Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment Final Report

Injury to Larval Fish in Prince William Sound

Fish/Shellfish Study Number 19
Final Report

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for:

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Distribution and Abundance of Larval Fishes in Prince William Sound, Alaska, During 1989
After the *Exxon Valdez* Oil Spill

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Study History: Fish/Shellfish Study Number 19 was initiated as a State/Federal Natural Resource Damage Assessment project as part of the 1989 *Exxon Valdez* oil spill study plan. A detailed report was issued in 1990 by B.L. Norcross, B. Holladay, M. Frandsen, and M. Vallarino, entitled Injury to Larval Fish in Prince William Sound, and includes a comprehensive inventory of all larval fishes captured in the study. This report is accessible at the Alaska Resources Library and Information Services in Anchorage, Alaska. The current report includes the chapter "Distribution and Abundance of Larval Fishes in Prince William Sound, Alaska, during 1989 after the *Exxon Valdez* Oil Spill" in Proceedings of the *Exxon Valdez* Oil Spill Symposium (1996) which focuses on the six most abundant finfish taxa encountered. This report also includes appendices providing distribution and abundance data for all species collected.

Abstract: Field studies were conducted in 1989 to determine spatial and temporal variation of finfish larvae in Prince William Sound in the months following the *Exxon Valdez* oil spill. This study contributes basic larval fish occurrence information for Prince William Sound. Unfortunately, it is biased as a baseline because it represents the ecosystem following an oil spill. The patterns of distribution are interpreted in the context of oceanographic patterns affecting transport of oil and larvae. Temporal and spatial distribution and abundance patterns are shown for the six most dominant taxa of larval fishes captured: walleye pollock *Theragra chalcogramma,* northern smoothtongue *Leuroglossus schmidti,* Pacific herring *Clupea pallasi,* capelin *Mallotus villosus,* rockfishes *Sebastes* spp., and flathead sole *Hippoglossoides elassodon.* Most larval fishes were in the upper 50 m of the water column and either concentrated in the oiled western portions of Prince William Sound or were transported through those areas by the same processes that moved the oil. Appendices provide temporal, spatial and geographic distribution and abundance of all fishes collected (44 species or species groups) on a gross scale including all of Prince William Sound and Resurrection Bay.

Keywords: Capelin, *Clupea pallasi*, distribution, *Exxon Valdez* oil spill, flathead sole, *Hippoglossoides elassodon*, larval fishes, *Leuroglossus schmidti, Mallotus villosus,* northern smoothtongue, Pacific herring, Prince William Sound, rockfishes, *Sebastes spp.*, *Theragra chalcogramma*, walleye pollock.

Project Data: *Description of data*: CTD information and zooplankton samples were collected from Prince William Sound, Alaska in 1989. Zooplankton samples were sorted for larval fish. Larval fish were identified to lowest taxonomic classification and measured. *Format*: All fish data is currently in R:BASE 3.1; CTD data is in raw data format on diskette or tape. *Custodian*: All data is on the computer of Michele Frandsen; copies are also on diskette or tape. All are located at the Fisheries Oceanography Laboratory, Institute of Marine Science, University of Alaska Fairbanks. *Availability*: Upon request.

Citation:

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Distribution and Abundance of Larval Fishes in Prince William Sound, Alaska, during 1989 after the *Exxon Valdez* Oil Spill

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Abstract.—Field studies were conducted in 1989 to determine spatial and temporal variation of finfish larvae in Prince William Sound in the months following the *Exxon Valdez* oil spill. This study contributes basic larval fish occurrence information for Prince William Sound. Unfortunately, it is biased as a baseline because it represents the ecosystem following an oil spill. The patterns of distribution are interpreted in the context of oceanographic patterns affecting transport of oil and larvae. Temporal and spatial distribution and abundance patterns are shown for the six most dominant taxa of larval fishes captured: walleye pollock *Theragra chalcogramma*, northern smoothtongue *Leuroglossus schmidti*, Pacific herring *Clupea pallasi*, capelin *Mallotus villosus*, rockfishes *Sebastes* spp., and flathead sole *Hippoglossoides elassodon*. Most larval fishes were in the upper 50 m of the water column and either concentrated in the oiled western portions of Prince William Sound or were transported through those areas by the same processes that moved the oil.

Several species of finfishes are sensitive to toxic hydrocarbons during the egg and larval stages (Kuhnhold 1974; Falk-Petersen and Kjorsvik 1987). Toxic effects of hydrocarbons on fish eggs can be both immediate and acute (Rice et al. 1976; Smith and Cameron 1979) or prolonged and sublethal (Kuhnhold 1977; Rice et al. 1978; Solbakken et al. 1984). The effects of oil pollutants on larvae depend on larval age, size, and species (L. Foyn and B. Serigstad, Institute of Marine Research, unpublished data). Environmental factors such as temperature and salinity also affect toxicity (Rice et al. 1978). The severity of these effects appears to be dependent on a complex interaction of factors, including spatial and temporal distribution of spawning, developmental stage of larvae, population dynamics of species, spill location and timing, and hydrodynamics of the area (Spaulding et al. 1985).

Not all fish larvae are affected equally by hydrocarbons. In Alaskan waters, Pacific herring *Clupea pallasi* are among the most sensitive to oil (Rice et al. 1979). Larvae exposed to oil display jaw deformities and cytogenetic defects (B. Norcross and colleagues, University of Alaska Fairbanks, unpublished). Clupeid larvae collected from the Gulf of Finland exhibit curvature of the posterior notochord (Urho 1991). Gadoid fishes in Norway show altered growth and development of eggs and larvae and morphogenic abnormalities (L. Foyn and B. Serigstad, unpublished data).

Before oil spill impacts on fish larvae can be assessed, there must be some baseline data about larval fish species composition, distribution, and abundance in the spill area. That information, together with field and laboratory studies on similar species, provides a basis for damage assessment. No such studies had been done before the TV *Exxon Valdez* oil spill. Therefore, the main objective of this study was to determine temporal and spatial presence of larval finfishes in Prince William Sound and to relate that to the general physical dispersal patterns affecting transport of oil and larvae in the region during 1989.

Methods

Field Collections

In response to the *Exxon Valdez* oil spill, six 1-week cruises were organized to determine the distribution of larval fishes around Prince William Sound in 1989 (Table 1). Four of the six cruises were conducted by the University of Alaska Fairbanks ship RV *Alpha Helix* (HX), one was by the National Oceanic and Atmospheric Administration (NOAA) ship *John Cobb* (CO), and one was by the chartered fishing vessel FV *Jennie Girl* (JG).

Strata representative of the characteristic hydrological, geological, and ecological areas within Prince William Sound were chosen to cover as much of the open area of the sound as possible. We used overflight maps of oil trajectories to geographically partition Prince William Sound into oiled (Naked Island and Montague) and non-oiled (southeast and north) areas (Figure 1). The specific station locations were randomly chosen within the representative strata. The same stations that were occupied on the first cruise were also occupied on following cruises (weather permitting), and additional stations were added as the season progressed.

TABLE 1.—Larval fish sampling effort in Prince William Sound after the 1989 Exxon Valdez Oil Spill.

Cruise or total	Dates	Number			Volume filtered (m^3)	
		Stations	Nets	Larvae	Mean	SD
HX121	5–11 April	8	13	796	397.4	193.7
HX123	5–11 May	15	42	13,243	42.1	16.5
HX125	1–6 June	15	34	4,037	59.0	21.8
CO8902	7–14 July	18	106	2,542	347.0	964.4
JG001	31 August–10 September	14	67	501	441.5	962.2
HX134	27 October–3 November	24	211	432	309.3	145.7

Early cruises were shared with other investigators and thus had limited time available for sampling larval fishes. The combination of number and location of stations was dependent upon what could be accomplished in 7 d, sampling 24 h per day. Conductivity-temperature-depth (CTD) profiles were taken at all stations at which fish were collected (Norcross et al. 1991).

The gear used to sample larvae during all cruises, except in October (cruise HX134), was a 1-m^2 Tucker Trawl rigged with two or three 505-μ mesh nets towed at 1 m/s. A TSK (Research Nets, Bothell, Washington) or General Oceanics (Miami, Florida) flowmeter was mounted in the mouth of the net to determine the volume of water filtered. A self-contained CTD (SeaBird SBE 19 Profiler, Bellevue, Washington) was attached to the net for each deployment and provided measurements of depth, temperature, and salinity. The net used on the final cruise (HX134) was a MOCNESS (Multiple Opening/Closing Net and Environmental Sensing System) (Wiebe et al. 1985) equipped with nine 1-m^2 505-μ mesh nets. During the first three cruises on the RV *Alpha Helix* (April, May, and June), sample depth was limited to 100 m. On later cruises, depths to 500 m were sampled. Oblique samples in increments of 0 to 25 m, 25 to 50 m, and 50 to 100 m were taken on all cruises, except in April when no 0 to 25 m sample was taken. Intervals of 100 to 200 m and 200 to 500 m were sampled in July (cruise CO8902), September (cruise JG001), and October (cruise HX134). Additionally, oblique tows of 0 to 50 m were sampled in June (cruise HX125), July, September, and October, and a 0 to 100-m interval was sampled in April (cruise HX121), July, September, and October.

After each tow, the contents of each net were immediately rinsed with seawater, sieved, and preserved in alcohol (100% ethanol or isopropyl alcohol) or 10% seawater-mixed formalin. Different preservatives were used in order to allow potential analysis of several factors (e.g., alcohol for aging of otoliths, formalin for identification of eggs). The initial preservative was changed after 24 h, 48 h, and again after 72 h.

Laboratory Analysis

Samples were analyzed at the Fisheries Oceanography Laboratory at the University of Alaska Fairbanks. We did not subsample or split samples. Using dissecting microscopes, the plankton were methodically sorted to isolate fish larvae and eggs.

Larval fishes were identified to lowest taxonomic level using criteria described by Matarese et al. (1989), Hart (1973), and R. Baxter (deceased, unpublished data). Additional larval identifications were made or confirmed by M. Busby and B. Vinter (National Marine Fisheries Service, personal communication). Standard length was measured to the nearest 0.01 mm using a Wild MZ3 dissecting microscope and BioQuant image-analysis system (Fowler 1988) interfaced to a computerized database. This process simultaneously enumerated the larvae because the length data were interfaced with the database containing the cruise information. Because samples had been preserved for more than 3 years before identification and measurement of larvae, lengths were not corrected for preservative shrinkage and condition factors could not be estimated. Fish larvae that were partially or wholly disintegrated or that could not be identified (<10% of total) were discarded and not used in the analysis. Abundance was standardized for volume of water filtered, and catch per unit effort (CPUE) was expressed as number of larvae per 100 m^3.

Statistical Analysis

Chi-square (χ^2) or analysis of variance (ANOVA); (F) followed by a Tukey honestly significant difference (HSD) multiple comparison test, as implemented in SYSTAT (Wilkinson 1988), were used to compare abundance of larvae among areas, sampling times and depths. Significance was established at values of $P < 0.05$, unless otherwise stated.

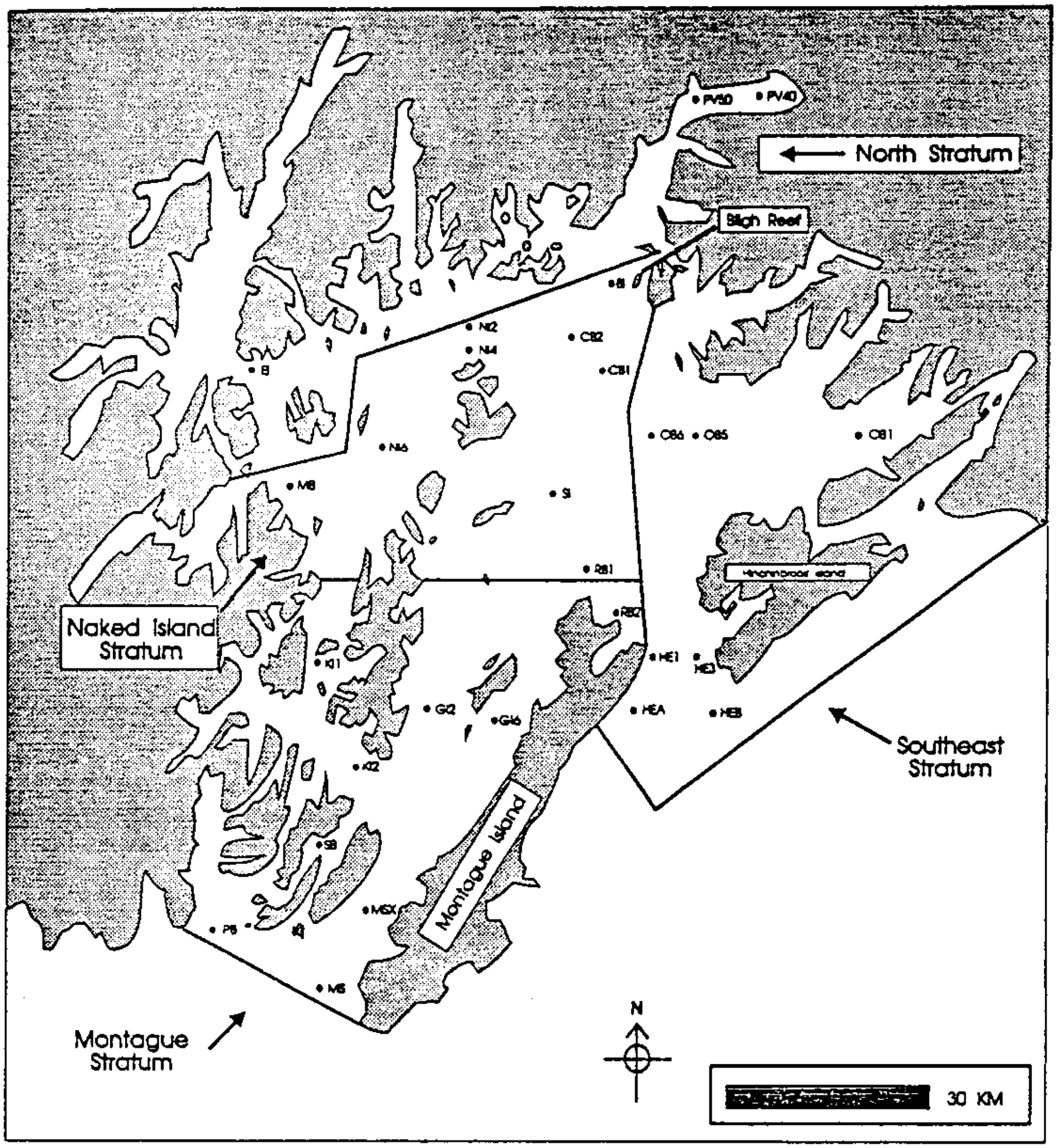


FIGURE 1.—Prince William Sound stations divided into oiled (Naked Island and Montague) and non-oiled (southeast and north) strata.

