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Experimental Hydroacoustic Estimation of Rockfish (*Sebastes* spp.) Biomass off Vancouver Island, November 13-25, 1991

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EXPERIMENTAL HYDROACOUSTIC ESTIMATION OF ROCKFISH (*Sebastes* spp.) BIOMASS OFF VANCOUVER ISLAND, NOVEMBER 13-25, 1991.

by

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ABSTRACT

Kieser, R., K. D. Cooke, R. D. Stanley, and G. E. Gillespie. 1993. Experimental hydroacoustic estimation of rockfish (*Sebastes* spp.) biomass off Vancouver Island, November 13-25, 1991. Can. Manuscr. Rep. Fish. Aquat. Sci. 2185: 40 p.

The precision of acoustic biomass estimates of rockfish (*Sebastes* spp.) was examined on the continental shelf off Nootka Sound, British Columbia. We assessed the differences between day and night biomass estimates from areas of about 250, 110, and 30 km^2 and examined the variability among estimates from several passes on two tracklines. School structure, distribution, and behaviour of *S. flavidus* was examined acoustically. The species distribution was restricted bathymetrically and its areal extent was governed by bottom slope and topographic features. Diurnal distributions were characterized by dense, vertically stacked schools. Nocturnal distributions showed much more diffuse aggregations, both near bottom and in the midwater. Transitional behaviour occurred very rapidly at twilight. The normal pattern was one of dispersal of diurnal schools in both horizontal and vertical directions at dusk and the subsequent regrouping of nocturnal aggregations at dawn, nearer the bottom.

RESUME

Kieser, R., K. D. Cooke, R. D. Stanley, and G. E. Gillespie. 1993. Experimental hydroacoustic estimation of rockfish (*Sebastes* spp.) biomass off Vancouver Island, November 13-25, 1991. Can. Manuscr. Rep. Fish. Aquat. Sci. 2185: 40 p.

Nous avons exminé la précision des estimations acoustiques de la biomasse de sébaste (*Sebastes* spp.) sur le plateau continental près de la baie Nootka (colombie-Britannique). Nous avons évalué les différences entre les estimations de la biomasse de jour et de nuit dans des zones d'une superficie d'evniron 250, 110 et 30 km^2, et nous avons examiné la variabilité entre les estimations à partir de plusieurs passages sur deux tracés. Nous avons examiné par des moyens acoustiques la structure des bancs de *S. flavidus*, la distribution et le comportement de ces poissons. La distribution de l'espèce était restreinte dans la dimension bathymétrique, et son étendue en superficie était régie par la pente du fond et par des caractéristiques de la topographie. Les distributions diurnes se caractéristisaient par des bancs denses et à fort empilage vertical. Les distributions nocturnes montraient des agrégations beaucoup plus diffuses, tant près du fond qu'à mi-hauteur de la colonne d'eau. Le comportement transitionnel se produisait très rapidement au crèpuscule. Le régime normal consistait en une dispersion des bancs diurnes dans le sens horizontal de dans le sens vertical au crépuscule, puis en un regroupement de agrégations nocturnes à l'aube, plus près du fond.

INTRODUCTION

The application of hydroacoustic technology for behavioural studies and abundance estimation of British Columbia's offshore rockfish stocks was initiated in 1990 (Leaman et al. 1990; Kieser et al. 1992). These studies followed suggestions that swept-area, bottom trawl surveys were substantially biased (Leaman and Nagtegaal 1982, 1986; Leaman and Stanley, in press). Results from the 1990 surveys indicated that rockfish are aggregating species with highly dynamic diel behaviour, and they are usually found in association with specific bathymetric features. Identification of specific habitat types suggested some species might be particularly amenable to acoustic abundance estimation. However, the characteristic rapid disaggregation of diurnal schools at dusk and subsequent vertical and horizontal dispersal of groups through the evening hours required that we investigate the repeatability of acoustic biomass estimation before we could assess the practicality of its use.

This report describes a study carried out in November 1991 off Nootka Sound, along the west coast of Vancouver Island, British Columbia, to examine the precision of hydroacoustic technology in estimating yellowtail rockfish (*Sebastes flavidus*) biomass (Figure 1). The survey was designed to test the repeatability of acoustic abundance estimation over three survey areas of approximately 250, 110, and 30 km^2. The results of these estimations are presented and will be used to evaluate the feasability of a coastwide acoustic estimation. We report acoustic observations collected through several diel cycles with detailed observations of single groups of rockfish during critical crepuscular (dusk and dawn) periods. The typical distributional changes observed between day and night surveys are described and their implications for acoustic stock assessment are examined. Trawl catch data used for identification of species are reported. We also present oceanographic profiles of the study area.

Subsequent reports to be published in the primary literature will firstly examine the variance among different transects and among repeated passes of the same transect. A second report will explore diel behavioural patterns in relation to topographic features and vertical salinity and temperature gradients.

METHODS

DATA ACQUISITION AND ANALYSIS

A calibrated echo integration system was operated from the R/V W.E. RICKER. The 'dry end' consisted of a BioSonics 38 kHz Model 101 echo sounder, a BioSonics Model 111 chart recorder, a BioSonics Model 121 digital echo integrator, a PCM/VCR tape recording system, 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. Bottom tracking was obtained with a 5 m bottom buffer. An echo integration sequence was completed every 60 pings (1 minute) 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 threshold level, some noise pulses were visible on the deeper portions of the echogram. Significant noise levels were excluded during the analysis. These included flow and vessel noise, as well as noise from the navigational sounder.

Standard data acquisition and analysis procedures were used (Burczynski 1982; Clay and Medwin 1977; Forbes and Nakken 1972; Kieser et al. 1987) to estimate fish density (kg/m^3) for the ensonified volume (Appendix 1). This estimate is converted to surface density (kg/m^2) by summing over all range strata of interest. Surface density is then multiplied by the appropriate surface area to obtain a biomass estimate (t). A target strength of -32 dB/kg was used for all surface density and biomass estimates (Kieser 1992).

SURVEY METHODOLOGY

We initially surveyed an area of ~250 km^2 along the shelf break off Nootka Sound, Vancouver Island to find concentrations of rockfish sufficiently dense to yield useful observations. Nine transects, at 2.8 km (1.5 nm) intervals and about 9-13 km (~5-7 nm) in length, were run between the 130 m and 500 m isobaths (Figure 2). The A series was covered once through the night and repeated the following day.

From the initial coverage of the study area, the northern half, which showed the greatest concentrations of rockfish, was selected for more detailed observation (Figure 2). The distance between transects was halved to 1.4 km (.75 nm) and the length of each reduced to between the 140 and 200 m isobaths. Eight of the nine transects comprising the B series were repeated through four 24-h cycles to assess variability among biomass estimates.

We selected two transects from the B series for repetitive soundings of single groups of fish, and for biological sampling. Diurnal and nocturnal distribution patterns as well as critical dusk and dawn transitions were monitored in an area small enough to allow for continuous observation over a relatively short time frame. Transects B5 and B6 were considered representative of the entire B series with respect to overall abundance and distribution of targets observed along each transect. A complete circuit of the B5-B6 block could be completed in 2 h, which allowed us to recognize and track individual aggregations on the echogram with each pass. Fishing operations were then directed toward specific targets to identify species and establish size composition of targets.

TRAWL AND BIOLOGICAL SAMPLING METHODS

We conducted three bottom trawl tows (Appendix Table 2) at tow locations provided by commercial fishermen. They refer to the fishing spots as 'clay bumps'. This topographic feature consists of two approximately 10 m high cliffs or steps along the east-west bottom profile. The cliffs are at about 140 m depth and run on a north-south axis. They are intersected by transects B9 and B2 about 1 and 5 nm east of the continental shelf break, respectively. They are no longer prominent along transect B1. The clay bumps are distinct from a trench that is located much closer to the shelf break on the same echograms (Figure 5).

Our tows targeted on rockfish which consistently aggregated near the clay bumps. Species composition from Tow 1 was determined using the sub-sampling method described by Gillespie and Stanley (1989). The smaller catches from Tows 2 and 3 were sorted by species into tubs and weighed.

Random samples of 100 yellowtail rockfish from Tows 1 and 2 were measured for fork length (to the nearest cm), sex, reproductive development stage (Appendix Table 3), weight and anal-dorsal length. Anal-dorsal length was measured with metered callipers from the insertion of the anal fin to the origin of the dorsal fin. An additional stratified sample of 100 fish was taken from Tow 1 to ensure equal representation of both sexes and to encompass the full range of lengths in the total sample. This information will be used to calculate a conversion rate for predicting round weight from processed (frozen, head off) fish, the results of which will be reported elsewhere. Paired otoliths were collected for age determination.

OCEANOGRAPHIC SAMPLING

Temperature and salinity versus depth profiles were collected using a high resolution CTD (Guildline 8770 Series) and logged directly to an AST 286 personal computer. The CTD casts were used to determine whether thermoclines or haloclines had any limiting effect on the diel behaviour.

RESULTS

SURVEY OPERATIONS: A SERIES

The initial study area, transects A1E - A9E (Figure 2), was surveyed from south to north once during the first night of operations, from 2200 h, November 13 through to 0600 h, November 14, 1992 (Table 1a). The grid was repeated, again from south to north, beginning just after sunrise at transect A8W and was completed by 1600 h, November 14. We did not attempt to repeat A9E owing to the limited daylight available at this time of year.

SURVEY OPERATIONS: B SERIES

Coverage of the B transects began November 14, 1991 (Table 1a). Only half of the grid was sounded before weather and sea conditions curtailed operations. Subsequent assessments of the B series were run on November 17, 20, 21-22 and 24-25. The grid was surveyed from south to north and began at the same start position for matched day and night pairs. This approach temporally separated like transects of a day and night series approximately equally. Storm conditions interrupted operations from 1700 h, November 22 to 2200 h, November 24. A final night and day survey was completed at 1600 h, November 25.

SURVEY OPERATIONS: B5 AND B6 GRID

We explored the variation of acoustic abundance estimates in greater detail by repeatedly covering a small area in a relatively short time. Transects B5E and B6W could be surveyed in 2 h allowing for relatively continuous observation of targets. The variation in school size, density, and distribution that was observed along these two transects provided important clues for the interpretation of the larger data sets. Ten continuous observations for the B5-B6 block were collected on November 21 (Table 1b, Events 260-344). An additional nine passes of the two transects were extracted as subsets from the complete B series surveys (Table 1a) providing a total of 19 executions of the B5-B6 block (Tables 1b, 2b; diurnal: D1-D7, nocturnal: N1-N10, dawn: Dwn, and dusk: Dsk).

BIOMASS ESTIMATES: A SERIES

The series of transects A1 through A8 covered an area of approximately 250 km^2. The diurnal and nocturnal abundance estimates for this area were 2153 and 3818 t, with a CV (coefficient of variation) of 30 and 15 %, respectively for the total estimate. Following standard practice, the CV estimate is based on the variance among transects (Forbes and Nakken 1972). We make the basic assumption that the transects provide independent random samples from a uniformly distributed fish population. The total and mean transect biomass are summarized in the following table:

	Total Biomass		M Tran Biomass	
	Day	Night	Day	Night
Biom t	2153	3818	269	477
CV %	30	15	84	44

As expected, CV_T, for the transect biomass, is larger than CV_B, for the total biomass. These quantities are given by:

$$CV_T = 100*(S_T/b_T)$$

$$CV_B = CV_T/\sqrt{n}$$

Where b_T is the mean transect biomass, s_T is the standard deviation and n gives the number of transects.

Additional information can be obtained from the biomass estimates that were made at one minute intervals along each transect. These measurements provide an indication of the fine- scale distribution of fish along each transect. The transect name, number of one minute intervals along each transect, average biomass (t) for each one minute interval and the CV (%) are summarized below:

	----- Diurnal -----				---- Nocturnal ----			
Tra	N	Biom	STDS	CV	N	Biom	STDS	CV
A8W	40	2.8	4.0	139	50	12.4	12.0	97
A7E	34	7.6	27.6	363	43	17.8	18.3	103
A6W	38	1.8	4.6	253	44	3.5	2.9	83
A5E	34	22.6	68.3	302	39	18.7	61.5	328
A4W	43	9.4	55.7	593	48	6.1	9.1	149
A3E	46	5.3	20.3	385	47	8.7	18.6	213
A2W	36	4.8	15.0	309	41	5.8	5.4	93
A1E	34	3.6	11.7	321	33	18.4	12.5	68
AVG	38	7.3		333	43	11.4		142
MIN				139				68
MAX				593				328

The diurnal biomass is smaller than that for the night. The reverse holds for the CV. The large diurnal CV correlates with the strong diurnal schooling which is contrasted by the nocturnal dispersion of fish aggregations and smaller CV. This pattern persists at the transect level, indicating high diurnal clustering at the spatial scale of one minute biomass measurements (~0.15 nm) and at transect separations of 1.5 nm.

