trend in population numbers and various indices of community health noted in earlier studies. Lastly, the first intertidal macroalgal community study was completed in the arm. Results were inconclusive for measuring impacts of Burrard Thermal operations, but provide a baseline from which to measure future changes.

Kathman, R.D., S.F. Cross and M. Waldichuk. Effects of Wood Waste on the Recruitment Potential of Marine Benthic Communities. Fisheries and Oceans, West Vancouver, B.C. 1984.

An assessment of wood waste effects on Benthos in 24 m of water in outer Burrard Inlet over 11 weeks. Cluster analysis showed three biotic groups:

1. Polychaetes /oligochaetes
2. Polychaetes and bivalves
3. Nematodes, shipworm and polychaetes preferring organic enrichment .

Greater potential enhancement appears to occur in sediments containing some wood (10-40% wood content). Higher levels were detrimental.

Kent, C.D. Assessment Study of Wastes Disposal at National Harbours Board Campbell Avenue Fishermen's Wharf.
Report to: Environmental Protection Services, Department of Fisheries and Environment, 1978.
By: Kent Engineering Ltd., West Vancouver, B.C.

The study assesses the fish processing operations, the existing waste handling facilities and problem areas. Waste sources,quantities and characteristics were identified along with solid waste and all emission. Receiving water impairment was confined to the area immediately adjacent to the wharf which impedes tidal flushing. The facility was not in compliance with Environment Guidelines. Procedures and alternatives to improve waste water control are outlined. Solid waste disposal and air emissions are acceptable.

Koch, F.A., K.J.Hall and I.Yesaki. Toxic Substances In the Wastewaters from a Metropolitan Area. Technical Report No. 12, 1977. Westwater Research Centre, University of B.C.,Vancouver,B.C.

As a preliminary investigation into sources of toxic substances discharged to the Lower Fraser River, twelve collection areas representing a multiplicity of land uses were monitored during the summer and fall of 1974 for trace metals (cadmium, copper, iron, mercury, manganese),phenols and surfactants.

In residential wastewaters, copper is the major trace metal contaminant and results from corrosion of piping in the potable water delivery system by the very soft water supply. Mixed system wastewaters which represent a combination of residential, commercial and industrial activities have higher concentrations of cadmium, mercury, nickel, lead and zinc than residential wastes alone. Metal finishing industries appear to contribute high concentrations of cadmium, nickel and zinc to the mixed wastewaters, and institutional wastewaters contain the highest level of mercury. There is considerably diurnal variation in trace metal concentrations, especially for copper, lead and zinc, at sewage treatment plants. Peak concentrations usually occur during mid-day coincidentwith peak flow periods and reflect transport of trace metals adsorbed to particulate materials. Urban stormwater is an important source of lead and to a lesser extent copper and zinc, and can represent an important source of contamination in combined systems during a rainfall period.

The concentrations of the organic pollutants, namely, hydrocarbons, phenols and surfactants, are low in wastewaters of the Vancouver area when compared to wastewaters from other cities. Within the metropolitan Vancouver wastewater system, highest hydrocarbon levels were found in mixed wastewaters implicating industries which utilize petroleum products as an important source. University wastewaters contained the highest levels of phenols, probably as a direct result of their use in laboratories

Krause, E.P. and A. G. Lewis. Ontogenetic Migration and the Distribution of Eucalanas bungii (Copepoda: Calanoida) in British Columbia inlets. Canadian Journal of Zoology. V.57(II) 1979.

Fourteen areas, including Indian Arm, were sampled by Clarke Bumpus sampler over one year (1975). Salinity and temperature data were taken from UBC data reports. Station IA-2 (49 degrees 23.5 N, 122 degrees 52.5'W) is at the deepest part of the inlet. E. bungii was quite rare in Indian Arm and found only below 100m at 0.3m-3 January - June and 2.0+m-3 July -December. Diagramatic sections of E. bungii distribution show it to be below 150m February, March, May-December and below 100m July - September.

A summary discussion of hydrography (Davidson, 1979) is given and its effect on E. bungii distribution in Indian Arm suggesting shallow water summer intrusia from the Strait of Georgia may introduce specimens into the inlet, the shallow sill of Indian Arm restricting the access observed as compared to those inlets with deeper sills. The bulk of the population spawns in early spring. Mature stages are found only in deeper water by September.

Latouche, Y.D. and M.C. Mix. The Effects of Depuration, Size and Sex On Trace Metal Levels in Bay Mussels.
Marine Pollution Bulletin. Vol. 13. No.1.

Examined Mn, Cu, Ni, Cd and Zn. Older mussels maintain higher levels Ni, Cd and Cu, whereas younger have Mn in somatic tissue. No significant difference in gonodal tissue. Mn and Zn greater in female gonods. Cd> in female somatic tissue. Mussels were sampled from a single population by hand. Metals by AA (flame) in duplicate.

LeBlanc, M.J. The Effect of Copper on Phytoplankton. M.Sc. Thesis, UBC Department of Zoology, Vancouver, B.C.

This study developed a sensitive and relatively rapid biological assay for copper activity in sea water using the marine diatom, Nitzschia longissima. Seawater from the Strait of Georgia (350m)(Geo 1748) was collected and 13 unialgal cultures of diatoms and dinoflagellates from UBC were used following a detailed bioassay procedure. DOC and copper analysis methods were after Cave (1977). No specific trends were found between diatoms or dinoflagellates in terms of sensitivity or in terms of different sized cells. It was found that cell division rather than photosynthetic pigment production or C14 uptake was more effected. Enzyme nitrate reductase was greatly increased by addition of low concentrations of copper suggesting a protective mechanism, possibly chelating the ionic copper.

Levings, C.D. The Ecological Consequences of Dreaging and Dredge Spoil Disposal in Canadian Waters. Department of Fisheries and Oceans, West Vancouver, B.C. 1979. NRCC Associate Committee on Scientific Criteria for Environmental Quality.

This document summarizes current knowledge of the ecological consequences of dredging and dumping on aquatic ecosystems in Canada. The review does not intend to establish the significance of this industrial activity in comparison to natural changes in ecosystems. Erosion and sedimentation resemble dredging and dumping qualitatively. Qualitative relationships can usually only be established in relatively closed systems. The local impact of dredging and disposal may be appreciable, and hence its immediate relevance and scale must be determined by lacustrine or coastal ecosystem managers. This document provides a perspective on research priorities that highlights the type of information required to upgrade knowledge for these people to use. The decision as to which ecosystem should receive the most immediate attention must be made by a variety of officals, including scientists.

The major impact of Canadian dredging is the physical disruption of ecosystems. Since the ecosystems themselves are so poorly understood, more emphasis is required on ecological research than on laboratory testing. Much of the dredging and dumping in Canada results in either frequent physical disruption on a small scale (<1 ha) (e.g. Atlantic fishing ports), or large-scale suction dredging (e.g. Fraser River).

Levings, C.D. The Zoarcid Lycodopsis pacifica in Outer Burrard Inlet British Columbia. J. Fish. Res. Bd. Canada, Vol. 26(9) 1969.

Aspects of the biology of Lycodopsis pacifica were investigated during December 1965-November 1966 in outer Burrard Inlet, British Columbia. Trawls were used as sampling devices.

After approximately age III, males appeared to have a different growth pattern than females. Females apparently had higher mortality rates than males. Spawning occurred from late August to January. Most males were mature at a length of 170 mm, and most females at 160 mm. The complements of mature eggs were small (average approximately 30). The mature eggs are large, with an average diameter of 5.0 mm. There is some evidence that parental care is involved in reproductive behaviour. The species fed primarily on molluscs, annelids, and Crustacea in the bottom mud.

Levings, C.D. and N. G. McDaniel. Invertebrates at the Maplewood Mudflats, A Rare Habitat in Vancouver Harbour. Pacific Environment Institute, West Vancouver, B.C. Fish. Res. Bd. Canada. Manuscript Report Series No. 1314. 1974.

As part of a study assessing the impact of industrial development of the shoreline at Maplewood mudflats (north shore of Vancouver Harbour), benthic invertebrates were sampled at 25 stations in February and March 1974. Small polychaetes (especially Manayunkia aestuarina)and crustaceans (amphipods, cumaceans) dominated the muddy substrates, while mussels (Mytilus edulis) and barnacles (Balanus glandula) were abundant on the coarser sediments. Soft shell clams (Mya arenaria) and lugworms (Abarenicola pacifica) were the most abundant macrofauna in the muddy sand substrates. Salinity of the water in the surface of sediments was directly related to distance from the mouth of a small stream, but chlorophyll a'levels in surficial material were inversely related to salinity.

Lewis, A.G., A. Ramnarine and M.S. Evans. Natural Chelators - an indication of activity with the calanoid copepod Euchaeta japonica. International Journal on Life in Oceans and Coastal Waters, V. 11 (1), p.1-4. 1971.

Survival of Euchaeta japonica Marukawa prefeeding stages in natural seawater is increased by the addition of a synthetic chelating agent. This increase occurs periodically in inshore waters and more frequently in near-oceanic water. The periodicity is associated with changes in chelator-like characteristics of the seawater. Changes in these characteristics are associated with changes in biological activity in the water.

Lewis, A.G., P.H.Whitfield and A. Ramnarine. Some Particulate and Soluble Agents Affecting the Relationship between Metal Toxicity and Organism Survival in the Calanoid Copepod Euchaeta japonica. Marine Biology 17, 215-221. 1972.

Particulate and water-soluble agents were tested to determine their ability to affect the relationship between metal toxicity and the survival of Euchaeta japonica (Copepoda, Calanoida). Clay minerals and diatoms were two types of particles capable of affecting this relationship. Ascorbic acid, sewage effluent, and water extracts of humic acid and two types of soils exhibited the same capability. The ability of the water-soluble agents was compared with that of a known chelating agent in an attempt to quantify the activity of the agents.

Lewis, A.G., P. Whitfield and A. Ramnarine. The Reduction of Copper Toxicity in a Marine Copepod by Sediment Extract. Limnology and Oceanography V.18(2) 1973.

