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LA PEROUSE PROJECT SEVENTH ANNUAL PROGRESS REPORT 1991

Pêches
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Canada

LA PEROUSE PROJECT

SEVENTH ANNUAL

PROGRESS REPORT

1991

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1. INTRODUCTION

The La Perouse/MASS Project is a multi-disciplinary, multi-species investigation conducted by the Pacific Biological Station and the Institute of Ocean Sciences in support of long-term management of the major fish stocks off the west coast of Vancouver Island. Inititated in 1985 following the major 1982/83 El Niño event in the Pacific Ocean, the primary focus of the La Perouse/MASS program has been directed toward describing and understanding the causes of annual and interannual variability of the fish and zooplankton stocks over La Perouse Bank on the southwest portion of the Vancouver Island shelf. Located within the coastal upwelling production zone that extends from northern Vancouver Island to Baja California (Fig. 1), La Perouse Bank is one of the most productive fishing areas in the Northern Hemisphere. In the last decade, the annual catch of commercial fish from this area has averaged 5-6 tonnes per square kilometre, or about 5 times the average yield per unit area of the eastern boundary of the Gulf of Alaska (Fig. 2). The La Perouse region fisheries presently generate a landed value to the British Columbia economy in excess of $40 million annually.

In summer the west coast of Vancouver Island is a migration corridor for large numbers of returning salmon, and is an important feeding ground for abundant trans-boundary migratory fish stocks from California such as Pacific hake. La Perouse Bank also supported large numbers of Pacific sardine prior to the collapse of the fishery in the mid 1940s. Salmon, hake, sablefish, herring and crab currently support important fisheries in the region.

This report integrates results for La Perouse Project and the MASS (Marine Survival of Salmon) Project into a single document.

Program Objectives

One of the most important goals of the La Perouse/MASS program is to improve the ability of the Department of Fisheries and Oceans to make accurate forecasts of multispecies fish production and potential yields a few years in advance. This would provide considerable benefits to the commercial fishing industry by minimizing potential fishery conflicts, and by optimizing the catch quotas to the general level of productivity in the system. The program will also enable us to anticipate the probable impacts of ocean climate change on the general productivity, and on the recruitment and distribution of the major species.

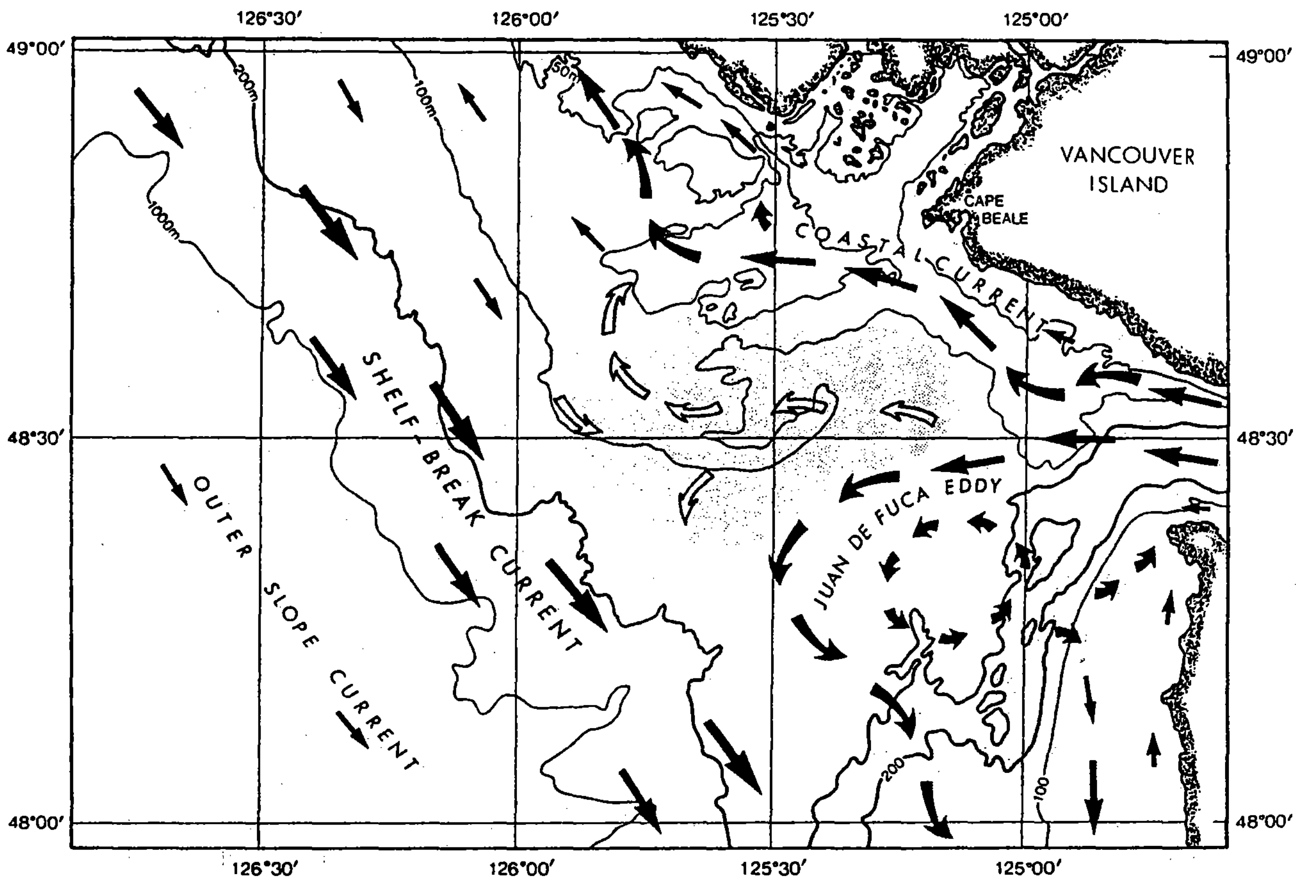

Figure 1a. General summer circulation pattern on La Perouse Bank and surrounding waters. Shaded region denotes an area of confused flow.

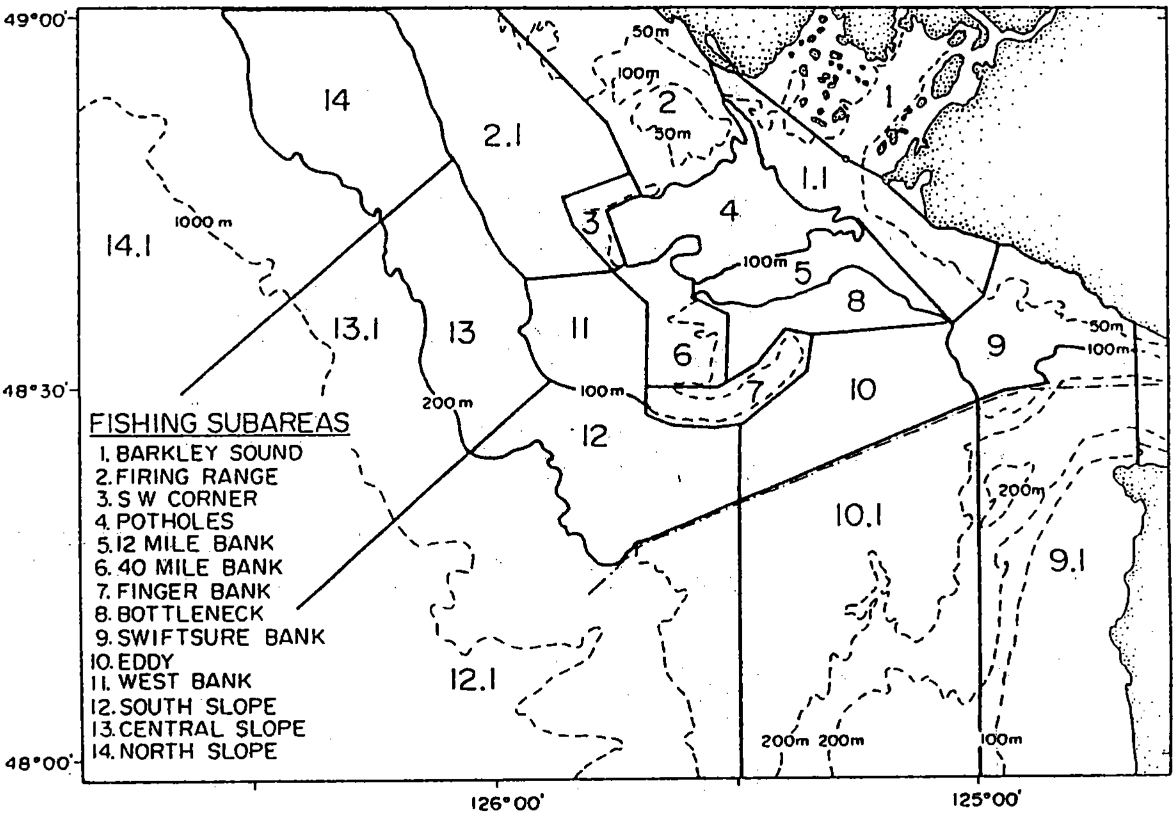

Figure 1b. La Perouse Bank fishing subareas. The map shows the locations of some important places mentioned in this report.

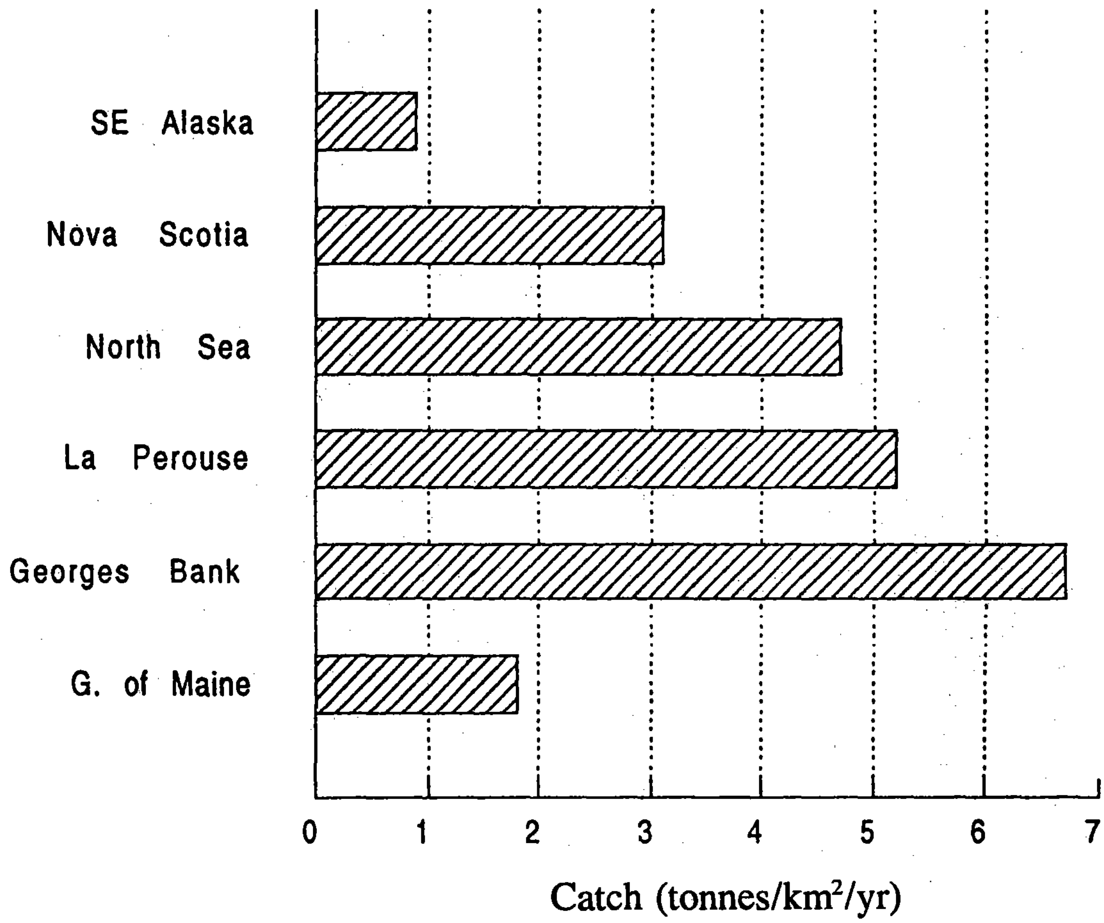

Figure 2. Average fisheries yields from major fishing zones in the northern hemisphere.

The principal objectives of the La Perouse/MASS Project are:

To determine the key physical and biological factors that affect commercial fish population distributions, abundances and natural mortality rates;

To determine the dominant predatory-prey relationships in this productive upwelling system and to use measurements of spatial and temporal distributions of predator and prey stocks to model the principal interactions in the system;

To use the emerging scientific results from the program to develop and verify sophisticated bio-physical models that can be used as operational tools in the long-term planning and management of the multispecies fisheries off the west coast of Vancouver Island.

Application of Results

The La Perouse/MASS Project has proven to be a highly successful fisheries-oceanographic investigation with immediate, practical implications. We can count a number of successes that have a direct impact on British Columbia's commercial fisheries, and on international negotiations on the harvesting of transboundary stocks. Specifically,

1. The La Perouse/MASS project has given us fundamental information on the seasonal patterns in the physical environment and the resulting primary and secondary productivity along the west coast of Vancouver Island. We have also developed new theories on how changes in ocean climate affect the general productivity of the system, especially the success of herring, salmon and sablefish year-classes. These results have been published and have been made available to the fishing industry and to the public.

2. The La Perouse/MASS project has increased our understanding of the seasonal distribution and biological response of fish stocks, like Pacific hake, to local oceanic and feeding conditions. This vital new information has been used successfully to secure a fair share of the North American west coast hake quota for Canadian fishermen. The arguments made to support Canada's position were based on scientific evidence collected by the La Perouse/MASS project. The annual landed value of the Canadian hake fishery is currently about $15 million.

3. The salmon component of the La Perouse/MASS project is using biological and physical oceanographic data to forecast the strength of the returning sockeye run, and the resulting fisheries potential for local fisheries managers. Recent

work predicted recovery of the Barkley Sound sockeye fishery after 3 years of closure, and helped assure the orderly harvest of 1.12 million commercial and 80,000 sport caught sockeye worth $15 million in 1991.

4. The La Perouse/MASS project has shown that one of the principal reasons why the Barkley Sound herring stock has been so unproductive in the last 5 years is due to the increased abundance of hake in the region, in association with abnormally warm oceanic conditions (warm water results in poor herring survival). Hake are the principal predator of herring. New information collected by the program is used at annual DFO-Industry meetings to explain why the herring stock is declining. Our scientific evidence and interpretations have been accepted generally by industry as a believable explanation of what is happening, and has made it easier for them to accept DFO's attempts to rebuild the stock. The average landed value of the Barkley Sound herring fishery over the last 5 yrs is about $10-11 million.

5. Our knowledge of fish distributions in the La Perouse region enabled us to anticipate, and forewarn DFO managers about, the serious potential consequences to salmon and herring of a summer trawl fishery for hake in, and near the mouth of, Barkley Sound, which is scheduled to begin in 1992. In a separate memo the La Perouse/MASS working group advised that Barkley Sound be closed to hake trawling in the summer to minimize the by-catch of salmon and herring.

The Operational Coupling of Fishery Science and Management

The La Perouse/MASS program is in the process of developing increasingly sophisticated numerical models of the oceanic circulation and fisheries oceanography off the west coast of Vancouver Island. The evolution of these models over the next few years will lead to operational tools for fisheries managers. These models won't be the only tool, but they could be important for developing multispecies fishing plans, and for fish recruitment, stock abundance and productivity forecasting. The La Perouse/MASS Project is demonstrating that intelligent coordinated fisheries-oceanography measurements, and empirical observations of species interactions can provide critical new information needed immediately for management of the British Columbia fisheries. In conjunction with this, our modelling research will lead to the development of important new operational tools needed for the integrated management of multispecies fisheries in the La Perouse Bank area. A first generation model of the system will soon be available. In the meantime, the La Perouse/MASS working group is willing to use the information we have to provide advice on potential multispecies fisheries conflicts and interactions in the La Perouse Bank region.

This manuscript contains the 1991 progress reports for the individual investigators in the La Perouse Project, as well as the MASS project. Annual meetings are held to review the design, recent progress and future plans of the three main components of the program:

1. The Physical Oceanography Program (headed by Rick Thomson);
2. The Biological Oceanography Program (headed by Dave Mackas);
3. The Fisheries Oceanography Program (headed by Dan Ware and Sandy McFarlane).

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2. STANDARD SAMPLING GRIDS

The standard sampling grids for CTD/hydro profile stations and plankton tow stations are presented in Figs. 3a and 3b, respectively. Figure 3a also shows the locations of the standard current meter moorings A1, B1, and C1. Mooring site B1 was not occupied during 1991. Generally, the area of interst is defined from north to south, between 48^{o}00.0′ and 49^{o}00.0′ N latitude, and from east to west, between 124^{o}40.0′ and 126^{o}50.0′W longitude. Furthermore, the sampling grid transect lines run perpendicular to the coast of Vancouver Island and pass through the above defined area at an approximate bearing of 235^{o} true N.

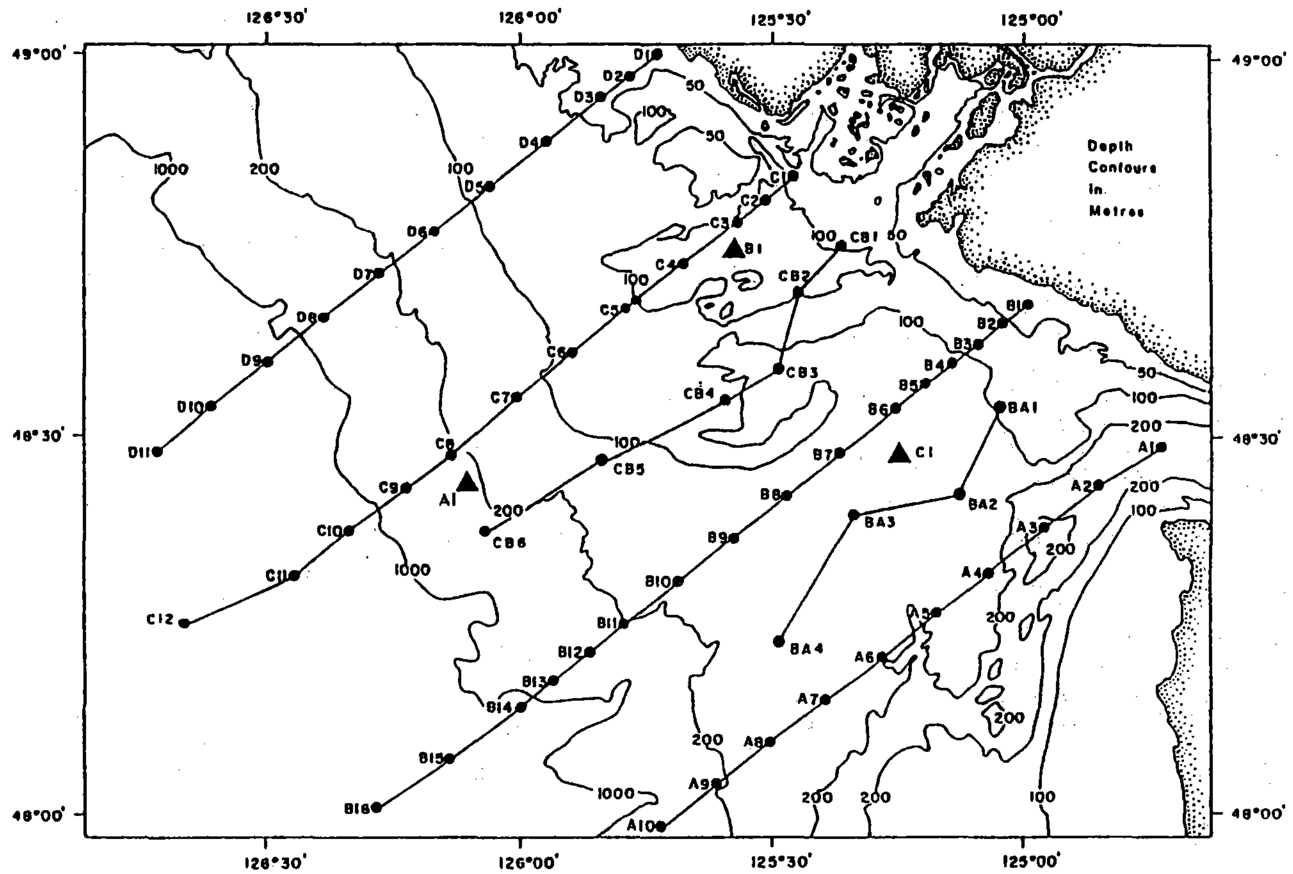

Figure 3a. La Perouse Bank CTD survey lines and current meter moorings (triangles A1, B1, C1).

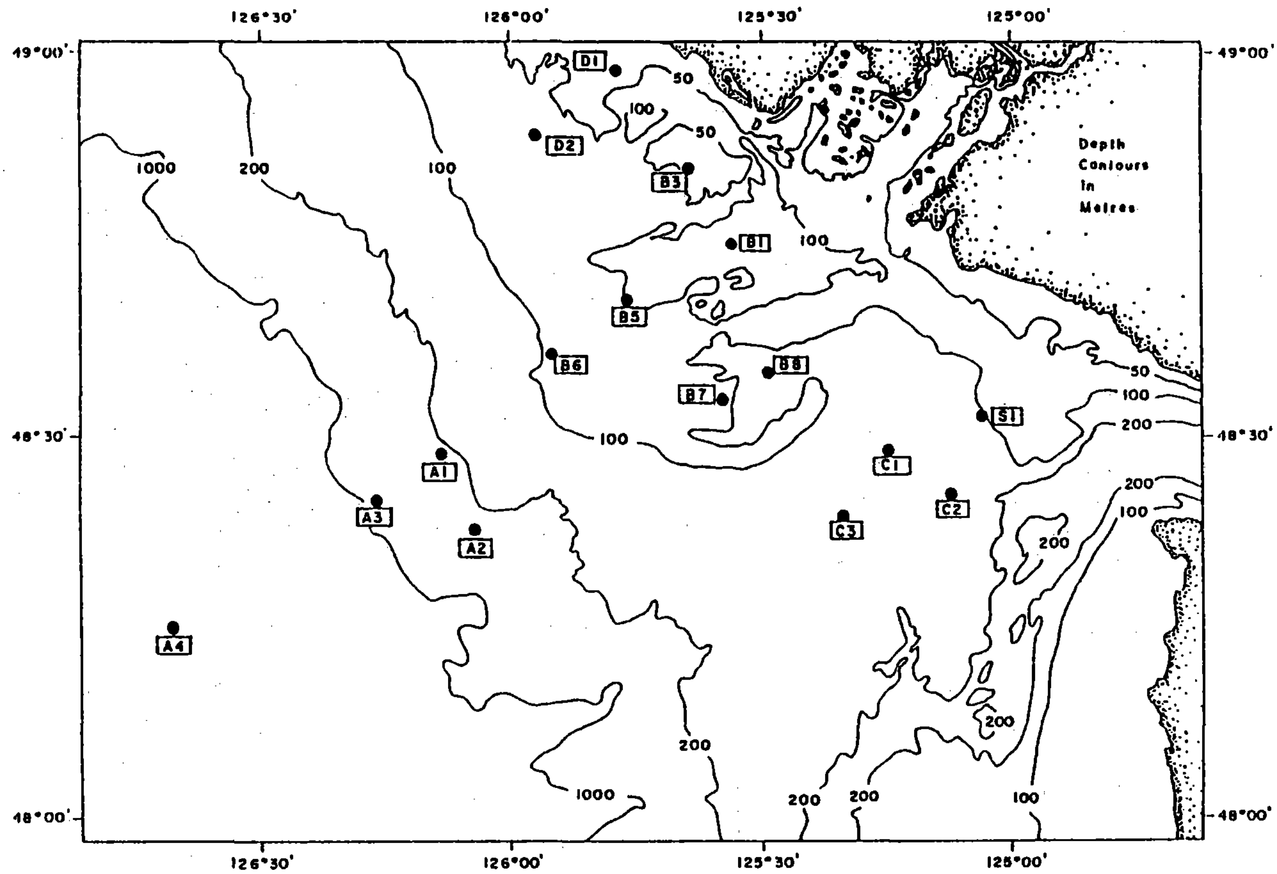

Figure 3b. La Perouse Bank plankton sampling stations.

3. INVESTIGATORS SUMMARIES

3.1 PHYSICAL OCEANOGRAPHIC PROGRAM

The physical oceanographic component of the La Perouse Project provides current and water property data along the west coast of Vancouver Island in support of fisheries and interannual climate investigations. The physical component also contributes to our understanding of the circulation dynamics over the shelf and provides a data base for El-Niño type oceanic variability in the northeast Pacific Ocean. Additional applications include the study of shelf/slope exchange processes, determination of the interannual variation in the timing and intensity of the Spring and Fall transitions, provision of input and calibration data for numerical circulation models, and calibration of remote sensing measurements. Observations collected during the program are used in the development of oil-spill trajectory models, in the interpretation of sea-bird distribution and in studies of sediment distribution and transport.

3.1.1 Current and Water Property Observations in 1991

The number of oceanic surveys conducted off the west coast in support of the La Perouse Project continued to decline in 1991. Data in the survey region (Figs. 3a,b) were collected during 6 dedicated La Perouse/MASS cruises between January 1 and December 31, compared with 9 dedicated cruises in 1990, 10 in 1989 and 17 in 1988. Several near-shore survey lines from the two Line P cruises in 1991 have also been added to the data set. The decline from 1988 to 1989 was due to structural problems on the *Ricker* which forced cancellation of scientific cruises during the main portion of the field season. The decline in 1991 is related to the transfer of the principal IOS research vessel CSS *Parizeau* from the west coast to the east coast fleet.

Archived water property files include plots and listings of individual vertical CTD profiles of temperature, salinity and light attenuation together with horizontal maps and cross-sectional maps of temperature, salinity, density, dissolved oxygen, light attenuation coefficient, dynamic height and geostrophic currents. Transect records from the shipboard SAIL system also are available but considerable processing is needed to make the data useful. A review and archiving of the SAIL collection and processing procedures is presently underway. As in previous years, the initial editing was conducted in-house by Joe Linguanti while the remaining analysis was done under contract. Profile data from the shipboard 150 kHz acoustic Doppler current profiler (ADCP) are processed under contract and kept in a separate archive. Copies of all data collected by the various contributing groups are available from Richard Thomson of the Institute of Ocean Sciences. Because of the government "freeze" on spending at the beginning of 1992, a significant portion of the data base has yet to be edited and processed.

Current Meter Moorings in 1991

The standard deployment positions for all La Perouse/ MASS current meter moorings are shown in Fig. 4. [Owing to heavy fishing activity and associated data losses in recent years, the deployment of mooring, B1, off Barkley Sound was suspended following the recovery cruise of April 1990.] Mooring C1 measures the variability in the flow over the central portion of the fishing bank while A1 records the variability in the wind-induced flow along the outer edge of the broad continental shelf to the west of the main fishing sites. Mooring E01 off Estevan Point monitors the poleward flow associated with the buoyancy-driven, near-shore Vancouver Island Coastal Current. At this "safe" quasi-permanent mooring site, the Coastal Current is known to be stable and well defined (Thomson et al. 1989).

Moorings E03 and A1 record the temporal scales and longshore coherence of the Shelf-Break "jet". With its core centered near the surface over the 200 m depth contour, the Shelf-Break Current is a direct measure of the summer upwelling intensity and extent along the Vancouver Island shelf. Thermistor chains between 100 and 150 m depth on moorings A1 and E03 provide detailed information on high frequency temperature variability during the upwelling period. Moorings A1 and E03 also help to establish the long-term timing and intensity of the spring and fall transitions off the west coast of the island. Mooring BP1, consisting of current meters at 35 and 75 m depth at the edge of the steeply sloping shelf, provides data on the intense and highly sheared flow past Brooks Peninsula and is maintained as an integral part of our long-term fisheries-climate program.

In addition to the La Perouse/MASS moorings, we deployed a single subsurface mooring (CRD1-A) near the Macaulay Point outfall in support of effluent dispersal research by the Capital Regional District (CRD). Four CTDs were taken in the vicinity of the mooring. The purpose of this sub-program was to provide long-term verification and calibration data for a non-linear frictional diagnostic model developed under contract to the CRD by Seaconsult Marine Research. Except for the shiptime and acoustic release, the work was funded by the CRD.

Recovery and Servicing Operations

Servicing of all moorings took place in May/June and October 1991 (Table 1). Moorings deployed in October 1990 were returned with some data loss but no instrument losses. Again, the main problem was slope station E03 moored on

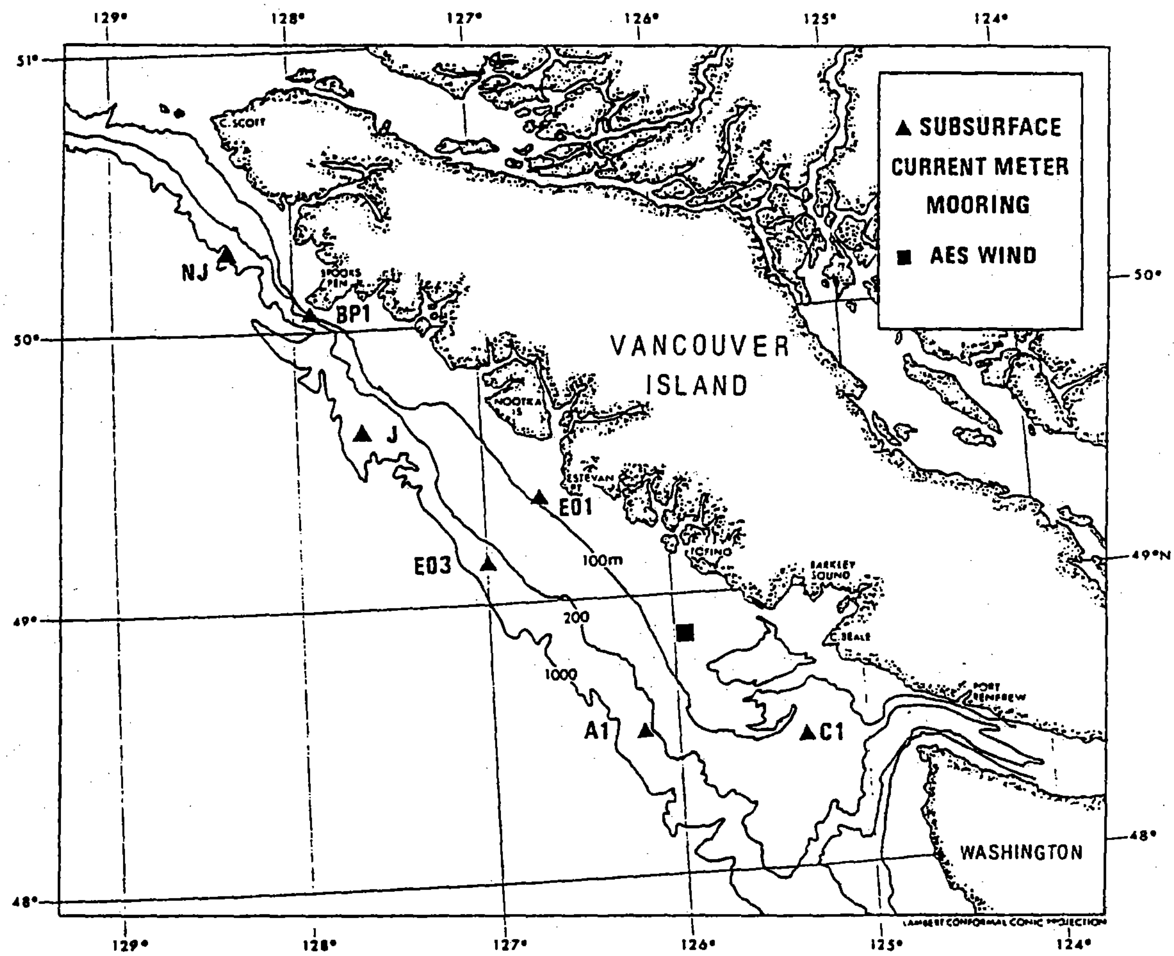

Figure 4. Location of current meter moorings on the west coast of Vancouver Island during 1991. Location of AES Weather Buoy (■) and moorings Jet (J) and NoJet (NJ) are shown (see Forbes et al. this report).

