Exxon Valdez Oil Spill
Restoration Project Annual Report

Forage Species Studies in Prince William Sound, 1998

Restoration Project 98163 A

Annual Report

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. . . .Screaming, the gulls watch,
Wild with envy and malice, cursing and snatching, what
hysterical greed!
What a filling of pouches! the mob
Hysteria is nearly human - these decent birds! - as if
they were finding
Gold in the street. It is better than gold,
It can be eaten: and which one in all this fury of wild-
fowl pities the fish?
. . . .

from Birds and Fishes by Robinson Jeffers

INTRODUCTION

Prince William Sound (PWS) is one of the largest areas of protected waters bordering the Gulf of Alaska (GOA). It, and the nearby open waters of the Gulf, provide foraging areas for populations of apex predators including piscivorous seabirds and marine mammals. These surface-dependent predators were adversely impacted by the EXXON VALDEZ oil spill (EVOS); and many experienced declines from which they have not recovered. Piscivorous seabirds and marine mammals in PWS are near the apex of food webs based on pelagic production of small fishes, including Pacific herring (*Clupea pallasi*), Pacific sand lance (*Ammodytes hexapterus)*, walleye pollock (*Theragra chalcogramma*), capelin (*Mallotus villosus*) and eulachon (*Thaleichthys pacificus*); and macroinvertebrates, especially euphausiids, commonly called krill. The lack of recovery by some seabirds may be due to long-term changes in forage species abundance. In this report we describe abundance and distribution patterns of small pelagic fishes in Prince William Sound, based on acoustic surveys.

OBJECTIVES

1. Provide an estimate of the distribution and abundance of forage species in study areas of Prince William Sound.

2. Describe species composition of the forage base and size distributions of the most abundant forage species in the three survey areas.

3. Gather basic oceanographic data describing salinity, temperature, and chlorophyll profiles of the water column in the three study areas.

FIELD METHODS

Sampling was conducted 13 - 31 July 1998. The research cruise objectives were:

1. Conduct a hydroacoustic survey of three survey areas within PWS

2. Collect samples of acoustic targets to describe species composition and size distributions.

3. Describe and quantify zooplankton and zooplanktivorous species at three process study sites.

Acoustic Survey:

We conducted a series of acoustic transects in four areas (Figure 1), using a Biosonics DT 4000, 120 kHz down-looking system. The transects were in a pattern of zigzags within 12 km segments of shoreline. The 12 km segments were laid out sequentially along the shoreline within each area. The number of 12 km segments within each study area were: North - 26, Central - 8, South - 21, Montague - 2. Within each 12 km segment there was a series of 20 transects (10 zigs and 10 zags). Each transect was about 1.2 km long. The subset of segments sampled in each area were:

North 1, 3, 5, 7, 9, 13, 15, 17, 19
Central 1-3, 6-8
South 2, 4, 6, 8, 10, 14, 16, 20
Montague 1

Field calibration of the acoustic equipment was done in the evening of July 24 using a standard target suspended under the transducer.

Acoustic targets found by the survey vessel were sampled using a fry seine, purse seine, dip net, jigging or ROV (Remote Operated Video).

CTD profiles were collected at 3 offshore sites in each survey area (Table 1, Figure 1). The water column was sampled to a depth of 150 m or within 20 m of the bottom.

PROCESS STUDIES:

Plankton samples were collected in three process study areas (Figure 2), with eight sampling locations per area (24 total). Plankton were sampled at night (1030 - 0430) with a 1 m^2 NIO/Tucker trawl with 500 micron mesh towed in a double oblique trajectory to a depth of 60 m or to 10 m above the bottom at shallower stations, and with a 20 cm Bongo net with 243 micron mesh towed vertically from 60 m (or 10 m above bottom) to the surface (Table 2). CTD measurements of temperature, salinity and chlorophyll were collected at all stations (Table 1).

Jellyfish were sampled to estimate their abundance in the North, Central and South process study areas by randomly setting a purse seine at each station in each area (Table 3). Jellyfish were also collected for digestion experiments and dip netted out of the process study area for analysis of gut contents.

SAMPLE PROCESSING:

Plankton samples were preserved in 5% buffered formalin. Fishes larger than about 50 mm were identified in the field and sorted to species. All fish were measured (fork length) unless net hauls contain large numbers of individuals of some species. Large catches were randomly subsampled by splitting the catch down to 100 - 200 individuals for measurement. Subsamples of all forage fish species were frozen and/or preserved in 10% buffered formalin.

ACOUSTIC DATA ANALYSES

Each data record consisted of 1 m depth increments from 1 m below the transducer to the bottom or about 115 m depth, whichever was greater. Averaging was done using geometric means. The program returned volume scattering, depth, and latitude and longitude for each record. Various parameters in the bottom tracking software were modified to avoid integrating through the bottom. The bottom window was varied from 20 to 40 m, with larger values for files with steeper slopes. A cross-section of the volume scattering for each transect was plotted using visual basic software. Cross-sectional plots were scanned visually, and estimates of species identification and size class were made for all substantial acoustic targets. The files were edited to remove any bottom integration left in the data. The portion of the total transect abundance or biomass value contributed by each integration was estimated by multiplying the integrated value by the integration distance divided by the total transect length. The volume scattering was corrected for calibration by the standard target.

The default sound scattering was assumed to be plankton with a target strength of -70 dB/g. For identified fish targets, estimates of the number of individual fish per cubic meter were determined by equations relating acoustic target strength to fish length.

Herring: TS = 20*log10(length(cm)) - 71.9

Pollock: TS = 20*log10(length(cm)) - 66

Capelin: TS = 20*log10(length(cm)) - 74.6

Rockfish: TS = 20*log10(length(cm)) - 67.5

Sand lance: TS = 20*log10(length(cm)) - 85

Estimates of fish numbers were converted to an estimate of biomass per cubic meter using the length-weight relationship for the dominant species. Equations to compute biomass (W - in grams, L - in mm) were:

pollock	$W = (1.89 \times 10^{-6})\ L^{3.272}$
herring	$W = (5.007 \times 10^{-6})\ L^{3.196}$
sand lance	$W = (4.81 \times 10^{-7})\ L^{3.451}$
capelin	$W = (2.40 \times 10^{-6})\ L^{3.213}$
rockfish	$W = (7.5 \times 10^{-3})\ L^{3.2}$ (length in cm)

Biomass per cubic meter estimates were converted to biomass per square meter of surface (biomass density) by integrating the results over the depth of the sampled water column. Biomass density for each transect was calculated by partitioning each transect into sections based on the targets present. Biomass density was estimated for each 12 km sampling segment by calculating the mean for all transects in the segment. Biomass density in each of the three study areas (North, Central, and South) was estimated by averaging all transects in the area. Geographic distributions of forage species were assessed with area plots of biomass density gradients determined through a kriging routine.

The procedures used to estimate biomass density in 1998 were similar to those used in 1997; however, the target-strength models used in 1998 were changed for several species. In order to make the estimates from 1996 and 1997 comparable to 1998 we reanalyzed the 1996 and 1997 acoustic data using the new target-strength models.

The 1996 data were collected with two BioSonics acoustic systems: a DT6000 130 kHz digital system and a 120 kHz ESP system. The DT6000 system was used for the South and Central surveys, but failed in the North survey two days before the end of the cruise. Therefore, the last two days of transecting in the North area were done with the 120 kHz ESP system. When tank calibrations were made on the DT6000 system following repair, changes in source level and receive sensitivity decreased the resulting volume scattering by about 5 dB from that computed by receive sensitivity and source level values read from the EEPROM (the system software program). Since no standard target calibration was done on this system prior to its field deployment, it was unclear which values were correct. In 1997 we ran standard target calibrations on the DT4000 system during field collections. In comparing the DT data from the two years, we found that the 1997 integrated volume scattering was very similar to that observed in the 1996 data, if the original 1996 data were corrected to incorporate the 5 dB decrease in volume scattering indicated in the 1996 post-season tank calibrations. Consequently we adjusted the 1996 DT6000 data by the 5 db increment indicated in the 1996 post-repair calibration. Also, for the 1996 North area data, direct comparison of the ESP data with the DT data is complicated by the fact that the DT systems are much quieter. When integrating the ESP data, the noise is summed as well as the actual acoustic backscatter, producing inflated estimates of volume scattering per unit area relative to estimates by the DT systems. Similar integrated volume scattering plots could be generated for data from the DT and ESP systems if the noise level for the ESP system were set to -60 dB in contrast to -80 dB for the DT systems. When this correction is applied to estimates of biomass using the ESP system, estimates for fish school biomass remains similar but plankton estimates drop. Comparison of plankton estimates obtained with the DT and corrected ESP data suggest that the -60 dB noise floor is more appropriate for the ESP system than the -80 dB noise floor used by the DT systems; therefore we used the -60 dB value in our calculations of the ESP data from 1996.

RESULTS

Physical and Biological Conditions

In July 1998 temperature and salinity were generally similar to patterns observed in the preceding three years (Figures 3, 4). Summer stratification is maintained largely by lower salinity in upper 30 m. Near-surface water in the central area was typically more saline than in the north and south. In 1996, salinity tended to be higher in the upper 30 m, especially in the North and South areas. Temperature was somewhat higher at many stations in 1997. In all years there is considerable variability in temperature and salinity within the Sound, largely due to localized inputs of fresh waters from rainwater run-off and melting of tidewater glaciers. For example, stations N1 and S2 are in channels near tidewater glaciers and were quite variable relative to stations in open-water parts of the Sound.

We measured chlorophyll and the abundance of euphausiids in the three process study areas. Chlorophyll was lowest in the South and highest in the Central area (Figure 5), although differences were not pronounced and were not significant. Euphausiid density did vary significantly among study areas (Figure 5). Density of euphausiids exceeded 50 m-2 in the South, but was less than 20 m-2 in the Central and North.

Acoustic Biomass Density - Within and Among Year Patterns

Acoustic target verification was conducted in all study areas. As in prior years, herring were by far the most abundant species identified as acoustic targets (Table 4).

In 1998 the South survey area had very high biomass density relative to the other areas. (Table 5). The exceptionally high value in the south was due to large and very dense schools of adult herring in the channels on the southwest side of the Sound, especially in Prince of Wales Passage. A division of overall biomass density into target category gives a more accurate estimate of the foraging environment available to avian predators, as several important species or species size groups are not vulnerable to birds (e.g. rockfish and adult herring). Of the seven categories of acoustic targets we analyzed, sandlance, YOY herring and 1+ herring are the Avian Vulnerable Energy Sources (AVES).