Seawater extracts of marine sediments from two areas were added to copper-enriched seawater in which the prefeeding stages (egg, NI, NII) of Euchaeta japonica(Copepoda: Calanoida) were maintained. Survival with the sediment extracts was greater than without, indicating an ability of some part of the extracted material to reduce the toxicity of the copper. The effect of the extracts was compared with that of a synthetic chelating agent to provide an "equivalent" value.

Lewis, D.H. Premier Street Sanitary Landfill Leachate Control Study.
For:The Corporation of the District of North Vancouver, 1983.
By:Associated Engineering Services Ltd.,Vancouver,B.C.

Describes site conditions, geophysical survey, hydrogeological methods and investigation, landfill, water balance and mitigative measures including hydrogeological logs and water quality analyses.

In summary the leachate emanates at a rate of 25 Igpm and at this time discharges into Lynn Cr. across the site boundaries. The report recommends the installation of an impervious curtain wall to curtail this flow. The report also recommends an evaluation of the leachate effect on the Lynn Cr. fishing and development of a cost/benefit ratio. Summary water quality data shows conductivity (124-1567), pH (6.5-8.0) T C (11.0 - 17.7); DO (0.6 - 2.4 mg/l) June 1983. Analyses after Ministry of Environment Manual or Standard Methods. In addition to physical parameters, dissolved Anions and dissolved and total metals, COD, Ammonia N, Phenols,Total K. Nitrogen and surfactants were analyzed.

Lockhart, J.M. Observations on the Ciliates Associated with the Blue Mussel, Mytilus edulis, of Vancouver,B.C. BA Thesis, UBC, Vancouver, B.C. 1953.

The examination of blue mussels, Mytilus edulis, around Vancouver, B.C. was undertaken. No survey of the protozoans living in molluscs in this area had previously been made.

Samples of mussels were collected from beach areas. They were taken to the laboratory, dissected, and examined microscopically. The vital stains methylene blue, neutral red, acetic methyl green and brilliant cresyl blue were used. The latter proved most satisfactory.

Seven species of ciliates were found and described. Three were in the mantle cavity and four in the byssus. One species, a thigmotrich, is believed to be an obligatory commensal of all mussels in the area. It was most abundant during May and June and was not found during October and November.

Samples were collected from five lcoations in Burrard Inlet.

McCann, S.B (Editor). The Coastline of Canada: Littoral Processes and Shore Morphology. Geological Survey Paper 80-10. Proceedings of a Conference held in Halifax, Nova Scotia, May 1-3, 1978.

This geological survey covers some aspects, at least, of each of the four coasts of Canada - Atlantic, Pacific, Northern and Great Lakes. Some of the papers are very specific, either by topic or geographic location, others provide a regional view of coastal characteristics. They are arranged on a regional basis, with the exception of two, more general papers, which are presented first. The disparity in the number of papers in each regional section, and the differences in the types of study reported for each region, are fair reflections of the disparity in research effort on the different coasts. Half of the papers in the volume deal with the Atlantic coast, south of Labrador, where two contrasting environments have received considerable attention in the last ten years, namely, the microtidal barrier shorelines of the southern Gulf of St. Lawrence and the macrotidal sedimentary regime of the Minas Basin, Bay of Fundy. These two particular environments are the concern of six and four papers, respectively, within the Atlantic coast section. There are seven papers on northern coasts, of which five are reconnaissance descriptions of coastal segments about which very little, if anything, has been written previously. The northern coasts extend as far south as 52 degress N in southern James Bay and southern Labrador. Generally, sea ice is present for six months and more each year, but there is a wide range of tidal and wave energy environments. The two papers on the Pacific coast are both reviews, the first providing a very thoroughly documented introduction to the coast as a whole, the second a commentary on some aspects of sedimentation on the Fraser Delta.

McDaniel, N.G., R.D. MacDonald, J.J. Dobrocky and C.D. Levings. Biological Surveys using in-water photography at three ocean disposal sites in the Strait of Georgia, British Columbia. Fisheries and Marine Service, Technical Report No. 713, 1976.

A photographic investigation of the Vancouver Harbour dump site among others employing several techniques described in detail. Observations of most of the bottom photographs depicted the area to have a silt-sand substrate which was generally lacking in macrobenthos (Pandalus, Pandalopsis, Chionoectes were the predmoninant epibenthos.)

McGreer, E. and B. Reid. Contaminant Mobilization and Bioaccumulation from Marine Sediments Adjacent to a ship repair facility. Project No. 474. Environment Protection Service, Environment Canada, by EVS. 1980.

Lab studies conducted on Cd, Cu, Pb, Zn, As, Hg, PCB's in sediments from Burrard Yarrows included Macoma balthica and M. edulis. Pb and PCB (Aroclor 1254) accumulated the greatest. Resident biota indicated significant accumulation of Pb, Aroclor 1254 and Cu. There was no apparent direct relationship between salinity and contaminant uptake.Nor was uptake related to contamination level in sediments.

M. edulis was collected off piles by hand and scuba diver and Teredo worms were obtained from a dredged log. C. magister were collected by baited traps, and M. balthica by sieve.

Sediments were collected by Ponar grab.Analytical procedures are outlined in detail.

McGreer, E.R. and D.R. Munday. Effects of Silt and Contaminated Sediment on Eggs and Larvae of Pacific Cod (Gadus macrocephalus). Report to: Fisheries and Oceans, Vancouver, B.C. 1982. By: EVS Consultants Ltd., North Vancouver, B.C.

Fertilized eggs of the Pacific cod (Gadus macrocephalus) were exposed to different concentrations of an uncontaminated marine sediment (silt) and a sediment contaminated with heavy metals and polychlorinated biphenyls. Each sediment concentration was tested under two experimental conditions: "quiescent" and "in suspension". Quiescent tests were designed to simulate burial of eggs by deposited dredge spoil. Effects measured included mortality during embryonic development, percent hatchability, and time to 50% hatch. The toxicity of test sediments to newly hatched larvae of Pacific cod, and the ability of larvae to ingest each sediment were also assessed.

Exposure to contaminated sediments resulted in greater mortalities in fertilized eggs than exposure to uncontaminated sediment (silt) at similar concentrations. Successful hatching of larvae was virtually eliminated when fertilized eggs were covered to a depth of only 1 mm with contaminated sediment, or exposed to suspended concentrations of 7.5 g/L or greater. Similar mortalities in tests with suspended, uncontaminated sediment occurred at a concentration of 30 g/L. Fertilized eggs which did not survive to hatching generally died in a very early stage of development. Time to 50% hatch for fertilized eggs increased with increasing depth of uncontaminated sediment over the eggs. Survival and feeding behavior of newly hatched larvae were not affected by short-term (4 h) exposure to contaminated sediment. Review of the literature indicated few published studies on the toxicity of contaminated sediments to demersal life stages of marine fish species. Recommendations included expanding acute toxicity testing of contaminated sediments for ocean disposal, and development of guidelines for sediment quality.

McGreer, E.R., B.J. Reid and H. Nelson. Mobilization, Bioaccumulation and Sublethal Effects of Contaminants from Marine Sediments. Canadian Tech. Report. Fish. Aquat. Sci 990: 130-151. 1981.

Laboratory studies were conducted to determine the mobilization and bioaccumulation of contaminants (Cd, Cu, Pb, Zn, As, Hg and PCB's) from marine sediments sampled near a ship repair facility. The deposit-feeding clam Macoma balthica and the filter-feeding mussel Mytilus edulis were used to assess bioaccumulation potential. Lead and the polychlorinated biphenyl (PCB) Aroclor 1254 were bioaccumulated to the greatest extent in laboratory tests. No direct relationship between salinity and contaminant uptake was apparent. Analysis of resident biota indicated significant accumulations of lead, Aroclor 1254 and copper in invertebrate tissues. The time required for 50% of the clam population to burrow (ET 50) ranged from 1.2 h in the control to 5.2 h in the contaminated substrate.

McHardy, R.A. A Study of the Taxonomy and some Aspects of the Ecology of Marine Ostracods in the Plankton of Indian Arm, B.C. M.Sc. Thesis. UBC, Vancouver, B.C. 1961.

In this study of the ostracod distribution in Indian Arm, Paradoscostoma striungulum Smith, Philomedes sp. Conchoecia elegans Sars and C. pseudohamata n.sp. were collected, described and illustrated. The latter two were found to be abundant in plankton and were studied in relation to T C, So/oo, DO and light. They were seldom found above the thermocline and halocline. Distribution may be influenced by mixing of resident and new water entering Indian Arm in waters 7 to 9 degree C and 26 to 28 o/oo salinity. Both occurred at depths greater than the inlet sill. Diurnal vertical migration differed between the two species except in the shallow of the water column. Maximal breeding in early summer for Conchoecia elegans and early summer to early autumn for C. pseudohamata. Both species are omnivorous.

Samples were collected over 10 cruises in 1960 at 6 locations on the centre line of Indian Arm over 24 hour periods and on flood and ebb tides.

McKelvey, R.W., I. Robertson and P.E. Whitehead. Effect of Non-Petroleum Oil Spills on Wintering Birds near Vancouver. Marine Pollution Bulletin Vol II, pp 169-171. 1980.

Reviews the effects of oil pollution on birds, bird use and oil pollution in Vancouver Harbour including English Bay, Inner Harbour and east Burrard Inlet. It notes that spills of vegetable oils have caused greater losses of birds than spills of petroleum oils and suggests that sites of storage and transshipment of vegetable oil may be overlooked in oil spill contingency planning.

