Proposed Fisheries Research Programs in Hecate Strait

Hecate Strait Research Coordinating Committee

Fisheries Research Branch

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INTRODUCTION

In November 1981, a committee was established by the Director, Fisheries Research Branch (FRB) to provide advice on how a coordinated research effort could be established in Hecate Strait. Section representatives of each species complex (salmon, herring, groundfish, invertebrates, and oceanography) were included on the committee. The committee was also to consult with the Institute of Ocean Sciences (IOS) to evaluate the feasibility of joint programs in the Strait.

Hecate Strait was identified as a major area of future investigation on the basis of the following events and considerations:

(1) Anticipated oil and natural gas exploration, and possible future exploitation, in the northern regions of Queen Charlotte Sound. Studies now could facilitate later evaluation of environmental impacts associated with this potential development.

(2) There has been in the recent past a disproportionately large research emphasis on British Columbia fisheries from Queen Charlotte Sound south. The need for more northern research to satisfy both biological and political concerns is real.

(3) Coincident with a reorganization of the Fisheries Research Branch and the recent downturn in the economy, an increase in collaborative

research between the various investigations within FRB is appropriate.

(4) Physical and biological studies on and at the edges of the shallow banks in Hecate Strait are presently being evaluated by IOS, making it opportune to consider joint investigations which might be both synergistic and cost-effective.

The following objectives were approved for the committee:

(1) To establish a linkage with IOS to identify joint programs and to coordinate research effort.

(2) To evaluate quality and completeness of past research on fisheries resources in Hecate Strait, and to identify knowledge gaps and areas of high sensitivity to perturbation and/or species survival.

(3) To identify major physical and biological processes that may affect fish and shellfish population dynamics in Hecate Strait.

(4) To identify physical oceanographic processes important to phytoplankton and zooplankton productivity in Hecate Strait.

(5) To identify and priorize areas of research to commence with the 1983-84 fiscal year.

LINKAGE WITH IOS

A number of meetings and phone conversations have been held between committee members and IOS staff. The intent of these meetings was to discuss our interest in initiating studies in Hecate Strait and to express our desire that collaborative studies would be welcomed.

This report provides in detail an outline of the specific research programs which the committee recommends for the Fisheries Research Branch, and it is hoped that this information can be used as a basis for future discussions between FRB and IOS. Plankton productivity in particular lies largely within the expertise of IOS and would seem to be a high priority study area.

HECATE STRAIT AND ITS OCEAN CLIMATE

A comprehensive review of the physical features, climatology and our current knowledge of the oceanography of Hecate Strait is provided in Appendix A. This section briefly summarizes this review.

Hecate Strait is a major coastal seaway separating the islands outlining the mainland of British Columbia from the Queen Charlotte Islands (Fig. 1). The axis of the Strait is a narrow, 220-km long, submarine canyon that hugs the mainland coast, with a broad shallow area on the northwestern side less than 22 m in depth.

Winds in Hecate Strait commonly blow parallel to the coast because of the channelling effect of the bordering mountains. From late fall to early spring, winds are often strong and are predominantly from the southeast, whereas from May to September, coastal winds are weaker and are predominantly from the northwest.

Wave conditions are most severe in autumn and winter, with the most dangerous aspect not the magnitude of the waves but the rapidity with which conditions change. Particularly heavy seas can occur over the broad shoal area in the northwestern part of the Strait.

The north-going flood tide in the offshore waters moves through Queen Charlotte Sound to meet the flood tide coming through Dixon Entrance in the northern part of Hecate Strait. The confluence of the tides appears to be about 50 km further north in winter than in summer. The combined tide swings westward across the Strait until it meets the Queen Charlotte Islands. This tidal circulation combined with wind-generated surface flows generates a general northward surface flow pattern in the winter (Fig. 2) but a more variable and complex flow pattern in the summer. During this latter period, a weak northward flow exists in the western Strait while a stronger southward flow occurs in the eastern Strait, possibly forming a small gyre over the shallow northwestern region of the Strait (Fig. 3).

Sea-surface temperatures between winter and summer range from about 6-14°C. However, in the deepest waters, high temperatures, high dissolved oxygen levels, and low salinities prevail in winter as compared to those for other seasons. The appreciable vertical gradients associated with the halocliene and summer thermocline that occur over most of the Strait are absent in the shallow areas in the northeastern part of the Strait.

REVIEW OF PAST RESEARCH

A. Salmonids

Past salmonid research in Hecate Strait has been reviewed as three components: catch and escapement (Appendix B), juveniles (Appendix C), and destinations of post-juvenile salmon in Hecate Strait (Appendix D). Each section is briefly summarized below.

