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SCIENCE REVIEW

1990/91

Fisheries and Oceans Pêches et Océans

Canada

INTRODUCTION

A full spectrum of science activities was carried out at the Pacific Biological Station (PBS), Nanaimo, the Institute of Ocean Sciences (IOS), Sidney, the West Vancouver Laboratory (WVL); and satellite facilities located at Cultus Lake, Vancouver and elsewhere. Studies in support of the Department of Fisheries and Oceans (DFO) mandate addressed priority research topics related to the fisheries resource and oceans and hydrographic activities on the Pacific coast, inland waterways and the Western Arctic.

This review describes programs carried out by the Science Branch in the Pacific Region. Additional details can be obtained by contacting the appropriate laboratory directly. Emphasis in 1990/91 was placed on strengthening of effort in the planning process for fisheries and oceanographic climate-related research, high seas studies and involvement in international negotiations related to the squid driftnet fishery in the North Pacific, and intensified work on dioxins and other contaminant problems. Attempts were made to strengthen scientific cooperation with Pacific Rim nations including Japan, China, the U.S.S.R. and the U.S.A. through negotiations leading to successful completion of an international science treaty and other related initiatives.

DFO science activities in the Pacific Region are administered by a Regional Director of Science and a Science Executive staffed by Branch Directors. National coordination with DFO's five other regions is achieved through a National Science Director's Committee. Consultation with a wide variety of clients takes place at all levels. Visiting faculty, graduate students and other individuals work closely with regional laboratories. Research vessel support is also provided to the university community and other government departments and institutions as part of a comprehensive program of science vessel operations.

Government restraint programs since 1984, coupled with the effects of inflation on resource allocations, have made significant inroads into the ability of Science to maintain existing programs and meet new demands. At IOS for example, the purchasing power of non-salary funding from all sources in 1990/91 was almost the same as it was in 1976/77, a decline of 17% from the 1984/85 level. Newly available funding from the Green Plan is thus an important contribution towards maintaining the excellence of the Science program in the Pacific Region. (*Contact: J.C. Davis*)

HYDROGRAPHY

The Canadian Hydrographic Service (CHS) fulfils DFO's mandate to provide the information necessary for the production of timely, accurate nautical charts and related publications such as Tide Tables and Sailing Directions. This information is distributed through a network of authorized chart dealers. The Pacific Region's area of responsibility extends from the western boundary of Canada's Exclusive Economic Zone east to the Saskatchewan/Manitoba border, and includes the western Arctic.

CHS activities are designed to meet the needs of the marine community and to promote the conduct of safe, orderly, and efficient marine transportation in Canadian and adjacent international waters. Ancillary products include mathematical models which can predict the trajectory of spilled pollutants and other flotsam and jetsam, and digital data files used in sensitivity maps and electronic charts.

Hydrography took the lead in organizing the first IOS Open House. It was a great success, with an attendance of 11,000. (*Contact: A.D. O'Connor*)

Field Hydrography

A survey for a new chart of the waters around Hakai Pass was conducted to replace surveys dating from the 1930's. Several uncharted shoals were reported for Notice to Mariners action. Despite vessel problems, the northernmost of two complicated field sheets was 90% completed. Survey work in the northern Hakai Pass area will be finished as soon as possible while surveys northward towards Queen's Sound will be continued during the 1991 season. (*Contact: G.H. Eaton*)

The new vessel R.B.YOUNG had a productive first season proving to be a flexible and efficient inshore survey vessel. Surveys of Duke Point and Horswell Channel (near Nanaimo) were completed. In a resurvey of Squamish Harbour (last surveyed 17 years ago), considerable sediment accumulation was found on the west side of the inlet. Scotty Bay on Lasqueti Island was surveyed for the benefit of small craft. A thorough investigation of a reported shoal in Chatham Channel was conducted and Tugwell Passage, a dredging site at the northern approach to Prince Rupert was surveyed. The YOUNG moved to the Queen Charlotte Islands in mid-August to finish a field sheet at the eastern entrance to Houston-Stewart Passage. (*Contact: M.V. Woods*)

Field work on the survey of Patricia Bay, initiated in 1988, was completed. A revisory survey of False Creek detected several obstructions off the old Expo site resulting in Notice to Mariners action. Two new marina facilities were surveyed in Campbell River and the channels into the Campbell River estuary were surveyed to assist the Coast Guard with placement of new aids to navigation. A survey party will return to the area in 1991 to help in placing the aids and to determine the depths along the new ranges. (*Contact: J.V. Crowley*)

Hydrographic surveys were conducted in Nootka Sound. Work completed included a plan of Gold River harbour facilities and standard charting surveys of Zuciarte Channel, Muchalat Arm and Tlupana Inlet. Surveys at the entrance to the Sound will be continued in 1991. (*Contact: J.V. Crowley*)

Revisory surveys of the Arrow Lakes were conducted to correct, verify and complete field sheets made by Terra Surveys Ltd. Datum changes for the Upper Columbia River will be applied to the field sheets together with the revisions. (*Contact: B.M. Lusk*)

Terra Surveys Ltd. was contracted to sound Dolphin and Union Strait using the LIDAR (Light Detection and Ranging) air-borne swath survey system. The geography of the area and other environmental conditions proved to be excellent for obtaining quality soundings after the ice cleared. Terra's innovative G.P.S. (Global Positioning System) controlled photo-mapping system provided inexpensive and accurate shoreline and topographic data. It is hoped that the CSS J.P. TULLY will be available next year to confirm the quality of the survey with thorough ground truthing. (*Contact: B.M. Lusk*)

Sailing Directions

The *Small Craft Guide, British Columbia, Volume 2*, and *Sailing Directions, British Columbia Coast, Volumes I* and *II* were produced using the Macintosh II desktop publishing system. Use of this system has improved productivity in the section and other computer applications handling up-date information are being considered.

A review of Arctic marine environmental literature was undertaken to evaluate possibilities for integrating environmental information into the *Arctic Pilot* or the need for a separate publication for the mariner. The results suggest that environmental information can be readily delivered to the mariner through the *Sailing Directions* series. (*Contact: A. Smith*)

Chart Production

Chart Releases during fiscal year 1990/91 consisted of the following New Charts:

3515 - Knight Inlet	1:80,000
3681 - Plans - Quatsino Sound	Various
3920 - Nass Bay, Alice Arm and Approaches	Various
3963 - Work Channel	1:40,000
7668 - Prince Albert Sound (Western Portion)	1:150,000
7669 - Prince Albert Sound (Eastern Portion)	1:150,000
7710 - Lambert Channel and Cache Point Channel	1:80,000
7776 - Dolphin and Union Strait	1:150,000
7777 - Coronation Gulf (Western Portion)	1:150,000
7778 - Coronation Gulf (Eastern Portion)	1:150,000
7779 - Dease Strait	1:150,000
7780 - Melville Sound	1:150,000
7781 - Bathurst Inlet	1:150,000
7782 - Queen Maud Gulf (Western Portion)	1:150,000
7783 - Queen Maud Gulf (Eastern Portion)	1:150,000

Other releases included twenty New Editions, twenty-three Reprints, four Reruns, sixteen Overprints, and eight Chart Amendment Patches.

The Navigation Information Unit promulgated 112 Notices to Mariners, produced 37 Navigational Aids Copies and assessed 478 plans for relevant charting action.

The Hydrographic Data Centre processed 439 plans as well as 534 MAREP (Canadian Power and Sail Squadron) reports. The Unit duplicated 253 Field Survey documents and responded to 459 queries from both the public and private sector.

The Photomechanical Unit processed approximately 6,500 exposures.

The Kongsberg plotter was operated at a success rate of just over 80%, utilizing 192 plots from a total of 237.

Staff took the Seamanship and Navigation Course and two cartographers from New Zealand visited Pacific Region for on the job training on the CARIS (Computer Aided Resource Information System) system. (*Contact: W.S. Crowther*)

Chart and publications sales generated a total revenue of $920K.

In the most intensive inspection program ever undertaken in the Pacific Region, a total of 65 on-site visits to CHS Chart Agents were conducted. New contracts formalizing the Agency relationship between CHS and 300 chart dealers in the region were issued in June. (*Contact: W.S. Crowther*)

Tides and Currents

Tides

Data from the 17 Pacific Coast stations in the Permanent Water Level Network was processed on a regular basis and sent to MEDS (Marine Environmental Data Service). Monthly mean water levels at Bamfield, Tofino and Prince Rupert were sent to Hawaii for IGOSS (Integrated Global Ocean Services System). Nine of the 17 stations provided continuous records in 1990-91 and 94% of all potential data was collected.

Construction was carried out at four stations on the Pacific Coast. New stilling wells were installed at Prince Rupert and Port Renfrew.

In accordance with an agreement with the Pacific Geoscience Centre (PGC), five long term temporary stations were maintained on Vancouver Island. Data from these stations are being used for crustal movement studies.

The six Western Arctic stations were visited in July and August. Bottom-mounted gauges were successfully recovered and new instruments installed at all stations except Spence Bay which was discontinued for economic reasons. Analog gauges at Tuktoyaktuk and Cambridge Bay were serviced and restarted. Logistic support for the Western Arctic work was provided by Energy, Mines and Resources (EMR - Polar Continental Shelf Project) and Ministry of Transport (MOT - CCGS MARTHA L. BLACK).

Information, instrumentation and advice was provided to three hydrographic survey parties conducting field surveys. In addition, chart datum information was provided for a major contract survey of the Columbia River and Arrow Lakes, and for a LIDAR survey in Dolphin and Union Strait.

Tsunami warning stations were maintained at Bamfield, Winter Harbour and Langara Island. A meteor burst VHF communication system was installed at Bamfield in May to complement the tsunami TATS (Tidal Acquisition and Telemetry System) and telephone line/modem link. Work on the new Rennell Sound station proceeded much more slowly than originally anticipated. (*Contact: F.E. Stephenson*)

Currents

Sea trials of the currents data processing system were completely successful. The hardware consisted of a two node Apollo network with removable magneto-optical technology for back-up of mass storage. Approximately 50% of the currents software and a smaller amount of the tidal software has been converted. (*Contact: M.J. Woodward)*

Seventeen current meter moorings were deployed in Queen Charlotte Sound and Hecate Strait and pressure recorders were installed at six nearshore locations in July, 1990. A program of CTD measurements and drifter deployments was also carried out. All survey objectives were accomplished.

The January PERD (Panel on Energy Research and Development) cruise was severely curtailed by bad weather with only three of 14 sea days suitable for mooring work. Nine moorings were recovered and two were deployed. Additional ship time was obtained in February, providing an opportunity to recover additional moorings, although insufficient time for redeployment. Eight moorings were recovered, and one mooring and three ARGOS satellite-tracked CTD profiles were deployed. (*Contact: M.J. Woodward*)

Field work for the drifter tracking and CTD measurement program was carried out under contract by Seakem Oceanography Ltd. using the MV WESTERLY WIND. The contractor has completed processing of the data and submitted a final report. (*Contact: W.J. Crawford)*

Turbulence measurements taken in February-March, 1990 were compared with measurements taken in the fall of 1987 from moored profiling CTD's, current meters and air-deployed expendable current meters. All results showed mixing in the 50 m of water below the wind-mixed layer during and after storms. (*Contact: W.R. Crawford*)

Numerical Modelling

In a collaborative experiment with the Pacific Biological Station (PBS), data was analyzed and a report prepared on salinity intrusion in the Campbell River estuary. Several model runs were carried out in conjunction with this report. (*Contact: A.B. Ages*)

Information and advice was provided to government agencies and the private sector on matters relating to tides and currents in the Fraser River, the Campbell River, and Victoria Harbour. Expert witness testimony was given in December at the Nestucca oil spill trial in U.S. State Court in Portland, Oregon. (*Contact: A.B. Ages*)

Work began on the re-calibration of the Fraser River model. The field data used for the original calibration of the model were collected in the early 70's. Since that time, continued dredging and other public works projects along the river have significantly lowered the low waters in the area of the model (0.3m - 0.6m). Two temporary stations were installed for six months in the lower reaches of the river. Additional data will be provided by the stations at Steveston and New Westminster, and stations upstream of New Westminster which are operated by Water Survey of Canada. In addition to water level measurements, CTD measurements will be taken during the freshet. (*Contact: A.B. Ages*)

Diving Unit

Fourteen IOS divers made a total of 107 dives in support of activities at IOS, including installation and recovery of bottom-mounted pressure gauges in the Western Arctic and on the B.C. coast. Stilling wells were inspected and tide staffs cleaned at a number of the permanent tide gauge stations.

IOS divers also installed temporary tide gauges for hydrographic surveys and inspected hulls, propellers and zincs on Marine Division ships and barges.

The program of diver recertification and upgrading initiated last year continued, bringing two divers up to the Rescue Diver level. (*Contact: F.W. Stephenson*)

Engineering Services

Work is underway on the development of a correlation signal processing module in conjunction with Oceanprobe, a local company. The module can be attached to any echo sounder to dramatically improve echo sounder returns (typically from 10-100 fold improvement). This would facilitate high speed surveys in deep B.C. fjords or high frequency, high resolution surveys in deeper waters. (*Contact: J.G. Galloway*)

Another major in-house acoustic project involves the development of an ice motion detector. The Correlation Sonar Project is using backscattered correlation signal processing to determine water speeds at right angle to the acoustic beam axis. It will be deployed in the Beaufort in August, 1991.

A third correlation project, using forward scattering, was developed to continuously measure currents in the Fraser River. Currents and tides will be monitored from January-August, 1991. The system is interrogated remotely by cellular radio.
(*Contact: J.G. Galloway*)

Major operational shortcomings of the DSF6000 echo sounder were noted upon completion of the 1990 field season. Test results after redesign indicate greatly improved performance. (*Contact: E.W. Hinds*)

A Battery Capacity Analyzer was designed and built to eliminate dangerous and unnecessary battery redeployments at isolated sites. (*Contact: E.W. Hinds*)

The Hysub 5000 performed a significant program on the east coast in August and achieved a depth capability of 2200 metres on the west coast in September. Major changes were made to the style of operation (live boating, as opposed to a cage deployment system). The dive demonstrated that a deep water single-mode fibre optic cable was operational, and that the Hysub 5000's depth capability exceeds that of the manned submersible PISCES. (*Contact: G.R. Smith*)

Industrial Liaison

Technology transfer in support of DFO's "Ocean Strategy" initiatives of fostering industrial development and enhancing of Canada's scientific and technological capabilities was a major focus over the year. (*Contact: T.A. Curran*)

IOS staff participated in the "Scientists in the Schools" Program sponsored by Science World. (*Contact: T.A. Curran*)

OCEAN PHYSICS

The Ocean Physics Division is responsible for collecting scientific information about the ocean's physical properties and the processes that control them. This information is used to predict changes and contributes to the understanding of fish distribution and survival, contaminant transport, and the role of the ocean in regulating and responding to climate change.