Results

During the 7 months (April–October) following the 1989 TV *Exxon Valdez* oil spill, six research cruises were conducted in Prince William Sound (Table 1). Altogether, 473 collections were made at various depth increments, with 21,551 fish larvae captured.

Water Characteristics

In April 1989 the open waters of Prince William Sound were nearly isothermal at 4°C (Norcross et al. 1991). Salinity gradually increased from 30 practical standard units (psu) at the surface to 32 psu near the bottom. By May the upper 10 to 20 m had warmed to 5 to 7°C with salinities of 29 to 31 psu,

TABLE 2.—Rank order of absolute abundance of dominant fish species captured in Prince William Sound in 1989.

Species	Total number of fish	Percent of total number
Walleye pollock	13,174	61.55
Northern smoothtongue	2,765	12.83
Pacific herring	1,991	9.24
Capelin	1,298	6.01
Rockfishes	933	4.33
Flathead sole	281	1.30
Other species	1,021	4.74

while the lower layers were 4 to 5°C and 32 psu. Warming progressed in June, with temperatures of 6 to 10°C and salinities of 28 to 30.5 psu; the warm surface layer had deepened to 20 to 50 m. The lower water layers were still 4 to 5°C with a salinity of 32 psu. In July the water temperature warmed to 6 to 15°C above the seasonal thermocline at approximately 50 m. The lower layers also increased in temperature to 5 to 6°C. The upper 5 to 10 m had salinities as low as 15 psu, but below that the salinity was uniformly near 34 psu. Stations near the ocean were cooler and better mixed than those well within the sound. By September surface waters were approximately 13°C at all locations, including those outside Hinchinbrook Entrance. The thermocline had deepened to approximately 50 m. The deep waters were 4 to 6°C. Salinities in September were similar to those in July, with a low-salinity shallow (<10 m) upper layer; however, there was a gradual increase in salinity to the seasonal halocline at approximately 50 m. Below that, salinities were 34 psu. By October the deep waters again were 4 to 6°C. The depth of the thermocline remained at about 50 m with temperatures reduced to 8 to 9°C. Surface waters within Prince William Sound cooled to 5°C, but remained as warm as 9°C outside of the sound. The very-low-salinity upper layer was gone, with surface layers again having a salinity of 28 to 30 psu. The halocline was still at about 50 m.

Presence and Abundance of Larval Fishes

Forty-three taxa of larval fishes were captured in Prince William Sound over 7 months. Gadidae, the single most abundant family of larval fishes, constituted 61.5% of all larvae captured. Other dominant families were at least an order of magnitude lower in abundance: Bathylagidae (13.4%), Clupeidae (9.2%), Osmeridae (6.1%), Scorpaenidae (5.3%), Pleuronectidae (2.1%), Cottidae (1.1%), Ammodytidae (0.4%), Stichaeidae (0.4%), and Bathymasteridae (0.3%). Six taxa made up 95.3% of the total catch for all cruises (Table 2): walleye pollock *Theragra chalcogramma*, northern smoothtongue *Leuroglossus schmidti*, Pacific herring, capelin *Mallotus villosus*, rockfishes *Sebastes* spp., and flathead sole *Hippoglossoides elassodon*.

Spatial and Temporal Distribution of Larval Fishes

The density of larvae peaked in May and decreased with time (Table 3). Most larval fishes were captured in May (82%). Larval abundance was lower in June (15%), July (17%), April (2%), September (<1%) and October (<1%). An ANOVA showed a highly significant difference in larval abundance among months ($F = 8.25$, $P < 0.001$) and a Tukey HSD indicated that abundance of larval fishes in May was significantly greater than that for the other 5 months sampled ($P < 0.001$).

Five of the six overall most abundant fishes, walleye pollock, northern smoothtongue, Pacific herring, flathead sole and rockfishes, were most abundant in May and June (Table 4). Walleye pollock made up 10% of the catch in April, 88% in May, and 43% in June. Though northern smoothtongue were collected in highest numbers in May, they constituted only 6% of the catch, which was dominated by walleye pollock. However, northern smoothtongues constituted 90% of April, 11% of June, 34% of July, 3% of September, and 35% of October catches. Pacific herring were 2% of May, 42% of June, and 3% of July collections. Capelins were found in greatest abundance in July (31%) and September (93%). Only one species, northern smoothtongue, was collected as larvae or very small juveniles during each of the 6 months.

Overall CPUE of larval fishes was not significantly different among strata ($F = 0.457$, $P =$

TABLE 3.—Number of fish larvae, standardized to catch per 100 m^3, by stratum and month in Prince William Sound in 1989.

Stratum	April	May	June	July	September	October
Southeast	1.35	1,320.27	35.29	1.19	3.28	1.02
North	58.25	511.16	101.09	12.37	0.00	0.43
Naked Island	7.44	942.82	180.38	9.11	2.59	0.40
Montague	1.62	408.59	284.26	14.39	0.54	0.33

TABLE 4.—Monthly densities (catches per 100 m³) and sizes of principal fish larvae caught in Prince William Sound (all stations); *N* is the number of larvae caught and measured.

Species	Catch/100 m³	Total length (mm) Mean ± SD	Minimum	Maximum	*N*
		April			
Walleye pollock	1.53	4.16 ± 0.46	3.13	5.28	79
Northern smoothtongue	13.61	9.04 ± 1.50	5.42	14.73	703
		May			
Walleye pollock	650.98	6.61 ± 1.14	3.15	11.0	11,518
Northern smoothtongue	45.44	9.43 ± 2.23	6.40	37.20	804
Pacific herring	18.14	8.16 ± 1.20	5.98	15.84	321
Capelin	0.06		4.57		1
Rockfishes	10.34	4.26 ± 0.55	3.02	6.17	183
Flathead sole	11.47	5.12 ± 1.15	3.70	12.23	203
		June			
Walleye pollock	82.58	13.88 ± 2.85	4.09	23.68	1,656
Northern smoothtongue	20.50	10.78 ± 2.72	4.84	21.76	411
Pacific herring	80.59	12.17 ± 1.87	7.93	19.91	1,616
Rockfishes	2.74	4.54 ± 0.59	3.33	5.80	55
Flathead sole	3.59	9.06 ± 2.80	4.65	17.22	72
		July			
Walleye pollock	0.03	33.11 ± 5.59	26.38	44.00	12
Northern smoothtongue	1.96	17.47 ± 5.37	5.86	73.00	721
Pacific herring	0.15	12.88 ± 3.23	8.58	23.24	54
Capelin	1.80	10.30 ± 3.19	3.86	22.83	661
Rockfishes	1.84	4.44 ± 0.58	2.42	6.22	678
Flathead sole	0.02	21.96 ± 1.71	18.75	23.50	6
		September			
Northern smoothtongue	0.05	40.64 ± 14.56	20.91	56.00	15
Capelin	1.42	13.14 ± 4.52	4.92	43.90	421
Rockfishes	0.06	4.07 ± 0.39	3.30	4.86	17
		October			
Northern smoothtongue	0.17	26.36 ± 3.76	18.53	53.00	111
Capelin	0.32	28.00 ± 8.68	9.53	52.55	212

0.713). The sampling effort in the strata in Prince William Sound was equitable, except in the north station, where the effort was less than that at the other three. The total number of fishes caught shows this, with 17.53% of the larvae captured in north, 18.21% in Montague, 34.95% in southeast, and 29.31% in Naked Island. The catch per unit effort of larval fishes seemed to vary over time (month) and space (strata) ($\chi^2 = 770$, $P < 0.001$). The stratum where abundance was highest varied from north in April, to Montague in June and July, to southeast in May, September, and October (Table 3), but an ANOVA of the number of larval fishes captured in each stratum within a month did not show significant differences among strata.

Each species of fish larvae had a characteristic geographical distribution pattern (Table 5). Walleye pollock were the most abundant larvae in all four strata. Walleye pollock were low in abundance in April, but were found in great abundances in all areas of the sound in May (Figure 2). The highest abundance captured during May was in southeast, followed by Naked Island, north, and Montague strata. By June, most walleye pollock were in the western strata of Naked Island and Montague. For all months combined there was no significant dif-

TABLE 5.—Spatial distribution of individual fish taxa combined over all time periods, standardized to number of larvae per 100 m³ among this study's strata in Prince William sound.

Species	Southeast	North	Naked Island	Montague
Walleye pollock	13.42	17.18	6.07	7.08
Northern smoothtongue	0.71	9.06	1.61	1.91
Pacific herring	0.14	0.64	0.79	3.31
Capelin	0.96	0.22	0.60	1.32
Rockfishes	0.09	0.62	1.19	0.73
Flathead sole	0.42	0.05	0.09	0.13