1. Catch and escapement

Data are only available since 1951. The number of coho and chinook caught in Hecate Strait itself (mostly by troll gear) amounts to less than 5% of the total B.C. landing of these species combined. Landings of pink, chum and sockeye are negligible because these species are caught almost exclusively by net fisheries conducted in the more sheltered waters adjacent to Hecate Strait. The origins of most coho and chinook are largely unknown, while the landings of the other species generally reflects the relative production from the immediate area.

Escapement to the 260 or so spawning streams around Hecate Strait ranges from 1.2-6.5 million fish. Pinks are the most abundant species in the Strait.

2. Juveniles

There have been no studies directed specifically at assessing the importance of Hecate Strait as a feeding area or migration route for juvenile salmon. There is no information, except by inference from coastal studies, as to the stock origins of young salmon in the Strait.

Some information as to the timing and biology of juvenile salmon in the Strait can be gleaned from other studies, notably on herring, but data is incomplete and very fragmented.

3. Tagging Studies

Most salmon taggings in Hecate Strait have not been directed exclusively at determining the origins of salmon in Hecate Strait. Objectives included determining national proportions (Canada or U.S.) for catch allocation, times of passage through fisheries adjacent to spawning rivers, and so on. The data must therefore be treated with caution in assessing the relative abundances of the various stocks in the Strait.

Recapture locations of salmon tagged in Hecate Strait are as follows:

(a) chinook: southeast Alaska to Oregon

(b) coho: southeast Alaska to southern B.C.

(c) chum: southeast Alaska to southern Johnstone Strait

(d) pink:

(i) even-year: southeast Alaska to southern B.C.

(ii) odd-year: northern B.C. to Washington

(e) sockeye: southeast Alaska to central B.C.

This indicates the complexity in studying salmon stocks in Hecate Strait.

B. Groundfish

Hecate Strait is the most productive region for groundfish in British Columbia, and in 1979-80, principal species landed were: Pacific cod (29.5%), Pacific halibut (10.2%), walleye pollock (9.3%), rockfish sp. (8.4%), rock sole (7.3%) and Pacific Ocean perch (7.3%). Because of the large number of species involved and the varying degrees to which they have been studied, an extensive summary of past research will not be presented here since a capsule review of each species is provided in Appendix E.

In general, early life histories and distributions for most species are poorly described, and the mechanisms causing the frequent extensive fluctuations in species' abundance are unknown.

C. Herring

Herring populations in Hecate Strait (Appendix F) have been identified by tagging during the reduction fisheries, and six populations have been defined. The biological basis for some of the stocks is unclear, and because the reduction seine fisheries were confined to nearshore waters, there is little information on the migratory movements of these populations and no recorded information on the movement of juveniles.

There may be some areas in the Strait where herring "hold" during the fall and winter months, but this may differ markedly from the summer distribution. Offshore herring appear to consist of a variety of age and size frequencies, often in the same general area at the same time.

Present herring research in Hecate Strait involves 1) mapping of major spawning grounds and the quantification of egg density to observable variables, and 2) further stock identification by tagging.

D. Invertebrates

The only long-term invertebrate fishery in Hecate Strait is for Dungeness crab (Appendix G). There are no commercial trap or trawl fisheries for shrimp, and bivalve mollusc species are exploited only on a recreational or subsistence basis. Most abalone are fished in nearshore waters bordering the mainland islands.

The crab fishery in the Strait has been in a depressed state for the past decade for causes unknown, and during this period there has been no crab research conducted in the area. Crabs are particularly concentrated in the shallow waters of the northwestern Strait. Shrimp and abalone abundance surveys have been conducted in the Strait, but little research has been attempted to define biological production parameters.

E. Summary

Our review of past research and observations of salmon, herring, crab and some groundfish species reveals that our knowledge is as yet insufficient to assess the importance of significant species in Hecate Strait to B.C. fish production. Some species, such as salmon and walleye pollock, are present in the Strait in commercial densities, but their duration, distribution, and behavior in the Strait are poorly defined. Virtually no information is available on sandlance, an important forage species, along with herring. Some groundfish species, invertebrates, and herring spend their entire life history in the Strait, but factors which determine their abundance are largely unknown. For most species, there has been no systematic effort to understand their presence in Hecate Strait in ecological terms.

RECOMMENDED FRB RESEARCH PROGRAMS

The general lack of past research in Hecate Strait and the large number of commercial species present provide for two alternate approaches:

a) an extensive faunal survey along the lines of the Scotian Shelf Ichthyoplankton Survey (SSIP) to provide baseline data to facilitate future research efforts, or b) the identification of specific research programs in two or three areas which focus on fisheries important to Hecate Strait but which also have broad fisheries application.