Fjords and Narrow Channels

Much of the development on Canada's Pacific Coast occurs on the shores of fjords and narrow passages which are the habitat of migrating and resident fish stocks and invertebrates and, increasingly, the site of aquaculture operations. The impact of industrial effluent on water quality is a continuing problem in many such areas, including Alberni Harbour. Pulp mill operations in Port Alberni have resulted in low levels of dissolved oxygen in the inner harbour. These levels frequently fall below acceptable limits posing an increasing risk to fisheries in the area. In 1990, a substantial number of returning sockeye salmon were lost. The low oxygen resulted in part from the elevated benthic oxygen demand of the organic rich sediments produced by the discharge of solids from the pulp mill. These results were used to brief DFO, Department of Environment (DOE) and industrial representatives. (*Contact: D.J. Stucchi*)

One of the major obstacles to better understanding and prediction of the distribution of natural (salt, oxygen, nutrients) and man-made (i.e. contaminants) materials in coastal waters is an inability to determine the sites of vertical mixing in the water columns and quantify vertical exchange rates. Ocean Physics personnel made the first successful direct measurements of buoyancy flux in the ocean (a crucial variable in describing the rate of vertical transport of heat and dissolved substances) in 1990. An acoustic doppler current meter was used to measure small scale variations in vertical velocity in conjunction with a free-falling conductivity-temperature-depth (CTD) instrument to measure small scale changes in temperature, salinity and density. (*Contact: A.E. Gargett*)

In a related project, results of laboratory and field studies on the different rates of diffusivity of salt and heat were used to explore the effects of using different diffusivities in a large scale ocean general circulation model (OGCM). The large scale distributions of salinity and temperature differed dramatically from those obtained with equal diffusivities.
(*Contact: A.E. Gargett*)

In cooperation with Seaconsult Marine Research, a German three dimensional numerical model of flow and water properties was adapted to Georgia Strait. A model of the buoyant spreading Fraser River plume was coupled to a three dimensional Georgia Strait model.
(*Contact: T.S. Murty*)

Preliminary experiments using various methods of modelling the dispersal of pollutants were conducted. Normally, numerical models cannot resolve scales smaller than their grid mesh, which is limited by a variety of factors including computer size. However, many pollutants enter marine waters from sources such as outfalls, which are very small compared to model grids. These models will be used to investigate the flow of contaminants in Howe Sound and the dispersal of sewage in the area of the Strait of Juan de Fuca south of Victoria. An earlier version of the model was used to forecast the spread of oil spills in the Persian Gulf by tidal and wind-driven currents. (*Contact: T.S. Murty*)

Continental Shelf

Understanding the global ocean carbon cycle requires quantification of exchanges of organic and inorganic carbon between continental margins and the deep ocean. Two sequential sediment trap moorings equipped with current meters and transmissometers, were deployed over the continental slope off Vancouver Island between April and October, 1990. One mooring was deployed under the path of a recurring upwelling jet while the other was deployed farther up the coast. Both traps showed a seasonal cycle in the rain of organic particles downwards from the photic layer but, contrary to expectations, the trap under the path of the recurring upwelling jet did not capture more particles. This work is part of the Joint Global Ocean Fluxes Study (JGOFS). (*Contacts: K.L. Denman, R.E. Thomson*)

The La Perouse Project is a multi-year cooperative study examining oceanographic and biological conditions in this productive area southwest of Vancouver Island to determine relationships between anomalous ocean conditions, as in 'El Nino' years, and recruitment of fish stocks of species such as sablefish, hake and herring. In the fifth year of the project, time series were compiled for frequently-sampled stations and current meter moorings, using data dating back to 1979 where possible. (*Contacts: R.E. Thomson, J.F.R. Gower*)

A two-dimensional, finite element tidal model previously developed for the La Perouse region was applied to the La Perouse and Marine Survival of Salmon (MASS) projects. Two methods were developed to remove tidal currents from shipmounted acoustic doppler current meter data to allow for more accurate underway mapping of nontidal current patterns over the continental shelf. Residual current patterns were used to investigate the possibility of closed current eddies over Swiftsure Bank and neighbouring banks that would retain passive particles and swimming fish. Results indicated that the currents around Swiftsure Bank are too weak to confer any energy advantage to fish that might wish to remain around the Bank to feed on high concentrations of zooplankton. A calculation was performed with corrected model currents to determine whether tidal mixed fronts might occur off southwest Vancouver Island. Tidal fronts appear to be marginally possible near Capes Flattery and Beale, but currents are too weak over the fishing banks. (*Contacts: M.G. Foreman, H.J. Freeland, P.F. Cummins, R.E. Thomson*)

Strong tidal currents in B.C. coastal waters can significantly alter wave conditions. A numerical model for the hindcasting of waves in shallow water and in the presence of current fields was applied to the Cape St. James area. The results indicated significant wave

- current interactions, with an increase of up to 30% in significant wave height under typical conditions. High quality wave and current measurements will be collected during a 1991 summer field program to test the model. (*Contact: D. Masson*)

A study of the correlation between currents off Vancouver Island, and coastal sea level and winds showed usefully high correlations between sea level and currents but lower correlation between shore winds and currents. Off Oregon, wind events lead current changes by less than one day, but off Vancouver Island the lag is closer to three days, possibly because shore winds in this area with its irregular shoreline are less representative of winds over the continental shelf. (*Contact: S. Tabata*)

Work on modelling and prediction of tsunamis was expanded to include an analysis of other natural hazards along B.C. coastlines such as storm surges, possible increases in sea level and underwater slumping of sediments. Advice on predicting the occurrence and effects of various man-induced and natural marine hazards was given to various United Nations organizations. (*Contact: T.S. Murty*)

Open Ocean

A cooperative study of interannual variability in the subarctic Pacific was initiated by IOS and the Pacific Oceanological Institute in Vladivostok, USSR. The first of 10 cruises planned for the next five years was conducted on the Soviet research vessel AKADEMIK VINOGRADOV. The large scale upper ocean survey data collected during this study are required for ocean climate research and will also be valuable for high seas Pacific salmon studies. (*Contacts: E.C. Carmack, M. Miyake, R.A. Lake*)

Physical and biological studies of the properties and behaviour of the plume emanating from the hot vents on Endeavour Ridge (48^0N, 129^0W) continued, in cooperation with BSB. A towed acoustic doppler current meter (ADCM) showed a layer of high acoustic backscatter at the top boundary of the thermal plume around a depth of 1800 m. Tows with opening/closing nets showed that the backscatter came from deep zooplankton, including several possible new species. (*Contacts: R.E. Thomson, T.A. Juhasz*)

Analysis of GEOSAT altimeter data has shown eddy structure over wide areas of the north-east Pacific, allowing tracking of individual features as they propagate westwards. These features represent a significant fraction of the energy in ocean circulation. (*Contact: J.F.R. Gower*)

The interpretation of satellite observations of sea surface topography to infer currents requires independent knowledge of the vertical structure of the sub-surface currents. The quiet eddy project involves maintaining a current meter mooring for three years in the open subarctic Pacific away from strong currents, where few current meter data have ever been obtained but where satellite altimetry data of sea surface topography are now available. The vertical structure of the eddies observed in GEOSAT altimeter records from the Gulf of Alaska, which are some distance away from any strong currents i.e. "quiet", will be examined.

The first current meter results show strong highly variable currents at the deepest current meter. (*Contacts: H.J. Freeland, P.F. Cummins*)

Several ocean general circulation models (OCGM) have been developed for a project to study the representation of small scale physical processes in commonly used types of OCGM's, to evaluate the impacts of errors in the representations, and to find ways to include processes presently ignored. Results of an analysis carried out at IOS indicated that most OGCM's do not accurately represent boundary currents because they may not include effects of currents being deflected by variable bottom topography. While increasing the spatial resolution of models has not improved the success, a method has been tested in which the interior model currents are relaxed to currents that are directed along paths of constant bottom depth with magnitude proportional to the local slope of the bottom. This algorithm will be incorporated in several of the largest OGCM's at other institutions to determine its usefulness. (*Contact: G. Holloway*)

Upper Ocean Processes

Ocean circulation is driven by forces exerted on its surface and by the surface exchange of heat and water. These processes must be described in order to predict the ocean's response to changing atmospheric conditions on all scales, from weather to climate. Drifting arrays of acoustical transducers were developed at IOS for the study of flow structures in the upper ocean. Organized helical flow patterns that tend to align with the wind (Langmuir cells) can now be observed acoustically because downwelling water entrains bubbles at the sea surface which reflect and scatter sound. A three dimensional visualization of other mixing processes such as breaking surface waves and internal waves in and at the base of the surface mixed layer is now possible. Field data were obtained in 1990 in a multinational cooperative project in the North Pacific. (*Contact: D.M. Farmer*)

A series of upper ocean mixed layer models is being developed in cooperation with UBC to be coupled with OGCM's and ultimately with the AES Canadian Climate Model. The report of the Intergovernmental Panel on Climate Change stressed that significant improvement in the ability to predict climate change requires the development of fully coupled ocean-atmosphere climate models with more realistic ocean models. (*Contact: G. Holloway*)

Arctic Studies

Pressure ridge keels on the underside of arctic ice are a hazard to seafloor pipeline and wellhead installations and to through-ice transportation. In addition, improved predictions of ice motion in response to winds require incorporation of the effects of pressure ridge keels into models. In a cooperative program with the National Research Council, a small, instrumented remote-controlled submersible (T.A.R.S.) was used for three-dimensional acoustic mapping of the underside of several ice keels which will be combined with topside surveys. In laboratory experiments and numerical models, the drag caused by pressure ridge

keels increases dramatically with increasing speed of ice motion over the water when the water is stratified. Stratified conditions often occur in the spring in the Beaufort Sea when Mackenzie River water runs under the ice but over the heavier salty seawater. The results of this study will be developed into formulations that can be implemented in ice forecasting models. This work was funded by the Panel on Energy Research and Development (PERD). (*Contact: D.R. Topham*)

In another PERD-funded project, an Ice Profiling Sonar developed at IOS is being used to obtain statistical data on the thickness and ridging of arctic sea ice in the Beaufort Sea on a year-round basis. The data will be used to specify pack-ice properties for numerical sea-ice models and design of offshore structures, and to study climate-related changes in ice thickness. (*Contact: H. Melling*)

A series of experiments were conducted to analyze the nature of the sounds caused by cracking sea ice. Analyses of study results led to formulations of a model for the propagation of sound in sea ice caused by fracturing. Information obtained on variations in the sound signature in response to ice conditions will be used to develop methods for forecasting the timing of ice breakup in the Arctic Ocean. (*Contact: D.M. Farmer*)

The objective of the Beaufort Sea Ice Motion project, funded by PERD, is to improve predictions of ice motion in the Beaufort Sea by extending the knowledge and models of ocean currents and their response to winds. Data from six years of field studies were analyzed and archived in preparation for scientific interpretation and incorporation into computer models being developed for simulating the behaviour of ice motion forced by winds and underlying ocean currents. (*Contact: H. Melling*)

Techniques for tracking ice using sequences of satellite imagery are being developed for use in climate and ice forecasting studies. A new software package, "Tracker 2", has been developed in a cooperative project with Arctic Sciences Ltd. Commercial applications of these techniques should become increasingly important once images from the new ERS-1 and Radarsat satellites are available. (*Contact: J.F.R. Gower*).

Climate change models predict Arctic regions will be the site of the largest warming trends and accumulation of certain airborne pollutants. To detect possible changes as early as possible, a mooring was deployed to a depth of 3300 m in the Canada Basin of the Arctic Ocean. The mooring contains current meters, upward looking sonar, CTD's and sequential sediment traps. For the third consecutive year, a CTD and bottlecast were carried out to 3300 m for physical and chemical samples. CTD sections were completed over the shelf off Banks Island and out from the Mackenzie River to determine the effect of the river input on shelf water properties. (*Contacts: E.C. Carmack, R.W. Macdonald*)

OCEAN CHEMISTRY

The objective of Ocean Chemistry research is to understand the distribution, variability, transportation and ultimate fate of natural and man-made chemicals in marine and freshwater environments. Research is conducted on applied problems relating to biogeochemical cycling of chemicals, fisheries resources and pollution.

Fraser River Studies

Analysis of resident fish samples collected in the Fraser River estuary and the Homathko estuary between 1987 and 1989 was completed. The body burden of measurable organochlorines in the Fraser River estuary was comprised predominantly of PCB's. Results of the analysis indicated a apparent decline in the average uptake of PCB's since the last major survey conducted in the 1970's. Regression analysis of penta- and tetrachlorophenol data showed a sharp decline over the sampling period which coincided with the phasing out of the use of chlorophenols as wood preservatives. However, the level of 2,4,6-trichlorophenol appeared to be slowly increasing. This substance is associated primarily with municipal sewage and its use as a household disinfectant. As expected, tri- and tetrachloroguaiacol were distributed uniformly throughout the estuary from an upriver source (pulp mills). Starry flounders bioaccumulated these compounds more readily than any other species analyzed. The only target compound detected in fish from the Homathko River was a trace of pentachlorophenol.

Analysis of liver samples from two adult white sturgeon captured in the upper Fraser River in 1988 showed PCB burdens in the middle range, but only very low levels of chlorophenols and chloroguaiacols. (*Contact: I.H. Rogers*)

Regional Dioxin Laboratory

Construction of a Regional Dioxin Laboratory at IOS began in January, 1991. A VG Autospec high resolution mass spectrometer will be used to quantify dioxins and furans in samples submitted for analysis by a variety of agencies. The laboratory is expected to be operational by March, 1992. (*Contact: I.H. Rogers*)

Protein Studies

A joint study with the NRC's Atlantic Research Laboratory continued. The objective of the study is to examine the feasibility of using ion-spray mass spectrometry as a tool in the study of metal-binding proteins isolated from marine invertebrates. To date, spectra of metallothioneins from crab, horse and rabbit have been analyzed. Excellent results were obtained indicating that the technique has promise, both as a quantitative tool and as a

method of determining molecular weights of small proteins. (*Contact: J.A.J. Thompson*)

A study of stress-related proteins in invertebrates and demersal fish in areas adjacent to coastal kraft pulp mill sites continued. Initial investigations focused on metal-binding proteins and the physiologically important metals, copper and zinc in Dungeness crab *Cancer magister.* Samples of *C. magister* and other benthic invertebrates were collected from pulp mill sites at Crofton, Port Mellon and Woodfibre. (*Contact: J.A.J. Thompson*)

A joint study was initiated with the University of Victoria to study the histopathology of English sole chronically exposed to pulp mill discharges at three coastal sites. Liver and gill tissues are being examined for the presence of lesions which may be related to contaminants. Ocean Chemistry personnel will assist in the measurement of related biochemical parameters. (*Contact: J.A.J. Thompson*)

Hydrocarbon Biodegradation Experiments

Analysis of the results of two hydrocarbon biodegradation experiments conducted in Patricia Bay in 1989/90 has revealed the time course of biodegradation of n-alkane and branched chain hydrocarbons and the relationship with bacterial growth and aggregation processes. The length of the lag phase before the onset of biodegradation varied between about one day in the first experiment and eight days in the second. It was not affected by the addition of dispersant or a small amount of re-suspended sediment, suggesting that the onset of degradation is influenced predominantly by the state of the microbial population and other environmental factors. This study was funded by PERD. (*Contact: W.J. Cretney*)

Dioxins

A sediment sampling and analysis program in Howe Sound and the Strait of Georgia continued. The program is using the sedimentary record to predict the rate at which the present surface sediment concentrations of dioxins and furans can be expected to diminish following implementation of new bleaching technology in area pulp mills. Several cores were collected, dated by Pb-210 and Cs-137 methods and analyzed for polychlorinated dibenzodioxins and dibenzofurans. Data from three cores were used to construct analytical two-layer advection-diffusion and numerical box models that satisfactorily reproduced the dioxin and furan profiles found in the cores. On the basis of the limited number of cores taken thus far, the models predicted that concentrations of pulp mill dioxins and furans at the sediment surface will decrease by approximately 50% a decade in areas undergoing bioturbation. In areas of little or no bioturbation, the decrease will be much more rapid. (*Contacts: W.J. Cretney, R.W. Macdonald*)

Extending a study initiated in 1989, a sediment transport analysis was conducted on surface sediment samples collected from the lower basin of Howe Sound and Thornbrough Channel. A selected number of samples were analyzed for polychlorinated dioxins and furans. Generally, tetrachlorodibenzodioxins and -dibenzofuran concentrations decreased with

distance from pulp mills, while octachlorodibenzodioxin concentrations remained fairly uniform throughout the study zone. These results were consistent with two principal sources - the pulp mills and multiple nonlocal combustion sources. (*Contacts: W.J. Cretney, R.W. Macdonald*)

Long Range Transport of Atmospheric Pollutants (LRTAP)

To investigate the possibility of long range transport of atmospheric pollutants from across the Pacific Ocean, a project was initiated to measure organochlorines in precipitation from the west coast of Vancouver Island and the Fraser River drainage district. Preliminary results support this conjecture. (*Contact: W.J. Cretney*)

OCEAN CLIMATIC CHEMISTRY

Research conducted by the Centre for Ocean Climatic Chemistry focuses on the role of the ocean in modulating levels of greenhouse gases such as CO_2, methane, freons and nitrous oxide in the atmosphere. The emphasis is on assessing the capacity of the oceans, in particular the North Pacific Ocean, to absorb fossil fuel CO_2. Scientists are participating in two major global ocean programs - JGOFS and the World Ocean Circulation Experiment (WOCE).