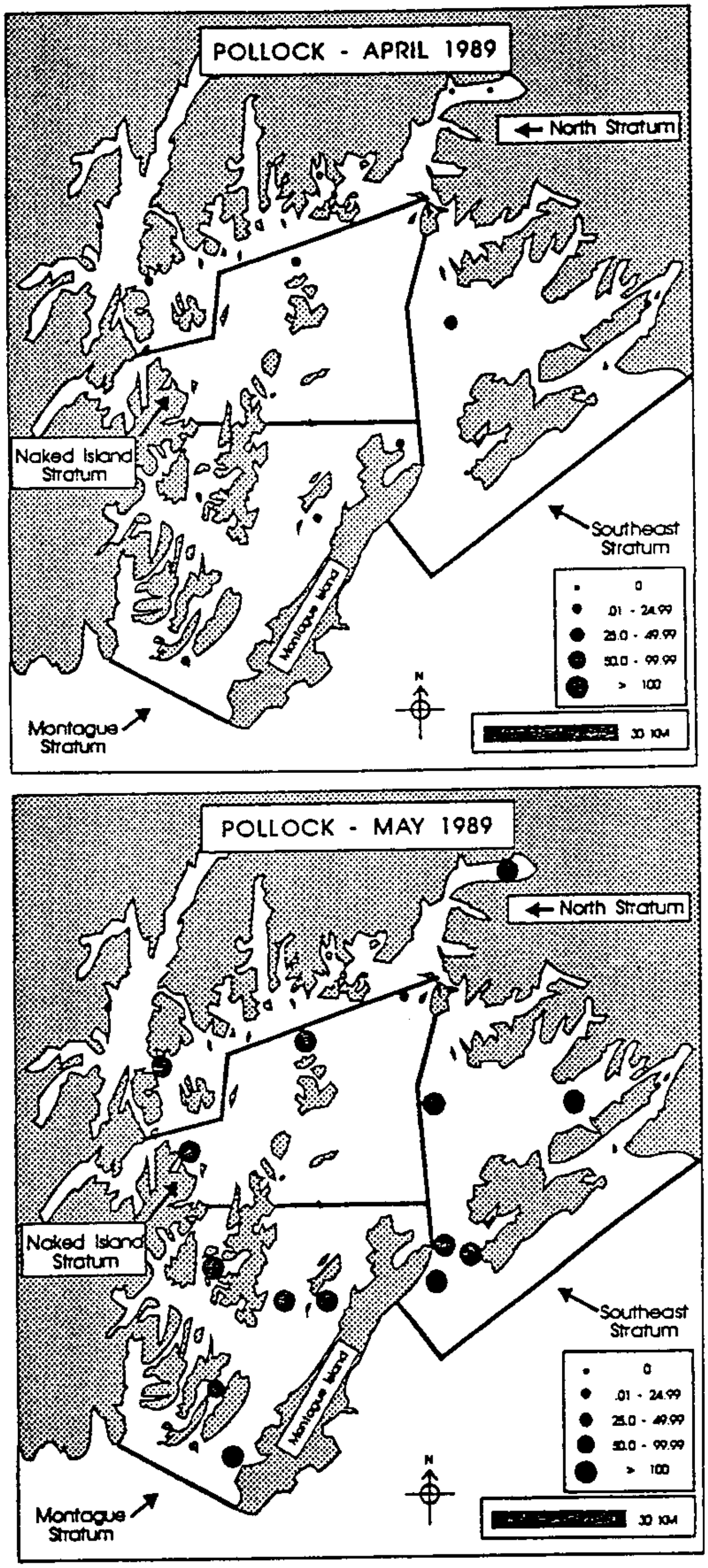
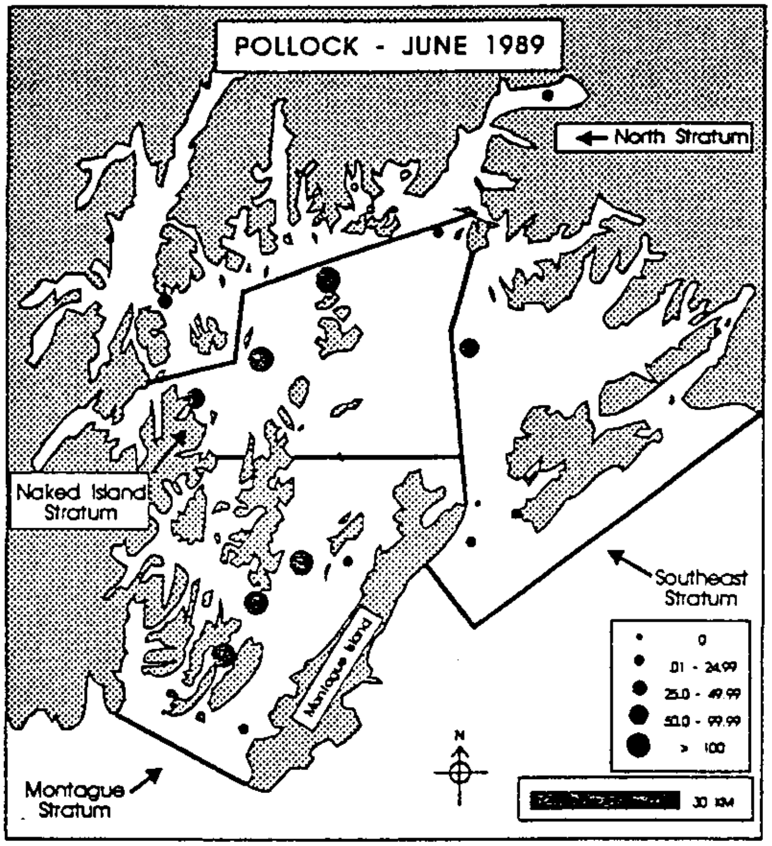


FIGURE 2.—Distribution of walleye pollock larvae in April, May, June, and July 1989, standardized to number per 100 m^3 water filtered.



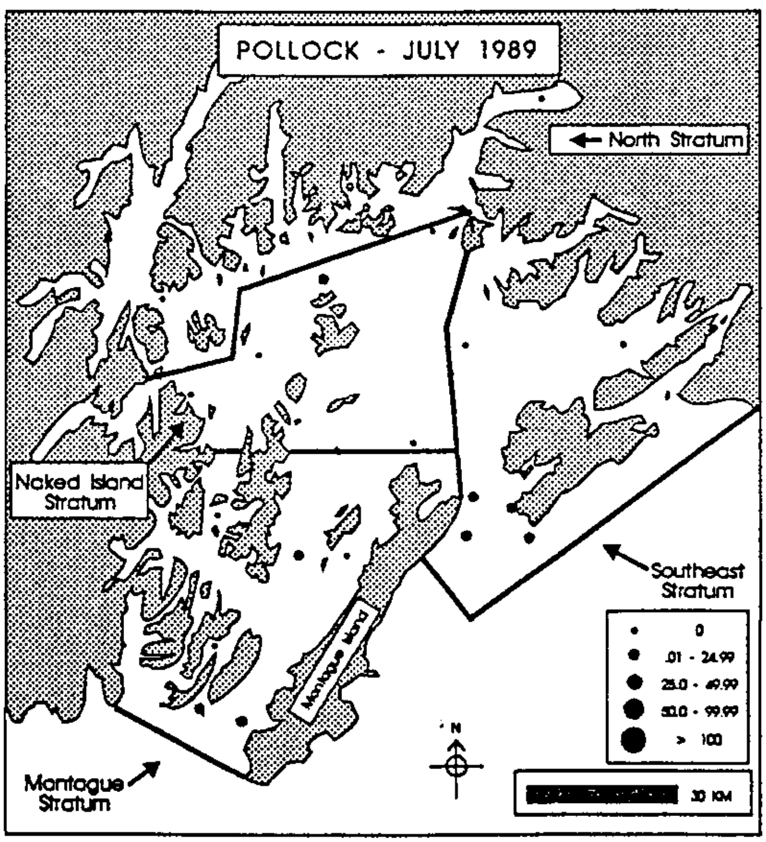


FIGURE 2.—Continued.

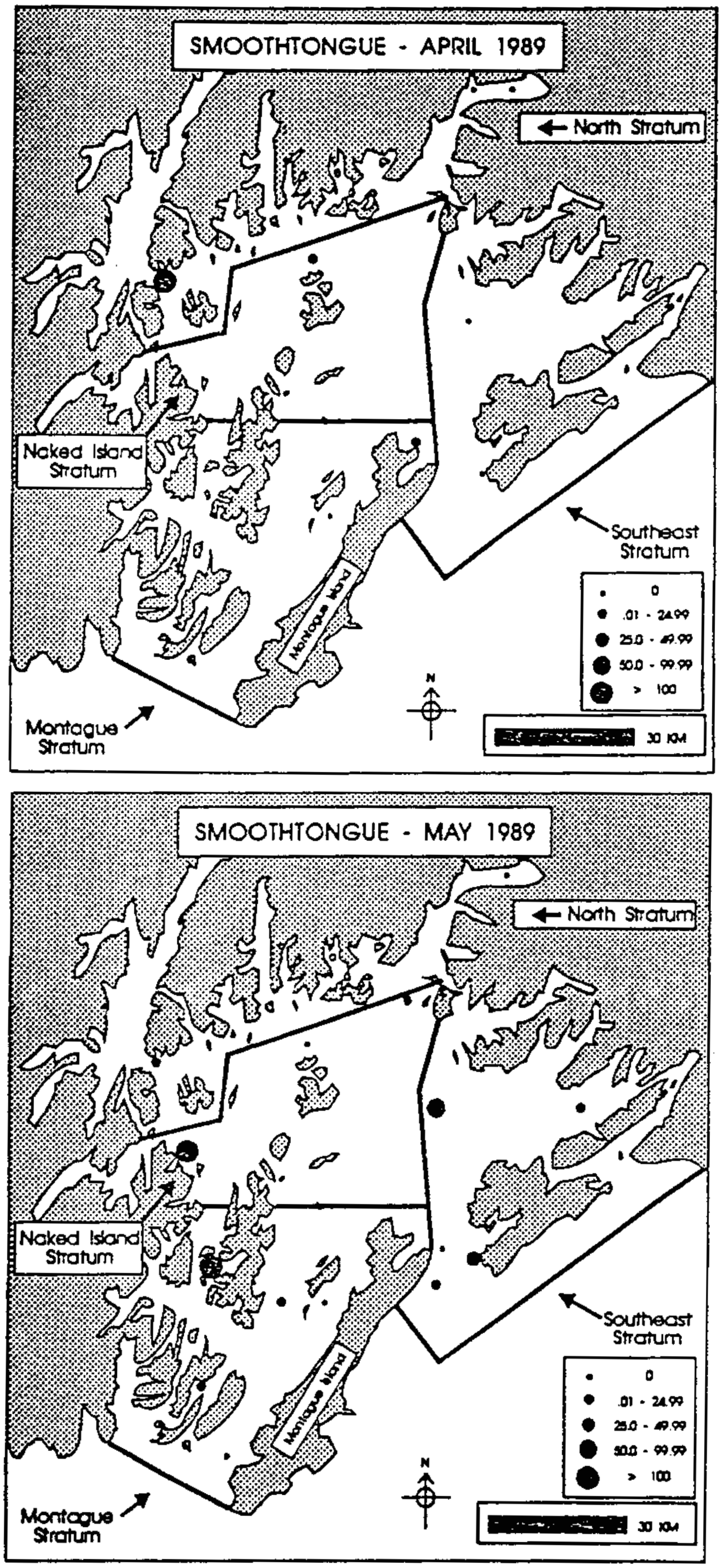
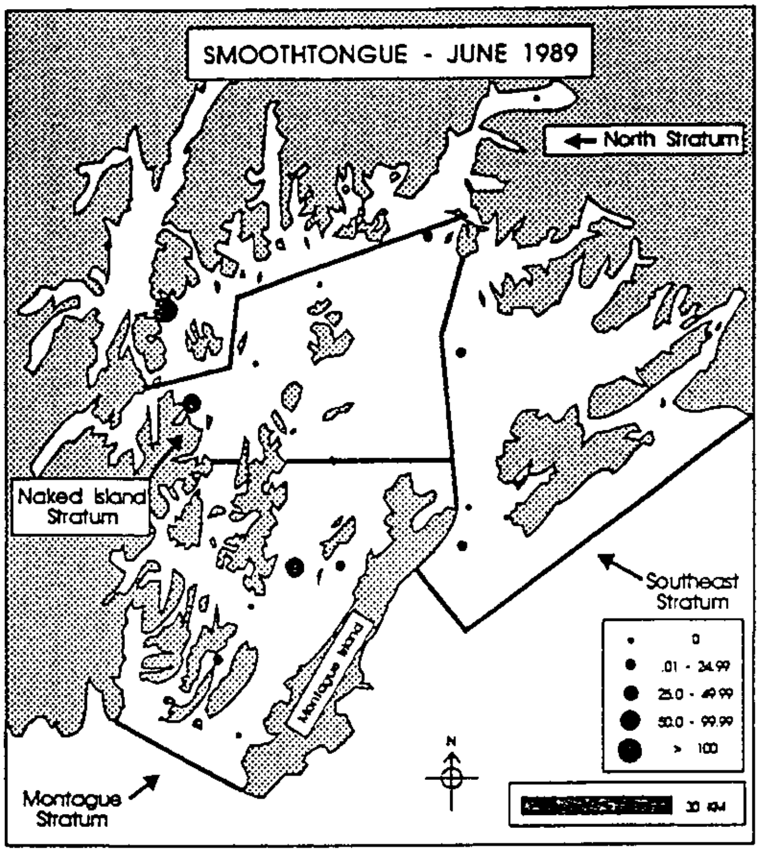


FIGURE 3.—Distribution of northern smoothtongue larvae in April, May, June, July, September, and October 1989, standardized to number per 100 m^3 water filtered.