McLeod, G., E. McGreer and N.Williams. Containment of Contaminated Dredge Spoil in a Foreshore Site at Coal Harbour, Vancouver. McLeod Geotechnical Ltd. for Western International Motels Ltd.1981

A report on the engineering aspects of dealing with contaminated soils on a site for commercial development. The site of an old industrial shipyard site on the Coal Harbour waterfront in Vancouver Harbour was redeveloped for a marina with a seawall dyke and parking area. Considerable dredging was involved both for the marina and to reach satisfactory bearing for the seawall dyke. Initially, ocean disposal of the dredged material which contained elevated levels of contaminants was prohibited by Environment Canada under the restrictions of the Ocean Dumping Control Act. (O.D.C.A.). The solution to the problem consisted of land storage of the contaminated dredge spoil on site. Existing subsoil conditions were taken advantage of in order to prepare a mud pit in which the contaminated dredged material could be contained. Detailed sampling and chemical testing of the material to be dredged delineated a zone of contamination concentrated in the surface layers of the bottom sediments. Thus the quantity of of contaminated spoil which could not be ocean dumped was only 20% of the total dredge spoil and could be handled by land storage on site. Location and final treatment of the stored spoil allowed for interim construction of an asphalt parking area on top with provision for future building construction in the same area.

Markham, J.W. An Ecological Study of *Laminaria sinclairii* and *L. longipes*. PhD. Thesis. UBC. Botany Department, Vancouver, B.C. 1969.

The distribution, ecology, growth and reproduction of *Laminaria* (kelp) were studied in the laboratory and in the field in B.C., Oregon and Alaska. Gross distribution appears to be controlled by temperature as is specie distribution. Salinity apparently has little influence on distribution since it has a tolerance for wide ranges of salinity, *L. sinclairii* in particular. Greatest growth occurs in summer with sori regeneration starting in January. Vegetative proliferation which occurs March to April is apparently the normal method of reproduction.

Marles, E.W.,B.M.Lusk and W.J. Rapatz, 1973. Summary of Hydrographic and Oceanographic Information on Some British Columbia Estuaries. Pacific Marine Science Report 73-7. Environment Canada.

Deals with Indian (Burrard) Arm (p.12) noting poor sounding coverage (chart 3435) [1985-notes 3495 as chart] but the oceanography is the most complete of any water and the understanding of inlet better than average. The Bibliography details IOU BC Cruises 1953 to 1970.

Marliave, J.B. High intertidal spawning under rockweed, Fucus distidus, by the sharpnose sculpin, Clinocottus acuticeps. Canadian Journal of Zoology V59(6) 1981. Vancouver Public Aquarium, Vancouver, B.C.

Spawning was monitored near First Narrows at Stanley Park where Clinocottus acuticeps spawns circular monolayer egg masses on rock surfaces at the 3.0- to 3.7-m tide levels from January through April. At these tide levels, air exposure occurs about half the time and most egg masses have clumps of Fucus distichus lying over them during low tides. Controlled removal of the F. distichus demonstrated a role of this plant in reducing egg mortalities and a preference by adult fish to spawn under macrophytic algae.

Early embryonic stages were most susceptible to mortalities resulting from removal of cover plants in the field. In laboratory air-exposure tests, desiccation was more important than temperature elevation in causing mortalities.

Marliave, J. (Unpublished) A Technique for Collecting Marine Fish Larvae Settling from the Plankton. Vancouver Public Aquarium, Vancouver, B.C. 1976.

The study was conducted adjacent to Lumbermans Arch, Stanley Park to evaluate cage design and faunal settling rates on two different substrates. Cages were set at weekly and monthly intervals (Oct. 1976 to August, 1977) and species settlement observed and with these data the minimum growth rates for the first month after transformation to benthic habits could be determined. The study showed obvious depth preferences for difference shrimp species, Pandalus hypsinatus settling only in shallow subtidal and P. danae at both shallow and deeper areas. Polychaetes, tunicates, snails, mussels and barnacles and cottids were also noted to occur.

Marliave, J. (Unpublished). Otter Trawl Data Sheets - Burrard Inlet and Indian Arm. Vancouver Public Aquarium, Vancouver, B.C. 1982.

Field notes on otter trawls carried out between January and May, 1982 at Cates Park, Second Narrows, entrance to Port Moody Arm, Belcarra Bay and Dollarton/Boulder Island area. Trawl catches were predominated by English and Rock Sole. Other species present included Pollock, Sea Poacher, Sea Perch, crab and shrimp.

Marliave, J.B. Lack of Planktonic Dispersal of Rocky Intertidal Fish Larvae.

Submitted to: Transactions of the American Fisheries Society, Feb. 1985. Vancouver Public Aquarium, Vancouver, B.C.

Planktonic dispersal was studied at several locations including Vancouver Harbour, east of Point Atkinson (49 degrees 20N, 123 degrees 15'30"W) in the spring of 1983 using horizontally towed SCOR nets.

Although planktonic drift is presumed for larvae of most marine fish species, the extent of larval dispersal for intertidal species is largely unknown. Oblique tows with a net of 500 micron mesh were made at distances of 0, 4, 20 and 500 m from steep rocky shores, divers guiding the 0m tows. Ichthyoplankton of the extreme nearshort was more dense than that of offshore waters. Species composition shifted radically from inshore to offshore, with intertidal species (cottid, stichaeid, pholid, gobiesocid) dominant inshore. Larvae of rocky intertidal fishes occurred more frequently along rocky shores than on an adjacent sandy beach. The evidence suggests that larvae of rocky intertidal fishes resist offshore and possibly longshore dispersal. In contrast to information for sandy beaches, the data for the rocky nearshore reveal that all larval stages remain inshore, rather than a narrow size range. Populations of rocky intertidal fishes may thus be relatively isolated genetically.

Miller, P. Humeral Immune System of the Sea Mussel, Mytilus edulis. B.Sc. Thesis. UBC, Department of Biology, Vancouver, B.C., 1980.

The study examined the memory response of the mussel immune system identifying that in response to rabbit esythrocytes injections there was none. Agglutination of E. coli and Vibrio was examined determining agglutination of the former but not the latter. Population exchanges between clean and sewage polluted habitats observed as consistent trends in agglutination strength of the mussels. Sample locations included Jericho Beach and the north shore of English Bay at the West Vancouver EPS Laboratory.

Moore, B. British Columbia Rail Intertidal Survey. Environmental Section Waste Management Branch of the Ministry of Environment Occasional Report. 1982.

The intertidal survey in the vicinity or Vancouver Wharves east of First Narrows was conducted at 3 locations to determine the effects of a diesel oil discharge originating from B.C. Rail property. The intertidal community was severely degraded in the immediate vicinity of the spill as compared to the control area (West of Vancouver Wharves). The report concludes that cessation and cleanup could allow for a limited recovery and due to the high fish usage of inshore areas protection is warranted.

Munday, D. Field Sampling and Analysis of Sediment Samples from the Proposed Seawall Development - Bayshore West Site Preparation Project.
Report to: McLeod Geotechnical Ltd., West Vancouver, B.C. 1979.
By: EVS Consultants, North Vancouver, B.C.

The study involves a disposal solution for contaminated sediments from a construction site in Coal Harbour, Burrard Inlet. Twelve sites are sampled and analyzed for PCB's,metals and particle size(Aroclors 1248, 1254 and 1260, metals - As, Hg, Cu, Zn, Pb, and Cd.).Extreme high levels of these parameters were encountered in the upper 3' and the report notes possible sources for this material (boat yards). Methodology for PCB follows procedures published by Inland Waters Directorate, Water Quality Branch 1974. An outline only is given for metals (no Certified Stds). Plan of site 1":50'.

Nelles, S. Comments on Juvenile Salmonid Utilization of Burrard Inlet and Vancouver Harbour. Fisheries and Marine Service Internal Report. Water Quality Division, Habitat Protection Unit. Fisheries and Environment, Pacific Region. Vancouver 1978.

A compilation of available information on juvenile salmon populations in the harbour area of use in the formulation of timing restrictions for industrial activities. Notes that large numbers of juvenile salmon and other organisms use the area from Capilano,Indian,and ,Seymour Rivers and Lynn Creek suggests use by stocks from Puget Sound and Vancouver Island.These data are a result of studies for the 3rd crossing of Harbour. Purse seining,Beach seining and Gill netting were accompanied by an Echo Sounding Survey. The latter indicated 1-200,000 underyearling chinook and 1-2000 underyearling herring (1973). S. Argue (1972) studied Pt. Grey to 2nd Narrows June to October estimating:

Herring (1972) - 4-500 tons - Brockton - 1st Narrows
- 7-0,000 tons - Capilano to Brockton Pt.
Salmon (1973) - chinook (pred.), Coho, and some chum. June to October.

Population estimates by the Bailey formula, Chinook 3.588m and Coho 1.018 m.

In summary Juvenile salmonds are usually present in Burrard Inlet, Vancouver Harbour and Indian Arm February to mid-October. - Estimates population of salmon (2x10 6th) and identifies need to surveille and regulate industrial activities/habitat modification to restrict work where possible to November - January inclusive and the need for more detailed stock assessment.

O'Brien, S.C. Morphological Variation of Costaria greville in Southwest British Columbia Coastal Waters. M.Sc. Thesis. Simon Fraser University, Burnaby, B.C., 1972.

Examines the morphological variation and taxonomic treatment of Costaria indicating species differentiation may be only morphological differences rather than true specific difrerences. Assessed phenology, ontogeny, compared mature plants and conducted transplants. Study areas include 3 locations on Vancouver Island and Indian Arms. Notes Costaria in Indian Arm has a crisp blade (tears readily), flattened ribs, large bellations and no perforations, finely ridged stipe considered due to environmental variation (phenotypic plasticity). Indian Arm site is characterized on Gilmartins (1962) work. Indian Arm has stratified system in terms of temperature and salinity and is sheltered. Species associations discussed, physical comparison made (photos). Transplant studies conducted February 27 to August 13, 1969. Comparative success of transplants discussed. Historic collections of Costaria made at Second Narrows and Stanley Park compared and found similar to those of Indian Arm. A summary of the range of variations is given.

O'Connor, D. Environmental Assessment of Mohawk Oil Co. Ltd. Used Oil Treatment Plant, North Vancouver.
Report to: Mohawk Oil Co. Ltd., Burnaby, B.C. 1984.

An overview of existing conditions on this industrial site in connection with a need to update operational procedures in order to alleviate problems in system process. Air emissions and wastewater treatment now meet permit conditions since the company installed a treatment system for the latter. No solid wastes are generated and any highly inorganically contaminated oils are sold to the U.S. Emergency procedures have been updated. The report notes the positive contribution this plant has in providing a safe non-polluting outlet for used oil.

