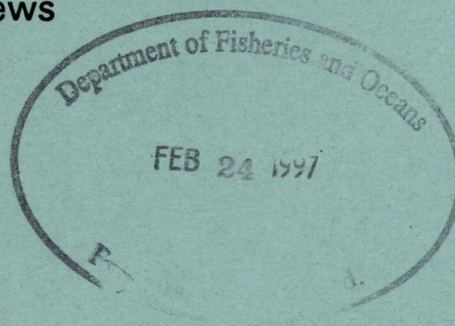




A Hydroacoustic Survey on the Continental Shelf off British Columbia to Evaluate New Fisheries Acoustic Instrumentation and to Obtain Pacific Hake Stock Assessment Information, May 28 - June 4, 1994

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A HYDROACOUSTIC SURVEY ON THE CONTINENTAL SHELF
OFF BRITISH COLUMBIA TO EVALUATE NEW FISHERIES
ACOUSTIC INSTRUMENTATION AND TO OBTAIN PACIFIC HAKE
STOCK ASSESSMENT INFORMATION, MAY 28 - JUNE 4, 1994

by

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ABSTRACT

Kieser, R., K. Cooke, and W. T. Andrews. 1996. A hydroacoustic survey on the continental shelf off British Columbia to evaluate new fisheries acoustic instrumentation and to obtain Pacific hake stock assessment information, May 28 - June 4, 1994. Can. Manuscr. Fish. Aquat. Sci. 2378: 35p.

A joint Canada/Japan research cruise was conducted to compare state of the art fisheries acoustic gear and procedures from both countries and to obtain new information of the Pacific hake stock off Vancouver Island, Canada. This report focuses on the biological and stock assessment information that was obtained. It also provides a summary of the measurements that were taken.

Key words: Pacific hake, hydroacoustic, biomass, target strength, estimate, survey

RÉSUMÉ

Kieser, R., K. Cooke, and W. T. Andrews. 1996. A hydroacoustic survey on the continental shelf off British Columbia to evaluate new fisheries acoustic instrumentation and to obtain Pacific hake stock assessment information, May 28 - June 4, 1994. Can. Manuscr. Fish. Aquat. Sci. 2378: 35p.

Une expédition de recherches conjointe Canada-Japon a permis de comparer les appareils et méthodes acoustiques pour la pêche les plus modernes des deux pays et d'obtenir des données sur le stock de merlu du Chili se trouvant au large de l'île de Vancouver (Canada). Le rapport présente les données ainsi recueillies sur la biologie et l'évaluation du stock et fournit un sommaire des mesures qui ont été prises.

Mots clés: Merlu du Chili, hydroacoustique, biomasse, intensité de cible, estimation, relevé.

INTRODUCTION

The harvesting and management of marine fish stocks is not only of local and national but often of international concern, as well. There are trans-boundary fish stocks, spawning/feeding migrations, long range fishing fleets and world wide oceanographic and climatic conditions that affect fish stocks within and outside national jurisdictions. Canada and Japan, as neighbouring Pacific Rim countries, have a common interest in protecting their fish stocks and in optimizing yield from their respective fisheries. Many factors contribute to understanding and successfully managing marine fish species. Both Canada and Japan have developed the sophisticated tools and methods required to obtain information on fish biology, stock abundance, habitat, and related factors. As well, both countries operate modern research vessels to conduct studies offshore.

During discussions at the Canada-Japan Fisheries Acoustic Workshop held in Parksville, B.C., Canada, February 24 to 26, 1993 (McFarlane and Kieser 1993), researchers from both countries suggested that this common interest and sea-going capability provided a good opportunity to conduct joint research.

A proposal was formulated whereby researchers from the National Fisheries University in Shimonoseki, Japan and from the Pacific Biological Station in Nanaimo, B.C. would carry out a joint research cruise utilizing their respective research vessels *TENYO MARU* and *W.E. RICKER*. Each of the research teams included industrial representatives from FURUNO Electric Co., Nishinomiya City, Japan, manufacturers of the acoustic system on board the *TENYO MARU* and from FEMTO Electronics Ltd., Lower Sackville, Nova Scotia, supplier of the hydroacoustic data processing system (HDPS) used by the Canadian researchers. Objectives of the program were to evaluate and compare the most recent fisheries acoustic instrumentation, data acquisition and analysis procedures, and survey methodology employed by each team. Specifically, we proposed to: 1) carry out a joint fisheries acoustic survey to assess the distribution and abundance of Pacific hake in a predetermined area, 2) conduct concurrent fishing and oceanographic surveys to complement the acoustic information, 3) conduct experiments to compare advanced fisheries acoustic instrumentation and procedures, including system calibration, data acquisition, backscatter and target strength (TS) measurements, and 4) conduct independent and joint Canadian and Japanese analyses which would include reporting of biological and technical results in the scientific literature. Industrial representatives from both countries assisted in the data collection and analysis, and in the assessment of the equipment to highlight its compatibility and potential for joint development.

We selected an area along the continental shelf off British Columbia's southern Vancouver Island coast where we were likely to locate Pacific hake (*Merluccius productus*) aggregations with sufficient variability in density and shoal structure to allow for a complete range of systems comparisons. Annual quantitative surveys of this area have been conducted since 1990 (Andrews et al. 1994; Cooke et al. 1992; Cooke et al. 1996; Saunders et al. 1992; Saunders et al. 1996; Smith et al. 1990). Our understanding of the behaviour and distribution of the hake stock provided the opportunity to collect TS measurements from individual fish and to capture representative samples of the ensonified targets. Fishing also provided specimens for precision laboratory TS measurements in Japan (Ye et al. 1996).

This paper focuses on the Canadian portion of the study. We report on the survey design, gear configuration and application, acoustic biomass estimates for all targets observed and for hake, and on the biological information obtained from fishing operations. Detailed TS and survey analysis results are presented in separate reports (Hamano et al. 1996; Kieser et al. 1995). These results are important as both countries are looking for better stock assessment and survey procedures; further post-cruise analyses will provide an opportunity to identify optimal procedures and develop recommendations for their implementation. In the DISCUSSION, we examine the potential for future information exchange, research, and industrial development.

MATERIALS AND METHODS

SURVEY AREA

The survey was conducted May 28 to June 4, 1994 using the *CSS W.E. RICKER*, a 58 m, 2500 hp research stern trawler and the Japanese training vessel, *TENYO MARU*, a 57 m stern trawler. The survey design was similar to those used in earlier surveys (Andrews et al. 1994; Barner et al. 1984; Cooke et al. 1992; Cooke et al. 1996; Kieser 1983; Saunders et al. 1992; Saunders et al. 1996). The overall survey area is a part of the traditional Canadian hake fishing grounds between 48E 15' and 49E (Figure 1). Positions were selected from transects A11, A12, A13, B2, B4, B6 and B8 from the 1993 survey grid (Saunders et al. 1996) to provide coverage from about 50 m depth to seaward of the shelf break as far as the 1000 m contour and to encompass a variety of habitats and target densities.

Vessel position relative to one another was of key importance to allow for ensonification of essentially the same

targets by each of the acoustic systems and to identify any aberrant target behaviour that might be observed by one or both vessels. To address this concern, ships alternated lead position for each pass along a survey line. An initial data set was collected in shallow water (<200 m) along segments of transects A11 through A13 (Table 1; Figure 2). This allowed each of the ships' captains and crews to establish a safe operating routine for working in close quarters. Subsequently, the trailing ship endeavoured to maintain a position 2 minutes aft and 30° to port or starboard of the lead vessel at a constant speed of 9 kn.

The first run through the A series gave researchers an opportunity to compare a small data set and identify any changes that may be required in the experiment with respect to data acquisition and analysis. The B series transects were then run to extend coverage beyond the shelf break and to assess targets deeper than 300 m. Typically, an area would be sounded in blocks of two transects with vessels exchanging lead position along the connecting leg between each transect. Positions along a transect where concentrations of targets requiring identification or verification were noted as possible fishing sites. Following completion of a series, one or both of the vessels would return to the fishing location and re-sound before setting trawl gear on the targets in question. Generally, fishing operations were carried out within 24 h of the initial observations.

In situ TS measurements were collected with both the Canadian and Japanese acoustic systems. Typical day time aggregations of hake are generally too dense to allow for accurate TS measurement, however their diurnal behaviour is such that at night, schools break up and individuals may be seen as separately identifiable targets. It was important to correlate any targets observed at night with their origins as aggregations seen during the day. For many pelagic and demersal species, daytime shoals seen at particular depths will disperse throughout the water column at night (Leaman et al. 1982; Stanley et al. 1996). We carried out a 24 h series on the B2-4 block and a continuous day through night series on a portion of transect B8 to document the change at dusk from concentrated day time aggregations to less dense nocturnal scattering layers.