In 1998 the abundance of AVES was highest in the South and lowest in the North (Table 6). In all areas 1+ herring were the dominant prey category present on acoustic transects. The distribution in 1998 differed from 1997 when the highest AVES biomass density occurred in the North survey area, and was comprised mainly of YOY herring. Comparison with 1996 is tenuous due to the complications identified in the acoustic methods section.

In the North there has been a steady decline in AVES availability from 1996 - 1998, and substantial differences among years in the prey categories within AVES. In 1996, the North area had high density of 1+ herring, and relatively large concentrations of sandlance, especially in Port Gravina. In 1997, there was a large decline in density of 1+ herring and sandlance; however, those losses were partially offset by relatively high density of YOY herring. In 1998 the only AVES component in the North were relatively scarce 1+ herring.

The Central survey area appears to have experienced increasing abundance of AVES from 1996 to 1998; due mainly to increased abundance of sandlance, especially in 1997, and the occurrence of 1+ herring in 1998.

In 1998 the South survey area had high abundance of 1+ herring that were responsible for a sharp increase over 1997, when both sandlance and YOY herring were present in modest numbers.

In all years, YOY and 1+ herring were the dominant prey categories in AVES biomass density estimates. A strong year-class of herring within PWS will appear as exceptionally abundant YOY herring in the summer after spring hatching, with subsequent high abundance of 1+ herring in the following summer; although it is possible that overwinter mortality of YOY fish could result in low abundance of 1+ herring even when the preceding summer had high abundance of YOY herring. In our surveys, 1996 had relatively high abundance of 1+ herring, but few YOY herring. In 1997, as expected, there were almost no 1+ herring, but substantial numbers of YOY fish were present, indicating a relatively strong 1997 year class. That 1997 year class produced the 1+ herring that dominated AVES biomass density in 1998.

The distributions of YOY and 1+ herring within the Sound appear to differ. YOY fish were always most abundant in the North study area, whereas 1+ herring appear more abundant in Central and South study areas. This shift is consistent with our observation that herring adults are concentrated in the South study area, where they occur in the narrow channels in the Southwest part of Prince William Sound. There may be an ontogenetic shift in distribution of herring within PWS during the first few years of life.

Geographic Distribution of Forage Fishes in PWS

In the North survey area the distribution of forage fishes has shifted markedly in the period 1996 through 1998 (Figures 6 - 8). In 1996 most schools of small fishes were encountered in the southern sections of the North survey area, with many schools of sandlance and herring in Port Gravina and Port Fidalgo (Figure 8). The pattern changed in 1997, as very few fish schools were encountered in Port Gravina, and the number of schools in Port Fidalgo was reduced (Figure 7). This trend continued in 1998, when relatively few schools were found in the North survey area, and the southern sections of Port Fidalgo and Port Gravina had very few fish schools present (Figure 6).

In the Central survey area the distributions of forage fishes have remained similar from 1996 - 1998 (Figures 9 - 11). The Naked Island complex consistently had schools of sandlance on the west side, with schools of rockfish present around that island group. In 1997, substantial schools of adult herring were found in the eastern parts of the Naked Island group (Figure 10); unfortunately, both the 1996 and 1998 surveys missed that area due to equipment malfunction and rough weather, respectively.

The South survey area has consistently had concentrations of age 1+ and adult herring in the channels that lead out of PWS to the southwest, especially Prince of Wales Passage (Figures 12 - 14). In 1998 those schools were notably larger and had dense concentrations of herring (Figure 12). Other schools of fishes have typically occurred on both sides of Dangerous Passage.

ACKNOWLEDGEMENTS

We were assisted in field, laboratory and data analyses by University of Alaska Fairbanks graduate students, Jill Mooney and Julia Mabry. Jennifer Purcell and Kim Black from the University of Maryland were valued participants in our field collections.

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Table 1. CTD casts collected in July 1998 on cruise 98-1.

Date	Time	Station #	Location	Lat.		Long.		Bottom Depth (m)	Gear Depth (m)
14/7	1640	2	N7	60	41.04	146	18.07	39	128
14/7	1733	4	N8	60	41.72	146	14.01	45	146
14/7	1910	6	N4	60	42.28	146	19.81	19	150
14/7	1940	7	N5	60	43.82	146	19.84	9	25
15/7	920	9	N3	60	40.66	146	23.48	13	40
15/7	110	12	N6	60	38.35	146	22.24	40	125
15/7	1230	14	N2	60	38.78	146	26	14	40
16/7	1600	17	N1	60	39.49	146	35.07	11	30
16/7	840	23	C5	60	43.43	147	15.15	47	150
16/7	955	25	C6	60	41.26	147	13.55	51	150
16/7	1110	27	C7	60	39.66	147	12.66	51	150
16/7	1240	28	C8	60	37.93	147	15.58	55	150
17/7	820	33	C4	60	36.76	147	36.29	167	150
17/7	910	34	C3	60	38.87	147	37.89	186	150
17/7	1117	37	C2	60	41.1	147	33.04	186	150
17/7	1630	41	OFFSHORE C1	60	42.13	147	34.17	93	150
17/7	1830	43	C1	60	44.29	147	34.24	149	150
18/7	940	44	S1	60	19.44	148	9.82	72	150
18/7	1050	46	S2	60	16.95	148	10.87	79	150
18/7	1235	48	OFFSHORE S2	60	14.54	148	9.93	93	150
18/7	1300	49	S4	60	13.62	148	10.57	93	150
18/7	1845	53	S3	60	16.24	148	7.73	76	150
19/7	715	55	S5	60	15.6	148	2.47	93	150
19/7	820	57	S7	60	13.95	147	59.59	93	150
19/7	1445	60	S8	60	9.32	147	59.6	557	150
19/7	1645	63	S6	60	12.08	148	4.84	73	150
19/7	1700	64	S6	60	12.08	148	4.84	73	150
21/7	1255	67	OFFSHORE N2	60	45.47	146	38.62	13	35
22/7	1020	77	OFFSHORE N3	60	56.54	146	42.5	62	150
22/7	1300	82		60	57.78	146	45.31	19	40
22/7	1545	84	REEF IS.	60	51.61	146	49.23	10	40
22/7	1625	85	OFFSHORE N1	60	50.42	146	56.44	53	150
23/7	900	88	N. NAKED IS.	60	41.33	147	27.78	7	20
23/7	1035	91	NW OF NAKED	60	41.27	147	28.99	7	20
23/7	1330	95	OUTSIDE BAY	60	38.85	147	26.4	8	20
23/7	1430	98		60	37.93	147	28.18	11	30
24/7	1425	105	NE INGOT IS	60	31.52	147	37.12	6	20
24/7	1810	109	BAY OF ISLES	60	25.02	147	37.58	40	35
25/7	1430	114	GREEN ISLAND	60	14.58	147	25.81	18	16
26/7	1600	119	FOX FARM	59	58.43	148	10.39	40	35
27/7	1248	122	N. EVANS ISLAND	60	7.17	147	53.38	35	30
29/7	1320	127	KNIGHT IS. PASS; OFFSHORE S1	60	12.84	148	59.87	350	150
29/7	1110	130	DANGEROUS PASSAGE	60		148			
29/7	1120	131	DAN. PASS. OFFSHORE S3	60	18.5	148	10.54	300	150

Table 2. Plankton samples collected in APEX process studies, cruise 98-1.
Gear codes: N = NIO/Tucker Trawl G = Bongo

Date	Time	Station #	Gear	Location	Lat. In	Long In.	Bottom Depth (m)	Gear Depth (m)
14/7	2327	1	G	981N8	60 41.873	146 14.372	146	60
14/7	2337	1	N	981N8	60 41.924	146 14.187	146	53
15/7	35	2	G	981N7	60 40.722	146 17.962	132	60
15/7	53	2	N	981N7	60 40.68	146 13.219	131	?
15/7	325	2	N	981N7	60 40.897	146 18.247	101	52
15/7	405	3	G	981N4	60 42.167	146 19.883	56	55
15/7	417	3	N	981N4	60 42.223	146 19.811	41	43
15/7	2242	4	G	981N5	60 43.976	146 19.777	25	22
15/7	2250	4	N	981N5	60 43.946	146 19.685	31	21
15/7	2327	5	G	981N3	60 41.622	146 23.026	41	35
15/7	2340	5	N	981N3	60 40.957	146 23.374	35	44
16/7	10	6	G	981N6	60 39.117	146 22.336	118	60
16/7	21	6	N	981N6	60 39.1	146 22.349	118	49
16/7	45	6	N	981N6	60 38.79	146 22.555	124	49
16/7	146	7	G	981N2	60 38.908	146 27.075	43	40
16/7	230	7	N	981N2	60 38.849	146 26.822	45	23
16/7	318	8	G	981N1	60 39.639	146 35.287	37	30
16/7	330	8	N	981N1	60 39.787	146 35.292	37	18
16/7	2252	9	G	981C8	60 37.829	147 17.273	105	60
16/7	2305	9	N	981C8	60 37.845	147 17.121	112	49
16/7	2325	9	N	981C8	60 37.944	147 16.280	156	46
16/7	2343	9	G	981C8	60 38.03	147 15.495	173	60
17/7	11	10	G	981C7	60 39.773	147 14.837	140	60
17/7	25	10	N	981C7	60 39.811	147 14.208	155	56
17/7	49	10	N	981C7	60 39.891	147 13.527	155	61
17/7	123	11	G	981C6	60 41.161	147 14.620	161	60
17/7	137	11	N	981C6	60 41.193	147 14.291	162	52
17/7	157	11	N	981C6	60 41.297	147 13.556	170	67
17/7	239	12	G	981C5	60 43.29	147 15.446	170	60
17/7	250	12	N	981C5	60 43.3	147 15.590	180	64
17/7	311	12	N	981C5	60 43.289	147 16.290	98	73
17/7	328	12	N	981C5	60 43.256	147 17.087	145	57
17/7	349	12	N	981C5	60 43.226	147 17.644	158	61
17/7	2255	13	G	981C1	60 43.92	147 33.803	592	60
17/7	2305	13	N	981C1	60 43.919	147 34.152	592	53
17/7	2326	13	N	981C1	60 43.94	147 33.235	>560	50
18/7	13	14	G	981C2	60 40.816	147 33.253	>275	60
18/7	23	14	N	981C2	60 40.82	147 33.066	>275	50
18/7	43	14	N	981C2	60 40.873	147 32.292	153	62
18/7	125	15	G	981C3	60 38.787	147 36.651	560	60
18/7	135	15	N	981C3	60 38.785	147 36.682	560	67
18/7	153	15	N	981C3	60 38.653	147 37.566	560	67
18/7	235	16	G	981C4	60 36.791	147 36.734	585	60
18/7	244	16	N	981C4	60 36.82	147 36.708	585	56
18/7	303	16	N	981C4	60 36.806	147 37.302	585	67
18/7	2234	17	G	981S2	60 16.808	148 11.346	151	60
18/7	2250	17	N	981S2	60 16.711	148 11.256	195	59
18/7	2325	18	G	981S1	60 18.934	148 10.219	181	60

Table 2 (cont).