BIOMASS ESTIMATES: B2 TO B9 GRID

The combined B series transects (B2 through B9) covered an area of approximately 110 km^2 (Table 2a and b). This area was surveyed four times during the day and four times during the night. The following biomass estimates were obtained:

	E1	E2	E3	E4	Mean	CV %
Diurnal t	1399	1689	1706	1362	1539	12
CV %	26	29	23	26		
Nocturnal t	1830	1568	2020	1397	1704	16
CV %	11	9	23	15		

Based on four exposures (E1 to E4) the mean diurnal and nocturnal biomass estimates were 1539 and 1704 t, with a sample CV of 12 and 16 %, respectively. These diurnal and nocturnal estimates are slightly different from, but follow the trend established by, the A transects. The mean CVs (last column of the table) were computed on the basis of the four independent biomass estimates in each category. They can be compared with those for single diurnal and nocturnal passes (rows 2 and 4 of the table) which are based on the variability between transects. Repetition-based CVs (last column) indicate smaller diurnal variation. This indicates that distribution changes between single passes of the area are smaller during the day than during the night. Although fish are in dense schools during the day, the schools are relatively stationary, thus by sampling a representative number with each coverage, a stable estimate can be obtained.

BIOMASS ESTIMATES: B5 AND B6 GRID

The B5 and B6 transects (Table 2b, Figure 4) covered an area of 30 km^2. The seven diurnal biomass estimates of B5 and B6 produced a mean biomass of 639 t, with a CV of 14 % and a combined single coverage CV of 36 %. The ten nocturnal estimates yield a mean of 489 t with a CV of 8 % and a single coverage CV of 26 %. The diurnal estimates ranged from 311 to 981 t. The nocturnal estimates were less variable, ranging from 318 to 769 t. These results are summarized in the following table:

B5+B6	N	Mean Bio t	CV %	Min	Max
Day	7	639	36	311	981
Night	10	489	26	318	769

In contrast to the A and B series results, the B5 and B6 transects indicate a greater biomass during the day than at night. They also show greater diurnal CVs of single repeats than are observed at night.

TRAWL AND BIOLOGICAL SAMPLING

Operational difficulties and inclement weather limited our fishing activity to three tows. It was therefore not possible to verify diurnal and nocturnal midwater targets observed on and near the continental shelf break. We directed the tows only on the schools associated with the 'clay bumps' on transect B6 (Figure 5).

The average catch was 86 % yellowtail rockfish (Table 3 and Appendix Table 2). This composition was consistent with previous research cruises and commercial catch records from the same location and time period. Subsequent discussions with commercial fishermen also suggest that our catch is representative for the schools in this area. This in turn suggests that the clay bumps are consistently inhabited by the same species. We suspect that nocturnal midwater tows would yield similar results in this area.

It is possible that widow rockfish (*S. entomelas*) are also present in the area. However, widow rockfish exhibit diel schooling behaviour which is atypical of other shelf rockfish species. Adult widow rockfish aggregate into dense midwater schools during the night. Wilkins (1986, 1987) characterized these schools as tall, slender columns suspended over rough or irregular bottom. These schools generally form at dusk and disperse at dawn. While it is not known whether these fish disperse into the water column or to the bottom, they are not captured by bottom trawl gear during the day in areas where large concentrations were sounded at night (Wilkins 1986). We did not observe these tall columnar schools at night during our survey, and believe that widow rockfish were not present in large numbers in the area.

FISH DISTRIBUTION AND BEHAVIOUR

Generally, distribution of the fish was limited by bathymetric range as reported by Leaman et al. (1990). In the southern half of the survey area, fish were primarily concentrated along the steep shelf edge between the 150 and 200 m contours and to a lesser extent in adjacent waters of 130 to 140 m (Figure 3a). Further north in the study area (Figure 3a and b), fish were irregularly dispersed, both day and night, possibly reflecting the more convoluted bottom topography of the region.

Typically, the dense isolated schools observed during the day broke up at twilight and continued to spread out during the early part of the night. Highly aggregated diurnal distributions near the shelf edge between 120 and 180 m (Figure 5, top) began to disperse and rise in the water column shortly after sunset (Figure 5, middle). The vertical and horizontal migration was completed by early evening with most targets scattered between 80 and 120 m (Figure 5, bottom). The diurnal and nocturnal distribution cycle was completed by rapid reformation of schools at dawn.

Four different school aggregation types were observed in association with distinct habitats (Figure 5). The most prominent group was located near the shelf break. Although thought to consist of rockfish, the species composition of this group is unknown. The next major collection of targets occurred in association with the clay bumps mid-way along our transect. Samples collected from the trawl sets indicated that these schools were primarily yellowtail rockfish (Table 3 and Appendix Table 2). The third and fourth types were less obvious. They consisted of small schools or individual targets at the shallow end of the transects and of light, scattered distributions over deeper water beyond the shelf edge. Again, the species compositions of these aggregations are unknown.

OCEANOGRAPHIC RESULTS

We completed one CTD cast in the middle of the southern half of the study grid and six casts along transect B5. Temperature profiles show a thermocline in the range from 30 to 100 m (Figure 7a-f). Day and night fish distributions (Figure 5) were well below the thermocline, with major aggregations in waters of 7.0 to 7.5°C. Subsequent work will examine the relationship of school behaviour to vertical variation in salinity and temperature.

DISCUSSION

The success of any fishing operation is largely dependent on the 'availability' of the target species. The term availability encompasses a range of factors including gear type, haul speed, and fish behaviour. Similarly, the effectiveness of acoustic observations depends on a number of factors which determine the 'detectability' of the target. The target must obviously be in the ensonified volume and must be distinguishable from bottom and surface echoes. Fish in the water column are generally easily seen, while those very close to the bottom or near cliffs are less likely to be detected. Fish target strength or back-scattering cross section is an important parameter that contributes to the detection and quantification of a target. Target strength is affected by fish behaviour, physiology and depth adaptation. For example, yaw, pitch, and roll, as well as swim bladder changes that may occur with time and depth, will effect target strength. Our instrumentation does not allow target strength measurements, thus we use the same value for the analysis of our day and night data. A literature survey (Kieser 1992) indicated that species dependent and day/night target strength changes could shift results by a factor of two. Future measurements will be required to clarify this point and to minimize the effect of target strength changes on our biomass estimates.

Our acoustic observations were based on echo integration measurements of fish density and were designed to evaluate acoustic biomass estimates of rockfish aggregations. We gathered information which will allow us to determine an optimal survey strategy by studying the diel behaviour patterns of large-scale fish distributions, as well as school structure and stability. Yellowtail and other semi-pelagic rockfish formed distinct and apparently stable day and night aggregations, therefore, reasonable biomass estimates can be obtained during either period. Although nocturnal estimates were generally less variable than diurnal estimates, they were characterized by a more complex species structure, thereby neccesitating greater sampling effort to establish target identification.

Generally, our results are in support of the findings of Leaman et al. (1990) who report that the accuracy of acoustic biomass estimates is partly dependent upon the degree of aggregation of the targets. The probability of ensonification of a small number of tightly grouped schools decreases with increasing aggregation and decreasing area surveyed. Boudreau (1992) observed similarly that average fish density for haddock (*Melanogrammus aeglefinus*) aggregations was relatively uniform over geographic scales in the order of tens of kilometers, but on a scale of hundreds of meters, aggregation patterns varied significantly and changed dramatically over 24 h.

In summary, our data indicate that acoustic diurnal and nocturnal surveys for yellowtail rockfish generate similar abundance estimates but that night surveys yield less variable results. The smaller nocturnal variance is due to the greater dispersal of targets. This, however, may be associated with greater mixing of species especially when several different habitat types are in close proximity. Consequently, there is an increased requirement for sampling operations during night surveys to determine species composition. A subsequent paper will exmaine more precisely the effects of diel changes on abundance estimates by focussing on biomass estimates near the cliff edge. This material will provide the baseline information for estimating the number and spacing of transects for biomass estimation over broader areas.

Further work is required to evaluate acoustic rockfish estimates under a wider range of conditions. More biological samples concurrent with the acoustic observations are required to provide for a better interpretation of various echogram patterns and habitats. Measurements are needed to assess the level and stability of rockfish target strength. Behaviour studies are also required which would examine the effects of temperature and salinity gradients, and geostrophic currents on fish distribution. Provided such information can be obtained, several semi-pelagic rockfish species could be assessed acoustically.

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Table 1a: Transect information including date, start time, and start and end latitude and longitude.

TRANSECT				START POSITION				END POSITION			
EVENT #	NAME	Date	Time	LATITUDE deg	min	LONGITUDE deg	min	LATITUDE deg	min	LONGITUDE deg	min
12.0	A8W	13-NOV-91	22:01	49	31.71	127	6.15	49	30.66	127	17.00
16.0	A7E	13-NOV-91	23:01	49	31.99	127	17.36	49	33.22	127	7.09
21.0	A6W	13-NOV-91	23:59	49	34.58	127	8.60	49	33.61	127	18.37
26.0	A5E	14-NOV-91	00:57	49	35.27	127	19.09	49	35.86	127	10.13
30.0	A4W	14-NOV-91	01:50	49	37.38	127	11.90	49	36.31	127	22.75
35.0	A3E	14-NOV-91	02:54	49	37.63	127	23.50	49	38.42	127	12.84
40.0	A2W	14-NOV-91	03:58	49	40.17	127	15.32	49	39.42	127	23.98
44.0	A1E	14-NOV-91	04:52	49	40.98	127	24.75	49	41.43	127	17.38
48.0	A8W	14-NOV-91	08:39	49	31.78	127	6.14	49	30.77	127	15.54
52.0	A7E	14-NOV-91	09:32	49	32.24	127	16.06	49	33.12	127	7.19
58.0	A6W	14-NOV-91	10:21	49	34.62	127	8.21	49	33.75	127	17.36
61.0	A5E	14-NOV-91	11:13	49	35.10	127	19.25	49	35.78	127	10.95
66.0	A4W	14-NOV-91	12:03	49	37.29	127	12.05	49	36.48	127	22.23
69.0	A3E	14-NOV-91	12:57	49	37.70	127	23.95	49	38.46	127	13.22
72.0	A2W	14-NOV-91	13:57	49	40.11	127	15.20	49	39.44	127	24.02
75.0	A1E	14-NOV-91	14:46	49	40.96	127	24.88	49	41.56	127	17.06
79.0	B9E	14-NOV-91	17:46	49	35.75	127	14.39	49	36.49	127	6.93
82.0	B8W	14-NOV-91	18:29	49	37.15	127	7.76	49	36.48	127	15.86
86.0	B7E	14-NOV-91	19:17	49	37.20	127	17.76	49	37.95	127	8.59
91.0	B6W	14-NOV-91	20:12	49	38.42	127	9.43	49	37.59	127	19.20
95.0	B5E	14-NOV-91	21:04	49	38.21	127	19.84	49	38.98	127	10.11
112.0	B9E	17-NOV-91	09:48	49	35.17	127	18.75	49	35.79	127	11.26
117.0	B8W	17-NOV-91	10:34	49	36.54	127	12.36	49	35.85	127	20.20
121.0	B7E	17-NOV-91	11:34	49	36.42	127	22.18	49	37.28	127	12.97
126.0	B6W	17-NOV-91	12:34	49	37.87	127	13.92	49	37.09	127	23.74
131.0	B5E	17-NOV-91	13:38	49	37.71	127	24.14	49	38.40	127	14.32
135.0	B4W	17-NOV-91	14:35	49	39.19	127	15.84	49	38.55	127	23.67
138.0	B3E1	17-NOV-91	15:28	49	39.50	127	23.83	49	39.69	127	21.40
139.0	B3E2	17-NOV-91	15:39	49	39.69	127	21.41	49	39.94	127	16.43
142.0	B2W	17-NOV-91	16:14	49	40.78	127	17.69	49	40.30	127	24.68
146.0	B9E	17-NOV-91	18:09	49	35.25	127	19.12	49	36.01	127	11.41
149.0	B8W	17-NOV-91	18:55	49	36.57	127	12.66	49	35.88	127	20.08
153.0	B7E	17-NOV-91	19:42	49	36.47	127	22.31	49	37.26	127	12.93
157.0	B6W	17-NOV-91	20:35	49	37.95	127	13.34	49	37.03	127	23.68
161.0	B5E	17-NOV-91	21:35	49	37.65	127	23.66	49	38.36	127	14.32
164.0	B4W	17-NOV-91	22:36	49	39.26	127	15.94	49	38.69	127	23.78
167.0	B3E	17-NOV-91	23:23	49	39.46	127	23.80	49	40.11	127	16.51
171.0	B2W	18-NOV-91	00:09	49	40.78	127	17.68	49	40.26	127	24.60
174.0	B1E	18-NOV-91	00:49	49	41.17	127	25.30	49	41.55	127	18.35
184.0	B9E	20-NOV-91	08:26	49	35.18	127	19.10	49	35.88	127	11.27
188.0	B8W	20-NOV-91	09:11	49	36.61	127	12.23	49	35.84	127	20.17
191.0	B7E	20-NOV-91	10:09	49	36.54	127	22.32	49	37.31	127	13.47
193.0	B6W	20-NOV-91	11:03	49	37.87	127	14.32	49	36.99	127	23.54
198.0	B5E	20-NOV-91	12:08	49	37.62	127	24.14	49	38.45	127	14.32
202.0	B4W	20-NOV-91	13:11	49	39.18	127	15.85	49	38.61	127	23.61
206.0	B3E	20-NOV-91	14:07	49	39.47	127	23.82	49	40.00	127	17.00
211.0	B2W	20-NOV-91	14:57	49	40.77	127	17.68	49	40.31	127	24.51
215.0	B1E	20-NOV-91	15:47	49	41.13	127	25.12	49	41.47	127	18.70

Table 1a: (cont'd.)