Table 1. Mooring Status as of October 1991. RCM is an Aanderaa current meter and TR is an Aanderaa thermister chain.

Station ID	Latitude °N	Longitude °W	Deployment DD-MM-YY	Depth (m)
CRD1-B	48 23.908	123 24.145	09-10-91	RCM 25
				RCM 50
				Water depth 56
A1-14(N)	48 31.84	126 12.14	10-10-91	RCM 35
				RCM 100
				TR 102
				RCM 175
				RCM 400
				Water depth 500
C1-14(N)	48 29.32	125 14.98	09-10-91	RCM 35
				RCM 100
				Water depth 152
E01-14(N)	49 19.26	126 37.12	12-10-91	RCM 25
				RCM 35
				RCM 75
				Water depth 90
E03-14(N)	49 04.47	127 56.78	12-10-91	RCM 35
				RCM 100
				TR 101
				RCM 175
				RCM 400
				Water depth 500
BP01	50 03.73	127 53.69	13-10-91	RCM 35
				RCM 75
				Water depth 102

October 10, 1990 in 500 m of water to the southwest of Estevan Point. This mooring was "hit" sometime in late April 1991 and sighted on April 26 by fishermen on the *Viking Sky*. The bottom portion of the mooring including the 400 m current meter was returned by fisherman on May 10. The top three instruments and floats were recovered by the *FPV Tanu* on May 19. Nearshore mooring E01 had tow line cuts on the upper floats at 20 m depth but was otherwise unscathed. All other moorings and thermistor chains were returned in June with full data records.

Redeployment of the entire La Perouse array and the single mooring off Macaulay Point, Victoria took place in early June. Only mooring C1 failed to make it through the summer. The top current meter on C1 was returned by a fisherman on July 1 while the deeper of the two meters was returned on July 29. The bottom portion of the mooring including the acoustic release and flotation were recovered on October 9. Standard recovery and servicing of all moorings was undertaken during the period 9-13 October 1991.

Safeguarding Moorings

Several steps are taken each year to safeguard the moorings. In March 1991, over 5000 full page flyers (some in Japanese, Russian and Polish) were sent for distribution to the fishermen licensing agencies through Ms. Judy Roberts of the Commercial Licensing Division-Pacific Region of DFO. Distribution to the trawlers was kindly handled by Mr. Athol Lang of the Hake Consortium. The flyers detail the instrument configurations and locations for each mooring and supply telephone numbers of institute staff. The exact positions are also supplied to Tofino Coast Guard Radio for direct transmission to marine traffic in the area of the moorings (Notice to Mariners).

In addition to the dissemination of mooring information and labelling of all equipment placed in the ocean, other steps taken to reduce data and equipment loss are: (1) in-house maintenance and pre-deployment testing of all mooring components; (2) proper design and selection of mooring components; (3) controlled deployment and recovery techniques combined with accurate (GPS, Loran-C, Radar) positioning techniques; and (4) provision for alternate recovery methods in conjunction with use of relocating aids such as VHF transmitters, Xenon flashing lights and Argos satellite beacons ("Witness Buoys"). A summary of all losses during the La Perouse/West Coast project prepared by Tom Juhász for the period November 1984 to October 1991 is presented in Fig. 5. For the 49 deployments in 8 years involving 242 individual instrument deployments, the potential loss (equipment hit, cut adrift or suffering component failure) was 36.4%; real losses (instruments not recovered or highly damaged) was 6.2%.

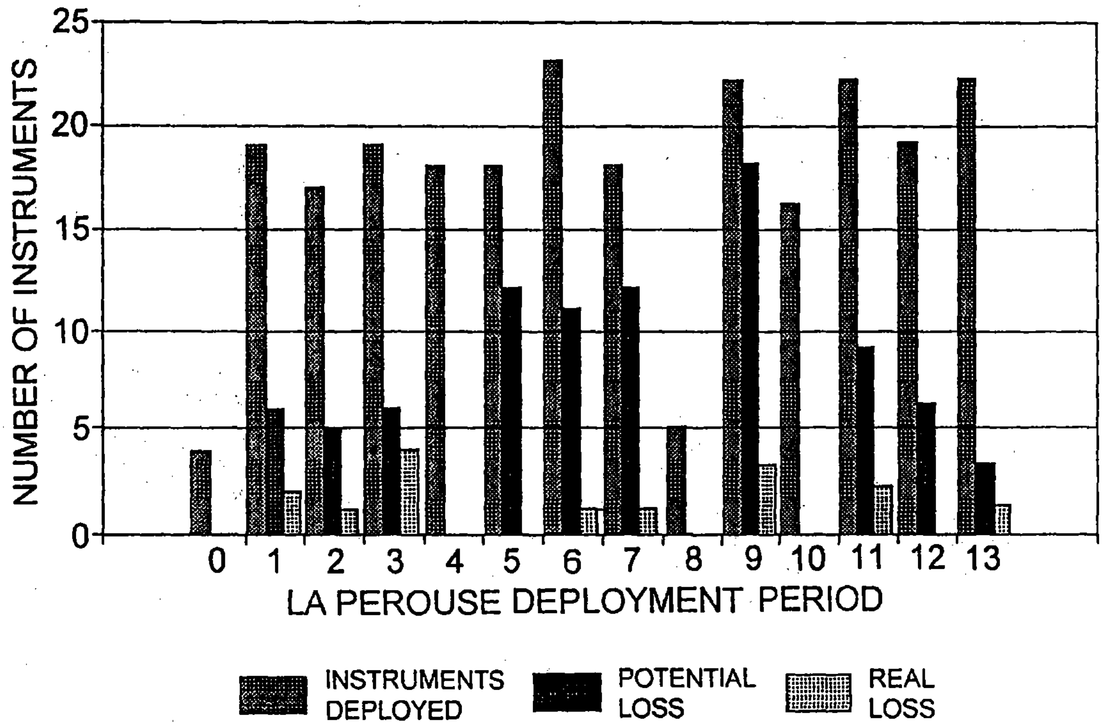

Figure 5. Summary of La Perouse mooring losses for the period November 1984 to October 1991. Bar graph shows total number of current meters, pressure gauges and transmissometers deployed during each field servicing period, the number of instruments (potential loss) that were damaged, failed to be recovered through normal operations or went adrift, and the actual (real) loss of instruments.

Oceanic Winds

The Atmospheric Environment Service has maintained a 3-m discus wind buoy at 48°50.05′ N, 125°59.74′ W on La Perouse Bank (Fig. 4) since November 1, 1988. Data are transmitted to shore via the GOES satellite and are archived by the Marine Environmental Data Service in Ottawa. All wind data are now archived at AES in Vancouver and arrangements have been made to have these data transmitted to Ocean Physics, IOS (contact Robin Brown).

Standard Oceanographic Products

The edited oceanographic data are processed using a set of standard techniques that have been customized for the La Perouse region. Standard products derived from these data are listed below. (Further details can be found in the 1988 Annual Report published in March 1989.) Also, seasonal mean, objectively-mapped water properties at specific La Perouse grid sites for specified standard depths can now be obtained (see Mike Foreman, IOS). Archived data products are:

1. Files and plots of 1-m averaged temperature, salinity and light attenuation as a function of depth for all oceanic surveys from June 1984 to January 1992. Dissolved oxygen profiles from water bottle casts at standard depths are available for many of the La Perouse grid stations.

2. Files at standard hydrographic depths (e.g. 0, 10, 20, 30, 50m, ...) of temperature, salinity, density (sigma-t), light attenuation coefficient, dissolved oxygen, sound speed, and dynamic height.

3. Objectively mapped water properties on horizontal surfaces at standard oceanic depths for each oceanic survey including temperature, salinity, density (sigma-t), dissolved oxygen, light attenuation coefficient, depth of sigma-t surfaces and geostrophic velocity (Fig. 6a,b). The digital grid data for each plot can be obtained via contract upon request.

4. Objectively mapped cross-sections of the above oceanic properties (including geostrophic velocity relative to several reference depths) along all cross-shore survey lines (Fig. 7a,b). The digital grid data for each plot can be obtained via contract upon request.

The program to calculate cross-sections of geostrophic velocity normal to the CTD survey line has been recently generated under contract. Velocities are determined relative to user-defined depths of 50, 100, and 300 m and smoothed with the standard objective cross-sectional mapping program.

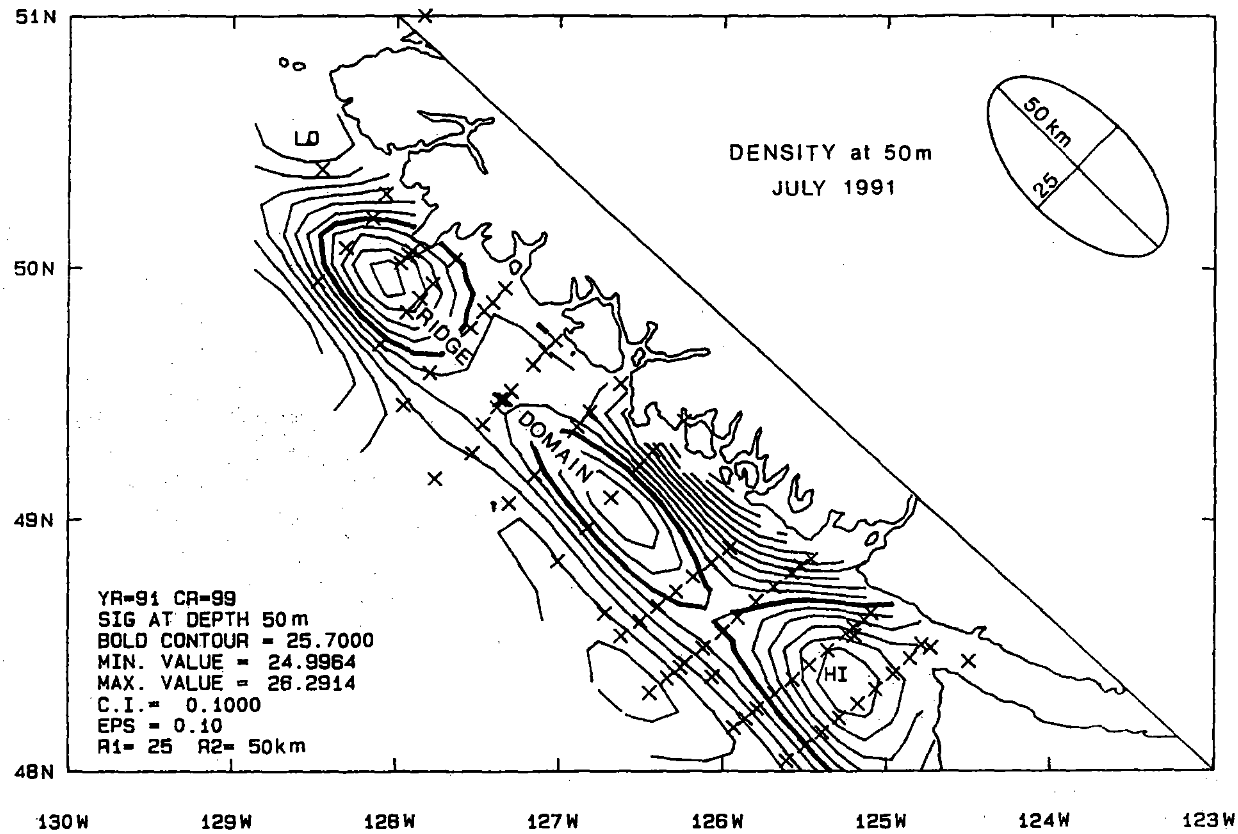

Figure 6a. Objectively derived map of density (sigma-t) at 50 m depth for the west coast of Vancouver Island for July 1991 (combined Hargreaves and Thomson survey data). Ellipse shows the assumed correlation mapping scales of 50 km longshore and 25 km across-shore used to smooth the data.

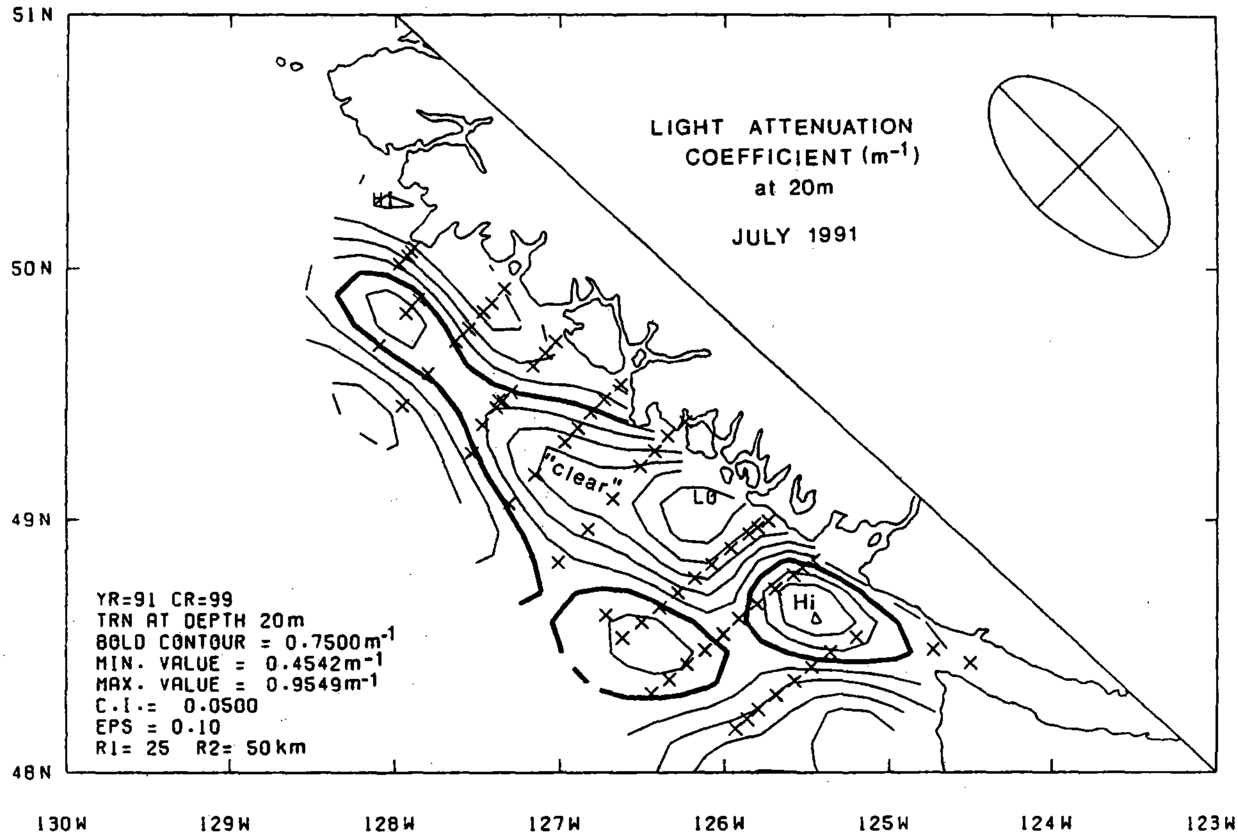

Figure 6b. Objectively derived map of light attenuation coefficient (m^{-1}) at 20 m depth for the west coast of Vancouver Island for July 1991 (combined Hargreaves and Thomson survey data). Ellipse shows the assumed correlation mapping scales of 50 km longshore and 25 km across-shore used to smooth the data.

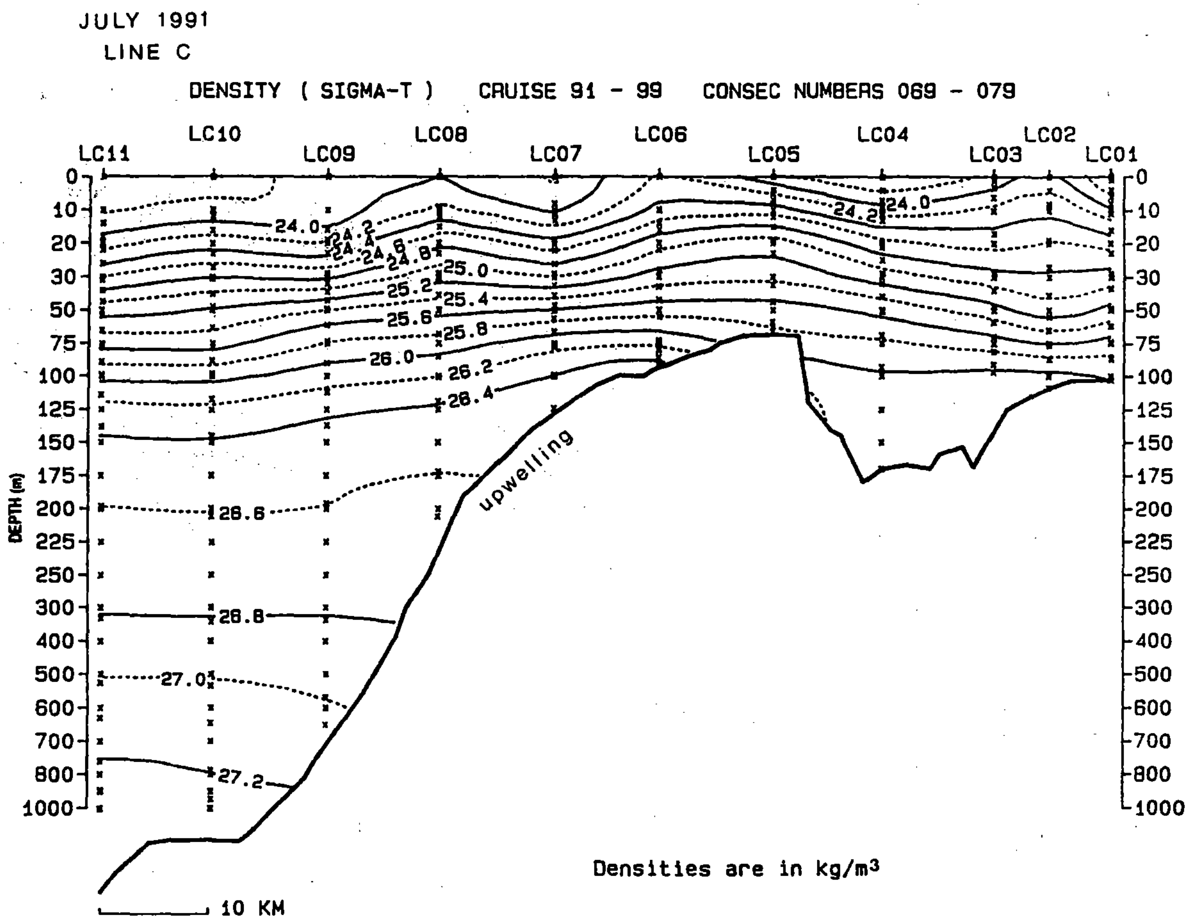

Figure 7a. Objectively derived density (sigma-t) cross section for Line C (see Fig. 2a) for mid-July 1991 (from IOS survey 91-14).

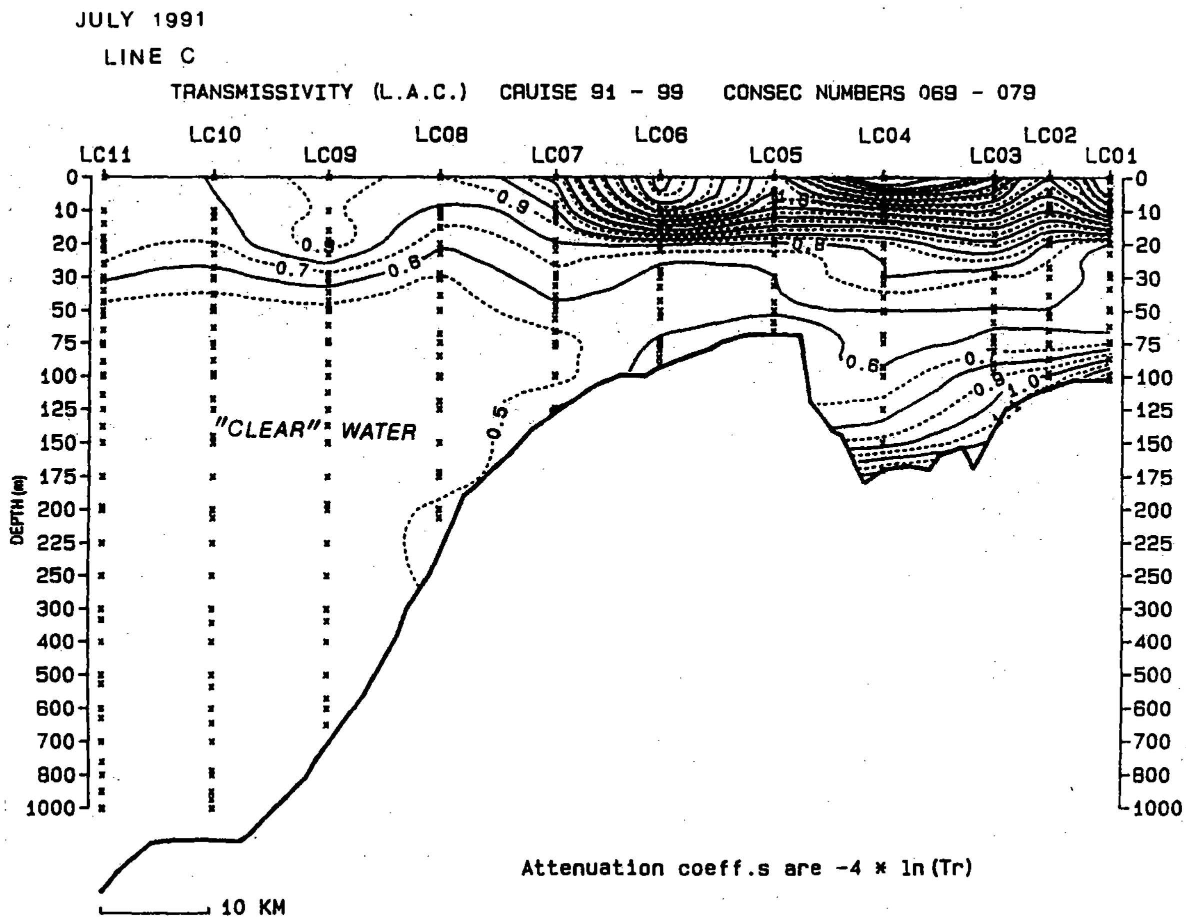

Figure 7b. Objectively derived light attenuation coefficient cross-section for Line C (see Fig. 2a) for mid-July 1991 (from IOS survey 91-14).

5. Three-dimensional maps of water properties for the La Perouse region including bottom topography. [Not available for 1991 data sets due to a lack of funds.]

6. Edited current meter records for all sites plus hourly and low pass filtered records. [The 1991 data are not yet available due to a lack of funds and computing support.]

7. Satellite thermal imagery (NOAA AVHRR data) for specific cruises. There is no mechanism to process the acquired data other than through contractors that specialize in these products (e.g. Borstad Associates and Arctic Sciences Ltd.) [The La Perouse Project has built an inventory that can be accessed upon request on a user-pay basis.]

8. Shipboard acoustic Doppler current profiler (ADCP) data consisting of horizontal currents and acoustic backscatter anomalies (Fig. 8). Problems remain with the analysis and dissemination of the shipboard ADCP data. The data files are large and there are many erroneous values that require labour-intensive editing. Observations mix time and space scales so that interpretation of the data is difficult. Considerable development work is needed. The contractor who normally does the analysis and who has written all the software (Luc Cuypers) is not always available. All data from Ocean Physics cruises have been archived and cruise tracks plotted (see Rick Thomson).

Research Projects

Because of a funding freeze, reallocation of support staff and confusion over ships within the Institute in 1991, there was reduced collection and post-editing of the La Perouse data sets. Data from some of the major cruises have yet to be put into the data base using 1992/93 funds. Much of our effort went into support of editing, software development and data dissemination for colleagues within the project. Project-related research conducted in 1991/92 is listed as follows:

Field Calibration of IOS/PBS Guildline CTDs

As part of a joint fisheries-oceanography program between B. Hargreaves and R. Thomson, a field intercomparison of the PBS and IOS Guildline Digital CTDs (CTD No. 57743 and 41226) was conducted to depths of 1000 m on July 23, 1991 at site 49^{o}28.7'N, 127^{o}20.7'W. Repeat casts using separate ships were conducted at two sites with time differences of about 1 hour between casts. Except in the upper 100 m and at pycnocline depths where high frequency oceanic variability due to surface mixing and internal wave motions is expected to be high, there was little difference in the temperature and salinity signals between the two instruments (Fig. 9). This allowed us to easily merge the

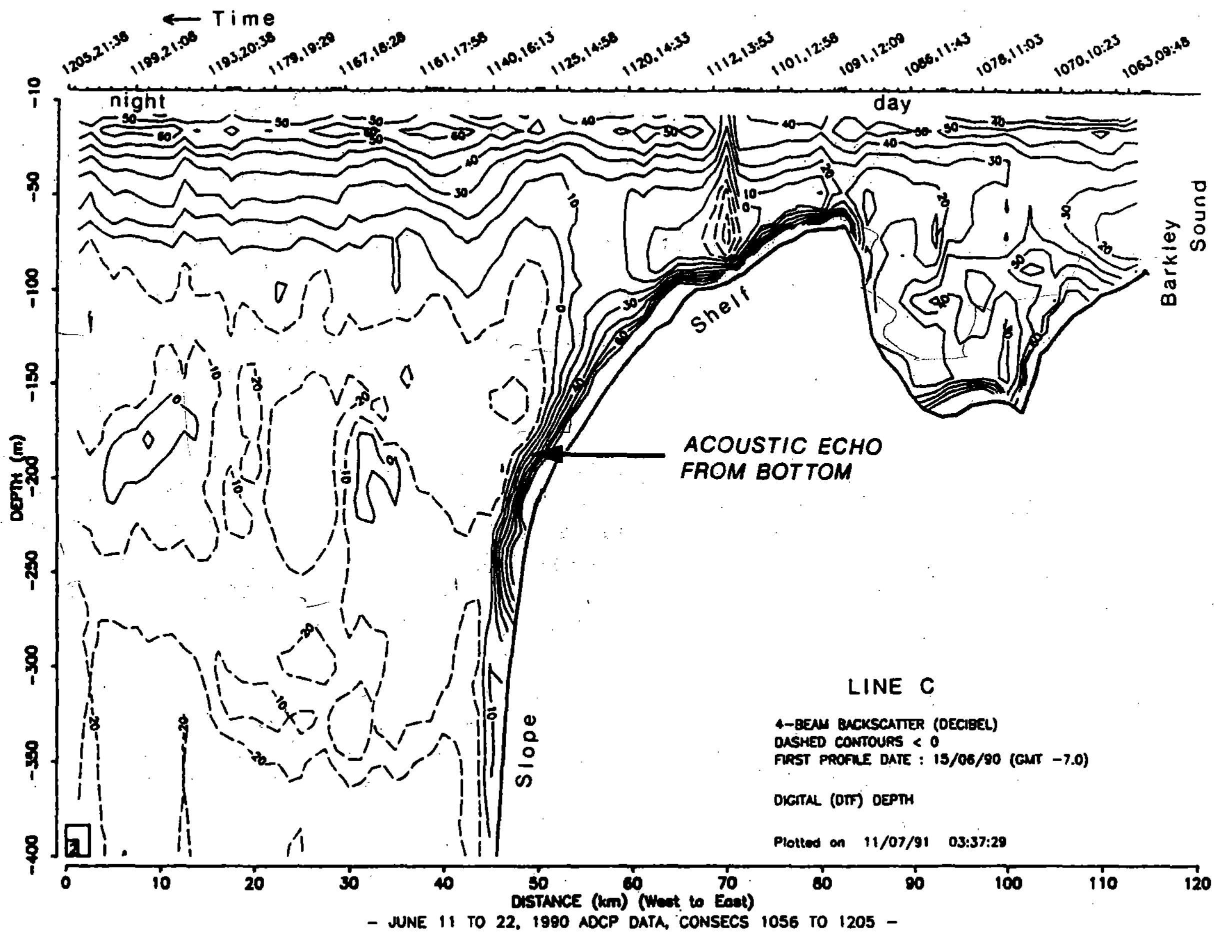

Figure 8. Cross-section of four-beam averaged backscatter intensity (in deciBels) taken on June 15, 1990 along Line C using the shipboard 150 kHz acoustic Doppler profiler on the CSS Parizeau. Each profile (tick mark) is based on a 5-minute average. The header gives the ensemble number (1055-1205) and local time (PDT). The large intensities near the bottom result from side-lobe backscatter from the seafloor; values within 15% of the bottom are not reliable.