Date	Time In	Station #	Gear	Location	Lat. In	Long In.	Depth (m)	Depth (m)
18/7	2335	`18	N	981S1	60 18.934	148 10.219	181	67
18/7	2352	18	N	981S1	60 19.329	148 10.161	181	64
19/7	35	19	G	981S3	60 17.184	148 7.824	94	60
19/7	46	19	N	981S3	60 17.107	148 7.880	86	64
19/7	107	19	N	981S3	60 16.561	148 8.198	137	55
19/7	152	20	G	981S4	60 13.362	148 9.920	108	60
19/7	206	20	N	981S4	60 13.317	148 9.928	114	49
19/7	224	20	N	981S4	60 13.229	148 10.649	137	55
19/7	243	20	N	981S4	60 13.448	148 10.957	238	70
19/7	303	20	N	981S4	60 13.749	148 11.552	238	66
19/7	2235	21	G	981S6	60 11.759	148 5.482	238	60
19/7	2246	21	N	981S6	60 11.817	148 5.413	238	53
19/7	2303	21	N	981S6	60 12.133	148 5.093	238	70
19/7	2345	22	G	981S5	60 15.604	148 3.635	485	60
19/7	2350	22	N	981S5	60 15.621	148 3.778	485	52
20/7	13	22	N	981S5	60 15.845	148 3.325	183	67
20/7	50	23	G	981S7	60 14.925	147 58.993	640	60
20/7	100	23	N	981S7	60 14.672	147 59.222	647	47
20/7	134	23	N	981S7	60 13.972	147 59.388	640	50
20/7	219	24	G	981S8	60 9.296	147 59.507	256	60
20/7	228	24	N	981S8	60 9.265	147 59.665	256	46

Table 3. Purse Seine sets in cruise 98-1 for jellyfish collection

Date	Time	Station #	Location	Lat.		Long.		Bottom Depth (m)
14/7	1520	1	N7	60	40.96	146	18.07	90
14/7	1715	3	N8	60		146		147
14/7	1845	5	N4	60	42.26	146	19.99	63
14/7	1947	8	N5	60	43.74	146	20	26
15/7	935	10	N3	60	40.54	146	23.61	43
15/7	1035	11	N6	60	38.4	146	22.98	129
15/7	1150	13	N2	60	38.89	146	27.69	41
16/7	1525	16	N1	60	39.54	146	36.03	40
16/7	808	22	C5	60	43.33	147	15.17	191
16/7	940	24	C6	60	41.21	147	13.34	174
16/7	1035	26	C7	60	39.7	147	12.55	179
16/7	1255	29	C8	60	37.92	147	15.57	175
17/7	745	32	C4	60	36.48	147	37.1	549
17/7	925	35	C3	60	38.85	147	37.87	610
17/7	1035	36	C2	60	40.9	147	33.09	610
17/7	1700	42	C1	60	44	147	34.06	4877
18/7	950	45	S1	60	19.48	148	10	235
18/7	1130	47	S2	60	16.87	148	10.61	274
18/7	1310	50	S4	60	13.61	148	10.57	305
18/7	1905	54	S3	60	16.22	148	7.66	244
19/7	730	56	S5	60	15.72	148	2.8	305
19/7	830	58	S7	60	13.99	147	59.57	305
19/7	1455	61	S8	60	9.43	147	59.35	244
19/7	1705	65	S6	60	12.06	148	4.75	241

Table 4. Samples to identify acoustic targets in cruise 98-1									
Gear Types: V=Video, J=Herring Jig, D=Dip Net, B=Beach Seine, F=Fry Seine									
Date	Time	Gear	Lat.		Long.		Bottom Depth (m)	Gear Depth (m)	ID
18/7	1710	V	60	19.55	148	9.2	21	5	jellyfish
19/7	1520	V	60	9.31	147	59.87	305	20	jellyfish
21/7	1015	V	60	44.04	146	43.99	27	21	herring ad
21/7	1350	V	60	49.21	146	39.09	46	14	herring
21/7	1440	V	60	48.69	146	42.29	30	9	herring
21/7	1620	V	60	49.71	146	19.54	0	6	jellyfish
22/7	935	V	60	56.24	146	37.81	107	14	salmon
22/7	1115	V	60	57.73	146	44.58	53	12	herring
23/7	1125	V	60	39.56	147	29.83		3	
28/7	945	V	60	3.34	148	7.79	200	40-60	
29/7	800	V	60	20.22	148	16.17	15	1-5	jellyfish
29/7	1045	V	60	19.06	148	11.68	25	10	herring
30/7	1030	V	60	16.51	147	20.06	25	50	herring YOY
21/7	1400	J	60	49.21	146	39.09	45	14	herring ad
22/7	1130	J	60	57.73	146	44.58	50	12	
27/7	1745	J	60	59.19	148	6.23	100	40	herring ad
27/7	1900	J	60	0.84	148	10.52	100	2	black cod
28/7	2015	J	60	1.81	148	8.87	125	20	herring ad
28/7	950	J	60	3.34	147	7.79	200	40-60	herring ad
24/7	1555	D	60	29.82	147	37.9	10	1	herring YOY
25/7	1320	D	60	15,25	147	24.46	5	3	herring YOY
26/7	955	D	60	4.44	147	50.53	10	1	herring YOY
30/7	1045	D	60	17.87	147	19.16	70	1	herring YOY
30/7	830	B	60	42.62	147	29.58	1	1	herring YOY
22/7	840	F	60	55.46	146	37.22			herring
22/7	1430	F	60	54	146	47.92			herring YOY
25/7	1300	F	60	15.25	147	24.46	5	3	herring YOY
26/7	1115	F	60	6.91	147	53.33	4	3	herring YOY

Table 5. Biomass density (g/m2) estimated in three study areas of PWS in July 1998.

CATEGORY	BIOMASS DENSITY (G/M2) NORTH	CENTRAL	SOUTH
ROCKFISH	0.008	0.075	1.116
SANDLANCE	0.001	0.011	0.000
YOY HERRING	0.000	0.000	0.000
1+HERRING	0.139	0.192	0.331
ADULT HERRING	0.009	0.000	19.063
POLLOCK	0.002	0.000	0.000
PLANKTON	0.047	0.081	0.064
TOTAL	0.206	0.358	20.573

Table 6. Biomass density (g/m2) of Avian Vulnerable Energy Sources (AVES) estimated in three study areas of PWS in July 1998

	BIOMASS DENSITY (G/M2)		
1996	NORTH	CENTRAL	SOUTH
SANDLANCE	0.087	0.002	0.001
YOY HERRING	0.027		0.003
1+HERRING	0.948		1.046
TOTAL	1.062	0.002	1.050
1997			
SANDLANCE		0.029	0.023
YOY HERRING	0.313	0.019	0.039
1+HERRING	0.005		
TOTAL	0.318	0.048	0.062
1998			
SANDLANCE	0.001	0.011	
YOY HERRING			
1+HERRING	0.139	0.192	0.331
TOTAL	0.140	0.202	0.331

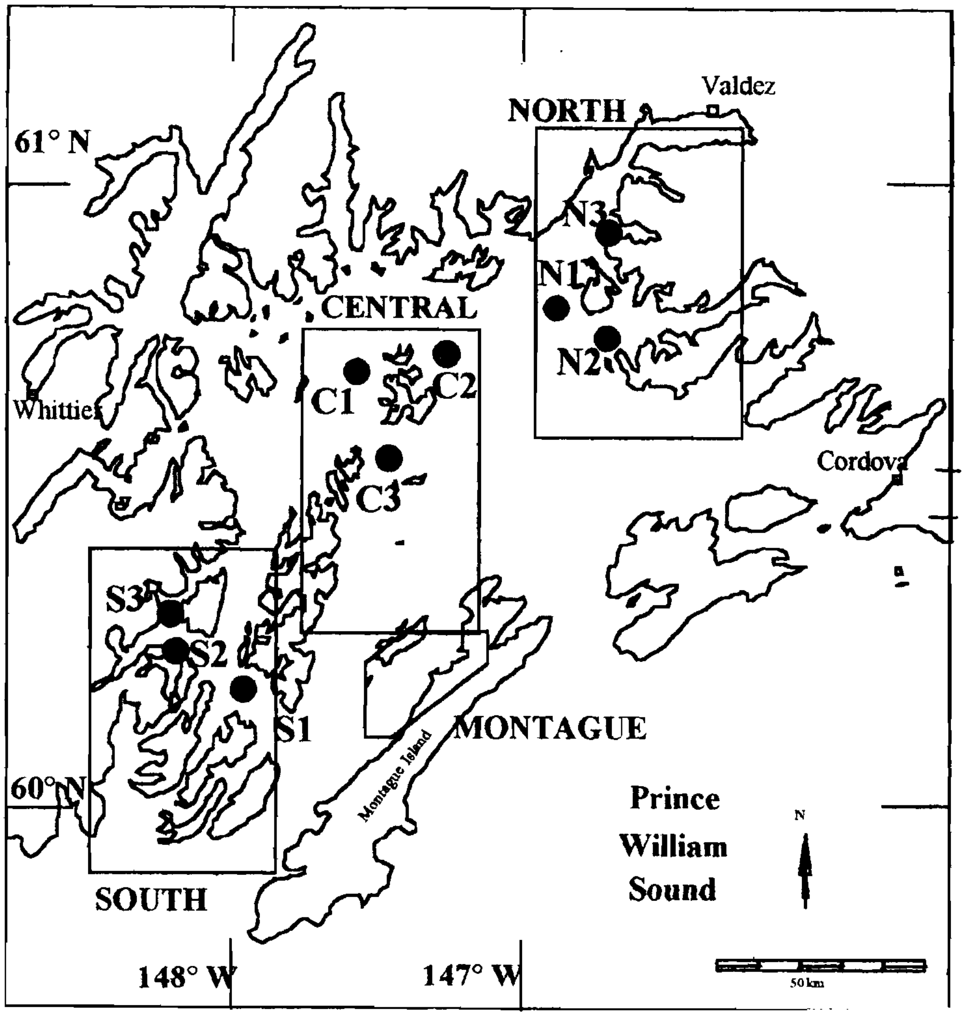

Figure 1. Locations of acoustic survey areas for the APEX project, with locations of CTD casts, 1995 - 1998.