TRANSECT				START POSITION				END POSITION			
EVENT #	NAME	Date	Time	LATITUDE deg	LATITUDE min	LONGITUDE deg	LONGITUDE min	LATITUDE deg	LATITUDE min	LONGITUDE deg	LONGITUDE min
220.0	B9E	20-NOV-91	18:01	49	35.27	127	18.75	49	35.85	127	11.41
224.0	B8W	20-NOV-91	18:48	49	36.59	127	12.18	49	35.90	127	20.01
227.0	B7E	20-NOV-91	19:46	49	36.54	127	22.15	49	37.52	127	12.84
231.0	B6W	20-NOV-91	20:46	49	37.91	127	14.11	49	37.08	127	23.47
234.0	B5E	20-NOV-91	21:44	49	37.69	127	24.07	49	38.45	127	14.33
238.0	B4W	20-NOV-91	22:50	49	39.16	127	15.76	49	38.61	127	23.61
242.0	B3E	20-NOV-91	23:41	49	39.44	127	23.85	49	40.08	127	16.41
250.0	B2W	21-NOV-91	00:57	49	40.67	127	18.26	49	40.25	127	24.75
254.0	B1E	21-NOV-91	01:33	49	41.09	127	24.84	49	41.53	127	18.55
352.0	B9E	21-NOV-91	22:51	49	35.19	127	18.90	49	35.94	127	11.36
356.0	B8W	21-NOV-91	23:34	49	36.57	127	12.16	49	35.91	127	20.39
360.0	B7E	22-NOV-91	00:18	49	36.61	127	22.00	49	37.36	127	12.92
363.0	B6W	22-NOV-91	01:08	49	37.85	127	13.81	49	36.99	127	23.62
367.0	B5E	22-NOV-91	01:58	49	37.62	127	23.79	49	38.43	127	14.20
372.0	B4W	22-NOV-91	03:33	49	38.93	127	18.45	49	38.58	127	24.01
374.0	B3E	22-NOV-91	04:09	49	39.51	127	23.77	49	40.13	127	16.09
378.0	B2W	22-NOV-91	04:59	49	40.81	127	17.78	49	40.51	127	24.88
380.0	B1E	22-NOV-91	05:39	49	41.16	127	24.98	49	41.56	127	18.15
386.0	B9E	22-NOV-91	08:03	49	35.46	127	16.07	49	35.92	127	11.34
391.0	B8W	22-NOV-91	08:40	49	36.75	127	12.94	49	35.85	127	19.90
395.0	B7E	22-NOV-91	09:31	49	36.54	127	22.18	49	37.39	127	13.10
402.0	B6W	22-NOV-91	10:34	49	37.91	127	13.99	49	37.00	127	23.27
410.0	B5E	22-NOV-91	11:30	49	37.71	127	24.10	49	39.03	127	14.90
414.0	B4W	22-NOV-91	12:47	49	39.16	127	16.01	49	38.55	127	23.76
418.0	B3E	22-NOV-91	13:35	49	39.44	127	23.75	49	40.01	127	16.32
422.0	B2W	22-NOV-91	14:41	49	40.75	127	18.04	49	40.22	127	24.65
425.0	B1E	22-NOV-91	15:28	49	41.00	127	25.31	49	41.47	127	18.63
429.0	B9E	24-NOV-91	22:32	49	35.22	127	18.40	49	35.93	127	11.21
431.0	B8W	24-NOV-91	23:10	49	36.59	127	12.33	49	35.87	127	19.57
435.0	B7E	25-NOV-91	00:00	49	36.60	127	22.32	49	37.24	127	13.14
438.0	B6W	25-NOV-91	00:48	49	37.81	127	13.80	49	37.01	127	23.50
442.0	B5E	25-NOV-91	01:39	49	37.62	127	23.98	49	38.38	127	14.33
445.0	B4W	25-NOV-91	02:31	49	39.19	127	15.89	49	38.55	127	23.84
449.0	B3E	25-NOV-91	03:14	49	39.51	127	23.86	49	40.08	127	16.29
453.0	B2W	25-NOV-91	03:55	49	40.75	127	17.64	49	40.26	127	24.74
456.0	B1E	25-NOV-91	04:33	49	41.13	127	25.05	49	41.47	127	18.49
462.0	B9E	25-NOV-91	07:51	49	35.25	127	19.14	49	36.05	127	11.32
465.0	B8W	25-NOV-91	08:32	49	36.61	127	12.47	49	35.76	127	20.57
468.0	B7E	25-NOV-91	09:20	49	36.54	127	21.93	49	37.29	127	12.82
471.0	B6W	25-NOV-91	10:06	49	37.87	127	13.66	49	37.04	127	23.46
474.0	B5E	25-NOV-91	10:55	49	37.68	127	23.90	49	38.37	127	14.31
477.0	B4W	25-NOV-91	11:47	49	39.19	127	16.46	49	38.57	127	23.97
480.0	B3E	25-NOV-91	12:27	49	39.52	127	23.98	49	40.16	127	16.07
485.0	B2W	25-NOV-91	13:08	49	40.77	127	17.75	49	40.28	127	24.62
488.0	B1E	25-NOV-91	13:43	49	41.11	127	25.13	49	41.48	127	18.49

Table 1b: B5 - B6 Transect information including date, start time, and start and end latitude and longitude.

TRANSECT				START POSITION				END POSITION			
EVENT #	NAME	Date	Time	LATITUDE deg	LATITUDE min	LONGITUDE deg	LONGITUDE min	LATITUDE deg	LATITUDE min	LONGITUDE deg	LONGITUDE min
91.0	B6W	14-NOV-91	20:12	49	38.42	127	9.43	49	37.59	127	19.20
95.0	B5E	14-NOV-91	21:04	49	38.21	127	19.84	49	38.98	127	10.11
126.0	B6W	17-NOV-91	12:34	49	37.87	127	13.92	49	37.09	127	23.74
131.0	B5E	17-NOV-91	13:38	49	37.71	127	24.14	49	38.40	127	14.32
157.0	B6W	17-NOV-91	20:35	49	37.95	127	13.34	49	37.03	127	23.68
161.0	B5E	17-NOV-91	21:35	49	37.65	127	23.66	49	38.36	127	14.32
193.0	B6W	20-NOV-91	11:03	49	37.87	127	14.32	49	36.99	127	23.54
198.0	B5E	20-NOV-91	12:08	49	37.62	127	24.14	49	38.45	127	14.32
231.0	B6W	20-NOV-91	20:46	49	37.91	127	14.11	49	37.08	127	23.47
234.0	B5E	20-NOV-91	21:44	49	37.69	127	24.07	49	38.45	127	14.33
260.0	B6W	21-NOV-91	02:55	49	37.91	127	14.22	49	37.08	127	24.11
262.5	B5E	21-NOV-91	03:46	49	37.50	127	23.50	49	38.37	127	13.80
269.0	B6W	21-NOV-91	04:40	49	37.92	127	13.99	49	36.96	127	24.16
272.0	B5E	21-NOV-91	05:33	49	37.55	127	24.02	49	38.40	127	14.50
275.0	B6W	21-NOV-91	06:29	49	37.86	127	13.89	49	36.94	127	24.13
279.0	B5E	21-NOV-91	07:23	49	37.61	127	24.07	49	38.47	127	14.15
284.0	B6W	21-NOV-91	08:23	49	37.78	127	14.08	49	36.94	127	23.45
287.0	B5E	21-NOV-91	09:19	49	37.62	127	24.00	49	38.48	127	14.38
292.0	B6W	21-NOV-91	10:24	49	37.77	127	13.91	49	37.04	127	23.52
297.0	B5E	21-NOV-91	11:21	49	37.58	127	24.32	49	38.21	127	14.12
300.0	B6W	21-NOV-91	12:23	49	37.81	127	13.97	49	37.04	127	23.33
304.0	B5E1	21-NOV-91	13:21	49	37.72	127	24.06	49	38.09	127	17.78
310.1	B5E2	21-NOV-91	14:28	49	38.10	127	17.88	49	38.41	127	14.31
313.0	B6W	21-NOV-91	14:55	49	37.78	127	13.86	49	37.05	127	23.57
319.0	B5E	21-NOV-91	15:54	49	37.53	127	24.02	49	38.38	127	14.35
324.0	B6W	21-NOV-91	16:49	49	37.80	127	13.94	49	37.02	127	23.47
328.0	B5E	21-NOV-91	17:50	49	37.57	127	24.12	49	38.45	127	13.78
332.0	B6W	21-NOV-91	18:45	49	37.84	127	13.91	49	36.90	127	24.04
336.0	B5E	21-NOV-91	19:43	49	37.55	127	24.06	49	38.46	127	13.95
340.0	B6W	21-NOV-91	20:40	49	37.83	127	13.99	49	37.00	127	24.00
344.0	B5E	21-NOV-91	21:28	49	37.73	127	22.71	49	38.45	127	14.06
363.0	B6W	22-NOV-91	01:08	49	37.85	127	13.81	49	36.99	127	23.62
367.0	B5E	22-NOV-91	01:58	49	37.62	127	23.79	49	38.43	127	14.20
402.0	B6W	22-NOV-91	10:34	49	37.91	127	13.99	49	37.00	127	23.27
410.0	B5E	22-NOV-91	11:30	49	37.71	127	24.10	49	39.03	127	14.90
438.0	B6W	25-NOV-91	00:48	49	37.81	127	13.80	49	37.01	127	23.50
442.0	B5E	25-NOV-91	01:39	49	37.62	127	23.98	49	38.38	127	14.33
471.0	B6W	25-NOV-91	10:06	49	37.87	127	13.66	49	37.04	127	23.46
474.0	B5E	25-NOV-91	10:55	49	37.68	127	23.90	49	38.37	127	14.31

Table 2a: Total biomass data for A and B series. Transect length, surface density cell area, volume and surface densities, and biomass by transect are given. The last column indicates day (D) or night (N) survey.