Long-term monitoring on a decadal time-scale produces important information on the rate of oceanic CO_2 uptake. Analysis of time-series measurements of partial pressure of carbon dioxide (pCO_2) conducted at Station P from 1973-1978 indicated that the N.E. Pacific Ocean is a weak CO_2 sink. Preliminary results of a comparison of pCO_2 from 1973-78 and in more recent years, suggest increases in oceanic CO_2 roughly in tandem with increases in atmospheric CO_2. Measurements of C-13/C-12 near Station P between 1970 and 1989 showed a decrease of -0.2 per mil due to oceanic uptake of fossil fuel CO_2 and carbon from woodburning, implying that at least half of oceanic uptake by subarctic waters remains in the upper ocean. (*Contact: C.S. Wong*)

An understanding of the organic and calcium carbonate flux in the ocean is required to address the question of removal of CO_2 into deep-water storage. Time-series measurements of particle fluxes in the N.E. Pacific were conducted to detect seasonal, interannual and episodic events affecting fluxes. A sediment trap at 500 m at coastal station L (48.5°N 126.5°W) off La Perouse Bank showed a carbon flux much larger than at open ocean sites, but with terrigenous carbon input. (*Contact: C.S. Wong*)

In a spatial distribution study of flux, sediment traps were moored at Station P (50°N 145.4°W), Station AG (56°N 145°W) in the Alaska Gyre and Station CA (49.5°N 138.5°W). An episodic event of extremely high calcium carbonate flux (up to 70% of the total mass flux) was detected in June, 1990 at Station P, and later in July and August at the other stations. (*Contact: C.S. Wong*)

DATA ASSESSMENT

The Data Assessment Division facilitates access to scientific information and data and provides advice about the impacts of industrial development on the marine environment. Program interests include environmental regulation, data management, and operational oceanography. The division is the science sector's first point of contact for a number of clients including DFO Habitat Management.

Use of Radar for Fisheries Surveillance

As part of a project investigating the feasibility of using aircraft and satellite radar for fisheries surveillance, a synthetic aperture radar (SAR) was flown off the west coast of Vancouver Island in June, 1990 by the Canada Centre for Remote Sensing. The area selected for overflights contained a number of fishing vessels as well as a short section of driftnet of the type used in the high seas squid fishery. The purpose of the experiment was to determine whether the all-weather, day and night capability of SAR could be used to supplement conventional surveillance of fishing activity.

Results of the experiment indicated that fishing vessels and larger ships could be seen even in degraded, quick look imagery. In addition, the airborne SAR showed considerable potential as a tool for detecting oil slicks in low wind conditions.

However, the SAR was unable to detect the floating driftnet either in quick-look radar imagery or in high resolution data. Winds during the driftnet deployment were around 20 knots and waves were breaking. Previous studies have indicated that SAR has potential for the detection of driftnets in the open ocean, but this study confirmed that it would only be useful in relatively calm conditions. (*Contacts: R.C.H. Wilson, J.F.R. Gower*)

The European Space Agency launched a satellite with a SAR sensor in June, 1991, and a similar Canadian satellite is scheduled for launch in 1993. It has been demonstrated that the two satellites are capable of the first detection of unauthorized fishing activity, although subsequent visual observation would be needed to confirm what was actually happening. (*Contacts: R.C.H. Wilson, J.F.R. Gower*)

Green Plan

The Green Plan, a comprehensive five year environmental action plan for Canada, was announced by DOE in December, 1990. With the announcement of the plan come significant opportunities for the DFO science sector to increase efforts towards the goals of cleaner water, sustaining renewable resources, maintaining the Arctic environment and developing solutions to global environmental problems. (*Contact: R.C.H. Wilson*)

Environmental Advice

A major review of Gulf Canada Resources' three year drilling program in the east Beaufort Sea was initiated. The company proposed to explore for oil about 50 km offshore in 30 m of water, for approximately 70 days each summer, using a mobile offshore drilling unit and four Class IV Arctic icebreakers.

The major concern was the unlikely, but serious threat of an uncontrolled well blowout which could discharge crude oil beneath the water or under sea ice, at a worst case rate of 40,000 barrels per day (6,500 m3/d). If the blowout did not plug itself naturally, a relief well might take 50 days to "kill" the flow, during which time two million barrels (ten times more than the Exxon Valdez spill) of crude oil would pollute the Mackenzie shelf waters and shores.

Gulf Oil's assessment of the behaviour and fate of spilled oil under typical and extreme summer conditions was reviewed by IOS staff. The results of the review concluded that Gulf had underestimated the extent of the impact from an uncontrolled blowout.

While the application reviews were underway, Gulf and others curtailed their Beaufort Sea drilling plans. However, it is anticipated that exploration will resume later in this decade. The challenge remains for government, industry and northern people to incorporate improved assumptions into a revised assessment of spill fate and effects. (*Contact: B.D. Smiley*)

The disposal of dredge spoils in the ocean continues to be a matter of some controversy. Ocean disposal is authorized under the Canadian Environmental Protection Act, administered by DOE, with Data Assessment providing advice on behalf of the science sector within the Region. As a result of policy changes it is becoming increasingly difficult to obtain permits for ocean dumping. Only 29 permits were issued in 1990/91, the lowest number in the last five years. Six applications were rejected due to the presence of contaminants in the sediment and several more were withdrawn by the applicant when contamination became evident.
(*Contact: R.C.H. Wilson*)

BIOLOGICAL SCIENCES

BRANCH

SALMON DYNAMICS

The Salmon Dynamics Section investigates causes of recruitment variation in salmon off the west coast of Vancouver Island and conducts research in support of salmon stock assessment and fisheries management. The section is also involved in research to evaluate the interception of Canadian salmonids in high seas fisheries.

Salmon Biology

In a project to develop runs of pink salmon in the Fraser River that will mature in even years, maturity of the 1989 broodyear of Chilliwack River pink salmon was accelerated using photoperiod and temperature controls. Mature adults, available by April 1991, were subsequently spawned and fry obtained. (*Contact: T.D. Beacham*)

Results of a study examining genetic variation in resistance to vibriosis, furunculosis, and bacterial kidney disease in chinook salmon from Kitimat, Quinsam, and Nitinat rivers showed chinook from Kitimat River to be more resistant to all three pathogens. Heritability of survival and time to death was low. (*Contact: T.D. Beacham*)

A method of ageing chinook salmon using otoliths was developed. There was close agreement between ages determined from otoliths and known ages determined from coded wire tags (CWT's). (*Contact: C.B. Murray*)

High Seas Salmon Program

Research in this new program is directed towards assessing the influence of global warming and salmonid enhancement activities in Pacific Rim countries on the carrying capacity and productivity of the North Pacific Ocean.

A joint Soviet-Canadian high seas research cruise was conducted in the Gulf of Alaska to examine the physical factors which determine salmon distribution in the ocean. The results indicated that salmon distributions in the spring are closely related to temperature, with salmon abundances dropping off sharply above a threshold temperature. Threshold temperatures in the spring of 1990 were 8.5°C (sockeye), 9.4°C (coho), and 10.3°C (pink and chum). (*Contact: D.W. Welch*)

Approximately 5% (one million) of adult sockeye salmon returning to the Fraser River have a single deep slash mark along one side of the body. These distinctive wounds have been reported in salmon fisheries from around the Pacific Rim over the past 30 years and have been attributed to attacks by salmon sharks or marine mammals, or to injuries caused by high seas driftnets. One sockeye, caught in the 1990 commercial fishery, had a fish jaw embedded in the base of the slash mark. The jaw has been identified as belonging to an unusual deep-water snake-like fish called the daggertooth, *Anotopterus pharao*. This is the first evidence that the daggertooth and related deep-sea fish may be important predators on Pacific salmon. (*Contact: D.W. Welch*)

Coho Program

Stock assessment and related biological advice on coho salmon was provided to the Pacific Salmon Commission and the Pacific Stock Assessment Review Committee (PSARC). Particular effort was devoted to the development of a fishery management program for Strait of Georgia coho salmon. (*Contact: R.K. Kadowaki*)

Coho smolts emigrating from three systems on the east coast of Vancouver Island were counted and tagged with CWT's. The estimates for Black Creek and French Creek were the highest on record. In the case of Black Creek, more than twice the average number of smolts left in 1990 as compared to the previous seven years. (*Contact: J.R. Irvine*)

Adult coho returning to spawn in these same three systems in the fall were counted. Over 50% of the fish returning to Black Creek and French Creek were jacks (precocious males), which is unusually high. (*Contact: J.R. Irvine*)

A study comparing the characteristics of the sub-legal sport catch of coho and chinook salmon in Saanich Inlet with fish caught in a seine net, revealed that fish released from hatcheries were three to seven times more likely to be caught by sport fishermen than wild fish. There were also significant differences in the size, sex and age composition of sport-caught fish compared to the fish in the inlet. (*Contact: L.B. Holtby*)

Preservation of the bio-diversity of coho salmon populations in B.C. depends on characterizing and understanding differences between populations. A study of the size and sex composition of coho spawners on the west coast of North America identified two distinct types of coho. Males and females were equal in size and number in about half of the 31 populations studied. In the other half, male salmon were more abundant but smaller than female salmon. This dichotomy appeared to be related to differences in the physical configuration of their spawning habitats. Thus, changes to spawning habitats in small streams could jeopardize the long-term survival of the local population. (*Contact: L.B. Holtby*)

Only 1%-20% of smolts entering the ocean survive to adulthood. Understanding the cause of yearly fluctuations in smolt survival is essential for accurate predictions of run strength which are part of the annual harvest plan. On the west coast of Vancouver Island, variability in coho smolt and fry survival is due to fluctuations in the near-shore ocean environment. Year to year differences in food supply related to near-shore upwelling affect the growth rate of smolts during their first few months in the ocean. Rapid growth reduces losses to predators resulting in high survivals. On the basis of these findings, an accurate model for predicting run strength one year in advance has been developed. The model uses sea-surface salinities which can be measured easily and inexpensively. (*Contact: L.B. Holtby*)

Counting fences for coho enumeration were operated from mid-April until early June and from mid-August until early November on the Lachmach River near Prince Rupert. Stratified indexed sampling was used to estimate escapement independent of the fence count. Preliminary analysis suggests that this method may be useful for this purpose. The data also showed that stream walking counts for coho in north coast brown water streams are of no value and that float counts

using one or two people are required. (*Contact: B.O. Finnegan*)

Analysis of a two year test on a 52 h oligotrophic lake at planting densities of 1000-1600 fry/h demonstrated fry to smolt survivals to be independent of fry source (hatchery vs. wild) but dependent on fry size at release. Fry sizes varied from 2.3 to 7.3 g and survival increased asymptotically from 13.0 to 19.2%. An indigenous population of trout is believed to be the cause of this selective mortality. Smolt yield in the second year was comparable to that in the first when allowing for the initial size differences, but yield in terms of biomass was greatly reduced, from 387 to 254 kg total population weight. (*Contact: R.A. Bams*)

Addition of phosphorus to a nutrient-deficient stream resulted in a two-fold increase in numbers of emerging insects (40 species) over seven weeks. Benthic insects were 1.75 times more abundant than in controls at the end of this period, demonstrating that stream enrichment can promote the production of the food organisms of juvenile coho salmon, and indicating that coho production may be increased without negative effects to fish stocks. (*Contact: J.H. Mundie*)

Pelagic Fisheries

The first joint Canada/Japan/United States summary report of catch and bycatch in the 1989 Japanese squid driftnet fishery was completed and released in July, 1990. The report documented the magnitude of the bycatch of mammals, salmon and other fishes, turtles, and birds in the fishery, leading to a greatly expanded observer program in the 1990 fishery. Seventy-four observers were placed on board Japanese commercial squid vessels. (*Contact: S.M. McKinnell*)

The southern range of salmon in the N.E. Pacific and the area of overlap of salmon with flying squid was identified during the fifth high seas cruise of the W.E. RICKER. Results of high seas salmon tagging in 1990 were consistent with 1988 tagging results. No salmon were caught in 1989. There were no salmon caught south of the 40°N boundary in 1990. Three pink salmon caught and tagged north of the driftnet boundary were recovered in Alaska and a tagged steelhead was recovered in Oregon. (*Contact: S.M. McKinnell*)

An experimental jig fishery for flying squid was conducted for the first time within Canada's 200 mile limit. Observers were placed on five Japanese squid jigging vessels to record catch and collect biological data. Squid were caught in commercial quantities infrequently during the three month trial. This may be attributed to unusual oceanographic conditions off Canada's west coast during 1990. (*Contact: S.M. McKinnell*)

Harbour Seals and Sea Lions

Sea Lions

Monitoring of trends in abundance of Steller and California sea lions wintering off southern Vancouver Island continued. A total of 2,381 Steller and 2,092 California sea lions were counted in this area in February, 1991. Although the wintering Steller sea lion population remained stable at 1,200 throughout the 1980's, the numbers increased in 1990 and again in 1991. The current population is about twice what it was in the 1980's. This may be due to the decline in

numbers of California sea lions (see below) which compete with Steller sea lions.

The wintering population of California sea lions which became established off southern Vancouver Island in the 1960's peaked at about 4,500 in 1984, declining to about 3,000 in the late 1980's and to 2,000 more recently. The reason for this recent decrease is unknown. (*Contact: P.F. Olesiuk*)

Harbour Seals

Research into the population trends and impact of harbour seals on fish stocks continued to be the highest priority in the marine mammal program.

Aerial censuses conducted during 1966-90 indicate that populations of harbour seals throughout British Columbia have been increasing at a rate of 12.5% per annum since the species was protected in 1970. Total abundance in B.C. is estimated to have increased from 9,000-10,500 in 1970 to 95,000-102,000 in 1990. The recent increases are due to recovery of populations maintained below natural levels by bounty kills from 1913-1964 and further depleted by commercial harvests for pelts from 1963-1969.

Analysis of scats collected in the Strait of Georgia indicated that the diet was predominated by codfishes (mainly hake) between April and November and herring between December and March. Although salmon comprised only 4.0% of the overall diet, predation was nevertheless significant in some estuaries supporting large concentrations of seals.

Detailed observational studies were conducted in Comox Harbour in to more precisely determine the impact on individual stocks. Preliminary analyses of 1989 data suggest that seals consumed about 46% of the potential escapement of fall chinook compared to 4% of pinks, 8% of coho and 7% of chum. Chinook salmon appear to be particularly vulnerable because they have a longer residency period in the estuary and river prior to spawning, and because the stock is severely depleted. (*Contact: P.F. Olesiuk*)

Cooperative Plankton Research

A long-term plankton and oceanographic monitoring program for the west coast of B.C. was initiated in 1990. Sampling activities were conducted monthly at nine stations. A total of 36 plankton samples from oblique bongo tows and 40 CTD casts were completed. The majority of sampling effort was south of Queen Charlotte Sound and was split between La Perouse Bank off the west coast of Vancouver Island and the Strait of Georgia. (*Contact: W.R. Shaw*).

Ocean Salmon

Research activities continued to focus on determining factors controlling the survival, abundance, distribution, and migration patterns of juvenile salmon during the early sea-life stages. Research activities conducted in Barkley Sound to determine the impact of predation by Pacific hake and other fishes on marine survival of juvenile sockeye, coho, chum, and chinook salmon included: 1) purse seining to determine the abundance, distribution, and migration timing of juvenile

salmon; 2) gillnet and balloon trawl sampling to determine the abundance, distribution, and rates of predation of fishes feeding on juvenile salmon; and 3) experimental releases of tagged chinook salmon from Robertson Creek Hatchery, designed to directly test the hypothesis that predation during the early sea life period is a major source of mortality of juvenile salmon.

The results indicated a return to more typical conditions for most species of juvenile salmon in Alberni Inlet and Barkley Sound in 1990. Migration timing for each species was similar to previous years, with sockeye showing the earliest peak in abundance in May, followed by coho and chum salmon in early June. As in previous years, the peak abundance of juvenile chinook occurred later, in late June and early July. Pacific hake were again the most important predators of all species of juvenile salmon. However, predator abundance was the lowest since 1987 because the offshore, migratory stock of hake did not arrive in Alberni Inlet and Barkley Sound until the middle of July. This is the latest arrival time for migratory hake observed in the four years of this study. Preliminary analyses of the 1990 data indicate that the predation mortality of juvenile salmon in Alberni Inlet and Barkley Sound was probably the lowest since 1987.