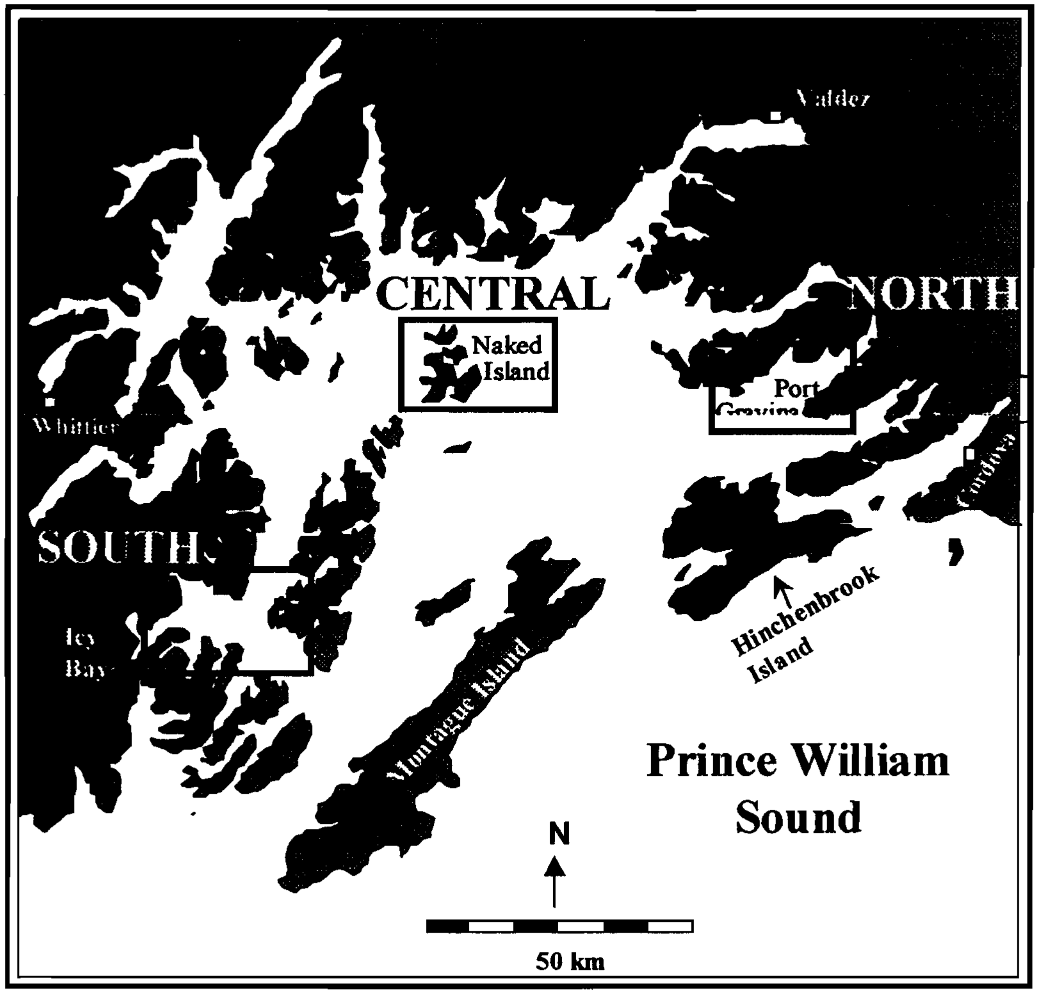

Figure 2. Location of process study areas in Prince William Sound.

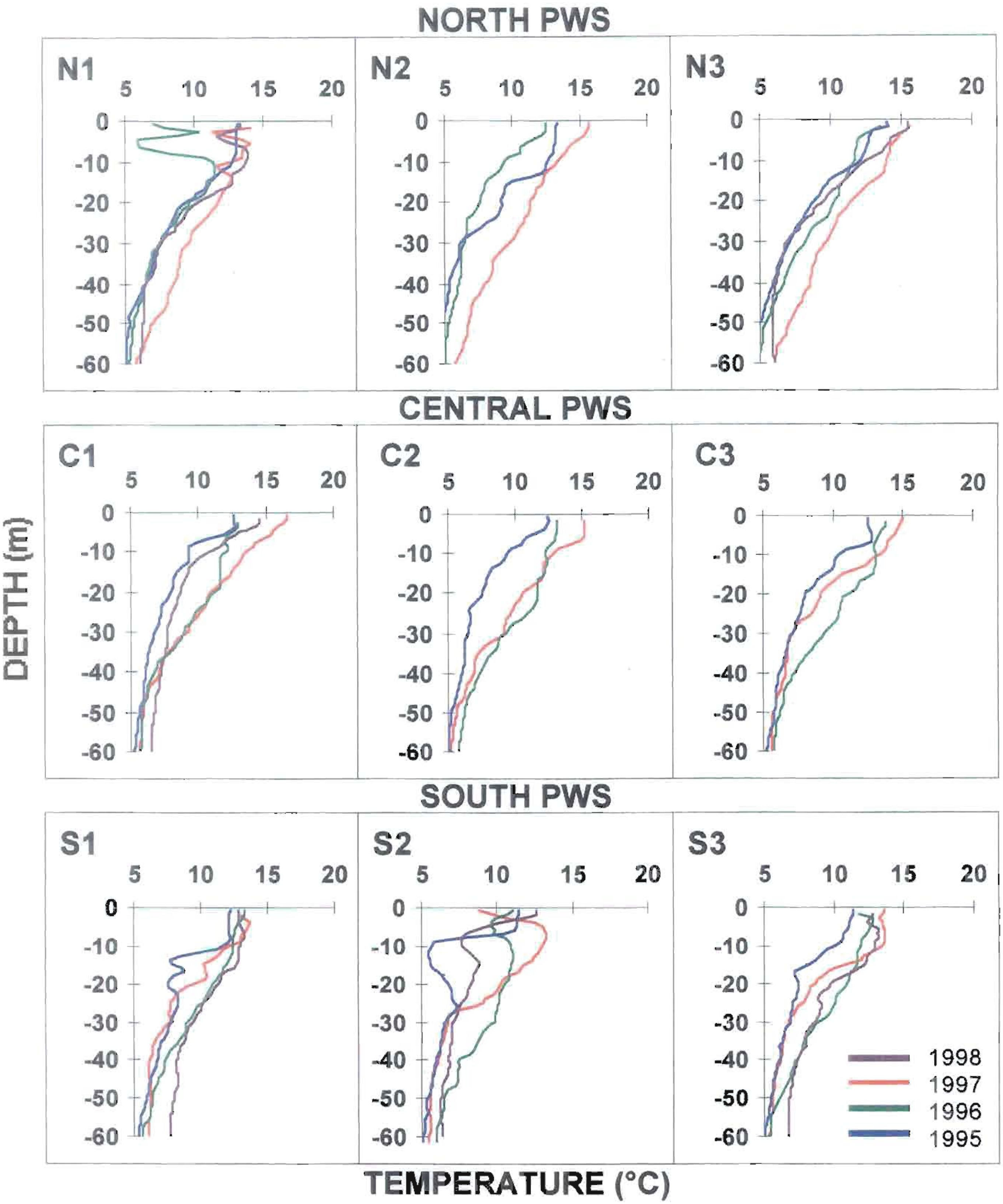

Figure 3. Temperature profiles for three stations in north, central, and south PWS taken between July 15 and August 1, 1995-98 (Fig. 1 shows station locations).