EVENT	NAME	Len km	Area km²	Vol Den kg/m³	Sur Den kg/m²	Biomass t	N #	Mean Area km²	Mean Biomass t	CV %	D/N
7.0	A9E	12.2	33.8	1.56E-04	1.41E-02	476.0	1	33.8	476.0		
12.0	A8W	13.2	36.6	1.85E-04	1.69E-02	620.0					
16.0	A7E	12.6	34.9	2.43E-04	2.19E-02	763.0					
21.0	A6W	11.9	33.0	5.33E-05	4.71E-03	155.0					
26.0	A5E	10.8	30.0	2.73E-04	2.43E-02	730.0					
30.0	A4W	13.2	36.6	9.00E-05	8.02E-03	293.0					
35.0	A3E	12.9	35.8	1.29E-04	1.15E-02	411.0					
40.0	A2W	10.5	29.1	9.54E-05	8.20E-03	238.0					
44.0	A1E	8.9	24.6	3.06E-04	2.47E-02	608.0	8	32.6	477.3	44	N
48.0	A8W	11.5	31.8	4.15E-05	3.58E-03	114.0					
52.0	A7E	10.8	30.0	1.09E-04	8.61E-03	258.0					
58.0	A6W	11.1	30.9	2.76E-05	2.27E-03	69.9					
61.0	A5E	10.0	27.9	3.08E-04	2.75E-02	768.0					
66.0	A4W	12.3	34.2	1.39E-04	1.18E-02	403.0					
69.0	A3E	12.9	36.0	7.61E-05	6.72E-03	242.0					
72.0	A2W	10.6	29.6	7.21E-05	5.90E-03	174.0					
75.0	A1E	9.4	26.2	6.13E-05	4.72E-03	124.0	8	30.8	269.1	84	D
79.0	B9E	9.1	12.6	3.14E-04	2.76E-02	347.0					
82.0	B8W	9.8	13.6	2.40E-04	2.05E-02	279.0					
86.0	B7E	11.1	15.4	2.26E-04	1.98E-02	305.0					
91.0	B6W	11.8	16.4	1.37E-04	1.20E-02	197.0					
95.0	B5E	11.8	16.3	1.37E-04	1.17E-02	192.0	5	14.9	264.0	26	N
112.0	B9E	7.1	9.8	2.78E-04	2.31E-02	226.0					
117.0	B8W	9.5	13.2	1.19E-05	9.89E-04	13.1					
121.0	B7E	11.2	15.5	1.18E-04	1.04E-02	161.0					
126.0	B6W	11.9	16.5	3.25E-04	2.78E-02	459.0					
131.0	B5E	11.8	16.5	9.75E-05	8.77E-03	144.0					
135.0	B4W	9.5	13.1	1.02E-04	8.48E-03	112.0					
139.0	B3E	6.0	8.3	2.49E-04	1.95E-02	163.0					
142.0	B2W	8.4	11.7	1.25E-04	1.03E-02	121.0	8	13.1	174.9	74	D1
146.0	B9E	9.4	13.0	2.96E-04	2.62E-02	341.0					
149.0	B8W	9.0	12.5	2.35E-04	2.00E-02	249.0					
153.0	B7E	11.4	15.8	2.00E-04	1.75E-02	275.0					
157.0	B6W	12.5	17.4	1.68E-04	1.45E-02	252.0					
161.0	B5E	11.3	15.7	1.79E-04	1.59E-02	249.0					
164.0	B4W	9.5	13.1	1.24E-04	1.06E-02	139.0					
167.0	B3E	8.8	12.3	1.19E-04	1.03E-02	126.0					
171.0	B2W	8.3	11.6	2.02E-04	1.72E-02	199.0	8	13.9	228.8	31	N1
174.0	B1E	8.4	11.6	2.40E-04	1.87E-02	217.0	9	13.7	227.4	29	
184.0	B9E	9.5	13.2	2.61E-04	2.35E-02	309.0					
188.0	B8W	9.6	13.4	7.55E-05	6.40E-03	85.6					
191.0	B7E	10.7	14.9	3.72E-05	3.37E-03	50.2					
193.0	B6W	11.2	15.5	3.93E-04	3.43E-02	533.0					
198.0	B5E	11.9	16.5	2.24E-04	2.01E-02	332.0					
202.0	B4W	9.4	13.0	5.25E-05	4.41E-03	57.4					
206.0	B3E	8.9	12.3	2.40E-04	2.03E-02	251.0					
211.0	B2W	8.2	11.4	7.47E-05	6.20E-03	70.8	8	13.8	211.1	83	D2
215.0	B1E	7.7	10.7	1.05E-04	8.16E-03	87.5	9	13.4	197.4	86	

Table 2a: (cont'd.)

EVENT	NAME	Len km	Area km^2	Vol Den kg/m^3	Sur Den kg/m^2	Biomass t	N #	Mean Area km^2	Mean Biomass t	CV %	D/N
220.0	B9E	8.9	12.3	2.10E-04	1.83E-02	225.0					
224.0	B8W	9.5	13.2	2.27E-04	1.85E-02	243.0					
227.0	B7E	11.3	15.7	1.90E-04	1.63E-02	257.0					
231.0	B6W	11.3	15.7	1.64E-04	1.40E-02	221.0					
234.0	B5E	11.8	16.3	1.41E-04	1.24E-02	202.0					
238.0	B4W	9.5	13.2	1.13E-04	9.54E-03	126.0					
242.0	B3E	9.0	12.5	1.61E-04	1.36E-02	170.0					
250.0	B2W	7.8	10.9	1.30E-04	1.14E-02	124.0	8	13.7	196.0	26	N2
254.0	B1E	7.6	10.5	1.59E-04	1.22E-02	128.0	9	13.4	188.4	28	
352.0	B9E	9.2	12.7	3.66E-04	3.26E-02	415.0					
356.0	B8W	10.0	13.8	1.99E-04	1.72E-02	237.0					
360.0	B7E	11.0	15.3	2.33E-04	2.06E-02	315.0					
363.0	B6W	11.9	16.5	3.72E-04	3.29E-02	542.0					
367.0	B5E	11.6	16.1	1.57E-04	1.41E-02	227.0					
372.0	B4W	6.7	9.3	7.88E-05	7.20E-03	67.0					
374.0	B3E	9.3	12.9	8.50E-05	7.13E-03	91.8					
378.0	B2W	8.5	11.8	1.20E-04	1.06E-02	125.0	8	13.6	252.5	66	N3
380.0	B1E	8.2	11.4	1.84E-04	1.38E-02	158.0	9	13.3	242.0	65	
384.0	B9E	1.8	2.4	4.01E-05	4.41E-03	10.7	1	2.4	10.7		
386.0	B9E	5.7	8.0	4.66E-04	3.57E-02	284.0					
391.0	B8W	8.5	11.8	2.19E-04	1.88E-02	222.0					
395.0	B7E	11.0	15.3	3.91E-04	3.40E-02	519.0					
402.0	B6W	11.3	15.6	1.17E-04	1.03E-02	161.0					
410.0	B5E	9.1	12.6	1.30E-04	1.19E-02	150.0					
414.0	B4W	9.4	13.0	1.23E-04	1.08E-02	140.0					
418.0	B3E	9.0	12.5	1.23E-04	1.00E-02	125.0					
422.0	B2E	8.0	11.1	1.10E-04	9.46E-03	105.0	8	12.5	213.3	64	D3
425.0	B1E	8.1	11.2	4.80E-05	3.63E-03	40.6	9	12.3	194.1	72	
429.0	B9E	8.7	12.1	2.38E-04	2.07E-02	251.0					
431.0	B8W	8.8	12.2	1.98E-04	1.63E-02	199.0					
435.0	B7E	11.1	15.4	2.17E-04	1.96E-02	302.0					
438.0	B6W	11.7	16.3	1.21E-04	1.08E-02	175.0					
442.0	B5E	11.7	16.2	9.62E-05	8.85E-03	143.0					
445.0	B4W	9.6	13.3	7.93E-05	7.03E-03	93.8					
449.0	B3E	9.1	12.7	1.22E-04	1.08E-02	136.0					
453.0	B2W	8.6	11.9	9.22E-05	8.19E-03	97.3	8	13.8	174.6	42	N4
456.0	B1E	7.9	11.0	1.26E-04	1.00E-02	110.0	9	13.5	167.5	43	
462.0	B9E	9.5	13.2	2.56E-04	2.29E-02	302.0					
465.0	B8W	9.8	13.7	3.65E-05	3.19E-03	43.7					
468.0	B7E	11.0	15.3	9.90E-05	8.74E-03	134.0					
471.0	B6W	11.9	16.5	2.84E-04	2.51E-02	413.0					
474.0	B5E	11.6	16.1	7.43E-05	6.76E-03	109.0					
476.5	B4W	9.8	13.6	5.33E-05	4.73E-03	64.1					
480.0	B3E	9.6	13.3	9.15E-05	8.09E-03	107.0					
485.0	B2W	8.3	11.5	1.85E-04	1.65E-02	189.0	8	14.2	170.2	75	D4
488.0	B1E	8.0	11.1	1.36E-04	1.12E-02	124.0	9	13.8	165.1	73	

Table 2b: Total biomass data for 'B5-6' series. Transect length, surface density cell area, volume and surface densities, and biomass by transect are given.

EVENT	NAME	Len km	Area km²	Vol Den kg/m³	Sur Den kg/m²	Biomass t	Mean Area km²	Mean Biomass t	Time	D/N
91.0	B6W	11.8	16.4	1.37E-04	1.20E-02	197.0				
95.0	B5E	11.8	16.3	1.37E-04	1.17E-02	192.0	16.4	194.5	2012	N1
126.0	B6W	11.9	16.5	3.25E-04	2.78E-02	459.0				
131.0	B5E	11.8	16.5	9.75E-05	8.77E-03	144.0	16.5	301.5	1224	D1
157.0	B6W	12.5	17.4	1.68E-04	1.45E-02	252.0				
161.0	B5E	11.3	15.7	1.79E-04	1.59E-02	249.0	16.6	250.5	2035	N2
193.0	B6W	11.2	15.5	3.93E-04	3.43E-02	533.0				
198.0	B5E	11.9	16.5	2.24E-04	2.01E-02	332.0	16.0	432.5	1103	D2
231.0	B6W	11.3	15.7	1.64E-04	1.40E-02	221.0				
234.0	B5E	11.8	16.3	1.41E-04	1.24E-02	202.0	16.0	211.5	2046	N3
260.0	B6W	12.0	16.6	2.11E-04	1.88E-02	312.0				
262.5	B5E	12.4	17.3	1.94E-04	1.72E-02	297.0	17.0	304.5	0255	N4
269.0	B6W	12.3	17.1	1.93E-04	1.71E-02	292.0				
272.0	B5E	11.5	16.0	1.63E-04	1.46E-02	234.0	16.6	263.0	0440	N5
275.0	B6W	12.4	17.2	1.84E-04	1.62E-02	279.0				
279.0	B5E	12.0	16.7	1.36E-04	1.22E-02	203.0	17.0	241.0	0629	N6
284.0	B6W	11.3	15.8	2.29E-04	2.01E-02	317.0				
287.0	B5E	11.6	16.2	1.43E-04	1.28E-02	207.0	16.0	262.0	0823	Dwn
292.0	B6W	11.6	16.1	3.64E-04	3.19E-02	515.0				
297.0	B5E	12.3	17.1	1.26E-04	1.12E-02	192.0	16.6	353.5	1024	D3
300.0	B6W	11.3	15.7	2.46E-04	2.12E-02	333.0				
304.0	B5E	11.6	16.0	5.26E-04	4.05E-02	648.3	15.9	490.7	1223	D4
313.0	B6W	11.7	16.3	1.05E-04	8.98E-03	146.0				
319.0	B5E	11.7	16.3	2.36E-04	2.08E-02	339.0	16.3	242.5	1455	D5
324.0	B6W	11.5	16.0	1.84E-04	1.54E-02	247.0				
328.0	B5E	12.5	17.4	1.21E-04	1.05E-02	183.0	16.7	215.0	1649	Dsk
332.0	B6W	12.3	17.1	1.81E-04	1.56E-02	266.0				
336.0	B5E	12.2	17.0	1.03E-04	8.99E-03	153.0	17.1	209.5	1845	N7
340.0	B6W	10.7	14.9	2.07E-04	1.76E-02	261.0				
344.0	B5E	10.5	14.5	1.54E-04	1.30E-02	189.0	14.7	225.0	2040	N8
363.0	B6W	11.9	16.5	3.72E-04	3.29E-02	542.0				
367.0	B5E	11.6	16.1	1.57E-04	1.41E-02	227.0	16.3	384.5	0108	N9
402.0	B6W	11.3	15.6	1.17E-04	1.03E-02	161.0				
410.0	B5E	9.1	12.6	1.30E-04	1.19E-02	150.0	14.1	155.5	1034	D6
438.0	B6W	11.7	16.3	1.21E-04	1.08E-02	175.0				
442.0	B5E	11.7	16.2	9.62E-05	8.85E-03	143.0	16.3	159.0	0048	N10
471.0	B6W	11.9	16.5	2.84E-04	2.51E-02	413.0				
474.0	B5E	11.6	16.1	7.43E-05	6.76E-03	109.0	16.3	261.0	1006	D7

Table 3: Total catch (kg) and percent of total catch of major species, R/V W.E. RICKER yellowtail rockfish hydroacoustic cruise, November 13-25, 1991. Other species includes those which accounted for less than 1% of the total catch weight.

Species	Weight (kg)	Percent of Total Weight
S. flavidus	2113.	85.89
S. paucispinis	152.	6.18
S. brevispinis	99.	4.02
Other species	96.	3.91
	------	------
	2460.	99.97

Table 4: Length frequency and reproductive development summaries of yellowtail rockfish, *Sebastes flavidus*, R/V W.E. RICKER yellowtail rockfish hydroacoustic cruise, November 13-25, 1991. See Appendix Table 3 for reproductive maturity stage descriptions.