DATA ACQUISITION and ANALYSIS

The calibrated echo integration system installed on the CSS W.E. RICKER consisted of a BioSonics 38 kHz echo sounder, a BioSonics chart recorder, a BioSonics digital echo integrator, a PCM/VCR tape recording system, FEMTO HPDS 2000 digital signal processor and auxiliary equipment. The 'wet end' included a towed body with a Simrad ceramic transducer and armoured tow cable. The echo integrator was programmed to analyze the return

echoes for a series of strata (range slices) starting just below the transducer and continuing to bottom. Standard data acquisition procedures were used (Burczynski 1982; Clay and Medwin 1977; Foote et al. 1987; Forbes and Nakken 1972; Kieser et al. 1987).

Two acoustic systems were used on the *TENYO MARU* and are fully described in Hamano et al. 1996. The primary sounder was a dual frequency FURUNO FQ74. The system included a towfish with a 50 kHz dual-beam and a 120 kHz quasi-ideal beam transducer and a SONY PC208A eight track digital recorder for data storage. A FURUNO 38 kHz single beam system with a hull mounted transducer was also used.

Figure 2a shows a portion of a BioSonics echogram that was recorded near the shelf break. Horizontal range, vertical sequence and short minute marks are indicated by the solid lines; the dashed line indicates an event marker. Bottom tracking is monitored by a line following the bottom. Although not visible on this echogram, a surface echo occasionally appears between 5 and 10 m range. This signal is used to estimate the depth of the towed body and transducer. It is excluded from the subsequent analysis. The range of the surface echo is added to the target range shown on the echogram to estimate target depth. Bottom tracking was obtained with an 8 m bottom window. An echo integration sequence was completed every 30 pings (1 minute) with a ping interval of 2 seconds (0.5 Hz) and the measured echo intensities were stored on a personal computer. The echo integrator and chart recorder thresholds were set to 0.2 V, thus, all integrated echoes were displayed on the echogram. At this low threshold level some noise pulses were visible, especially on the deeper portions of the echogram.

The integrated output was processed with custom software to exclude ocean bottom, flow and vessel noise, echoes from plankton and some juvenile fishes layers, as well as signals from porpoises that swam in the vicinity of the towed body. The total or 'all species' estimates includes echoes from all fish-like targets. Surface densities for adult hake and all species other than hake were calculated using target strengths of -35 and -32 dB/kg, respectively (Cooke et al. 1992; Kieser 1992). We used GIS based proximal analysis (Kieser and Langford 1991; Kieser et al. 1995; Langford 1992; Langford 1996) to expand the measured surface densities to the entire survey area. The survey area is divided into a large number of small, rectangular cells and each cell assumes the surface density of the nearest measured location. Biomass is estimated by multiplying the sum of all surface density values by the constant cell area.

SPECIES IDENTIFICATION

We used echograms for target identification and to direct trawling operations. Trawl catch information is used for verification of echogram data and to obtain biological data. Targets observed on the echogram are classified according to several criteria. Day time rockfish schools are typically seen at a range of 100 m to bottom (~160 m) near the shelf break; herring are often characterized by dense 'haystack-type' schools near the bottom or 'needle shaped' schools in mid-water (Figure 2a). Column-like schools just beyond the shelf break or near steep slopes or pinnacles often indicate rockfish. In Figure 2b hake appear between 160 and 240 m in a dense band that continues outward from the shelf break; plankton are indicated by a diffuse scattering layer starting at the shelf break and underlying the hake distribution. In the day, hake schools often form cone-like clusters which produce a zigzag pattern across the echogram. At dusk, Pacific hake disperse over a considerable depth range to form layers of single fish (Figure 3). These layers persist until dawn before they again regroup into the tight aggregations seen in the day. Other potentially confusing species include pollock, herring, rockfish and dogfish. Pollock are mixed with the hake and cannot be separately identified. However, test fishing showed pollock contributed very little to hake schools. The target strength of dogfish is so low that they generally appear as a haze on the echogram and contribute relatively little to the measured echo intensity.

FISHING SURVEY

Both vessels carried out trawling operations to verify identification of targets, gather biological information and compare fishing procedures and yields. Test sets were conducted on the *CSS W.E. RICKER* using a Canadian Diamond-7 midwater trawl with a 13.5 m vertical opening and a 3.8 cm cod end mesh, a pair of 5 m² Superkrub midwater trawl doors, 80 m sweep wires with 300 kg chain weights, and a SIMRAD FS3300 third wire headrope transducer. Fishing positions were selected to sample major fish concentrations encountered during the acoustic survey. In our normal survey operations, sets are made generally less than 2 hours after a target aggregation was surveyed and selected for sampling (Saunders et al. 1996). However, for this cruise, we did not want to interrupt the continuity of the comparative soundings between the two vessels thus, two days were identified for fishing on targets selected for sampling during the sounding operations. In this case, fishing was carried out some 24 h after the targets were observed acoustically. Prior to setting the gear, we would re-sound the area selected previously to determine if targets similar to what had been observed during the acoustic survey were still present. In all cases, similar

aggregations were seen and set positions were very near the original site of observation.

The *W.E. RICKER* also provided night time fishing to complement the TS measurements collected on the *TENYO MARU*. This fishing was done concurrent with the soundings during the final pass along transect B8 (Tables 1 and 2a).

Trawl catches were spilled from the codend into a below deck hopper and sorted by species off a conveyor belt into tubs. All tubs of fish were weighed on a platform scale to the nearest kilogram. Representative subsamples of hake were selected by retaining at least 3 tubs of fish from the start, middle and end of the hopper load for routine biological sampling. For small hauls the entire catch was sampled.

Measurements of fork length to the nearest mm, sex and maturity (Weir et al. 1978) were recorded for all hake sampled. Otoliths were collected and stored in a 1/1 glycerine/freshwater solution with thymol at 0.3% for subsequent age determination. The stomach contents of hake from 1 or 2 tubs were examined with prey items being identified to the lowest possible taxon. The volume of each prey item was estimated visually to the nearest 1 cc. The state of digestion was recorded for each prey item and any identifiable herring remains were counted and measured.

OCEANOGRAPHIC DATA

Conductivity and temperature were sampled at one meter depth intervals at preselected stations using a GUILDLINE CTD (8770 series) oceanographic probe. Sea surface temperatures were collected at 10 minute intervals using the CSAIL software/hardware system (Revlis Electronics Ltd. Vernon, B.C., and Simmie Software Solutions, Regina, Sask.; Saunders et al., 1992). The seawater intake is approximately 4 m below the surface. Plankton samples were collected at pre-selected stations for use by the COPRA (Cooperative Plankton Research) program. The sampling gear consisted of a bongo net frame with two 0.5 m diameter 230 micron mesh nets attached. Oblique tows were conducted to within 20 m of the bottom or to a maximum depth of 500 m. Wire was paid out at a rate of 1 m/sec and retrieved at a rate of 0.3 m/sec. The samples were preserved in 10% formalin.

RESULTS

BIOMASS ESTIMATES

A total of 8 different transects were run with some tracks or portions of them repeated to: 1) assess the

distribution and behaviour of Pacific hake in a defined area, 2) compare acoustic instrumentation and procedures for data acquisition, echo analysis, and signal display, and 3) collect target strength measurements on fish concurrently being sampled by trawling.

The biomass distribution for all species and for hake only are shown in Figures 4 and 5, respectively. Corresponding biomass estimates by transect are given in Table 2a. Estimates for the repeat transects are summarized in Table 2b.

Observations on diel distribution changes and species specific behaviour were obtained from four successive passes of the B2-4 and successive passes of B8W1 through B8E4 transects (Tables 1 and 2b, Figure 3). During the day, aggregations of hake were characterized by relatively continuous, dense, and vertically stacked schools located near the 200 m shelf break (Figure 3, top). Schools located shoreward of the shelf break were typically at 100 to 180 m range and appeared very close to or on bottom (Figure 2a). Deeper hake aggregations were found to depths of 300 m off the shelf edge (Figures 2b and 3). Rockfish species were often found in association with the hake at the shelf break (Figure 2a), but generally were recognizable from hake by narrower and more vertically stacked shoals and proximity to the shelf edge and bottom (Leaman et al. 1990; Kieser et al. 1993). Transitional movement between day to night formation occurred very rapidly at twilight. At dusk the normal pattern was one of dispersal of diurnal schools in both horizontal and vertical directions, including a net motion towards the surface (Figure 3, upper and lower middle). Nocturnal echograms show much more diffuse distributions that include considerable mixing of species (Figure 3, bottom). At dawn schools rapidly regrouped nearer the bottom to complete the diel cycle.

FISHING RESULTS

A total of 5 midwater sets were conducted on the *CSS W.E. RICKER* to obtain species composition and biological samples (Figures 1, 4 and 5). Tables 3a and 3b list bridge log and species composition for the *W.E. RICKER* and *Tenyo Maru* sets, respectively. Pacific hake were present in all sets and accounted for 98.7% and 92.9% of the *W.E. RICKER* and *Tenyo Maru* catches (Table 4). Table 5 lists the number and fraction of Pacific hake by haul for depths <100 and >100 m. The length frequencies by set, are presented in Tables 6a to 6c; oceanographic station locations for CTD and COPRA are listed in Table 7.