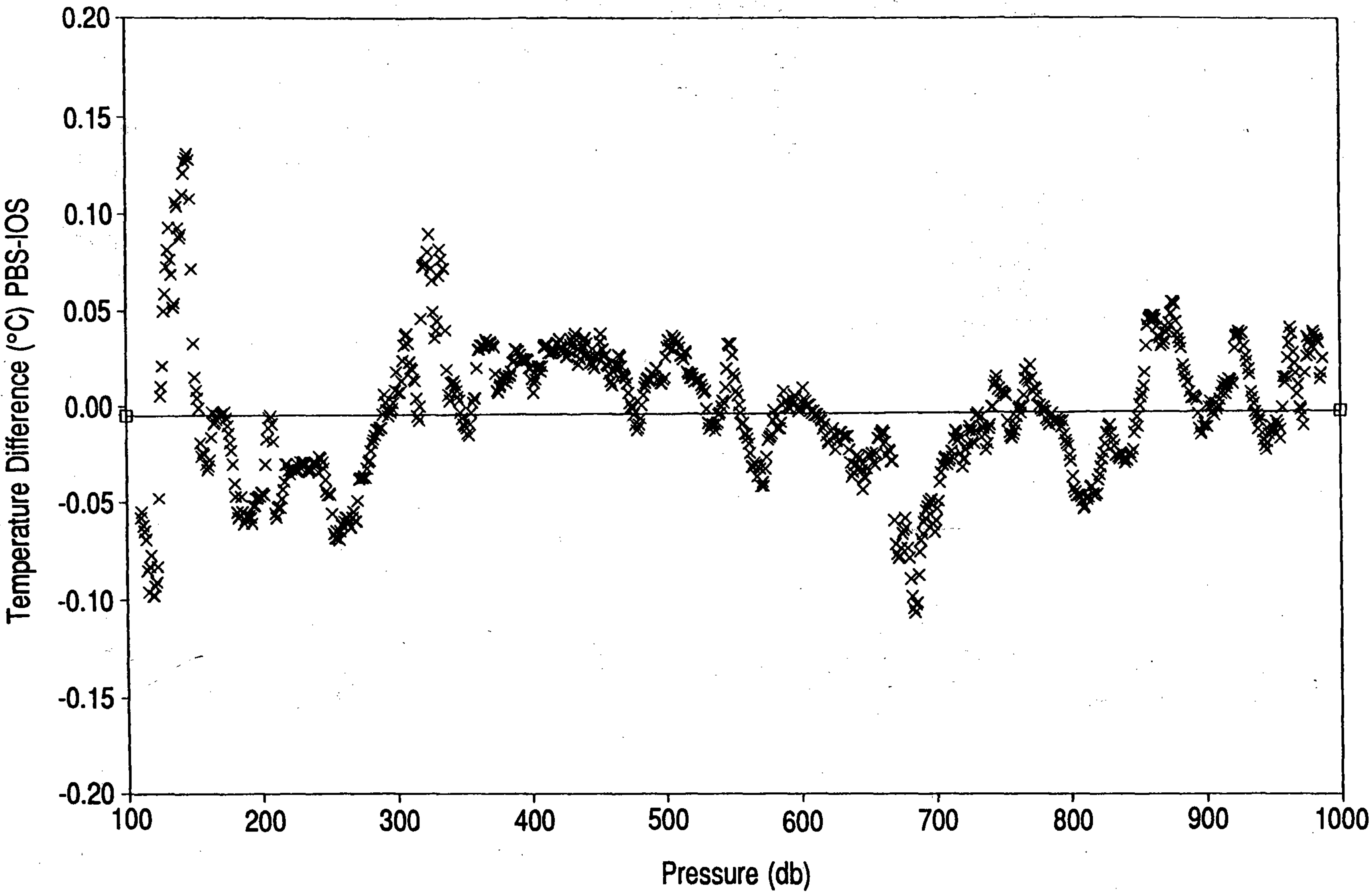

Figure 9a. Inter-comparison of temperature data collected from the PBS and IOS Guildline CTD systems on July 23, 1991 at 49°28.7'N; 127°20.7'W (diff = PB-IOS). Only values for depths greater than 100 decibars (about 100 m) are shown. The least squares linear fit to the data is displayed.

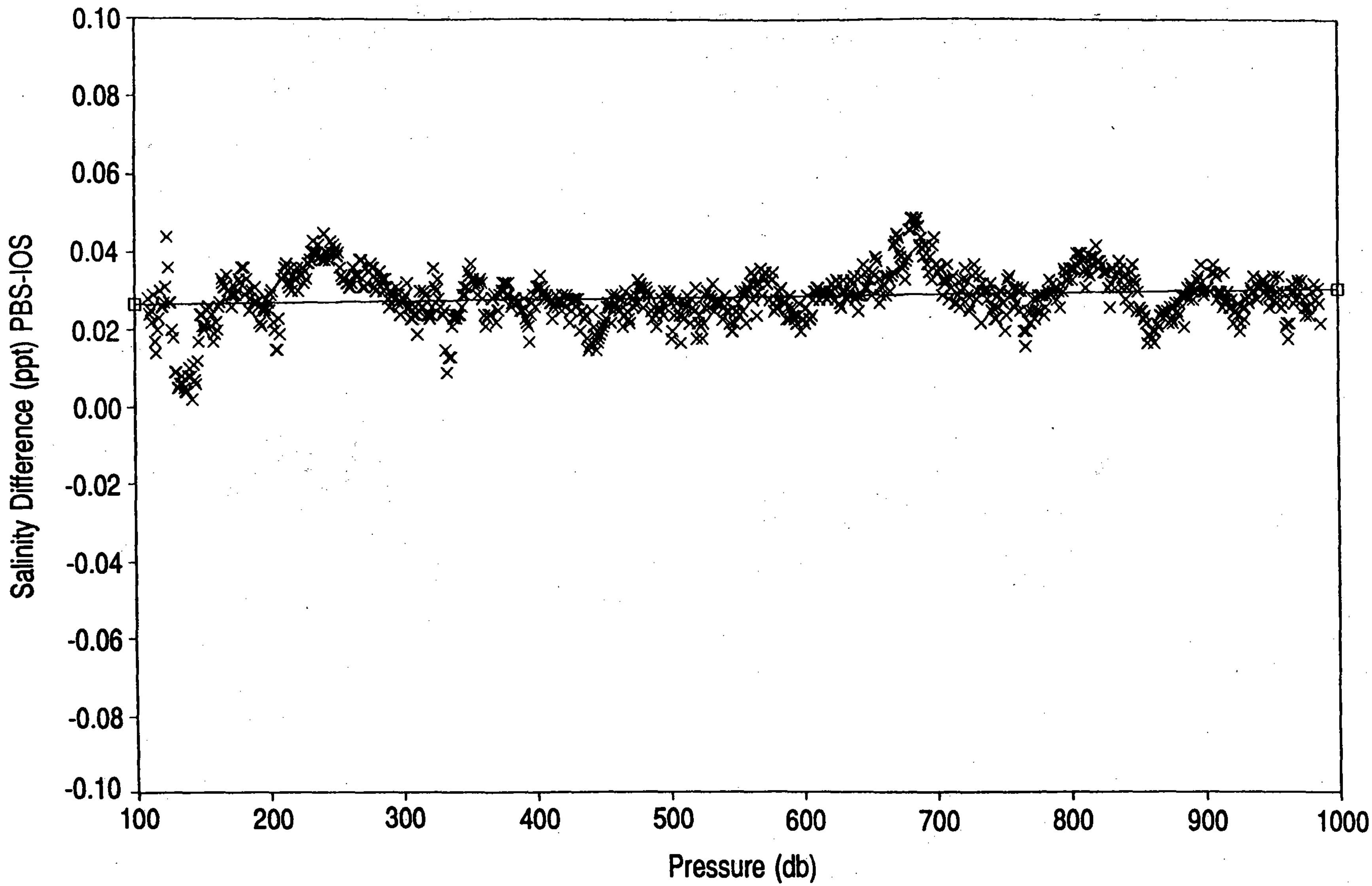

Figure 9b. Inter-comparison of salinity data collected from the PBS and IOS Guildline CTD systems on July 23, 1991 at 49°28.7'N; 127°20.7'W (diff - PBS-IOS). Only values for depths greater than 100 decibars (about 100 m) are shown. The least squares linear fit to the data is displayed.

two CTD surveys into one detailed data file covering the entire length of Vancouver Island. These data are, in turn, being used to interpret the salmon distribution data collected by the Ocean Salmon Group at PBS.

Synthetic Aperture Radar (SAR) Study

The June 1990 La Perouse survey was combined with a high resolution airborne radar imaging survey of the west coast of Vancouver Island by the Canadian Centre for Remote Sensing (CCRS, Ottawa) and G.A. Borstad Associates (Sidney). The primary purpose of this study was to test SAR's ability to map oceanic features such internal gravity waves, oil slicks, currents and fronts under different atmospheric and oceanic conditions. Processing of the SAR/oceanic data was completed in 1991.

Several cross-shore and alongshore flight tracks were flown off the coast from Juan de Fuca Strait to Cape Scott over a three day period. Oceanic surface features are detected through changes in ocean radar-scale "brightness" patterns associated with modifications to the capillary and short wavelength (centimetre-scale) surface gravity waves. Simultaneous water properties and ADCP currents obtained from the ship plus coastal wind records and satellite thermal imagery provide ground-truth data for the survey. The radar data showed a number of interesting features which support the use of this technique for oceanic studies. These include numerous examples of internal wave fields propagating normal to the Shelf-Break, the presence of mesoscale oceanic eddies and an excellent delineation of the "near-laminar" southeastward flow off Brooks Peninsula that is consistent with the ADCP measurements (Vachon et al. 1992). One of the most unexpected findings were the "imprints" of atmospheric gravity waves detected in the capillary wave pattern on the ocean surface (Thomson et al. 1992). A sequence of SAR images taken over a period of 2.5 hours reveals that the atmospheric waves traveled toward the northwest at 3 to 6 m s-1, counter to the prevailing surface winds, and had wavelengths of 1.2 to 2.3 km. The oceanic imprints were associated with atmospheric internal gravity waves trapped within a 0.75 km thick temperature inversion overlying a 1 km thick weakly-stratified marine boundary layer.

The Vancouver Island Coastal Current

The poleward flowing, buoyancy-driven Vancouver Island Coastal Current (VICC) is a permanent feature of the circulation off the west coast of Vancouver Island (Fig. 1a). Evidence from the La Perouse project indicates that in summer the current originates with outflow from Juan de Fuca Strait but is not organized into a well-defined boundary current until north of Barkley Sound. In a sense, the

Coastal Current "emerges" from the region of low density water and confused circulation that forms over La Perouse Bank and only rarely is the consequence of direct outflow from the strait (see Sixth Annual La Perouse Report 1991).

Work in 1991 included a detailed analysis of all monthly mean current meter observations in the VICC region starting from 1979 to present. Moorings deployed off Estevan Point at mooring site E01 provide the most complete long-term record of the Coastal Current. Based on four years of complete data, the monthly averaged longshore flow (positive toward 315^{o}T) is maximal (≈25 cm/s) in late fall and winter during the time of strongest southeast winds and maximum coastal runoff (Fig. 10). The Coastal Current is weakest (≈10 cm/s) in late spring and early summer during times of minimal coastal runoff and variable longshore prevailing winds. Standard deviations are similar for all months with possible maximum variability in May at the time of the spring transition. Long-term observations are clearly needed to better define the seasonal cycle. Work on the shorter period variations is underway.

Shelf-Break Current/JGOFS

The study of upwelling and stability of the Vancouver Island Shelf-Break Current is continuing. In conjunction with Andrew Willmott of Exeter University who was on a 3 month NSERC-funded sabbatical to IOS in 1991, we developed a theory for the formation of eddy-like subinertial flow variability in Queen Charlotte Sound and along the west coast of Vancouver Island. The theory suggests that the generation of mesoscale eddy-like features on the west coast may be related to groups of propagating subinertial shelf waves generated by the longshore wind, diurnal tidal currents or by propagating offshore circulation cells. The patterns associated with the wave groups propagate poleward along the shelf and closely resemble the eddy-like features seen in satellite imagery (Willmott and Thomson 1992).

In conjunction with Gordon Staples of the Department of Oceanography (UBC), we have been using satellite thermal imagery from 1982 to 1991 to determine the causes for the intensification and break-up of the shelf break flow off northern Vancouver Island. Preliminary analysis suggests that Cape Scott and Brooks Peninsula are regions where nutrient-rich upwelled water from depths up to 400 m penetrates directly into the surface layer. The Shelf-Break study compliments the JGOFS mooring and sediment program conducted from April to September, 1990. Results suggest that the near-surface currents measured by the offshore JGOFS moorings can be interpreted in terms of the flow instability process suggested by the Shelf-Break study.

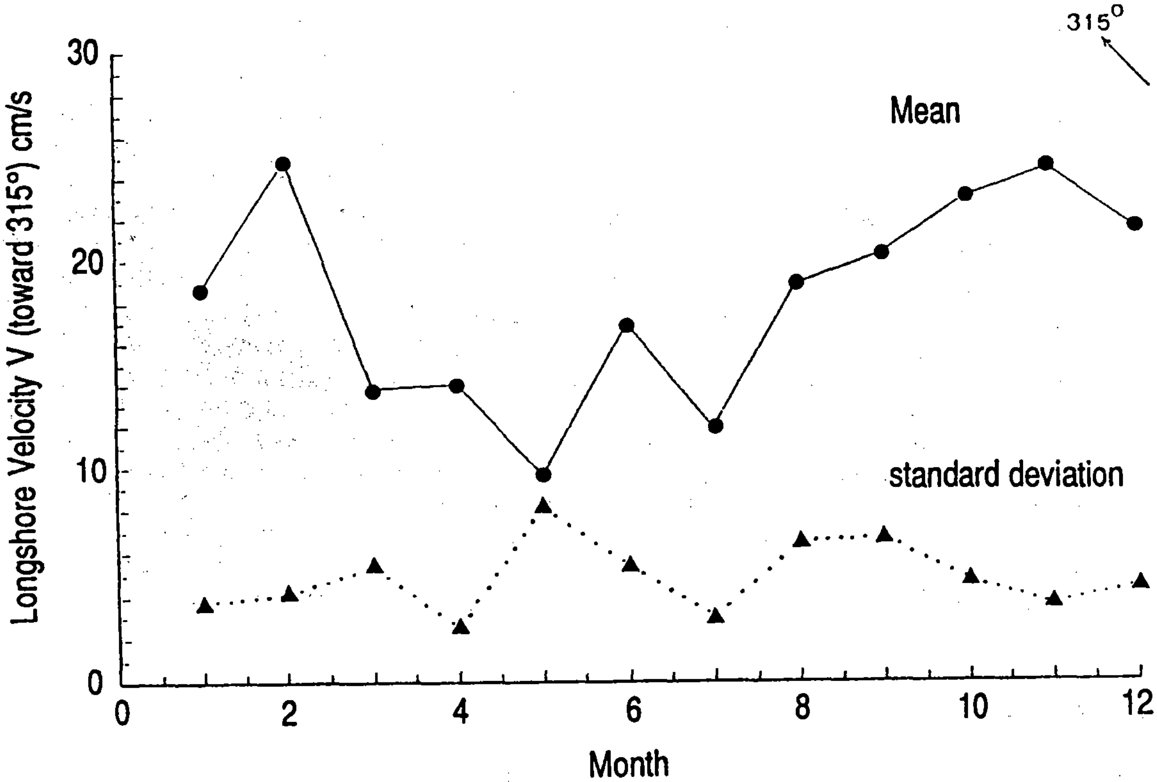

Figure 10. Mean and standard deviations of monthly values of longshore velocity (positive along 315° True) at mooring site E01 off Estevan Point (see Fig. 2). Averages cover the period 1979-1980 and 1989-1991.

Seasonal cycles in Coastal Sea Level

Long-term (> 50 year) monthly mean records of water density, wind velocity, and sea level are being used to examine the factors affecting the seasonal and interannual cycles in observed sea level along the west coast of North America for the period 1899 to 1990. Conducted in conjunction with William Hsieh (UBC) and Dan Ware (PBS), the preliminary research indicates that the seasonal cycle of 10 cm in sea level at Tofino on the west coast of Vancouver Island is highly correlated (correlation coefficient = 0.98) with the longshore wind stress calculated at Station "C" (47.5^{o}N, 127.5^{o}W) off the southern tip of the island. A multiple regression of longshore wind stress, cross-shore wind stress, and wind-induced transport in the offshore region indicates that the seasonal cycle in sea level is almost entirely due to the longshore wind stress with relatively low sea levels in summer arising from intensified northwesterly winds. The residual sea level (after the wind effect is removed) has a 6-monthly cycle of around 3 cm. There is no apparent correlation of the residual cycle with the steric (density-induced) sea level record. The cause of the residual sea level record remains unknown.

R.E. Thomson

3.1.2 Numerical Model Results for the West Coast of Vancouver Island

In 1991/92, attention turned from two-dimensional tidal models (Foreman and Walters, 1990) and their applications (Foreman and Freeland, 1991; Foreman et al., 1992), to three dimensional models.

Through a contract to Seaconsult Marine Research, Jim Stronach extended his high resolution (400m) barotropic tidal model for Barkley Sound and Alberni Inlet to an upper layer model whose forcing included not only tides, but also wind and freshwater input. The tidal model was validated against all available tide gauge and current meter data but there was little data for forcing and validating the upper layer model. Attempts to reproduce the salinity patterns observed by the Ocean Ecology Group in 1988 were satisfactory, but limited by accurate wind forcing. In an effort to improve the wind field (that was previously based on interpolations from observations at Port Alberni Airport and the lighthouses at Cape Beal and Amphitrite Point), a regional atmospheric model was developed and two anemometers were deployed in the summer of 1991. The first anemometer was mounted on a buoy at Baeria Rocks in Imperial Eagle Channel while the second was mounted on land near China Creek in Alberni Inlet. Testing of the atmospheric model continues and further details of the barotropic tidal model and the upper layer models can be found in Stronach et al. (1992).

Work also continued on the development and tuning of a diagnostic three-dimensional model for computing buoyancy currents along the west coast of Vancouver Island. The numerical technique was improved and the triangular grid was refined and extended to the north end of the island. Using temperature and salinity observations from specific La Perouse cruises, three-dimensional density and density gradient fields were computed to provide the primary forcing for the model. The model can be viewed as an improvement of the standard geostrophic current (or dynamic height) computation in the sense that the effects of bottom friction, topographic and coastal steering, wind, boundary inflow/outflow, and vertical velocities are also included in the calculations. Further details can be found in Lynch et al. (1992) and Foreman et al. (1992).

Figure 11 shows the buoyancy currents at 30m depth arising from an extensive CTD survey (150 stations) during Rick Thomson's Vancouver Island Coastal Current Experiment in June 1984. Twelve current meter moorings were operational at the time of the cruise and the circled vectors in Figure 11 are the detided, averaged, values for that period. The model predictions are seen to agree closely with the observations nearest Tofino and Estevan Point and, to a

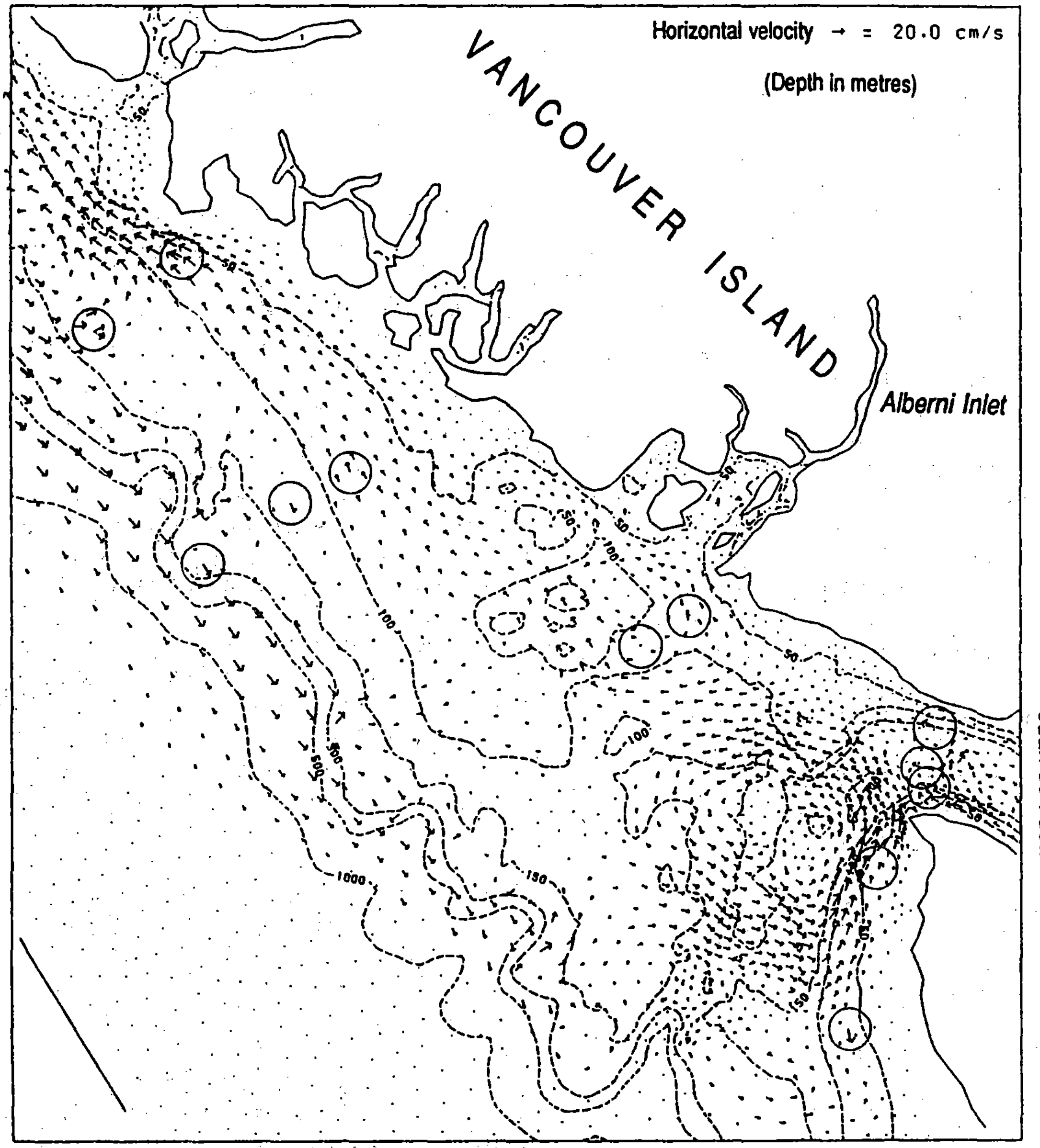

Figure 11. June 1984 buoyancy currents at 30m depth for the southwest coast of Vancouver Island. Circled vectors are the flows measured by current meters moored at 30m. Each full shaft in multi-shafted vectors represents a horizontal current of 20 cm/s. Bathymetric contours are in metres.

lesser degree, with the other three observations offshore from those same sites. Although the agreement is not good across the entrance to Juan de Fuca Strait and along the Washington coast, we suspect that this is because both these regions lie near the edge of the CTD grid and thus did not have complete forcing information. Note that Fig. 11 clearly shows the three characteristic summer features of the region; namely, the Vancouver Island Coastal Current, the Juan de Fuca Eddy, and the Shelf-Break Current.

Figure 12 shows the vertical velocities at 100m depth for the same model calculation. Although the noisy pattern in Juan de Fuca Canyon suggests the need for better resolution, an interesting pattern of downwelling and upwelling at other shelf break canyons is evident. In particular, a comparison with Figure 11 shows that the upwelling is associated with horizontal velocity excursions of the Shelf-Break Current onto the shelf. If these preliminary model results can be verified, the implication is that the regions around offshore canyons such as Clayquot, Barkley and Nitnat are centers for transferring Shelf Break Current nutrients onto the shelf. In fact, there is observational evidence that this may occur. Thomson et al. (1992) describe an upwelled, nutrient-rich, eddy inshore from Clayquot Canyon that attracted a high concentration of fishboats (and presumably fish) in July 1988.

Work in the coming year will attempt to verify the vertical velocities and the shoreward transfer of Shelf-Break Current water computed by the model. The model will also be applied to other CTD cruise data that was accompanied by moored current meter observations.

M. Foreman

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Lynch, D.R., Werner, F.E., Greenberg, D.A., and Loder, J.W. 1992. Diagnostic model for baroclinic, wind-driven and tidal circulation in shallow seas. Continental Shelf Research, 12, 37-64.

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Thomson R.E., Healey M.C., Morris J.F.T., and Borstad G.A. 1992. Commercial troll fishing vessel distribution off Vancouver Island during July 1988: relation to observed physical oceanography, Canadian Journal of Fisheries and Aquatic Sciences, 49(4), 820-832.

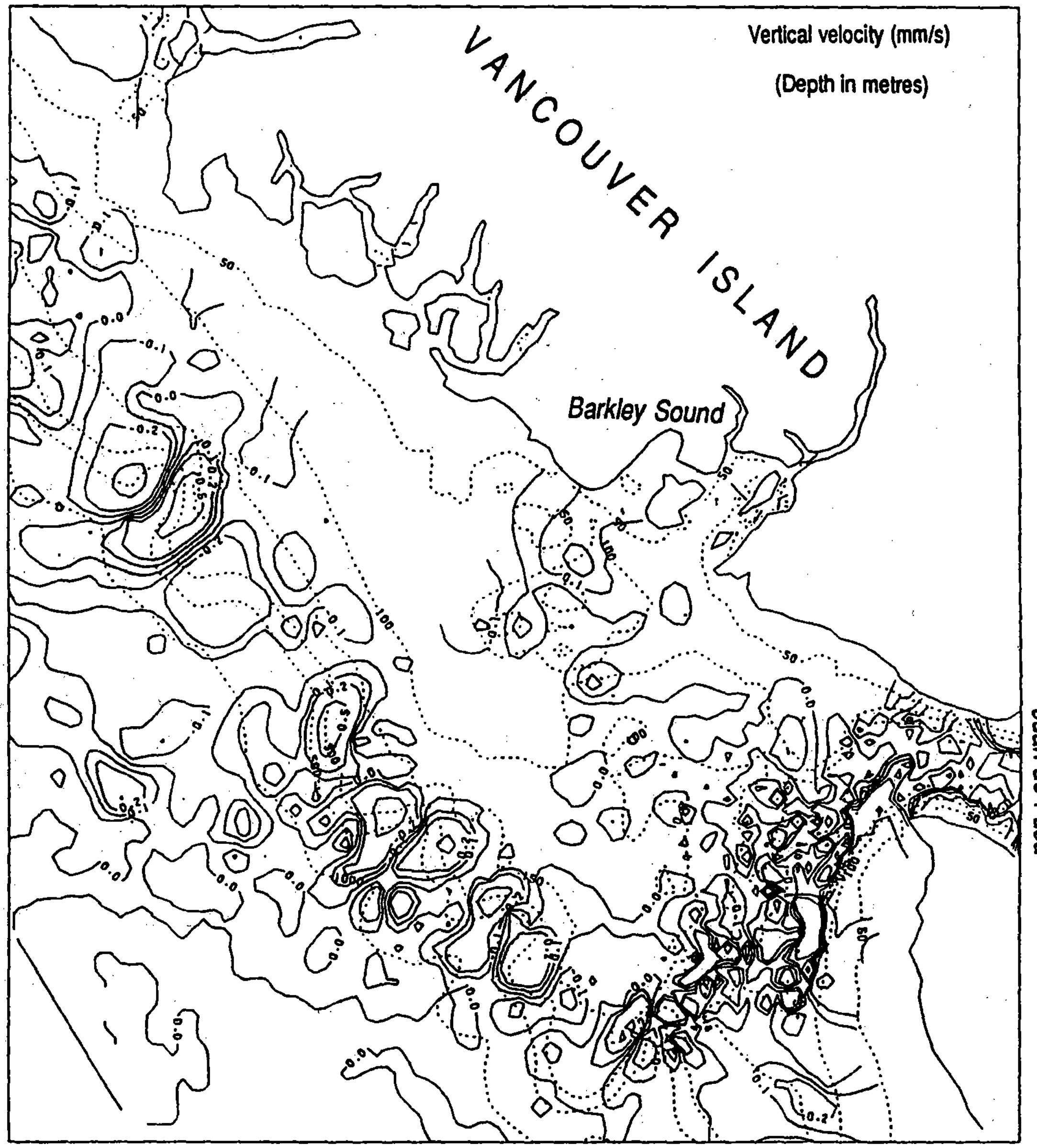

Figure 12. Vertical velocities (mm/s) (positive is up) at 100m for the same model calculation as in Figure 11.

3.1.3 Data Management Activities at I.O.S.

This document presents a summary of some of the data management activities underway at the Institute of Ocean Sciences (IOS) that are related to the La Perouse and MASS programs.

Data Archive Database

An electronic inventory of off-line oceanographic data (the Data Archive Database) has been created at IOS. This is implemented as a relational database in ORACLE, running on a MicroVAX II (soon to be moved to a MicroVAX 3100). This database links information about oceanographic stations (EVENTS), measurements made (PARAMETERS), file storage name, tape I.D., as well as more general information about who collected the data and why. This database contains "header" data (metadata) and pointers to the actual data files on off-line storage - it does not contain the actual data. There is sufficient information in the data inventory to fully automate the recovery of data from off-line storage, but this feature has not yet been implemented.

The database structure follows the oceanographic data model developed by the Bedford Institute of Oceanography and will accept a wide variety of data types - basically, any information that has a set of measurements with a geographic location (a single latitude and longitude or a latitude and longitude pair to indicate a transect or aerial survey) and a location in time (a single time or time range) may be included in such an inventory. There is also provision for extensive comments or non-structured supporting information relating to individual stations or events, as well as at higher levels (cruises and datasets). Information about cruises is retained in the data inventory, but it is not required that data have a cruise affiliation. Additional data types that could be easily inventoried using this database structure are:

- SAIL data
- vessel-mounted RDI current meter data
- plankton tows
- drifting buoy tracks
- computer model output (predicted flow fields, density fields etc.)

It is our intention to use this inventory to keep track of data acquired, processed or used at IOS (this includes CTD data from PBS that is processed at IOS). At present we have "loaded" the inventory with 6704 CTD stations from 1973 to 1990. In addition, the archive will soon be loaded with summary information from 360 current meter deployments. A sample of a summary "high level" report from the data archive database in shown in Table 2.

Table 2. Sample summary information from data archive database.