Area	3D, 25		3D, 25		3D, 25		Total	
Date	Nov 18		Nov 18		Nov 18			
Depth (m)	150		150		148			
Haul	1		1		2			
Length (cm)	M	F	M	F	M	F	M	F
35	0	0	0	0	1	0	1	0
36	0	0	0	0	0	1	0	1
37	1	0	1	0	0	0	2	0
38	3	0	1	1	0	1	4	2
39	4	0	4	0	1	1	9	1
40	3	4	6	2	5	2	14	8
41	9	1	3	8	5	2	17	11
42	6	3	5	7	10	7	21	17
43	5	4	6	6	10	6	21	16
44	10	4	1	4	3	1	14	9
45	6	7	5	3	4	7	15	17
46	6	4	4	6	3	6	13	16
47	1	3	3	7	1	7	5	17
48	2	5	2	3	3	3	7	11
49	0	4	2	6	0	3	2	13
50	0	2	0	4	1	0	1	6
51	0	0	0	0	0	4	0	4
52	0	3	0	0	0	0	0	3
53	0	0	0	0	0	1	0	1
54	0	0	0	0	0	0	0	0
55	0	0	0	0	0	1	0	1
Total	56	44	43	57	47	53	146	154
Reproductive Development Stages								
1	0	0	0	0	0	1	0	1
2	7	11	13	19	42	21	62	51
3	28	33	23	37	2	31	53	101
4	0	0	0	1	0	0	0	1
5	2	0	0	0	0	0	2	0
6	18	0	4	0	0	0	22	0
7	1	0	3	0	1	0	5	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	2	0	2	0

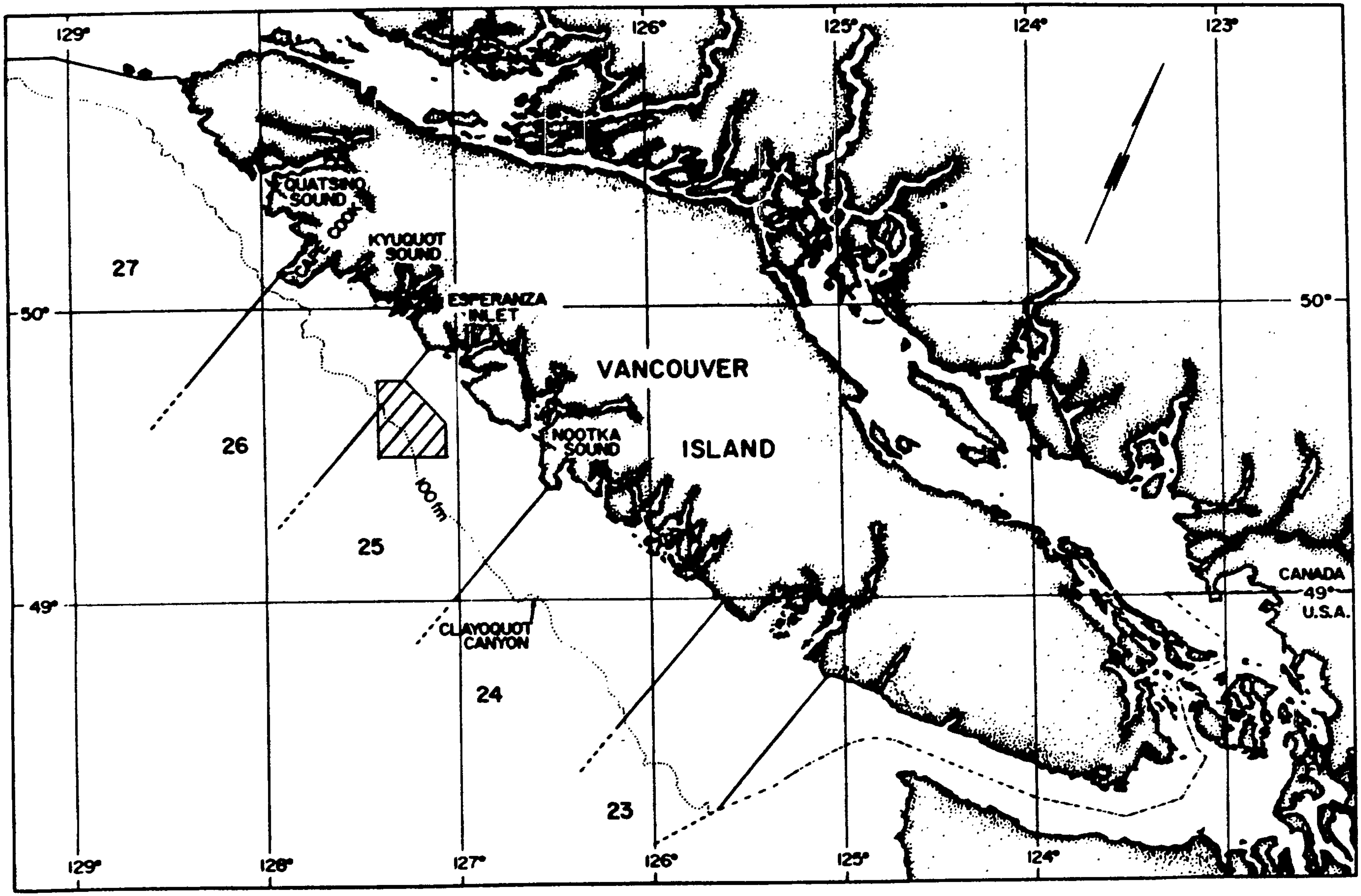


Figure 1. Chart of Vancouver Island and westcoast fisheries statistical areas 23 - 27. The hatch marks indicate the area surveyed during the experimental hydroacoustic estimation of yellowtail rockfish biomass on the R/V W.E. RICKER, November 13 - 25, 1991.

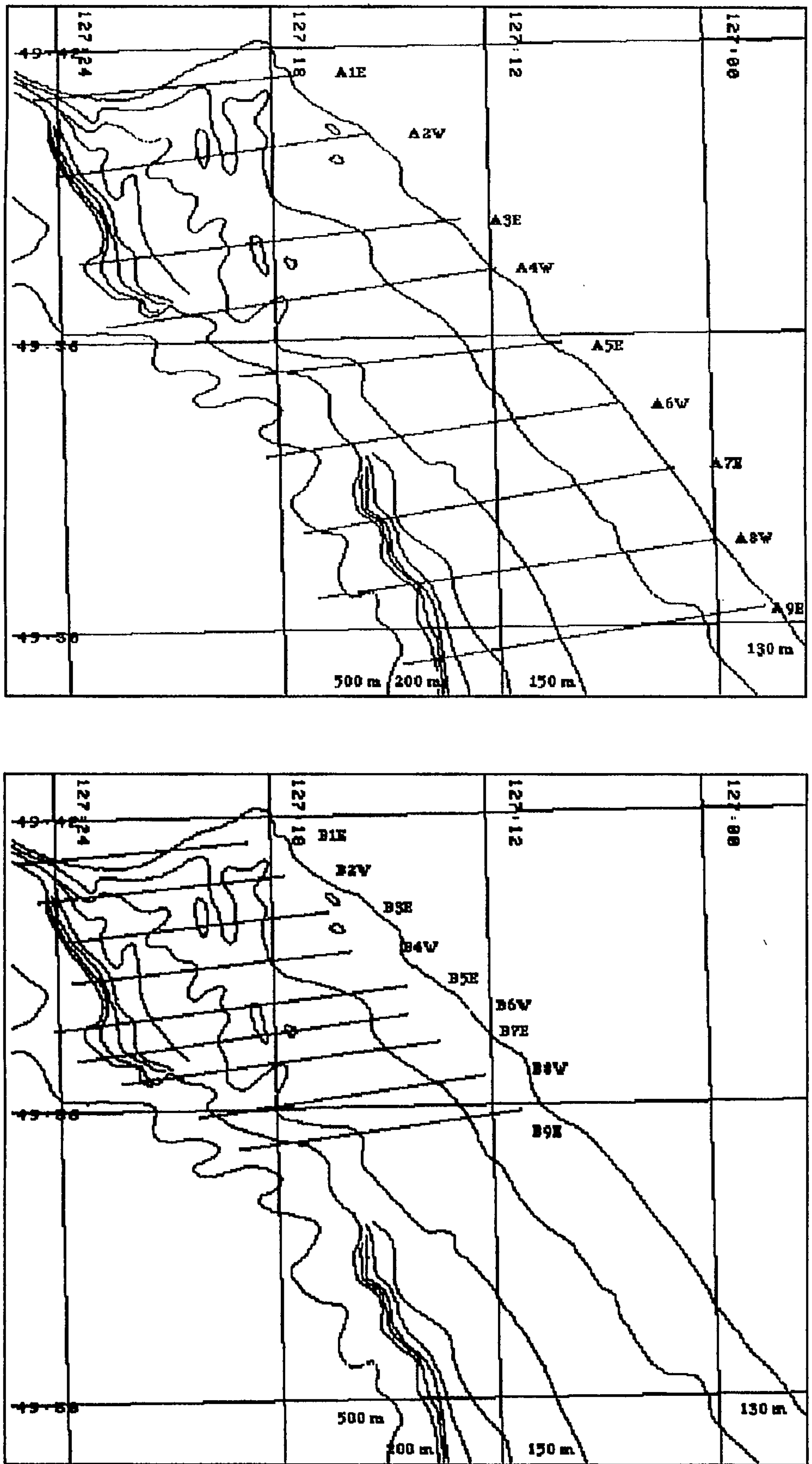


Figure 2. Series A (top) and B (bottom) transects occupied during the yellowtail rockfish hydro-acoustic survey, W.E. RICKER, Nov. 13-25, 1991.

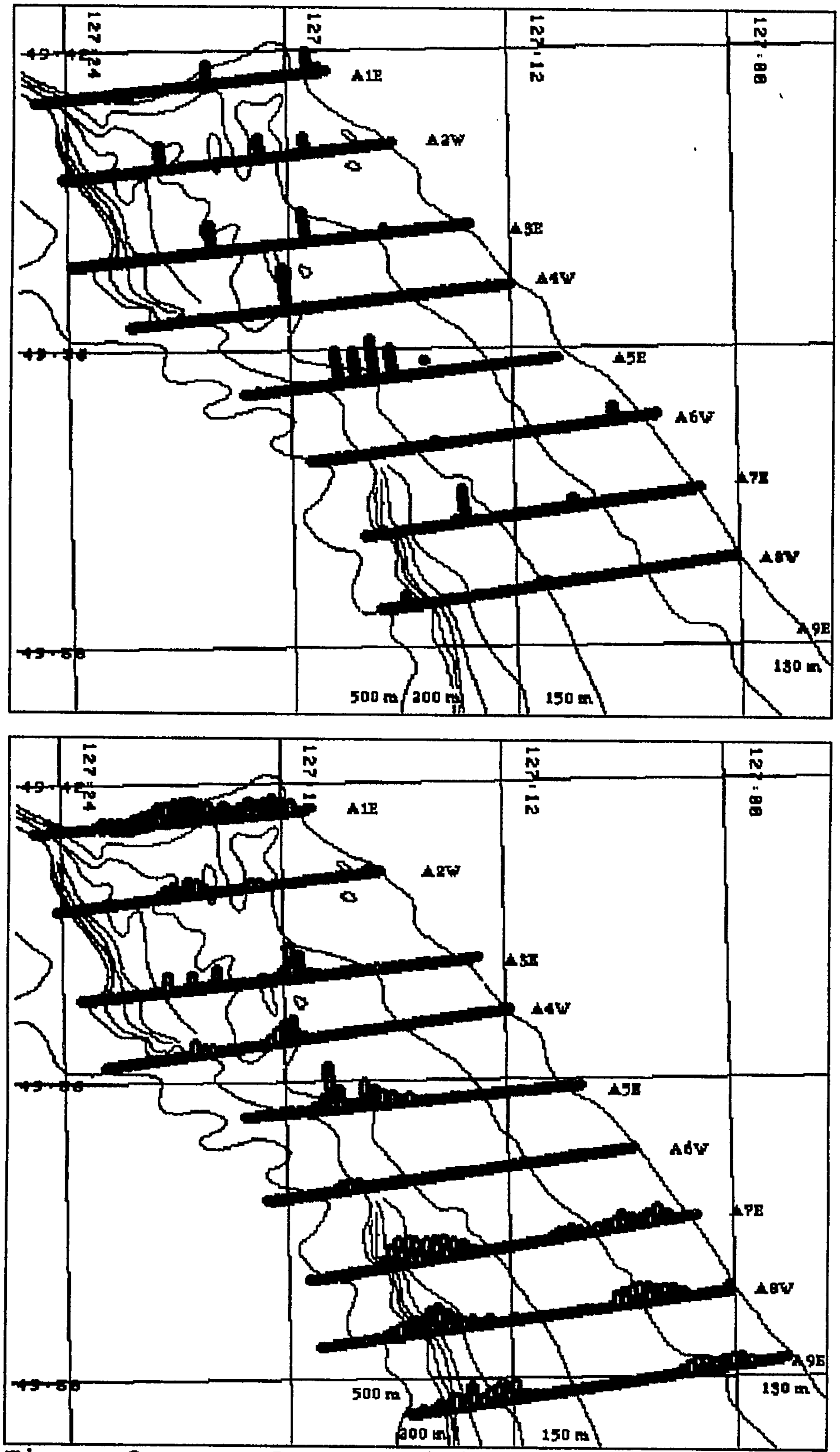


Figure 3a. Surface densities for day (top) and night (bottom) repeats of A series, November 13-14, 1991. Surface densities are represented by vertical bars on a log scale ranging from 0.01 to 1.0 kg/m^2.