DISCUSSION

The 1994 Canada-Japan intership comparison surveyed 2700 km² of the traditional hake fishing grounds off southwest Vancouver Island from just north of the Canada/U.S. boundary (approximately 48E 15') to almost 49E. Eighteen separate lines, selected from earlier August hake surveys (Saunders et al. 1992), were run which covered areas from about the 50 m depth contour to seaward of the continental shelf. Lengths of each line varied depending upon offshore target distribution and time constraints. The focus of the offshelf component of the survey was to gather information on the structure and vertical distribution of the deep water acoustic sign (>200 m) and to measure acoustic target strengths for hake observed at these depths (Hamano et al. 1996).

Total biomass inshore of the continental shelf (transects A11 - A13) was about 15 kt, which was made up of primarily adult hake but also included some herring and small aggregations of rockfish along transect A11. This total compares with estimates of about 60 kt from each of the annual coastwide stock assessment surveys in 1993 and 1994 for the same transects (Saunders et al. 1996; Cooke et al. 1996). This difference is not unexpected given that transect lengths were much reduced during this cruise. Area covered is only about half of that surveyed during annual assessments. Furthermore, herring are generally found along the shallower portions of transects A11 through A13 and it was these sections which we purposely avoided in order to focus on monospecific hake aggregations.

Transect A11 was only surveyed once, however, portions of lines A12 and A13 were repeated. Total biomass for the first pass of A12 and A13 was estimated at 10.5 kt over 350 km²; hake biomass was 10.4 kt. On the second pass, 11.9 kt total biomass and 9.8 kt hake biomass were estimated in a slightly smaller area of 300 km². In 1993, 47 kt total biomass and 39.7 kt hake biomass was estimated along the full lengths of A12 - A13, which represents about 550 km². During the 1994 annual hake survey, estimates for a comparable area of 595 km² were 26.6 kt total biomass and 15.6 kt hake biomass (Cooke et al. 1996). This suggests that during our shortened coverage of transects A11 through A13, we observed about two thirds of the hake biomass available in 1994. At the same time we avoided the majority of non-hake biomass, primarily herring, that is typically found in this region.

The deep scattering layer seaward of the continental shelf was composed almost exclusively of adult hake with an underlying, and often dense, plankton and myctophid layer to about 300 m. A surface scattering layer, likely composed of phytoplankton, was also observed, generally to 30 m range but occasionally down to 80 m. This layer is usually found near the shelf break and is associated with upwelling of colder and

nutrient-enriched waters from offshore (R. Thompson, Institute of Ocean Sciences, pers. comm.). A small, near-shelf component of rockfish was also observed. Daytime biomass estimates for all fish species were 40.2 kt and 67.2 kt for two passes of the B2-4 block and 43.2 kt for one pass of the B6-8 series. This compares with 79.7 kt and 36.8 kt, respectively for comparable areas in 1993 (Saunders et al. 1996) and 35 kt and 17.8 kt, respectively for the two areas in August 1994 (Cooke et al. 1996).

Hake biomass estimated for two passes of B2-4 was 24.7 kt and 39.6 kt, and, for B6-8, 22.8 kt. Similar coverage in 1993 resulted in biomass estimates for hake of 49.8 kt along B2-4 and 31.3 kt along B6-8 (Saunders et al. 1996). In August 1994, only the odd-numbered B series transects were surveyed. For the area comparable to the B2-4 and B6-8 blocks, 22.6 kt and 9.9 kt of hake, respectively, were estimated (Cooke et al. 1996).

A relatively stable aggregation of hake biomass was observed near the shelf edge along transect B8. With each successive pass, we reduced the length of the transect, and consequently the area of coverage, to home in on the maximum horizontal distribution of targets. Five repeats, decreasing in area from 457 km² to 74 km², gave estimates of 5.6 kt, 6.6 kt, 7.8 kt, 2.4 kt, and 5.3 kt, respectively (Table 2b). We monitored the nocturnal dispersal of these targets from tight daytime aggregations to individually dispersed targets in the upper 100 m near the shelf break. Trawl samples were then taken on the *CSS W.E. RICKER* in conjunction with *in situ* target strength measurements of adult hake collected simultaneously on board the *TENYO MARU*. A literature review confirmed a TS -35 dB/kg to be appropriate for adult fish (Kieser 1992). The TS data that were collected during this cruise data will be fully presented at the Symposium on Fisheries and Plankton Acoustics in Aberdeen, Scotland, June 12 - 16, 1995 (Hamano et al. 1996).

The internship calibration also focused on comparison of hake abundance estimates from two independent acoustic systems, using three different frequencies: 38 kHz, 50 kHz, and 120 kHz. Much of this information will be the subject of a joint Canada-Japan report and will examine variability in abundance estimation as it relates to instrumentation and procedures, including frequency of operation, system calibration, data acquisition, echo analysis, and signal display.

This joint venture program stems from original discussions held at the Canada-Japan Fisheries Acoustics Workshop, Parksville, B.C. February 24 - 26, 1993. At that workshop, representatives of the Canadian and Japanese scientific and business communities discussed on-going research and technology development in the area of fisheries acoustics. Because of the similarities between types of fisheries, issues and problems, and the capabilities and priorities of the respective research communities, participants were able to

quickly identify specific areas where future collaboration would be both mutually beneficial and have a high likelihood of success. As a result of those discussions, researchers in this program have begun building personal working relationships and business ventures have been initiated. This cruise represents only the first step in that process, but already it is clear that significant scientific and economic benefits will be realized for both countries.

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Table 1. Transect information including date, start time, and start and end latitude and longitude for the CSS W.E. RICKER joint Canada-Japan fisheries acoustic survey, May 28 - June 4, 1994.

EVENT #	NAME	DATE	TIME	LENGTH km	LATITUDE deg min	LONGITUDE deg min	LATITUDE deg min	LONGITUDE deg min
4.0	A11W	28-MAY	12:55	24.8	48 32.48	124 40.08	48 32.32	125 0.27
11.0	A12W	28-MAY	15:37	42.5	48 30.04	125 5.01	48 30.00	125 39.65
18.0	A13EA	29-MAY	06:43	18.4	48 27.69	125 36.87	48 27.63	125 21.91
21.0	A13EB	29-MAY	08:34	14.4	48 27.54	125 21.58	48 27.48	125 9.82
23.0	A12WA	29-MAY	10:07	33.0	48 29.67	125 10.01	48 30.07	125 36.89
25.0	A13EC	29-MAY	13:03	32.1	48 28.01	125 36.24	48 27.78	125 10.12
32.0	B2W	31-MAY	06:43	63.0	48 17.90	125 38.54	48 17.86	126 29.65
46.0	B4E	31-MAY	12:35	61.5	48 22.90	126 29.65	48 22.85	125 39.66
60.0	B2WA	31-MAY	18:02	8.1	48 17.61	125 39.45	48 17.77	125 45.99
62.0	B2WB	31-MAY	19:05	31.2	48 17.79	125 44.56	48 17.81	126 9.85
65.0	B4EA	31-MAY	22:54	36.9	48 22.74	126 9.78	48 22.79	125 39.77
68.0	B2WC	01-JUN	02:52	37.1	48 17.81	125 39.66	48 17.84	126 9.76
74.0	B6W	03-JUN	07:18	68.8	48 27.77	125 43.64	48 27.88	126 39.69
88.0	B8E	03-JUN	13:11	49.3	48 32.79	126 40.05	48 32.74	125 59.86
91.0	B8W1	03-JUN	17:09	22.5	48 31.63	125 59.99	48 31.87	126 18.34
97.0	B8E2	03-JUN	19:12	14.5	48 32.84	126 17.66	48 32.78	126 5.82
102.0	B8W3	03-JUN	20:29	12.8	48 31.78	126 5.87	48 31.86	126 16.32
104.0	B8E4	03-JUN	21:47	8.0	48 31.86	126 15.02	48 31.79	126 8.49

Table 2a. Total and Hake Biomass by transect for the *CSS W.E. RICKER* acoustic survey, May 28 - June 4, 1994. Transect length, area covered, mean surface densities, and biomass by transect are given. TOTAL BIOMASS includes Pacific hake and all other species. A target strength (TS) of -35 and -32 dB/kg is used for Pacific hake and other species, respectively.