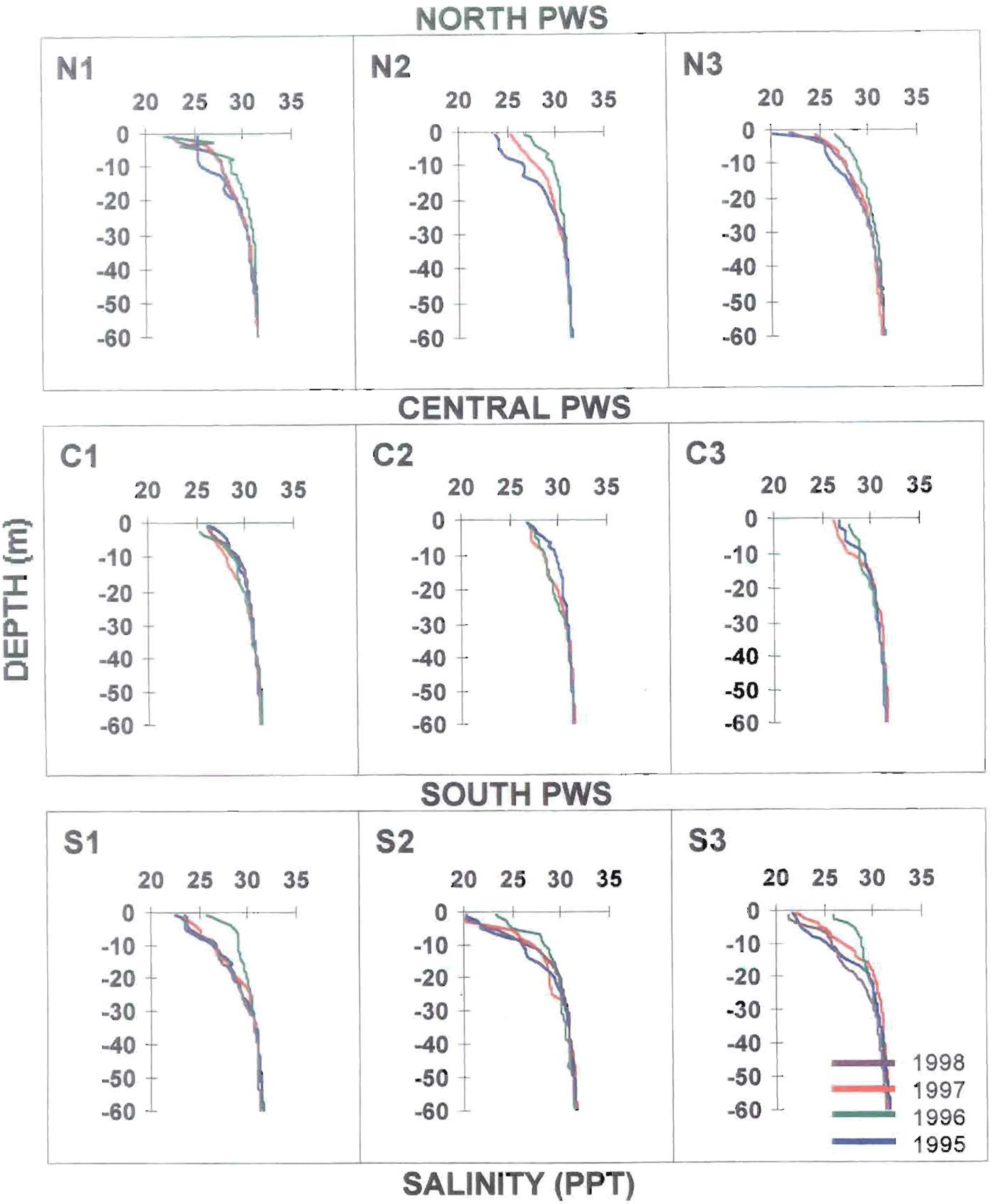

Figure 4. Salinity profiles for three stations in north, central, and south PWS taken between July 15 and August 1, 1995-98 (Fig. 1 shows station locations).

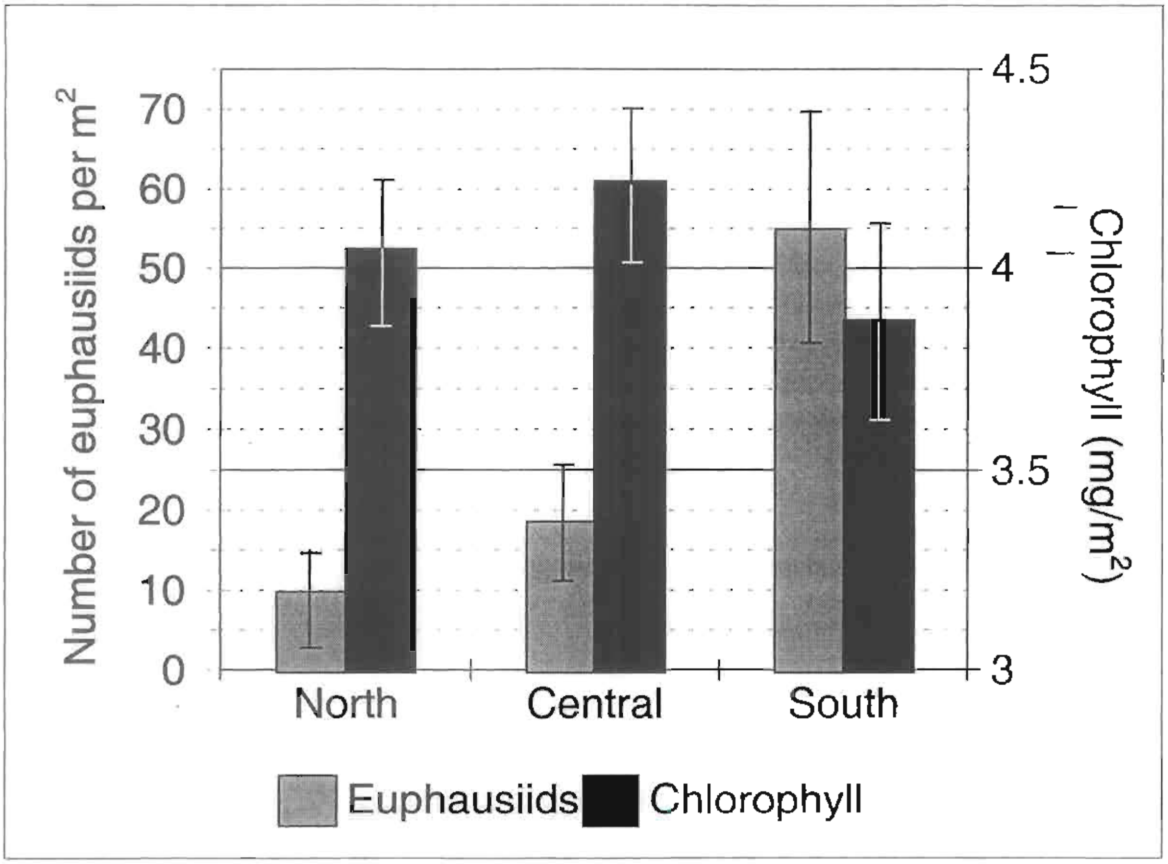

Figure 5. Density of adult euphausiids (*Euphausia pacifica*, *Thysanoessa inermis*, *T. longipes*, *T. raschi* and *T. spinifera*) per m^2 and chlorophyll concentration (mg/m^2) integrated to 50 m or the deepest depth at shallower stations in the North, Central and South study areas. Vertical bars represent $\pm$ one standard error.

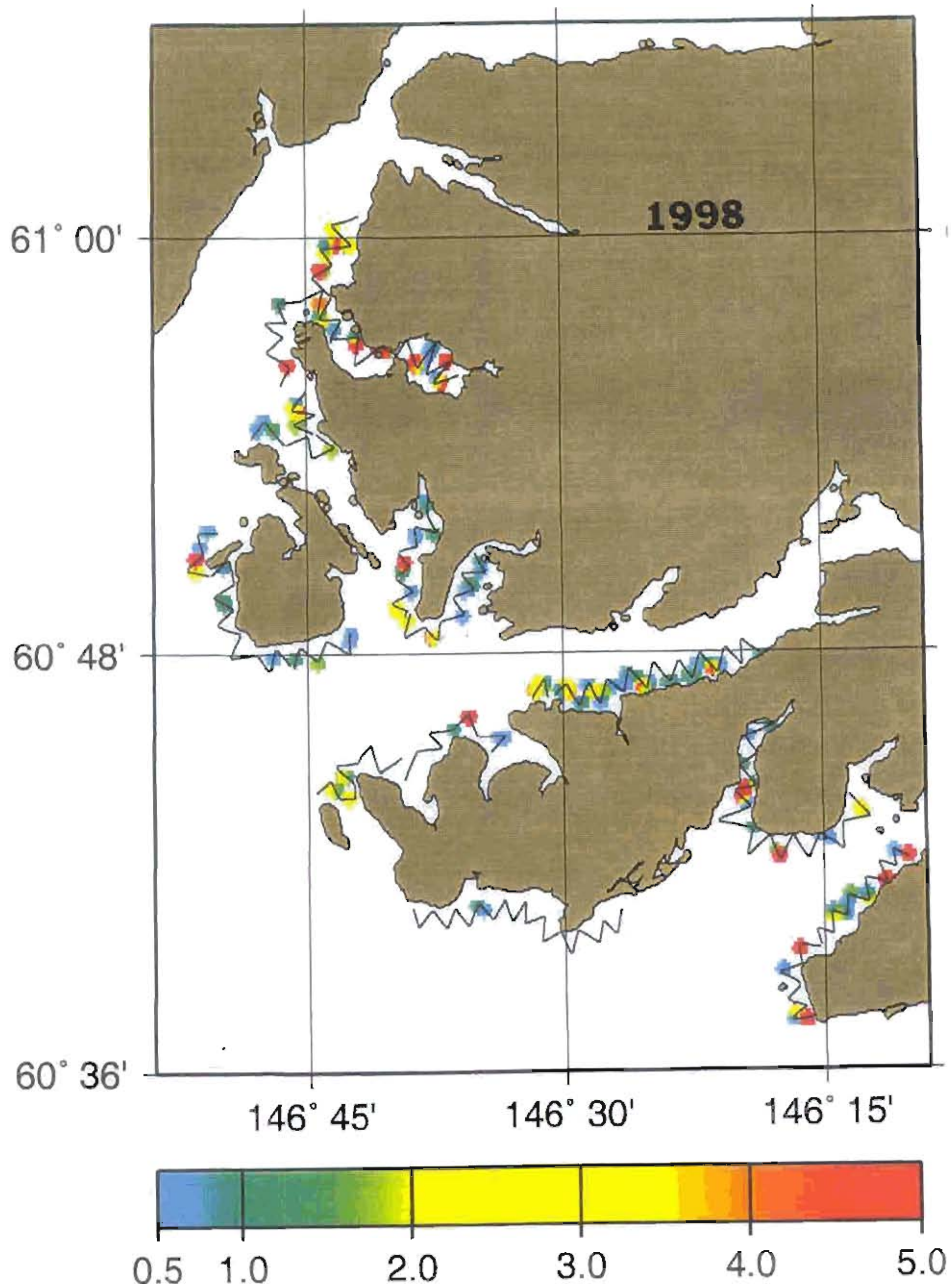

Figure 6. Geographic distribution of acoustic biomass in the North study area in 1998. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.