Parsons. T.R. and J. Parslow (Unpublished) Biological Productivity. University of British Columbia, Institute of Oceanography. Vancouver,B.C.,1977.
Supported by Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO).

A mathematical model will be constructed to describe plankton and fish production in the Strait of Georgia as compared with Weather Station P. Data Available.

Paul, J.M. Metabolites, Decomposition Products and the Survival of a Marine Organism in Copper Enriched Water. B.Sc. Thesis, UBC, Vancouver, B.C. 1978.

The growth medium of three separate species of phytoplankton, and the cellular extract of a species of eelgrass were bioassayed to determine their ability to reduce copper toxicity in the embryonic phase of a calanoid copepod (Euchaeta japonica). None of these preparations reduced copper toxicity. A reduction did occur with the growth medium of a marine yeast. It is suggested that due to the concentration of yeast, its excretion and decomposition products may be part of the natural complexing agents found in marine environment.

Copepods and yeast were obtained from Indian Arm, IOUBC Station IA2.

Pickard, G.L. and B.R. Stanton. Pacific Fjords: A Review of their Characteristics. Manuscript Report No. 34, 1979. UBC, Department of Oceanography.

An overview of fjord characteristics incorporating data from UBC cruises including the characteristics of fjord morphology, topography, climate, fresh water inputs, tides and surface and internal waves, temperature, salinity, dissolved oxygen, turbidity, and water density.

Data from oceanographic cruises into Indian Arm and Burrard Inlet are referenced.

Popham, J.D. The Occurrence of Abnormalities in the Tissue of Bottom-Dwelling Fish.
Report to: Environmental Protection Service, Environment Canada, 1984.
By: Seakem Oceanography Ltd.

A pilot histological survey, primarily of the livers of fish collected in Vancouver waters and in Satellite Channel was undertaken. English sole collected from Burrard Inlet had a higher proportion of lesions in the livers than those collected from Satellite Challel. One specimen was found to have adenomatous foci in the liver. Papillomas were found on English sole collected off Iona Jetty. This study has demonstrated the feasibility of using histological investigations of demersal fish for monitoring water quality.

Popham, J.D. and J. M. D'Auria. A New Sentinel Organism for Vanadium and Titanium. Marine Pollution Bulletin. Vol. 13, No. 1, 1982.

Examined feather duster tube worms (E. vancouveri) and Mytilus edulis for Ti, V, Mu, Fe, Ni, Cu, Zn, Pb. M. edulis had higher metal concentrations near pollution sources (storm sewer). Worms accumulated Ti and V. Analysis by X-ray energy spectroscopy. Samples were collected from a storm outfall and floats in the District Municipality of North Vancouver on 20 July and 13 August 1980.

Popham, J.D. and J.M. D'Auria. Effects of Season and Seawater Concentrations on Trace Metal Concentrations in Organs of Mytilus edulis Arch.Environment Contaminate Toxicology 11, 273-282. 1982.

Examined M. edulis gills and visera for Pb, Cu, Zn, Mn and Fe. Tissue and seawater analysis (total, Diss. Ions) monthly over one year in Burrard Inlet at the Seabus Terminal and Rocky Point in 1979. X-ray spectroscopy and Atomic Absorbtion Spectroscopy (?). All elemental concentrations except Cu correlated to seawater levels. seasonal variation in Pb, Zn, Cu. and Fe in tissue but only Fe and Zn in seawater. Significant correlation between Cu in both organs and Pb and Zn concentrations in seawater. (Facilitative elements for Cu uptake.) XES method used as in Stump etal.

Popham, J.D. and J.M.D'Auria. Statistical Approach for Deciding If Mussels (M. edulis) have been Collected from a Waterbody Polluted with Trace Metals. Environmental Science and Technology, Vol.17, p.576. 1983.

M. edulis, considered a sentinal organism for heavy metals,were analyzed by X-ray electron spectroscopy and statistically compared in two areas. Discusses the need to detect pollution effects and differentiate them from a reference population. Determines a means of resolving a "pollution signal'. Points out problems with analytic techniques/data/use in statistics. It notes that greater reliability is attainable if data from mussels has been pooled so result is more representative of population and has a function of reducing cost. XES procedure used for analyses. Mussels collected by hand from mid-litteral area.

Popham, J.D. and J.M. D'Auria. Mussels (M. edulis) as 'Point Source' Indicators of Trace Metal Pollution. Marine Pollution Bulletin, Vol. 11. p.261. 1980.

X-ray spectroscopy measurements of Pb, Cu and Zn in Mussels sampled at intervals of 1km and less (0.25) exhibited dramatic concentration variations. Mussels 30m from a Point Source exhibited background levels.Includes a plan of the Harbour North Shore with data and wharf details. XES procedure and analysis. Insitu temperature and salinity collected by YSI 33 SCT.

Rawn, A.M., J. Oliver and C.G. Hyde. Sewerage and Drainage of the Greater Vancouver Area,British Columbia.
A report to the Chairman and members Vancouver and Districts Joint Sewerage and Drainage Board. 1953.

A long range plan for the collection, control and treatment of sewerage and drainage in the Greater Vancouver Area including major sewers, pump statistics, treatment works and outfalls or other means of disposal to provide for a predictable future development of population and industry. Investigation and evaluation of methods for storm water drainage. Identifying the protection of shores and waters, inland surface and underground waters,the . placement and layout of facilities to minimize community impacts and provide cost estimates. The report recognizes the importance of environmental habitats in a general sense including aesthetic, recreational and utilitarian values.

Since 1953, the GVRD has carried out its work based on the Rawn Report.

Regan, L. Euphausia pacifica and other Euphausiids in the Coastal Waters of British Columbia: Relationships of Temperature, Salinity and Other Properties in the Field and Laboratory. PhD Thesis, UBC Vancouver, B.C. 1968.

In this study of abundance and distribution of four species of euphausiids all species were found to be useful biological indicators of oceanographic changes in Indian Arm. E. pacifica was most tolerant to local conditions and fluctuations of temperature and salinity particularly between 10m and the surface. Deeper populations were influenced by other regulatory factors in that adults were absent and nauplii restricted in distribution. In laboratory work specimens preferred "home" waters to "foreign" waters. Specimens also survived longer in "home" water. It was postulated that the properties unique to different waters and the euphausiids reaction to them were important in the abundance and distribution in Indian Arm and their migration and survival in the laboratory. Migration decreased with increased temperature and decreased salinity.

Reich, C.M. Burnaby Eastern Burrard Inlet Marine Park System Development Plan.
Report to: The Corporation of the District of Burnaby, 1975
By: Northwest Research Analysts, Vancouver, B.C.

A master plan including an overview of environmental resources, physical site characteristics recreation opportunities and demand is presented along with a plan. The overall development plan includes marina facilities, recreation core area and development concepts, their implementation stages, costs and management concepts. This report is a statement of Burnaby's interest in developing marine foreshore areas for passive and active recreation purposes (Plans included).

Water quality and surface water temperatures were within Provincial standards set for bathing beaches. Tidal currents ranged from 0.9 to 7 knots and maximum waves were predicted at 3.5 feet.

Reid, B.J., R.W.Deverall, P.M. Chapman and A.W. Maynard. Experimental Investigation into the Accumulation of Cadmium by the Polychaete Worm Capitella capitata and the Bivalve Macoma balthica. Report to: Institute of Ocean Sciences, Sidney, B.C. 1981 By: EVS Consultants Ltd. North Vancouver, B.C.

The bioavailability of sulphide-bound cadmium phases to the bivalve Macoma balthica and the polychaete Capitella capitita was determined. Sixty day laboratory experiments were conducted using 109 Cd and 115m Cd-labelled sediments from False Creek, B.C., under constant temperature and salinity conditions. Laboratory data were compared with measurements of background cadmium levels in selected False Creek biota. Measurable levels of 109 Cd in M. balthica were determined on day 60; similarly, release of 109 Cd to the overlying water was determined on day 60 of the experiment. Results of the sediment characterization and selective extraction suggested that cadmium sulphide phases were not available for uptake by biota due to their lack of solubility. Contrary to the laboratory experiments, measureable cadmium body burdens were detected in False Creek biota, suggesting that cadmium was present in an available form in this area. Highest body burdens were detected by Mytilus edulis and lowest levels were detected in C. capitata, suggesting that cadmium uptake is primarily from the water column, which is consistent with published information. Cadmium body burdens in False Creek biota were elevated in some areas, and the elevated levels were typical of polluted, industrial nearshore sites.

Roelofs, A.K. The Distribution of Diatoms in the Surface Sediments of British Columbia Inlets. PhD Thesis, UBC, Department of Botany, Vancouver, B.C. 1983.

The study examined diatom distribution in the surface sediments of ten southern B.C. inlets including Indian Arm and outer Burrard Inlet where five locations were sampled. A small group of species dominated most sites. Good correlation was found between sediment assemblages and phytoplankton dominants. Estuarine circulation did not appear to alter the spatial relationship of species in the water column to those in the sediments. Patterns of distribution could be related to inlet type, zonal and within inlet patterns. Analysis showed zonal correlation between dominant species in sediment and primary productivity, salinity and temperature in the surface waters.

Ronalds, I.F. Indian Arm Causeway, Vancouver Harbour, B.C. - Preliminary Study. Foundation of Canada Engineering Corp. Ltd., Report 1967. Fenco Vancouver, B.C.

An engineering report on the crossing of Indian Arm conducted because of the apparent combination of advantages at the time. The study includes proposed routes, general arrangements and dimensions and in this connection field reconnaissance and a seismic survey were carried out. Advantages and benefits are described as: improved safety and navigation, berthing,dredging and construction in the Harbour through reduced tidal currents from 6 to 2 knots; rail access to the northshore; a new highway access reducing existing loadings. The report suggests this project would not have an adverse effect on marine life or oceanography.