EVE	TRANSECT		Area km ²	TOTAL BIOMASS		HAKE BIOMASS	
	NAME	Len km		Surf D kg/m ²	ALL FISH t	Surf D kg/m ²	HAKE t
4.0	A11W	24.8	114.3	3.63E-02	4.08E+03	3.48E-02	3.99E+03
11.0	A12W	42.5	196.0	1.96E-02	3.69E+03	1.79E-02	3.52E+03
18.0	A13EA	18.4	85.6	4.49E-02	3.82E+03	4.49E-02	3.82E+03
21.0	A13EB	14.4	66.7	4.52E-02	3.02E+03	4.52E-02	3.02E+03
23.0	A12WA	33.0	152.5	5.14E-02	6.59E+03	3.48E-02	5.31E+03
25.0	A13EC	32.1	148.7	4.09E-02	5.32E+03	3.06E-02	4.55E+03
32.0	B2W	63.0	583.8	5.54E-02	2.22E+04	2.06E-02	1.20E+04
46.0	B4E	61.5	569.2	4.15E-02	1.82E+04	2.23E-02	1.27E+04
60.0	B2WA	8.1	74.1	2.15E-01	1.55E+04	1.98E-01	1.48E+04
62.0	B2WB	31.2	288.7	8.62E-02	2.16E+04	6.34E-02	1.83E+04
65.0	B4EA	36.9	341.0	1.57E-01	3.01E+04	1.89E-02	6.46E+03
68.0	B2WC	37.1	343.6	8.17E-02	1.70E+04	1.75E-02	6.00E+03
74.0	B6W	68.8	637.8	6.80E-02	3.03E+04	2.70E-02	1.72E+04
88.0	B8E	49.3	456.5	4.58E-02	1.32E+04	1.22E-02	5.57E+03
91.0	B8W1	22.5	208.8	1.00E-01	1.37E+04	3.19E-02	6.64E+03
97.0	B8E2	14.5	134.0	1.14E-01	1.16E+04	5.81E-02	7.81E+03
102.0	B8W3	12.8	118.7	7.27E-02	5.53E+03	2.05E-02	2.43E+03
104.0	B8E4	8.0	74.3	9.77E-02	6.26E+03	7.10E-02	5.27E+03

Table 2b. Total and Hake Biomass for comparative repeats of transects A12-13, B2-4, B2, and B8 from the CSS W.E. RICKER Pacific hake survey, May 28 - June 1, 1994. Transect length, surface density cell area, mean surface densities, and biomass by transect are given. TOTAL BIOMASS includes Pacific hake and all other species. A target strength (TS) of -35 and -32 dB/kg is used for Pacific hake and other species, respectively.

TRANSECT EVE	NAME	Len km	Area km ²	TOTAL BIOMASS		HAKE BIOMASS	
				Surf D kg/m ²	ALL FISH t	Surf D kg/m ²	HAKE t
11.0	A12W	42.5	196.0	1.96E-02	3.69E+03	1.79E-02	3.52E+03
23.0	A12WA	33.0	152.5	5.14E-02	6.59E+03	3.48E-02	5.31E+03
*18.0	A13A+B	32.8	152.3	4.50E-02	6.84E+03	4.50E-02	6.84E+03
25.0	A13EC	32.1	148.7	4.09E-02	5.32E+03	3.06E-02	4.55E+03
32.0	B2W	63.0	583.8	5.54E-02	2.22E+04	2.06E-02	1.20E+04
46.0	B4E	61.5	569.2	4.15E-02	1.82E+04	2.23E-02	1.27E+04
*60.0	B2A+B	39.3	362.8	1.51E-01	3.71E+04	1.31E-01	3.31E+04
65.0	B4EA	36.9	341.1	1.57E-01	3.01E+04	1.89E-02	6.46E+03
68.0	B2WC	37.1	343.6	8.17E-02	1.70E+04	1.75E-02	6.00E+03
**88.0	B8E	49.3	456.5	4.58E-02	1.32E+04	1.22E-02	5.57E+03
91.0	B8W1	22.5	208.8	1.00E-01	1.37E+04	3.19E-02	6.64E+03
97.0	B8E2	14.5	134.0	1.14E-01	1.16E+04	5.81E-02	7.81E+03
102.0	B8W3	12.8	118.7	7.27E-02	5.53E+03	2.05E-02	2.43E+03
104.0	B8E4	8.0	74.3	9.77E-02	6.26E+03	7.10E-02	5.27E+03

* Length, area and biomass estimates for separate sections of transects A13EA and A13EB as well as B2WA and B2WB have been added and mean surface densities averaged to provide additional passes of transect pairs for comparison.

** Lengths of each pass of B8 have been decreased to maintain acoustic observation of targets located near the shelf break on each successive pass.

Table 3a. Bridge log and species composition, by haul, for the joint Canada-Japan Pacific hake acoustic survey May 28 - June 4 1994, on the *CSS W.E. RICKER*.

SET NO.	1	2	3	4	5
DATE	MAY 30	JUNE 1	JUNE 1	JUNE 2	JUNE 3
AREA(MAJ-MIN-LOC)	1-20-1	3-23-10	3-23-10	3-21-6	3-23-10
TIME START (PST)	0800	0927	1457	1331	2300
DURATION (min)	33	27	11	7	41
START N. LAT. (deg)	48	48	48	48	48
(min)	31.6	17.4	22.6	27.8	31.5
W. LONG. (deg)	124	125	126	125	126
(min)	36.1	57.0	5.6	13.8	10.2
DIRECTION (deg true)	289	241	270	270	270
FINISH N. LAT. (deg)	48	48	48	48	48
(min)	31.8	17.0	22.7	27.7	31.6
W. LONG. (deg)	124	125	126	125	126
(min)	37.5	58.7	6.5	14.5	13.5
TARGET DEPTH (Modal, m)	60	300	280	75	85
(Min)	50	300	260	70	85
(Max)	70	260	300	80	85
CAPTURE DEPTH (Modal, m)	75	300	280	75	95
(Min)	72	300	260	72	100
(Max)	75	280	285	79	90
TYPE OF GEAR	CANADIAN DIAMOND NO. 7 MIDWATER TRAWL.....				
MOUTH OPENING (m)	10	11	14	10	10
ROUNDFISH (kg)					
PACIFIC HAKE	1940	342	200	904	282
CHINOOK SALMON	2	..	..	..	..
LAMPREYS	..	..	..	..	1
SELACHII (kg)					
DOGFISH	29	..	..	15	2
TOTAL CATCH (kg)	1971	342	200	919	285

Table 3b. Bridge log and species composition, by haul, for the joint Canada-Japan Pacific hake acoustic survey May 28 - June 4 1994, on the *TENYO MARU*.

SET NO.	1	2	3	4	5
DATE	MAY 30	MAY 30	JUNE 1	JUNE 1	JUNE 1
AREA (MAJ-MIN-LOC)	3-21-6	3-21-6	3-23-10	3-23-10	3-23-10
TIME START (PST)	0816	1144	0850	1127	1418
DURATION (hr:min)	1:00	1:00	0:30	1:00	1:00
START N. LAT. (deg)	48	48	48	48	48
(min)	28.2	28.2	22.1	22.5	23.9
W. LONG. (deg)	125	125	126	126	126
(min)	15.9	15.9	8.8	4.4	10.1
FINISH N. LAT. (deg)	48	48	48	48	48
(min)	29.6	27.4	23.2	22.4	21.3
W. LONG. (deg)	125	125	126	126	126
(min)	11.6	20.0	5.4	9.2	7.5
TARGET DEPTH (Modal, m)	86	85	225	258	360
(Min)	85	77	200	250	383
(Max)	87	94	250	276	340
CAPTURE DEPTH (Modal, m)	86	85	225	258	360
(Min)	85	77	200	250	383
(Max)	87	94	250	276	340
TYPE OF GEAR	MIDWATER TRAWL.....				
MOUTH OPENING (m)	15	13	14	14	10
ROUNDFISH (kg)					
PACIFIC HAKE	639	2712	..	231	81
WALLEYE POLLOCK	114	..	..	..	..
LINGCOD	10	..	..	..	..
ROCKFISH (kg)					
<u>S. FLAVIDUS</u>	1	5	..	..	..
SELACHII (kg)					
DOGFISH	19	133	..	..	..
TOTAL CATCH (kg)	783	2850	0	231	81

Table 4. Catch rates and species breakdown by vessel and haul during the joint Canada-Japan Pacific hake acoustic survey May 28 - June 4, 1994.

W.E. RICKER				TENYO MARU			
Set#	Species	Catch (kg, %)		Set#	Species	Catch (kg, %)	
1	Hake	1940	98.4	1	Hake	639	81.6
	Dogfish	29	1.5		Pollock	114	14.6
	Chinook	2.4	0.1		Dogfish	19	2.4
		-----			Lingcod	9.5	0.2
	Total	1971.4			Yellowtail	1.5	0.2

2	Hake	341.9	100		Total	783	
3	Hake	199.9	100	2	Hake	2712	95.2
4	Hake	904	98.4		Dogfish	133	4.6
	Dogfish	14.6	1.6		Yellowtail	5	0.2
		-----				-----	
	Total	918.6			Total	2850	
5	Hake	281.9	99.3	3	No fish		
	Dogfish	1.5	0.5	4	Hake	231	100
	Lamprey	0.5	0.2	5	Hake	81	100

	Total	283.9					

Catch rates (kg/hr)					
Set#	Species	Catch rate		Set#	Catch rate
1	Hake	7185		1	Hake 639
2	Hake	4380		2	Hake 2712
3	Hake	1868		3	no fish
4	Hake	7851		4	Hake 231
5	Hake	415		5	Hake 81

Table 5. Numbers of Pacific hake caught by haul and depth range during the Canada-Japan acoustic survey May 28 - June 4, 1994.