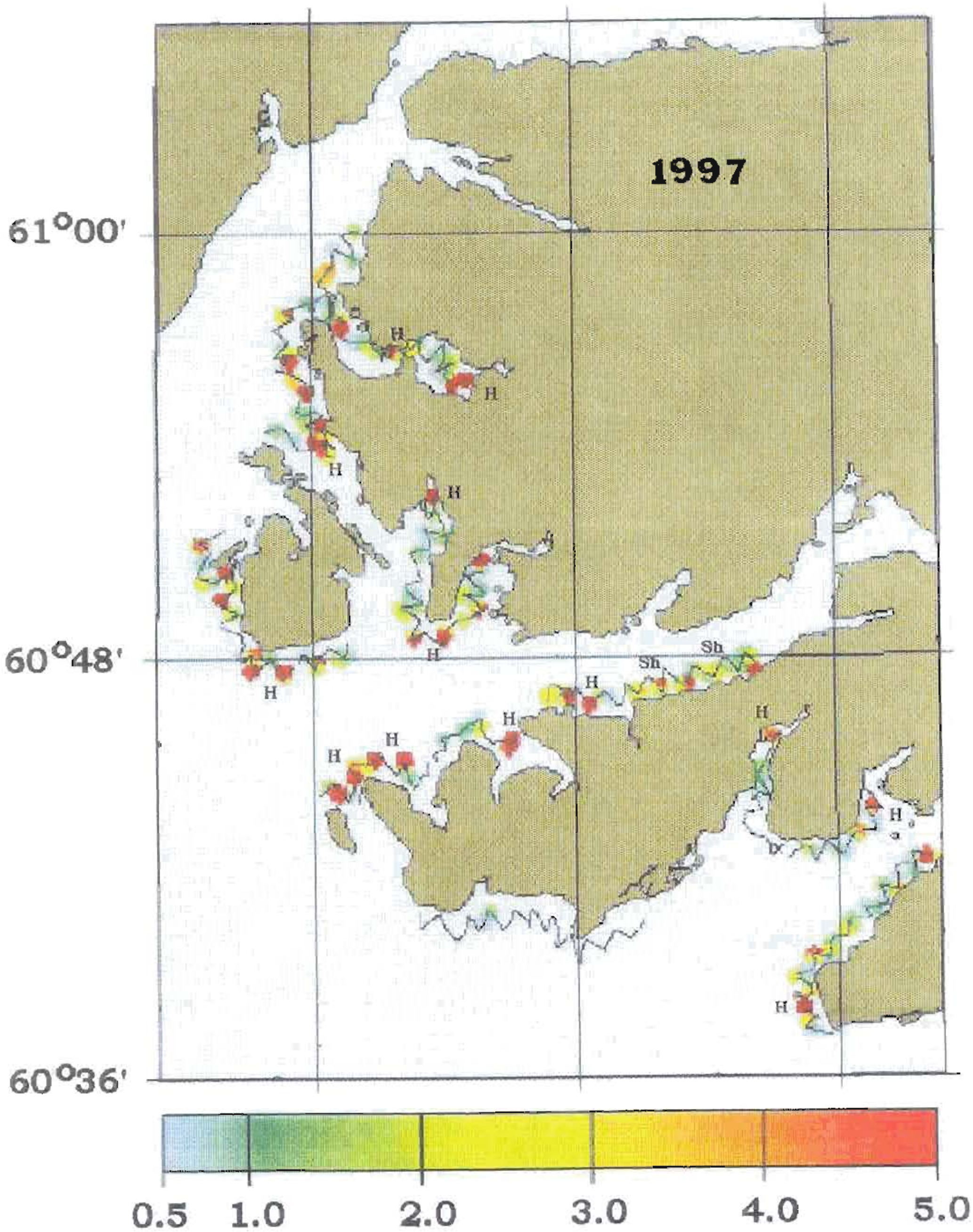

Figure 7. Geographic distribution of acoustic biomass in the North study area in 1997. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.

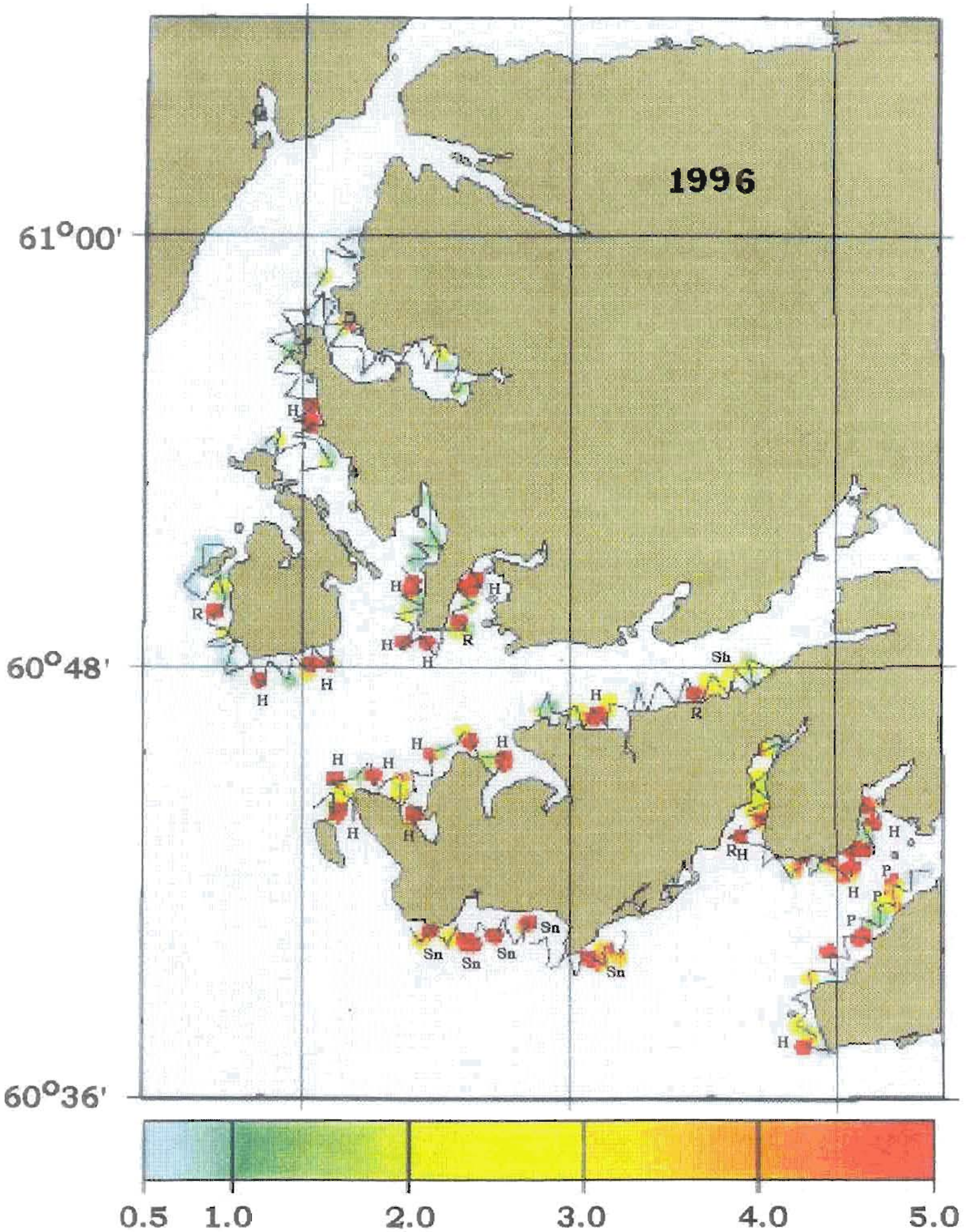

Figure 8. Geographic distribution of acoustic biomass in the North study area in 1996. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.

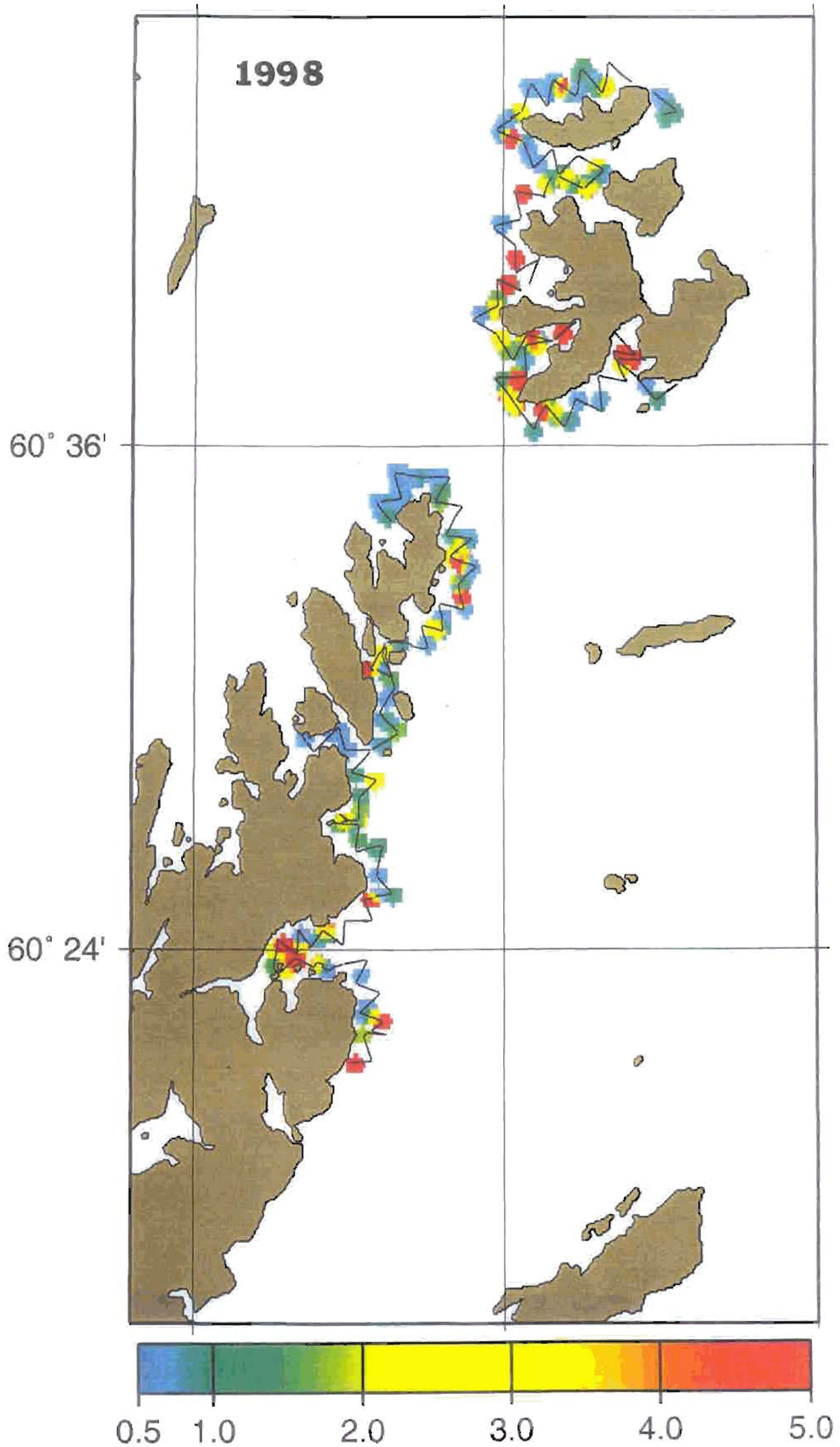

Figure 9. Geographic distribution of acoustic biomass in the Central study area in 1998. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.