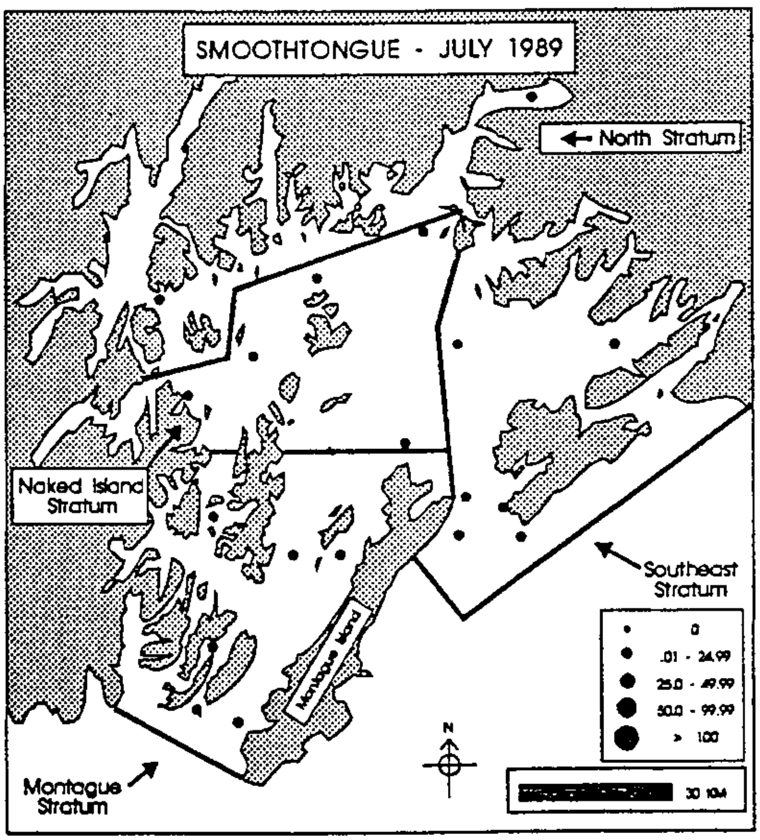
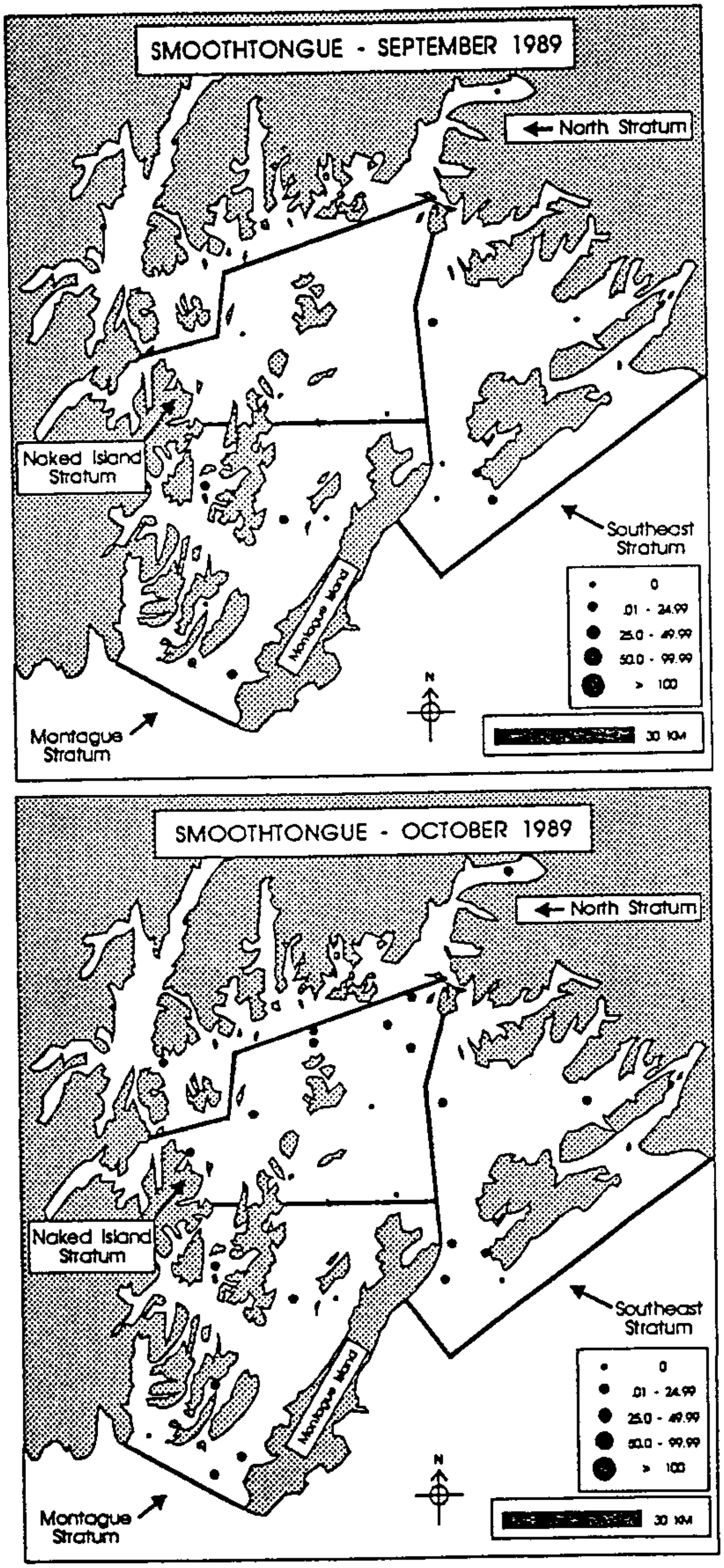


FIGURE 3.—Continued.



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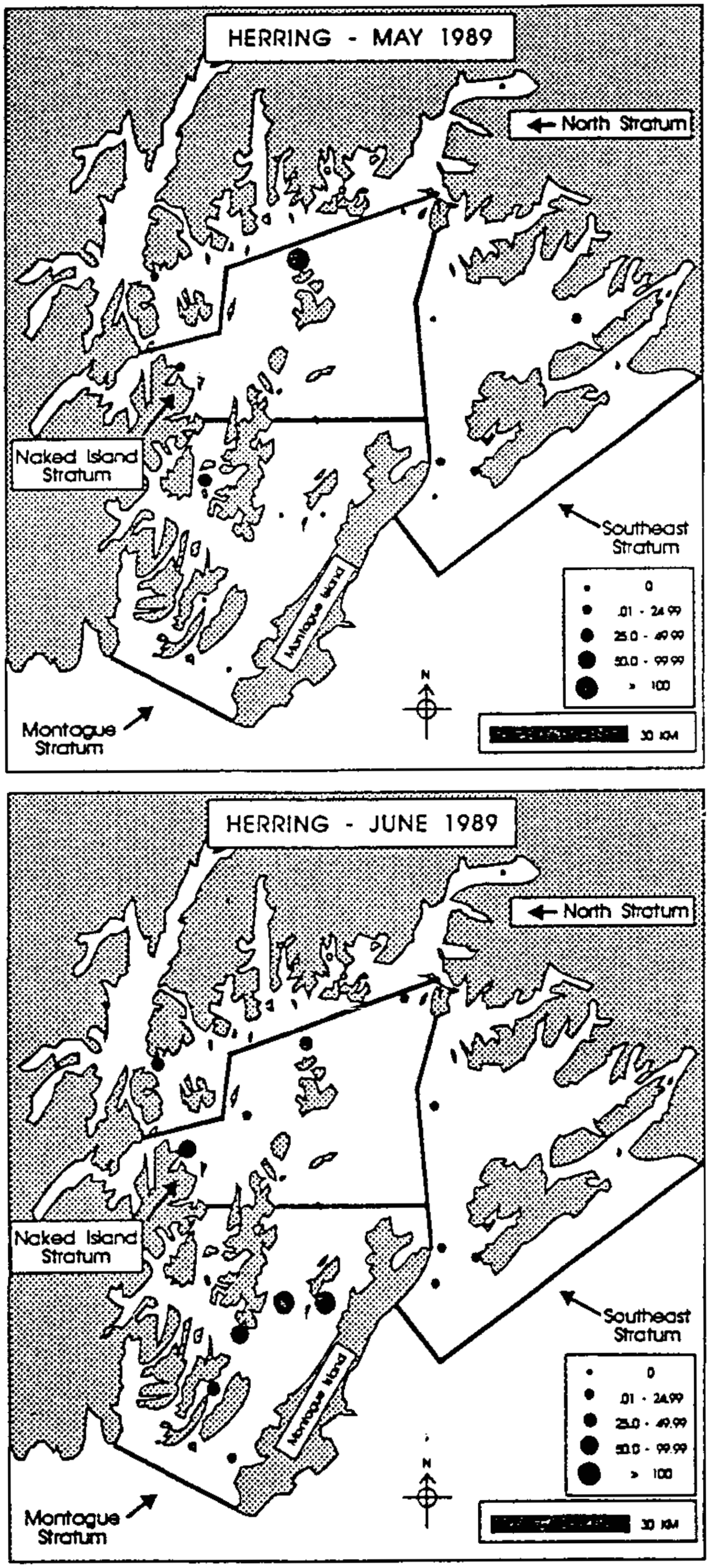


FIGURE 4.—Distribution of Pacific herring larvae in May, June, and July 1989, standardized to number per 100 m^3 water filtered.

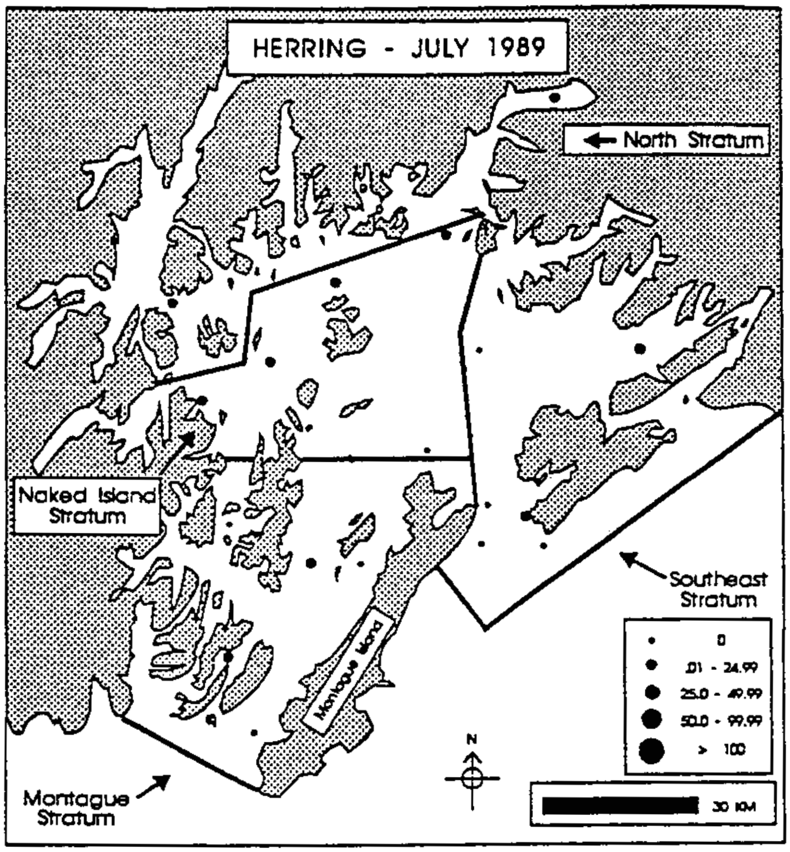


FIGURE 4.—Continued.

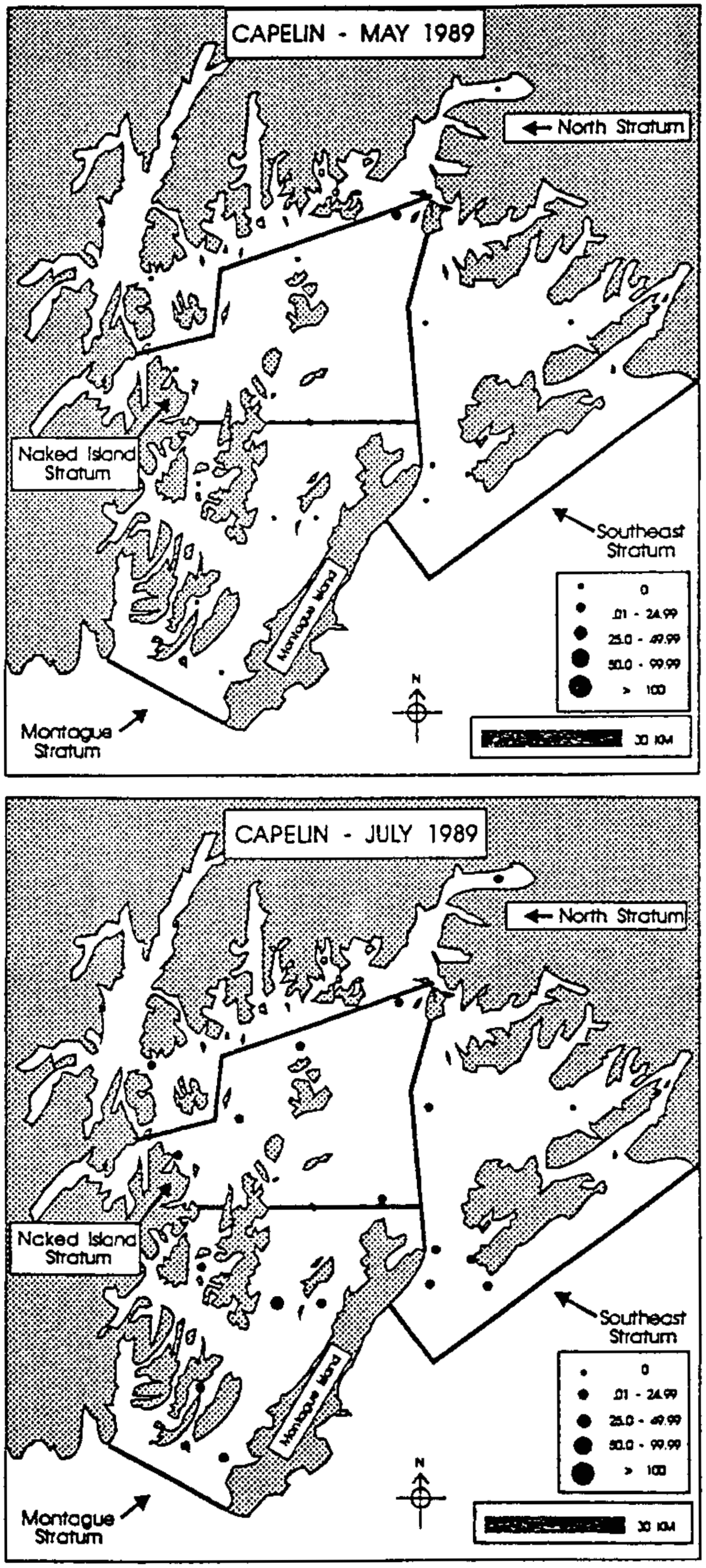
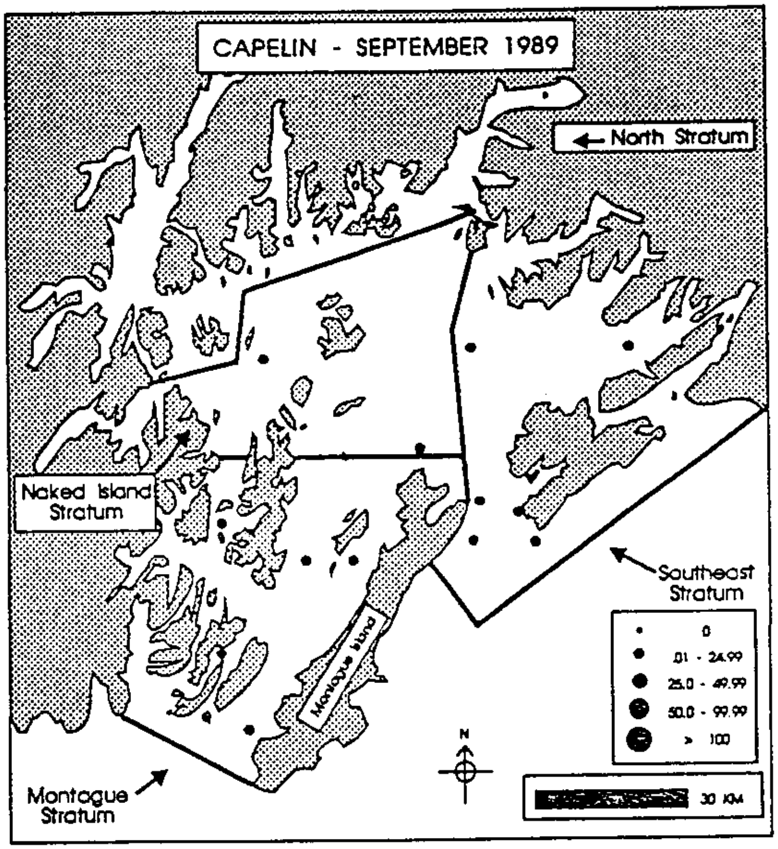