Shallow hauls 70 - 100 m						
W.E. Ricker Haul	#	1		4		5
SEX	#	%	#	%	#	%
MALE	152	42.7	162	44.8	203	49.9
FEMALE	204	57.3	200	55.2	204	50.1
TOTAL	356		362		407	
TENYO MARU Haul						
SEX	#	%	#	%		
MALE	119	35.5	145	49.5		
FEMALE	216	64.5	160	52.5		
TOTAL	335		305			
Deep hauls > 100 m						
W.E. Ricker Haul	#	2		3		
SEX	#	%	#	%		
MALE	127	38.8	137	44.9		
FEMALE	200	61.2	168	55.1		
TOTAL	327		305			
TENYO MARU Haul						
SEX	#	%	#	%		
MALE	160	44.4	52	43.7		
FEMALE	200	55.6	67	56.3		
TOTAL	360		119			

Table 6a. Length frequency of Pacific hake, by haul, for the CSS W.E. RICKER, May 28 - June 4, 1994.

Haul #	1			2			3			4			5			TOTAL		
FORK LENGTH (CM)	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
37	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	1
38	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0	0
39	-	1	1	2	-	2	-	-	-	-	-	-	1	1	2	3	2	5
40	2	3	5	0	-	0	-	-	-	2	-	2	5	4	9	9	7	16
41	3	2	5	2	1	3	-	-	-	4	1	5	3	1	4	12	5	17
42	5	2	7	3	7	10	-	3	3	4	3	7	5	5	10	17	20	37
43	4	12	16	3	7	10	4	0	4	12	5	17	7	7	14	30	31	61
44	18	12	30	6	4	10	6	2	8	13	7	20	14	7	21	57	32	89
45	26	20	46	22	9	31	16	7	23	28	28	56	30	16	46	122	80	202
46	34	24	58	24	34	58	21	18	39	34	30	64	31	21	52	144	127	271
47	17	36	53	24	29	53	38	27	65	19	24	43	37	25	62	135	141	276
48	22	41	63	14	33	47	23	34	57	19	23	42	21	28	49	99	159	258
49	7	20	27	12	27	39	10	22	32	14	25	39	19	25	44	62	119	181
50	6	12	18	8	22	30	8	22	30	5	20	25	11	20	31	38	96	134
51	2	5	7	2	6	8	3	14	17	5	10	15	9	17	26	21	52	73
52	3	9	12	3	5	8	6	6	12	1	10	11	3	12	15	16	42	58
53	2	2	4	1	6	7	0	3	3	0	6	6	3	6	9	6	23	29
54	0	1	1	0	2	2	1	0	1	1	4	5	2	1	3	4	8	12
55	1	2	3	1	1	2	1	2	3	1	0	1	-	3	3	4	8	12
56	-	0	0	1	1	2	-	0	0	-	1	1	-	0	0	1	2	3
57	-	1	1	-	2	2	-	2	2	-	1	1	-	0	0	-	6	6
58	-	0	0	-	2	2	-	0	0	-	1	1	-	2	2	-	5	5
59	-	0	0	-	0	0	-	1	1	-	0	0	-	1	1	-	2	2
60	-	0	0	-	0	0	-	0	0	-	0	0	-	-	-	-	0	0
61	-	0	0	-	1	1	-	0	0	-	0	0	-	-	-	-	1	1
62	-	0	0	-	0	0	-	0	0	-	0	0	-	-	-	-	0	0
63	-	0	0	-	0	0	-	1	1	-	0	0	-	-	-	-	1	1
64	-	0	0	-	0	0	-	0	0	-	0	0	-	-	-	-	0	0
65	-	0	0	-	0	0	-	1	1	-	1	1	-	-	-	-	2	2
66	-	1	1	-	0	0	-	0	0	-	-	-	-	-	-	-	1	1
67	-	-	-	-	1	1	-	1	1	-	-	-	-	-	-	-	2	2
TOTAL	152	206	358	128	200	328	137	166	303	162	200	362	201	203	404	780	975	1755

Table 6b. Length frequency of Pacific hake, by haul, for the Tenyo Maru, May 28 - June 4, 1994.

Haul # FORK LENGTH (CM)	1			2			4			5			Total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
36	1	-	1	-	-	-	1	-	1	-	-	-	2	-	2
37	0	-	0	-	-	-	0	-	0	-	-	-	0	-	0
38	0	-	0	-	-	-	1	-	1	1	-	1	2	-	2
39	0	-	0	1	-	1	0	-	0	0	-	0	1	-	1
40	1	-	1	0	1	1	0	1	1	0	-	0	1	2	3
41	0	-	0	2	2	4	1	4	5	1	1	2	4	7	11
42	2	3	5	0	2	2	1	3	4	0	0	0	3	8	11
43	6	2	8	7	5	12	5	3	8	0	1	1	18	11	29
44	9	5	14	10	6	16	7	4	11	3	1	4	29	16	45
45	10	10	20	11	9	20	17	11	28	5	6	11	43	36	79
46	20	18	38	23	15	38	26	23	49	11	10	21	80	66	146
47	15	19	34	29	27	56	31	30	61	8	8	16	83	84	167
48	15	31	46	22	18	40	26	28	54	11	13	24	74	90	164
49	13	34	47	13	16	29	16	29	45	4	9	13	46	88	134
50	8	28	36	12	15	27	16	24	40	4	5	9	40	72	112
51	5	17	22	6	13	19	4	20	24	3	6	9	18	56	74
52	7	18	25	5	3	8	3	6	9	0	3	3	15	30	45
53	2	14	16	2	6	8	2	2	4	1	1	2	7	23	30
54	2	7	9	0	6	6	1	2	3	-	0	0	3	15	18
55	1	3	4	0	3	3	0	3	3	-	1	1	1	10	11
56	0	0	0	1	3	4	1	4	5	-	1	1	2	8	10
57	0	1	1	0	2	2	0	3	3	-	0	0	0	6	6
58	1	1	2	0	3	3	0	-	0	-	1	1	1	5	6
59	0	0	0	1	0	1	1	-	1	-	-	-	2	0	2
60	1	2	3	-	1	1	-	-	-	-	-	-	1	3	4
61	-	0	0	-	1	1	-	-	-	-	-	-	-	1	1
62	-	1	1	-	0	0	-	-	-	-	-	-	-	1	1
63	-	1	1	-	0	0	-	-	-	-	-	-	-	1	1
64	-	1	1	-	2	2	-	-	-	-	-	-	-	3	3
65	-	-	-	-	0	0	-	-	-	-	-	-	-	0	0
66	-	-	-	-	0	0	-	-	-	-	-	-	-	0	0
67	-	-	-	-	0	0	-	-	-	-	-	-	-	0	0
68	-	-	-	-	0	0	-	-	-	-	-	-	-	0	0
69	-	-	-	-	0	0	-	-	-	-	-	-	-	0	0
70	-	-	-	-	1	1	-	-	-	-	-	-	-	1	1
TOTAL	119	216	335	145	160	305	160	200	360	52	67	119	476	643	1119

Table 6c. Length frequency of Walleye pollock, by haul, for the Tenyo Maru, May 28 - June 4, 1994.

Haul #	1			TOTAL		
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FORK LENGTH (CM)	M	F	T	M	F	T
30	1	-	1	1	-	1
31	3	1	4	3	1	4
32	1	5	6	1	5	6
33	2	10	12	2	10	12
34	5	10	15	5	10	15
35	3	12	15	3	12	15
36	11	20	31	11	20	31
37	4	9	13	4	9	13
38	0	7	7	0	7	7
39	1	2	3	1	2	3
40	-	1	1	-	1	1
TOTAL	31	77	108	31	77	108

Table 7. Summary of CTD and plankton stations occupied by the CSS W.E. RICKER and the TENYO MARU during the Pacific hake acoustic survey May 28 - June 4, 1994.