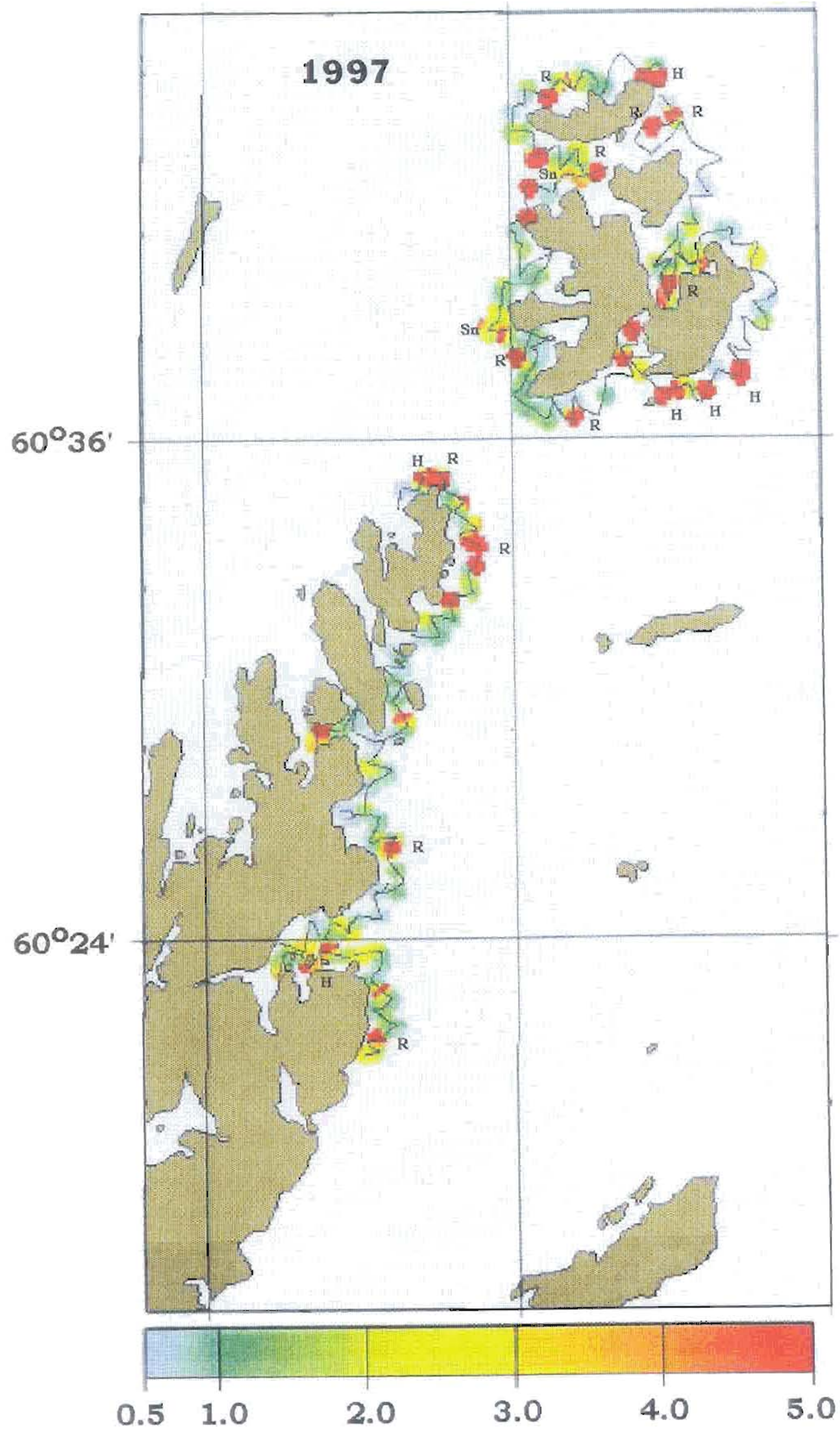

Figure 10. Geographic distribution of acoustic biomass in the Central study area in 1997. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.

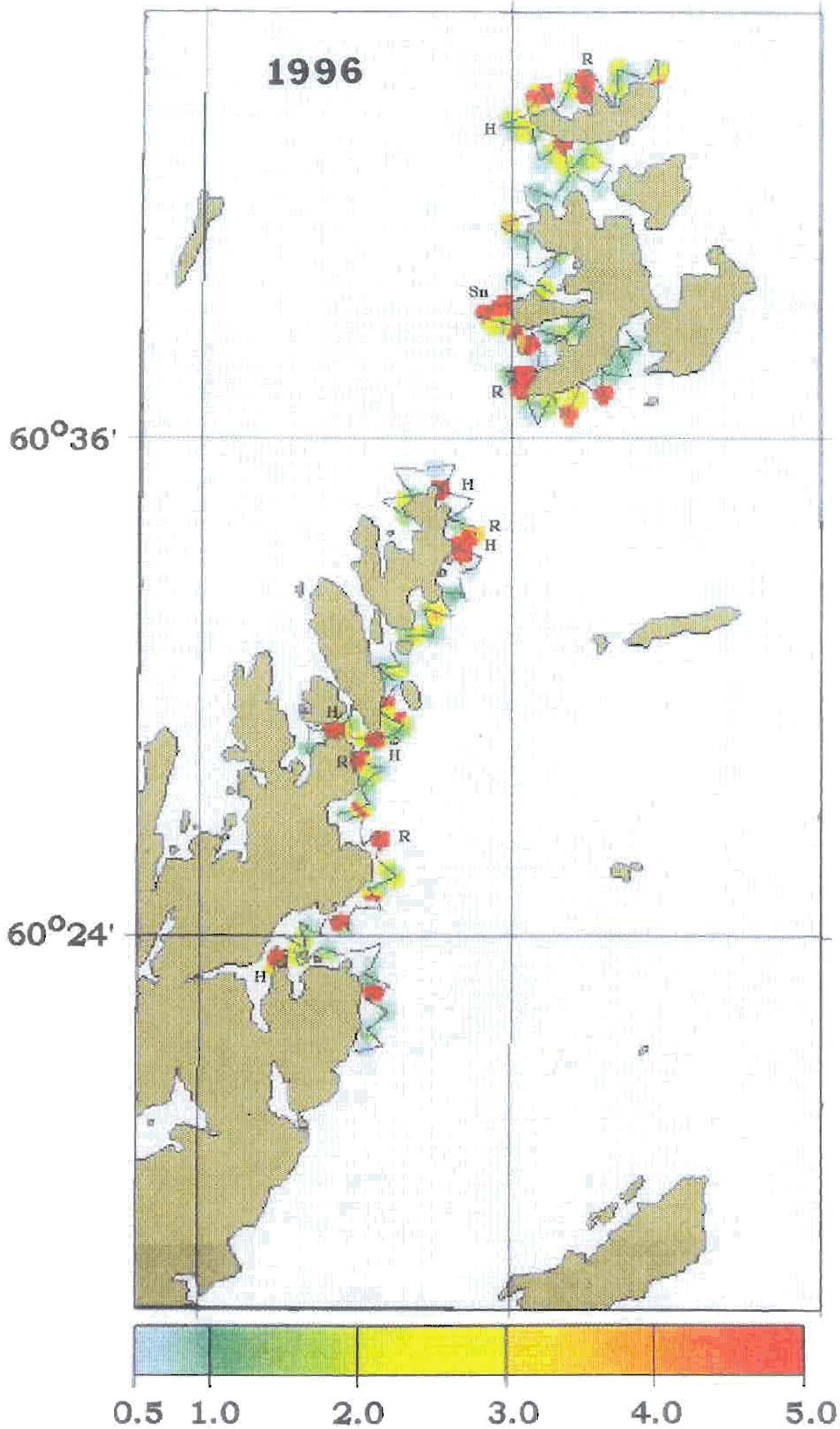

Figure 11. Geographic distribution of acoustic biomass in the Central study area in 1996. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.