Run: April 14, 1992
By: OPS$DATAMAN

DFO_IOS Scientific Computing Services
*** LIST OF CRUISES ***

Page: 4
CRUISE_LIST.SQL VER 1.3

DSID	CRID	CRUISE	AGY	PROJECT	VESSEL	DESCRIPTION	STARTDATE	END_DATE	SCIENTIST	GEOGRAPHIC_AREA
62	62	86-15	101	HOT VENTS	PARIZEAU	CTD/TRANSM. & HYDRO CASTS, CM MOORINGS.	08-SEP-86	19-SEP-86	THOMSON RE	ENDEAVOUR, WCVI
62	62	86-15	101	LAPEROUSE	PARIZEAU	CTD/TRANSM. & HYDRO CASTS, CM MOORINGS.	08-SEP-86	19-SEP-86	THOMSON RE	ENDEAVOUR, WCVI
63	63	86-16	101	LAPEROUSE	PARIZEAU	CTD & HYDRO CASTS, CM MOORINGS.	09-NOV-86	11-NOV-86	THOMSON RE	WCVI
64	64	86-30	101	LAPEROUSE	PARIZEAU	CTD/TRANSM. & HYDRO CASTS	12-JUN-86	20-JUN-86	THOMSON RE	WCVI
65	65	86-31	101	LAPEROUSE	PARIZEAU?	CTD/TRANSM. & HYDRO CASTS.	23-AUG-86	24-AUG-86	THOMSON RE	WCVI
66	66	86-40	101	NCODE		CTD PROFILES.	27-SEP-86	01-OCT-86	CRAWFORD WR	DIXON ENTRANCE
67	67	86-80	101	LAPEROUSE	GB REED	CTD PROFILES & PLANKTON.	25-FEB-86	03-MAR-86	SHAW W	WCVI
68	68	86-81	101	LAPEROUSE	GB REED	CTD PROFILES, ...	03-APR-86	07-APR-86	SHAW W	WCVI
69	69	86-82	101	LAPEROUSE	GB REED	CTD PROFILES, ...	11-MAY-86	15-MAY-86	SHAW W	WCVI
70	70	86-83	101	LAPEROUSE	GB REED?	CTD PROFILES	12-AUG-86	26-AUG-86	SHAW W	WCVI
71	71	86-90	101	LAPEROUSE	ENDEAVOUR	CTD PROFILES.	13-JAN-86	21-JAN-86	THOMSON RE	GEORGIA, JUAN DE FUCA, WCVI, JERVIS
72	72	86-91	101	LAPEROUSE	ENDEAVOUR	CTD PROFILES	10-MAR-86	26-MAR-86	THOMSON RE	GEORGIA, JUAN DE FUCA, WCVI, JOHNSTONE, JERVIS, ALBERNI
73	73	87-01	101	LINE P	ENDEAVOUR	CTD & HYDRO CASTS, SEDIMENT TRAPS, XBT'S	30-MAR-87	09-APR-87	TABATA S	LINE P
74	74	87-02	101	LINE P	PARIZEAU	CTD/TRANSM. & HYDRO CASTS, AES BUOY & DRIFTERS, THERMISTOR CHAINS, NUTRIENTS, SAIL, XBT'S	22-SEP-87	16-OCT-87	TABATA S	LINE P, NE PACIFIC
74	74	87-02	101	OCEAN STORMS	PARIZEAU	CTD/TRANSM. & HYDRO CASTS, AES BUOY & DRIFTERS, THERMISTOR CHAINS, NUTRIENTS, SAIL, XBT'S	22-SEP-87	16-OCT-87	TABATA S	LINE P, NE PACIFIC
75	75	87-03	101	OCEAN STORMS	PARIZEAU	CTD, DRIFTING BUOYS, SUSIE, FLY	23-OCT-87	07-NOV-87	CRAWFORD WR	NE PACIFIC
76	76	87-04	101	LINE P	PARIZEAU	CTD & HYDRO CASTS, PRODUCTIVITY, SEDIMENT TRAPS	24-NOV-87	09-DEC-87	TABATA S	LINE P, NE PACIFIC
76	76	87-04	101	OCEAN STORMS	PARIZEAU	CTD & HYDRO CASTS, PRODUCTIVITY, SEDIMENT TRAPS	24-NOV-87	09-DEC-87	TABATA S	LINE P, NE PACIFIC
77	77	87-10	101	LAPEROUSE	ENDEAVOUR	CTD/TRANSM. & HYDRO CASTS, CM MOORINGS, PLANKTON	11-FEB-87	19-FEB-87	THOMSON RE	WCVI
77	77	87-10	101	SHELF BREAK '87	ENDEAVOUR	CTD/TRANSM. & HYDRO CASTS, CM MOORINGS, PLANKTON	11-FEB-87	19-FEB-87	THOMSON RE	WCVI
78	78	87-11	101	LAPEROUSE	ENDEAVOUR	CTD/TRANSM. & HYDRO CASTS, CYCLESONDE	10-MAR-87	15-MAR-87	THOMSON RE	WCVI

In the coming year, we intend to:

- complete the transfer of data processing comments into the database
- add historical HYDRO (bottle cast) data to the inventory
- improve the interface to the database (improve existing forms and reports)

ODAS (Ocean Data Acquisition System)

The Departments of Transport (Coast Guard), Environment (Atmospheric Environment Service) and Fisheries and Oceans (Physical and Chemical Sciences) have established a network of meteorological buoys off the west coast of Canada that report their data in real time. This network is part of a larger, international network of buoys in the eastern Pacific (Fig. 13). The detailed positions and identifiers of the Canadian buoys are shown in Figs. 14a (north coast) and 14b (south coast). The position of automated shore-based meteorological stations are also shown.

The network of buoys was installed for :

- improving forecasts (especially the offshore buoys)
- improving local weather reports
- real-time support for environmental emergencies and SAR
- long term monitoring of oceanographic conditions

These buoys report the following measurements every hour:

- wind speed and direction
- wave height and period
- barometric pressure
- air temperature
- sea surface temperature

The data from these buoys are received and archived at the Pacific Weather Centre of Atmostpheric Environment Service (AES) in Vancouver. We currently download the data from all the Canadian buoys from their computer about twice a month. The data are sorted into monthly files of ocean-related parameters (sea surface temperature, wave height, wave period, air temperature and air pressure) and the wind information (wind speed and direction, gust velocity). Daily and monthly averages are generated for comparison with lighthouse time series and for incorporation into the monthly northeast Pacific sea surface temperature maps generated by Howard Freeland and the Marine Environmental Data Service (MEDS, Ottawa).

These real-time data are replaced every six months with updated versions of the AES archive data. These data have been through initial stages of quality control (including deciding which sensors are providing accurate data). Data for the period prior to the beginning of the local AES/PWC

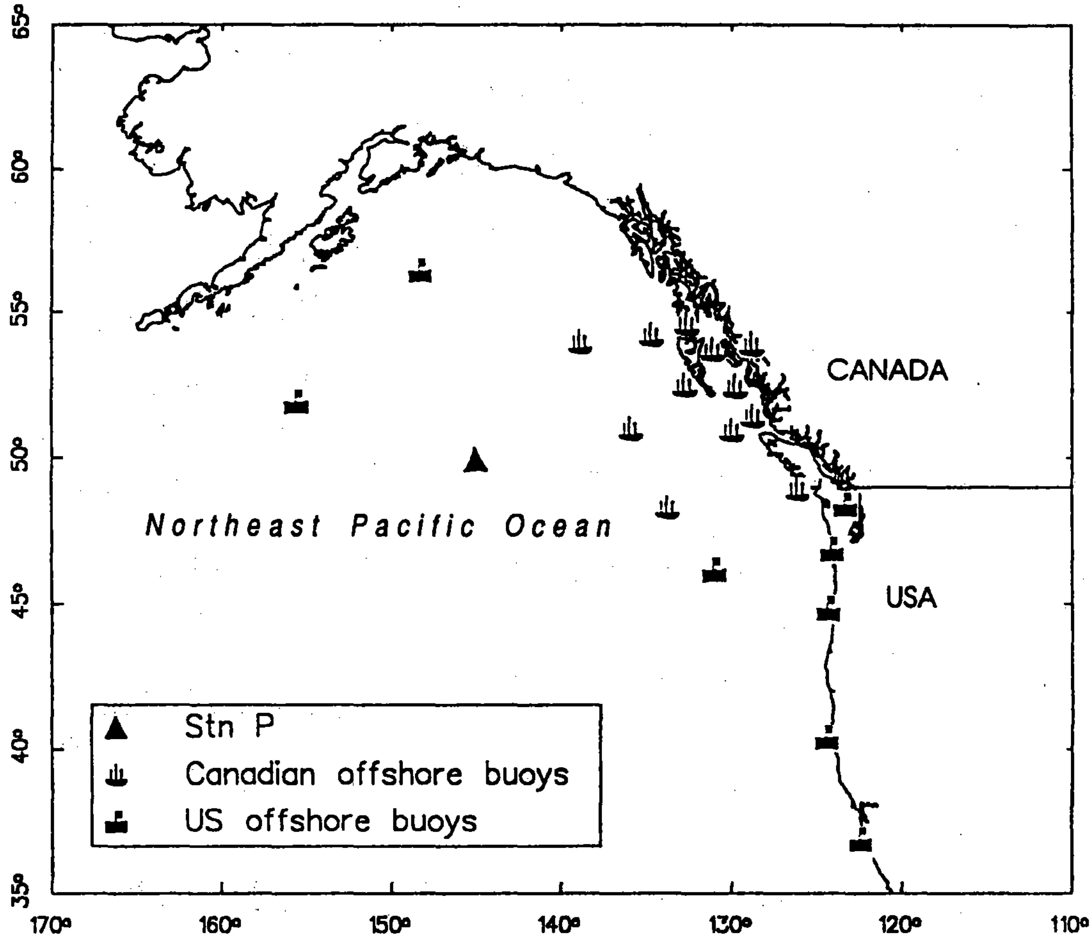

Figure 13. Offshore buoys in the Northeast Pacific Ocean.

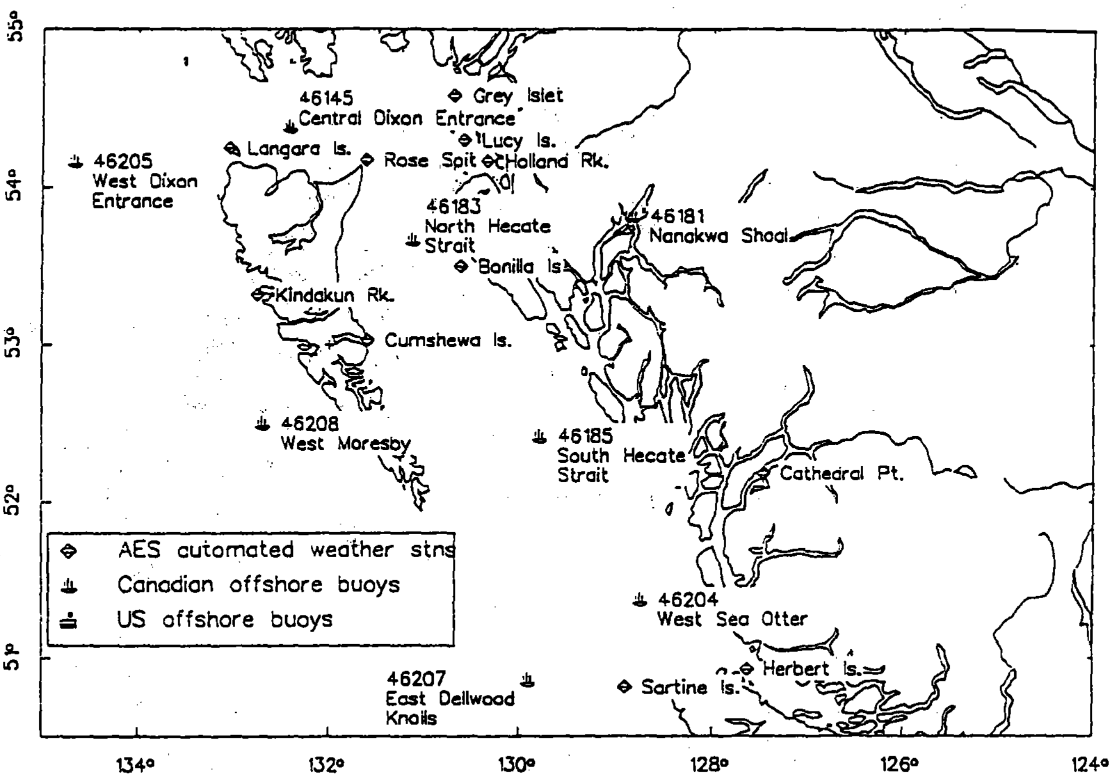

Figure 14a. Meteorological buoys and automated meteorological stations - North coast.

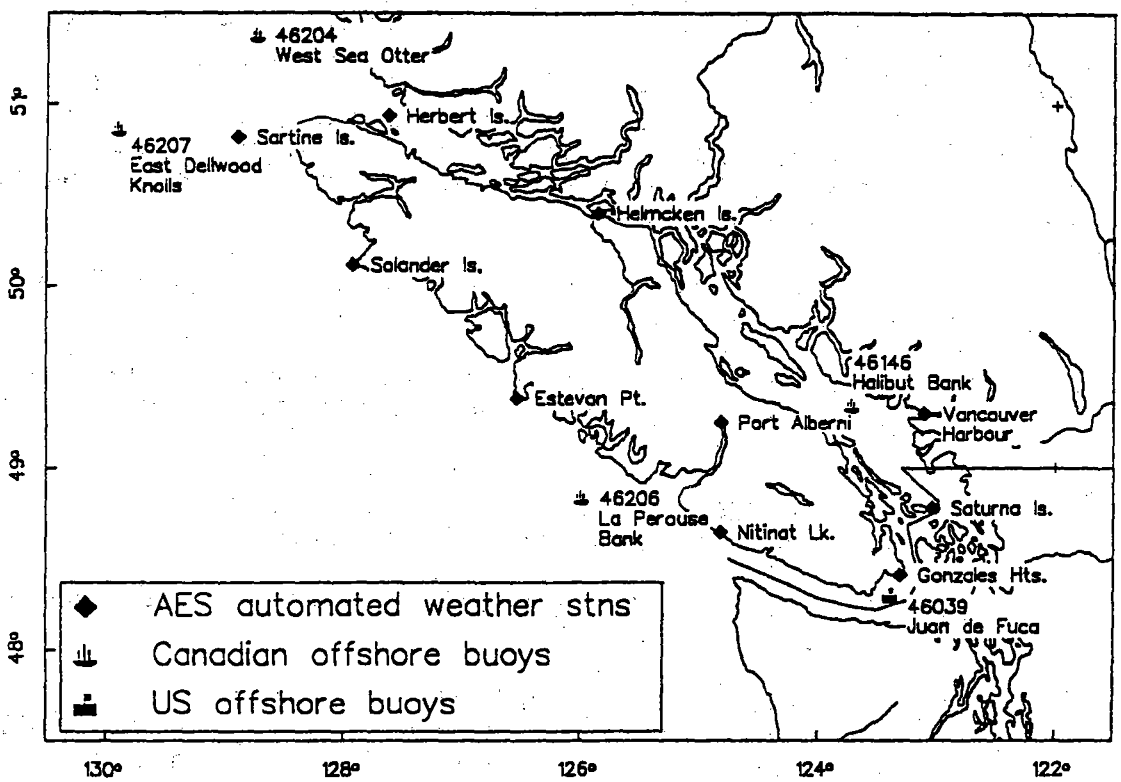

Figure 14b. Meteorological buoys and automated meteorological stations - South coast.

archive (May, 1990) was retrieved from MEDS. Table 3 shows the data availability at each site.

SAIL Data

The Engineering Services group at IOS (under the direction of Jim Galloway) has undertaken the development of a menu-driven SAIL data acquisition and display program (CSAIL) plus a VAX-based processing, display and archival system. The data acquisition program has been used on the C.S.S. *Parizeau*, C.S.S. *John P. Tully* and the F.R.V. *W.E. Ricker* for the last two years and is considered to require only minor fixes and repairs.

The VAX based processing stream is not yet complete. At present, there are routines for:

CALIBRATION of the data (one module at a time) using pre-cruise or post-cruise calibration coefficients supplied by the user

TRACK PLOTTING - to show where a cruise has gone and to aid in detecting errors in position

TIME-SERIES PLOTTING - plots of up to 4 parameters per page may be created.

DATA ARCHIVAL AND RESTORATION - support files and DCL routines exist that allow a user to restore SAIL data from off-line storage with a minimum of intervention. These routines also track where various SAIL datasets are archived.

There are some significant components that are missing from the data processing system. These include a routine to "rebuild" the calibrated data from individual sensors into tabular form, with values from all sensors being reported for each sampling period and an interactive graphics-based editor for removing spikes in the data. These system components were not overlooked - the money to complete these tasks dried up before they could be completed. The following steps have been taken as an interim measure:

-DCL routine has been written to rename files from each module and copy them to a specified work directory
-A QuikBASIC program (SAIL2XL) has been written to build the tabular files. The files created are ASCII files that are compatible with the interactive graphics editor and suitable for loading into spreadsheets for subsequent display and processing
-An interactive graphical editor (EDITSAIL) has been written to locate and delete erroneous data. This is a simple editor and does currently support advanced features such as filtering and interpolation.

Table 3. Data availability from offshore buoys.

1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	BUOY	NAME
											X-----	-----	------	------	------	X	46001	Gulf of Alaska
											X-----	-----	------	------	------	X	46003	S. Aleutians
X	-----	-----	-----	-----	-----	-----	-----	------	-----	-----	-----	-----	------	------	------	X	46005	Washington
												X---	------	-----X			46030	Blunts Reef
																	46039	Juan de Fuca
											X-	-----	------	------	------	X	46040	C Foulweather
											X-	-----	------	------	------	X	46041	?
																	46042	Monterey
																	46043	Gray's Hbr
												X	------	---| =	= =	X =	46004	Middle Nomad
											X	------	------	--| =	= =	X =	46036	South Nomad
															| =	=	46145	Cent Dixon En
																|	46146	Halibut Bank
															| =	=	46181	Nanakwa Sh.
														| =	= =	=	46182	Pam Rocks
															| =	=	46183	N. Hecate Str.
											X	------	------	--| =	= =	=	46184	North Nomad
														| =	= =	=	46185	S. Hecate Str
													X	--| =	= =	=	46204	W. Sea Otter
												X	------	--| =	= =	=	46205	W. Dixon Entr
												X	------	--| =	= =	=	46206	LaPerouse Bk
													X	--| =	= =	=	46207	E. Dellwood
														| =	= =	=	46208	West Moresby

X---- data from MEDS archive

| = = data from local IOS /PWC archive

The overall strategy is to provide basic processing, display and archival on the VAX to produce a working data set that users can use in whatever manner they see fit.

RDI Acoustic Doppler Current Meter data

The data from the vessel-mounted acoustic Doppler current profiler (ADCP) that was installed on the C.S.S. *Parizeau* have been processed under contract. A complete data processing and display system has been written for the PC. The main output products from this system are maps showing current vectors and vertical section contours. The data are not without their problems, however - erroneous data are frequently collected during rough weather and while the ship is maneuvering. In addition, the ADCP can confuse plankton layers with the bottom and switch to tracking mid-depth plankton layers without warning. Based on results with other hull-mounted transducers on the C.S.S. *John P. Tully*, we expect to get somewhat poorer quality data from the ADCP which is to be installed on this vessel.

During 1992, I will be working with Rick Thomson (and a contractor) to create a VAX-based archive of the data and to compile data across cruises (by area) to look for persistent features in the ADCP data set.

Remote Sensing

Jim Gower and John Wallace (Ocean Physics, IOS) have put together an inexpensive satellite data receiving station, complete with a tracking antenna. At present, they are recording all the NOAA satellite passes that occur during normal working hours. The passes are picked up off California and extend to the southern Beaufort Sea. The data are archived to DAT tape at IOS. Data of interest may be recovered from DAT tape, written out to nine-track tape and transferred to the PDP-11 or SUN image processing stations.

Future plans for this system include:

-installation of a programmable antenna controller to allow unattended data acquisition (summer, 1992)
development of "quick-look" enhanced image archive in some common image format (GIF, TIF, PCX or ?). The quick-look files could then be made accessible on DFONET.
-transfer of the complete image processing system from the PDP-11 and SUN stations to a PC system (this rather large task will begin in 1992).

Satellite image data continues to be available from the UBC Remote Sensing facility operated by the Department of Oceanography.

6) LIGHTHOUSE Sea Surface Temperature and Salinity Time Series

Howard Freeland (Ocean Physics, IOS) continues to receive, verify and update these data (see Fig. 15 for station locations). The updated files are posted to a publicly-accessible directory on a routine basis. At the present time, routines are in place to automatically update a local copy of these files at PBS from the IOS archive (see Ron Tanasichuk at PBS for details).

The continuation of the sea surface temperature time series at Cape St. James is uncertain. AES are closing their manned station at this site, so any continuation of the time series will require substantially increased effort.

Computer Conferences/Bulletin Boards

A number of computer conferences have been established at IOS using the VAXNOTES software. The list of conferences or bulletin boards include:

OCEANOGRAPHIC_DATA_SETS: - interesting items on offshore buoys, Station P data archive, climatological data from IOS and other sources, lighthouse data etc.

SAIL - information on data acquisition and processing

CRUISES: cruise plans, cruise identifiers, status of data processing, cruise reports etc.

Access to these bulletin boards requires that the user have an account on the IOS central computer system. Robin Brown will coordinate the setting up of new accounts (if required) and demonstration/training for interested parties.

R. Brown

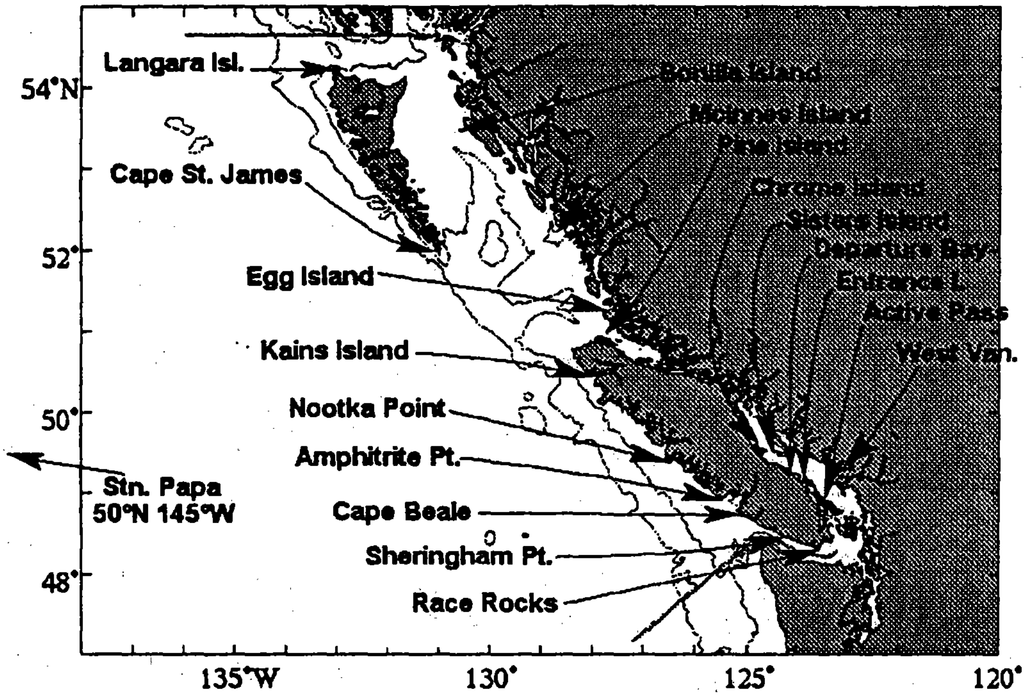

Figure 15. Lighthouse sea surface temperature and salinity time series sampling locations.

3.1.4 El Niño Update

El Niño is a large scale change in the global weather and oceanic conditions that is driven by perturbations in the prevailing atmospheric pressure systems over the southern equatorial Pacific. Though a global phenomenon, the effects are most pronounced in the Pacific Ocean.

The Global Picture

The southern oscillation index still shows substantially negative values. This means that the atmospheric circulation in the equatorial Pacific is still anomalous and so is still forcing the El Niño. The El Niño cannot recede until the atmospheric circulation returns to normal. The values of this index indicate that we are experiencing an El Niño that is significantly stronger than the 1986-87 event, but weaker than the 1982-83 event. The latter being the strongest El Niño of the 20th century. Sea surface temperatures are above normal along the entire coast of North America from the equator to Alaska. The average conditions for April show the largest temperature anomalies near Cape Mendocino (California). The biological response to the 1991-92 El Niño is, however, very strong and perhaps closer to the 1982-83 response than anything else. A recent U.S. cruise between Valparaiso (Chile) and San Diego surveyed the seabird populations. The report says: ..the Pacific rim of the Americas is temporarily dead, except for a pocket of guano birds near the Chilean border and another off southern Baja California. In between is a wasteland. At the Farallon Islands (a bird sanctuary off San Francisco) all species have failed totally to reproduce. This is important because birds are near the top of the marine food chain and integrate the status of the whole food chain below them. Because of their high metabolic rate they are sensitive to anomalies.

So what is to come? The computer model of Cane and Zebiak (Columbia University) indicates that the current warm conditions will persist late into the year. They predict a return of normal conditions in November or December. If true this El Niño would rate as not the strongest, but perhaps the most persistent of the century.

Conditions off the British Columbia coast

Off southern Vancouver Island sea surface temperatures rose abruptly in January and have remainded high ever since (Fig. 16). During April temperatures at times exceeded 2^{o}C above normal. Considering that the difference in temperature between the normal winter low and normal summer high is only 5^{o}C, this anomaly is clearly large. The warming can be seen in the sea surface sampling done at the lighthouses around the coast as well as the ship of

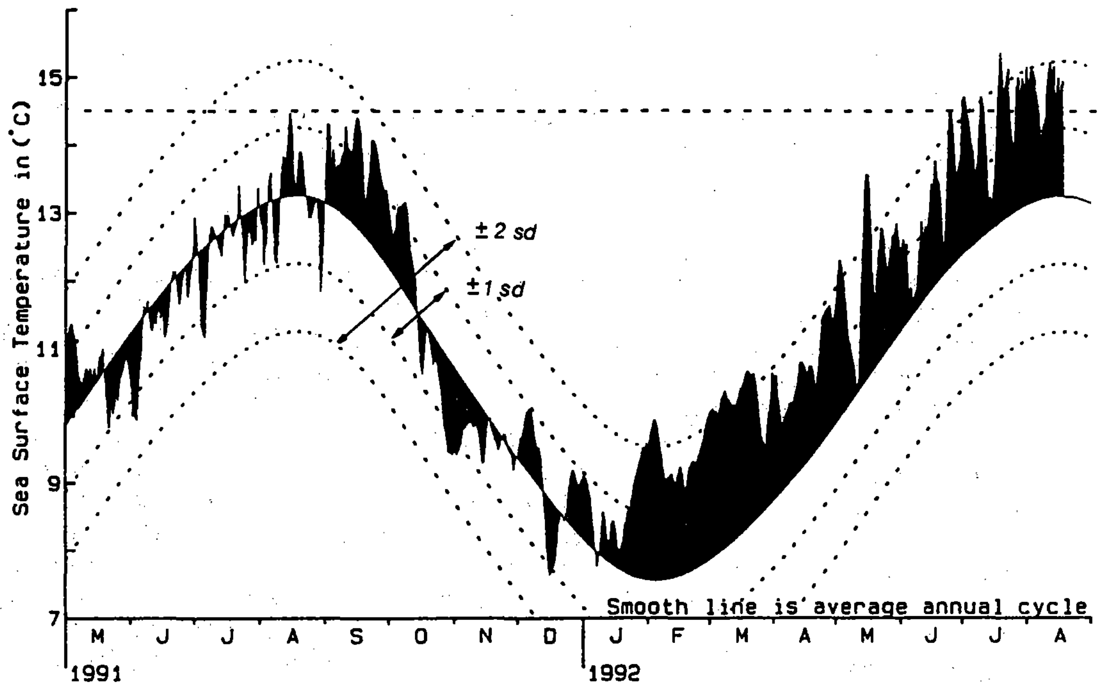

Figure 16. Daily average sea surface temperature (°C) at Amphitrite Point, southwest coast of Vancouver Island, for the period 1 May 1991 to August 1992. Dashed lines denote ±1, ±2 standard deviations.

opportunity data received by MEDS from the IGOSS system and edited and mapped at IOS. The data indicate that all areas are significantly warmer than normal, including the inside waters of the Strait of Georgia and Queen Charlotte Sound. A Line P survey in January 1991 showed the warming extending down to almost 100 metres depth and 400 km offshore. During April a survey was executed by the IOS Ocean Ecology group on the J.P. Tully as part of the La Perouse project. Comparing the unprocessed data with cruises from the same time of year in 1985 and 1987 indicate that 1992 is significantly warmer than the non-El Niño year (1985) and a little warmer than the moderate El Niño year (1987). Surprisingly, near surface temperatures are only about 1^{o}C (1992 cf 1985), but the difference increases steadily as we move down in the water column to 2.3^{o} warmer at 70 metres and 2.1^{o} warmer at 100 metres. We have no information on the vertical extent of warming in the Strait of Georgia or Queen Charlotte Sound due to cancellation of cruises on the CSS *Vector* to accommodate the fiscal restraint policy.

H. Freeland

3.2 BIOLOGICAL OCEANOGRAPHY PROGRAM

3.2.1 Seasonal Cycle of Plankton Biomass and Species Composition

The goals of the Biological Oceanography component of the La Perouse Project are to quantify the spatial, seasonal, and interannual variations in plankton biomass and community composition off the southern Vancouver Island outer coast, and to learn how variability of the plankton is transmitted up the food chain to commercially exploited fish stocks. Activities can be grouped into two major categories.

The first is time series sampling of zooplankton biomass and species composition using standardized collection methods at a standardized set of locations (Fig. 3b). This provides a steadily improving estimate of the average spatial and seasonal pattern, and the year-to-year deviations from this average.

The second group of research activities consists of individual process studies to establish causation for the observed pattern of spatial and time variability. Unlike the time series sampling, both site and detailed objective vary from cruise to cruise. 1991 activities and accomplishments in both areas are summarized below.

La Perouse Time Series

Two papers describing the average plankton seasonal and spatial patterns in the La Perouse region during the period 1979-1989 have now been published (Mackas, 1992; Mackas and Galbraith, in press). "Inner shelf", "Gyre", and "Offshore" regions can be distinguished during most cruises based on both zooplankton species composition and physical oceanographic characteristics such as current patterns and water properties. Peak zooplankton biomass was usually in late spring-early summer. Food supply to zooplankton is high from spring through autumn. Advective export of surface layer plankton appears to be the major control on zooplankton population size during the summer upwelling season.

1991 field sampling was undertaken during four IOS and PBS research cruises (February, June, August and October). Multi-year seasonal and spatial averages have been updated to include 1990 and 1991 data. Spatial averages for both the 1991 cruises and the 1979-1991 overal seasonal averages are shown in Fig. 17. Since early 1988, there appears to have been a general increase in the abundance of the euphausiid *Thysanoessa spinifera* and a decrease in the spring and summer biomass of continental shelf copepods such as *Calanus marshallae*. Because of differing life histories for these groups, one consequence is that spring zooplankton biomass

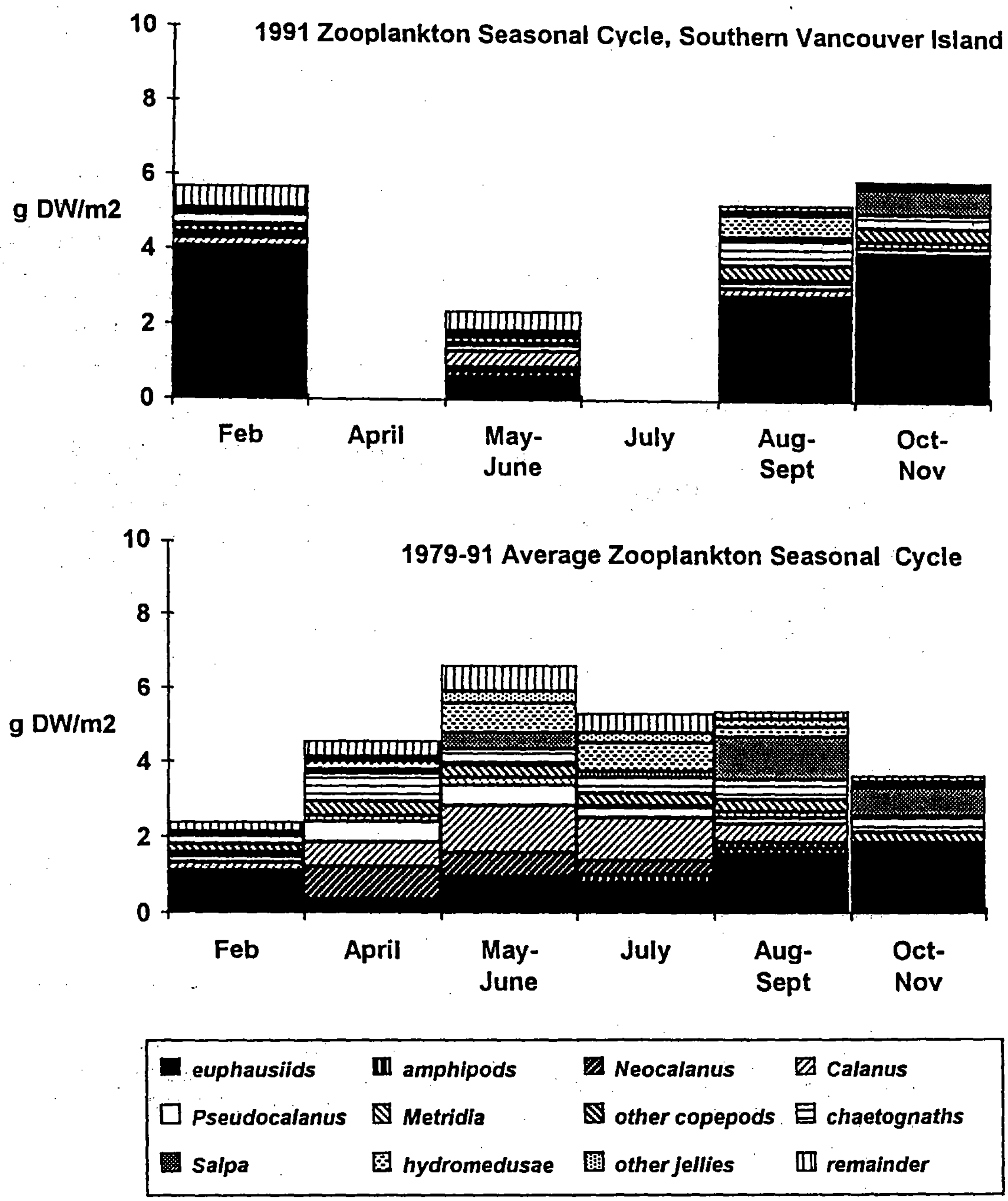

Figure 17. Zooplankton composition and biomass (estimated from size and abundance data) for the four 1991 sampling periods and averaged within season over the period 1979-1991.

has been lower, and late-summer-to-autumn biomass estimates higher than in the preceding decade. An analysis of between-year variability is being prepared for the planned autumn Symposium on Climate Change and Northern Fish Populations.