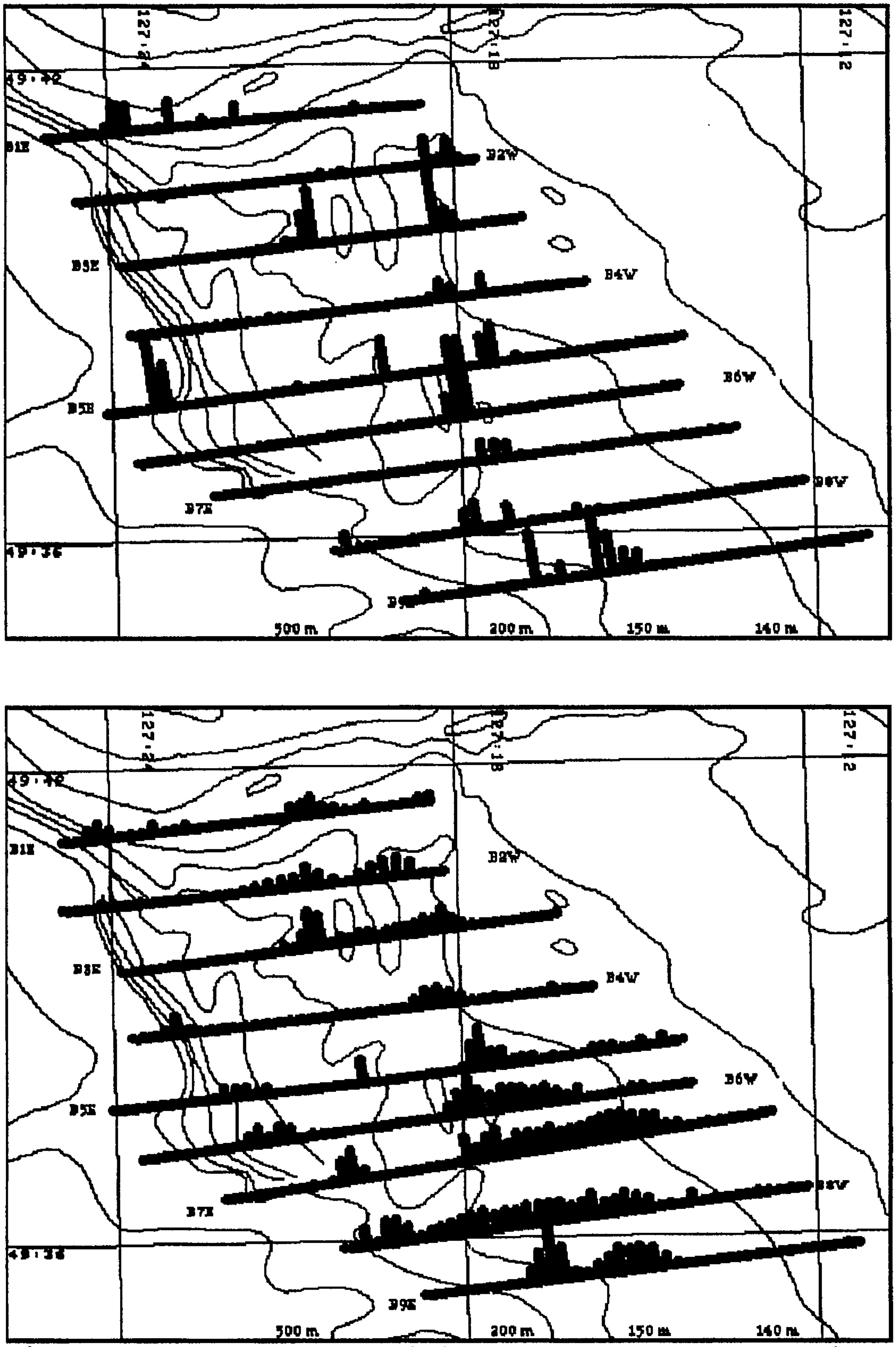
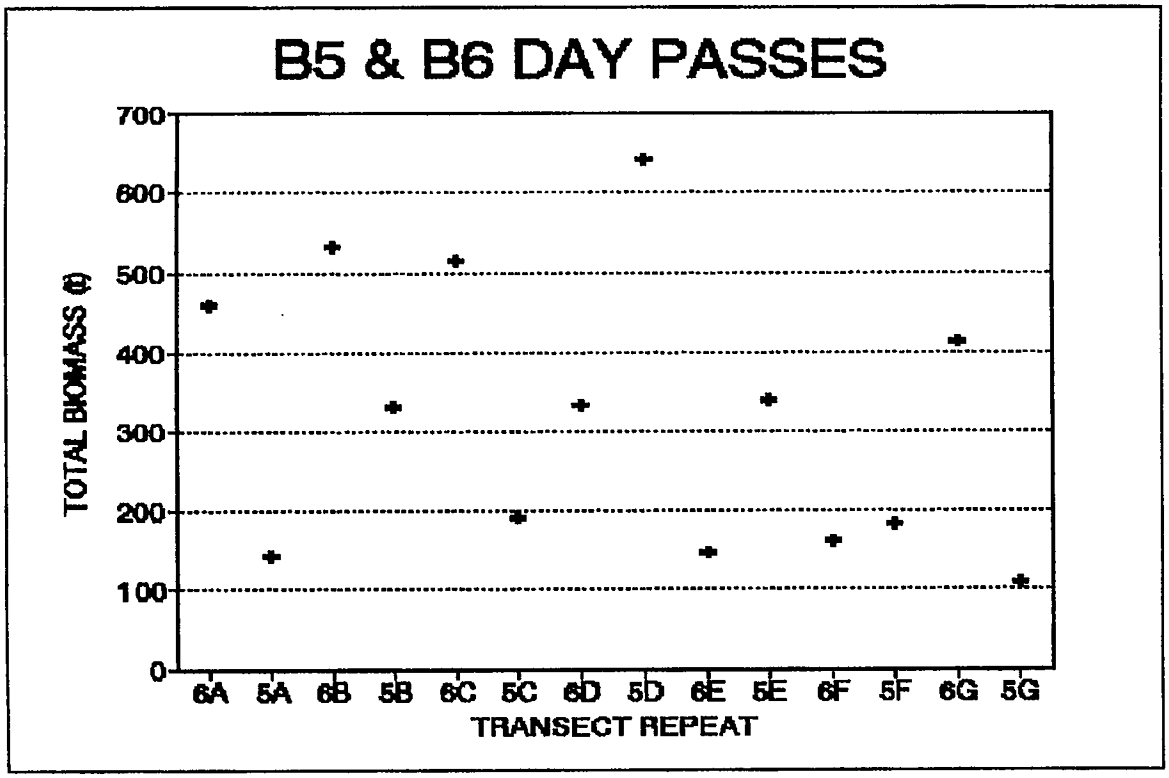


Figure 3b. Surface densities for day (top) and night (bottom) repeats of B series, November 20, 1991. Surface densities are represented by vertical bars on a log scale ranging from 0.01 to 1.0 kg/m^2.



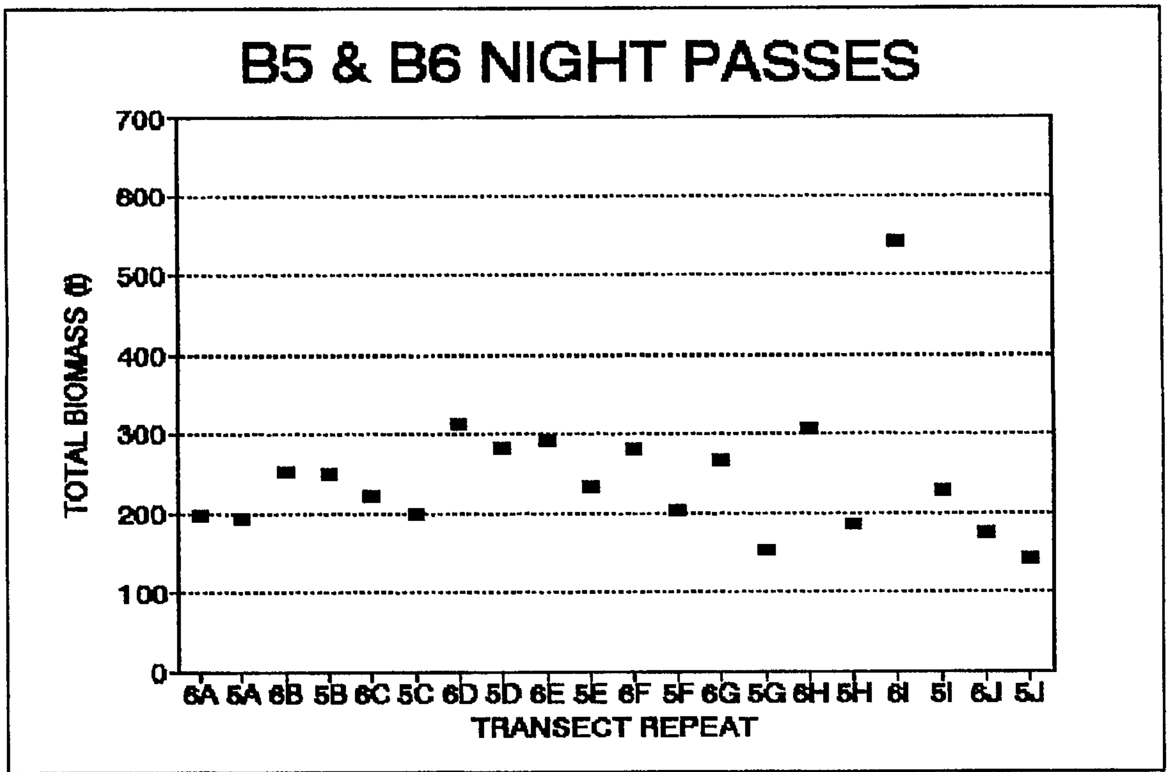


Figure 4. Comparison of the day (top) and night (bottom) biomass estimates from successive passes of transects B5 and B6, November 13 - 25, 1991. Estimates are in tons.