Station	Vessel	Date	Time	Latitude	Longitude
PB07 ¹	WER	05/28	19:55	48 31.80	-125 35.40
PB08 ¹	WER	05/28	21:00	48 33.90	-125 30.00
PLC2 ¹	WER	05/28	23:16	48 27.40	-125 8.11
PLC3 ¹	WER	05/29	00:59	48 23.37	-125 20.91
LB02	TM	05/29	17:50	48 38.90	-125 02.36
LB03	TM	05/29	18:26	48 37.40	-125 05.40
LB04	TM	05/29	19:07	48 35.70	-125 08.50
LB06	TM	05/29	20:07	48 32.20	-125 15.40
LB07	TM	05/29	21:05	48 28.70	-125 22.00
LB08	TM	05/29	21:59	48 25.30	-125 28.60
LB09	TM	05/29	22:48	48 21.90	-125 34.70
LB10	WER	05/29	19:49	48 18.62	-125 41.16
LB11	WER	05/29	20:43	48 15.21	-125 47.34
LB12	WER	05/29	21:23	48 13.00	-125 51.68
LB13	WER	05/29	22:12	48 10.63	-125 55.97
LB14	WER	05/29	23:07	48 8.18	-125 0.03
LB15	WER	05/30	00:23	48 4.17	-125 8.44
LC04	WER	05/30	16:03	48 43.37	-125 40.70
LC03	WER	05/30	17:04	48 46.89	-125 34.27
LC02	WER	05/30	17:35	48 48.73	-125 30.97
PLA2	TM	05/30	18:40	48 22.80	-125 03.80
LC09	TM	05/30	20:11	48 25.80	-125 13.50
LC10	TM	05/30	21:38	48 22.53	-125 20.10
LC11	TM	05/30	22:33	48 18.90	-125 26.40
LD02 ¹	WER	05/30	20:32	48 58.15	-125 46.95
LD03	WER	05/30	21:11	48 56.55	-125 50.20
LD04 ¹	WER	05/30	21:54	48 53.22	-125 56.88
LD05	WER	05/30	22:50	48 49.71	-125 3.45
LD06	WER	05/30	23:37	48 46.19	-125 9.97
LD11	WER	06/01	18:44	48 28.76	-125 42.95
LD10	WER	06/01	19:54	48 32.20	-125 36.61
LD09	WER	06/01	20:50	48 35.68	-125 29.90
LD08	WER	06/01	21:41	48 39.14	-125 23.30
LD07	WER	06/01	22:30	48 42.60	-125 16.74

¹ CTD cast and oblique bongo plankton tow at these stations.

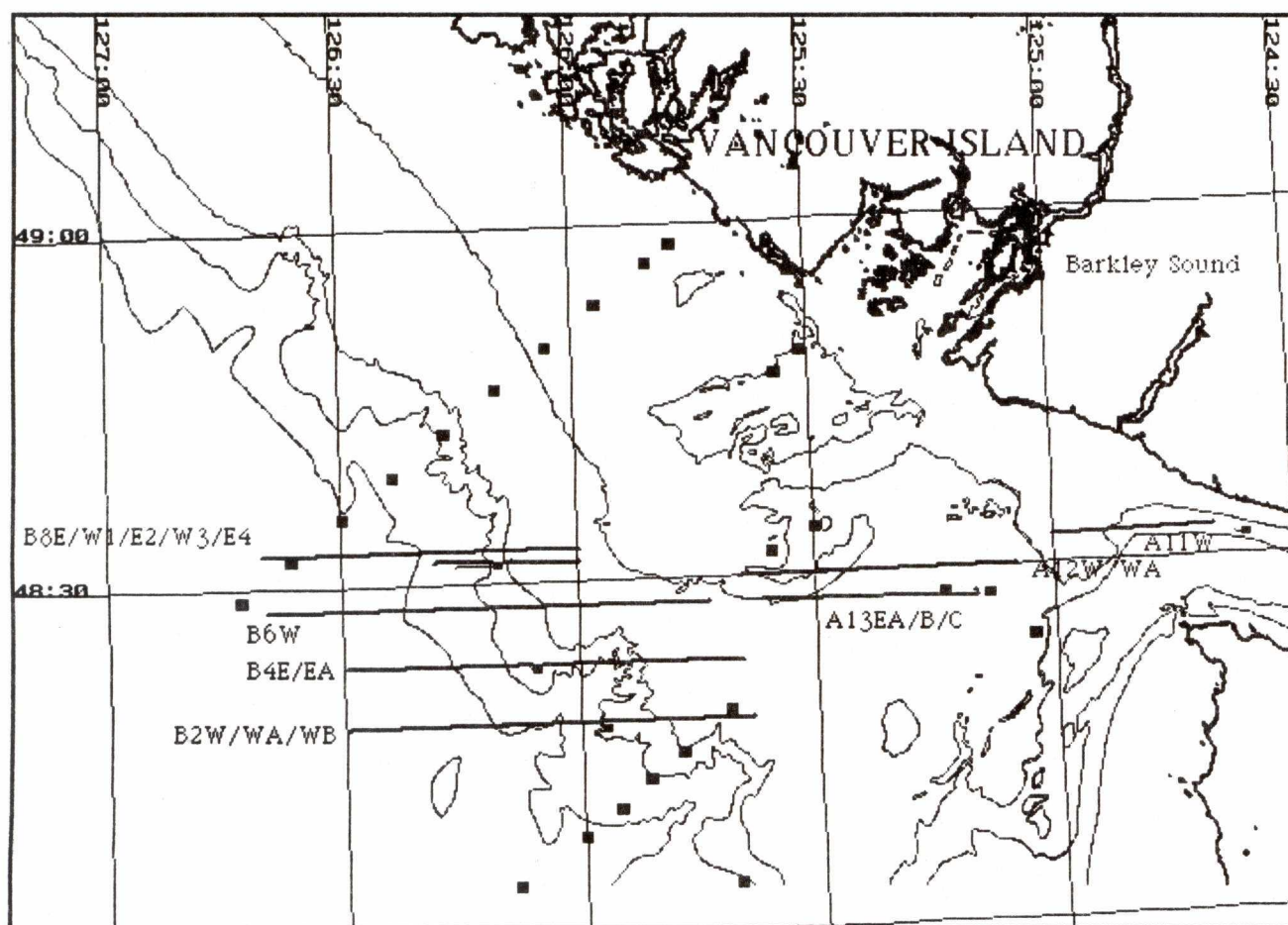


Figure 1. Transects occupied during the joint Canada-Japan Pacific hake acoustic survey May 28 - June 3, 1994, on the C.S.S. *W.E. RICKER*. CTD stations are shown as a grid of solid blocks distributed throughout the survey area.

Figure 2a. Portion of an echogram collected off the west coast of Vancouver Island, May 31, 1994 during the joint Canada-Japan Pacific hake acoustic survey May 28 - June 4, 1994, on the C.S.S. W.E. RICKER. Typical rockfish schools are shown at ranges from 60 m to bottom. A characteristic 'needle-shaped' herring aggregation is seen near the surface. Bottom track, range, sequence and event marks are labelled.