St. John, M.A. Food Resource Utilization, Digestive Rate and Daily Ration of Juvenile Chum Salmon (Onchorhynchus keta) in Burrard Inlet, B.C. B.Sc. Thesis, UBC, Department of Biology and Oceanography, Vancouver, B.C. 1984.

The study examined juvenile chum salmon and their use of zooplankton from Burrard Inlet near the Fisheries and Oceans West Vancouver Laboratory. Salmon were collected over 24 hours on May 6-7, 1983 by means of a 14.7m beach seine. Ten juveniles were collected at each sampling, measured and weighed and stomach weight taken, and fixed in 10% formaldehyde. Digestive tracts alone were also weighed. Weight ratios were then determined. At each time of sample three guts were examined, contents enumerated and identified. Zooplankton were also taken by means of a drift or ladder sampler.

Juvenile chum salmon were observed to use epibenthic or benthic communities of zooplankton in an opportunistic manner possibily allowing a broader food base, an advantage if one community does not supply enough food. Suggests hatchery releases should be controlled so as not to overload the system (resource) and to improve juvenile survival rate.

Shan, K.C. Systematic and Ecological Studies on Copepoda in Indian Arm, British Columbia. M.Sc. Thesis, UBC. Vancouver, B.C. 1982.

A study of the distribution and water properties relationship of 4 copepoda species which predominate Indian Arm. A systematic study is made and suggests on their taxonomy made. Life cycles and history are described for two of the species. Adult female and male of both Calanus sp. and Gaetanus armiger are demonstrated as inhabiting waters with different ranges of properties, juvenile Calanus sp. occurring in a range between male and female.

The investigation suggests there are two local forms of Calanus sp. The male and copepodid stages of G. armiger are described for the first time. The characters of Paraeuchaeta and Euchaeta are reviewed and comparative data from other locals considered inadequate. Calanus sp. brood twice each year in spring and late summer, G. armiger brooks once spring-summer. It is suggested the fjord may be subdivided into surface, intermediate and deep waters. Adult Calanus sp. females were found concentrating in 60-90m whereas males were collected from deep to intermediate depths. G. armiger were found in deeper water. Each consecutive stage may be more tolerant of the properties studied since depth distribution became greater as they aged.

Shim, J.H. Distribution and Taxonomy of Planktonic Marine Diatoms in the Strait of Georgia, B.C. PhD Thesis, UBC. Botany Department, Vancouver, B.C. 1976.

The primary objectives of this study were the identification and measurement of diatom genera and species making up the diatom communities in the plankton of the Strait of Georgia/Juan de Fuca Strait System, and factors influencing their distributional ecology.

The results indicate that the total abundances of diatom communities and the species population changes were strongly correlated with season and location parameters (in which the exact regulating parameters are unknown) as well as specific nutrient concentrations and hydrographic factors. Major influences on population distributions varied with the principal species responsible for the observed species successions.

Two distinct distributional patterns in total diatom standing crop were observed in the study area. Maximum standing crops observed during spring and/or summer did not usually result in the depletion of critical nutrients (such as silicate and nitrate).

The distribution of recurrent groups of diatoms was related primarily to the physical conditions. Within the study area there was some seasonal consistency in the composition of the species groups. There were radical changes in community structure with different seasons, as was expected. Two hundred and nineteen taxa were identified including 68 new records.

Sirois, J. Brief Presented to the Stanley Park Master Plan Team.
Report to: Vancouver Parks Board, Stanley Park Master Plan Team 1984.
By: Canadian Wildlife Service, Delta, B.C.

The brief provides some information on the locations and times of the year where wildlife can be observed and suggests ways to enhance both wildlife habitat and the visitor opportunities and understanding. Ten (10) major wildlife habitats exist and are discussed in the context of birds, mammals, amphibians, fish, invertebrates and vegetation.

Stewart, G. Fish Monitoring Studies in the Seymour River Estuary During 1984.
Report to: Canadian National Railways, Surrey, B.C. 1985.
By: Envirocon Ltd., Vancouver, B.C.

This study monitors the fishery effects of the C.N. rail double tracking on the north shore of Second Narrows, where existing habitat was reduced and habitat compensation made in a nearby area. Concurrent assessments are and will be made over three years to evaluate and possibly modify programs/intensity of effort of the "replacement" program. This work identifies the lost area and replacement habitats along with two control sites, one on either side of the Seymour estuary. Salmonid populations were sampled by means of Beach seining and approximately 10% of those caught were kept for gut analysis. In general the data showed salmon and trout densities to be low in both the replacement and control areas (.01-.06 fish/m 2). For coarse fish the densivy was .2 to .7 fish/m2. In summary, it is concluded that the replacement habitat provides suitable bearing habitat for juvenile salmon and trout. Beach seining data details the catch by species and number over time and it is interesting to note a greater use by coarse fish at the replacement site (3 times) than the control.

The methods used in this work are described in insufficient detail.

Stich, H.F., B.P. Dunn,and A.B. Acton,F. Yamasaki, K. Oishi and T. Harada. The Distribution of Benzo (a) Pyrene in Bottom Sediments and of Neoplasms in Bottom-Dwelling Flatfish Species of the Pacific and Atlantic Oceans, North, China, Bering and Beaufort Seas, and the Sea of Okhotsk. Environmental Protection Agency Report EPA-600/9-82-013, July, 1982.

Symposium: Carcinogenic Polynuclear Aromatic Hydrocarbons in the Marine Environment. N.L.Richards and B.L. Jasksar, Eds. Gulf Breeze, Florida. USA.

Human and animal populations are continuously exposed to hundreds of carcinogenic, mutagenic, clastogenic and recombinogenic agents. These chamicals can interact, leading to extremely large numbers of possible permutations and combinations that can either enhance or reduce their genotoxic or carcinogenic activity. It is impossible to examine all these interactions for economic and logistic reasons. Thus, other approaches to identify high risk areas must be sought. In this paper, they explore the feasibility of using naturally occurring animal populations as an early warning system to detect carcinogenmutagen contamination of a particular environment. The basic idea is simple. In animals, tumors may appear within months, whereas in man the latency period may well exceed 16 or more years. Thus by screening indigenous animal populations for benign and malignant neoplasms, we should be able to recognize carcinogen-contaminated areas long before they adversely affect man. There is no shortage of examples of making use of "built-in" organisms to detect agents with a general toxic action. However, the practicability of a naturally occurring indicator organism for chemical carcinogens or mutagens is still unproven. In this paper, they critically review the difficulties encountered in an attempt to use neoplasms of bottom-dwelling fish populations as a possible indicator for man-made or naturally occurring contamination of shallow estuarine nursery grounds that might at some time be developed for intensive aquacultural usage.

Stich, H.F., A.B. Acton, B.P. Dunn, K. Oishi, F. Yamazaki, T. Harada, G. Peters and N. Peters. Geographic Variations in Tumor Prevalence Among Marine Fish Populations. Int. J. Cancer: 20780-791, 1977.

A global epidemiological study on the frequency of skin papillomas among various flatfish species (Pleuronectids), eels and the virus induced lymphocystis has revealed particular distribution patterns. Flatfish populations were sampled by otter trawl and sediments were collected by mechanical grab.

Histopathologic diagnosis and estimates of benzo(a)pyrene were carried out for which methods are outlined. Behavioural aspects of the species are discussed in relation to their suitability for geographical analysis. In Vancouver within a four year period tumor prevalence in the English sole has not varied significantly, nor has there been a major change in the Sand Sole. Since yearly prevalence peaks occur, sampling over 3-4 months is required. Local variations are great such that within 20 miles the prevalence can range from 0.01 to 58% within a species. These local variations are usually related to man-made activity where prevalence is higher. Lymphocystis appears to follow the reverse pattern to papillomas such that it is absent in the Vancouver area whereas this same area exhibits one of the greatest global prevalences for papillomas. B(a)P exhibits no simple correlation with papillomas since areas with low B(a)P may exhibit high papilloma prevalence. Discussion follows on epidemiological information on man for comparison and identifying areas of tumor risk and its relation to other environmental factors and the value of fish as a tool in this work.

Stockner, J.G. and D.D. Cliff. Phytoplankton Ecology of Vancouver Harbour. Department of Fisheries and Oceans, West Vancouver, B.C. Jour. Fish.Res. Bd. Canada, V.36(1) 1979.

Phytoplankton production and distribution were examined over a 2-year period in the Burrard Inlet system, which includes a true fiord (Indian Arm), a shallow blind inlet (Port Moody Arm), and a turbulent narrows region that is contiguous to the Port of Vancouver. Greatest annual production occurred in Port Moody Arm with a mean of 532 gC.m-2.yr-1 while the lowest values were in Indian Arm and the Narrows region, averaging about 260 gC.m-2.yr-1. Nitrate and zooplankton grazing were the main factors limiting phytoplankton production in Indian Arm, while flushing and poor light conditions influenced phytoplankton growth in the Narrows and outer Burrard Inlet. Most of the discharges of domestic and industrial wastes have been diverted to the Fraser River, and Vancouver Harbour can be considered relatively clean and pollution-free because of strong tidal mixing and seaward flushing. The only sign of eutrophication in the inlet is in Port Moody Arm where sufficient nutrients from sewage discharges and a relatively stable mixed-layer depth create near optimal conditions for phytoplankton growth. Daily production here is among the highest recorded in the literature for Pacific coastal marine waters.

Stukas, V.J. and C.S. Wong. Accurate and Precise Analysis of Trace Levels of Cu, Cd, Pb, Zn, Fe and Ni in Sea Water by Isotope Dilution Mass Spectrometry. Plenum Publishing Corp. 1983.
From: Trace Metals in Sea Water, Edited by Wong, Boyle, Burland, Burton and Goldberg.