Zooplankton Process Studies in 1991

The major effort in 1991 was to examine the association of outer shelf euphausiid aggregations with the Shelf-Break Current and California Undercurrent, and their alongshore transport by these currents. Seven cross-shelf acoustic lines spread along the length of Vancouver Island were sampled in August. Acoustic Doppler Current Profiler (ADCP) and CTD sections (to give estimates of geostrophic currents) were done on the same lines.

Along two of these lines, a more detailed spatial survey compared cross-shore distributions of euphausiids and hake. This work was a collaboration with PBS scientists (Saunders, Kieser, McFarlane). Vertically-integrated estimates of hake and euphausiid biomass were strongly correlated both within and between survey lines (Fig. 18). Both species were most abundant beneath the inshore margin of the Shelf-Break Current, and in a region of strong shelf-edge upwelling.

D. Mackas

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Mackas, D.L. and M. Galbraith. in press. Zooplankton on the west coast of Vancouver Island: distribution and availability to marine birds. in: Vermeer and Butler, eds. The ecology, status, and conservation of marine and shoreline birds of the west coast of Vancouver Island. Can. Wildlife Serv. Spec. Publ.

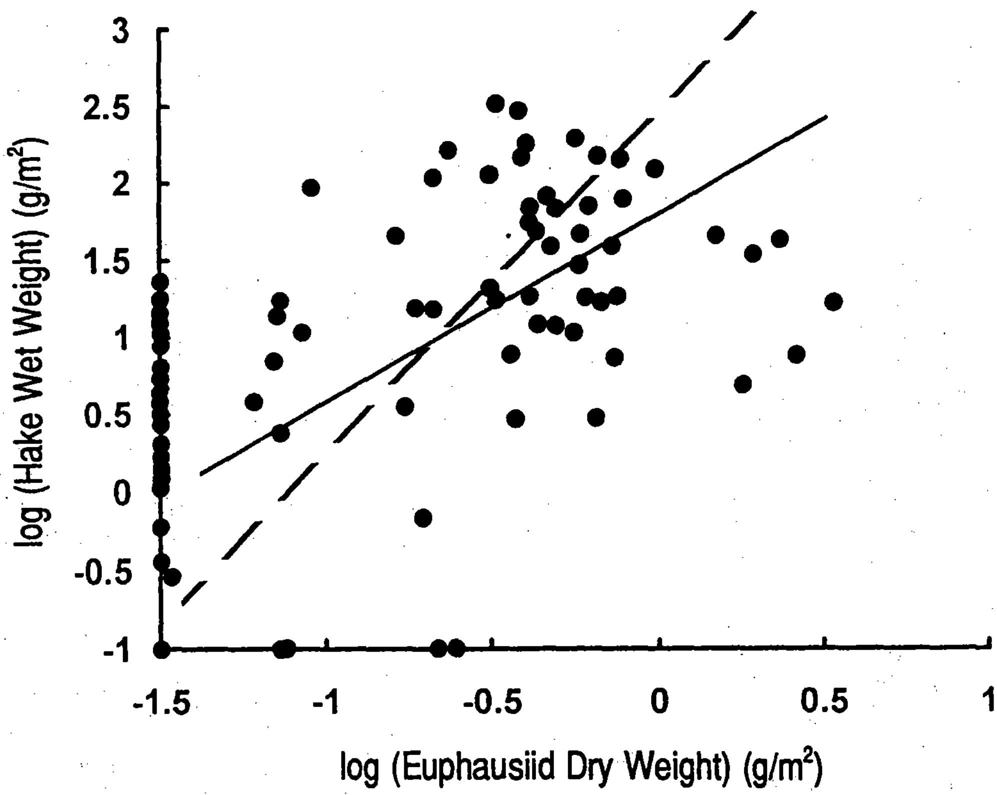

Figure 18. Correlation of hake and euphausiid biomass within shelf-break detailed survey areas seaward of Barkley and Nootka Sounds. Solid and dashed lines show best-fitting least-squares and functional regressions. Euphausiid and hake biomass were both low shoreward and seaward of the detailed survey areas.

3.2.2 Losses of Continental Shelf Production to the Deep Ocean off Brooks Peninsula

Since 1986, we have studied the trajectories and the development of plankton populations in cold water filaments that form recurrently off Brooks Peninsula. These filaments transport a substantial proportion of nutrient input and production on the shelf to the deep ocean. We have been able to document the offshore fluxes of nutrients, phytoplankton and zooplankton carried by these wind-driven upwelling filaments. An additional objective is to estimate the vertical particulate loss rates at the shelf edge that are attributable to these filaments.

We report here analyses of sediment trap samples from two sequential sediment traps that were moored along the shelf break from 26 April to 30 September 1990. Current meter data from meters attached to the sediment trap moorings and associated water property data from CTD/Rosette stations are also reported. One trap was moored in a path frequently traversed by filaments (JET) and one to the north of the filament path (NOJET) (Fig. 19). Each mooring had a current meter and beam transmissometer at 30 m depth, a 12-cup sequential sediment trap at 200 m depth and a current meter 6.5 m below the trap.

Surface currents at the time of the mooring deployments in April were weak and variable. In July the Shelf-Break current, which moves to the southeast, was relatively strong and located further offshore than usual. Surface drifters showed the presence of a well-developed filament over the site of the JET trap. Cross-shelf sections of *in vivo* fluorescence passing through the NOJET and JET sites (Fig. 20) show that the core of the filament was inshore from the trap sites. Surface water temperatures off the west coast of Vancouver Island from January to the end of September were generally 1 to 2^{o}C higher than usual. Mass flux (total dry weight) to both sediment traps was substantial and highly variable. The integrated mass flux over the full deployment period was approximately equal at both sites. High chlorophyll levels recorded several times during the summer in the study area were not reflected in flux to the traps, which both showed peak flux in late May.

Particulate organic carbon (POC) and nitrogen (PON) fluxes roughly paralleled the total mass flux (Fig. 21), with POC typically comprising between 10 and 25% of the total. The proportion of carbon and nitrogen making up the total flux was substantially less at high flux rates than at lower rates (Fig. 22). We interpret this to mean that material at high flux rates was significantly more processed, presumably via grazing, than that at low rates. Such processing may partially explain the failure of the traps to indicate the high phytoplankton biomass in surface

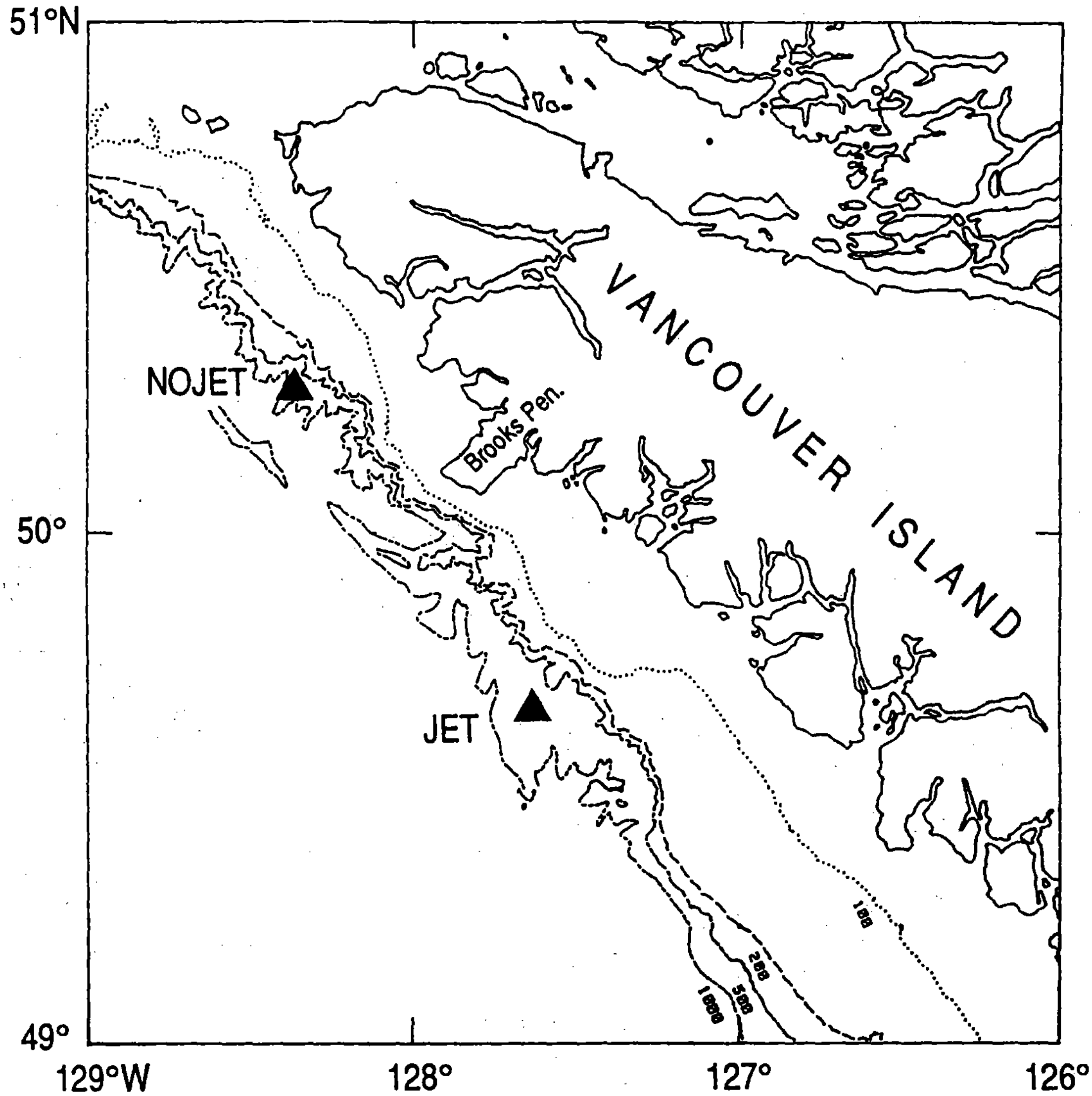

Figure 19. Location of sediment trap sites.

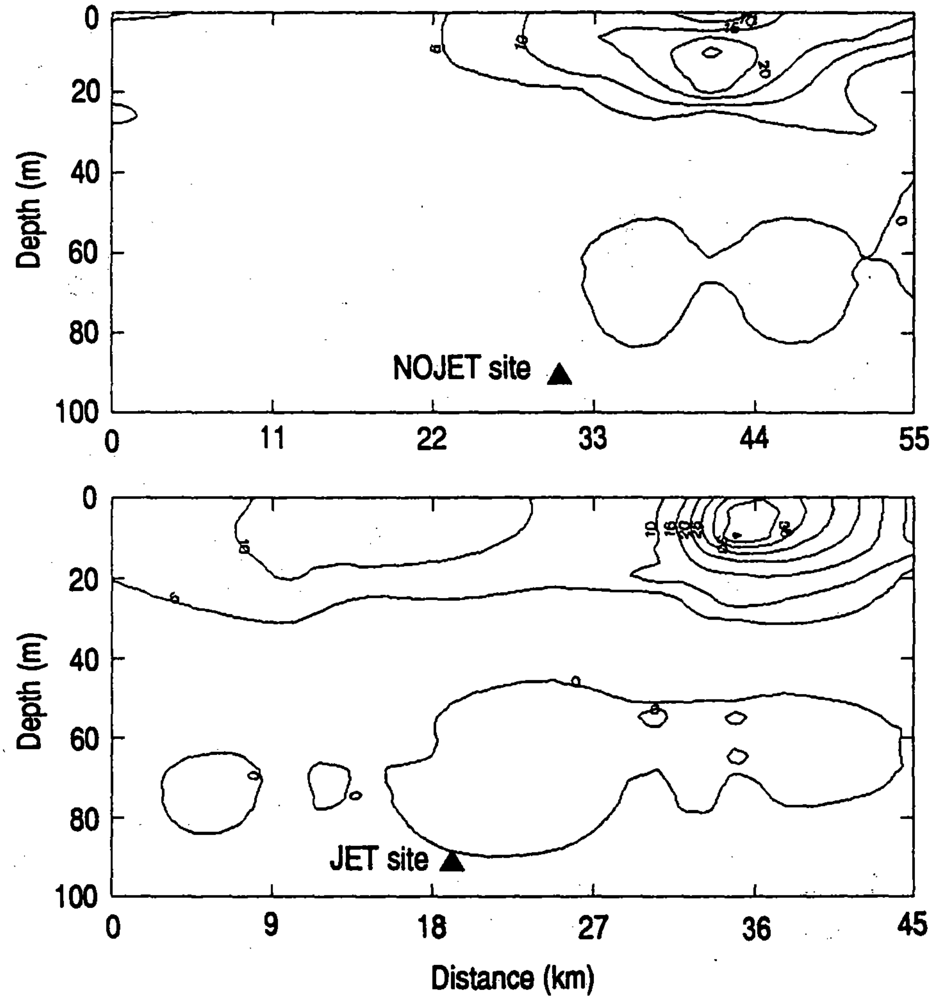

Figure 20. Cross-shelf sections of in vivo fluorescence. Upper panel: section north of Brooks Peninsula crossing over NOJET site. Lower panel: section south of the peninsula over the JET site. 0 km represents the outer (offshore) ends of the sections.

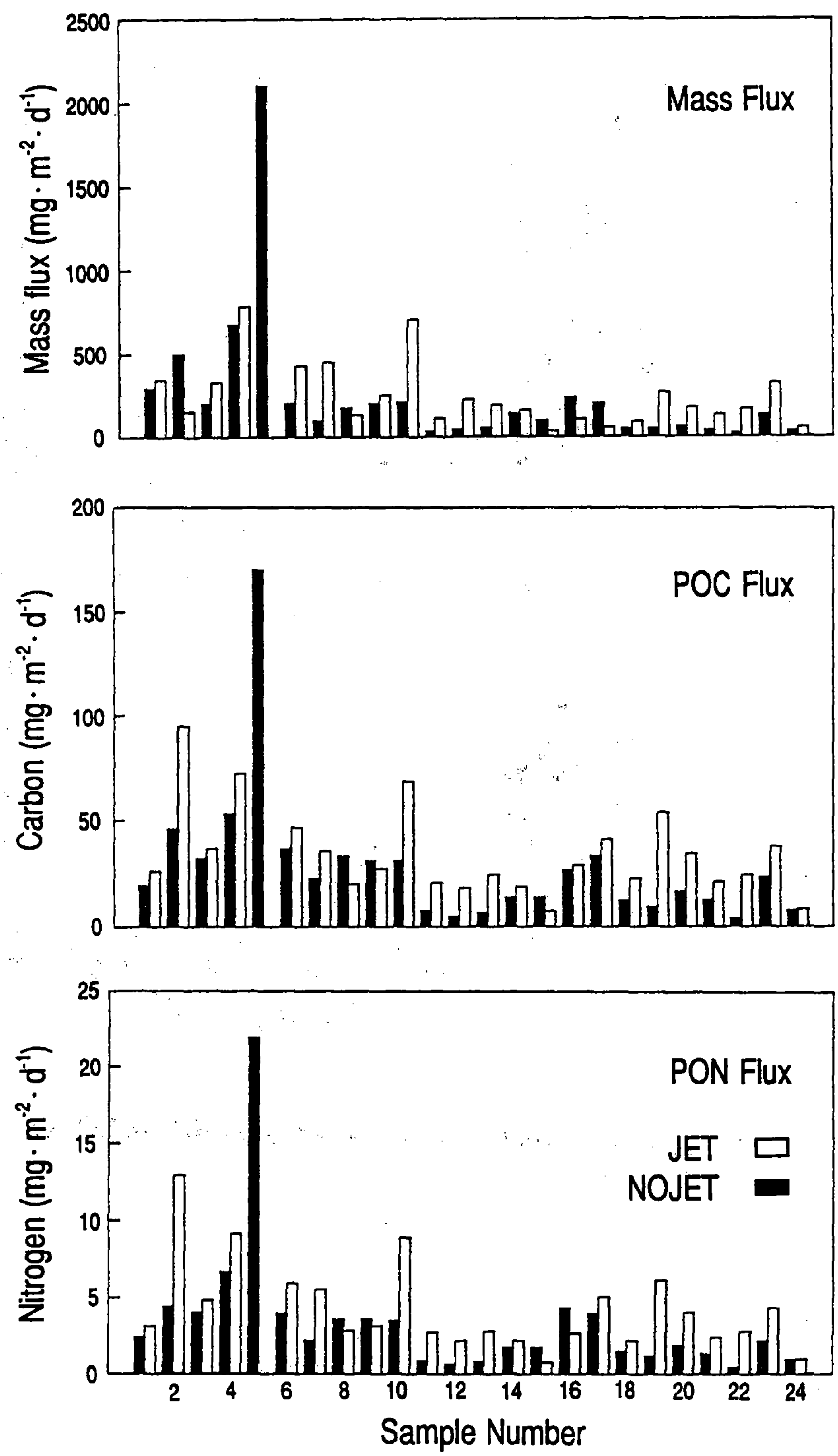

Figure 21. Mass flux (dry weight), particulate organic carbon flux (POC) and particulate organic nitrogen flux (PON) at JET and NOJET. The time series starts in April and ends in September, with each sample representing one week.

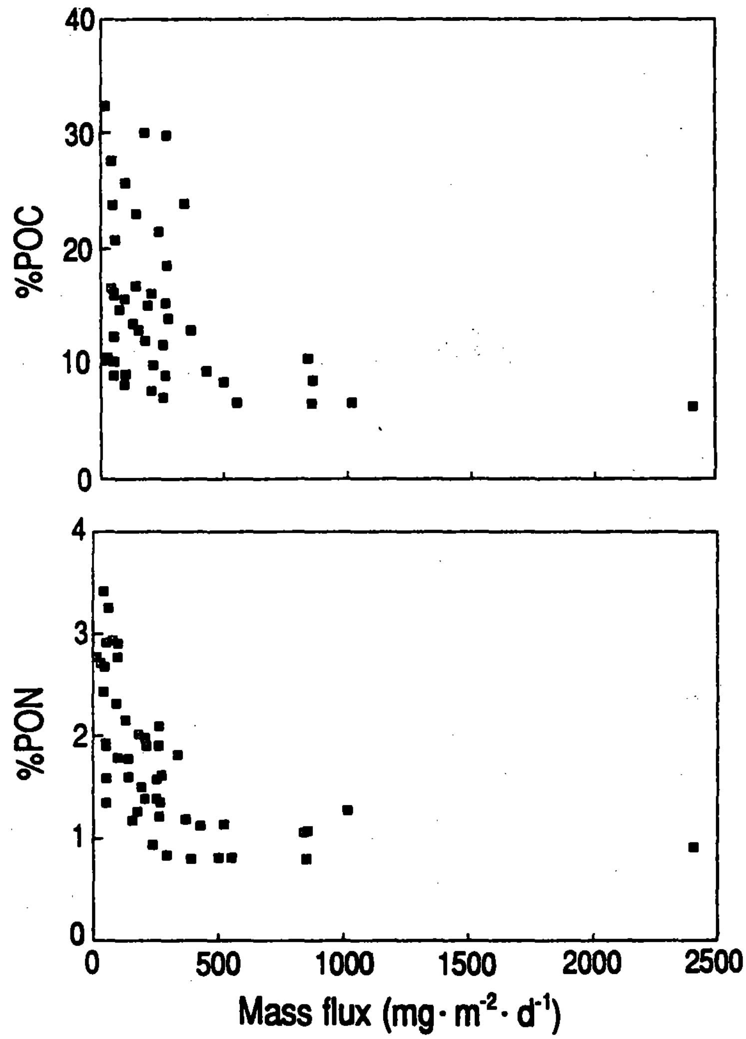

Figure 22. POC and PON as a percentage of mass flux.

waters during the summer. Total mass flux was 39.9 $g.m^{-2}$ at JET and 43.3 $g.m^{-2}$ at NOJET over the period of trap deployment. Equivalent values for POC were 4511 $mg.m^{-2}$ and 5728 $mg.m^{-2}$, and for PON were 541 $mg.m^{-2}$ and 714 $mg.m^{-2}$.

A clear relationship between surface currents and flux to the sediment traps has not been established. However, based on an analysis of data from April to July (Fig. 23), we hypothesize that peaks in flux at both sites follow by one to two weeks a shift in mean integrated longshore transport from NNW to SSE. Such a shift in direction of the mean transport indicates the onset of upwelling-favorable wind conditions.

R. Forbes
K. Denman
R. Thomson

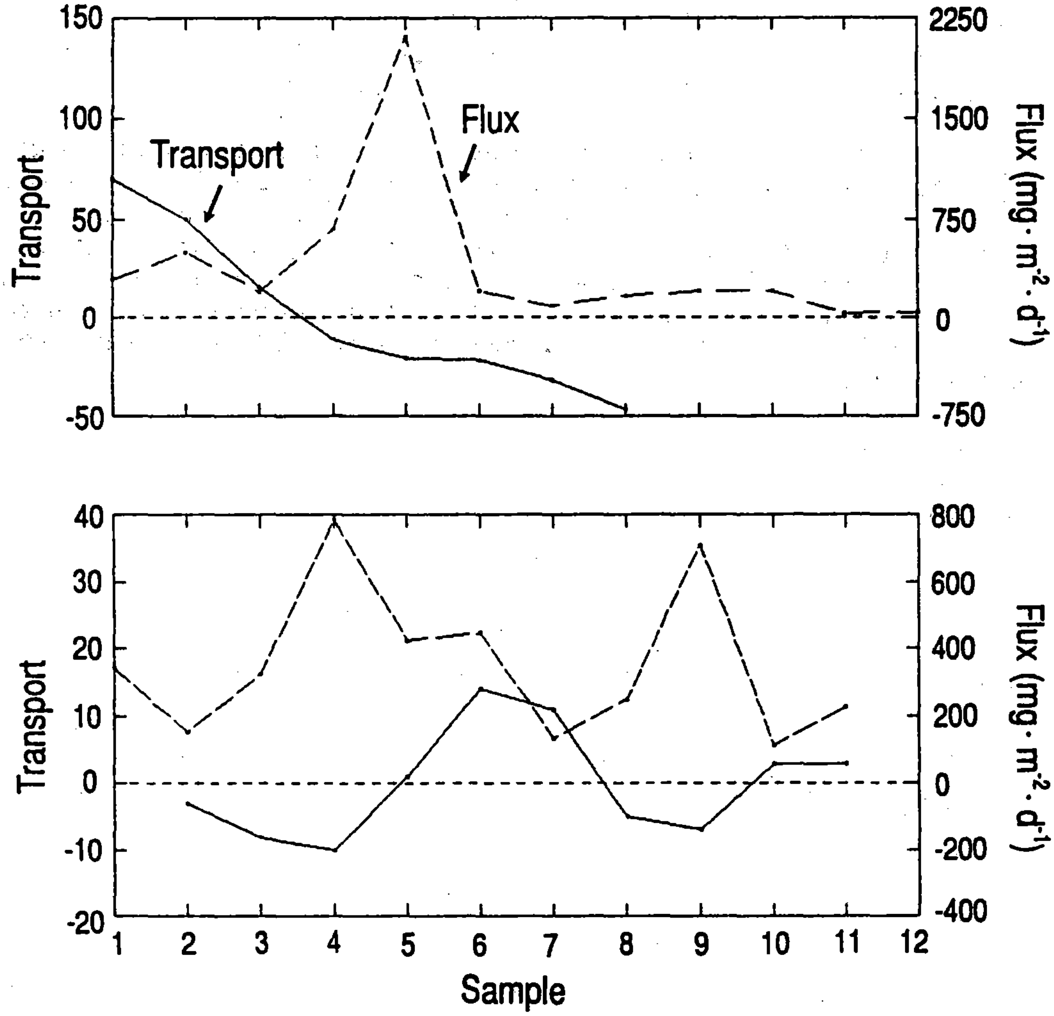

Figure 23. Mean longshore integrated transport (solid line) versus mass flux (dashed line) at JET (upper panel) and NOJET (lower panel). Positive values of longshore transport represent northward water movement; negative values represent southward transport. Sample numbers are as in Figure 21. Transport is in arbitrary units of volume.

3.2.3 Modelling plankton production in the La Perouse region

A generalized micro-computer simulation model has been developed that describes the seasonal feeding interactions and production dynamics of diatoms, copepods, and euphausiids in the 'eddy area' of the La Perouse region. Surface mixed layer plankton dynamics were forced daily by variability in upwelling, offshore transport, water temperature, and solar radiation as observed during 1985-89.

Simulated seasonal patterns in copepod and euphausiid biomass were validated using data collected and analyzed primarily by D. Mackas (see Mackas 1992). The simulated copepod seasonal pattern matched the empirical data after few 'adjustments' to model parameters. The period of greatest deviation of observed to simulated biomass occurred in late fall and may be due to the absence in the model of invertebrate predation on copepods.

The simulated seasonal euphausiid biomass pattern for 1985-89 was found to be mainly forced by the seasonal cycle of pelagic fish predation as determined by Ware. Because of the large biomass loss of euphausiids to pelagic fishes in July, D. Ware hypothesized that a mechanism of biomass re-supply to the eddy region was required to validate the observed euphausiid seasonal biomass pattern. In the model, euphausiid resupply was linked to the pattern and intensity of upwelling and the simulate euphausiid biomass trajectory resulted in a good fit with observed data.

A first order estimate of annual primary production from the 1985-89 model simulations is 300-350 $gC/m^2/yr$. Two periods were identified as being important in influencing annual plankton production. Plankton trophodynamics during the winter (November to February) strongly influenced spring plankton production dynamics. Similarly, environmental variability during spring (March to May) strongly affected plankton production dynamics during the upwelling season.

Simple single parameter perturbation model experiments indicate that from about June to September, diatoms were primarily influenced by environmental variability. For example, a +/- 10% change in the upwelling rate resulted in roughly a 10-15% change in annual diatom production. In contrast, diatom production variability was only slightly influenced by copepod and even less so by euphausiid production dynamics. Copepod production was only slightly affected by euphausiids, while the latter were strongly influenced by fish predation. These results simply that during the upwelling season the La Perouse plankton production system is forced primarily by bottom-up (resource) rather than by top-down (predation) processes.

A description of the plankton production model and the generalized simulation results for 1985-89 has recently been submitted to the *Journal of Plankton Research.* Further, the plankton model is presently being coupled with D. Ware's model describing the dominant pelagic fish trophodynamics in the La Perouse region. Two major reasons for developing a coupled plankton/fish model are: (1) to evaluate the influence of interannual variability in the oceanic environment on whole system productivity; and (2) to compare and contrast the current state with a historical state of the La Perouse system when it was dominated by Pacific sardines.

C. Robinson

3.2.4 Spring Larval Fish Assemblages - West Coast of Vancouver Island

The objective of this program, which began its data analysis phase in 1991, is to identify assemblages of larval fishes during spring off the west coast of Vancouver Island, and mechanisms influencing their formation. Samples were collected during surveys in April 1984 to 1989, with an additional survey conducted in April 1992. Larval fishes have been identified from all surface samples and depth-integrating bongo samples, and their lengths measured.

Assemblages of larval fishes were identified using various techniques of cluster analysis. Clustering of fish taxa consistently produced 3 or 4 groupings in each year (survey), which could be related to particular habitats: inshore fishes (e.g.herring), shelf fishes (e.g. lingcod, sand lance), and slope fishes (e.g. sablefish, lanternfish). Clusters of stations based on similarity of their larval fish compositions always indicated the strongest separations were between the shelf and slope regions, in particular off the La Perouse area (see Fig. 24). However, the boundaries of these two groups and the amount of overlap in the distributions of their component taxa varied between years. The extent of cross`shelf distribution of larval fishes may be critical to recruitment success since, for example, it has been suggested that sablefish must reach nearshore and lingcod remain on the shelf for survival to adult stages.

April is also the time of the Spring Transition in currents along the continental shelf, switching from northward-flowing (winter) currents to the southward-flowing (summer) pattern. We hypothesize that variability in the timing of this transition, which may be under large-scale climate control, is an important factor in determining the extent of cross-shelf distribution of larval fishes in the La Perouse area, and in maintaining the assemblages described above. This suggests these currents may also be important in determining the recruitment success and assemblage composition of commercially fished populations off Vancouver Island. This aspect of the problem is also being investigated.