Another major research project focused on determining the abundance and distribution of juvenile salmon along the west coast of Vancouver Island, following their migration from the near-shore areas. The first major research survey using the new BERNARD-SIGMUND BEAM TRAWLS was completed successfully in July. This unique new fishing gear was developed by members of the Ocean Salmon Program to sample juvenile salmon, herring, and other commercially important pelagic fish species in the surface waters of the continental shelf and open waters of the North Pacific Ocean. During a sixteen day survey aboard the W.E. RICKER, 329 trawl sets were successfully completed, capturing more than 6,000 juvenile salmon. The abundance of juvenile pink, chum, and sockeye salmon tended to be fairly even from near shore out across the continental shelf. High concentrations of juvenile salmon, were found in one area far offshore near Barkley Sound, and in another close to shore, just south of Brooks Peninsula. In general, the main concentrations of juvenile salmon were found along the outer edge of the continental shelf, rather than near-shore. These results contradict the current, widely accepted, idea that the great majority of juvenile salmon remain within a narrow coastal belt less than 20 miles wide as they migrate north. Large numbers of juvenile fish of several other important species were also captured on this survey, including more than 1,100 sablefish, 61,000 herring, and 800 rockfish. The new data on juvenile sablefish is particularly exciting, as there is little information on the abundance and distribution of the juvenile phase of this important commercial species. (*Contact: N.B. Hargreaves*)

SALMON PRODUCTION

Research programs include stock assessments and information systems for conservation and management of Canada's Pacific salmon resource, biological studies of Pacific salmon, development of computer software and analytical methods for fishery science, and studies of nutrient application to sockeye nursery lakes to increase the catch of sockeye salmon.

Chinook and Coho Assessment

An examination of the accuracy of reported catches of chinook salmon in southern B.C. seine fisheries was completed. Results of the study indicate that the reported catch of chinook in these fisheries significantly underestimates the total catch of small chinook, but that the magnitude of the underestimate varies annually.

To test the feasibility of reducing the incidental catch and total mortality of chinook salmon in seine fisheries, two new programs were implemented. The first involved testing of three seine mesh sizes used in the commercial fishery to define the relationship between body size of salmon and retention within the seine as opposed to "gilling" (becoming caught in the net web), or passing through the mesh. Experimental seine nets provided the first quantitative measurement of these relationships. Larger mesh sizes clearly reduced the catch of small chinook but significantly increased loss and gilling of sockeye salmon. The most desirable mesh will be determined by the "best trade-off" between retention of target species (sockeye, pink or chum salmon) and minimizing retention of small chinook and coho salmon. (*Contact: A.J. Cass*)

In the second program, sonic tracking was used to examine the survival of chinook salmon released from seine nets. Sonic transmitters were inserted into 13 chinook, which were tracked for a total of 172 hours and 673 kilometres. Individual fish were tracked for periods of two to twenty four hours. Further tracking will be conducted in 1991 to increase the sample size. (*Contact: J. Candy*)

Evaluation of the status of the Cowichan River chinook continued with construction of a fish counting weir and trap for biological sampling and broodstock collection. Although the numbers of chinook returning to the river have increased from a record low in 1987, there have not been progressive annual increases. However, very large numbers of small males returned in 1990 which may indicate improved returns in future years. (*Contact: B.E. Riddell*)

Electrophoretic studies of protein variability between chinook populations in southern B.C. continued, confirming differences detected in 1989. The degree of electrophoretic differences between these populations is consistent with their geographic proximity and differences in biological characteristics such as age-at-maturity and ocean distribution. (*Contact: B.E. Riddell*)

Salmon Data Development and Analysis

Specific projects related to the development of salmonid databases and related software included: a computerized mapping program to show catch data in relation to the Pacific Coast; an exchange of salmon production and coded-wire tag data with American agencies; and a database containing wild salmon spawning information (SEDS: the Salmon Escapement Database System) with flexible query and reporting software.
(*Contacts: M.A. Holmes, G. Serbic, G. Hudson, A.R. Kronlund*)

Researchers continued analyses to identify statistical error in the interpretation of fisheries data. An examination of the statistics of embedded replicate coded wire tags demonstrated that embedded codes are inappropriate for variance estimation. A survey of methods for assessing uncertainty in conventional mark recovery experiments has subsequently been compiled. (*Contact: J.T. Schnute*) A second project investigated the use of salmon orientation data to identify behavioral characteristics. A statistical theory has been devised to select one of ten possible behavioral descriptions most appropriate to a given data set. (*Contact: J.T. Schnute*)

In a project examining the mortality of chinook and coho salmon caught and released by sport fishermen, utilization of a new statistical approach demonstrated that hook type affected the location of hooking, which subsequently determined whether the fish survived or died. (*Contacts: A.R. Kronlund, T.J. Mulligan, T. Gjernes*)

An investigation of multiple growth strategies within a single fish population demonstrated that Pacific Ocean perch displayed size-at-age structure consistent with a multiple growth thesis. (*Contact: T.J. Mulligan*)

In a project examining echo integration measurements of offshore rockfish to see if species-specific characteristics could be found, a classification technique was developed which correctly classified up to 97% of the observed fish aggregations. (*Contact: T.J. Mulligan*)

Analysis of preliminary results from an experiment to mark salmon through diets enriched in selected elements indicates that levels of strontium incorporated into a fish scale remain constant. This method would allow marking of all fish from a hatchery without individual handling. (*Contact: T.J. Mulligan*)

Sockeye Biology and Assessment

The freshwater growth of young sockeye is density dependent - the more sockeye fry that enter nursery lakes, the smaller they are at the time they go to sea. Results of a study initiated to determine the effect of the juvenile sockeye size when leaving Chilko Lake on survival in ocean environments clearly indicated a survival advantage for larger smolts. Increases of approximately 20-30% in the size of juveniles resulted in a two to three-fold increase in marine survival. These results are very important for determining the number of adults required to maximize returns of sockeye salmon. (*Contact: M.A. Henderson*)

A study was initiated at Babine Lake to determine whether sockeye that spawn in the lake ("lake spawners") contribute to fry production as efficiently as those that spawn in tributary streams. In most years, part of the sockeye spawning escapement to Babine Lake is prevented from spawning in Fulton and Pinkut rivers and the artificial spawning channels to avoid excessive densities on the spawning grounds. The reproductive success of these "surplus sockeye" is unknown. Research is underway to ascertain whether sockeye which spawn naturally in the lake are genetically distinct and perhaps better able to find and utilize suitable lake spawning habitat than surplus river-spawning sockeye. If the surplus river-spawning sockeye are unable to reproduce successfully by spawning in Babine Lake, there may be opportunities for harvesting the surplus in terminal areas. (*Contact C.C. Wood*)

The northern squawfish is a major freshwater predator of juvenile sockeye. In 1990, the Fishing Vessel Owner's Association volunteered seine fishing equipment and services to remove about 5,500 northern squawfish from Cultus Lake. An additional 2,000 squawfish were removed using trap nets. This represents a total removal of about 15-20% of the squawfish population, estimated at 40,000 fish. The abundance of juvenile sockeye is being monitored to compare survival before and after squawfish removal. The abundance and reproductive potential of squawfish remaining in Cultus Lake are also being monitored to determine how quickly squawfish can "bounce back" after these removals. These results will help to determine whether such predator removal programs can provide sustainable benefits or merely a temporary increase in sockeye production. (*Contact C.C. Wood*)

Juvenile sockeye and kokanee (the non-anadromous form of sockeye salmon) can now be identified before smolting using biochemical genetic procedures. Analysis of samples to estimate the abundance of each form from year to year indicates that sockeye and kokanee do not follow the same four-year cycle in abundance in Shuswap Lake. The factor(s) maintaining four-year cycles in Shuswap sockeye appear(s) to affect sockeye and kokanee differently, despite the fact that both forms are intermixed, compete for the same food while in the lake, and mature primarily at four years of age. Simulation models have demonstrated that four-year cycles might be maintained naturally through the interaction of the predominant age four sockeye with rarer age five sockeye, provided that age at maturation is genetically determined. Experiments were initiated in 1989 and 1990 to investigate the heritability of age at maturation in sockeye. (*Contact C.C. Wood*)

Sockeye enhancement programs in the Stikine and Taku rivers continued with evaluation of the early growth and survival of 1.04 million sockeye fry outplanted to Tahltan Lake on the Stikine River in June 1990, the first joint Canada/U.S. enhancement project on these northern transboundary rivers. The outplanted fry came from eggs taken at Tahltan Lake in 1989 and incubated in an Alaskan hatchery. While overall survival from egg to fry was much lower than expected (only 35%), this still represents a large increase over natural survival. Evaluation studies included limnological observations, hydroacoustic surveys, and beach and midwater trawl sampling to capture both wild and outplanted fry. While very few fish were captured in trawls, beach seine samples indicate comparable survival of enhanced and wild fry for at least the first six weeks of lake residence, although the outplanted fry were smaller. Examination of the smolt run in 1991 will provide further information on growth and survival. (*Contact: R.B. Morley*)

In 1990, 4.8 million sockeye eggs were taken at Tahltan Lake and enhancement activities were expanded to include two Taku system lakes, Little Tatsamenie (1.1 million eggs; fry to be outplanted to Tatsamenie Lake), and Little Trapper (2.4 million eggs; fry to be outplanted to Trapper Lake). Further pre-enhancement baseline data were collected at Trapper, Little Trapper, Tatsamenie, Little Tatsamenie, and Tuya lakes to provide additional information on seasonal and annual variability in food supply and carrying capacity. (*Contact: R.B. Morley*)

Research to improve techniques for identifying stocks of sockeye salmon in mixed-stock fisheries continued. The nematode parasite *Philonema oncorhynci* can be used in conjunction with age to identify Fraser River sockeye caught in northern fisheries. Studies conducted in 1989 and 1990 have demonstrated that it is feasible to detect *Philonema* in sockeye samples from mixed-stock fisheries. This identification technique is simple and cost effective, and can be used as an independent check on the accuracy of estimates from traditional scale pattern analysis. *(Contact: D.T. Rutherford)*

Lake Enrichment and Fraser Lakes Research

Research is conducted to determine the carrying capacity (plankton production) of B.C.'s sockeye salmon (*Oncorhynchus nerka*) nursery lakes and assess the responses of plankton and juvenile fish during lake enrichment and during exceptionally high/low sockeye abundance cycles. Minute phytoplankton, better known as autotrophic picoplankton (APP), are the most important component of production processes in most sockeye nursery lakes. APP respond very rapidly to application of nitrogen and phosphorus fertilizer and are largely responsible for the enhanced primary production seen in treated lakes. Their major predators, microflagellates and ciliates, provide additional food for the zooplankton that are so important in the diet of lake-rearing, planktivorous juvenile sockeye salmon. Whereas food chains based on picoplankton-microzooplankton tend to be long and inefficient in unproductive coastal lakes, they are shorter and more energy efficient in Fraser lakes where larger phytoplankters are more common. Juvenile sockeye rearing in Fraser lakes tend to be larger and grow faster than in coastal lakes. (*Contact: J.G. Stockner*)

Lake Treatment

Five sockeye nursery lakes (Great Central, Henderson, Hobiton, Long and Chilko) were fertilized in 1990. Helicopters were used for fertilizer application in the first year of full-scale fertilization of a Fraser River lake (Chilko), resulting in a 20-30% reduction in costs over the DC-6 water bomber used in previous years. The use of helicopters permitted a more controlled application of fertilizers to the lake surface, resulting in up to 10-fold increases in lake dispersal areas. (*Contact: E.A. MacIsaac*)

Fraser Lakes Research

Studies continued on Chilko, Quesnel and Shuswap lakes. Preliminary data analyses of five year studies of Quesnel and Shuswap lakes indicate considerable spatial heterogeneity in thermal regimes and in water chemistry in both lakes, resulting in a considerable range of productivities in various regions of the lakes. Juvenile sockeye distribution in each lake is variable and

dynamic. Cyclic dominance (four year cycles in juvenile abundance) results in extreme variation in density among years, with substantial effects on phytoplankton and zooplankton. (*Contact: K.S. Shortreed*)

Chilko Lake was fertilized for 12 weeks (June-September) in 1990. Results of preliminary data analyses indicate significantly higher photosynthetic rates and zooplankton density after fertilization. (*Contact: K.S. Shortreed*)

Quantitative measurements of the spatial and temporal distribution of crustacean zooplankton are required to estimate lake carrying capacity and understand the quadrennial cyclic production of sockeye salmon in the Fraser River system. A new technique using advanced hydroacoustic technology was developed for determining zooplankton abundance in large oligotrophic lakes. Tests using this technique were successful in rapidly acquiring and processing large quantities of data for determining detailed zooplankton distribution. Coupled with direct biological sampling, the technique provides better information on zooplankton distribution in sockeye nursery lakes. (*Contact: K.F. Morton*)

Analyses of fish samples collected by midwater trawl are an important tool in obtaining population estimates of fish species from a mixed limnetic population. Where sockeye occur in distinct stratified layers, contamination of the continuously open trawl results in errors in population estimates. To avoid this, a closing trawl system capable of opening and closing at depth was designed and developed for use on small boats. Estimates using the closing system more than doubled previous sockeye abundance estimates made with a continuously open trawl in a lake with three limnetic fish species. (*Contact: J. Hume*)

SALMON HABITAT

Salmon habitat research is conducted to determine the productivity of freshwater, estuarine and marine habitats for salmon stock and habitat management as well as habitat restoration. Research data are provided on the impact of industrial activity including forestry, transportation, wastewater discharge, hydroelectric generation and agriculture on the capacity of the regional habitat base to produce salmon. Projects are conducted to define the utilization of habitats by fish and dependence of fish stocks on specific types of habitats.

Placer Mining

A major study of the biological, physical and economic impacts of placer (gold) mining in the Yukon was completed as was another laboratory-based study on the effects of placer mining sediments on Arctic grayling eggs and juvenile chinook salmon. The results of these studies will be used to validate changes to the Yukon Fisheries Placer Mining Authorization which regulates sediment discharge levels for the protection of aquatic organisms. (*Contact: I.K. Birtwell*)

Oil

A three year experiment was initiated to test the hypothesis that additional stress imposed by exposure of juvenile pink salmon to oil, in addition to other factors normally encountered in the wild, may be reflected in the number of adults returning to natal streams. Batches of 30,000 juveniles were exposed to 'high' and 'low' concentrations of the water soluble fraction of crude oil. Another group of 30,000 served as a control. A total of 90,000 juvenile fish were released into Discovery Passage near Campbell River in 1990. (*Contact: I.K. Birtwell*)

Anti-sapstain Chemical Assessment

Research on the effects of the anti-sapstain lumber treatment chemical was completed, revealing that the new compound is highly toxic to juvenile salmon at parts per billion levels and causes a variety of sublethal effects. (*Contact: I.K. Birtwell*)

Fraser River Pollution Impacts

Knowledge of contaminants and pollution impacts at the sublethal level is essential for preservation of the fisheries resource and habitat management. The objective of Fraser River pollution impacts research is to detect sublethal responses of juvenile chinook and coho salmon to organic and inorganic contaminants and effluents in the Fraser River basin.

Results of a laboratory study measuring the acute lethal toxicities of mixtures of ammonia and Fraser River suspended sediments using underyearling chinook salmon, indicated that the nature of joint toxic action was less-than-additive for ammonia-suspended sediment mixtures. Experimental results based on toxic units were used to define non-lethal and lethal mixtures of un-ionized ammonia and suspended solids. (*Contact: J.A. Servizi*)

Experimental studies with coho indicate that acute lethal toxicity of suspended sediments is temperature dependent. Coho are most tolerant at about 7°C and less tolerant at higher and lower temperatures. In general, the data suggest that tolerance of suspended sediments may be related to capacity to clear the buccal cavity of particles via the cough reflex, which, in turn, appears to be related to oxygen transfer, oxygen saturation levels, metabolic rates and capacity to do work. (*Contact: J.A. Servizi*)

Fish/Forestry Interaction

The relationship between forestry activities and the productive capacities of aquatic environments in the interior of B.C. is poorly understood. Funded under the Green Plan, a project examining the effects of forestry practices on fish stocks in the B.C. interior and the carrying capacity of the habitat occupied by these stocks was initiated in the Stuart/Takla drainage in the Middle River area. Biological and physical measurements are being collected from four adjacent watersheds in the Stuart/Takla drainage. These watersheds are largely unlogged, although logging will begin in approximately two years.

The forest harvest guidelines generated from this study will be applicable to logging throughout central B.C. (*Contact: J.S. Macdonald*)

MARINE FISH DIVISION

The mandate of the Marine Fish Division is to provide advice on the status and consequences of management actions for the groundfish, pelagic fish and invertebrate marine resources of the Pacific Region. Stock assessments are conducted by a team of approximately 60 scientists, biologists and technicians who also undertake research projects to produce data bases and the biological understanding required to conduct stock assessments and develop scientific advice.