Accurate and precise determinations of natural levels of trace metals in sea water are highly reliant upon the size and variability of the analytical blank, the method for determining the yield, and, to a lesser extent, the inherent precision of the instrument used. Thermal source, isotope dilution mass spectrometry together with ultra-clean room techniques were successfully used in the determinations of Cu, Cd, Pb, Zn, Ni and Fe in sea water. Multi-element analyses were performed in a single experiment owing to the differing release with filament current for each element. A single Re filament loaded with a substrate of silica gel and phosphoric acid gave high precision (0.1% to 0.5%) for the determination of a single ratio, and allowed low detection limits (from 0.02 pmol Cd to 0.07 pmol Fe). Yields were accurately and uniquely determined in the same sample by the addition of two isotopically enriched spikes, one before, and one after an extraction. Blanks were assesed as the summation of individual contributions determined in separate experiments prior to sample analysis. Simply obtaining one value for a total blank contribution can be misleading and can generate larger errors. Rigorous clean room procedures allowed very low blanks. Comparison of the sea water results with FAA and ASV methods indicated that for these metals, the IDMS approach was the most precise and the most accurate.

Stukas, V.J. and C.S. Wong. Stable Lead Isotopes as a Tracer in Coastal Waters. Institute of Ocean Sciences, Sidney, B.C. Science, V.211, p.1424-1427, 1981.

The natural abundances of the stable isotopes of lead are used to identify natural and industrial sources of lead in the coastal waters of British Columbia, Canada. The 206Pb/207Pb ratios, used to characterize the lead source, had values of approx. 1.24 for coastal oceanic water, approx. 1.22 for fjord waters receiving lead from mine tailings, and approx. 1.163 for waters near urban centers. The lead concentration data are in agreement with presently accepted seawater values.

Data from English Bay (1978) exhibited urban characteristics where total Pb is 170 plus or minus 2 ug/kg and dissolved Pb is 100 plus or minus 2 and 206 Pb/207 Pb ratio was 1.1634.

Stump, I.G., J. Kearney, J. D'Auria and J. Popham. Monitoring Trace Elements in the Mussel Mytilus edulis using X-ray Energy Spectroscopy. Marine Pollution Bulletin, Vol.10, No. 9 1979.

XES provided rapid, multi-elemental, quantititative analyses of mussels for Mn, Fe, Cu, Zn, As, Se and Pb in gills and visera. The usefulness of the technique is discussed. Samples collected from north and south shores of Burrard Inlet and Indian Arm. The data suggests x-ray work should be followed by quantitative analyses. The procedure is good for general monitoring in known polluted areas. Methodology details sampling and analytical procedures.

Swain, L.G. Storm water Monitoring of the Residential Catchment Area. Vancouver, B.C. Aquatic Studies Branch, B.C. Ministry of Environment, 1982.

Reports on stormwater in the Rupert-Rosemont (S. Vancouver) area detailing 20 storm events, flows, constituents,and duration. Site is approx 13 ha. with average hourly flow rates of 23 m3-166 m3 lasting 2-15 hours (median of 6.5 hours). Report examines literature, the site, rainfall, air quality, infiltration and runoff, storm runoff and interprets results and identifies loadings contributed by urban runoff.

Tabata, S. A Brief Oceanographic Description of the Waters of Burrard Inlet and Indian Arm. In: The Burrard Inlet-Howe Sound Area: Preliminary Description of the Existing Environmental Conditions. Department of Environment, 1973. Marine Sciences Directorate, Department of Environment.

The report provides a physiographic description of the entire inlet system and describes the main fresh water sources and their drainages and flow composition and their seasonality. Heat flow and dynamics are described along with tides and tidal current characteristics and mixing processes. The chemical and physical characteristics of the water are discussed including salinity, temperature, oxygen, colour and turbidity and their season distributions in the inlets. Water quality in terms of recreational values are presented identifying needs for improvement and noting the domestic waste originating from harbour vessels.

Taccogna, G. Salmon Enhancement Program Third Quarterly Report. Fisheries and Oceans, Field Office, New Westminster, B.C. 1985.

A summary of Fisheries and Oceans activities improving fishery stocks in a number of streams in the Lower Mainland including Burrard Inlet and Indian Arm streams. Mossom Co. has an incubation and rearing facility for chum and coho from which 60 adults have returned. Noons Creek has a facility for coho to which a 4-500 return was observed. Nelson and Rogers Creeks have chum incubation boxes starting in 1984. Maplewood and McCartney Creeks have two streamside incubators and a few, and up to 100 adults ,respectively,were noted to have returned. Myrtle Creek work has been cancelled and a tributary of Wagg Creek is being examined. Habitat work is ongoing on many of the streams. McKay Creek had a coho return of about 100. Hastings Creek has had habitat improvement. Richards Creek had 20-30 coho spawners in 1984.

The report notes a great deal of enthusiasm and interest for these projects. Habitat improvement is still a key aspect to be dealt with. A note: total 79-83 average recorded escapement for Burrard Inlet and Indian Arm is 37,864 coho.

Tanner, C.D. The Taxonomy and Morphological Variation of Distromatic Ulvaceous Algae (Chlorophyta) from the Northeast Pacific. Ph.D. Thesis, UBC, Botany Department, Vancouver, B.C., 1979.

This work evaluates the generic and specific taxonomic criteria for Ulva, noting the large degree of morphological and anatomical variation some of which is due to environmental differences. Samples from Vancouver (Ulva fenestrata) had a very different form compared to those from the west coast. Studies were made of reproduction, development and inter specific hybridization potential. Temperatures for development ranged from 7-19 degree C. A cytological study examined specific chromosomal patterns determining all were similar. Locally samples were taken from Brockton Point, Vancouver.

Tanner, G. et al 1973. A Study on Wastewater Characteristics of Greater Vancouver Sewage Treatment Plants and Major Sewers. Environmental Protection Service, Report EPS5-PR-73-11.

The study documents the toxicity of heavy metals and chemical contaminants of Greater Vancouver sewage at Lions Gate and Iona island Plants. Lions Gate data taken over 1 year in 1971. Incoming wastewater is primarily domestic with some industrial waste. Storm water is separate and direct to Burrard Inlet. Primary treatment of wastes and digested sludge discharge.

All sampling and analytical procedures by Standard Methods 12th Ed. Plan of Sampling Points at Plants and in sewers. Lions Gate influent/effulent analysis - metals Cu, Zn, Cr, Ni, Cd, Pb and Fe.

Taylor, F.J.R. and J. Mayer (Unpublished). Electron Microscopy of Nannoplankton Communities (1971 - contin.). UBC, Institute of Oceanography, Vancouver, B.C. 1977. NRCC Laboratory and Field Projects.

The discovery of a lysogenic virus within cells of Micromona pusilla from the Strait of Georgia has led to a study of ultrastructural aspects of this infection (mode of entry, lysis, purification of the virus, spectrum of infectivity) for a phD thesis. This virus is apparently similar to that found by Pienaar and R. E. Norris at Friday Harbour.

Thomas, A.C. The Effect of Tidal Transport on the Zooplankton Population of a Local Inlet. M.Sc. Thesis, UBC, Department of Oceanography and Zoology, Vancouver, B.C. 1982.

Four copepod species sampled in Indian Arm, Vancouver Harbour and Georgia Strait over 14 months using Clarke-Bumpus, SCOR and 1m conical nets identified tidal exchange to be the dominant transport process. The study examined the Indian Arm populations as effected by life histories and tidal exchange. Corycaeus angelicus occurs surface to mid depth, predominately in Vancouver Harbour, peaking in the fall and remaining high throughout the winter. Euchaeta japonica exhibits ontogenetic depth preferences, juvenile deeper, adults over the water column. It reproduces through the year in Indian Arm and Strait of Georgia. During summer the Indian Arm population is isolated. Metridia pacifica is transported at all times of the year, moving more at night due to its strong diel migration. Eucalanus bungii, an ontogenetic migrator, spring surface spawner and is transported only in summer while in surface water. This can account for the overwintering population. The data suggests they do not reproduce in Indian Arm. Zooplankton community changes occur in association with hydrographic properties and not necessarily tidal movement. Effects very from species to species.

Thompson, J.A.J. and D.W. Paton (Unpublished) Heavy Metals in Benthic Organisms from a Marine Dump Site. Department of Fisheries and the Environment, and Institute of Ocean Sciences, Sidney, B.C. 1977

In 1976, as part of a study in support of the Canadian Ocean dumping legislation, a comprehensive study of a long-used Port Grey dump site in the strait of Georgia off Vancouver, B.C. was undertaken. Part of this study centered around a sampling of benthos from the area and subsequent determination of Cu, Pb, Cr, Cd and Zn in one selected species. The one chosen was the holothurian, Molpadia intermedia, because of its relative abundance, size and distribution. After the analysis of this initial sampling it was concluded that data were insufficient, owing to sample sizes and numbers.

A second, more intensive sampling was made in July 1977, with at least 5 specimens of M. intermedia obtained at each of 19 test and 2 control stations.Analysis of these samples has yet to commence. Data may indicate whether the influx of metal-laden sediments dredged from Vancouver harbour has had a measurable effect upon levels in this particular animal. From this some conclusions as to effects upon benthos in general may be drawn.

Thomson, R.E. Oceanography of the British Columbia Coast. Canadian Special Publication of Fisheries and Aquatic Sciences, No. 56 p.291. Department of Fisheries and Oceans, Ottawa 1981.

An overview of B.C. oceanographic features including historical and current perspectives,general physical oceanography, ocean waves and oceanography of inshore and offshore waters. Refers to charting, currents, physiography, rainfall, runoff, salinity, temperature, tides, waves and winds in Burrard Inlet and Indian Arm.

Timascheff, M. Assessment Study Potential for Shore Reception Facilities - Federal Small Craft Harbours.
Report to: Department of Fisheries and Environment, 1979.
By: Fenco Consultants

The study examines all Federal facilities located on tidal waters, rivers and lakes in the Interior of British Columbia, assessing each from boating utilization aspects and its strategic value as a sewage reception point in a skeleton network of such facilities to be developed for this Region.

To simplify the analysis of boating activities, only commercial fishing boats and pleasure craft have been considered in the study. Other commercial vessels such as tugs, Coast Guard, barges, transport craft, etc.have not been included in the statistics, nor have live-aboards although they are discussed.

A review and analysis of available data and development of a basic network of reception facilities at Federal small craft harbours in the Pacific Region, selecting sites, size and type of system, assessing its cost and recommending a program of implementation in accordance with priorities established in the course of the study on the basis of greatest effectiveness for each dollar spent.