FIGURE 5.—Distribution of capelin larvae in May, July, September, and October 1989, standardized to number per 100 m^3 water filtered.



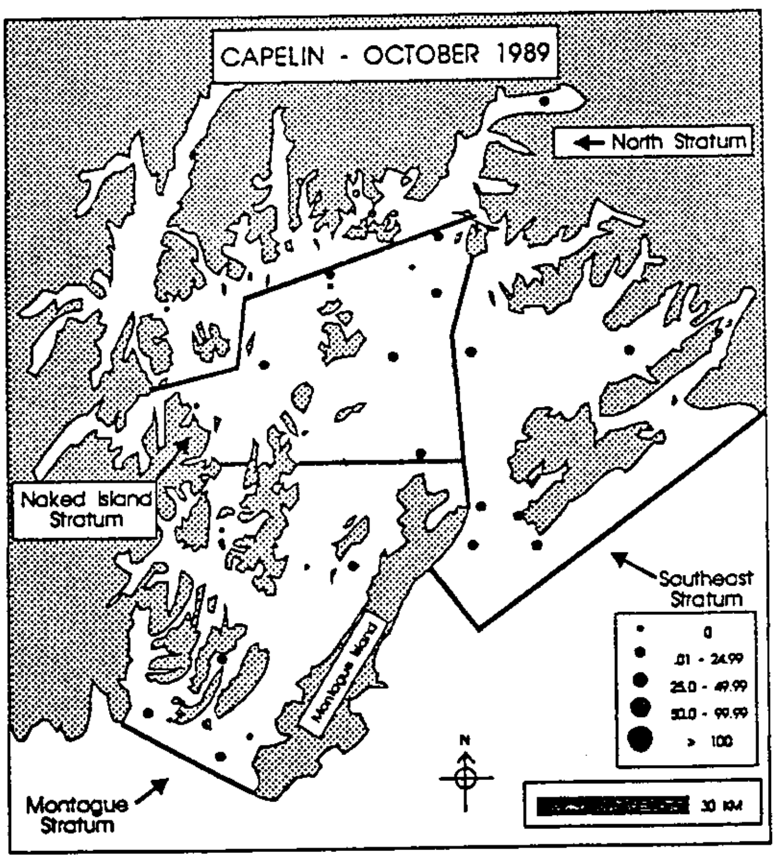


FIGURE 5.—Continued.

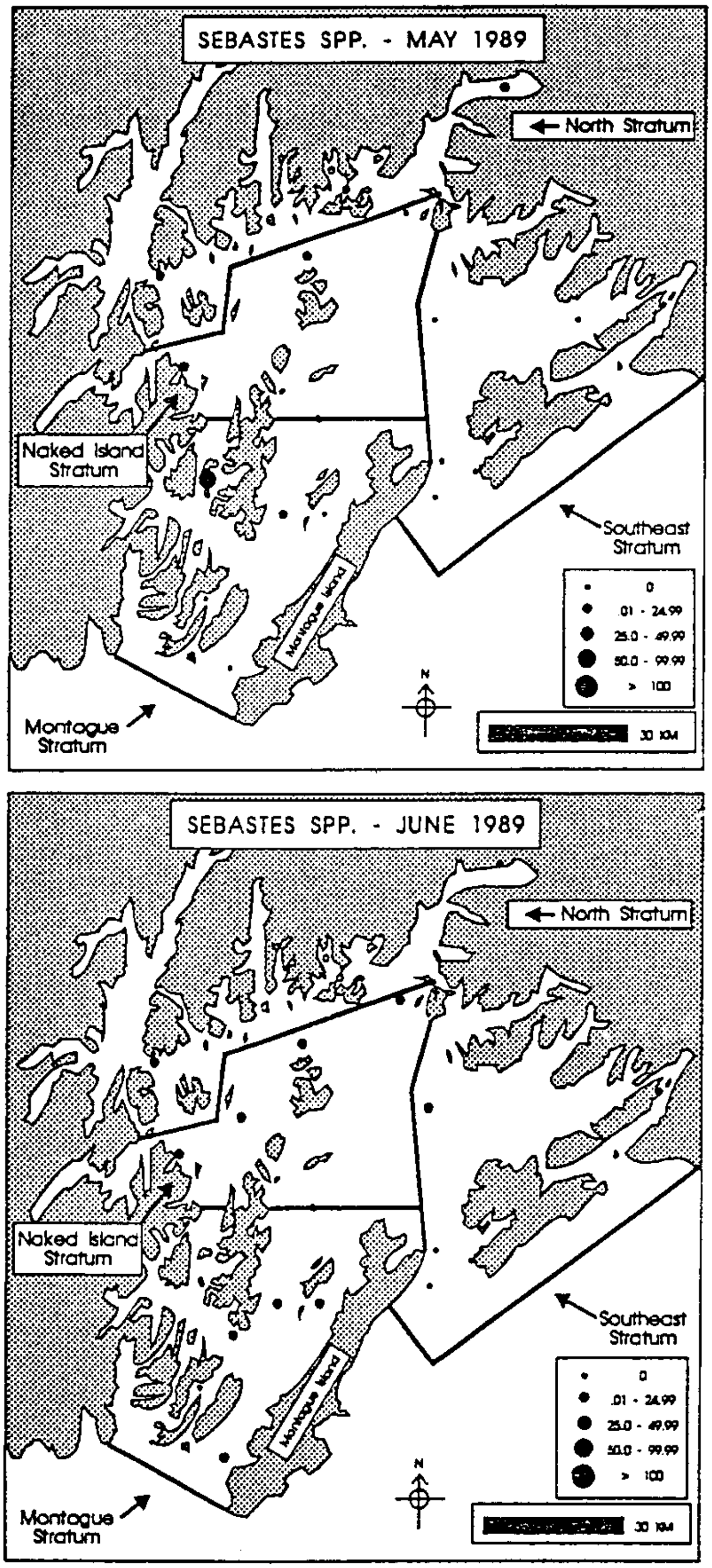
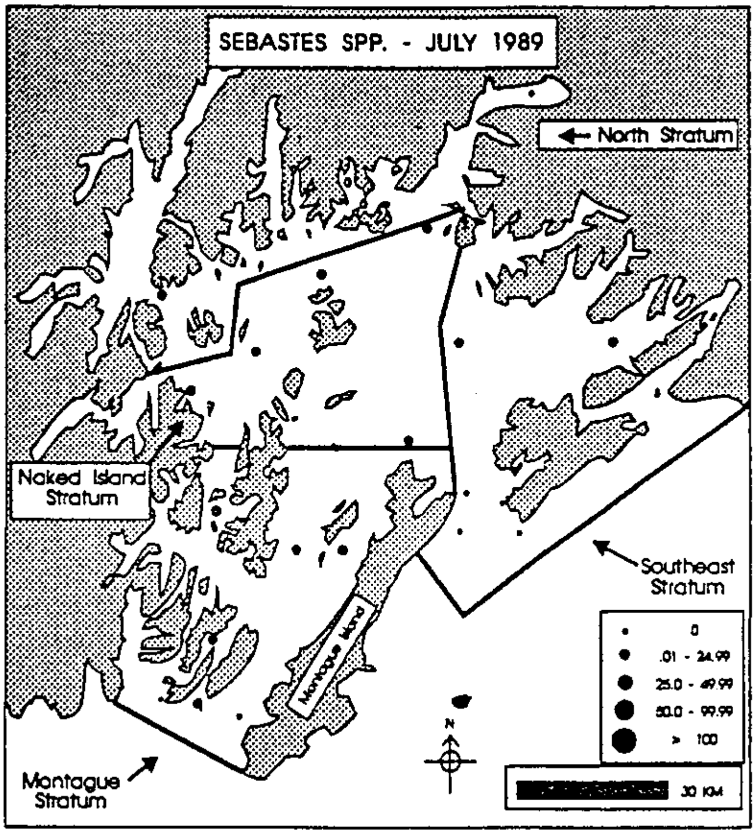


FIGURE 6.—Distribution of *Sebastes* spp. larvae in May, June, July, and September 1989, standardized to number per 100 m^3 water filtered.



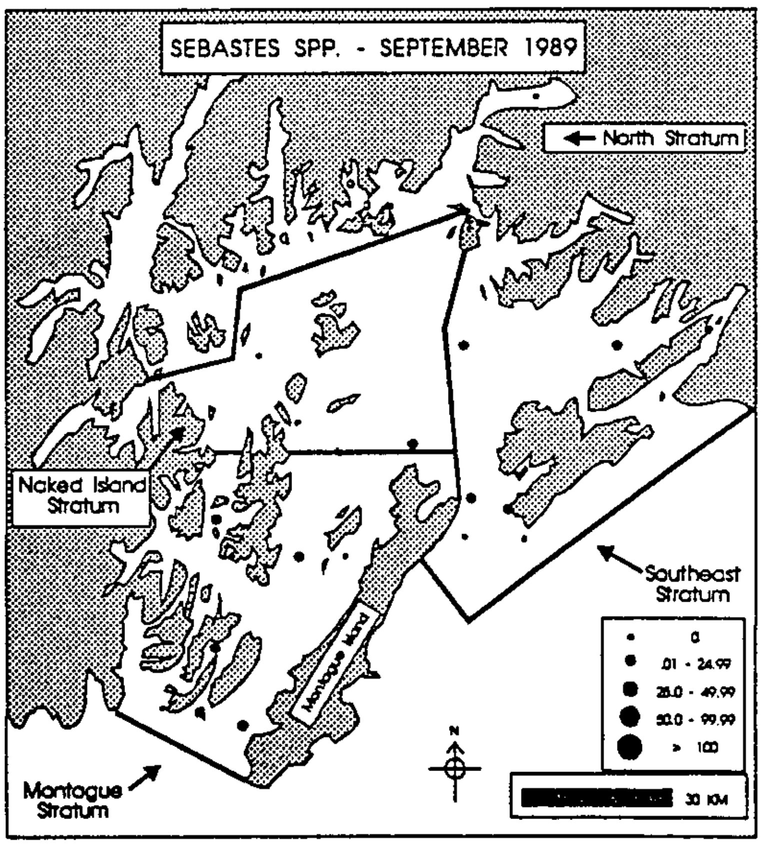


FIGURE 6.—Continued.