Marine Division staff also participate in the annual PSARC stock assessment process, including preparation of assessment and advisory documents for departmental and industry audiences. To ensure effective communication of scientific advice and information to a diverse group of clients, members of the division also attend a variety of formal and informal meetings with industry and other branches of DFO. (*Contact: J. Rice*)

GROUNDFISH RESEARCH

Groundfish research provides the scientific basis for rational management of approximately 60 stocks of fish. Timely and accurate assessments are required to provide advice on appropriate yield and the biological consequences of management strategies. Groundfish research in support of these assessments involves: identification of individual stocks within species; determinations of annual and seasonal abundance and production; determination of biological properties such as growth, longevity, natural and fishing mortality rates, fecundity and life history; and development of mathematical models incorporating these parameters to simulate the stock dynamics and explore the consequences of management actions and environmental events. Substantial research effort is devoted to the development of more complex modelling involving relationships between stocks of different species occupying the same fishing grounds.

Other research objectives reflect our mandate to provide the scientific basis for conservation and management of groundfish resources. Studies focus on the development of increased understanding of recruitment variation through studies of reproductive biology and effects of the biological and physical oceanographic environment on survival trends for egg, larval and juvenile stages, spawning timing and spawning conditions. Other studies examined the biotic and abiotic factors which determine year-class success, particularly for sablefish, Pacific cod and Pacific hake. The La Perouse and Hecate Strait programs will facilitate an examination of the relationship between climate change and ecosystem dynamics.
(*Contact: G.A. McFarlane*)

Stock Assessment

Stock assessments were conducted for lingcod, Pacific cod, petrale sole, Dover sole, rock sole, English sole, sablefish, Pacific hake, spiny dogfish, walleye pollock, Pacific ocean perch, yellowmouth rockfish, rougheye rockfish, redstripe rockfish, silvergray rockfish, yellowtail rockfish, canary rockfish, quillback rockfish, copper rockfish, and hagfish. A number of different analytical methods were employed in the assessments, including surplus production analysis, virtual population analysis, and dynamic pool models. Biological factors were the only consideration for the assessments and yield options. Yield options in the form of catch limitations or other management procedures were recommended to DFO fisheries managers, allowing them to consider high risk and low risk yields in relation to a stock's potential productivity. (*Contact: B.M. Leaman*)

Statistics and Sampling

Maintenance of the catch and effort database for trawl and trap fisheries continued. Logbook records were merged with sales slip information on an interactive system in use for the first time and the database was converted to a tow-by-tow format. Biological data on the species landed (length frequency, sex, age structures, gonad condition, etc.) were collected. (*Contact: R.D. Stanley*)

Pacific Hake

In a hydroacoustic survey of offshore hake biomass from the La Perouse region to Queen Charlotte Sound, hake were found along the 200 m contour extending into Queen Charlotte Sound. Assuming a target strength value of -35.0 dB/kg, the biomass of hake in the Canadian zone was 317,338 t, of which 178,802 t was found north of 49^0 N.

The sixth annual species interaction trawl survey was conducted in August to determine the impact of Pacific hake and other predators on herring survival and recruitment.

Studies examining variation in length-at-age in Pacific hake off Vancouver Island were completed. Male and female hake sampled in the summer off southern Vancouver Island since 1976 show a general decline, plus marked variability, in mean lengths-at-age. Multiple regression analysis related the length-at-age pattern to von Bertalanffy and density-dependent growth, length-selective fishing mortalities and a suite of oceanographic covariates (sea level height, temperature, and salinity anomalies). Because offshore Pacific hake migrate annually between southern California and British Columbia, with larger fish migrating further north, it would appear that the summer fishery in Canadian waters selectively removes the larger hake each year, causing a decline over time in mean lengths-at-age. (*Contact: G.A. McFarlane*)

During a cruise conducted in February,1990 to examine the winter distribution of offshore hake from Canada to the U.S./Mexico border, spawning concentrations were found at approximately 35 and 37^0N and from 60 to 100 nm offshore. The age and length frequencies, age and growth parameters and occurrence of parasites (*Kudoa sp.*) matched those of concentrations fished during summer months in nearshore areas.

Examination of the factors influencing the distribution of offshore hake was continued. Hake concentrate in basins and along the 200m shelf break from La Perouse Bank to Queen Charlotte Sound. Preliminary results indicate the fish occur in association with euphausiid populations. (*Contact: G.A. McFarlane*)

Sablefish

A species interaction trawl survey was conducted in August to assess the impact of sablefish on Pacific hake and herring stocks in the La Perouse region.

A sablefish trap survey was conducted in November off the west coast of Vancouver Island to collect abundance (number and weight) information and biological samples from three selected indexing sites. Traps were set at four discrete (100 fm) depth strata to examine the variation in abundance and life history parameters with depth. Preliminary results indicate that deeper sets contain age frequencies dominated by older and slower-growing fish. The survey will be expanded in 1991 to cover eight sites, coastwide. (*Contact: G.A. McFarlane*)

An examination of biotic and abiotic factors controlling year-class success was completed. Analysis of stomach contents from first-feeding sablefish (*Anoplopoma fimbria*) showed that larval sablefish feed mainly on calanoid copepods. Along the west coast of Vancouver Island these copepods were the dominant zooplankton at the depth that sablefish larvae developed. It appears that strong year-classes in sablefish populations occur in conjunction with exceptional production of copepods. Periods of exceptional copepod production appear to be correlated to climate and ocean conditions. The longevity and fecundity of sablefish probably ensures that a sufficient number of eggs are present in the ocean when the climate and ocean conditions are favourable. (*Contact: G.A. McFarlane*)

Spiny Dogfish

Results of analysis of dogfish age-at-maturity indicate that female dogfish mature at 35 years of age in the Strait of Georgia. This allows the population to maximize the number of young produced. (*Contact: M.W. Saunders*)

Walleye Pollock

Results of a study examining age determination structures from five stocks of pollock in the NE Pacific Ocean indicate that the most appropriate structure/method for age determination may vary among stocks. Pectoral fin-ray sections, otolith surfaces and burnt otolith sections are all suitable structures for stocks consisting of mainly younger fish. For other stocks, the burnt otolith annuli were the easiest to identify. The burnt otolith section consistently produced older age estimates. Using this age structure, it was still possible to identify strong year-classes in Bering Sea pollock in 1978 and 1973. (*Contact: M.W. Saunders*)

Offshore Rockfish

Investigations into slope rockfish school structure, diel behaviour and response to sampling trawls were initiated. Hydroacoustic and trawl sonar equipment was used to examine the diel behaviour of *Sebastes reedi/S. proriger/S. alutus* aggregations, as well as the behaviour of the fish around the mouths of midwater and bottom trawls. The transition from diurnal on-bottom, aggregated patterns to nocturnal, dispersed patterns occurred over a 30 minute period. The timing of the transition was strongly correlated with ambient light conditions. Aggregations of *S. reedi* and *S. proriger* showed no distinct pattern of behaviour within the mouth of the trawl, although aggregations of all species dove with its approach, entering the net in the bottom one-half to one-third of the bottom trawl, although pre-trawling aggregations extended up to 15 m off bottom. It appears that the fishing vessel rather than the trawl may be the major factor influencing fish movements in response to fishing. (*Contacts: B.M. Leaman, R. Kieser*)

A review of the impact of extended fisheries jurisdiction on the conservation and management of fisheries marine fisheries resources on the west coast of Canada noted that, while some stocks had not recovered from pre-extension fishing, most had improved records of production. The benefits were largely associated with data capture, assessments, and

enforcement. The review indicated that the frequency of assessment activities should reflect the underlying biology of the species. The effects of the joint capture of several slope and shelf rockfish species on the management of B.C. rockfish stocks was also examined. The joint occurrence of these species results in a complex management program which attempts to achieve multiple, often contradictory objectives. These programs have been generally successful although the Goose Island Gully stock of *S. alutus* has been maintained well below optimum levels. (*Contacts: B.M. Leaman, R.D. Stanley*)

Lingcod

A research program was initiated in 1989 to develop strategies for rebuilding lingcod stocks in the Strait of Georgia, which have been declining in abundance since the 1940's. Results of larval purse seine surveys conducted in May 1989 and 1990 indicate that peak densities reached 2543 lingcod/km^2 in 1989 and 588 lingcod/km^2 in 1990. SCUBA surveys of nest-guarding male lingcod conducted in early 1990 and 1991 at a reef near Nanaimo showed a decrease in nesting density from 3600 to 2000 nests/km^2 between 1990 and 1991.

Ultrasonic tags were used to monitor lingcod home ranges and homing tendencies in April, 1990. Six lingcod tagged and released at their capture site remained on their original reef throughout the study period. To determine the homing ability of lingcod, five lingcod were moved up to 2.75 km from their capture site and their movements monitored. Four of the lingcod returned to their capture site within 72 hours. Movement occurred only at night. (*Contact: L.J. Richards*)

Pacific Cod

The fecundity of a female fish is an estimate of the number of viable eggs that an individual will release during a single spawning. Pacific cod spawn once a year during February and March. Fecundity was compared for the south-west Vancouver Island and Hecate Strait stocks. Fish from Hecate Strait had a greater fecundity-at-size (weight) than did those from SW Vancouver Island. The difference in fecundity was as much as 20% at the largest sizes of fish. The fecundity-at-size relationship for Hecate Strait was the same as reported in another study 25 years ago, indicating that fecundity is a conservative property. Egg counts ranged from 0.230 million to 5.670 million eggs per fish, depending on the size of fish. Egg size also varied, with smaller oocytes in smaller fish.

A computer model was developed for estimating potential yields for the Hecate Strait cod stock. Stock size estimates indicated that spawning biomass at the start of 1991 would be adequate to provide good recruitment provided there are good conditions of mild water transport during the first quarter of the year. (*Contact: A.V. Tyler*)

Flatfish

A study of the reproductive biology of English sole in Hecate Strait was completed. The spawning period for this species is protracted, with peaks in spawning occurring in September-October and November-January. The timing of spawning is, at least partly, size

dependent, with larger fish spawning in September-October and smaller fish spawning November-January. It appears that fish spawning for the first time spawn separately from the rest of the population. Differences among sexes in growth rate after maturity may be related to different partitioning of energy into growth and reproduction. (*Contact: J. Fargo*)

Hydroacoustics

A Graphic Information System (GIS) was used to analyze digital echograms for bottom and fish schools. The system allows automatic recognition of both bottom and fish schools while logging information on school size, depth, density, etc. This information will be used to develop a school species index. (*Contact: R. Kieser*)

Hecate Strait Program

Four relatively stable fish assemblages have been identified in Hecate Strait. These assemblages were dominated by flatfish species and characterized by depth and bottom type. Although the relative abundances of component species within assemblages did change seasonally, there was little change in dominant species. Geographical boundaries of the assemblages were also relatively stable over the four surveys completed between 1984 and 1989. Persistent boundaries were found in the 50-60 m range and 130-140 m range.

The effect of commercial trawling effort on north and south assemblages was examined. From 1980 until 1987, consistent with the historical pattern, fishing effort expended in northern Hecate Strait more than doubled fishing effort in southern Hecate Strait. Although the levels of fishing effort in both areas were more consistent between 1988 and 1990, there is no evidence that this has influenced the assemblage structure.

Results of analysis of research surveys show no significant differences in diversity or catch rates consistent with expected fishery effects. (*Contact: A.V. Tyler*)

Strait of Georgia Program

The third year of a study examining species interactions in the Strait of Georgia was completed. The factors influencing early marine survival of juvenile salmon released from the Big Qualicum Hatchery have been the focus of study. For the third year, spiny dogfish were the major marine predator in the area, increasing in abundance in the nearshore waters of the Big Qualicum estuary prior to the period of salmon smolt releases from the hatchery. At this time of year, abundance of potential prey species (eg. juvenile herring, euphausiids) is high. During the post release period, juvenile salmon are found in the stomachs of spiny dogfish. For the second year, adult salmon meat was found in spiny dogfish stomachs throughout the year.

A midwater trawl survey conducted at the time of hatchery salmon release in the same area identified some predation by Pacific hake on juvenile salmon. Results of a seine study of the distribution of salmon smolts leaving the Big Qualicum River indicate that smolt residence in the Qualicum area may be affected by peak Fraser River discharges.

A pilot project using sunken gillnets to examine spiny dogfish diet during hatchery releases from the Puntledge River Hatchery was conducted in Comox Harbour. Crustacean species predominated the dogfish diet, although there was some evidence of predation on salmon smolts. (*Contact: B.L. Thomson*)

FISH AGE DETERMINATION

The Fish Ageing Lab aged approximately 68,100 fish, including 40,800 herring, 15,100 groundfish and 12,200 salmon.

Age data and criteria documentation for various freshwater fishes were provided to DOE for dioxin studies. Chinook salmon age data were provided to Habitat for the Nechako Project. Age data were also provided for a Bering Sea pollock ageing workshop held in Poland. Discrepancies in ageing methods between five countries were examined at the workshop. The lab provided age data for calibration for a radioisotope validation study of sablefish otoliths at the Alaskan Fisheries Science Centre.

An examination of eight different bony structures from chinook salmon fed a diet containing tetracycline revealed an identifiable mark (tag). This technique could be used to identify cultured chinook by examining structures used for ageing.

Results of a preliminary age structure study indicate that it may be possible to use fins and scales to age yellowtail.

Mr. Zhongren Guo, a visiting scientist from China, completed a one year visit to the Lab. (*Contact: S.E. MacLellan*)

HERRING RESEARCH

Herring research provides the scientific basis for the conservation and rational management of this resource in B.C. The major research focus is related to population dynamics. This includes the development and evaluation of analytical assessment methodology; development of hydroacoustic assessment methods; studies on recruitment processes and development of recruitment forecasting models; stock identification studies; and studies on the impact of nearshore developments on herring. Research results and advice are communicated to fishery managers, clients and the scientific community.

Larval Distribution and Survival

A survey of larval herring was conducted in the Strait of Georgia in April, approximately three to four weeks after the major herring spawning period. Larvae were observed in the same general locations as in 1989. In both 1989 and 1990 herring larvae were found primarily in shallow nearshore waters throughout the Strait of Georgia. In contrast, groundfish larvae were most abundant in the central, deeper waters of Georgia Strait. It is clear that herring larvae are thoroughly mixed between the many, small spawning areas in the Strait of Georgia. Such mixing of larvae virtually eliminates any probability that each small spawning area represents a separate genetically distinct population. Instead, it is probable that most herring in the Strait of Georgia are part of one large population, although separate, smaller populations may exist in some relatively isolated areas and inlets. (*Contact: D.E. Hay*)

Nearshore Herring Environment

Further funds were committed by the B.C. Ministry of Agriculture and Fish for a cooperative project examining the utilization of fish farm food by wild fish. The objective of the work is to use fatty acid profiles in wild fish to determine if they have been influenced by fish foods provided to netpens. Samples of wild fish were collected in the vicinity of netpens located in southern Johnstone Strait in November and analysis of the samples is underway at PBS. (*Contact: D.E. Hay*)

Winter Herring Survey

Following the fifth in a series of hydroacoustic cruises to estimate total herring biomass in two major winter concentrations on the B.C. coast, herring biomass was estimated at 15,000 t in Browning Entrance and 32,000 t in Juan Perez Inlet. These trends approximate 1990 biomass estimates and conform with the trend for relatively low abundance of herring in the Prince Rupert District. (*Contact: D.E. Hay*)

Juvenile Recruitment

Four surveys of the distribution and relative abundance of juvenile herring in Georgia Strait were completed. Fish were collected for measurement and gut analysis, and plankton

samples were collected for abundance and composition. Nearshore seine catches yielded approximately 100-fold more herring than catches four km offshore. Night-time experimental hydroacoustic surveys conducted in October, 1990 indicated that juvenile herring were ubiquitous, with major concentrations near Crofton, Deep Bay, and Powell River. A plankton layer beyond the 100 m contour was encountered on most transects from the surface to 100 m. However, juvenile herring occurred mostly inside the 100 m contour. (*Contact: C.W. Haegele*)

Biological Sampling, Data Acquisition and Management

Basic biological data for herring stock assessments is collected and verified to ensure the continuity and integrity of the herring data bases. This provides a basis for research into various aspects of herring population dynamics and fluctuations associated with fishery induced and external environmental impacts, such as climate change and oil spills. The primary data sources are spawn survey data, commercial catch landing data, and biological sampling data from commercial fishery, pre-fishery charter, and research catches. The information is available in computer databases for the period 1950 to the present.