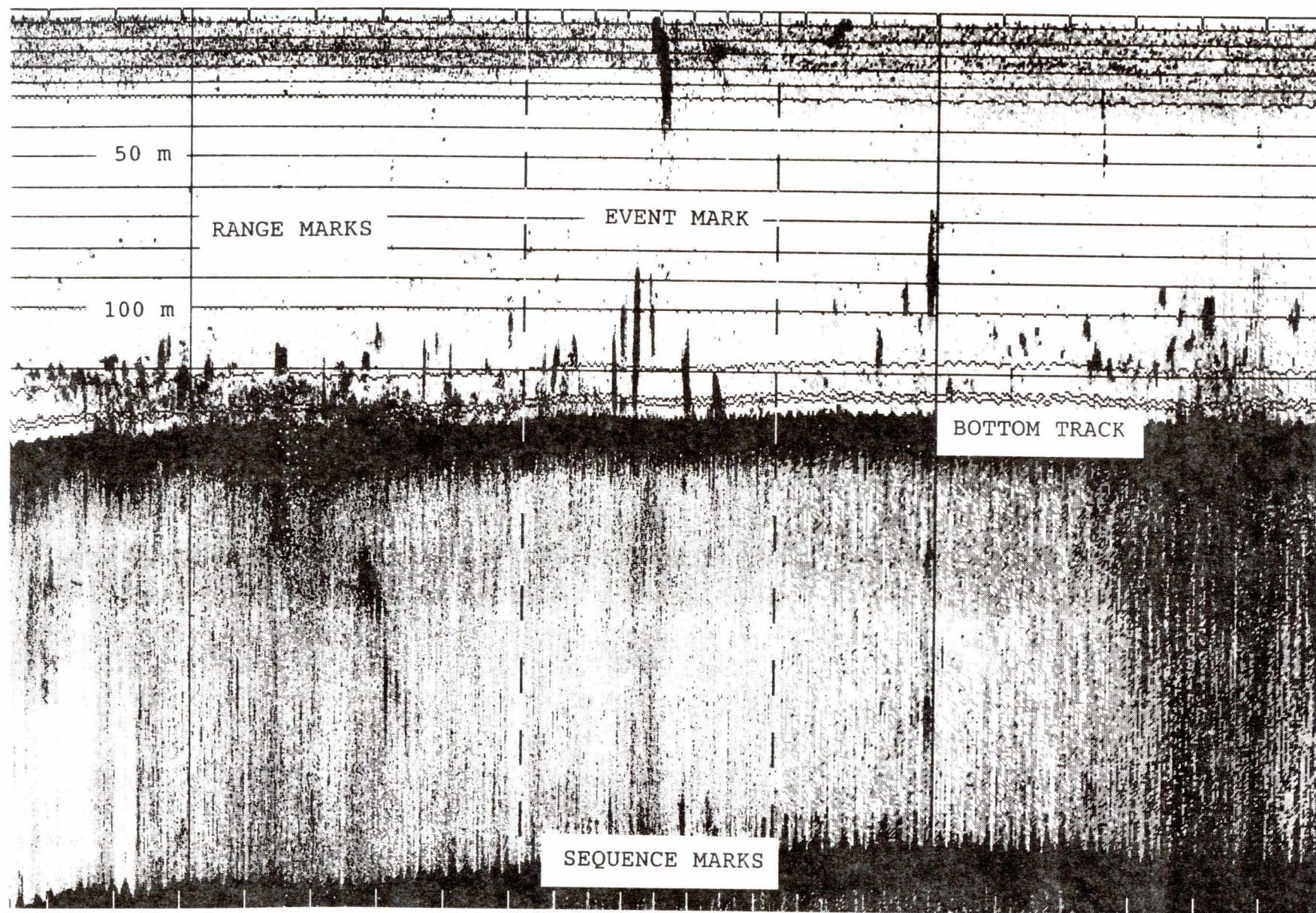
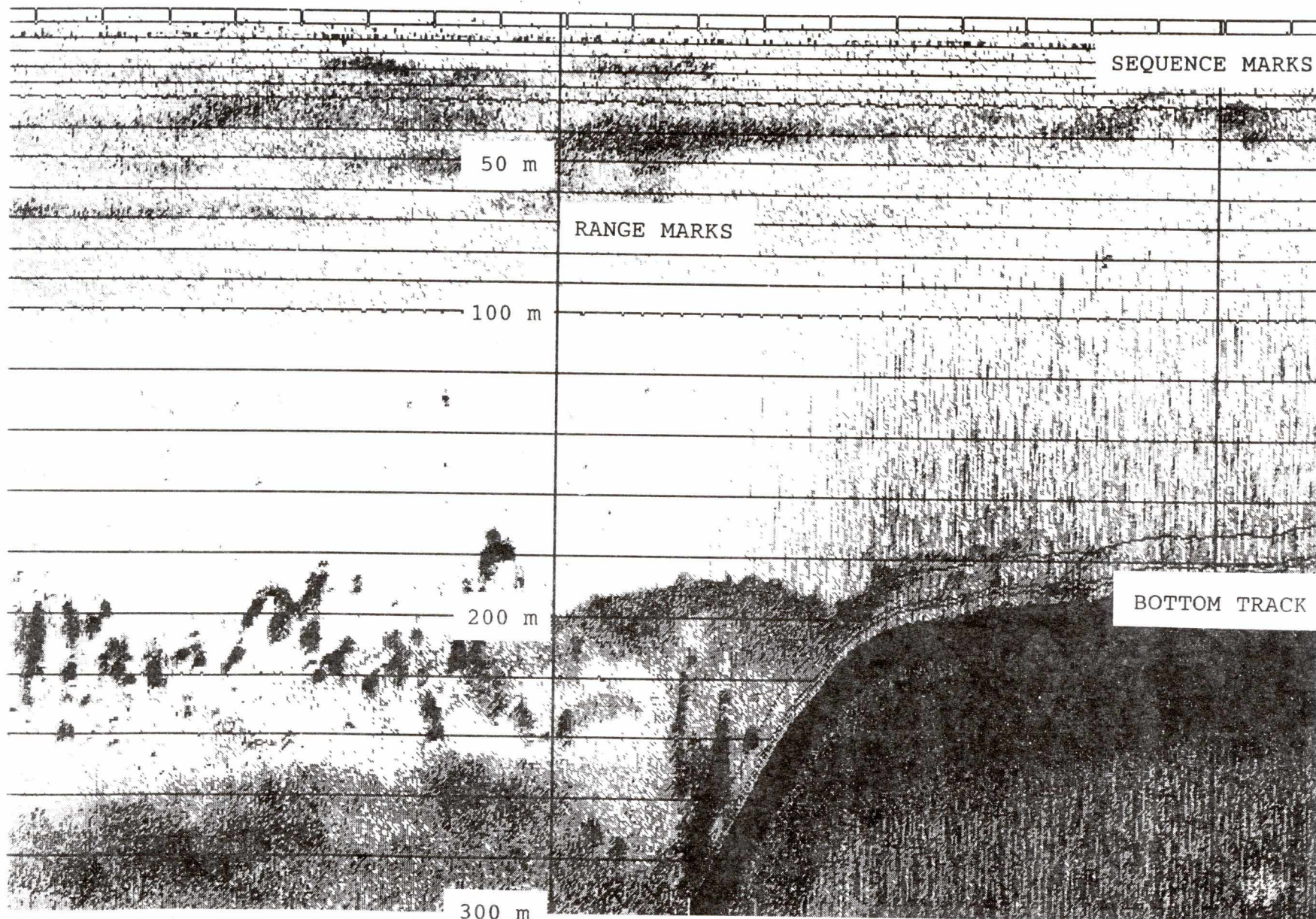


Figure 2b. Portion of an echogram collected June 3, 1994 during the joint Canada-Japan Pacific hake acoustic survey May 28 - June 4, 1994, on the C.S.S. W.E. RICKER. Typical adult hake aggregations are shown between 160 and 240 m range. Underlying the hake layer is a diffuse scattering of plankton extending from the shelf break offshore to at least 300 m range. Rockfish are visible near the shelf edge from 240 to 280 m. Bottom track, range, and sequence marks are labelled.



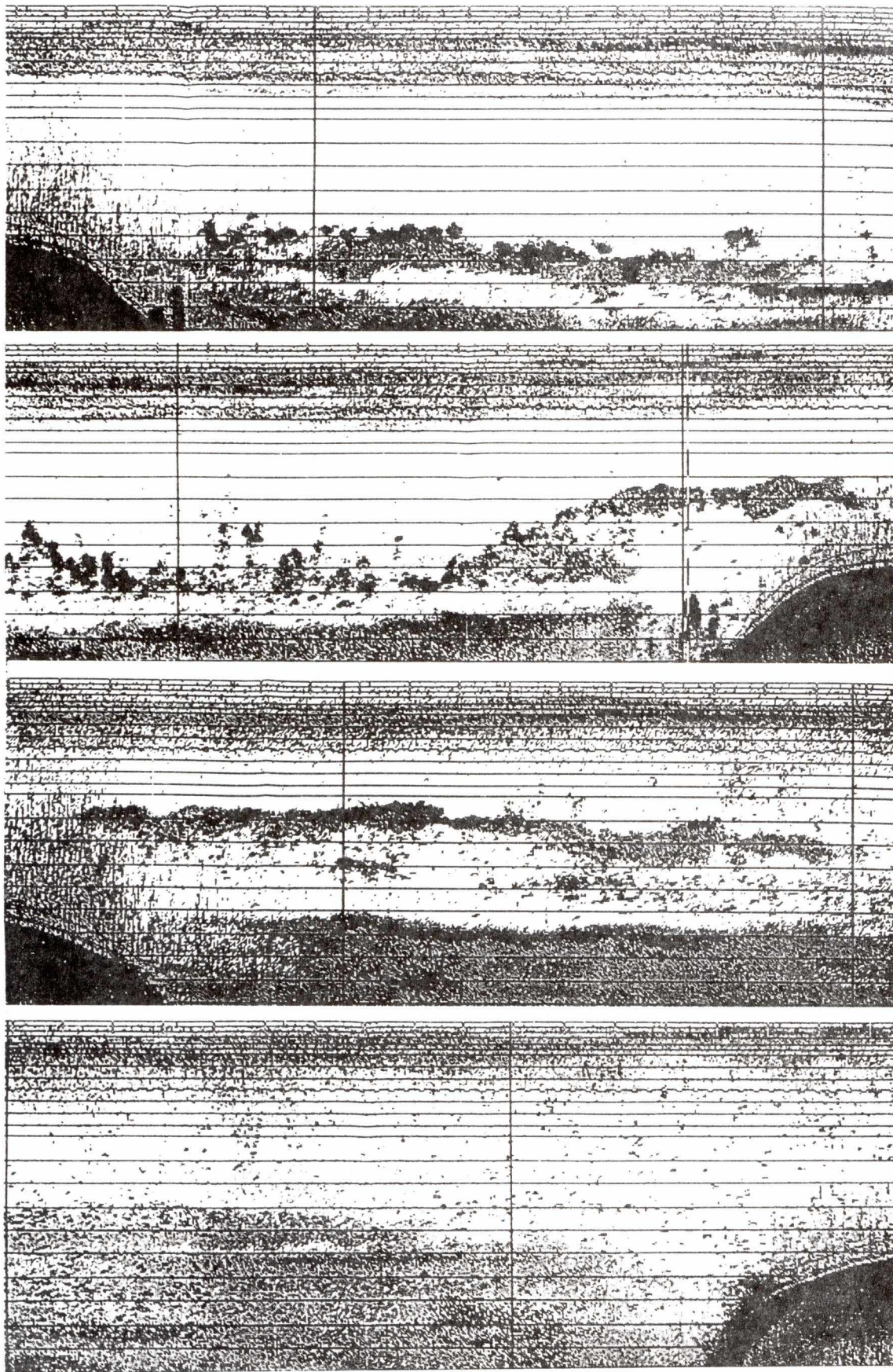


Figure 3. Echograms from four successive passes on transect B8, June 1, 1994 showing diel behavior of Pacific hake. Targets observed during the day on B8W1 from 200 m to the 260 m (top) rise and separate between 120 m and 220 m (upper middle) at dusk (B8E2). Schools disperse both horizontally and vertically at night along B8W3 (lower middle) until individual targets are distributed throughout the water column for the final pass of B8E4 (bottom).