Trites, R.W. 1955. A Study of the Oceanographic Structure in British Columbia Inlets and some of the Determining Factors. PhD Thesis, UBC,Vancouver,B.C.

A general overview of inlet oceanographic structure examining,through a a mathematical model, fresh water mixing and entrainment to determine a diffusion coefficient which is nearly constant in inlet upper reaches, increasing rapidly toward the mouth in the brackish layer. A technique determining total fresh water inflow (precipitation and river flow data base) was developed showing significant input from inlet sides. Results are analyzed for relationship between inlet dimension and mixing intensity. The mean seaward movement of the brackish layer based on heat budget is determined and this method is also used to determine the depth from which salt water is entrained.

Tusnady, P. Land Reclamation and Access for the Burrard Inlet Shore Development.
Report for: The Corporation of the District of Burnaby, Burnaby, B.C.
By: N.D. Lea and Associates ltd., 1973.

This technical feasibility report studies the ways of land reclamation for the Burrard Inlet shoreline park development in Burnaby. Modes of access and provision of parking for park visitors are also discussed in the report. Land reclamation was determined by land fill (contract) or free fill from construction sites. The report provides a description of Barnet Beach, Texaco to Bestwood to Gulf Beach. Environment aspects of currents, waves,and intertidal ecology are addressed along with traffic and transportation elements (See Birtwell 1973 for intertidal data).

Urhahn, H.J. Assessment of a Proposal to Locate a Ready Mix Plant in the Maplewood Area of North Vancouver.
Report to: Rempel Brothers, 1984
By: Tera Environmental Consultants Ltd., Vancouver, B.C.

An assessment of the Rempel Ready Mix Plant for potential adverse impact on existing natural resources. Concludes that these are no significant impacts to Air, Land or Water resources. Adverse impacts and mitigation measures are outlined and for wash water
1. a coarse granular percolation area is suggested to absorb water and control solids from procedure, or
2. redirection to the water recycling system.

Vaudry, A. and J. Laud. A Migratory Bird Survey of the Maplewood Mudflats and Maplewood Area October 1972-May 1973. Canadian Wildlife Service, Vancouver, B.C. (Unpublished), 1973.

A survey of migrating bird use in Burrard Inlet was carried out in late 1972 as part of a program to provide baseline information for the Burrard-Inlet Howe Sound Preliminary environmental study. The survey examined the frequency and distribution of migratory birds in Maplewood Mudflats and Port Moody areas. The report examines species by general group and their relative abundances over time in the area. Total numbers and species observed are listed.

Waldichuk, M. Sewage Pollution in British Columbia in Perspective. Fisheries and Oceans Canada, West Vancouver Laboratory, West Vancouver, B.C. Workshop on Municipal, Marine Discharges, Sheraton Plaza Hotel, Vancouver, B.C. Feb. 1984.

The historical development of sewage disposal, in the context of its effect on the environment, is reviewed briefly, starting with unconfined land disposal, then the outdoor privy, through the septic tank and tile field disposal system, and finally, the various forms of municipal sewage collection, treatment and disposal into fresh and marine waters. The characteristics of sewage, ie...., solids, micro-organisms, dissolved organic constituents, nutrients and metals, that affect the aquatic environment and ecosystem are discussed. A brief review is given of the three levels of treatment: primary, secondary and tertiary. Then four case studies of sewage treatment and ocean disposal in coastal areas of British Columbia (Greater Vancouver, Greater Victoria, Comox-Courtenay, and Nanaimo) are reviewed in some detail. Other areas are discussed with respect to specific problems. The perceived problems are largely associated with the impact of sewage bacteria and viruses on shellfish and the potential hazard to consumers. Closure of shellfish beds to harvesting, because of sewage pollution, has had a major economic impact. An unanticipated effect of effluent disposal from the Iona Island Sewage Treatment Plant has been depressed oxygen in waters overlying Sturgeon Bank and debilitation of fish exposed to these waters, particularly during the warm months of summer.

Waldichuk, M. Publications and Reports Pertaining to False Creek, the Point Grey Dumpsite and Contiguous Waters. Unpublished Bibliography, Fisheries and Oceans, West Vancouver, B.C. 1983.

Waldichuk, M. Currents from Aerial Photography in Coastal Pollution Studies. Third International Conference on Water Pollution Research,Section III, Paper 13. 1966. Water Pollution Control Federation, Washington, D.C.

The paper describes how aerial photography was applied for investigating coastal currents in the vicinity of Vancouver and Victoria, B.C. Aerial photos were evaluated and comparative analysis with historic oceanographic data was made. Characteristics of tracers and targets for aerial photography are presented. From these data the dispersion of sewage at specific locations was predicted. The system was found to be rapid, reliable and provided synoptic data on surface currents.

Waldichuk, M. Water Exchange in Port Moody, British Columbia and its effect on Waste Disposal. Fisheries Research Board of Canada, Biological Station, Nanaimo, B.C. J.Fish. Res. Bd. Canada, 22(3) 1965.

Port Moody is a comparatively shallow appendage of the Burrard Inlet-Indian Arm System on the southern coast of British Columbia. Although highly stratified, it receives little direct runoff, its oceanography being strongly influenced by the properties of contiguous waters. Wastes from varous industries surrounding the harbour have altered the natural characteristics and created mildly polluted conditions. Exchange occurs mainly by turbulent diffusion and advection arising out of tidal action. From current measurements at the entrance to Port Moody, taken on a number of surveys since 1957, net currents were evaluated for periods of a tidal day. A layer of no net motion near 10m corresponded to a dissolved oxygen minimum. Volume transport through different layers of the harbour was estimated from current data and compared with transport derived from predicted tide heights. The ratios of predicted to measured transport averaged 0.77 on both flood and ebb but ranged from 0.71 to 1.01 on the flood and from 0.55 to 1.00 on the ebb. Estimates of flushing rates, based on exchange ratios in different layers of Port Moody, show that for a survey in September 1962 slightly more than 50% of an introduced contaminant was removed from the upper 12.5m layer, 83% from the 12.5-17.5m layer, and 74% from the near bottomlayer, in one tidal day.

Waldichuk, M. Physical Oceanography of the Strait of Georgia, B.C. Journal of the Fisheries Research Board of Canada, 14(3), pp.321-486, 1957.

A descriptive and quantitative analysis of the physical oceanography of the Strait of Georgia showing it is largely affected by runoff, inflowing seawater, tidal mixing at the sills, and meteorological conditions. Three distinctive water masses exist in the Strait of Georgia-Juan de Fuca Strait system:
1. The brackish upper layer in the Strait of Georgia, varying from 5 to 25 0/00 in salinity, is influenced by the large runoff.
2. The high-salinity, inflowing deep water of Juan de Fuca Strait, at about 33.8 0/00, is of oceanic origin.
3. The mixture of (1) and (2), forming the surface outflowing water in Juan de Fuca Strait and the deep inflowing water in the Strait of Georgia, is maintained at about 31.0 0/00.

Seasonal variations of runoff and inflowing sea water subject the system to large seasonal changes at the extremities where these variables are most pronounced. Total runoff, on a monthly average, varies from about 1.5 x 10 3 m.3/sec. in February to 13 x 10 3 m.3/sec. in June. Salinity of inflowing water in Juan de Fuca Strait ranges only from about 33.5 0/00 in February to 34.0 0/00 in August. But, because of the large volumes of water involved in this inflow, the effects on the overall salinity of the Strait of Georgia can be very significant. The peak in runoff is followed closely by the peak in salinity of the source water, so that there is a compensating effect in the region of mixing. Thus the deep water in the strait of Georgia undergoes only small seasonal salinity changes.

Formation of Bottom Water, of about 7 degree C. and 31.1 0/00, occurs in late autumn when surface cooling sets in. A warm Intermediate Water, of about 9 degrees C. and 31.2 0/00, penetrates into the basin in late summer. Replacement of Deep water occurs partially by displacement and partially by turbulence. Temperatures can be used as a tracer to follow the flushing process in the Deep Water.

Density of the Surface Water in the Strait of Georgia is governed mainly by salinity. However, temperatures can be significant in altering the density of the deep, inflowing water. Also, in certain instances, severe winter cooling of the vertically mixed water in the Northern Strait can introduce instability. During some cold winters, a code Intermediate Water of northern origin at about 29.5 0/00 and 6 degrees C. is formed by this process.

The various water masses in the Strait of Georgia-Juan de Fuca Strait system can be characterizedquite well by T-S diagrams. Juan de Fuca water is identified by T-S relationships forming a wedge-shaped envelope. These T-S curves undergo a seasonal rotation pivoted near the low-temperature end. The Strait of Georgia T-S curves show a wider variability because of the extreme surface influences. Mixing of the two source water masses occurs across the surfaces at the connecting channels.

Waldichuk, M., J.R. Markert and J.H. Meikle. Fraser River Estuary, Burrard Inlet, Howe Sound and Malaspina Strait. Physical and Chemical Oceanographic Data. 1957-1966. Vol. II September, 1962 - July, 1966. FRBC M.R.S. No. 939. Biological Station, Nanaimo, 1968

This report identified the importance of waters along Lower Mainland. Current measurements in Burrard Inlet (Port Moody), Phenol determinations, turbidity, water transparency, salinity, dissolved oxygen, pH, alkalinity and temperature from surface to 300m. Sampling and analytical procedures followed Strickland and Parsons, 1965. Salinity by conductivity meter Aussi (CSIRO) and Fjarlie Bottle/Reversing Thermometers. Current - Std. Ekman Current Meter and CBI drogue. Relevant Stations include 15, 16, 17, 17A,B, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 and C-1 covering Burrard Inlet to Port Moody (27, 28 and 29 - Indian Arm). Current data at 30A - Admiralty Point at the junction of Burrard Inlet and Indian Arm.

Walmsley, M.E. Shoreline Characteristics of the Greater Vancouver Area. (A Plan, 1:50,000). Environment Canada, Lands Directorate, Vancouver, B.C. 1976.