Sample collections are concentrated around the roe herring fisheries and spawn surveys conducted during March and April each year. During the 1990/91 season, 118 samples from 16 roe fisheries, 279 pre-fishery charter samples, 11 food fishery samples, and 13 research samples were collected and processed for biological data. A total of 365 kilometres of herring spawn was surveyed by SCUBA divers, mostly Fishery Officers, who collected data along 631 transects. Another 248 kilometres of spawn was surveyed using surface survey methods. Fishery Officers also collected 54 spawn samples for escapement model evaluation. (*Contact: J.F. Schweigert*)

Stock Assessment

Stock assessment research evaluates, modifies, and develops new methods for determining current herring stock status and forecasting abundance for the next fishing season. Annual stock assessments and quota recommendations are provided to PSARC and the fishing industry. Two assessment methods, an escapement model and an age-structured model, are used to determine the abundance of seven major herring stocks.

To provide stock forecasts for the seven assessment regions on the B.C. coast, a weighted run is determined from the two assessment models. The forecast weighted run size for the B.C. herring stocks in 1991 was 186,400 t, which represents a nine percent decrease from the previous year. Herring stocks show natural fluctuations in abundance due to interannual variations in recruitment. A study was conducted to develop recruitment forecasting models for each of the seven herring stocks. A number of models were identified which provide better forecasts of recruitment than assuming the long term historical mean. Further evaluation of these models in conjunction with risk analysis is in progress prior to incorporation into routine stock assessment analyses.

Fisheries management decisions, particularly the establishment of catch quotas, are often

based on the assumption that the point biomass estimates are correct and measured without error. Recognizing that this is not the case for herring, bootstrap analyses of the age-structured assessment model have been conducted and similar studies have been started for the escapement model.These studies evaluate and quantify the statistical variance and hence the degree of uncertainty associated with the estimates of stock abundance generated for fisheries management. (*Contacts: V. Haist, J.F. Schweigert*)

Stock Identification

An understanding of the genetic differentiation of herring populations is crucial to the management of the various herring fisheries along the B.C. coast. Studies of herring population structure were conducted using nuclear DNA analysis, analysis of historical tagging data, and analysis of size and age information.

In the study of genetic differentiation of Pacific herring populations using nuclear DNA analysis, significant difficulties were again encountered in obtaining high molecular weight DNA extractions, apparently the result of excessive temperatures during preservation. Tests determined that high molecular weight DNA could be extracted successfully from tissues preserved in ethanol rather than freezing as had been done previously. However, fewer than 20 fish collected in 1990 provided useable DNA and exploratory probing of these samples proved unsuccessful. (*Contact: J.F.Schweigert*)

Results of a study to estimate the rates of immigration and emigration between herring stocks using historical belly tagging information indicate very low rates of net migration (5-10%) between stocks on the west coast of Vancouver Island. Analyses are underway for other areas of the coast.

An analysis of size and age data for various herring populations throughout B.C. indicates significant differences among the seven assessment regions and supports the concept of discrete minor populations in all assessment regions. However, there is no evidence of differentiation between the two major spawning populations considered to be separate stocks within Georgia Strait. (*Contact: J.F. Schweigert*)

Salmon Herring Interactions

As part of a study investigating the importance of juvenile and adult herring to the growth and survival of coho and chinook salmon within Georgia Strait, 500 salmon stomachs were collected and processed between July and October. Preliminary results indicate that herring form the primary diet for chinook salmon, while a combination of herring and euphausiids are prevalent in coho stomachs. About 30% of the stomachs were empty.

The study is also evaluating herring recruitment or relative abundance of the young of the year herring on the basis of their abundance in salmon stomachs. We found that the 1990 year class was as common in salmon stomachs as the 1986 year class and considerably less common than the relatively large 1987 year class of herring in Georgia Strait.
(*Contact: J.F. Schweigert*)

SHELLFISH RESEARCH

The Shellfish Section provides biological and scientific advice for the conservation, management and enhancement of invertebrate and marine plant resources by conducting research on the distribution, life history, ecology, physiology, and behaviour of commercial invertebrate and marine plant species; conducting resource surveys and sampling of commercial catches for stock assessments; conducting research into the impact of natural and human-induced factors on invertebrate and marine plant habitats; maintaining fishery databases; using and developing analytical methods to advise on appropriate exploitation; providing biological advice to fishery managers, and communicating research results to clients and the scientific community.

Scallop Culture

Program effort was directed towards providing consultation and advice to a newly established commercial scallop hatchery. In spite of start-up problems, the hatchery successfully produced about three million juvenile Japanese scallops (*Patinopecten yessoensis*).

In experimental work to determine causes of mortalities of very young juvenile scallops, examination of the gills of early spat indicated that they may be unable to efficiently filter out cultured, small unicellular algae for feeding.

An experiment to compare the effects of loading densities and wave action on growth and survival of juvenile Japanese scallops in pearl nets during the nursery stage was conducted. Juveniles held under quiet conditions at densities of up to 50 per net showed excellent growth and survival. (*Contact: N. Bourne*)

Mussel Culture

Research continued to focus on the summer mortality of Pacific blue mussels. Transplanted Nova Scotian mussels were reared through the juvenile stage and, while Pacific mussels died after their first spawning as one year olds, no such mortality was observed in the Nova Scotian mussels, which continued to grow. The mortality was not due to local environmental conditions or the result of any obvious disease or parasite, suggesting that it was the result of a natural senescence. (*Contact: G.S. Jamieson*)

Invertebrate Nutrition

The survival of cultured bivalves is largely dependent on the levels of stored energy reserves available to sustain developmental changes during embryogenesis, metamorphosis, or periods of seasonal food deprivation. Stored energy reserves are extremely important during the transition from larvae to juveniles, when locomotion and feeding ability are limited.

Results of a study of the energetic competence of pre- and post-metamorphic rock scallop

(*Crassadoma gigantea*) clearly demonstrated the crucial reliance of early juvenile scallops on the stored reserves accumulated by the pre-metamorphic larvae from microalgal diets. Reasons for the inability of post-metamorphic scallop larvae to assimilate exogenous energy are unclear but are probably due to the inability of the newly metamorphosed juvenile to capture sufficient particles or to digest them adequately. (*Contact: J.N.C. Whyte*)

Clam Studies

Temperature tolerance studies were conducted on two size classes of manila clams at water temperatures ranging from 15°C to 40°C and salinities ranging from 10-40$^{0}/_{00}$. While 94% of the clams died within 15 minutes at a water temperature of 40°C, regardless of salinity level, complete mortality of the remaining clams did not occur for another five hours. The manila clam exhibited remarkable tolerance to high temperatures at a wide range of salinities, and would undoubtedly survive any intertidal temperature increase caused by global warming. (*Contact: J.N.C. Whyte*)

Invertebrate Dive Fisheries

An assessment of abalone stocks on the basis of divefishery logbook records from 1977-1990 was initiated. Data on catch rates and landings are being analyzed to generate annual estimates of commercial biomass, recruitment and exploitation rate. (*Contact: G.S. Jamieson*)

A long-term field experiment was initiated to study geoduck (*Panopea abrupta*) population dynamics and experimentally harvest and reseed geoduck juveniles in two half hectare plots near Gabriola Island. Geoduck growth rates are rapid during the juvenile stage but slow after maturity with some individuals reaching 116 years of age. (*Contact: A. Campbell*)

Growth and size at maturity of horse clams (*Tresus nuttallii*) from two areas in southern B.C. were estimated. Growth rates of *T. nuttallii* from Newcastle Island were slower than those from Lemmens Inlet. Examination of histological sections of gonads indicated that size at maturity occurred at about 68mm shell length (three years of age) for horse clams from Lemmens Inlet. (*Contact: A. Campbell*)

Fishery Studies

Distances between the annual growth rings in geoduck clam shells were analyzed to test for growth trends in the last 80-100 years. These analyses can be used to assess the impacts of climate change and other environmental disturbances. (*Contact: D.J. Noakes*)

An experiment to determine the effects of repeated digging on pre-recruit and recruit manila clams (*Tapes philippinarum)* was initiated in the Baynes Sound area. Experimental plots were established and juvenile manila clams (seed) were marked with fluorescent paint and planted in the plots at a density of 500 per sq m. Different plots will be dug once, twice and four times annually to compare juvenile clam mortalities and assess annual production under different digging regimes. (*Contact: N. Bourne*)

Shrimp and Prawn Studies

Assessment of the biological impacts of a commercial fishery on prawn stocks by experimental manipulation of the commercial fishery in three experimental areas continued. Experimental manipulation was directed towards exploitation rates, seasonal timing and duration of the fishery. Tagging studies to examine seasonal prawn mortality continued. (*Contact: J.A. Boutillier*)

The data base for the west coast shrimp fishery was established in 1973 to determine the variations in abundance of pink shrimp year classes. These assessments are used to make recommendations for management strategies to prevent growth overfishing and to help industry plan for environmentally-induced recruitment failures. The 1990 area swept trawl shrimp survey off the west coast of Vancouver Island was completed. Recommendations to PSARC suggested that the fishery be delayed to prevent growth overfishing in 1991. (*Contact: J.A. Boutillier*)

Crab Studies

Investigations of factors affecting the annual abundance of Dungeness crab (*Cancer magister*) off the west coast of Vancouver Island and the Strait of Georgia demonstrated that these populations are effectively isolated by oceanographic conditions in Juan de Fuca Strait and by larval behaviour. As a result, each population remains reproductively isolated from the other. (*Contact: G.S. Jamieson*)

OCEAN ECOLOGY

The major research goals of the Ocean Ecology group are to quantify the regional distribution and productivity of the planktonic and organisms that form the base of the marine food web, and to learn how these rates and distributions are controlled by oceanographic processes and changed by natural and anthropogenic environmental variability. Major study areas are the continental shelf and slope waters off the west coast of Vancouver Island, the Strait of Georgia, and several major mainland inlets (fjords). Some additional process-oriented and climate-related research is done further afield (e.g. open Subarctic Pacific, California Current system), which provides valuable intercomparisons and interpretation of our observations within Canada's EEZ. Research is often multidisciplinary and collaborative with physical oceanographers at IOS and fisheries biologists at PBS.

Continental Shelf Plankton Studies

The continental shelf waters off Vancouver Island are very productive because of strong seasonal upwelling and mixing of dissolved nutrients into the sunlit surface layer. This vertical input is controlled by physical processes and is often spatially localized around coastline and seabed irregularities. Satellite and shipboard observations make it possible to trace the subsequent biological incorporation and spatial redistribution as the nutrients pass through the food web.

Examination of the role of localized "upwelling filaments" in transporting nutrients and plankton biomass seaward from the immediate coastal zone continued. Off B.C., summer satellite observations frequently show filaments extending more than 100 km seaward from the vicinity of Brooks Peninsula. Sequencing sediment traps and current and turbidity meters were moored beneath the filament track and at a control site outside the filament to monitor the "fallout" of organic matter. Surprisingly, the major difference was between seasons rather than between locations: both sites showed a large sedimentation of surface-produced organic matter in late spring and relatively little during the summer and early autumn. This implies that organic matter transported seaward by the filament in summer is utilized and recycled with high efficiency within the offshore surface layer and relatively little is lost by sedimentation to subsurface layers or the seabed. (*Contacts: J.R. Forbes, K.L. Denman*)

Program staff participated in a comparison study of a very large filament located off the central California coast in 1988. Laboratory and statistical analysis of these samples was completed in 1990. The cold surface water seen in satellite images formed the southern and inshore margin of a narrow (about 20 km) and intense (50-75 cm s^{-1}) jet-like current. A distinctive zooplankton species assemblage and high zooplankton biomass were found within the cold core of the filament. These animals were growing and reproducing rapidly as they were being transported seaward. (*Contact: D.L. Mackas*)

La Perouse

The goal of the La Perouse Project is to quantify the seasonal and interannual variability in physical environmental conditions, plankton biomass and community composition off southern Vancouver Island, and to learn how lower trophic level variability is transmitted up the food web to commercially exploited stocks.

The basic observation program is a standard grid of zooplankton and CTD stations which have been sampled several times annually since 1985. Superimposed on this are more detailed process studies of particular locations or species interactions. Plankton data from the La Perouse Project have been combined with earlier data (1979-1984) to produce composite "average" annual cycles of zooplankton biomass and species mix. These can now be used to calculate annual deviations from the average pattern. Spatial zonation within the study area is quite evident in the zooplankton data and is strongly linked to seabed topography and current patterns.

In general, peak biomass was lowest and earliest on the inner shelf banks, higher and more persistent in offshore and deep water locations. Within each subregion, time series of environmental conditions and population size have been used to estimate local population input and loss rates. On the continental shelf, phytoplankton biomass is generally high and growth conditions for herbivorous zooplankton are excellent throughout the spring, summer and early autumn. Predation mortality is high for large-bodied, visually conspicuous zooplankton species such as euphausiids, but appears to be relatively low for smaller-bodied taxa such as copepods. Advective input and export rates are very important in determining zooplankton biomass and species composition. (*Contact: D.L. Mackas*)

The most extensive red tide on record for B.C. occurred on the Vancouver Island continental shelf in August 1990. High concentrations of *Gonyaulax spinifera* (up to 90 million cells per litre) extended from inner Juan de Fuca Strait at least 400 km northwest to Brooks Peninsula and as far as 100 km offshore. The bloom extended into Nootka and Barkley Sound but no other inlets. *G. spinifera* is not known to be toxic, and PSP toxin concentrations in shellfish from the bloom area generally declined during the bloom period. High mortality of shellfish was reported, especially for Barkley Sound, but the cause appeared to be low dissolved oxygen concentrations rather than toxicity from the phytoplankton. High sea surface temperatures (2° above normal) may have triggered the bloom. (*Contacts: J.R. Forbes, K.L. Denman*)

Inner Coast Macrozooplankton Distribution Studies

Euphausiids (shrimp-like zooplankton, 1-2 cm body length) are an important prey item for many planktivorous finfish species, including salmon, hake, herring, and dogfish. The spatial distribution of euphausiids is extremely patchy. Differences in biomass of a factor of a hundred or more occur between locations separated by a few kilometres, causing large spatial gradients in the availability of euphausiids as prey. The euphausiid patches are dynamic features that move around horizontally and form and disperse daily with the cycle

of diurnal vertical migration. Acoustic mapping surveys indicate a strong association with steeply sloping bathymetric features such as bank edges, fjord sills, and the continental shelf break. We are now exploring the cause for this spatial association in the Strait of Georgia and neighbouring inlets. It appears to be an interaction between the swimming behaviour of the euphausiids, their transport by ocean currents, and the perturbation of current speed and direction caused by irregularities in seabed topography. (*Contacts: D.L. Mackas, D.R. Yelland, D.F. Moore*)

Benthic studies

Benthic invertebrates provide the food supply for many demersal finfish species. Because of their low motility, they are also valuable indicators of local environmental quality, and in particular the impact of and recovery from episodic or point source pollution events. Work in 1990 included processing and statistical analysis ofsamples from Alice Arm and Vancouver Harbour, plus completion of baseline surveys of all major mainland inlets north of Howe Sound. Recovery of the Alice Arm benthic community has been progressive since the tailing release ceased in 1982 and is now nearly complete. Work has also continued on the taxonomy and evolutionary biology of aquatic oligochaetes (an important indicator group), resulting in several publications in scientific journals. (*Contacts: R.O. Brinkhurst, D.F. Moore*)

AQUACULTURE DIVISION

The Aquaculture Division consists of the Fish Health and Parasitology, Biotechnology, Genetics and Nutrition, and Fish Culture sections, and has functional responsibility for invertebrate and marine fish species aquaculture. The Division Head acts as the contact point for liaison with the aquaculture industry and for federal/provincial relations related to aquaculture in B.C. (*Contacts: T.A. Tebb, J.A. Boutillier*)

BIOTECHNOLOGY, GENETICS AND NUTRITION RESEARCH

The activities of the Biotechnology, Genetics and Nutrition Section are directed towards the development of technologies for improving the feasibility and economic viability of commercial finfish aquaculture. The Biotechnology and Genetics components of the section comprise the DFO Centre of Disciplinary Expertise (CODE) for Biotechnology and Genetics in Aquaculture. (*Contact: E.M. Donaldson*)

Reproduction Biotechnology

Research and technology transfer efforts are focusing on assisting the aquaculture industry with the production of monosex stocks of chinook salmon from diverse genetic backgrounds, optimization of treatment parameters and implementation of hormonal (direct feminization) and chromosome set manipulation techniques for the production of monosex female stocks of Pacific and Atlantic salmonids. This research is being conducted in collaboration with commercial hatcheries. (*Contacts: E.M. Donaldson, I.I. Solar*)