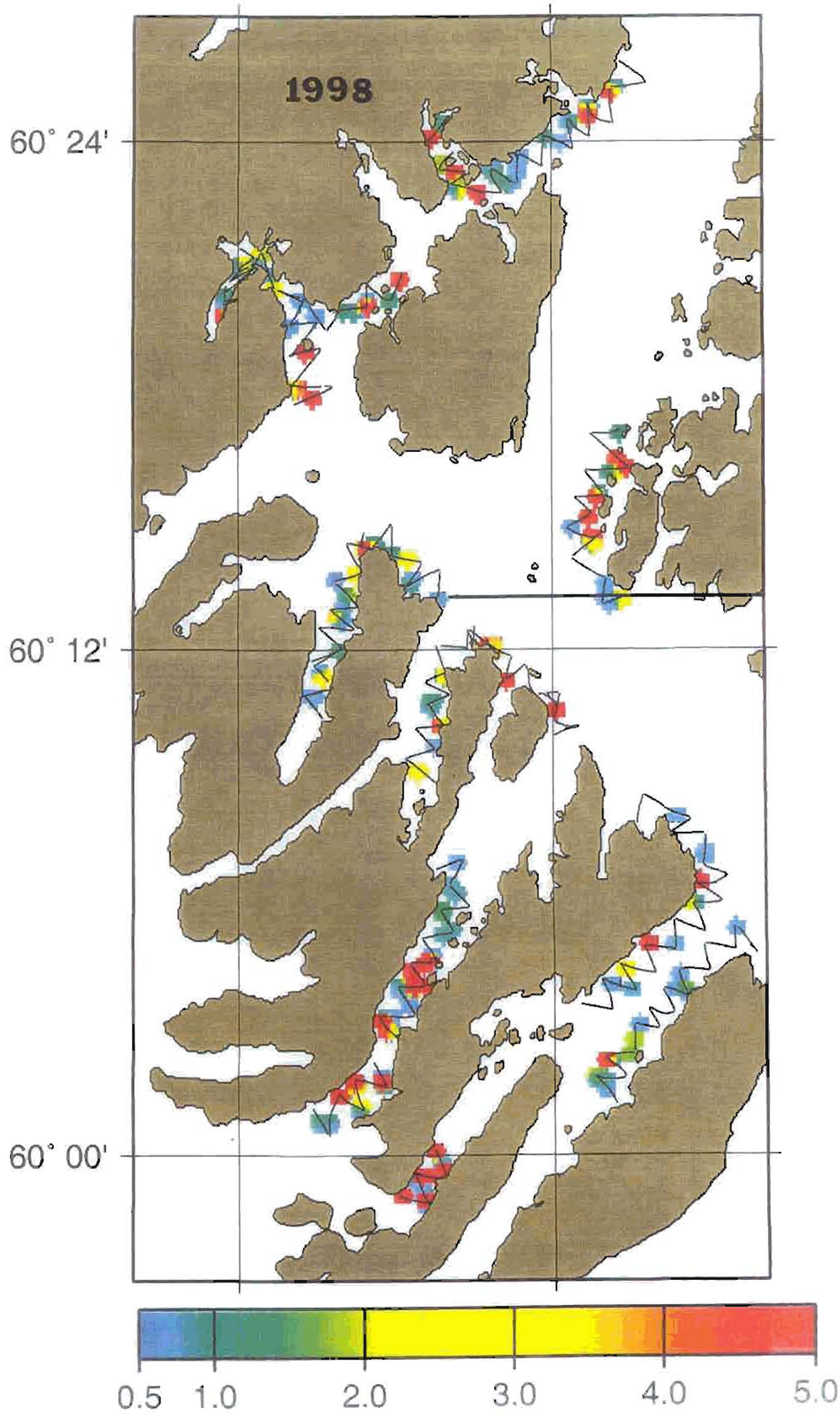

Figure 12. Geographic distribution of acoustic biomass in the South study area in 1998. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.

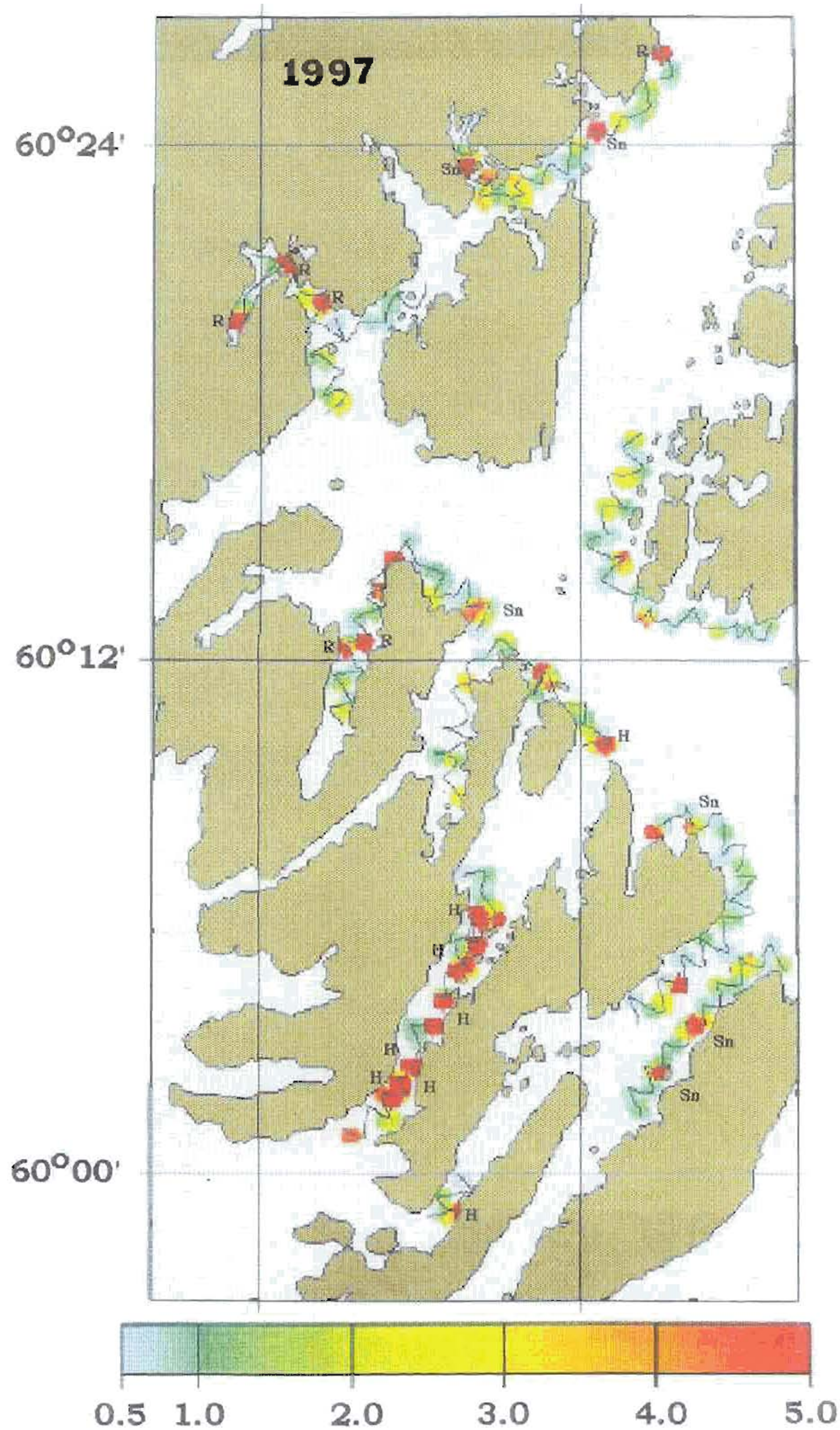

Figure 13. Geographic distribution of acoustic biomass in the South study area in 1997. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.

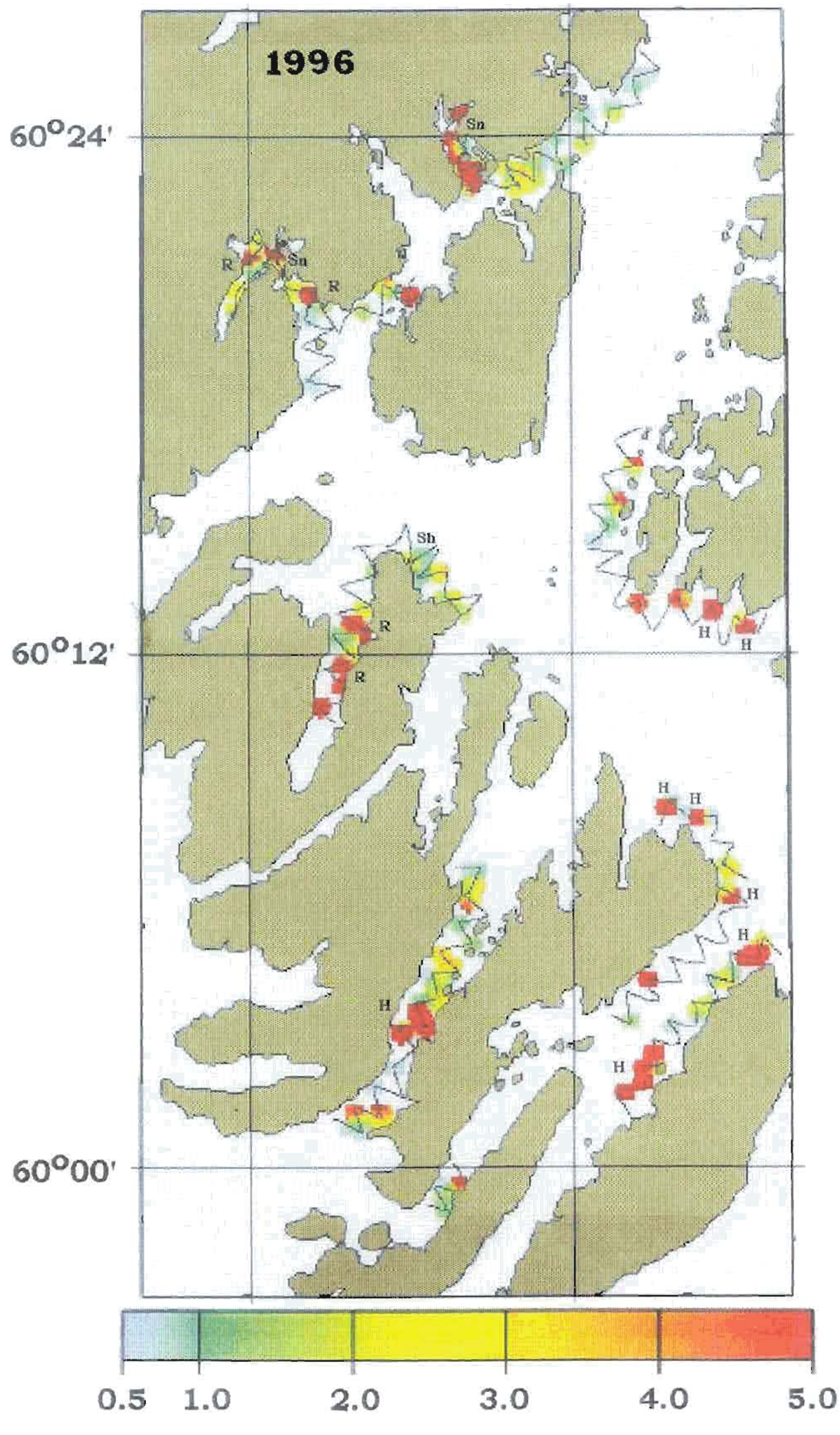

Figure 14. Geographic distribution of acoustic biomass in the South study area in 1996. Color scale units are grams/m^2. Codes for species are H - herring, Sn - sandlance, R - rockfish.