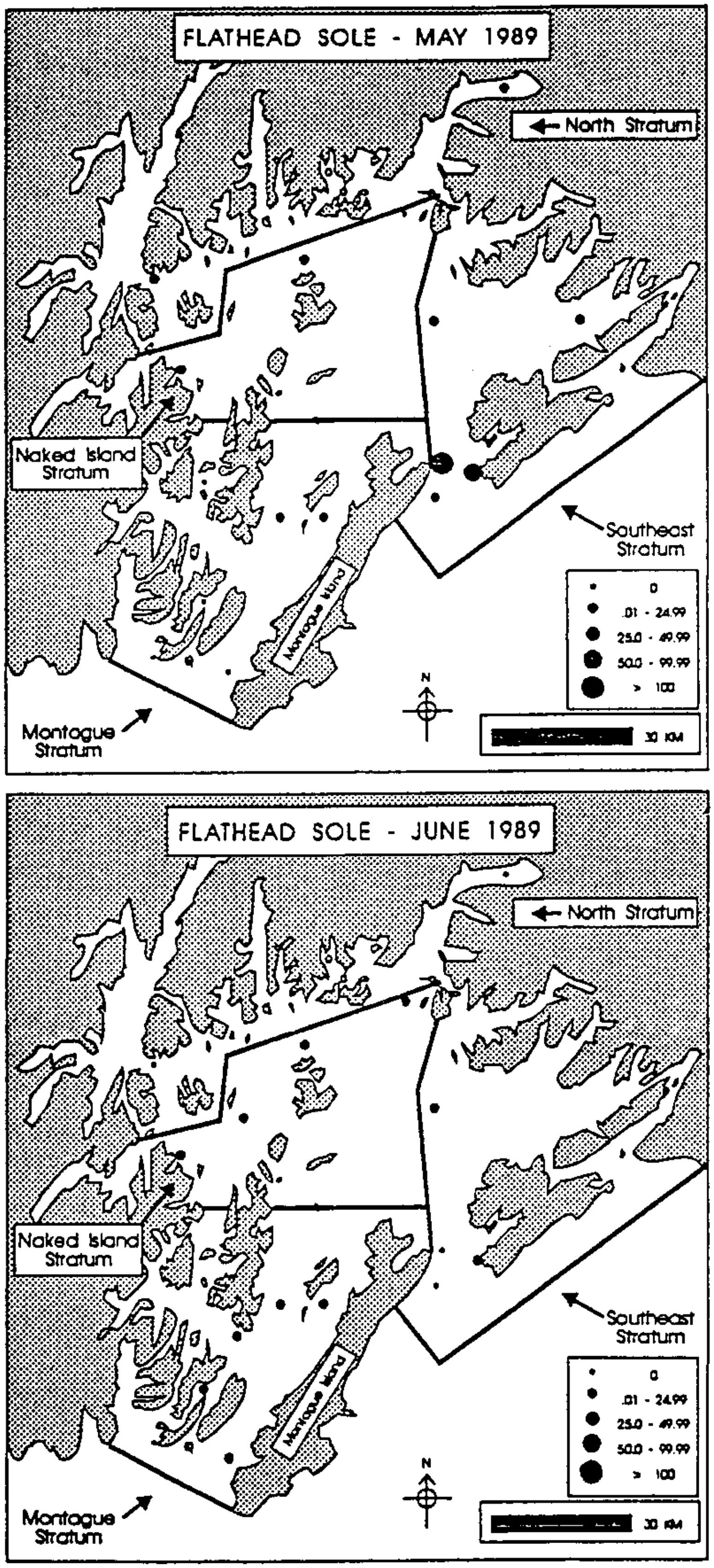


FIGURE 7.—Distribution of flathead sole larvae in May, June, and July 1989, standardized to number per 100 m^3 water filtered.

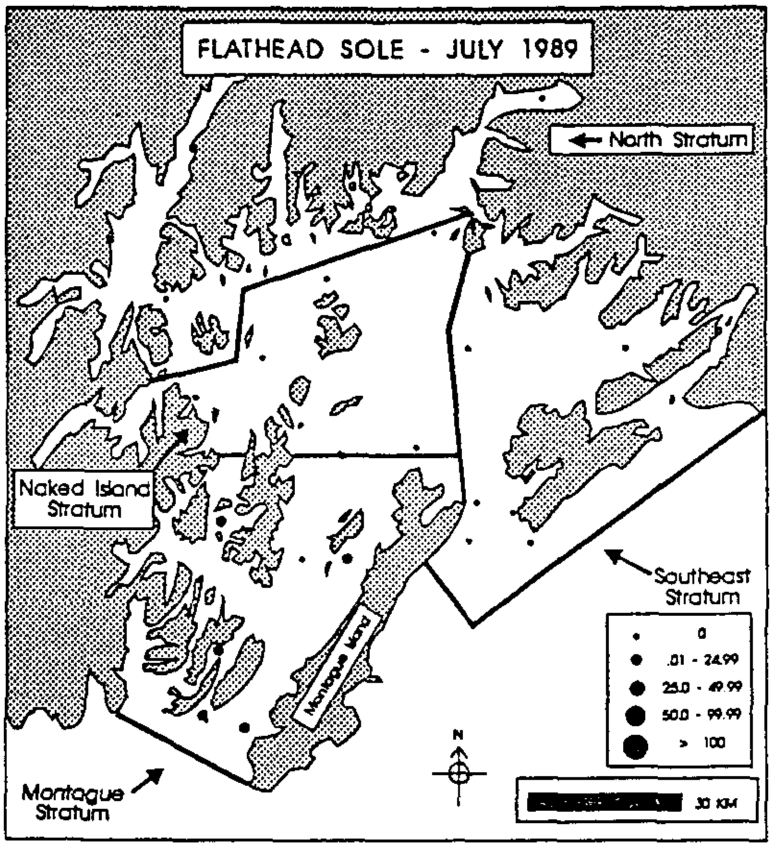


FIGURE 7.—Continued.

result in a significant difference (F = 1.115, P = 0.334).

Depth Distribution of Larval Fishes

All six species were captured principally in the upper 50 m (Table 6). In April walleye pollock and northern smoothtongues were captured between 0 and 100 m. In May most walleye pollock, Pacific herring, rockfishes, and flathead soles were in the upper 25 m, while most northern smoothtongues were between 25 and 50 m. The depth distribution of species was similar for June, except that most Pacific herring were found in the 25- to 50-m depth interval and many northern smoothtongues were in the 50- to 100-m depth range. The dominant larval fish in the upper 25 m in July was capelin. Northern smoothtongues were found mainly between 50 and 200 m. Each species, except flathead sole, was also found to a depth of 500 m in July. In September

TABLE 6.—Depth distribution of individual fish taxa combined over all time periods, standardized to number of larvae per 100 m^3 among this study's strata in Prince William Sound. Columns 0–50 m and 0–100 m, not sampled on all cruises, do not include fish from 0–25 m, 25–50 m, or 50–100 m.

Species	0–25 m	25–50 m	50–100 m	100–200 m	200–500 m	0–50 m	0–100 m
Walleye pollock	110.02	7.64	0.75	0.01	0.01	0.22	0.18
Northern smoothtongue	1.39	18.26	1.51	0.85	0.29	0.26	3.27
Pacific herring	9.05	15.30	0.05	0.01	0.05	0.21	0.02
Capelin	1.92	2.56	0.72	0.17	0.09	1.84	0.60
Rockfishes	2.16	1.29	0.07	0.09	2.27	0.17	0.10
Flathead sole	2.13	0.53	0.02	0.00	0.00	<0.01	0.01

northern smoothtongues and capelins were found to a depth of 200 m, while rockfishes were found to 500 m. The two species found in October, capelin and northern smoothtongue, were collected at depths to 500 m.

Vertical distribution of fish larvae varied significantly. Abundance of walleye pollock at each depth interval sampled was statistically different from every other depth interval at $P < 0.001$. Abundance of northern smoothtongue larvae, a species not often found in the upper 25 m, was significantly different between all depth strata ($P < 0.001$). In contrast, Pacific herring, which were mainly found in the upper layers, only showed significant differences in depth distribution between 0 to 25 m and 100 to 200m, 25 to 50 m and 50 to 100 m, and 50 to 100 m and 100 to 200m ($P < 0.05$). Capelin, another species found mainly in the upper layers, showed significant differences in CPUE between shallow and deep strata: 0 to 25 m and 50 to 100 m; 50 to 100 m and 100 to 200 m; and 100 to 200 m and 200 to 500 m ($P < 0.002$). Rockfishes were found relatively evenly distributed vertically. The only significant difference was between 0 to 25 m and 200 to 500 m ($P < 0.05$). There were few flathead sole larvae, but there were significant differences between 0 to 25 m and 25 to 50 m ($P < 0.001$).

Length Analysis of Larval Fishes

We examined length distributions for the six most abundant species of fish. Modal lengths of walleye pollock larvae were 3.8 mm in April, 6.5 mm in May, and 13.0 mm in June; these values were quite similar to mean lengths (Table 4). The maximum size of walleye pollock larval lengths progressively increased from April through July, but the minimum size was 4.1 mm or less in April, May, and June.

Northern smoothtongues showed no change in size between the modal April length of 7.5 mm and the modal May length of 7.0 mm or between the somewhat larger mean lengths (Table 4), though the maximum size increased from April to May. The modal (10.0 mm) and mean lengths increased in June, but the range in sizes did not. The modal length in July was 15.0 mm, with the minimum size remaining small but the maximum size increasing. During the later months few northern smoothtongues were captured. Modal length was 26.5 mm for September and 27.5 mm for October. The minimum size increased, but the maximum size decreased.

Modal length of Pacific herring larvae was 7.5 mm in May. Yolk-sac larvae made up 32% of the May collection of Pacific herring, but no larvae in the later cruises had yolk sacs. In June the modal length was 11.5 mm. The average change in modal length over the 27 d between the mid-dates of the May and June collections was 4.0 mm or 0.15 mm/d. Using mean sizes of 8.2 mm in May and 12.2 mm in June (Table 4) results in an identical estimated growth of 0.15 mm/d. There was no change in modal size between June and July, though the mean size increased to 12.9 mm.

Capelin modal lengths (July:9.00 mm, September:12.0 mm, October:20 mm) progressively increased as did their means and ranges (Table 4). In contrast, rockfishes modal (May:4.0 mm, June:4.4 mm, July:4.6 mm, September:4.2 mm) and mean lengths and ranges did not increase (Table 4). Numbers of flathead sole larvae decreased as mean lengths and ranges increased (Table 4). Change in modal size from 4.5 mm in May to 9.0 mm in June was 0.17 mm/d.

Discussion

Abundance and Distribution of Larval Fishes

There are no previous records of fish larvae in the open waters of Prince William Sound. Therefore, it is not possible to say whether the community composition of larvae in 1989 is "normal" or affected by the *Exxon Valdez* oil spill. It is possible to report presence of species but not to document absence. Of the six most abundant species (Table 2), four are commercially important: walleye pollock, Pacific herring, rockfishes, and flathead sole. One species, capelin, is a primary forage fish. Little is known about the sixth species, northern smoothtongue.

Larval fish composition in Prince William Sound in 1989 is similar, but not identical, to that found in other areas of the Gulf of Alaska. In the western Gulf of Alaska from Cook Inlet to the Shumagin Islands, the 14 most abundant species included all but herring of the 6 most abundant species collected in this study (Rugen 1990). The collection of fish in Resurrection Bay, a glacial fjord, from April to July 1988 consisted of walleye pollock, flathead soles, Pacific herring and Pacific sand lances *Ammodytes hexapterus*, in decreasing order of abundance (Paul et al. 1991).

In northern southeast Alaska from Frederick Sound to Lynn Canal, Mattson and Wing (1978) sampled enclosed bays, the middle of deep channels, and the edge of deep channels from April to November 1972. Most fish were identified to family level. Gadids, followed by osmerids and bathylagids, were the three most abundant families captured. The most abundant gadid was walleye pollock and the predominant osmerid was probably capelin *M. villosus*, although identification was not made to the species level. Northern smoothtongue was the most abundant bathylagid. In decreasing order of importance, Scorpaenidae, Cottidae, Stichaeidae, Ammodytidae, Bathymasteridae, Cyclopteridae, and Pleuronectidae were captured, although not in high abundances. Clupeidae were expected but were not collected.

In a more restricted area of southeast Alaska, Auke Bay (Haldorson et al. 1993), the five dominant taxa in spring 1986 to 1989 were Osmeridae (not identified to species), Pacific sand lance, walleye pollock, flathead soles and rock sole *Pleuronectes bilineatus*. All of the dominant taxa in our study, except rockfishes, also were collected in Auke Bay, however northern smoothtongue and Pacific herring were not among the top five in the 4 years sampled. Both in the Gulf of Alaska and in southeast Alaska studies, walleye pollock larvae predominated as in Prince William Sound.

Circulation of Prince William Sound and the Exxon Valdez Oil Spill

The general circulation of Prince William Sound is thought of as flow inward through Hinchinbrook Entrance in the southeast and flow outward through Montague Strait in the southwest, with additional fresh water contributed from streams and glacier melt within the sound. Thus, oil spilled at Bligh Reef should only affect the western sound. According to overflight sightings, the oil spread throughout the western portion of the sound without affecting the eastern sound, which is consistent with a simulated drift model based on the strong winds experienced from 26 to 28 March (Venkatesh 1990). These strong northerly winds played a significant role in pushing the oil out of Prince William Sound and covering much of the Naked Island and Montague strata in its wake. After 10 d, most of the surface slick was out of the sound, yet oil was still leaking from the tanker (Royer et al. 1990) and continued to leach from beaches for many months. These strong winds only persisted for days (Royer et al. 1990). Under model simulations (Venkatesh 1990) of reduced winds, the oil is carried further west. With no wind but only residual circulation, the oil remains in the sound and affects the western islands and shore. Satellite-tracked drifters with drogues at 3-m depth were released in the sound from late 1989 to early 1990 to simulate the oil movement. Several of these drifters never left the sound (Royer et al. 1990), which supports Venkatesh's (1990) model with reduced wind.