R. I. Perry
G. A. McFarlane
R. E. Thomson

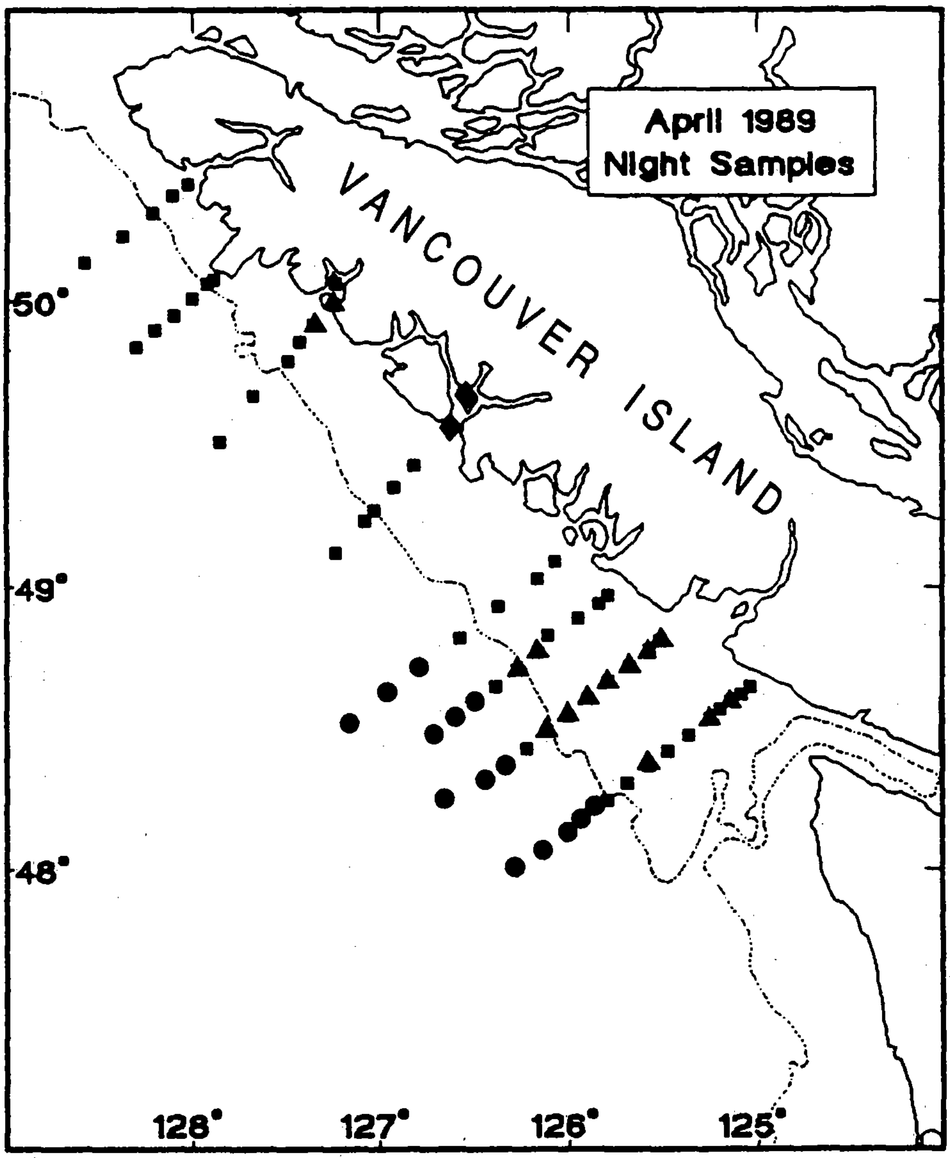

Figure 24. Clusters of stations based on their larval fish composition, from samples collected during night Neuston tows in April 1989. Different symbols represent different groupings of stations. Three principal clusters are indicated (dots, squares and triangles).

3.3 FISHERIES OCEANOGRAPHY PROGRAM

3.3.1 Pacific Hake Distribution and Recruitment

Pacific hake (Merluccius productus) is the most abundant species in waters off the west coast of Canada and is a major component of the groundfish fishery. The offshore stock is migratory and, after spawning off California and Mexico during the winter, moves northward to feed during the summer from northern California to Queen Charlotte Sound. Schools of adult hake first appear off Vancouver Island in late May and remain until late November. The southward migration may be triggered by the onset of the fall transition.

Total reported catches in the Canadian zone averaged 87,880 t over the five year period 1987 to 1991. The catch in 1991 increased to 99,000 t from 76,680 t in 1990. Participating countries in 1991 were Japan, Poland, and China. In 1991, most hake was landed through a joint venture with Canadian fisherman with a small supplemental allocation given to Poland. Interest in domestic processing of hake, in particular in the Ucluelet area, continues to grow.

The proportion of the stock supporting the Canadian fishery is in good condition as the Canadian fishery continues to be supported by a series of strong year-classes, in particular, the 1980, 1984 and 1987 year-classes. The stock overall is beginning to decline as the strong 1984 and 1980 year-classes are dropping in abundance and recruitment since 1984, with the exception of the moderately strong 1987 year`class, has been below average. It is anticipated that quotas will drop over the next several years unless recruitment increases.

The objectives of this study are: (1) to determine the distribution and relative abundance of Pacific hake in Canadian waters on an annual basis; (2) to examine distribution in relation to oceanographic and biological features; (3) to determine biotic and abiotic factors controlling year-class success; and (4) to determine the impact of Pacific hake and other predators on the abundance of Pacific herring (with D. Ware and R. Tanasichuk).

Research on the distribution, abundance and biology of this stock has been conducted annually since 1977. Qualitative surveys examining the distribution of hake were conducted annually from 1985 to 1989. Hake was found from the Canada-U.S. border to Queen Charlotte Sound. In 1990 and 1991 hydroacoustic surveys were conducted over this range. In general, large concentrations were found in the basins adjacent to La Perouse Bank and adjacent to Brooks

Peninsula. Smaller, dense schools were found along the 150-200 m isobath.

The total biomass of hake in the Canadian zone surveyed, increased from 316 thousand t in 1990 to 568 thousand t in 1991. The distribution of hake biomass varied between 1990 and 1991 (Figs. 25a,b and 26a,b). In 1990, 56% of the hake biomass was found north of 49 degrees in the Brooks Peninsula area. In 1991 only 21% was found north of 49 degrees and a large concentration of biomass was found just south of 49 degrees along the shelf break, in an area that contained few fish in 1990.

The 1990 and 1991 survey data were used extensively in analysis related to Canada/U.S. negotiations regarding allocation of yield. Briefly, negotiators agreed to use coastwide surveys conducted by the U.S. to determine the proportion of total coastwide biomass found in the Canadian zone. This same proportion would be used to split available yield. The U.S. surveys however, did not go beyond 50 degrees with one going only to 49 degrees. The Canadian surveys provided evidence of substantial quantities of fish north of the U.S. survey limits and formed the basis for increasing the proportion accredited to Canada.

During 1991 work continued on the factors affecting the distribution of hake has been to examine the effect of physical and biological environmental conditions on hake distribution. COMPUGRID software, a Geographic Information System (GIS) was used to display and overlay the host of factors.

The distribution of hake matched closely the distribution of euphausiids reported by Simard and Mackas (1989). Given the importance of euphausiids in the diet of hake it appears that the distribution of hake is linked to the distribution of their primary prey. Field work was conducted in 1991 with D. Mackas using hydroacoustics to establish the link between hake and euphausiids and to examine the fine scale physical and biological oceanographic factors influencing their distribution along the shelf break.

Future research will include the following:

1. A cooperative survey with industry to examine the migration of hake into and within the Canadian zone.
2. Continue to examine the factors influencing the summer and winter hake distribution.
3. Examine factors controlling hake year-class success.

M. W. Saunders
G.A. McFarlane

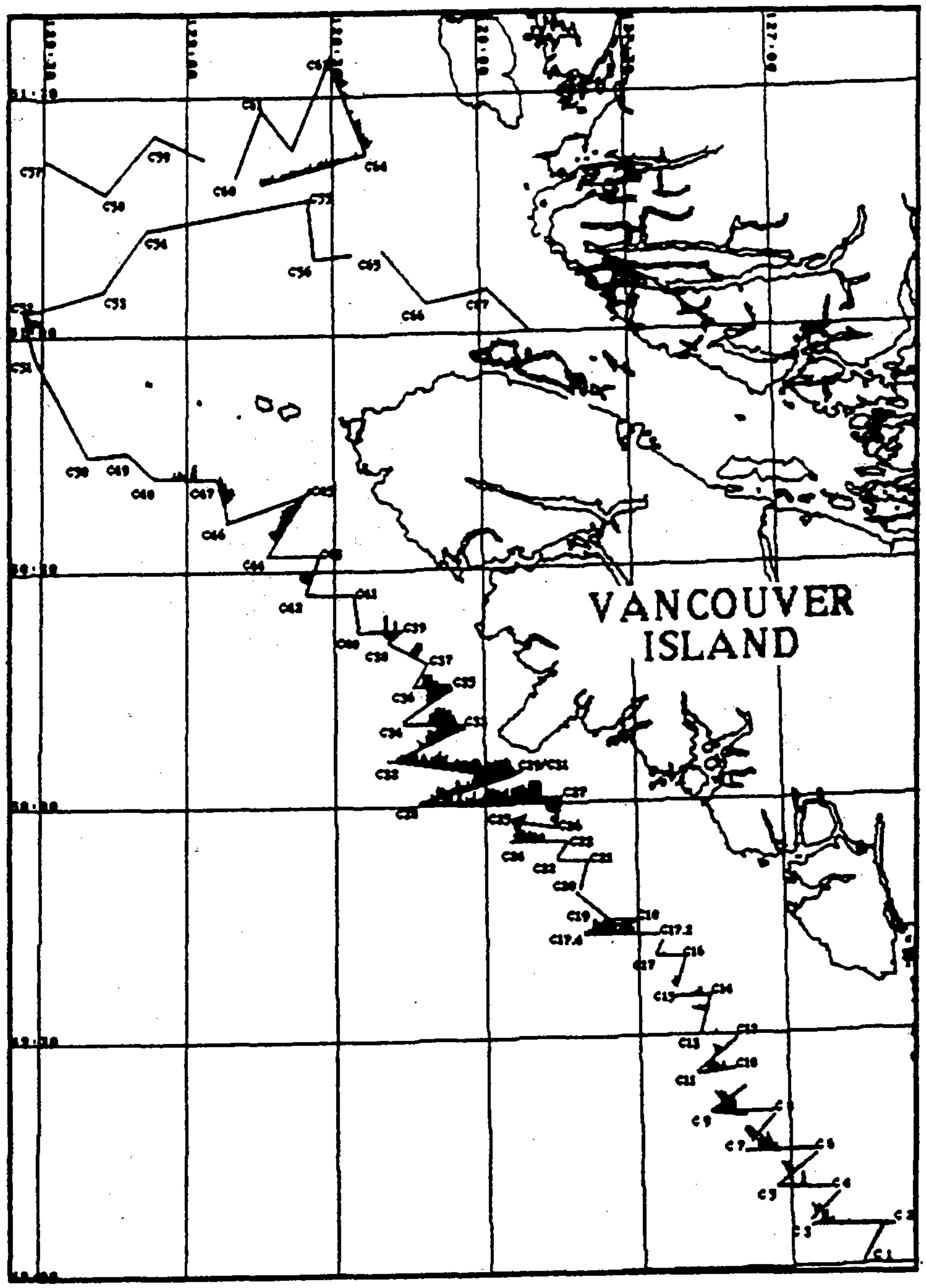

Figure 25a. Distribution of hake biomass during August 1990 based on hydroacoustics. Surface densities are represented on a log scale ranging from 0.01 to 1.0 kg/m^2. Target strength= -35 dB/kg. North coast.

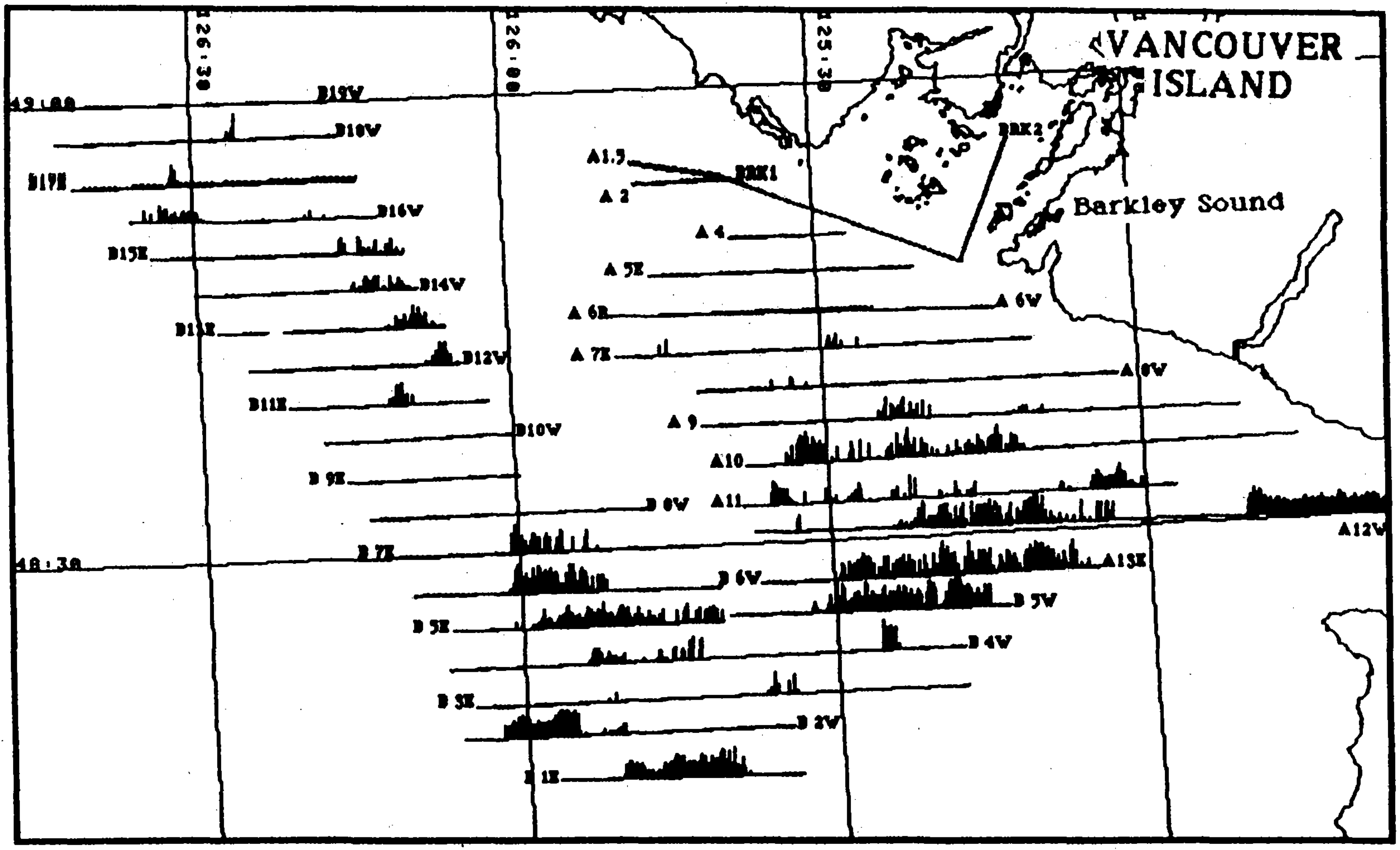

Figure 25b. Distribution of hake biomass during August 1990 based on hydroacoustics. Surface densities are represented on a log scale ranging from 0.01 to 1.0 kg/m^2. Target strength= -35 dB/kg. West coast.

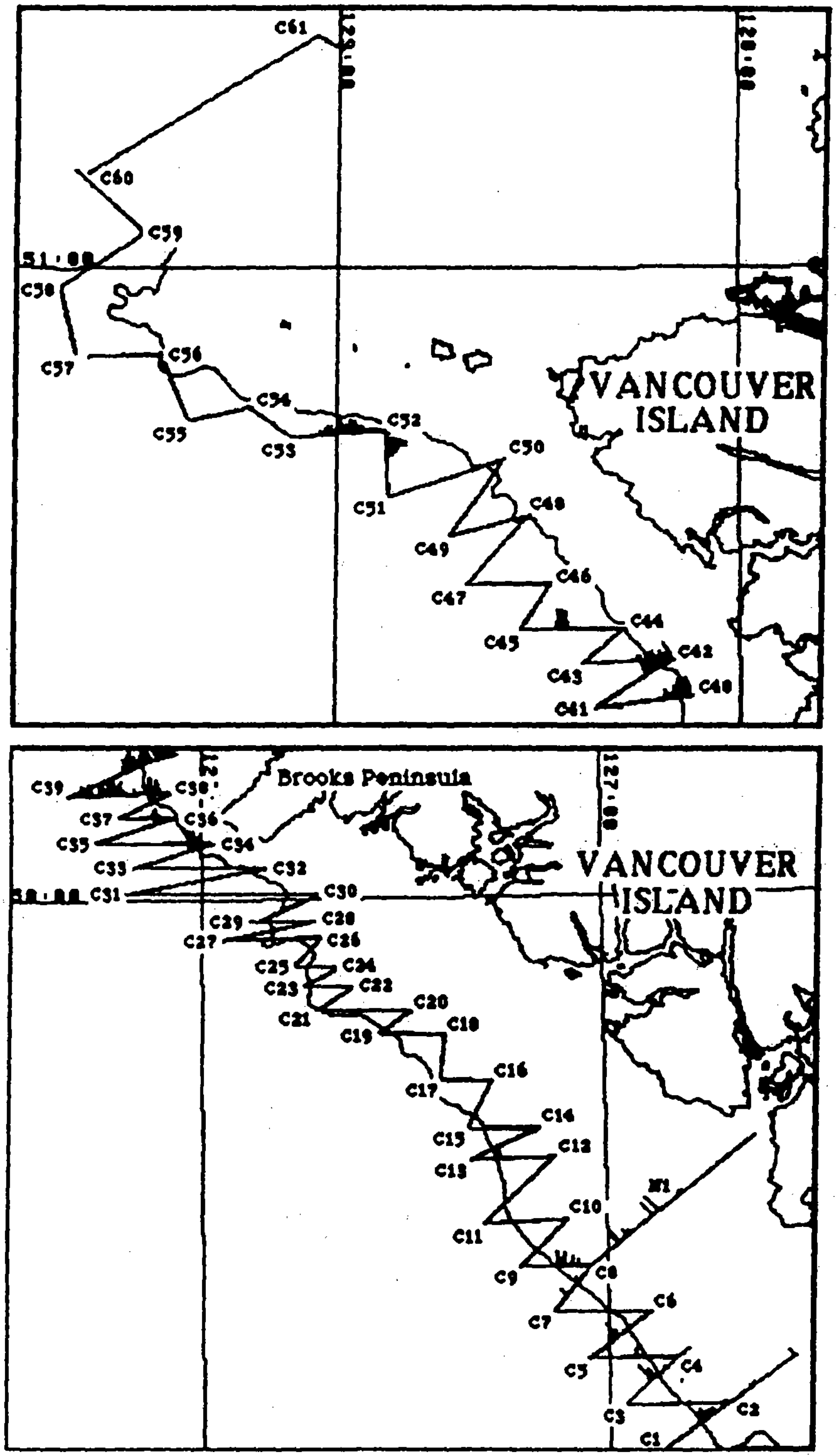

Figure 26a. Distribution of hake biomass during August 1991 based on hydroacoustics. Surface densities are represented on a log scale ranging from 0.01 to 1.0 kg/m^2. Target strength= -35 dB/kg. North coast.

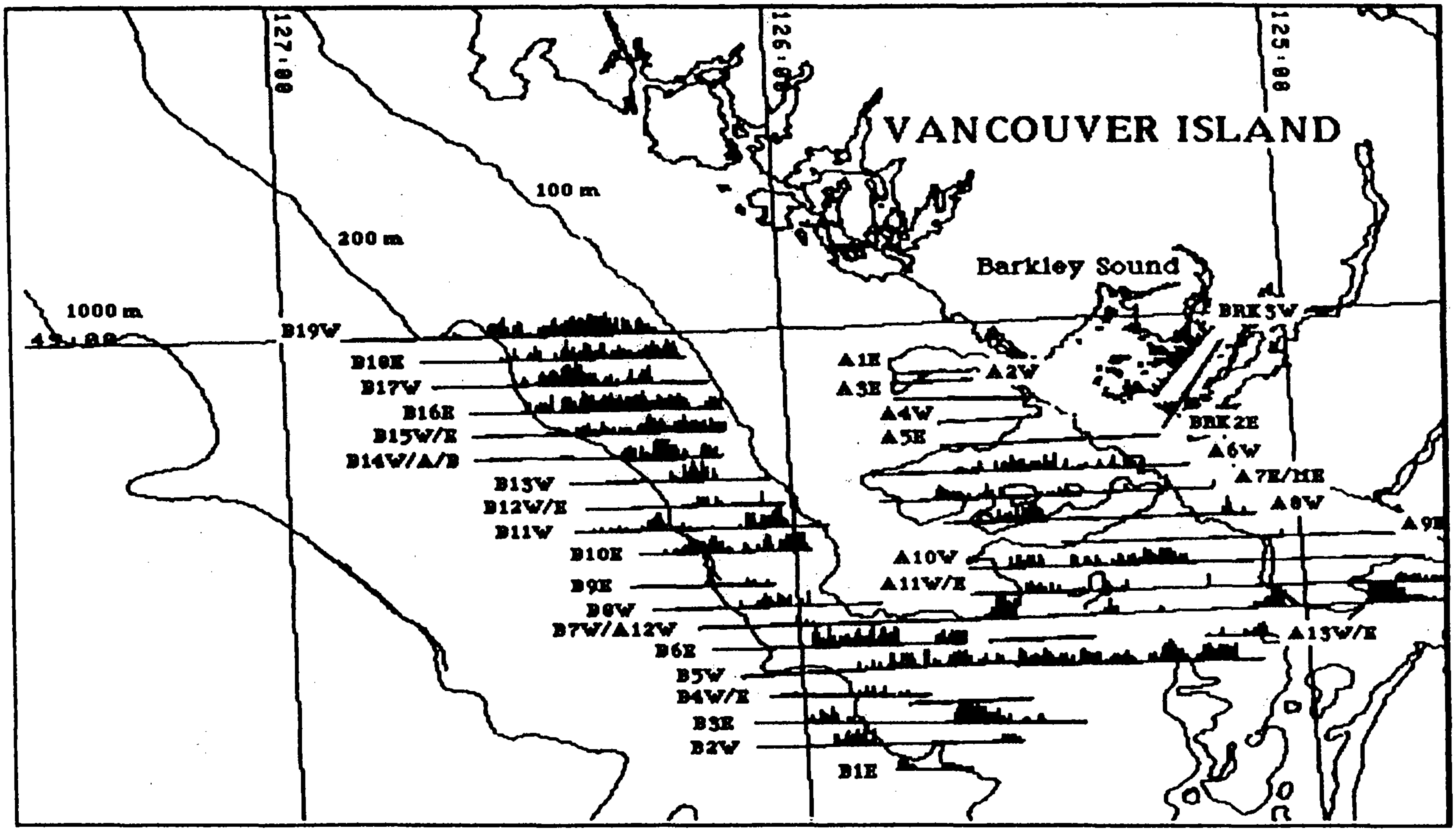

Figure 26b. Distribution of hake biomass during August 1991 based on hydroacoustics. Surface densities are represented on a log scale ranging from 0.01 to 1.0 kg/m². Target strength= -35 dB/kg. West coast.

3.3.2 Euphausiid Population Biology Studies

Planktivorous fish (Pacific hake: Merluccius productus; Pacific herring: Clupea pallasi and spiny dogfish: Squalus acanthias) represent 80-90% of the fish biomass in the La Perouse ecosystem. Hake is the most abundant planktivore. Its biomass over the summer feeding period probably averages 250,000 tonnes (Ware and McFarlane, in prep.).

Tanasichuk et al. (1991) estimated daily ration for hake for each month over the summer feeding period. Hake feed most intensively in June with the ration averaging 3.9% body weight per day (BWD) (Fig. 27). Daily ration then drops to about 1.3% BWD from July through September.

Euphausiids are the most important prey for hake and dogfish (Tanasichuk et al. 1991) and herring (Ware and Tanasichuk, unpubl. results). They represent over 90% of the diet for these fish species. I determined the species and size composition of euphausiids consumed by hake over the summer feeding period using samples of euphausiids from hake stomachs collected by observers. Thysanoessa spinifera and Euphausia pacifica were the only species eaten. T. spinifera accounted for virtually all of the euphausiids taken until the end of August when hake had consumed about 80% of their summer ration (Fig. 27).

The impetus for studying the population biology of T. spinifera comes from this euphausiid's importance to energy flow within the La Perouse ecosystem and an inverse relationship we found between summer sea temperature in the La Perouse area and adult euphausiid abundance (Tanasichuk and Ware, in prep.). Understanding the population biology of T. spinifera and how oceanographic conditions affect it is crucial to learning how the ocean can influence fish production in the study area through fish feeding. The inverse relationship is intriguing; is it due to a greater predator (hake) biomass during summers of warm water or a direct oceanographic effect on T. spinifera biology?

This study of the population biology of T. spinifera investigates the effects of interannual variation in oceanographic conditions on reproduction, growth, feeding and mortality, and production. The project is designed to last 3 years and involves sampling throughout the year. I collect euphausiids in Barkley Sound, next to the La Perouse study area, because of logistics. I had hoped for a significant warming event during the study. Sampling began in March 1991 and an El Niño event, with an anomaly of about +2^{o}C, reached the study area in January 1992. Data presented here are for fresh adults collected between April 1991 and June 1992. Preserved samples have not been sorted yet.

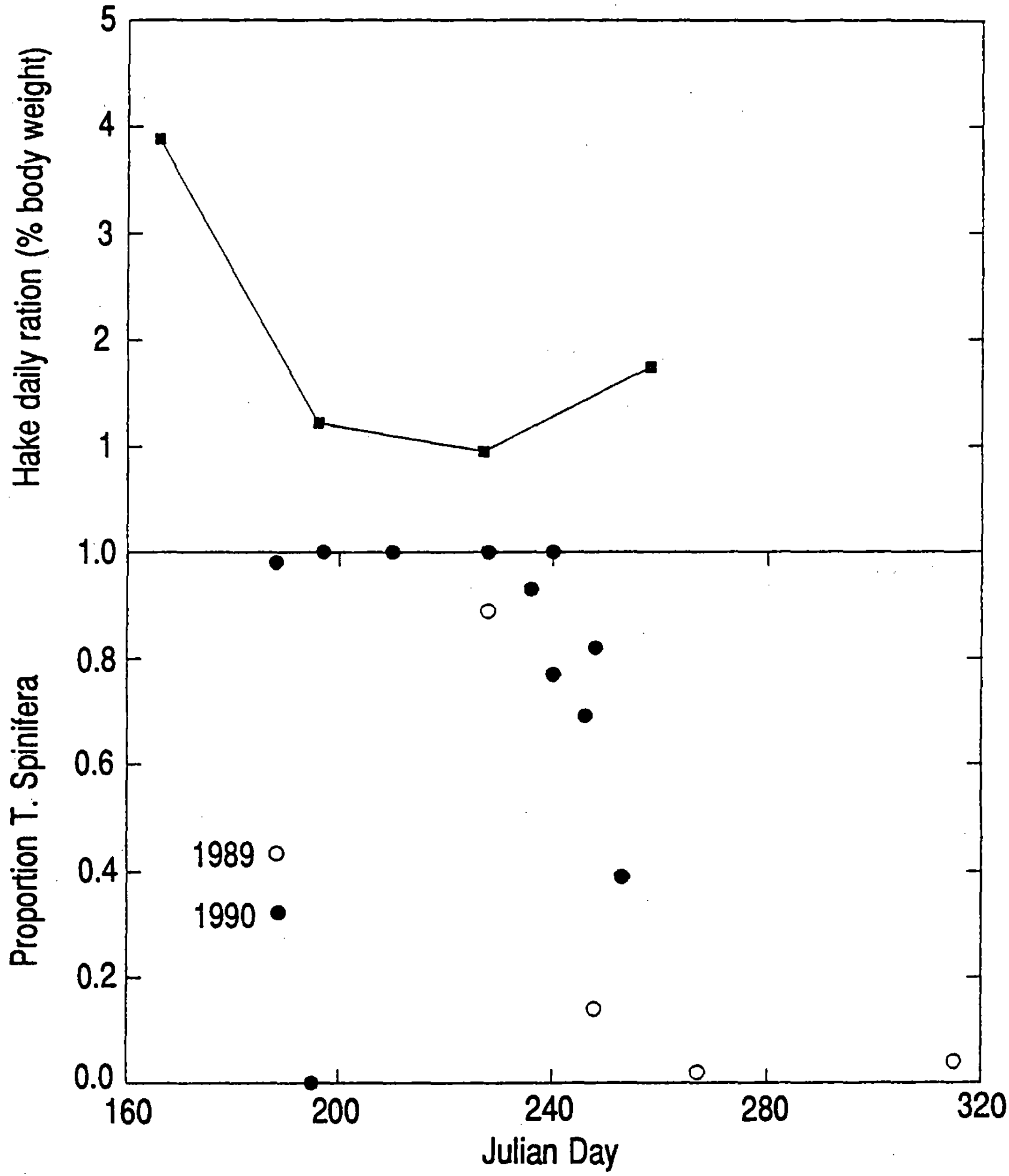

Figure 27. Hake daily ration and proportion of T. spinifera as euphausiid component of hake diet.

Mean length, total weight and adjusted mean weight by sampling date for T. spinifera are shown in Fig. 28. Length frequencies were multi-modal for all samples. I assigned animals to cohorts after assuming that length within a cohort was normally distributed. Subsequent quantile plots of length supported my cohort assignments. Length trajectories show 5 cohorts in the samples. Considering that growth in length ends by June, I suggest that these cohorts represent ages 0+ (cohort1), 1+ (cohorts 2, 3 and 4) and 2+ (cohort 5). Variation in size between cohorts 2, 3 and 4 likely reflects animals from early, intermediate and late spawnings. Unlike length, weight varies through the year. In general, weight increases between April and June, declines between October and January, and then increases between January and April. Seasonal variations in adjusted mean weight (weight-at-length) reflect mean weight changes. The adjusted estimates came from a series of analyses-of-covariance. Results showed no significant differences ($p>0.05$) in weight-length regressions among cohorts for a given sampling event but showed differences between samplings.

Seasonal variations in weight appear related to the reproductive cycle (Fig. 29). T. spinifera spawned until July in 1991 and began spawning intensively in April 1992. Length specific weight changes reflect how gonad weight would be expected to change over the reproductive cycle. Changes in weight-at-length are intriguing for two reasons. They are unusual in that they imply that T. spinifera develops a gonad over the winter when endogenous energy stores are minimal. Secondly, they suggest that the ripe gonad may account for up to 37% of total animal weight which is double that reported for other euphausiids. Quantitative descriptions of the seasonal cycle of body composition and gonad weight would test these suggestions. These analyses are part of the study.

Oceanographic events are providing ideal experimental conditions for testing their influence on T. spinifera. Sea temperatures were average over most of the first year of the study, are high during the second year, and hopefully will be average over the third year. Sampling and sample analysis are such that I can test the influence of temperature on all life stages. Ultimately, this study will provide an understanding of the effect of the ocean on the biology and productivity of T. spinifera, the link between primary and fish production in the La Perouse Bank area. The results of this work are an important contribution to stock assessments of planktivores in the La Perouse area and for other fish species whose main prey is euphausiids.