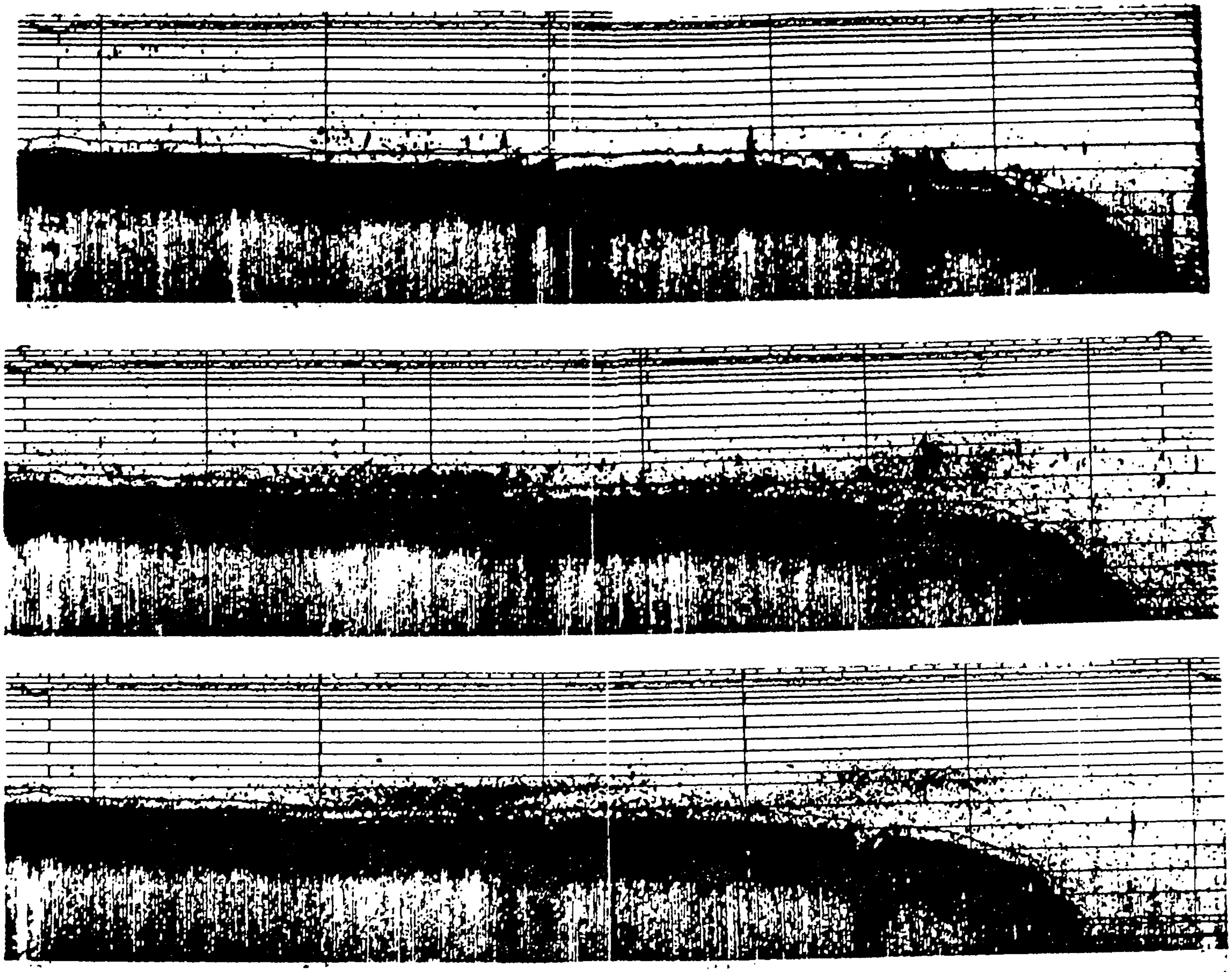
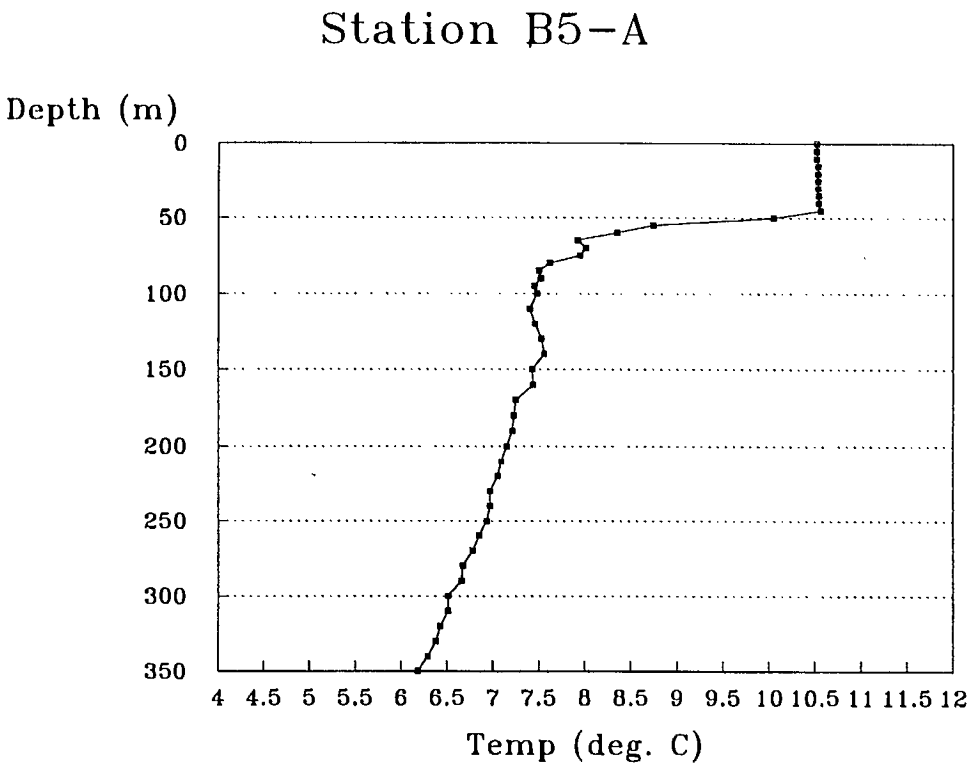


Figure 5. Echograms of transect B6W collected November 20, 1991 during the hydroacoustic survey of yellowtail rockfish on the **W.E.RICKER**. Diel distribution patterns are shown for aggregations of rockfish observed during the day (top), dusk (middle), and night (bottom). Arrows on the day (top) echogram indicate fishing locations referred to as "clay bumps".



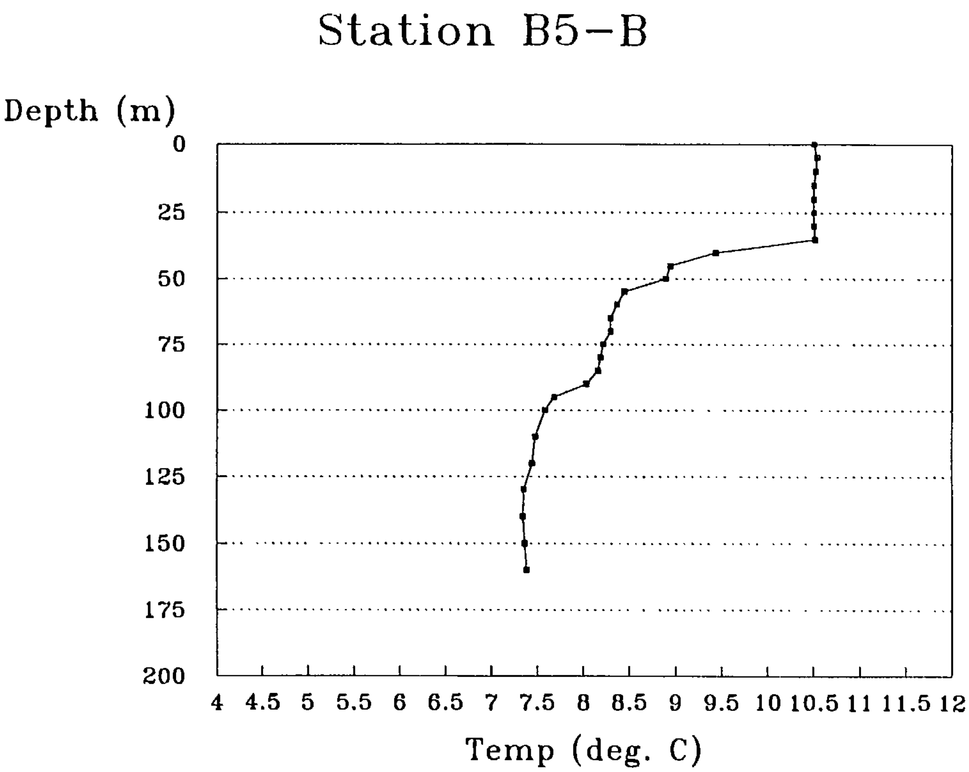
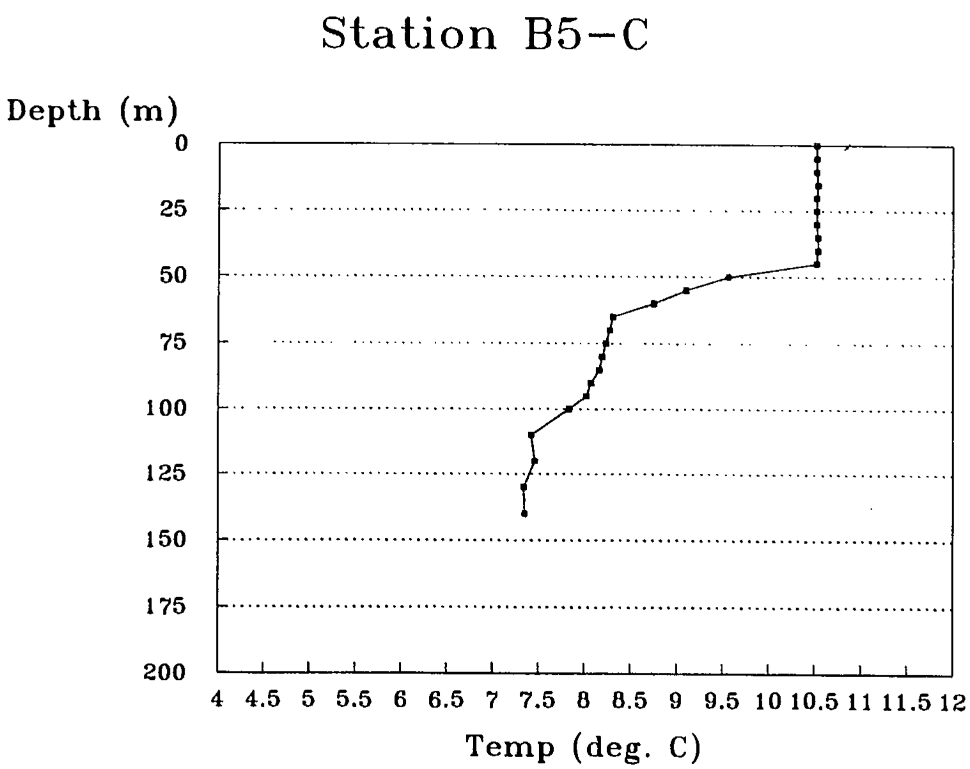


Figure 6a (top) and 6b (bottom). Temperature-depth profiles from stations on hydroacoustic transect B5, during the hydroacoustic survey of yellowtail rockfish, November 13-25, 1991.



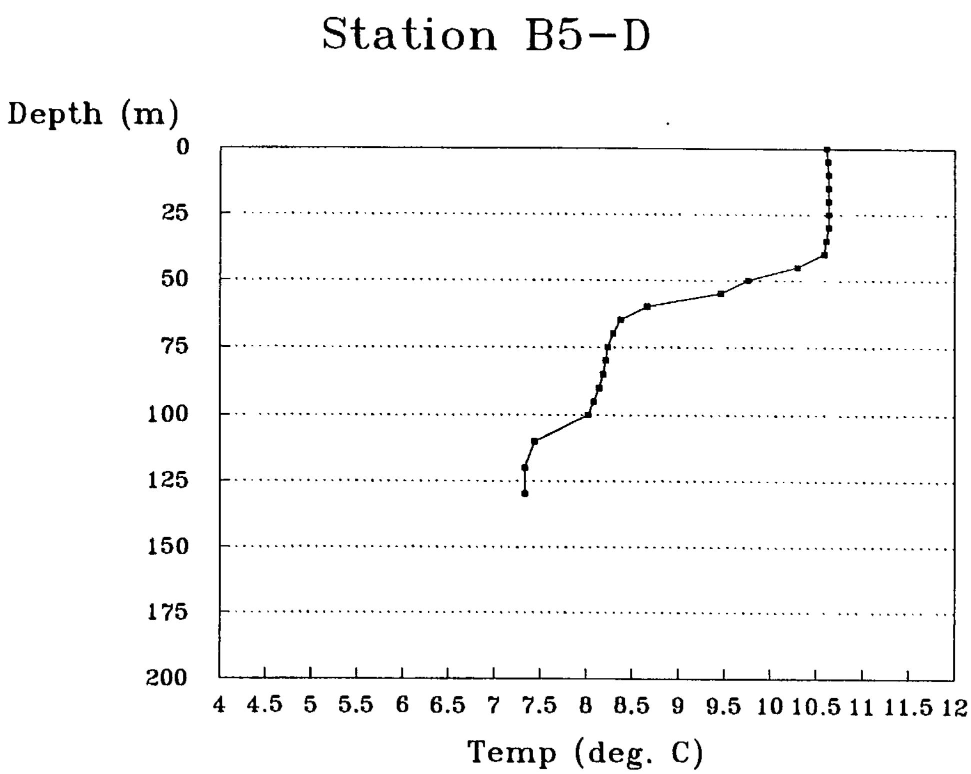
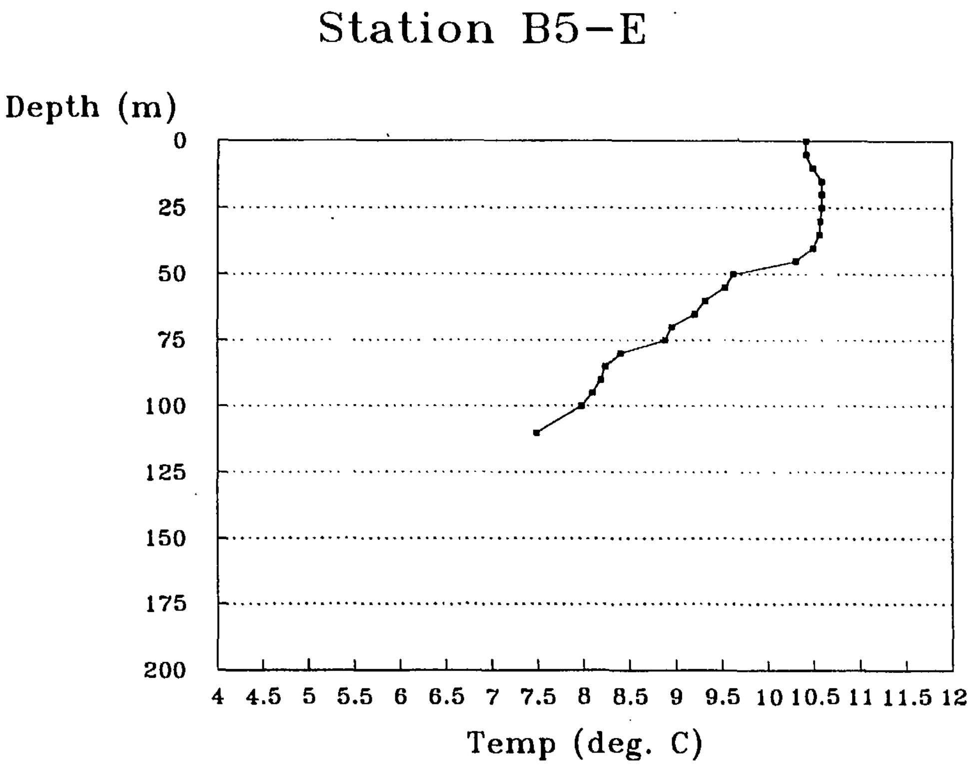