Although the major flow is inward through Hinchinbrook Entrance, down-fjord winds that converge in the central sound can cause flow out through Hinchinbrook Entrance (Royer et al. 1990). Such flow was observed with an Acoustic Doppler Current Profiler (ADCP) in April 1989 (Norcross et al. 1991). The same effect, flow out through Hinchinbrook Entrance, can also occur when residual currents are removed from the simulated drift model (Venkatesh 1990). Under that scenario, the flow of the oil is almost straight south forced by the prevailing winds. Although the residual currents were never actually completely eliminated as in the model, they were reduced at the time of the spill. The *Exxon Valdez* oil spill occurred at the minimum in the seasonal circulation cycle. Additionally, the freshwater discharge that drives the residual currents was the lowest recorded discharge in 59 years in 1989 (Royer et al. 1990).

Distribution of Larval Fishes in Relation to Oil Distribution

The pattern of oil spilled from the *Exxon Valdez* in the days following the spill was easily traced by aircraft overflights (Wolfe et al. 1996, this volume). These sightings were used to produce maps of gross movement of the heaviest parts of the slick. Based on the sightings, the oil appeared to be present only in the western portion of the sound in our Naked Island and Montague strata.

In April, the time period covered by overflight maps, there were few larvae. Those present were northern smoothtongue that were concentrated in the non-oiled north stratum (Table 3; Figure 3). However, there are two complication factors. Because fish larvae are planktonic, those in the upper waters are expected to move with the same flow patterns that affect the trajectory of the oil. Also, even though oil was no longer visible from the air, toxins from the *Exxon Valdez* oil were still present to a depth of at least 25 m throughout the path of the spill in Prince William Sound for the first few months following the spill (Short and Harris 1996, this volume). Additionally, oil continued to be present on beaches (Wolfe et al. 1996) and in subtidal sediments (Braddock et al. 1996, this volume; O'Clair et al. 1996, this volume) for at least 2 years. Thus, after the initial dispersal of the visible slick and in places where there was no documented slick, oil was still available to the biota. The dispersed oil may have been a significant source of oil exposure to larval fishes (Short and Harris 1996).

In May when larval fishes were the most abundant, they were found in every stratum, but the highest densities, mainly of walleye pollock, were in southeast stratum (Table 3). Based on flow patterns of the sound, larvae from the non-oiled southeast stratum probably passed through the sound via the oiled waters of Montague stratum. The next most abundant fishes in May, northern smoothtongues and Pacific herring, were concentrated mainly in oiled Montague and Naked Island strata.

In May and June walleye pollock were found in the western sound in the strata through which the oil had passed. The numbers and sizes of walleye pollock larvae in Prince William Sound and Resurrection Bay in April and May 1989 (Müter and Norcross 1994) indicate spawning occurred during this time in both places. The size of larvae in May indicates they are less than 25 d old (Müter and Norcross 1994). Walleye pollock eggs are laid deep in the water column and rise to near the surface (Kendall and Kim 1989). In spring 1989 walleye pollock were concentrated above the pycnocline in the upper 25 m of the water column; therefore, walleye pollock could have been exposed first as embryos and then as larvae to oil from the *Exxon Valdez* spill.

Exposure of walleye pollock embryos to water-soluble fractions of oil can slow initial development, produce shorter larvae, and cause morphological abnormalities in larvae, including body curvatures, deformations of eye, brain, jaw, and intestine and fin erosion (Carls and Rice 1990). Average size of walleye pollock at hatch is 3 to 4 mm (Matarese et al. 1989). The smallest size of walleye pollock larvae that we collected was 3.13 mm. Oil and other stresses may produce premature hatch. Larval survival is complicated by both natural and anthropogenic effects, and there are no data from a non-oil-spill year to compare larval walleye pollock abundance in Prince William Sound to assess abundance changes. Thus, it is not possible to determine an effect of the *Exxon Valdez* oil spill on walleye pollock larvae from the available data.

The second most abundant fish, northern smoothtongue, occurred throughout Prince William Sound, with high abundances found mostly in the western portions of the sound. This species is a deep-sea smelt that coexists with walleye pollock and Pacific hake (*Merluccius productus*) in the Strait of Georgia, British Columbia (Mason and Phillips 1985). The eggs develop and hatch below 200 m, and following hatching, larvae ascend to approximately 40 to 90 m below the surface. Northern smoothtongue larvae metamorphose at approximately 22 mm at 90 d. By 120 d and 26 mm, the juveniles descend to depths greater than 150 m (Mason and Phillips 1985). Young larval northern smoothtongue were found in the upper 100 m, but were most abundant at 25 to 50 m of the water column in April, May, and June after the oil spill. No samples deeper than 100 m were taken during the first 3 months. By July northern smoothtongue were throughout the water column but were concentrated at 50- to 200-m depth and had increased in size.

Though northern smoothtongue is known to have very slow growth (0.16 mm/d) (Mason and Phillips 1985), there was no apparent change in modal size between April and May in Prince William Sound in 1989 and still little by June. This apparent lack of growth could be attributed to continued spawning, though a kurtotic curve would be expected in that instance. It may be that the larval cohort from April is missing and was replaced by a new cohort appearing in the May collections. Because there is only limited information about northern smoothtongue and no information about the effect of oil on this species, it is difficult to draw any conclusions about the effect of the *Exxon Valdez* oil spill.

The larval Pacific herring distributions found are in agreement with the general oceanographic circulation of Prince William Sound (Royer et al. 1990; Venkatesh 1990). Although Pacific herring spawned in April, Pacific herring larvae were found only in open waters of Prince William Sound in limited numbers at the beginning of May 1989. The highest concentrations of Pacific herring larvae were adjacent to or downstream from oiled spawning sites (Norcross et al., unpublished). By June Pacific herring were more abundant, well distributed in the sound, and found in greatest numbers in the waters flowing out through the Montague Strait region. Pacific herring larvae were predominantly in the upper layers above the pycnocline. As horizontal distribution of larvae is largely determined by upper layer flow (Müter and Norcross 1994), Pacific herring from all spawning locations probably passed through this region in a manner analogous to the flow of oil.

One cohort of Pacific herring larvae came from the major spawning that occurred between 31 March and 20 April and hatched between 30 April and 10 May (McGurk et al. 1990). The estimated change in size of 0.15 mm/d presented here is approximate because it is based only on increments in modal length over 27 d between the May and June cruises; however, it represents one of the lowest growth rates recorded for Pacific herring when compared to 0.31 to 1.48 mm/d (Wespestad and Moksness 1990), 0.30 mm/d (McGurk et al. 1993), and 0.18 to 0.29 mm/d (McGurk 1984a). The small sizes of larvae collected in May could be attributed to exposure of Pacific herring eggs to oil immediately after the oil spill (McGurk and Brown, in press). It is difficult to explain the apparent lack of size increase from June to July without invoking oil as an explanation (Norcross et al., unpublished).

When Pacific herring eggs are stressed by delayed spawning, physical conditions, or toxicity, the time to hatching decreases (Hay 1986). The emerging larvae may be premature and less viable. Exposure of herring eggs to petroleum is a stressor that has been noted to retard hatching and development (Struhsaker et al. 1974; Lindén 1978; von Westernhagen 1988) and reduce subsequent growth of herring larvae (Lindén 1978; Smith and Cameron 1979). Exposure of eggs to Prudhoe Bay crude oil for 12 h or longer reduced the size of newly hatched larvae (Smith and Cameron 1979). Larvae hatched in uncontaminated waters may be adversely affected when encountering an oil spill during larval drift (von Westernhagen 1988). Pacific herring exposed in the larval stage to oil are foreshortened with compressed myomeres and damaged notochords (Urho 1991), have inhibited feeding and swimming abilities (Struhsaker et al. 1974), and starvation exacerbates the negative effects of oil (von Westernhagen 1988). Some deformations of larvae persisted even after oil was no longer detectable (Urho 1991).

Jaw malformation seen in Pacific herring larvae in Prince William Sound in 1989 (Norcross et al., unpublished) may have restricted the feeding ability of Pacific herring larvae. Incidence of jaw malformation appeared to be related to smaller-sized herring larvae. Thus, the small lengths of larvae captured in May may be caused in part by poor growth because of physical inability to feed. The time from hatching to irreversible starvation is 28 to 37 d for Pacific herring larvae in water temperatures of 6 to 8°C (McGurk 1984b), such as those experienced in Prince William Sound in May of 1989. In the month between the May and June cruises, we assume these severely affected larvae died and were removed from the population. This is supported by the cytogenetic studies that revealed severe genetic defects in the Pacific herring larvae collected in May (Norcross et al., unpublished).

Capelins hatched after the heaviest concentrations of oil were out of the sound, and modal size continued to increase over time. Rockfishes did not appear to grow between April and September, but because these were analyzed as a genus complex this could be explained by sequential spawning of different species. Flathead soles showed continuous increase in size and decrease in numbers, indicating they were growing out of the planktonic stage. Because no more detailed data are available, an effect of oil on capelins, rockfishes, or flathead soles was not readily seen.

This study contributes basic larval fish occurrence information for Prince William Sound that can be used for future comparisons. Unfortunately, it is biased as a baseline because it represents the ecosystem following an oil spill. General physical oceanographic flow patterns are applied here to explain movements of larvae and oil within Prince William Sound during 1989. Still, there is not sufficient information to estimate population size nor to quatitate the effects of the *Exxon Valdez* oil spill (or a future oil spill) on the population structure of larval fishes in Prince William Sound.

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APPENDIX A

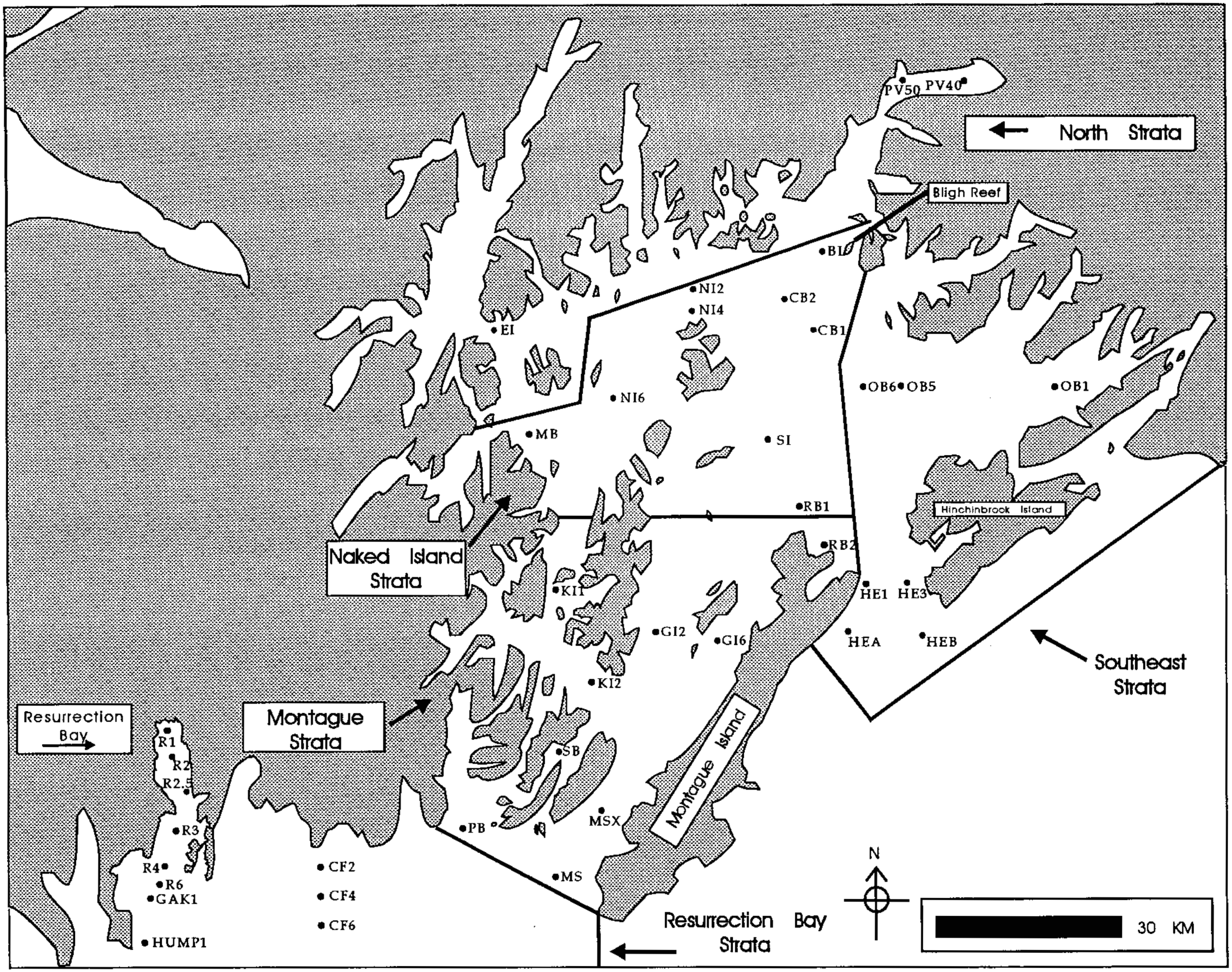

Figure A-1. Stations sampled in Prince William Sound and Resurrection Bay, Alaska in 1989.