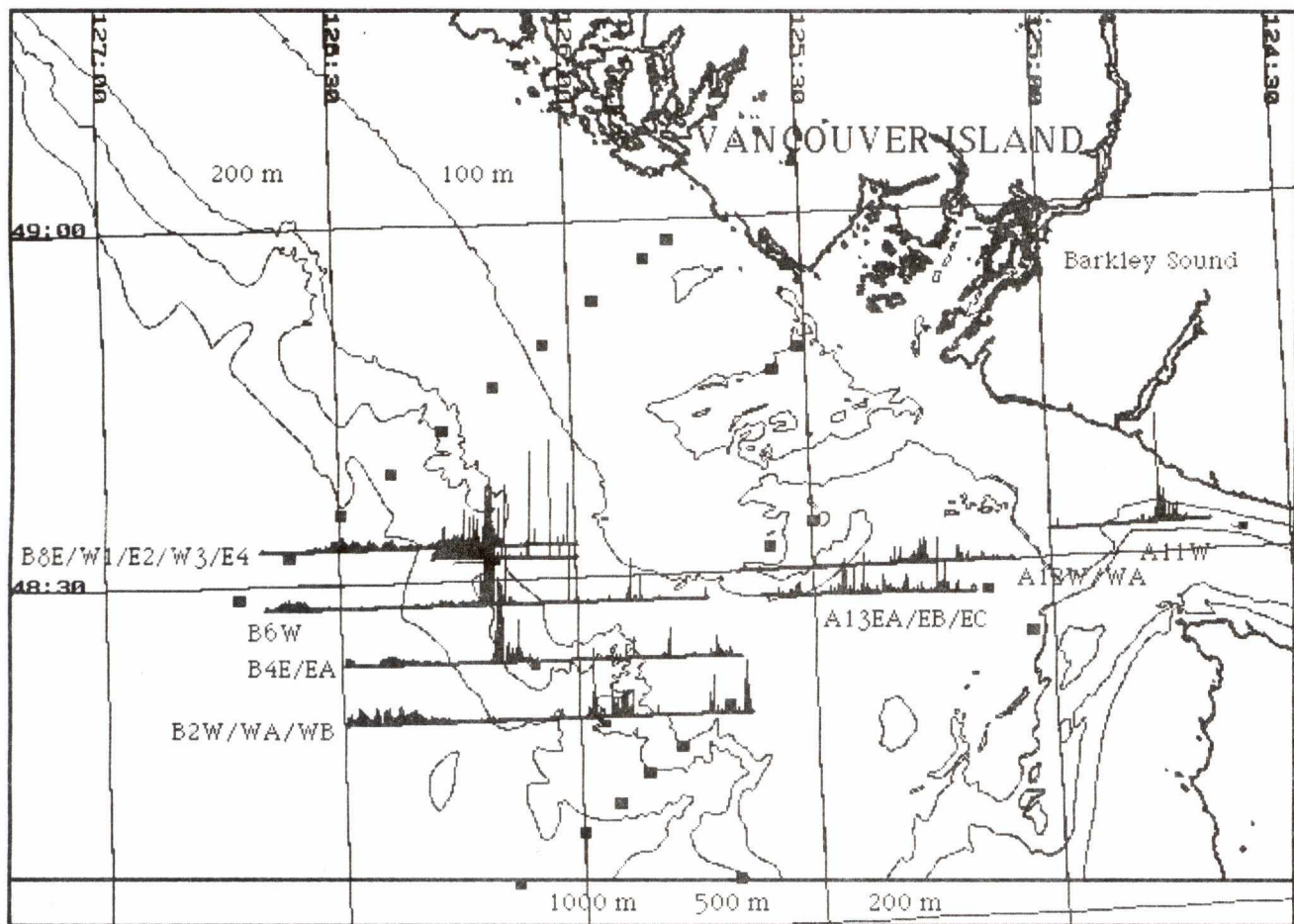


Figure 4. Surface densities for all species for the A and B transects from the joint Canada-Japan Pacific hake acoustic survey May 28 - June 3, 1994, on the C.S.S. W.E. RICKER. Densities are shown as vertical bars on a linear scale from 0.01 to 1.0 kg/m².

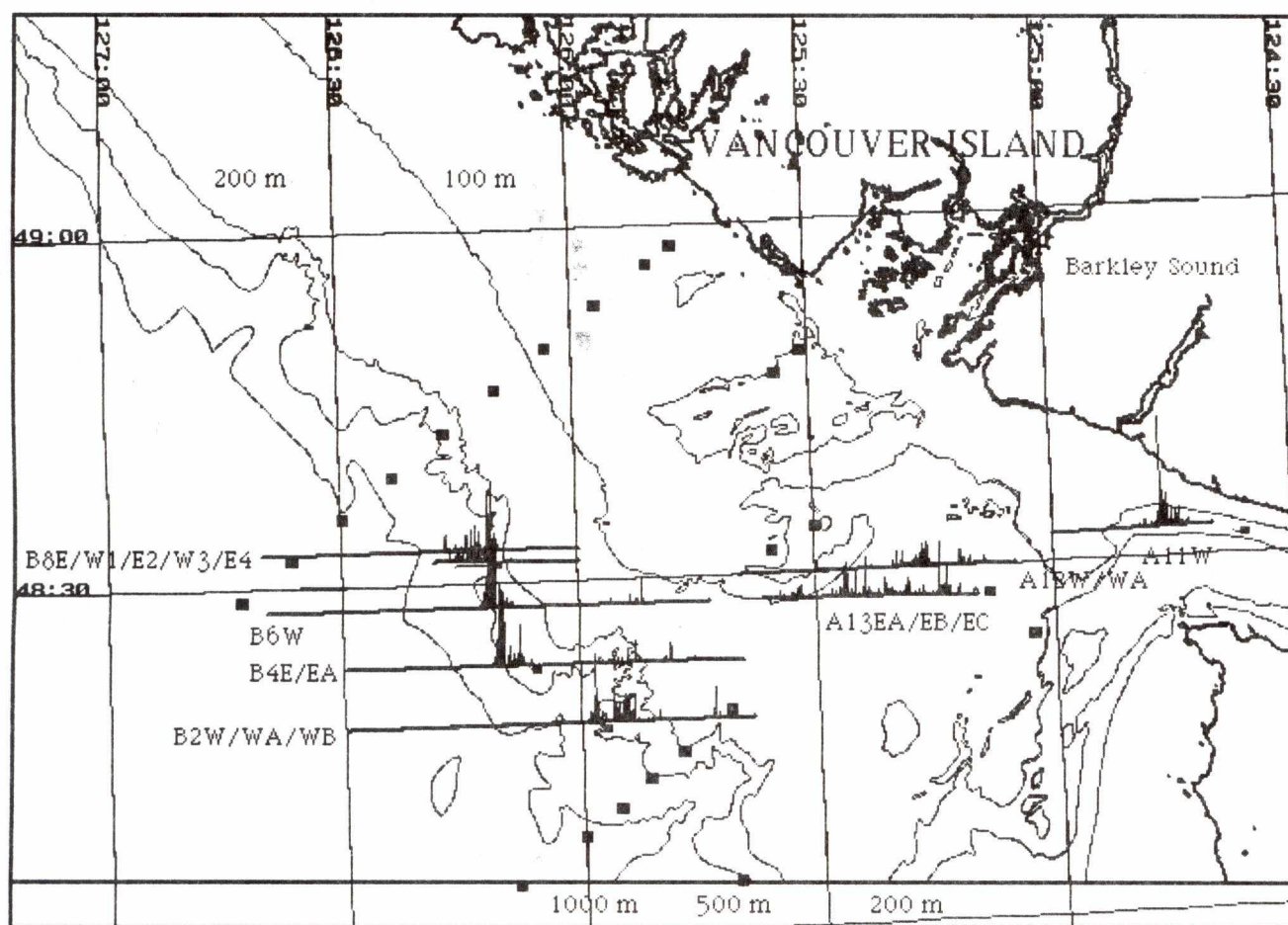


Figure 5. Surface densities for hake (adult only) for the A and B transects from the joint Canada-Japan Pacific hake acoustic survey May 28 - June 3, 1994, on the C.S.S. W.E. RICKER. Densities are shown as vertical bars on a linear scale from 0.01 to 1.0 kg/m².