R. Tanasichuk

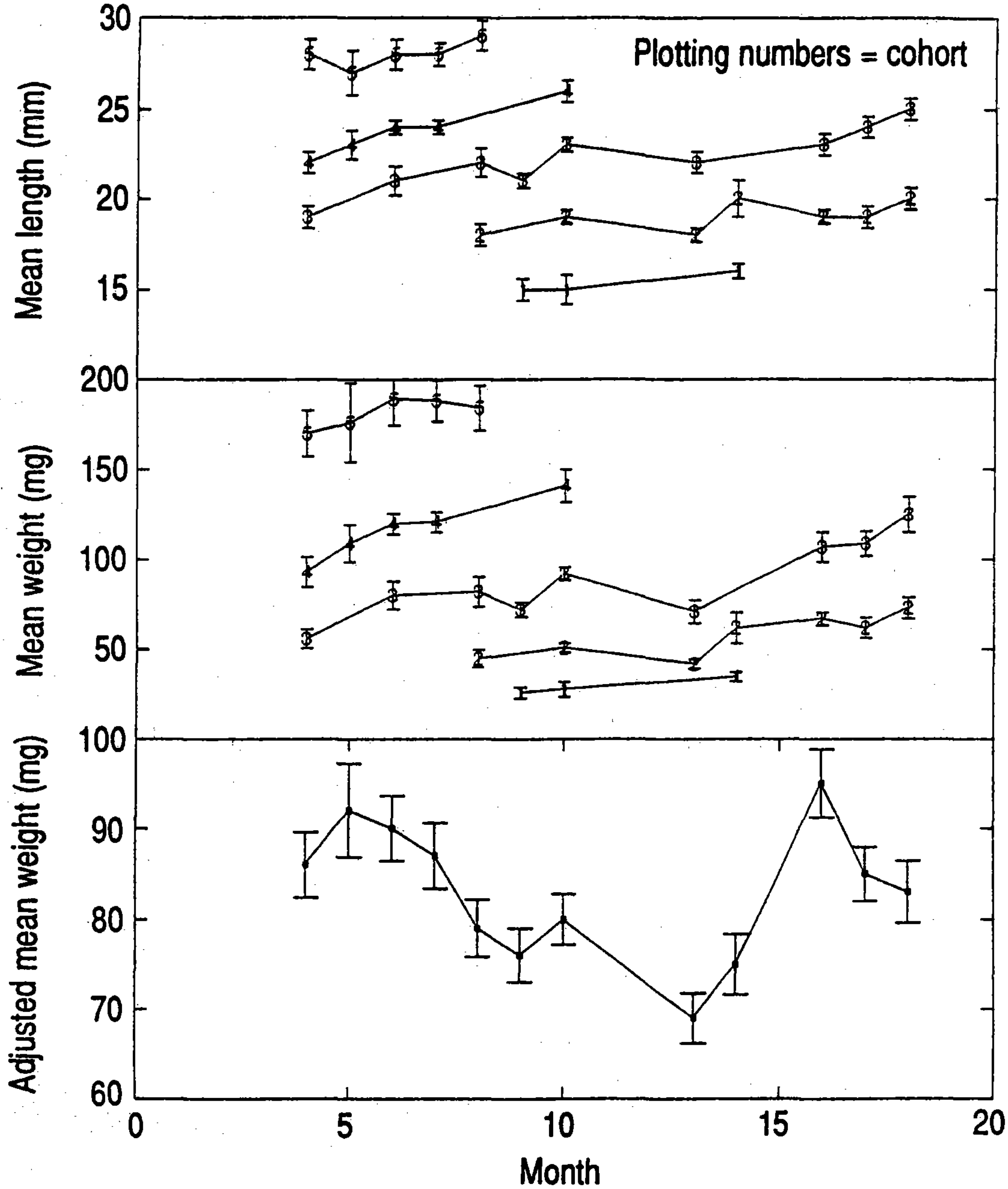

Figure 28. Mean length, total weight and adjusted mean weight for T. spinifera. Error bars are 2 S.E. Month 1 = January 1991.

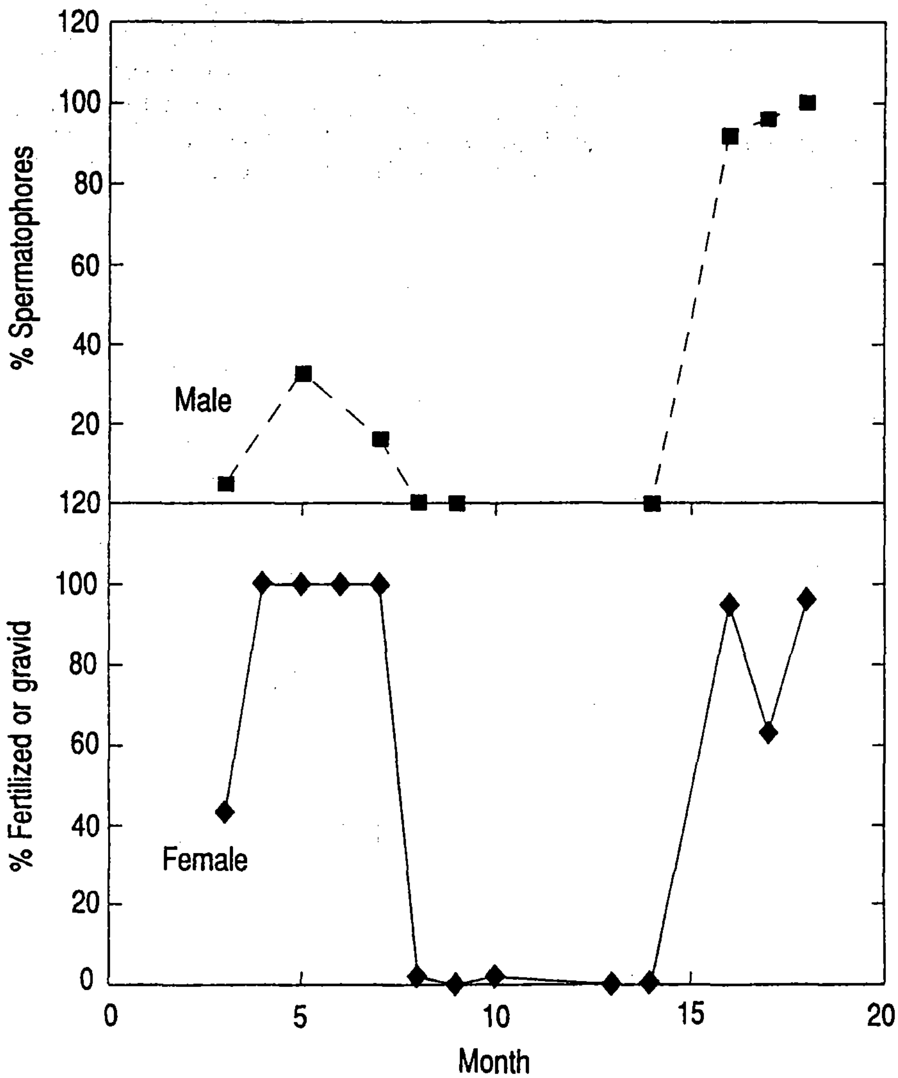

Figure 29. Percent T. spinifera males with spermatophores and females ferilized or gravid. Month 1 = January 1991.

References

Tanasichuk, R. W., D. M. Ware, W. Shaw and G. A. McFarlane. 1991. Variations in the diet, daily ration, and feeding periodicity of Pacific hake (Merluccius productus) and spiny dogfish (Squalus acanthias) off the lower west coast of Vancouver Island. Can. J. Fish. Aquat. Sci. 48:2118-2128.

3.3.3 Herring Distribution, Mortality and Recruitment

An exploratory analysis of the existing oceanographic and fisheries data for the 1960-81 period (Ware and McFarlane 1986) at the onset of this project indicated that year-class strength of the lower west coast of Vancouver Island (LWCVI) Herring stock was negatively correlated with: 1) the biomass of hake in the Canadian zone, and 2) annual surface water temperature. These findings were recently corroborated by a more extensive analysis of herring recruitment and growth using the complete historical data base which extends back to the 1930's (Figs. 30, 31; see Ware 1991).

Guided by these relationships, a program was designed to determine if the mortality of pre-recruit and adult herring was related to the spatial and temporal overlap in the herring, and offshore predator distributions on the continental shelf, and by the abundance of alternative prey during the upwelling season (May to October). Historically, the LWCVI herring stock currently averages about 48 thousand tonnes in mid-summer. There are eight key predator species around the La Perouse Bank area. In order of importance according to the size of the stocks and the amount of herring they eat, they are: Pacific hake, chinook salmon, coho salmon, lingcod, Pacific cod, dogfish, sablefish and halibut. Pacific hake alone account for 1/3 of all the predator-related herring deaths, which makes them the single most important predator species. This corroborates the statistical evidence noted above which found a significant negative correlation between herring recruitment and hake biomass. Preliminary estimates also indicate that virtually all of the estimated natural mortality rate of the LWCVI herring stock (average of about 90,000 tonnes of all age-groups) is eaten by predators.

The two most abundant prey species of commercial-sized fish in the La Perouse Bank area are euphausiids and herring. Euphausiids are the dominant prey accounting for 21-63% of the mid-summer diet of the offshore predators; herring make up 12-71% of the diet.

1991 Multispecies Survey

A mid-water trawl survey of the herring, hake and dogfish stocks off the lower west coast of Vancouver Island was conducted by the M/V *Caledonian* between July 31 and August 8, 1991. The survey covered 6000 km of the continental shelf from the U.S.-Canada border, north to 49 degrees latitude, and seaward to the 200 m isobath. Fishing operations were conducted in previously designated fishing subareas (Fig. 1b). Twenty-three mid-water tows were made to determine the diet, length composition, and age composition of the dominant pelagic fish species in the area. This multispecies trawl survey has been conducted for the last 8

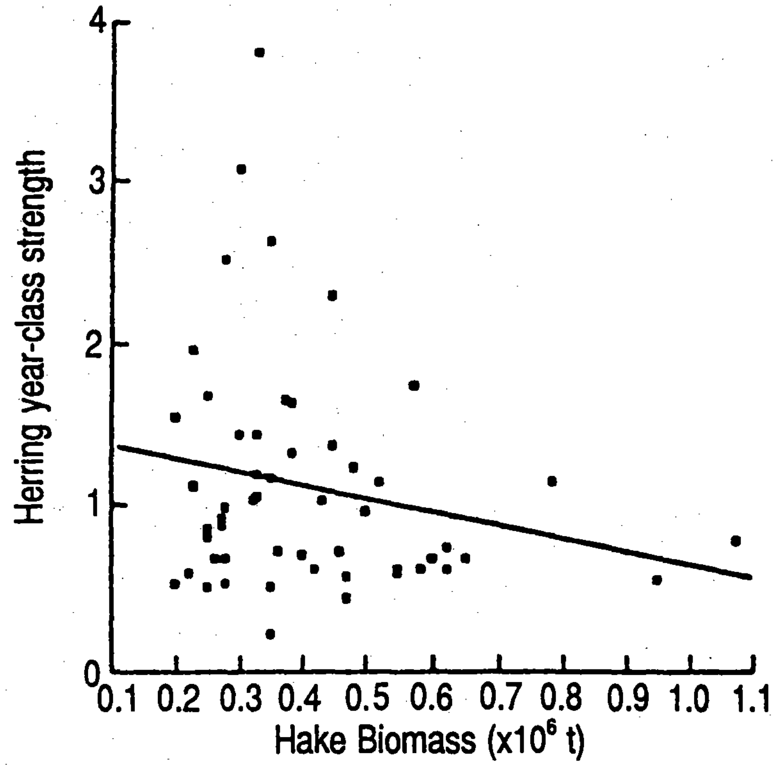

Figure 30. **Relationship between estimated biomass of hake in the Canadian fishing zone and herring year-class strength (1935-84).**

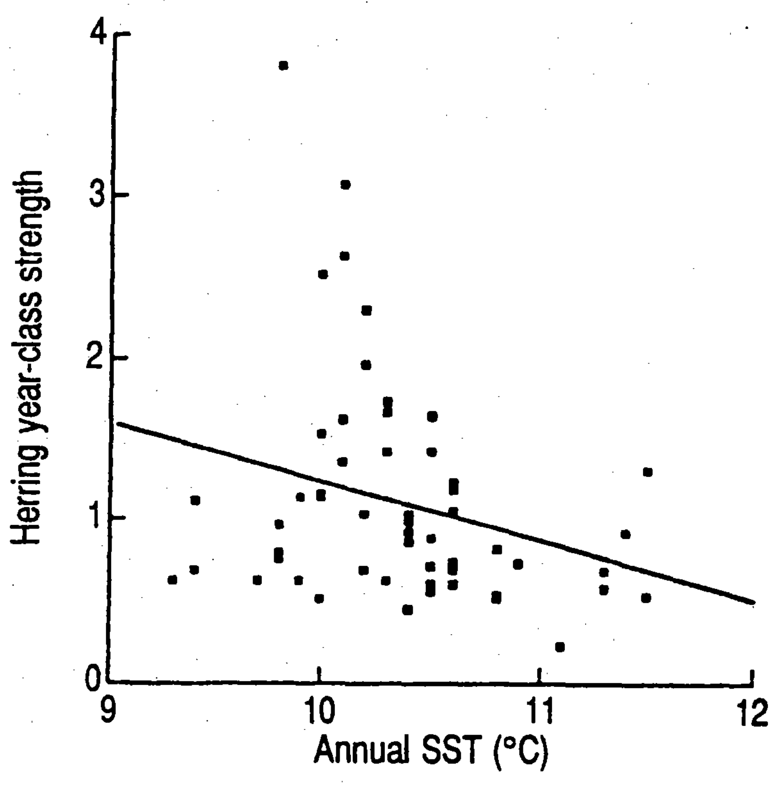

Figure 31. **Relationship between SST (°C) at Amphitrite Point and Barkley Sound herring year-class strength (1935-84).**

years, as part of the La Perouse Bank Project. A principal objective of this project is to quantify how interannual changes in oceanic conditions, and in the distribution and abundance of offshore predators, affect herring recruitment, mortality and production.

Predator Distribution and Diets:

The distribution of hake was a little different in August 1991. The stock was most concentrated off the mouth of Barkley Sound in subarea 4 (Fig. 1b). There was a secondary concentration in subarea 10 near the Canada-USA border, which is typically where the main body of hake is found that time of year. The diets of 1105 hake, and 160 dogfish were examined at sea. Euphausiids made up 63%, and herring 26% of the diet (by weight) of hake. The 8 yr average values for August are 60% and 32%, respectively. Euphausiids made up 67%, and herring 12% of the diet (by weight) of dogfish. The 8-yr average values are 58% and 12%, respectively. Thus both hake and dogfish had higher proportions of euphausiids in their diets during the summer of 1991.

A retrospective analysis of 15 years of midwater trawl survey data in the La Perouse Bank area (8 years of our own surveys and 7 others dating back to 1968) convincingly demonstrates that significantly more hake occur in the La Perouse survey area in warm summers. For each $1^{o}C$ rise in summer temperature, 178,000 more tonnes of hake cross the border and move into the region ($p<0.001$). We have also found that hake eat significantly more herring in warm summers. For each $1^{o}C$ rise in summer temperature 28% more herring (by weight) appear in the hake diet ($p= 0.03$; Fig. 32).

With these findings, we now have independent, empirical evidence to corroborate the mechanism that we hypothesized was behind the negative correlations between herring year-class strength, and hake biomass, and water temperature. These results are being incorporated into 1) a multispecies predator-prey model that will be used to estimate interannual variability in herring natural mortality rates, and 2) into a model which describes the seasonal dynamics of the system from nutrients to fish (see summary by Cliff Robinson).

Herring Distribution:

The herring age composition varied markedly between subareas which is typical. Young-of-the year herring (age 0+) were not plentiful offshore during the survey; they were still be concentrated in the inshore nursery areas like Barkley Sound (Fig. 1b). Juvenile herring (age 1+ and small 2+) were most abundant in the SW corner (subarea 3; Fig. 1b). There were three modal size groups of herring (age

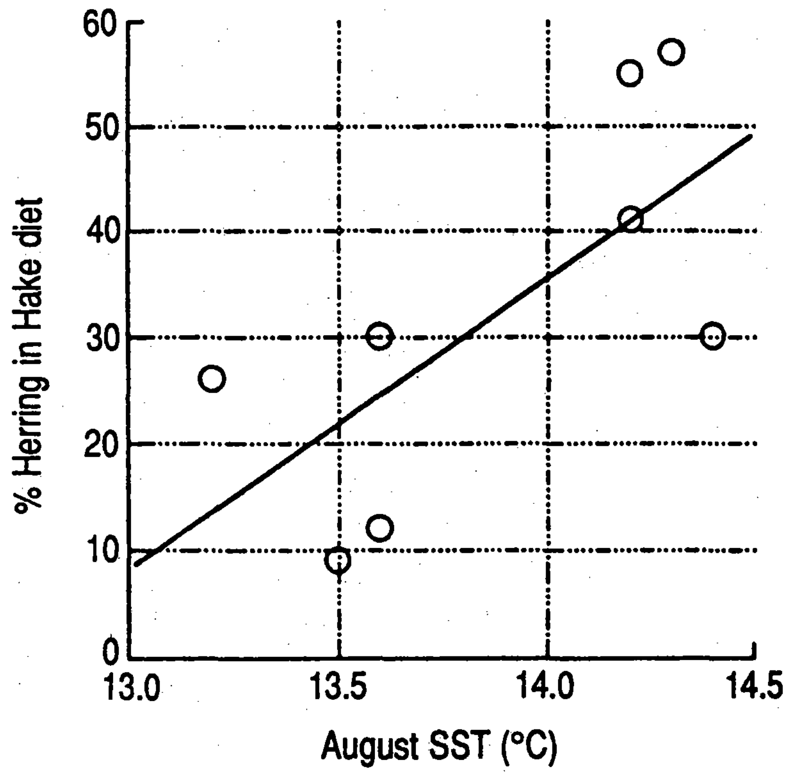

Figure 32. Relationship between % of herring in the hake diet (by weight) and the average August water temperature (°C) during the survey.

1+,2+, and 3+) on 40-mile Bank (subarea 6). There were two modal size groups (age 2+, and 3+) on Swiftsure Bank (subarea 9). We found large concentrations of adult herring (age 3+ and older) near the outer edge of the continental shelf near the "Rathole" (subarea 12). This was the best showing of herring we have seen near the outer shelf during the 8-yr history of the survey.

Herring Recruitment Forecast:

The relative abundance of maturing age 2+ fish encountered during the August trawl survey was used to forecast the proportion of 3-yr old herring (= recruit spawners) in the Barkley and Clayoquot Sounds spawning stock in March 1992. This forecast is used in association with the age-structured herring stock assessment model to determine the abundance of new recruits, and hence the fishing quota.

In making the forecast we assumed that maturing age 2+ herring ranged between 160-205 mm. Because of their small size, we also assumed that the age 2+ fish in the SW Corner fishing area would not mature this spring, so they were not included in the recruitment forecast. The herring concentration in this area was very small and, therefore, won't have much affect on the forecast.

Based on the relative abundance of age 2+ herring encountered during the survey we forecast that 44% of the Barkley and Clayoquot Sound spawning stock will consist of 3-yr old recruits in the spring of 1992. A frequency this high implies that the 1989 yr-class is slightly better than average. Fig. 33 summarizes the 'track-record' of the forecast since its inception in 1987. To date, our sampling procedure has produced a fairly accurate recruitment estimate. The 1991 forecast was remarkably close in the sense that we anticipated a recruitment frequency of 15%, which is exactly what was measured by the pre-fishery charters in Barkley and Clayoquot Sounds prior to the 1991 fishery.

D. M. Ware
R.W. Tanasichuk

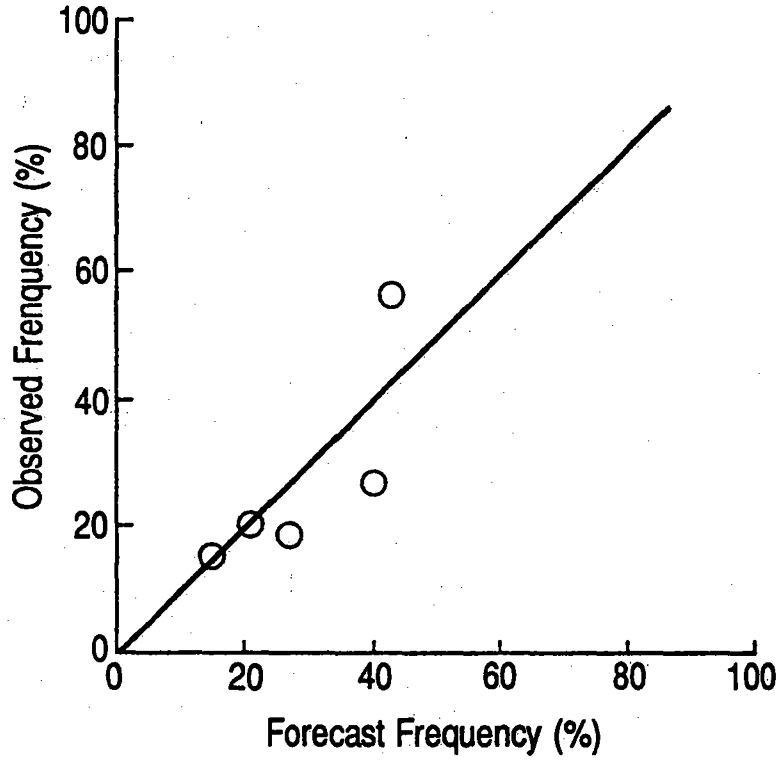

Figure 33. Relationship between forecast and observed frequency (%) of age 3 herring in the lower west coast of Vancouver Island spawning stock.

4. MASS INVESTIGATOR SUMMARIES

Predation Mortality of Juvenile Salmon in Alberni Inlet and Barkley Sound, B.C. in 1991.

Introduction

The Marine Survival of Salmon (MASS) program is a collaborative, multi-disciplinary research program involving both fisheries biologists and oceanographers. The primary purpose of the MASS research is to improve our understanding of the mechanisms underlying the observed variations in survival of salmon in the ocean, and the growing evidence that the survival and recruitment of all species of Pacific salmon in the ocean are strongly influenced by events during the early sea life stages. Planning of the MASS program was initiated in 1986, field work began in 1988 and has continued to 1991.

This report documents the progress made in 1991 in the Predation Mortality sub-project of the MASS program. Extensive work completed in this sub-project from 1987-1990 has shown that predation by other fishes during the early sea-life period is a major source of mortality for juvenile salmon in the area chosen for this study, Alberni Inlet and Barkley Sound (Fig. 34). Pacific hake, walleye pollock, and spiny dogfish have been identified as predators of juvenile salmon in near-shore areas. Large seasonal and interannual variations in predator abundance and mortality of juvenile salmon have been observed, which ultimately may account for much of the previously unexplained variation in the recruitment of adult salmon. Experimental studies, involving releases of tagged juvenile salmon, have also been conducted each year since 1988 to directly test the predation mortality hypothesis.

Activities and Progress in 1991

In 1991 the main focus of our field work was again directed at determining the predation mortality of juvenile salmon by other fish species during the early sea life period. Due to funding and support staff reductions this year, the field activities were reduced from previous years. The two main activities we conducted in Alberni Inlet and Barkley Sound in 1991 included: 1) Gillnetting and balloon trawling to determine the abundance, distribution, and rates of predation of fishes feeding on juvenile salmon; and 2) experimental releases of tagged chinook salmon from Robertson Creek Hatchery, designed to test the hypothesis that predation during the early sea life period was a major source of mortality of juvenile chinook salmon. A cooperative research project with the Salmonid Enhancement

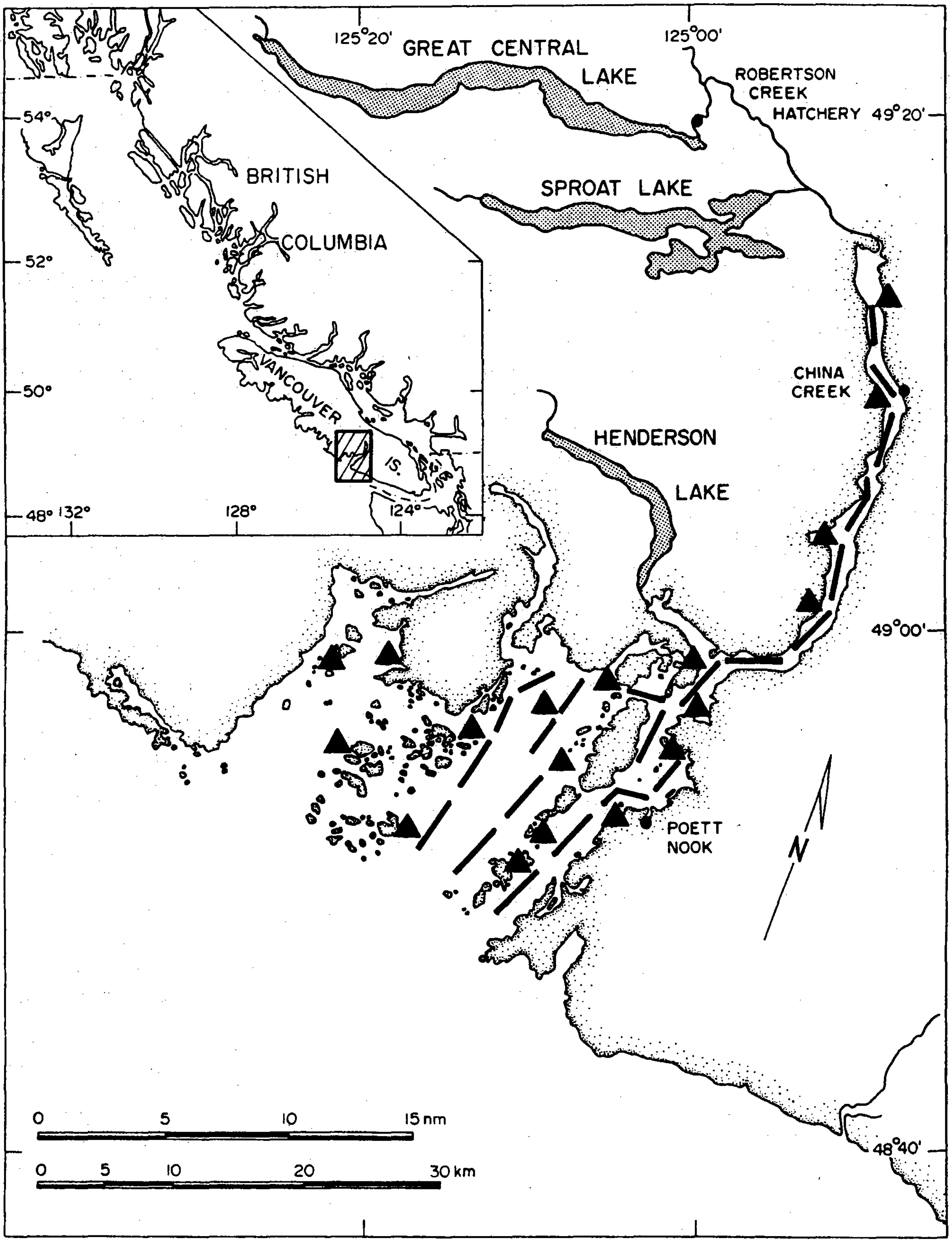

Fig.34. Standard locations for fish samples collected with floating gillnet (▲) and balloon trawl (—) in 1991.

Program (S.E.P.) Branch of DFO was also continued in 1991 to prepare for a large mass-marking experiment which is planned for next year, in which all of the chinook released from Robertson Creek Hatchery in the spring of 1993 will be mass-marked. This will allow positive identification of wild and hatchery chinook in our subsequent sampling of smolts in Alberni Inlet and Barkley Sound in 1993, and also will assist in resolving the problem of assessing wild versus hatchery production of chinook in subsequent years as the adult fish return to the Somass River system.

The S.E.P. again contributed substantial funding in 1991 to support both the predation work and experimental releases of coded wire-tagged chinook in Barkley Sound. However, no SEP staff participated in field work in Barkley Sound this year due to the reduced sampling program.

Methods

In 1991 we sampled potential fish predators of juvenile salmon using a small balloon trawl deployed as close as possible (c.a. between 3-10 m) to the sea surface from the DFO vessel *Keta*, and a variable mesh floating gillnet deployed from the chartered commercial fishing vessel *Dalehurst*. The fishing activities of both vessels were conducted biweekly, on four consecutive nights each week, between April and July (22-25 April, 6-9 and 20-23 May, 3-6 and 17-20 June, and 1-4 July 1991). All of the sets made with both gear types were between dusk and dawn. During each of the above time periods a series of fish samples was collected at 22 specified locations with the balloon trawl, and 18 locations with the gillnet (Fig. 34). In 1991 a total of 135 sets were completed using the balloon trawl fishing gear, and 92 sets were made with the gillnet. An additional 19 sets were made with a sinking gillnet in Alberni Inlet and Barkley Sound during 24-26 June in an attempt to determine the distribution of hake during the day. The total of 246 sets completed in 1991 was substantially lower than the total sampling effort in this project in previous years (Fig. 35), due mainly to the elimination of the purse seine sampling of juvenile salmon in 1991.