Research continued on the investigation of alternatives for the production of sterile salmon for aquaculture. Studies underway include the use of androgens and the induction of triploidy (and triploid-female fish) by heat and pressure shocks. Studies on the effect of the combined application of heat and electroshock on the induction of triploidy in coho salmon were conducted in collaboration with the Laboratory for Aquaculture, Ruder Boskovic Institute, Yugoslavia. Results indicated that heat shocks applied in combination with electric shocks are more effective in inducing triploidy in coho salmon than heat shock alone. (*Contacts: E.M. Donaldson, I.I. Solar*)

A study on the use of photoperiod control to delay sexual maturation and extend the fall market window for cultured salmon demonstrated that exposure to long photoperiod delays the endocrine changes associated with sexual maturation in coho and chinook salmon. (*Contacts: E.M. Donaldson, W.C. Clarke*)

Biologically Active Peptides

Studies continued to characterize the permeability of the fish gut to production-related therapeutants. The salmonid gut is able to transport a wide variety of intact, and physiologically active, peptides and proteins. Comparative studies with other fish species indicate that this phenomenon is perhaps universal for all vertebrate species. Results generated so far indicate that this technique may be used to deliver therapeutants to fish orally, offering a means of controlling production-oriented metabolic processes in cultured finfish, without requiring anaesthetization and handling. (*Contacts: E.M. Donaldson, E. McLean*)

While oral administration is the preferred means of therapy for cultured finfish, this method requires much greater quantities of bioactive material to produce the responses obtained using following injections. Thus, methods of modifying the absorption of specific bioactive materials were examined to reduce the dosage required for maximum physiological effects. Three strategies were used: 1) protection of material from the acidic environment of the stomach with various antacids; 2) delivery of materials in conjunction with anti-enzymes to limit the action of luminal proteases and; 3) simultaneous administration of bioactive material with a range of absorption enhancers and mucosal penetrants. Successful application of these techniques was achieved with salmonids and field trials are currently underway. (*Contact: E. McLean*)

Long-term studies on the effects of accelerating growth in coho salmon with a sustained release device capable of delivering somatotropins over a $\geq$ 16 week period entered their second year. Animals which received somatotropin therapy for a period of 20 weeks retained their growth advantage over control animals, demonstrating the utility of this approach. A patent application entitled "Controlled Release Delivery of Growth Hormone to non human animals" was filed with the U.S. patent office. (*Contacts: E.M. Donaldson, E. McLean*)

The ability of triploid salmonids to respond to external somatotropin therapy was also examined. Previous studies indicated that these animals grew less effectively than normal diploid fish when maintained under identical conditions. Triploid fish, injected and fed with somatotropin, grew as well as diploid controls. Results of an evaluation of the potential of hyperosmotic immersion as a means of delivering somatotropin to salmonids demonstrated successful growth acceleration following shorter immersion periods than previously reported. The shorter immersion periods significantly reduced levels of stress in treated fish. (*Contact: E.M. Donaldson*)

A variety of peptides were evaluated for their efficacy in controlling the release of growth hormone from the salmonid pituitary after *in vivo* administration. This study provided novel information on the effects of peptides in salmonids. (*Contacts: E.M. Donaldson, E. McLean*)

Molecular Biology

Molecular biology studies were directed towards: improvement of growth; control of reproduction and; development of diagnostics for environmental pollutants and stress-inducing compounds.

Two sockeye salmon growth hormone genes were isolated and completely sequenced (the first characterization of both genes from any fish), providing genetic tools for a number of current projects. Growth hormone genes were injected into Pacific salmon eggs to produce a new (transgenic) genetic strain with accelerated growth characteristics. (*Contact: R.H. Devlin*)

Insulin-like growth factors (IGFs) are proteins produced in response to growth hormone treatment and are believed to be direct mediators of growth in vertebrates. In a project funded by Monsanto Canada, four forms of IGF were isolated and sequenced from chinook salmon. These genes are being used in the transgenic program and to monitor the molecular response of the gene to external growth hormone treatment. (*Contact: R.H. Devlin*)

Studies of the DNA sequence of noncoding regions of growth hormone genes from Pacific and Atlantic salmon and rainbow trout has demonstrated that the latter species belongs to the genus *Oncorhynchus*. The studies provide information that allows clear distinctions to be made between different species and varieties of fish for regulatory and management purposes. (*Contact: R.H. Devlin*)

Controlled Reproduction

Controlled reproduction technologies have had a major impact on the profitability of salmon farming in Canada. Two projects within the molecular biology program have been undertaken to extend and refine methods for the production of monosex stocks, while another two projects are developing effective methods for genetic containment to allow introduction of genetically altered fish into the aquaculture industry.

The first Y-chromosomal DNA sequence from any fish species was isolated. This probe can be used to determine the genetic sex of chinook salmon and has been used to verify existing, and facilitate development of new, all-female (monosex) populations for the aquaculture industry. A rapid polymerase-chain-reaction-based assay was developed and transferred to a biotechnology company to provide this service for the aquaculture industry. Work is currently under way to isolate a similar probe for Atlantic salmon and rainbow trout. (*Contact: R.H. Devlin*)

Aromatase is a key enzyme involved in the regulation of sexual differentiation (converts testosterone to estrogen). A clone for this enzyme has been isolated, allowing study of its structure and function, and for its production in transgenics.

A comprehensive evaluation of the fertility of interspecific hybrids of Pacific and Atlantic salmon and rainbow trout was completed. Results of the study will be used by programs designed to utilize hybrids to produce new strains of salmon for aquaculture and in determining the potential genetic threat of escaped non-native species.

Effective reproductive containment of genetically altered salmonids will be required before introduction into commercial aquaculture facilities can be considered. A gene construct was designed for use in transgenic animals to cause germ-line lethality and subsequent infertility. It has been introduced into coho salmon on an experimental basis. (*Contact: R.H. Devlin*)

Preliminary work was initiated to develop sensitive molecular assays to allow detection of the biological response to environmental pollutants and stress-inducing factors. Salmonid gene probes were isolated for metallothionein, an enzyme activated by exposure to metals, and stress-shock proteins. (*Contact: R.H. Devlin*)

Salmon Genetics

The B2-2 probe, a chinook salmon DNA fragment, was found to produce DNA fingerprinting patterns when hybridized with DNA extracted from other chinook salmon. The probe can be used to visualize unique DNA band patterns for individual fish. DNA was extracted from Big Qualicum chinook salmon parents and offspring to confirm that each individual inherits some bands from each parent. The DNA patterns of closely related fish are more similar than those of distantly related individuals. The probe may prove useful for pedigree analysis of domesticated chinook salmon stocks. (*Contact: R.E. Withler*)

The B2-2 probe produces stock-specific DNA band patterns when it is hybridized to DNA extracted from other chinook salmon treated with the Bam H1 restriction enzyme. The band patterns from 10 chinook stocks (50 fish per stock) are now being quantified. The nucleotide sequence of the B2-2 probe is being determined so that simplified methods (using the polymerase chain reaction) can be developed to use the B2-2 probe to screen chinook salmon DNA samples for stock identification. (*Contact: R.E. Withler*)

The first selected generation (F1) of coho salmon was produced in each of an odd-year and an even-year broodline of coho salmon to improve smoltification, BKD resistance and saltwater size in the odd-year broodline (spawned in 1989), and to improve smoltification and saltwater size in the even-year broodline (spawned in 1990). In both broodlines, smoltification and a correlated trait, freshwater growth rate, were higher in the selected families than in unselected Kitimat control families. In the odd-year broodline, saltwater weight in the selected families was greater than in the control families, but there was no difference between selected and control families for BKD resistance. Saltwater weight in the even-year broodline will be measured in March 1992. (*Contact: R.E. Wither*)

Crosses among chinook salmon from ocean-type (Conuma River) and stream-type (Quesnel River) populations have shown that the ocean-type juvenile life history pattern (photoperiod-independent smoltification at age 0+) is dominant in F1 hybrids. F1 crosses and backcrosses are now being reared to determine whether life history pattern is under Mendelian (single gene) or polygenic control. (*Contacts: W.C. Clarke, R.E. Withler*)

Fish Nutrition

Research was directed towards: 1) optimization of the amount of dietary protein in relation to non-protein energy (mainly lipid) for culturing chinook salmon in sea water; 2) improvement of the digestibility and quality of protein furnished by marine fish sources in diets for cultured salmonids; 3) identification and development of suitable economical alternative plant protein sources to expensive fish meal for use in diets for cultured salmonids and; 4) optimization of

salmonids and; 4) optimization of feeding husbandry practices e.g. period of starvation in relation to refeeding and ration level in relation to degree of exercise for chinook salmon in sea water. (*Contact: D.A. Higgs*)

FISH CULTURE RESEARCH

Fish culture research is directed towards developing culture methods for salmonids and marine fish species. Experiments are conducted on incubation of eggs of salmon, sablefish and halibut, development and nutrition of sablefish and halibut larvae, the influence of environmental factors such as temperature and light on growth, development, and sexual maturation of salmon, sablefish and halibut, and examination of new husbandry techniques to maximize efficiency of feed utilization by salmon in commercial salmon farms.

Incubation and Water Quality

A collaborative project was initiated with the Salmonid Enhancement Program (SEP) to develop methods for more efficient operation of spawning channels. The study involved monitoring, identifying and developing quantitative relationships for conditions in spawning channels (i.e., water flow and dissolved oxygen requirements) that influence or limit development and survival of salmonid fishes from egg fertilization to emergence. Initial results indicated that water flows could be reduced by approx 25% without having any adverse effects on egg survival. This allowed the operator to reduce flows during winter floods so as to decrease accumulation of silt in the channel.

A series of 10 computer programs (six incubation programs, two rearing programs, and two total gas pressure programs), were developed in collaboration with SEP. These programs will be useful for salmon fish culturists, college and university students, biologists, and fisheries researchers interested in salmonid egg and larval development and juvenile rearing. The egg and larval development models can also be used to predict the potential adverse effects of global climatic change.

Another PBS/SEP project was conducted at the Quinsam River Hatchery to determine the relationship between egg size and fry mortality syndrome in chinook salmon. Eggs were sorted into three size groups to facilitate transfer of fry to feeding ponds at different times corresponding to their size-dependent developmental rates. Fry from large eggs consistently exhibit significantly greater mortality than fry from small and medium eggs. The results indicate that the incidence of fry mortality syndrome can be reduced by sorting eggs into homogeneous size groups. (*Contact: J.O.T. Jensen*)

Aquaculture Environmental Factors

Progeny of crosses between coastal and interior populations of chinook salmon were reared in the laboratory to ascertain whether different patterns of growth and smolting are environmentally or genetically determined. The first generation hybrids exhibited the "ocean-type" pattern of smolting of the coastal population. When the hybrids were backcrossed to the interior parental type, the resulting offspring exhibited a bimodal size distribution comprised of larger smolts and smaller parr, demonstrating that differences in freshwater life history patterns among chinook populations are genetically controlled. (*Contact: W.C. Clarke)*

Aquaculture Seawater Husbandry

Improved efficiencies in the utilization of feed by salmon in seawater netpens would considerably reduce operating costs for commercial salmon farming. Currently, feeding costs account for about half of the variable operating costs for commercial salmon farms. Results of a laboratory study measuring the growth and feed conversion efficiency in relation to ration level and water temperature. showed that temperature had a strong influence; optimum growth and feed conversion rates were obtained between 10.5 and 12.5°C, independent of ration level. Reducing the ration level to 80% of satiation yielded considerably better all-round growth than did rations either at 100 or at 60% of satiation. (*Contact: H. Kreiberg*)

A second experiment was conducted at EWOS Canada's research farm to examine the effect of diet type and feeding method. Better growth and conversion rate was obtained with the use of a high quality diet and hand feeding. The lowest efficiency was obtained when using lower quality diets fed and demand feeders. (*Contact H. Kreiberg*)

Marine Fish Culture

Sablefish and halibut presently support the two most important groundfish fisheries along the Pacific coast. Full utilization of the existing wild stocks and continued market demand for a quality product has stimulated interest in the cultivation of these species for enhancement and aquaculture. Sablefish eggs collected at sea were incubated in upwelling cone incubators with 50% survival to hatch and 5% survival to start of feeding. Captive female halibut broodstock ovulated repeatedly for the first time at PBS and 90,000 fertilized eggs were obtained. (*Contact: W.C. Clarke*)

Larval Fish Nutrition

Fatty acid profiles of eggs of English sole (*Parophrys vetulus*), sablefish (*Anopoploma fimbria*), and halibut (*Hippoglossus stenolepsis*) suggest that high levels of these essential fatty acids are required in the diets of cold-water larval fish. Commonly used larval fish diets include the rotifer, *Brachionus plicatilis*, and the brine shrimp, *Artemia salina*. During feeding trials blackcod larvae were given *B. plicatilis* fed with the algae *Nannochloropsis oculata*, Tahtitian *Isochrysis*, or *Chroomonas salina* for 40 days after first feed, after which they were given brine shrimp (also fed *N. oculata, T. Isochrysis* or *C. salina*) for 40 days. No larval sablefish survived beyond 60 days of exogenous feeding. Ranking the diets against survival and size gain of fish larvae corresponded to dietary rotifers fed *N. oculata*, Tahitian *Isochrysis* and *C. salina* in declining order of effectiveness. Survivability in these feeding trials was correlated with the content of essential fatty acids supplied by the *B. plicatilis* diets. Larval mortalities increased markedly upon conversion to the *A. salina* diets. It would appear that sablefish larvae mortality was due in part to insufficient essential fatty acid content in the diets. Future investigations will focus on culturing zooplankton with essential fatty acid levels suitable for cold-water larval fish growth and development. (*Contact: J.N.C. Whyte*)

FISH HEALTH and PARASITOLOGY RESEARCH

Research is directed towards determining causes of diseases of fish (particularly salmonids) and shellfish and at developing methods for their prevention and control in government enhancement facilities and commercial aquaculture. Staff participate in the development and implementation of policies to prevent the introduction and spread of diseases of aquatic resources in the Pacific Region and organize and participate in fish health workshops and courses. Research is also directed at assessment of the impact of diseases and parasites on the ocean survival of salmon and exploring the use of parasites as natural markers for stock identification in salmon for domestic and international fisheries management. (*Contacts: L. Margolis, T.P.T. Evelyn*)

Bacterial Kidney Disease (BKD)

Results of tests to determine whether vertical transmission of the causative agent of BKD, *Renibacterium salmoninarum* (Rs), can be prevented by a "broodstock injection technique" yielded very promising results. Vertical transmission of the pathogen was almost entirely eliminated in naturally and heavily infected female pink salmon that received a single prespawning injection of the antibiotic erythromycin or the antibiotic combination erythromycin-rifampicin: only one of a total of 450 eggs examined from the treated females (50 eggs per female) proved positive for viable Rs. In contrast, the single heavily infected female from the untreated control group that survived to spawn yielded eggs with an unprecedented infection rate of 62%. These tests confirm results obtained earlier with experimentally infected coho salmon in which vertical transmission of Rs was completely prevented using erythromycin. If field tests yield similar results, a major source of Rs infections on salmon farms will have been eliminated. (*Contact: T.P.T. Evelyn*)

Studies to explain why Rs is the only bacterial pathogen of salmonids commonly transmitted from parent to progeny via the egg have revealed that the bacterium's resistance to high levels of the enzyme lysozyme may be a factor. The enzyme, bactericidal for a number of bacteria, was found to occur in salmonid eggs in high concentrations (ca. 2000 units per mL of yolk). Rs proved refractory to the enzyme at these levels. Other bacteria, including pathogens frequently found in spawning salmon (*Aeromonas hydrophila, A. salmonicida, Lactobacillus piscicola*), all proved highly susceptible to the enzyme. (*Contact: T.P.T. Evelyn*)

Vibriosis

Using highly purified cell wall component (lipopolysaccharide = LPS) from *Vibrio ordalii*, one of the causative agents of vibriosis in pen-reared salmon in B.C., we proved that the active immunizing component of the pathogen is LPS. The LPS was extremely immonogenic, picogram (pc) quantities being sufficient to elicit strong anti-vibrio immunity in individual fish (< 100 pc per 5 g fish). Using this potent substance, it was demonstrated that immunization by injection stimulated the same type of immune response (a systemic response resulting in circulating antibodies) as immunization by immersion and that the circulating antibodies consitituted the important protective arm of the response. A localized

skin-associated immune response, reported to be of survival value in some fish, could not be demonstrated in Pacific salmon. The only difference in immune response that occurred as a result of administering the LPS by different methods (i.e., injection versus immersion) was in the strength of the response. Injection resulted in a stronger immune response. This difference was most likely a reflection of the fact that injection permits larger quantities of immunogen to reach and stimulate the immune system. (*Contact: T.P.T. Evelyn*)

Infectious Hematopoietic Necrosis (IHN)

The infectious hematopoietic necrosis (IHN) virus causes high mortality in sockeye salmon in spawning channels and lakes at several locations in B.C. It is found in some of the lakes being used by the B.C. salmon farming industry for netpen rearing of chinook and Atlantic salmon. In addition, some salmon farmers are rearing sockeye salmon, which could be carriers of the virus, along with chinook and Atlantic salmon in seawater netpens. Studies were conducted to investigate the susceptibility of chinook, sockeye, and Atlantic salmon to IHN using waterborne exposure to the virus in fresh and sea water, and by cohabitation exposure to infected salmon. The disease was readily transmitted to sockeye and Atlantic salmon by freshwater and seawater exposure, and by cohabitation with infected fish in sea water. Atlantic salmon were found to be more susceptible to IHN than chinook and sockeye while in seawater. Results of the study indicate that IHN is of potential concern for netpen culture of Atlantic salmon. (*Contacts: G.S. Traxler, M.L. Kent*).