Figure 6c (top) and 6d (bottom). Temperature-depth profiles from stations on hydroacoustic transect B5, during the hydroacoustic survey of yellowtail rockfish, November 13-25, 1991.



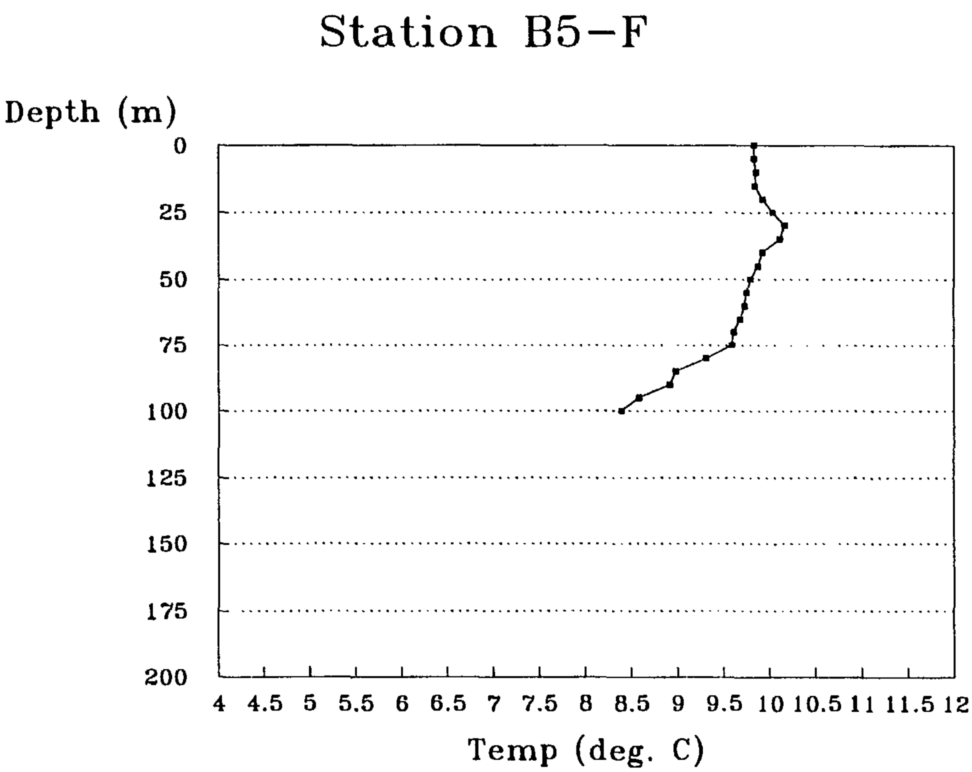


Figure 6e (top) and 6f (bottom). Temperature-depth profiles from stations on hydroacoustic transect B5, during the hydroacoustic survey of yellowtail rockfish, November 13-25, 1991.

APPENDIX Table 1.

ECHO INTEGRATION EQUATION and SYSTEM CALIBRATION CONSTANTS

Echo integration can be described by an equation that accounts for the physical aspects of the hydroacoustic measurement. The equation is valid if a good signal to noise ratio is present and an average fish target strength can be defined. For convenience, the parameters are given in logarithmic form. For each range stratum and integration sequence, the integrator outputs an intensity, I, that is given by:

$$I = TL + RS + SG + SA + \Omega + CT + BW + RG + TS + \rho$$

The following definitions are used:

I		Echo Intensity, dB re: 1 V^2
TL		Transmit level, dB re 1μPa at 1 m
RS		Receive sensitivity, dB re 1V/μPa at 1 m
SG		Two way gain through shell of the towed body, dB
SA		Spreading and absorption gain, $-(20 \cdot \log \cdot R_0 + 2 \cdot \alpha \cdot R_0)$
	R_0	Reference range, m
	α	Absorption, dB re 1/m
Ω		Beam factor = $10 \cdot \log[\iint b^2(\theta,\Phi) \cdot \sin(\theta)\, d\theta d\Phi]$
	$b(\theta,\Phi)$	One way transducer directivity function, Power
CT		Range increment = $10 \cdot \log(c \cdot \tau/2)$
	c	Velocity of sound in water, m/s
	τ	Transmit pulse width, s
BW		Bandwidth factor = $10 \cdot \log(I_1/I_0)$
	I_1	I generated by a bandwidth limited input pulse
	I_0	I generated by a square input pulse of equal height
RG		Receiver gain setting, dB
TS		Average fish target strength, dB re 1/kg
ρ		Fish volume density, kg/m^3

APPENDIX Table 1 (cont'd.)

The following values are used in the echo integration equation.

Quantity			Source/Comment
TL		219.70 dB	mean value; see NOTE 1
RS		-134.37 dB	mean value; see NOTE 1
SG		-0.6 dB	see NOTE 2
SA		-0.0198 dB	
	R_0	1.0 m	
	α	0.0099 dB/m	
Ω		-17.55 dB	
CT		-3.50 dB	
	c	1490 m/s	
	τ	0.6 ms	
BW		- 0.8 dB	Kieser et al. 1987
RG		-12.0 dB	
TS		-32.0 dB	TS value for rockfish
ρ			Fish density to be estimated

NOTE 1: mean values for TL and RS calculated from calibrations March 1990, August 1990, and July 1991 at Applied Physics Laboratory, University of Washington, Seattle (Kieser; unpubl. data).

NOTE 2: shell gain established from March 1982 calibration at Applied Physics Laboratory, University of Washington, Seattle (Kieser; unpubl. data., plots 3717 and 3718).

TL, RS, SH, and $b(\theta,\Phi)$ were measured at the hydroacoustic calibration barge of the Applied Physics Laboratory, University of Washington, Seattle. The calibration is performed periodically and provides a check on the overall system performance and stability. The receiver sensitivity, RS, refers to a reference range of 1.0 m, however, it is measured with TVG at 30 m. The echo sounder was operated with 20 log R + 2 α R time varied gain, 0.6 ms transmit pulse length, 1,000 W power and 1 Hz repetition rate. With this gain, echo levels of 0.2 V to 10.0 V correspond to densities of 0.00104 to 2.59 kg/m^3.

APPENDIX TABLE 2

Bridge log of the R/V W.E. RICKER, yellowtail rockfish hydroacoustic cruise, November 13-25, 1991. See Appendix Table 4 for common and scientific names of species captured. BT refers to Bottom Trawl gear type; T refers to trace catch.

Haul Number		1	2	3
Date		Nov 18	Nov 18	Nov 18
Area (Major, Minor)		3D,25	3D,25	3D,25
Start Time	(PDT)	8:52	10:45	12:27
Duration	(Min)	11	21	21
Start N. Lat.	(Deg)	49	49	49
	(Min)	37.8	37.5	36.9
W. Long	(Deg)	127	127	127
	(Min)	17.5	16.4	16.5
Finish N. Lat.	(Deg)	49	49	49
	(Min)	37.9	37.2	36.7
W. Long	(Deg)	127	127	127
	(Min)	18.7	18.3	18.4
Haul Distance	(km)	1.5	2.4	2.2
	(nm)	0.8	1.3	1.2
Direction	(Deg.True)	259	260	240
Bottom Depth	(m)	147- 153	146- 150	151- 150
	(fm)	80- 84	80- 82	83- 82
Modal Depth	(m)	150	148	146
Gear Type		BT	BT	BT
Total Catch	(kg)	1989	393	78
Remarks		Usable	Usable	Usable

APPENDIX TABLE 2 (cont'd.)

Haul Number	1	2	3
Date	Nov 18	Nov 18	Nov 18
Area (Major, Minor)	3D,25	3D,25	3D,25
Arrowtooth flounder	T	9	7
Dover sole	T	1	1
English sole	T	6	3
Pacific halibut	..	3	..
Petrale sole	T	3	2
Rex sole	T	3	2
Other flatfish	..	T	T
S. brevispinis	75	18	6
S. entomelas	17	2	1
S. flavidus	1756	327	30
S. paucispinis	141	11	T
S. proriger	T	1	1
S. zacentrus	T	..	2
Other rockfish	T	T	T
American shad	T	1	1
Lingcod	T	..	13
Pacific cod	T	..	1
Sablefish	T	2	2
Other roundfish	..	T	..
Longnose skate	T	..	6
Spiny dogfish	..	5	..
Spotted ratfish	T	1	T
Other selachii	..	..	..
Total Catch (kg)	1989	393	78

APPENDIX TABLE 3

Description of rockfish reproductive development stages.

Code	Gonad Condition
Females	
1	Immature (translucent, small)
2	Developing (small, yellow eggs, opaque or translucent)
3	Developed (large yellow eggs, opaque)
4	Fertilized (large, orange-yellow eggs, translucent)
5	Embryos or larvae (includes eyed eggs)
6	Spent (large, flaccid, red ovaries, a few larvae may be present)
7	Resting (moderate size, firm, red-grey ovaries)
9	Undetermined
Males	
1	Immature (translucent, string-like)
2	Developing (swelling, brown-white)
4	Developed (large, white, easily broken)
5	Ripe (running sperm)
6	Spent (flaccid, red)
7	Resting (ribbon-like, small brown)
9	Undetermined

APPENDIX TABLE 4

Common and scientific names of species captured on the R/V W.E. RICKER, yellowtail rockfish hydroacoustic cruise, November 13-25, 1991.

Rockfishes	
Silvergray rockfish	*Sebastes brevispinis*
Greenstriped rockfish	*S. elongatus*
Widow rockfish	*S. entomelas*
Yellowtail rockfish	*S. flavidus*
Rosethorn rockfish	*S. helvomaculatus*
Bocaccio	*S. paucispinis*
Canary rockfish	*S. pinniger*
Redstripe rockfish	*S. proriger*
Pygmy rockfish	*S. wilsoni*
Sharpchin rockfish	*S. zacentrus*
Flatfishes	
Arrowtooth flounder	*Atheresthes stomias*
Slender sole	*Eopsetta exilis*
Petrale sole	*Eopsetta jordani*
Rex sole	*Errex zachirus*
Flathead sole	*Hippoglossoides elassodon*
Pacific halibut	*Hippoglossus stenolepis*
Dover sole	*Microstomus pacificus*
English sole	*Pleuronectes vetulus*
Roundfishes	
Sablefish	*Anoplopoma fimbria*
Pacific cod	*Gadus macrocephalus*
Lingcod	*Ophiodon elongatus*
Selachii	
Spotted ratfish	*Hydrolagus colliei*
Longnose skate	*Raja rhina*
Spiny dogfish	*Squalus acanthias*
Other fishes	
American shad	*Alosa sapidissima*
Eulachon	*Thaleichthys pacificus*