Potential predators of juvenile salmon caught in both type of fishing gear were immediately sorted by species and the length of each fish was measured. The stomach contents were then obtained either by flushing the stomach with seawater (for salmonids) or by killing the fish and then dissecting out the stomach contents (all other species). The contents of the stomachs were immediately identified into major groups (e.g. fish, copepods, euphausiids, amphipods, insects, etc.), and the total volume of each group in the stomach was estimated by visual reference to

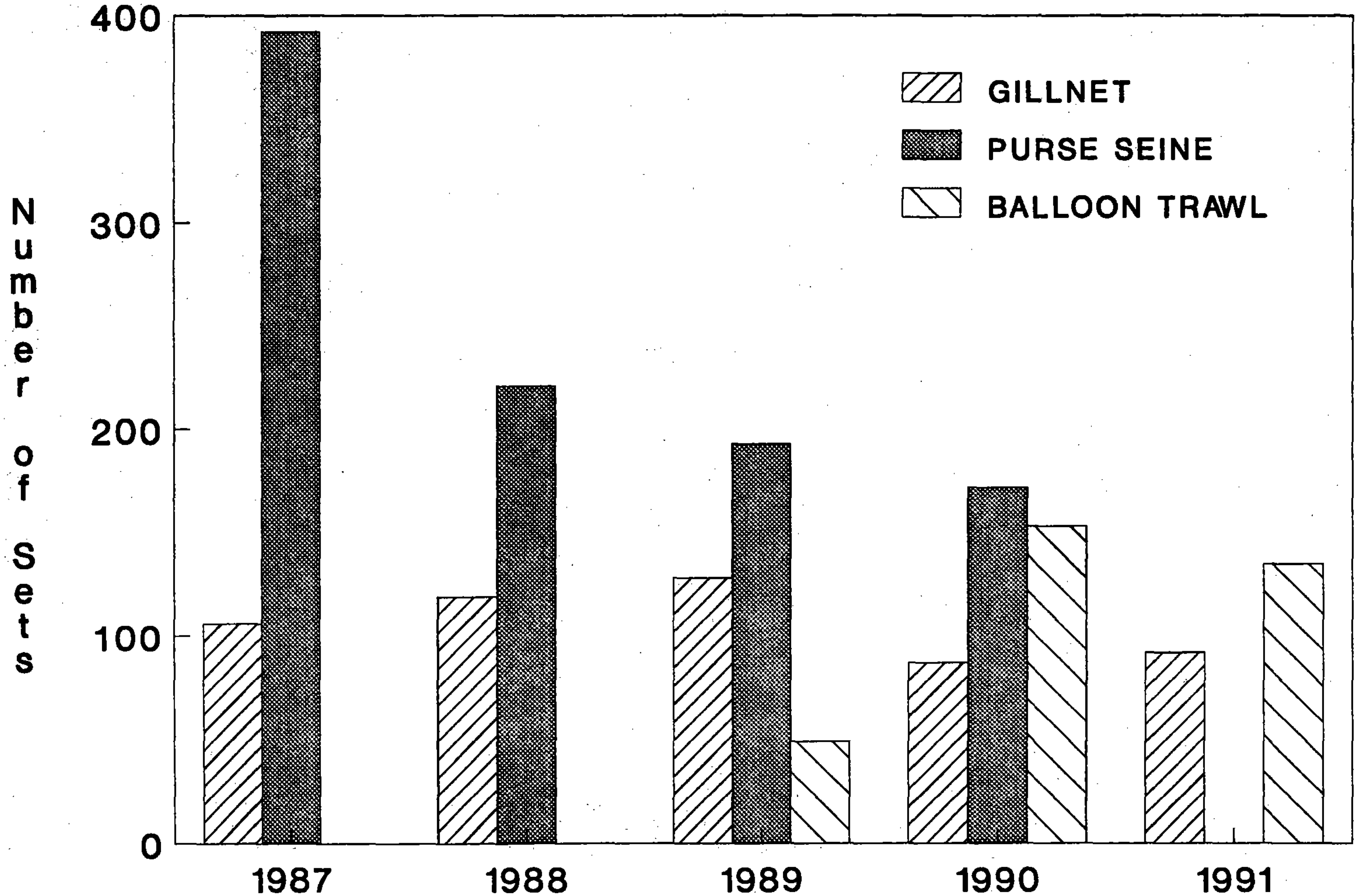

Fig.35. Summary of total sampling effort with each type of fishing gear, for each year of this study. No purse seine sampling was done in 1991.

standard (calibrated) volumes (e.g. 10 cc. euphausiids, 3 cc. fish remains). Any juvenile salmon found in the stomach contents were counted and identified to the species level, if possible. If the remains of the fish were too digested to determine the salmon species the number of fish was determined and each was recorded as either "salmonid" or "possible salmonid". Any contents that were clearly fish remains but could be identified were recorded as "fish remains". All salmon and possible salmonid remains from each fish were then preserved in 10% formalin in seawater solution and retained. All the calculations of predation rates on juvenile salmon included in this report include only the data for which the fish found in the stomachs were clearly recognizable as juvenile salmon.

Results

Juvenile Salmon Abundance, Distributions and Migrations

No purse seine sampling was conducted in 1991, so no new information on the distribution, abundance, or migration timing of juvenile salmon in Barkley Sound was obtained. Based on qualitative information from visual observations of juvenile salmon schooling and feeding near the sea surface, the general patterns in 1991 appeared to be similar to previous years. However, there also appeared to be some significant differences. For example, the visual observations suggested that large numbers of juvenile salmon may have migrated out of Barkley Sound through Trevor Channel in 1991. The migration pattern appeared to be similar to what we observed in 1988, but not in any year since then. Unfortunately without the purse seine catch data we cannot quantify this and other changes in the behaviour of juvenile salmon suggested by the visual observations in 1991.

Abundance and Distribution of Predators of Juvenile Salmon

The abundance and distribution of hake and other fish predators in Alberni Inlet and Barkley Sound in 1991 showed several unusual variations from previous years. Allowing for the variations in fishing effort, the total catches of hake indicate that the overall abundance of hake in 1991 was similar to 1990, but still much lower than the high abundance observed in 1989. The balloon trawl catch-per-unit-effort (CPUE;catch-per-set) data indicated that the abundance of hake was unusually high in early May, much higher than was observed in 1990 (Fig. 36). For example, in 1991 we captured 503 hake between May 6-9, compared to a total of 987 hake in all sets made in 1990 between April and July. However the abundance of hake had declined dramatically by the next sampling period two weeks later.

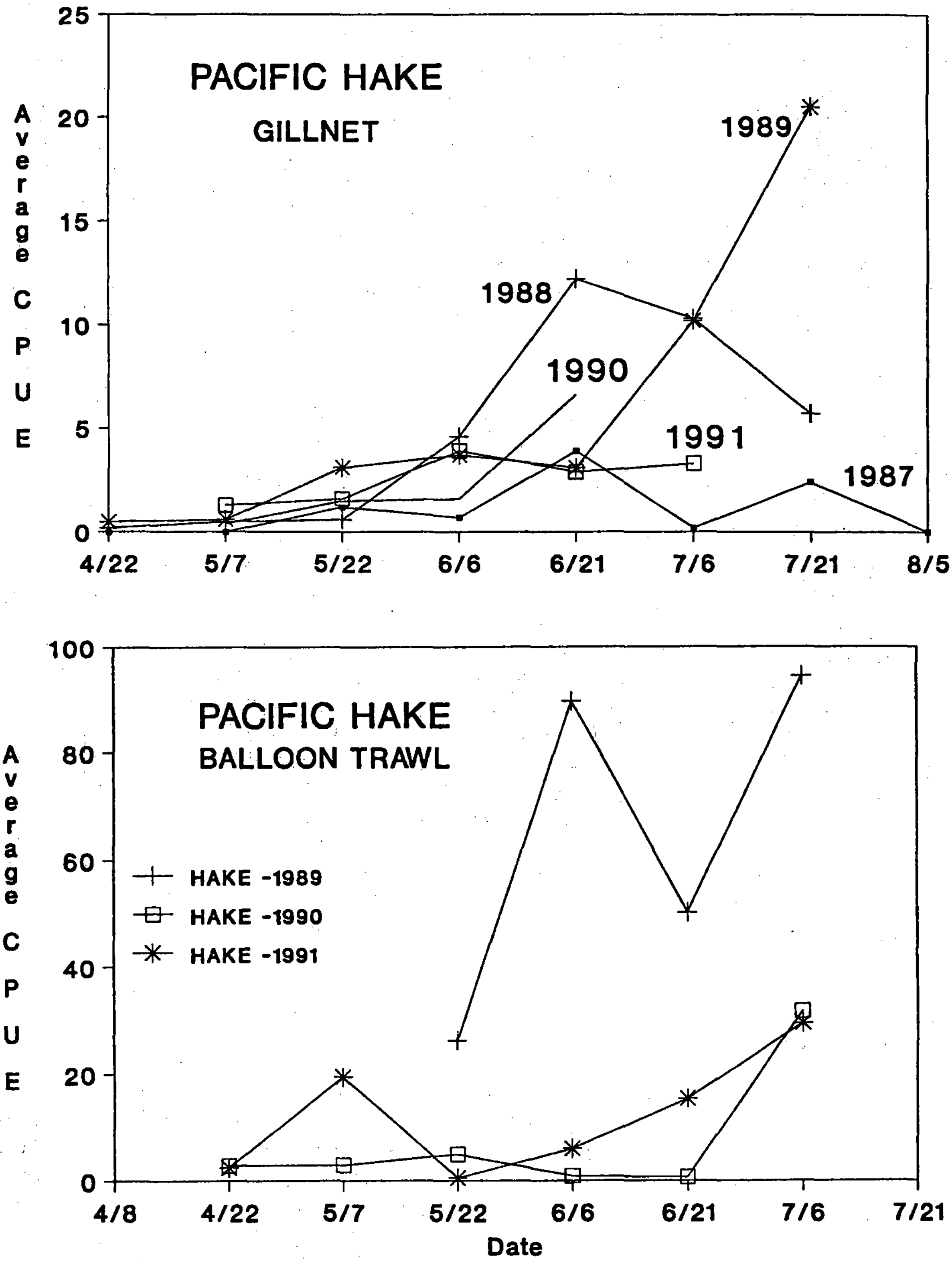

Fig.36. Relative abundance (average catch-per-unit-effort) of Pacific hake caught by gillnet (upper panel) and balloon trawl (lower panel) each year.

Our general impression in the field was that the large concentration of hake observed in early May had moved out of Alberni Inlet and Barkley Sound by late May.

Our 1991 data did not provide a clear indication of the time of arrival of the large offshore, migratory stock of hake into Barkley Sound. The hake CPUE data from the gillnet sampling indicated a small increase in hake abundance in early June, but then the abundance appeared to remain relatively constant until our sampling terminated in July (Fig. 36). The CPUE data from the balloon trawl showed a steady, but only gradual increase in the abundance of hake during June and July, following the abrupt decrease in abundance which occurred in late May (Fig. 36). The consistent difference between the average size of all hake caught by each type of gear again indicated that the gillnet tends to selectively capture more of the larger hake than the balloon trawl (Fig. 37). However, the average size of hake caught in each type of gear did not change substantially during May-July, as typically has happened in previous years when the much larger migratory hake suddenly arrive in Barkley Sound each year. Based on these observations we conclude that there was probably no substantial influx of the migratory stock of hake into Barkley Sound in 1991 before at least mid-July. This continues the apparent trend from previous years of the offshore hake arriving in Barkley Sound later and later each year.

Predation Mortality of Juvenile Salmon

Pacific hake were again the only significant predator of juvenile salmon that we identified in the study area in 1991. We captured and examined the stomach contents of a total of 1705 potential predators of juvenile salmon (Table 4). Of these, 30 of the 480 fish caught in the gillnet and 118 of the 1705 fish caught in the balloon trawl had at least one juvenile salmon in their stomach contents. All except one of the fish which were feeding on juvenile salmon in 1991 were hake (Table 4). As in 1990, none of the 267 spiny dogfish we captured and examined in 1991 had preyed upon juvenile salmon. The overall incidence of predation this year was 6.3% for the gillnet catches and 6.9% for the balloon trawl catches, the highest level of predation we have observed since this study began in 1987. Also, in 1991 the proportion of the total hake catches that had more than one salmon in their stomach was much higher than in any previous year, so the effective predation rate was even higher than indicated by the overall percentages indicated above.

The spatial and temporal patterns of hake predation on juvenile salmon showed large temporal and spatial variations. In Alberni Inlet the overall pattern of predation was again very similar for hake caught in both the gillnet

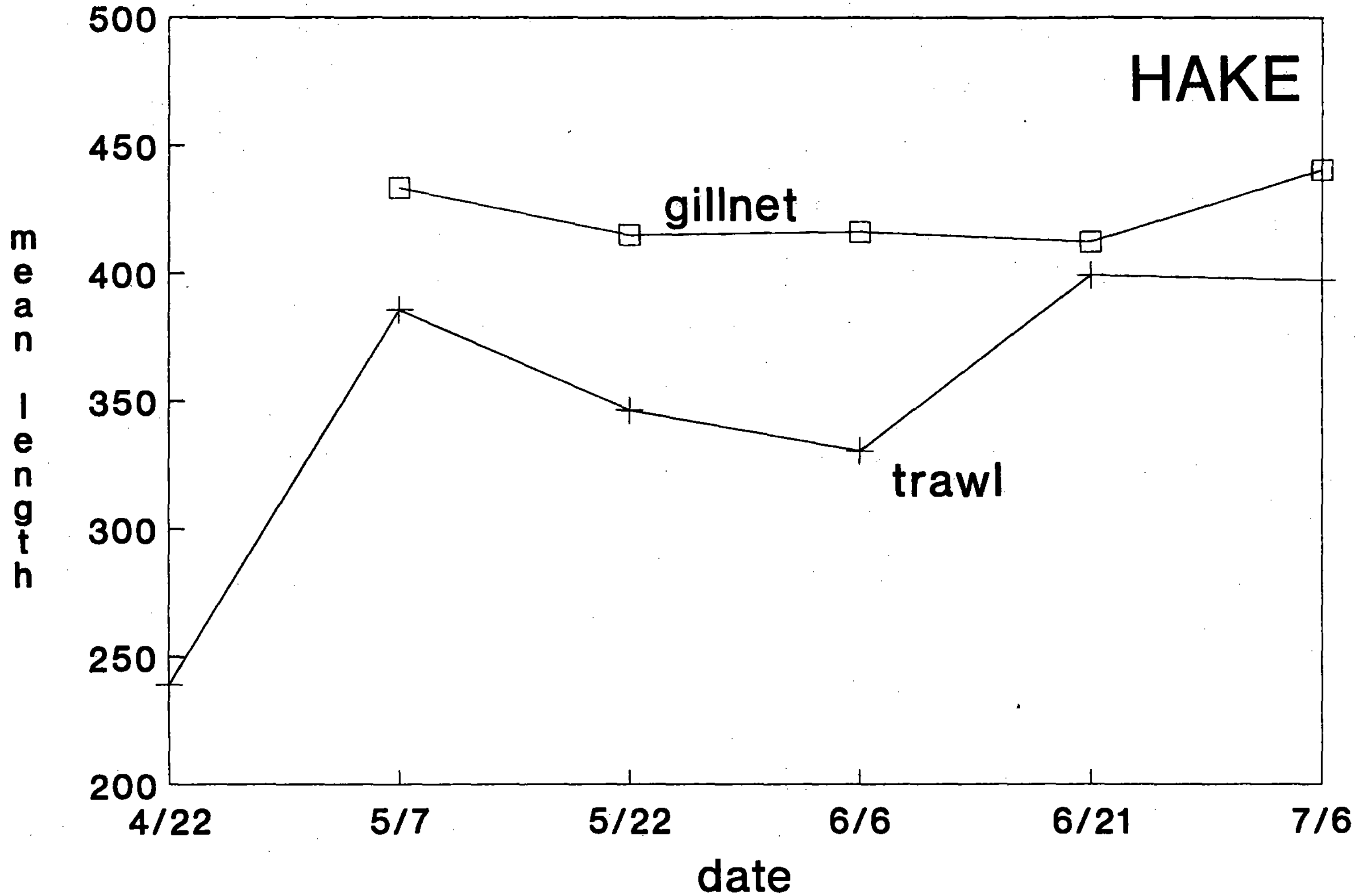

Fig. 37. Comparison of average length of Pacific hake caught by gillnet and balloon trawl in Barkley Sound during April-July 1991.

Table 4. Summary of predator stomach contents data for 1991.

SPECIES	NUMBER EXAMINED / NUMBER EATING SALMON							
	1987	1988	1989		1990		1991	
	Gillnet	Gillnet	Gillnet	Trawl	Gillnet	Trawl	Gillnet	Trawl
HAKE	146/7	530/44	507/43	2746/34	189/12	798/22	240/29	1469/118
POLLOCK	12/3	40/11	33/3	83/0	9/0	22/0	7/1	13/0
DOGFISH	116/2	136/0	1097/5	92/0	52/0	205/0	190/0	77/0
OTHER	263/1	143/0	301/2	104/0	22/0	58/0	43/0	146/0
Totals:	537/13	849/55	1938/53	3025/34	272/12	1083/22	480/30	1705/118
Percent:	2.4	6.5	2.7	1.1	4.4	2.0	6.3	6.9

and balloon trawl. The highest incidence of hake predation on juvenile salmon observed in 1991 again occurred in Alberni Inlet during early May, when 52.4% of the hake caught in the gillnet, and 38.1% of the hake caught in the balloon trawl had eaten salmon (Fig. 38). In previous years the predation rates during this same time period were 46.2% in 1990 and 75.0% in 1989 for gillnet catches, and 48.9% in 1990 and 11.8% for hake caught in the balloon trawl. However in 1991 the predation rate for hake caught in both types of gear declined sharply in the second sampling period, near the end of May. The sudden decline in predation rate in late May was unusual compared to previous years and appeared to be related to the coincident decline in abundance of hake indicted by the balloon trawl catches (Fig. 36). Later in early June the predation rate increased again to more typical levels, and then gradually declined to almost zero percent by early July, as hake and other predators gradually switched to feeding primarily on euphausiids and juvenile (young-of-the-year) herring. Further seawards, the predation rate for hake caught in Trevor Channel (Barkley Sound) was again lower than in Alberni Inlet, but the overall pattern was identical. The highest predation rate in Trevor Channel occurred in early May, the predation rate then dropped dramatically in late May, increased again to more typical levels in early June, and then gradually declined to low levels by early July. The proportion of hake caught in Trevor Channel that were feeding on juvenile salmon was 0% for hake caught in the gillnet (identical to 1989 and 1990), and 8.8% for hake caught in the balloon trawl during early May. In previous years the predation rates for hake caught with the balloon trawl during this time period were 0% in 1990, and 8.9% in 1989.

For the rest of Barkley Sound, in 1991 we did not observe predation on juvenile salmon by any fish species which were captured at the locations sampled in either Imperial Eagle Channel or Loudoun Channel). This is consistent with the results obtained in previous years.

Salmon Marine Survival Prediction

In general, our preliminary analyses of the 1991 data indicate that the predation mortality of juvenile salmon in Alberni Inlet and Barkley Sound was very high in 1991, probably higher than in any year since the study began in 1987. Although the abundance of hake was lower than observed in some other years (e.g. 1989), both the proportion of hake that preyed on juvenile salmon, and the average number of salmon consumed by each pred-ator, were higher in 1991. If the predation mortality hypothesis is correct, then the juvenile chinook and sockeye salmon that went to sea in the spring of 1991 should show the lowest marine survival rate of any year class since 1987.

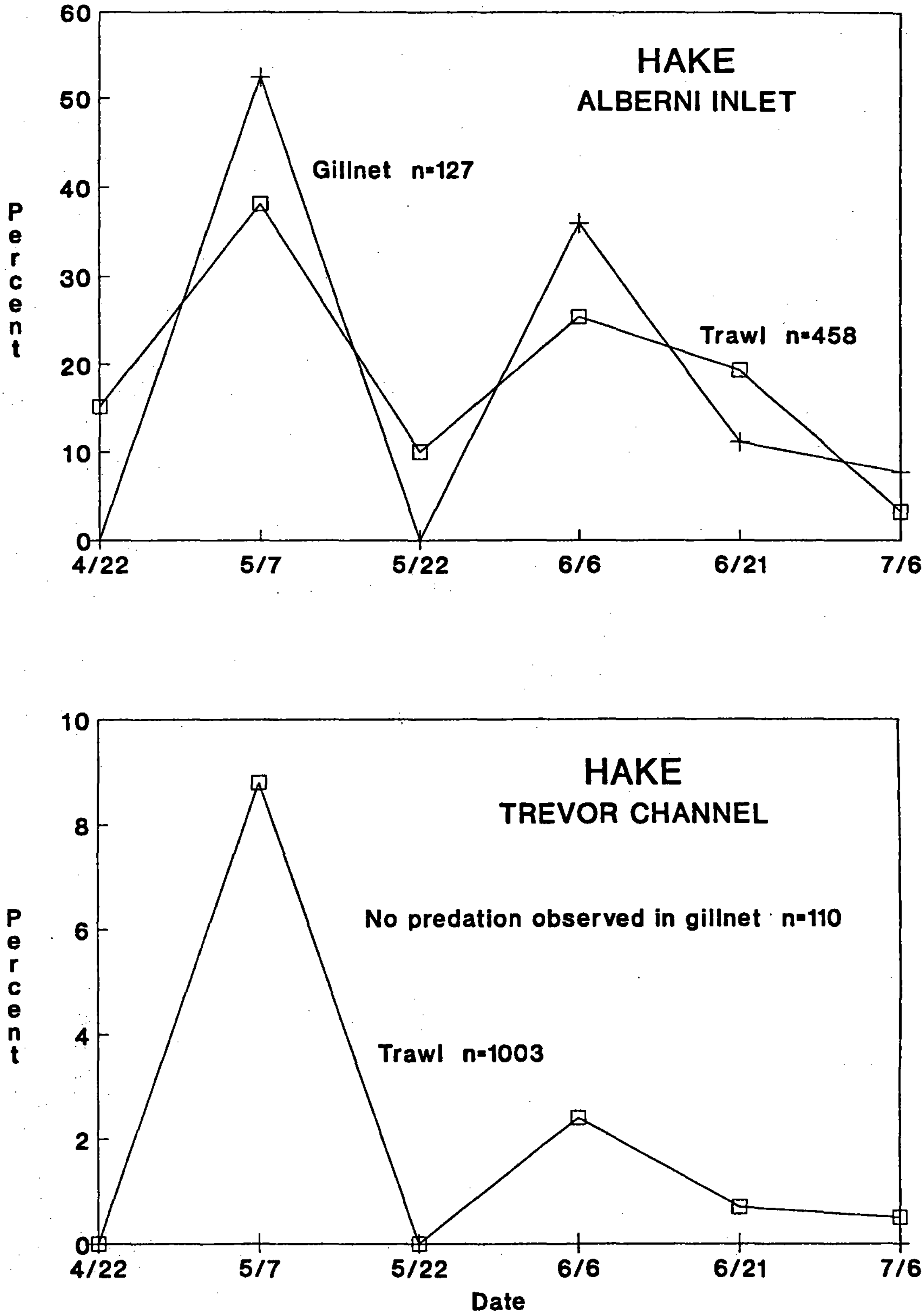

Fig.38. Percent of hake caught in 1991 by gillnet and balloon trawl in Alberni Inlet (upper panel) and Trevor Channel (lower panel) with juvenile salmon in their stomachs.

Experimental Release of Hatchery Chinook

In 1991 we again conducted an experimental translocation (offsite release) of hatchery-reared chinook to: 1) Determine the importance of release site on subsequent marine survival; and 2) test our hypotheses that predation by Pacific hake in Alberni Inlet and Trevor Channel is an important source of mortality for juvenile salmon. The experiment conducted in 1991 was again a cooperative effort, co-funded by the Biological Sciences Branch (BSB) and the Salmonid Enhancement Program of DFO, and involved many staff from both the BSB and SEP. All the 1991 releases were successfully completed during the week of 19-23 May. Due to funding reductions this year, the releases included a total of only three groups of 50,000 juvenile chinook. These fish were coded-wire tagged and then transported the same distance by tanker truck from Robertson Creek Hatchery. Two groups of 50,000 chinook each were held for 24 hours in sea pens at China Creek (Alberni Inlet) and Toquart Bay (Loudoun Channel) and then released. A third (control) group of 50,000 was transported by tanker truck the same distance and then returned to and released at the hatchery. The 1991 experiment went very smoothly, there was a total of only about 100 dead fish from all groups, and the fish appeared to be in very good condition when released.

Preliminary Results of Chinook Translocation Experiments

This was the fourth year that this type of experiment has been conducted as part of the MASS program in Barkley Sound. The purpose of these experiments is to directly test the hypothesis that predation during the early sea life period is an important factor controlling the total marine mortality of juvenile chinook salmon released from Robertson Creek Hatchery. The working hypothesis is that hake are the major predators. Hake are absent in freshwater, but apparently prey heavily on juvenile chinook in Alberni Inlet, somewhat less severely on chinook in Trevor Channel, and do not prey on chinook throughout the rest of Barkley Sound. To reach the open ocean chinook released from Robertson Creek Hatchery must normally swim out through the Somass River, through the entire length of Alberni Inlet, and then out through Barkley Sound via either Trevor Channel, Imperial Eagle Channel, or Loudoun Channel. If hake are important predators then mortality of juvenile chinook typically should be minimal in the Somass River, high in Alberni Inlet, somewhat lower in Trevor Channel, and minimal in the rest of Barkley Sound. Therefore the prediction to be tested is that the total marine survival of chinook should increase for groups of juvenile chinook that are physically transported and released further and further away from the hatchery, thereby decreasing the opportunity for hake to prey on them.

The final analyses and conclusions will not be available until all of the surviving adult salmon from each year of this experiment have been caught in the fisheries or returned to the hatchery (or saltwater release sites) to spawn. For example, for the experiment conducted last year (1989), the final results will not be available until 1994 when the last age group (five year old fish) have returned.

For the 1988 experiment (Table 5), as of 1 December 1991 a total of 1261 coded-wire tagged (CWT) chinook had been recovered from the four control groups of chinook released at the hatchery (Somass River), and a total of 1158 CWT chinook had been recovered from the four experimental groups of chinook released directly into saltwater at China Creek (Alberni Inlet). A simple statistical analyses of the recovery data obtained so far indicate that the average survival of chinook released at China Creek was not significantly different ($t=-0.217$, $p>0.05$) than the survival of chinook released directly from the hatchery into the Somass River.

This means that we cannot reject the null hypotheses that the average survival of the chinook released from the hatchery and at China Creek were the same. The total number of returns from all tag groups are sufficiently high to obtain reliable results from the statistical analyses. However close inspection of the survival data for each release group in 1998 indicates that the survival of fish released from the hatchery was actually substantially lower than survival rates for fish released at China Creek, for all release groups except one. This particular group of fish (tag code 024804) apparently had a survival rate of 2.158%, which appears to be anomalously high when compared to all the other release groups. If this group is eliminated from the statistical test, then the survival of chinook released at China Creek is significantly higher than the remaining groups of chinook released from the hatchery. Therefore the correct con-clusion for the 1988 results depends on the validity of including or rejecting the survival data for the chinook with tag code 024804. Possibly this problem will disappear as additional tagged fish are recovered in 1992 and 1993.

For the 1989 experiment, as of 1 December 1991 a total of 222, 342, and 322 CWT chinook had been recovered from groups released from the hatchery (Stamp River; control groups), China Creek (Alberni Inlet) and Poett Nook (Trevor Channel), respectively (Table 6). A similar statistical analyses of these preliminary recovery data indicate that the average survival rates of chinook released at both China Creek and Poett Nook were significantly higher than the average survival of the control groups released directly from the hatchery. This result is consistent with the

Table 5. Preliminary results for the 1988 chinook translocation experiment.

Stamp River (hatchery release)

tag code	# tagged	total recovered	percent survival
024803	31791	256	0.805
024804	28912	624	2.158
024805	29111	178	0.611
024806	32201	203	0.630
		μ_1 = mean =	1.051
		variance	5.522E-01

China Creek

tag code	# tagged	total recovered	percent survival
024937	27033	332	1.228
024948	24137	259	1.073
024949	24691	275	1.114
024950	26264	292	1.112
		μ_2 = mean =	1.132
		variance	4.486E-03

H_1: $\mu_2 > \mu_1$ $t' = -0.217$ ns

Table 6. Preliminary results for the 1989 chinook translocation experiment.

Stamp River (hatchery release)

tag code	# tagged	total recovered	percent survival
025630	10385	37	0.356
025640	9780	34	0.348
025643	9704	33	0.340
025645	9645	51	0.529
025646	9723	29	0.298
025648	9805	38	0.388

μ_1 = mean = 0.376
variance 6.400E-03

China Creek

tag code	# tagged	total recovered	percent survival
025663	9902	76	0.768
025701	9893	76	0.768
025702	9878	46	0.466
025703	9864	37	0.375
025704	9730	60	0.617
025705	9888	47	0.475

μ_2 = mean = 0.578
variance 2.758E-02

Poett Nook

tag code	# tagged	total recovered	percent survival
025651	9783	50	0.511
025653	9805	33	0.337
025654	10091	67	0.664
025657	9875	55	0.557
025658	9882	89	0.901
025660	10258	28	0.273

μ_3 = mean = 0.540
variance 5.185E-02

H_1: $\mu_2 > \mu_1$ $t' = -2.684$ * $p < 0.025$

H_2: $\mu_3 > \mu_1$ $t' = -0.217$ $p < 0.100$

hypothesis that hake predation in Alberni Inlet (between China Creek and the hatchery) reduced marine survival of chinook released from the hatchery. However, the statistical results indicate that the average survival of chinook released at Poett Nook was not significantly greater than the average survival of chinook released at China Creek. This result is not consistent with the hake predation hypothesis, as it implies that chinook released at China Creek and Poett Nook were subjected to similar predation mortality. The predation model predicts that survival of the chinook released at Poet Nook should have been higher due to the additional predation suffered by chinook released at China Creek as they migrated out through Alberni Inlet before entering Trevor Channel.

The reader is again cautioned that all the conclusions regarding the results of the chinook translocation experiments are based on only preliminary data and analyses. The conclusions may change as additional tagged chinook are recovered as adults in subsequent years.

Acknowledgements

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Brent Hargreaves
Bob Hungar
Bruce Patten

5. Summary of 1991 Surveys

CRUISE ID	SCIENTIST	START	END	SAMPLING COMMENTS
OP91-81 PBS91-01	Saunders	Feb 4	Feb 6	4 COPRA Stations
OP91-03	Freeland (STN P)	Mar 9	Mar 10	MB , MA lines off Tofino
OP91-83 PBS91-03	Hay	April 12	April 12	4 COPRA stations
OP91-08	Freeland (STN P)	May 9	May 9	MA line off Tofino
OP91-84 PBS91-04	Boutillier	May 11	May 11	4 COPRA Stations
OP91-10	Thomson	May 28	June 6	LA, LB, LC, LD, LG, LJ, LBP, SQ, TCB, LCS lines
OP91-87 PBS91-07	Hargreaves	July 16	Aug 16	LA, LB lines plus numerous other lines, entire coast
OP91-12	Thomson	July 20	July 25	LB, LC lines plus additional lines to the north of La Perouse
*OP91-99 OP91-12 OP91-87 PBS91-07	Thomson / Hargreaves	July 16	Aug 16	merged data set from Hargreaves/Thomson two ship operation (merge OP91-12 and OP91-87)
OE 91-07 OP 91-??	Mackas	Aug 11	Aug 22	LA, LB, LC, LD, LH, SK, LBP and 3 COPRA stations
OP91-88 PBS91-08	Saunders	Aug 14	Aug 18	4 COPRA stations
OP91-89 PBS91-09	Hargreaves	Sept 9	Sept 26	4 COPRA stations plus LB, LC, LD (?)
OP91-14	Thomson	Oct 5	Oct 14	LA, LB, LC, LD, LG, LBP, LCS plus stations in Juan de Fuca Strait

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7. LIST OF PARTICIPANTS

Name	Affiliation	Invited	Attended
R. Beamish	DFO/PBS	Y	Y
R. Brown	DFO/IOS	Y	Y
W. Crawford	DFO/IOS	Y	N
J. Davis	DFO/IOS/PBS	Y	N
K. Denman	DFO/IOS	Y	N
R. Forbes	DFO/IOS/PBS	Y	Y
M. Foreman	DFO/IOS	Y	Y
H. Freeland	DFO/IOS	Y	N
K. Groot	DFO/PBS	Y	Y
B. Hargreaves	DFO/PBS	Y	Y
W. Hsieh	UBC/Oceanogr.	Y	N
K. Hyatt	DFO/PBS	Y	Y
G. Jamieson	DFO/PBS	Y	Y
E. Loggerwell	PBS Visitor	Y	Y
G. A. McFarlane	DFO/PBS	Y	Y
D. Mackas	DFO/IOS/PBS	Y	Y
I. Perry	DFO/PBS	Y	Y
J. Rice	DFO/PBS	Y	Y
C. Robinson	PBS Ph.D. Student	Y	Y
M. Saunders	DFO/PBS	Y	Y
W. Shaw	DFO/PBS	Y	N
S. Tabata	DFO/IOS	Y	N
R. Tanasichuk	DFO/PBS	Y	Y
R. Thomson	DFO/IOS	Y	Y
B. Waddell	DFO/PBS	Y	Y
D. Ware	DFO/PBS	Y	Y
M. Woodward	DFO/IOS	Y	N