Plasmacytoid Leukemia (Marine Anemia) in Chinook Salmon

Plasmacytoid leukemia (PL), an infectious disease of pen-reared chinook salmon, continued to cause high losses at several fish farm sites in the Sechelt area. The disease was also detected at several sites in the Campbell River area and on the west coast of Vancouver Island. In laboratory experiments, PL was easily transmitted between chinook by intraperitoneal injection of affected tissue. The disease was also experimentally transmitted to sockeye salmon and Atlantic salmon, although it has not been detected in any pen-reared salmon other than chinook. It has been established that a retrovirus is associated with PL and studies are now underway to determine if this virus is the cause of the disease. (*Contact: M.L. Kent*)

Netpen Liver Disease of Atlantic Salmon

With the expansion of netpen culture of Atlantic salmon in B.C., the prevalence of netpen liver disease (NLD) in cultured Atlantic salmon has increased. Observations and experiments suggest that NLD is caused by a natural hepatotoxin in the biota growing on netpens. Fish are apparently exposed to the toxin by feeding on this biota. If this hypothesis is correct, it should be possible to control NLD by keeping the netpens clean. Laboratory studies are underway to determine the source and identity of the toxin. (*Contact: M.L. Kent*).

Disease Control Activities

Activities in the Fish Pathology Program are directed towards determining the cause of disease or poor health among fish reared in Federal culture facilities. Other functions of the program include recommending corrective measures for disease problems; monitoring the occurrence and distribution of diseases among the wild salmonid stocks of the Pacific Region; administering the Canadian Fish Health Protection Regulations; and providing assistance to the Federal/Provincial Transplant Committee which adjudicates applications for the transplant of fish within B.C. (*Contacts: G.E. Hoskins, D. Kieser*)

A disease survey of mountain whitefish collected from the Columbia River and Kootenay River system was recently completed. The types of abnormalities observed were generally characteristic of chronic irritations; increased susceptibility to parasites and stress-related bacterial infections indicated that the general health of the Columbia River whitefish, as compared to fish from the Kootenay River, was impaired. Before corrective measures can be taken, the environmental factor that causes this impairment must be identified. (*Contacts: G.E. Hoskins, D. Kieser*)

Poor environmental conditions (particularly high water temperatures) were thought to be the cause of a severe sea lice infestation in sockeye salmon returning to Sproat Lake on Vancouver Island in 1990. Ninety percent of the migrant adult sockeye gillnetted from Alberni Inlet late in the run were heavily infested with lice. (*Contact: G.E. Hoskins*)

Testing for certification purposes under the Canadian Fish Health Protection Regulations, was carried out at six freshwater fish farms. (*Contact: D. Kieser*)

In addition to the requirements of the Fish Health Protection Regulations, extra safeguards for disease control were applied to Atlantic salmon eggs imported into B.C. from eastern Canada where the viral disease infectious pancreatic necrosis is enzootic. These safeguards included inspection of quarantine facilities that housed Atlantic salmon eggs imported by five salmon farming companies and health checks to ensure that the resulting fry were healthy. (*Contacts: G.E. Hoskins, D. Kieser*)

Monitoring of the occurrence and distribution of fish pathogens within the Pacific Region continued. (*Contacts: G.E. Hoskins, D. Kieser*)

Shellfish Diseases

In addition to routine surveys conducted on native littleneck clams and manila clams from two different localities in B.C., imported flat oysters (*Ostrea edulis*) from Nova Scotia and Scotland were assayed and found free of *Bonamia ostreae* (a pathogen that has devastated the flat oyster industry in Europe). In addition, two populations of Pacific oysters (from Puget Sound, Washington and Barkley Sound, B.C.) were assayed and found free of Denman Island Disease. Unusually high mortalities and green pustules in shucked Pacific oysters from a newly established culture facility on Nootka Island, B.C. were found to be caused by

Denman Island Disease accidentally introduced with seed purchased from a contaminated source. Disease certifications were carried out on one group of oysters to permit export to the United States. (*Contact: S.M. Bower)*

The cause of high mortalities (greater than 75%) and inflammatory lesions (up to 100%) among cultured Japanese scallops during the grow-out phase at seven localities in 1989 was attributed to infection with an intracellular bacterium that invades the haemocytes (the scallop's defence cells against disease). The causative bacterium has been successfully maintained in the laboratory by serial passage in scallops. Attempts to culture the bacterium and develop a treatment are in progress. (*Contact: S.M. Bower*)

Laboratory studies on the protozoan parasite *Mikrocytos mackini,* the cause of Denman Island Disease in oysters, indicated that a modification of methodology used to obtain purified suspensions of a related pathogen (*Bonamia ostreae*) from the flat oyster can be used to concentrate *M. mackini.* The concentrated suspension was infective for Pacific oysters and produced extremely heavy and lethal infections within seven weeks. The ability to produce heavy infections in the laboratory should facilitate the development of sensitive techniques for detecting the pathogen and facilitate the selection of disease resistant oysters.

(*Contact: S.M. Bower*)

A new disease, first observed in a few prawns (*Pandalus platyceros*) from Howe Sound in 1989, was associated with a rickettsia-like intracellular bacterium. Preliminary laboratory studies have indicated that this disease is infectious and lethal. To date, diseased prawns have only been observed from various localities throughout Howe Sound. However, field sampling suggests that the more severely affected areas in Howe Sound have about one half the population density as those with low or no infections. (*Contact: S.M. Bower*)

Parasite-Caused Diseases in Netpen-Reared Salmonids

Juvenile salmonids reared in netpens in B.C. lakes for subsequent transfer to seapen farms or for release in streams to enhance stock production are subject to infection by nematodes of the genus *Philonema.* The nematodes localize in the body cavity of the fish, causing accumulation of large amounts of fluid, with accompanying distention of the abdomen and subsequent mortality. Studies on the biology of the parasite in pen-reared steelhead and coho in O'Connor Lake on northern Vancouver Island, indicated that the parasite has an annual life cycle, with infections apparently acquired mainly prior to July. After several months of growth and development, the parasite matures by the following spring. The infective stage of the parasite develops in a cyclopoid copepod, which is eaten by the pen-reared salmonids. The annual developmental cycle suggests a possible method of control related to time of stocking in the lakepens. (*Contacts: L. Margolis, T.E. McDonald*)

A juvenile tapeworm (*Gilquinia squali*) infection in the eyes of seapen-reared chinook salmon was associated with mortalities among juvenile fish at several farm sites in B.C. The adult tapeworm occurs in the intestine of dogfish, *Squalus acanthias,* which often congregate around netpens, providing infective stages that are transmitted to salmon through an as yet

unidentified crustacean. The parasite is found in dogfish throughout the year and seems to have an annual developmental cycle. The majority of ovigerous worms are found from April to June and the newly acquired worms are found from October to February. (*Contacts: L. Margolis, M.L. Kent, D.J. Whitaker*)

Sea lice (parasitic copepods of the family Caligidae) are one of the most important causes of mortality among seawater farmed salmonids. The common species of sea lice in B.C. salmon farms are *Lepeophtheirus salmonis* and *Caligus clemensi*. A third species, *Lepeophtheirus cuneifer*, was recognized in 1990-91. Experimental studies confirmed that Atlantic salmon are most susceptible to *L. salmonis*, coho least susceptible, with chinook intermediate between these two species. Developmental rates of *L. salmonis* were related to temperature and salinity. Toxicity tests of the chemotherapeutant Ivermectin, a potential sea lice control substance, indicated that Ivermectin was not toxic for seawater-reared rainbow trout when fed every third day for 42 days at 0.05 mg or 0.1 mg/kg of fish. (*Contacts: L. Margolis, M.L Kent, D.J. Whitaker*)

Biology of Myxosporean Protozoans

Myxosporeans are important parasites of salmonids and other fishes. Some of them cause disease, others affect the quality of fish products, while others have proved useful as biological tags for stock identification. Although myxosporeans are common parasites of fishes, their life cycles have been an enigma and the parasites cannot be transmitted directly from fish to fish. Aquatic oligochaetes have been implicated as intermediate hosts for some myxosporeans. *Myxobolus arcticus*, a parasite of the central nervous system of salmonids, is being used as a model species to investigate the life cycle of *Myxobolus* spp. This myxosporean has been transmitted in the laboratory by exposing sockeye salmon to an aquatic oligochaete, *Eclipidrilus* sp. (Lumbriculidae), collected from a lake where the myxosporean infection is prevalent in salmon. This finding indicates that the worm is a vector, if not an intermediate host, of *M. arcticus*. Studies are underway to determine if *M. arcticus* undergoes development in the worm. (*Contacts: M.L. Kent, L. Margolis, D.J. Whitaker*)

Myxidium salvelini is a freshwater-acquired myxosporean parasite of the kidneys of salmonids. Because of its disjunct distribution among Fraser River stocks of juvenile sockeye salmon it is potentially useful, in combination with other parasites, for distinguishing among stocks of Fraser River post-smolts caught in the Strait of Georgia. However, until recently, the duration of the parasite's survival after seawater entry of sockeye smolts was unknown. Results of experiments involving confinment of smolts in fresh and sea water, demonstrated that spore production of *M. salvelini* ceases within 12 weeks after seawater entry of smolts, but resumes if fish are returned to fresh water. This indicates that the infection persisted in a latent or arrested form during the seawater holding period. This is the first time that this type of arrested development has been demonstrated for a myxosporean. (*Contacts: L. Margolis, M.L. Kent*)

MARINE DIVISION

The Marine Division provided ship, launch and depot support for scientific and hydrographic programs, fisheries patrol vessels and research conducted by other federal agencies and universities.

FRV CALIGUS Home Port: PBS
Length 17 metres; gross tonnage 41.36

The CALIGUS spent 149 operational days and steamed 3086 miles in support of Biological Sciences Branch activities related to salmon and shellfish in the Strait of Georgia and Howe Sound.

FRV W.E. RICKER Home Port: PBS
Length 58 metres; gross tonnage 1105.52

The W.E. RICKER steamed 27041 miles in 209 days in support of Biological Sciences Branch activities related to salmon, herring, hake, groundfish and rockfish surveys off the west coast of Vancouver Island, Hecate Strait and offshore waters. She made one trip to the California coast and another to Honolulu.

JOHN P. TULLY Home Port: IOS
Length 69 metres; gross tonnage 2199

The JOHN P. TULLY steamed 14,966 metres in 171 days in support of work conducted by Ocean Physics, Ocean Chemistry, the Pacific Geoscience Centre (PGC), the University of British Columbia (UBC), the Royal B.C. Museum and the Defence Research Establishment Pacific (DREP). The vessel made one trip to Ocean Station Papa.

PARIZEAU Home Port: IOS
Length 64.3 metres; gross tonnage 1414

The PARIZEAU steamed 23149 miles in 199 days in support of work conducted by Ocean Physics, Ocean Ecology, Ocean Chemistry, Tides and Currents and PGC. The vessel made two trips to Ocean Station Papa and performed S.A.R. duties during the roe herring fishery.

VECTOR Home Port: IOS
Length 64.3 metres; gross tonnage 516

A total of 211 operational days and 12086 miles were dedicated to Ocean Physics, Ocean Chemistry, Tides and Currents, Ocean Ecology, PBS, Environmental Protection Service, DREP and UBC projects.

R.B. YOUNG Home Port: IOS
Length 32.3 metres; gross tonnage 299.96

The R.B. YOUNG steamed 3497 miles in 166 days in support of Hydrography. The vessel also performed S.A.R. duties during the roe herring fishery.

Barges **L. PACIFICA** and **PENDER**
Home Port: IOS

Between April and October, the PENDER was used to support oceanographic activities in Hecate Strait. The L. PACIFICA supported MASS program field work in Barkley Sound and Nootka Inlet from April until August.

Depot Workshops

Major refits on the BONILLA ROCK and KITIMAT 2 were completed, including rebuilding of all mechanical systems and wiring renewal. Main engines were overhauled on the ATLIN POST, BAJO REEF and COMOX POST, and new engines installed on the HERON ROCK and STAR ROCK. Fifteen hydrographic launches were modified for field work.

MANAGEMENT SERVICES DIVISION

Institute of Ocean Sciences

Support was provided to approximately 500 Science Sector and Marine Division personnel in the areas of contracting and procurement, inventory control, vehicles, warehousing and stores, Library services, telecommunications, records management, and health, safety and security. Management Services is also responsible for the maintenance, upkeep, modification and contruction of the Institute's buildings and grounds.

The first two phases of modifications to the marine repair facility, including construction of a building to house winch and buildings and grounds maintenance, were completed. Construction of an expanded carpenter shop was initiated. (*Contact: J.H. Coldwell*)

Pacific Biological Station/West Vancouver Laboratory

Support was provided to research and operational programs in the areas of facilities management, purchasing, contracting, health/safety, security, vehicle management, warehousing, inventory control, Library services, publications, telecommunications, records management and stationery supply.

Approximately $900,000 was spent at PBS to address numerous health and safety issues, rectify crowded conditions in the Whitmore Building (South Coast Division) and upgrade the salt water system.

Installation of a backup well at the West Vancouver Laboratory was completed. (*Contact: W.B. Ross*)

SCIENTIFIC COMPUTING

Institute of Ocean Sciences

Several upgrades were made to IOS central systems, including incorporation of the Oracle Database micro-VAX II, the Chart Production VAX-785, and the Arctic Physics micro-VAX 3100 into the central VAXcluster. A Versatec colour electrostatic plotter was also installed, primarily for Chart Production and Field Hydrography. User documentation for the Central systems and network was also prepared.

Planning and implementation of network expansions continued for Ocean Physics, Marine Division, Engineering Services and Ocean Chemistry. Ethernet interfaces and Digital PathWorks software were installed and training conducted for the users. A high-speed link was established between the IOS local area network and BCnet, CA*net and Internet (research networks). (*Contact: K. Teng*)

Pacific Biological Station

The Annex data communications LAN, including a fibre optic link, was installed, resulting in improved data communications for scientific staff in the building. The LAN installation in the main building was completed and a data link with the Cultus Lake Laboratory was installed.

Computing staff participated in the development of regional informatics plans, a data communications strategy and a data security awareness program. Other activities included development of an operations manual and network diagrams, verification of tape inventory and updating of the hardware inventory. (*Contact: M. Marshall*)

PERSONNEL BRANCH

Personnel services were provided to staff in the Science Sector, Marine Division, Management Services Branch, Comptroller's Branch, and Communications Branch, located at IOS, PBS and other facilities. Personnel Branch staff were actively involved in the Biologist (BI) group classification review, the Engineering and Scientific Support (EG) group classification conversion and the CR/ST equalization payment. (*Contact: L.D. Foreman*)

COMMUNICATIONS

The major focus of communications activities during the year was on planning and preparations for Open Houses held at IOS and PBS in September, 1990. The Open House at PBS attracted an estimated 15,000 visitors over a five day period, including 5,000 students from Vancouver Island and the Lower Mainland. Special tours were provided for school groups. Almost 11,000 people visited IOS during the institute's first Open House since it was opened in 1978.

Information requests from client groups, students and the general public were fulfilled. The ongoing tour program at the Institute of Ocean Sciences continued to attract an increasing number of visitors, including school groups, tourists, service clubs, visiting scientists, and the general public. Staff shortages resulted in the curtailment of the regular tour program at the Pacific Biological Station.

Publications completed in 1990/91 included brochures for IOS and PBS and the Pacific Region Science Review, 1989/90. (*Contact: K.L. Francis*)

PUBLICATIONS 1990

INSTITUTE OF OCEAN SCIENCES

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