Table. A-1 Rank order of abundance of all taxa captured in Prince William Sound and Resurrection Bay in 1989.

	Fish species	Total #	% Total
1	*Theragra chalcogramma*	28,098	73.84%
2	*Leuroglossus schmidti*	3,120	8.20%
3	*Clupea pallasi*	2,191	5.76%
4	*Mallotus villosus*	2,006	5.27%
5	*Sebastes* spp.	1,269	3.33%
6	*Hippoglossoides elassodon*	418	1.10%
7	*Ammodytes hexapterus*	276	0.73%
8	*Pleuronectes bilineatus*	129	0.34%
9	*Pleuronectes vetulus*	97	0.25%
10	*Malacocottus zonurus*	82	0.22%
11	*Gadus macrocephalus*	56	0.15%
12	*Stichaeus punctatus*	51	0.13%
13	*Bathymaster* spp.	49	0.13%
14	*Artedius meanyi*	28	0.07%
15	*Atheresthes stomias*	19	0.05%
16	*Eleginus gracilis*	17	0.04%
17	Cottidae	16	0.04%
18	*Stenobrachius leucopsarus*	12	0.03%
19	Cyclopteridae	12	0.03%
20	Zoarcidae	12	0.03%
21	*Artedius* spp.	10	0.03%
22	Agonidae	10	0.03%
23	*Hippoglossus stenolepis*	10	0.03%
24	*Pleuronectes asper*	9	0.02%
25	*Radulinus asprellus*	8	0.02%
26	*Hexagrammos octogrammus*	5	0.01%
27	*Pleuronectes isolepis*	5	0.01%
28	*Hemilepidotus hemilepidotus*	4	0.01%
29	*Errex zachirus*	4	0.01%
30	*Xeneretmus latifrons*	4	0.01%
31	*Hexagrammos decagrammus*	3	0.01%
32	*Artedius harringtoni*	3	0.01%
33	*Zaprora silenus*	3	0.01%
34	*Liparis* spp.	3	0.01%
35	*Gasterosteus aculeatus*	2	0.01%
36	*Ronquilus jordani*	2	0.01%
37	*Nectoliparis pelagicus*	2	0.01%
38	*Bathylagus pacificus*	1	<0.01%
39	Macrouridae	1	<0.01%
40	*Hexagrammos lagocephalus*	1	<0.01%

Table. 1 Continued.

	Fish species	Total #	% Total
41	*Ptilichthys goodei*	1	<0.01%
42	*Lumpenus maculatus*	1	<0.01%
43	*Psettichthys melanostictus*	1	<0.01%
44	*Hemilepidotus spinosus*	1	<0.01%

Table A-2. Number of fish larvae, standardized to catch per 100m ^{3}, by strata and month. Totals are not additive as they are for total effort within each strata or month.

	Apr	May	Jun	Jul	Sep	Oct	Total
Southeast	1.96	1,544.31	37.66	0.96	2.10	1.22	12.67
North	68.71	750.22	180.84	8.3	0.80	0.55	23.62
Naked Island	7.44	944.01	186.39	8.18	2.99	0.59	10.06
Montague	2.66	715.66	336.67	6.89	0.61	0.60	13.18
Resurrection Bay	0.21	176.32	17.19	0.66	1.20	0.86	26.78
Total	12.67	286.94	43.38	3.34	1.43	0.75	

Table. A-3 Temporal distribution of individual taxa combined over all strata, standardized to number larvae 100m³.

	Apr	May	Jun	Jul	Sep	Oct
Clupeidae						
Clupea pallasi	0	3.36(3)	12.55(2)	0.12	0	0
Bathylagidae						
Bathylagus pacificus	0	0	0.01	0	0	0
Leuroglossus schmidti	11.22(1)	8.71(2)	3.23(4)	1.14(2)	0.32(2)	0.19(2)
Osmeridae						
Mallotus villosus	0	0.01	6.19(3)	0.52(3)	1.00(1)	0.40(1)
Myctophidae						
Stenobrachius leucopsarus	0	0.02	0	0.01	0	0.01
Gadidae						
Eleginus gracilis	0	0.01	0.11	0	0	0
Gadus macrocephalus	0	0.33	0.17	0	0	0
Theragra chalcogramma	1.25(2)	266.66(1)	17.43(1)	0.01	0	0
Macrouridae	0	0	0	0	0	<0.01
Gasterosteidae						
Gasterosteus aculeatus	0	0	0	0	<0.01	0
Scorpaenidae						
Sebastes spp.	0	1.89(5)	0.26	1.45(1)	0.06	0
Hexagrammidae						
Hexagrammos decagrammus	0	0.03	0	0	0	0
Hexagrammos lagocephalus	0	0	0	0	<0.01	0
Hexagrammos octogrammus	0	0	0	0	0.01	0
Cottidae	0.06	0	0.08	0	0	0
Artedius spp.	0	0	0.07	0	0	0
Artedius harringtoni	0	0	0	0	0.01	0
Artedius meanyi	0	0	0.15	0	0.01	0
Hemilepidotus hemilepidotus	0	0	0	0	0	0.01
Hemilepidotus spinosus	0	0	0	0	0	<0.01
Malacocottus zonurus	0	0.05	0.32	0.03	0.0	0.01
Radulinus asprellus	0	0	0.06	0	0	0
Agonidae	0	0.02	0.05	0	<0.01	0
Xeneretmus latifrons	0.02	0.03	0	0	0	0
Cyclopteridae	0	0	0.06	0	<0.01	0
Liparis spp.	0.05	0	0	0	0	0
Nectoliparis pelagicus	0	0	0	0	<0.01	0
Bathymasteridae						
Bathymaster spp.	0	0.07	0.18	0.02	<0.01	0
Ronquilus jordani	0	0.02	0	0	0	0
Zoarcidae	0	0	0	0	<0.01	0.02

Table. 3 Continued.

	Apr	May	Jun	Jul	Sep	Oct
Stichaeidae						
Stichaeus punctatus	0	0.43	0.07	0	0	0
Lumpenus maculatus	0	0	0	0	0	<0.01
Ptilichthyidae						
Ptilichthys goodei	0	0.01	0	0	0	0
Zaproridae						
Zaprora silenus	0	0	0.02	0	0	0
Ammodytidae						
Ammodytes hexapterus	0.02	0.77(7)	1.34(5)	0.01	0	0
Pleuronectidae						
Atheresthes stomias	0.05	0.13	0.01	0	0	<0.01
Errex zachirus	0	0	0.03	0	0	0
Hippoglossoides elassodon	0	3.10(4)	0.85(6)	0	0	0
Hippoglossus stenolepis	0	0	0.07	0	0	0
Pleuronectes asper	0	0	0	0.01	0	0
Pleuronectes bilineatus	0.02	1.26(6)	0.01	0.01	0	0
Pleuronectes isolepis	0	0.01	0.03	0	0	0
Pleuronectes vetulus	0	0	0	<0.01	0.01	0.11
Psettichthys melanostictus	0	0	0	0	0	<0.01

Table. A-4 Spatial distribution of individual taxa combined over all time periods, standardized to number larvae 100^3.

	Southeast area	North area	Naked Island area	Montague area	Resurrection Bay area
Clupeidae					
Clupea pallasi	0.11	0.98(4)	0.73(4)	3.14(2)	0.21(5)
Bathylagidae					
Bathylagus pacificus	0	0	0	0	<0.01
Leuroglossus schmidti	0.71(2)	7.22(2)	1.63(2)	1.93(3)	0.20(6)
Osmeridae					
Mallotus villosus	0.70(3)	0.16	0.59(5)	0.59(5)	1.63(2)
Myctophidae					
Stenobrachius leucopsarus	0	0	<0.01	0	0.02
Gadidae					
Eleginus gracilis	0.01	0	0	0.03	0
Gadus macrocephalus	0.05	0.02	0	0.01	0.04
Theragra chalcogramma	10.52(1)	13.33(1)	5.65(1)	5.95(1)	23.75(1)
Macrouridae	0	0	<0.01	<0.01	0
Gasterosteidae					
Gasterosteus aculeatus	0	0	<0.01	0	0
Scorpaenidae					
Sebastes spp.	0.07	1.61(3)	1.22(3)	0.97(4)	0.01
Hexagrammidae					
Hexagrammos decagrammus	0	0	0	0.01	0
Hexagrammos lagocephalus	<0.01	0	0	0	0
Hexagrammos octogrammus	0.01	0	0	<0.01	0
Cottidae	<0.01	0.02	<0.01	0.02	0
Artedius spp.	0	0	0	0.02	0
Artedius harringtoni	<0.01	0	0	<0.01	0
Artedius meanyi	<0.01	0	<0.01	0.05	0
Hemilepidotus hemilepidotus	0	0	0	0.01	0
Hemilepidotus spinosus	0	0	<0.01	0	0
Malacocottus zonurus	<0.01	0.19	0.03	0.04	0.03
Radulinus asprellus	0	0	0	0	0.01
Agonidae	0	0.01	<0.01	0.02	0
Xeneretmus latifrons	0	0	0	<0.01	<0.01
Cyclopteridae	0	0	<0.01	0.02	0
Liparis spp.	0	0	0	0.01	0
Nectoliparis pelagicus	<0.01	0	0	<0.01	0
Bathymasteridae					
Bathymaster spp.	0	0.03	0.03	0.06	<0.01
Ronquilus jordani	0	0	0	<0.01	0
Zoarcidae	0	0	0.01	0	0.01
Stichaeidae					

Table. 4 Continued.

	Southeast area	North area	Naked Island area	Montague area	Resurrection Bay area
Stichaeus punctatus	0	0.02	0.01	0.09	0
Lumpenus maculatus	0	0	0	0	<0.01
Ptilichthyidae					
Ptilichthys goodei	0	0	<0.01	0	0
Zaproridae					
Zaprora silenus	0	0	0	0	<0.01
Ammodytidae					
Ammodytes hexapterus	0.07	0	0.03	0.03	0.33(3)
Pleuronectidae					
Atheresthes stomias	<0.01	0.01	<0.01	0.01	0.02
Errex zachirus	0	0	0	0	0.01
Hippoglossoides elassodon	0.32(4)	0.02	0.08	0.11	0.24(4)
Hippoglossus stenolepis	0	0	0	<0.01	0.01
Pleuronectes asper	0.01	0	<0.01	<0.01	0
Pleuronectes bilineatus	0.01	0.01	0	0	0.20(6)
Pleuronectes isolepis	0	0	0.01	<0.01	<0.01
Pleuronectes vetulus	0.06	0	0.02	0.04	0.05
Psettichthys melanostictus	0	0	0	0	<0.01

Table A-5. Depth distribution of larval fish. X = captured in that depth interval.

	0-25 m	25-50 m	50-100 m	100-200 m	200-500 m
Clupeidae					
Clupea pallasi	X	X	X	X	X
Bathylagidae					
Bathylagus pacificus				X	
Leuroglossus schmidti	X	X	X	X	X
Osmeridae					
Mallotus villosus	X	X	X	X	X
Myctophidae					
Stenobrachius leucopsarus			X	X	X
Gadidae					
Eleginus gracilis	X	X			
Gadus macrocephalus	X		X		
Theragra chalcogramma	X	X	X	X	X
Macrouridae				X	X
Gasterosteidae					
Gasterosteus aculeatus	X	X	X		
Scorpaenidae					
Sebastes spp.	X	X	X	X	X
Hexagrammidae					
Hexagrammos decagrammus	X				
Hexagrammos lagocephalus	X	X			
Hexagrammos octogrammus	X	X			
Cottidae	X	X	X		
Artedius spp.		X			
Artedius harringtoni	X	X	X		
Artedius meanyi	X	X	X		
Hemilepidotus hemilepidotus	X	X	X		
Hemilepidotus spinosus	X				
Malacocottus zonurus	X	X	X	X	X
Radulinus asprellus	X				
Agonidae	X	X			
Xeneretmus latifrons		X		X	
Cyclopteridae		X		X	
Liparis spp.			X		
Nectoliparis pelagicus	X	X			
Bathymasteridae					
Bathymaster spp.	X	X	X	X	
Ronquilus jordani	X				
Zoarcidae	X			X	
Stichaeidae					
Stichaeus punctatus	X	X			

Table 5. Continued.

	0-25	25-50	50-100	100-200	200-500
Lumpenus maculatus			X		
Ptilichthyidae					
Ptilichthys goodei	X				
Zaproridae					
Zaprora silenus	X	X	X		
Ammodytidae					
Ammodytes hexapterus	X	X	X	X	
Pleuronectidae					
Atheresthes stomias	X	X	X		
Errex zachirus	X				
Hippoglossoides elassodon	X	X	X	X	X
Hippoglossus stenolepis	X	X			
Pleuronectes asper	X	X	X		
Pleuronectes bilineatus	X	X	X	X	X
Pleuronectes isolepis	X			X	
Pleuronectes vetulus	X	X	X	X	X
Psettichthys melanostictus	X	X	X		