A plan subdividing the littoral habitat of the Greater Vancovuer area (Burrard Inlet/Indian Arm) into physical habitat types based on shoreline characteristics (mud, pebble, gravel, cobble, bed rock,and industrial).

Ward, A.B. and D.L. Sullivan. A Review of Existing and Historical Ocean Dumpsites in the Pacific Region. Regional Program Report: 80-5. 1980. Environmental Protection Service, Environment Canada, Pacific Region.

This report records the present and historical use of dumpsites in B.C. Burrard Inlet and False Creek have long been used as spoil disposal sites largely for NHB projects improving shipping facilities. Boulder Island and Raccoon Island in Indian Arm are also known dumpsites which received spoil in the past from shoreline works.

Prior to the implementation of use ODC ACT in 1976 records are poor except where NHB projects were involved. All dumpsites in this area are now on the inactive list.

The report discusses the dumpsites, dredging and dumping activities, equipment, sources of material and Ocean Dumping Control Act administration.

Webster, I. Dye Discharge Study of English Bay.
Report to: Environmental Protection Service, Environment Canada, 1976.
By: Dobrocky-Seatech Ltd.

A study on currents in English Bay to provide oceanographic support for a study to assess the pollution potential of ships anchored in the NHB anchorages. Dispersion rates of dye from a mooring buoy were determined but overall current patterns were not deduced. Drogues were employed to identify surface currents and a current meter was moored at the buoy. In all studies the integrated concentration decreased further from the dye discharge, probably due to dye entrainment in lower water. Winds, tide, topography and density complex patterns in the bay. Surface currents in particular are effected by winds and in the absence of wind the current direction is mainly east. Dilution rates are likely less in the summer partially due to increased stratification.

Whitfield, P.H. Seasonal Changes in Hydrographic and Chemical Properties of Indian Arm and their Effect on the Calanoid Copepod Euchaeta japonica. M.Sc. Thesis, UBC, Department of Zoology and Institute of Oceanography, Vancouver, B.C. 1974.

This study examines seasonal changes in the relationship between a test organism and changes in the hydrographic and chemical properties of Indian Arm, a coastal fjord including manganese, copper, zinc, cadnium and nickel. There is a close relationship between changes in the hydrographic properties of the water and changes in the metal complexing ability of water in the inlet, as determined with the test organism.

The relationship between the organism and the availability of metals changes with time; the complexing ability of natural water increases at the time of the major intrusion of water from the Strait of Georgia into Indian Arm, and then decreases. The addition of a variety of metals under experimental condituions affects the relationship between the organism and the complexing ability of the water.

Additional studies examine the effect of material extracted from sediment samples on the toxic effect of copper enrichment. The ability of the extracted material to reduce the toxic effect changes and is related to the seasonal productivity in the surface waters of the inlet.

Whitfield, P.H. and A.G. Lewis. Control of the Biological Availability of Trace Metals to a Calanoid Copepod in a Coastal Fjord. Estuarine and Coastal Marine Science ( ) 4;255-266, 1976

Organic material present in natural waters and in sediments was found to act in a manner which alters the availability of trace metals to the pre-feeding stages of a calanoid copepod (Euchaeta japonica Marukawa). In the laboratory, survival of the organism was found to decrease with a decrease in the amount of u.v. photo-exidizable material. Replacement of the material with a known chelating agent (ethylenediaminetetraacetic acid; EDTA) increased survival. Comparison of survival in untreated water with that in different EDTA concentrations provided an EDTA equivalent value which was used to indicate the natural complexing ability of the water. An EDTA equivalent value was also obtained for saltwater extracts of bottom sediments.

Examination of a coastal fjord over a year indicates that the natural complexing ability of the deep water increases after a major intrusion of deep water and decreases with increasing residence time of the water. In contrast, the complexing ability of saltwater extractable material in bottom sediments appears to be dependent upon nearsurface productivity.

Wiegand, R.C. Observations of Small Scale Distribution of Chlorophyll and Related Physical Parameters in British Columbia Coastal Waters M.Sc. Thesis, UBC, Department of Physics and Institute of Oceanography, Vancouver, B.C., 1976.

In the spring of 1973 continuous horizontal measurements were made of temperature, salinity, oxygen and chlorophyll a in British Columbia coastal waters including Indian Arm, south of Croker Island at 16 locations. The sampling procedure involved a towed pumping system and on-board instrumentation.

An effort is made to describe the distributions of the measured parameters with particular emphasis on the smaller scales, less than 250 m. To this end, techniques of power spectral analysis were utilized to examine the data.

Results show that there is variability in the nature of the distributions and that the relatedness of the parameters is not consistent, but that on average different experiments show similarities. It appears that to a large extent the distribution of chlorophyll a' in an estuarine environment is related to physical transport processes.

Wilson, H., F.R. Bunnell, D.L. MacKay and G.W. Carlisle. Consolidation of Amendments to the Rawn Report on Sewerage and Drainage of the Greater Vancouver Area, B.C. and Including Plans. Greater Vancouver Sewerage and Drainage District. 1970.

An update of the Rawn report to meet the changing needs of the GVS and DD. In summary the report deals with four sewerage areas: North Shore, Vancouver, Richmond-Delta and Fraser. Emphasis is on the placement of interceptors to collect waste water and divert it to Iona and Lions Gate plants including serving all of the north shore and diverting sewage from Brockton Point and other outfalls into Vancovuer Harbour and Burrard Inlet.

Wilson, R.G., J.B. Mills and E.P. Wituschek. 1984. A Report on the Assessment of Photo-chemical Oxidants in the Lower Mainland. Queen's Printer for British Columbia, Victoria. Joint Province, GVRD, Federal Paper.

The report states "it is likely that exposure to oxidant pollution has profound and long lasting effects on trees and natural eco systems." Significant effect on health and materials in urban area (rubber, dyes and textiles) identifies oxidants of organic species such as ketones, aldehydes, peroxyacetylnitrate and peroxy compounds. Ozone most abundant oxidant. Lower Mainland levels noted. Eastern Burrard Inlet most affected area. (Plan) identifies emission sources (Vehicles, refinery, gas marketing) and notes the miss fueling of cars. Discusses dispersion model, monitoring, impact studies, control assessments, plants (L.T.). No reference to aquatic effects.

Wiltens, J. and W. Vidover (Unpublished) Photosynthetic and Ultra structural Aspects of Desiccation Tolerance in Intertidal Algae. (1974 - Cont.) Simon Fraser University, Biological Sciences Department, Burnaby, B.C. 1977. NRCC Laboratory and Field Projects ongoing.

Many higher intertidal region algae are highly resistant to extended periods of desiccation, while lower- or sub-tidal algae tend to show little tolerance even to mild water loss. The ecological necessity for desiccation tolerance by plants frequently emersed is obvious; however, the physiological and structural resistance features are not well understood.

Using chlorophyll `a' fluorescence induction as an indicator, partial reactions of photosynthesis were progressively inactivated with desiccation in both species. Rehydration of tolerant plants resulted in a rapid reactivation even after all photosynthetic activity ceased; sensitive plants recovered only from the earliest stages of inactivation.

Ultrastructural studies showed both similarities and differences in desiccation effects as follows:

1. Plasmolysis was minimal to tolerant plants, which tend to have small vacuoles;
2. Drying can result in extensive cytoplasmic vesicle formation in sensitive and tolerant forms, which often correlates with the disappearance of endoplasmic reticulum and dictyosomes; and cellular disintegration, reversible only in tolerant algae, accompanies rehydration of lethally dried sensitive plants;
3. Sensitive plant mitochondrial cristae lose their staining properties; tolerant plant cristae does not;
4. Drying often causes rupture of the chloroplast envelope and mitochondrial disruption in sensitive plants and;
5. In sensitive plants only, the nuclear membrane is frequently disrupted and the nuclear material may appear condensed.

Tolerance of intertidal algae to desiccation is indicated by the extent to which photosynthetic activity, as determined by chlorophyll a fluorenscence induction, is reconstituted. At the ultrastructural level, tolerance is reflected by resistance to membrane or organellar disruption and a capacity to recover from cytoplasmic vesiculation

Wong, C.S. and R.W. MacDonald (Unpublished). Trace Metals in the Marine Environment. Department of Fisheries and the Environment and Institute of Ocean Sciences, Sidney, B.C. 1977.

The objectives of this project are to:

1. Understand the origins (natural and anthropogenic), pathways, fate and chemical form of physiologically important trace metals in the marine environment, in particular lead, mercury, cadmium, zinc and copper, using FAA, GC and MS instrumentation and clean-room techniques; and
2. Study the recent geochemical and anthropogenic records in the marine environment using the PB-210 dating technique.

Woodhouse, C.D. A Study of the Ecological Relationships and Taxonomic Status of Two Species of the Genus Calanus (Crustacea: Copepoda), Ph.D Thesis, UBC, Vancouver, B.C. 1971.

The study identified Large and Small Forms distribution at several locations including Indian Arm. The Large Form was generally associated with the cooler more saline deep water whereas the latter occurred at shallow depths. Population overlap occurred only with Large Form females rising to shallow depths. Data showed different breeding times for both forms and on the basis of morphology the Large Form appeared to be Calanus glacialis and the Small Form C. pacificus californicus. Differences in types of water and yearly cycles appear to maintain species integrity. They are Allopatric with respect to the water column in Indian Arm.

Wu, R.S.S. and C.D. Levings. Energy Flow and Population Dynamics of the Barnacle Balanus glandala. Marine Biology 54,83-89, 1979.

The energetics and population dynamics of a barnacle (Balanus glandula Darwin) population in British Columbia, Canada, were studied. Consumption, energy flow, production and mortality were 6844.6, 6667.0, 2896.5 and 2522.8 Kcal m-2 year-1, respectively. These energy flow and production values are among the highest for animal populations reported, and therefore strongly suggest the functional importance of B. glandula in littoral systems. The young age groups of the first-year settlements were most important in contributing to the energy flow, production and reproduction of the entire population. Most of the assimilated energy in the older age groups was used in respiration.