It is the consensus of the committee that the second approach be adopted, as from a scientific perspective, it is likely to be most productive and cost-effective at this time. After reviewing the submissions from each of the sections pertaining to past, present, and future research programs, a number of research programs were identified. After intensive discussion, the following three programs are proposed as a framework for future research by FRB in Hecate Strait. It should be noted that considerable temporal and geographical overlap is likely to occur in the carrying-out of the following proposed research programs. This cannot be avoided and indeed should be encouraged, as it is simplistic to treat each species in a complex system individually. Joint usage of capital and PY resources, both within FRB and possibly with IOS as well, should optimize both data collection and analysis.

1. Year-class Abundance

One of the greatest challenges in fisheries management has been to determine the causes, exogenous or endogenous, of year-class abundance. Optimal management generally requires an understanding of the stock-recruitment relationship and the environmental factor influencing it. Study of this process has high research importance, and so to identify an optimal species or stock for investigation, the following criteria are proposed:

a) significant economic value,
b) considerable fluctuation in past year-class strength,
c) short life span,
d) distribution confined to Hecate Strait, and
e) extensive data base.

Two species, Pacific cod and Dungeness crab, meet most criteria. Pacific cod abundance has fluctuated about ten-fold over the past 30 yr, with cycles lasting about 9-10 yr (Fig. 2). Few cod live beyond 5 yr of age and sexual maturity is reached at age 3. There may be two stocks in Hecate Strait, one habiting the northern area (Fig. 3: Two Peaks-Butterworth area) and the other the southern area (Fig. 3: Horseshoe). The commercial catch data base extends back to 1946, although it has only been since 1960 that there has been extensive fishery development. No sustained research has been carried out on cod in the field.

Crab abundance also fluctuates dramatically (Appendix G) and although crab are difficult to age accurately, maturity is reached at about age 3 and they recruit to the fishery about age 4. Some past research has been carried out on crab in Hecate Strait but the factors influencing abundance have never been systematically studied.

Inter-species comparisons of year-class abundance and potential interactions are likely to produce useful results and facilitate long-term management.

2. The Importance of the Queen Charlotte Lowland in Fish and Invertebrate Production

A predominant bathymetric feature of Hecate Strait is an extensive area of shallow water in the northwestern region which is vertically mixed by tidal currents. By analogy with areas in the Strait of Georgia, the frontal mixing processes associated with this feature causes nutrients to be brought to the surface. This in turn results in high primary productivity, particularly during the summer months, which may affect fish survival and growth. The hydrographics of this area merits further study, coincident with intensive study of its biota. Principle species in this area are crab, dogfish, sandlance, juvenile flatfish, and possibly juvenile salmon.

3. Species Distribution

The consensus of the committee was that salmon had the most urgent need for species distribution studies. Our review of salmon work in Hecate Strait reveals that our knowledge is as yet insufficient to assess the Strait's importance to B.C. salmon production. The Strait is an important pathway for incoming, maturing salmon from and outgoing juveniles stocks based largely in coastal areas more or less remote from the Strait itself. Year-class variability in stock abundance is much more likely to be associated with conditions prevailing at early life stages and the role of the Strait in this respect is virtually unknown. To investigate this, it is necessary to determine when juvenile salmon are present, where they are and what their survival is associated with. It is therefore necessary initially to sample for juvenile salmon systematically over if not the entire Strait, then at least those areas suggested as being of high productivity. Sampling should be monthly between late June and November, and bi-monthly at other times of the year. Subsequent research would focus in on those times and places where juveniles are abundant.

This program may also be of interest to the herring and groundfish programs.

IOS RESEARCH PROGRAMS

Past and present IOS research activities in Queen Charlotte Sound-Hecate Strait have been summarized by Dr. C. R. Mann, Director-General in Appendix H. In 1982, their activity will be centered on offshore oceanography and currents in Queen Charlotte Sound, especially around the edges of the banks in the central sound. Plans for work in Hecate Strait have been delayed because of budgetting and shiptime constraints.

Plans for work in 1983 are still indefinite, and it is hoped by this committee that this report can be reviewed by IOS before their final planning is completed.

Areas of IOS activity, as suggested by their Director, in 1983 include a) a study of currents in Queen Charlotte Sound and southern Hecate Strait by the Tides and Currents, Coastal Zone, and Offshore oceanography groups; and b) studies by the Ocean Ecology Group around the islands in Queen Charlotte Strait on the edges of the banks in Queen Charlotte Sound, and on or at the edges of the shallow banks in Hecate Strait.

For the physical oceanographic groups at IOS, there appears to be a consensus that they will gradually work their way northward through Hecate Strait, but they are not sure at this time how they will priorize research in such a large area.

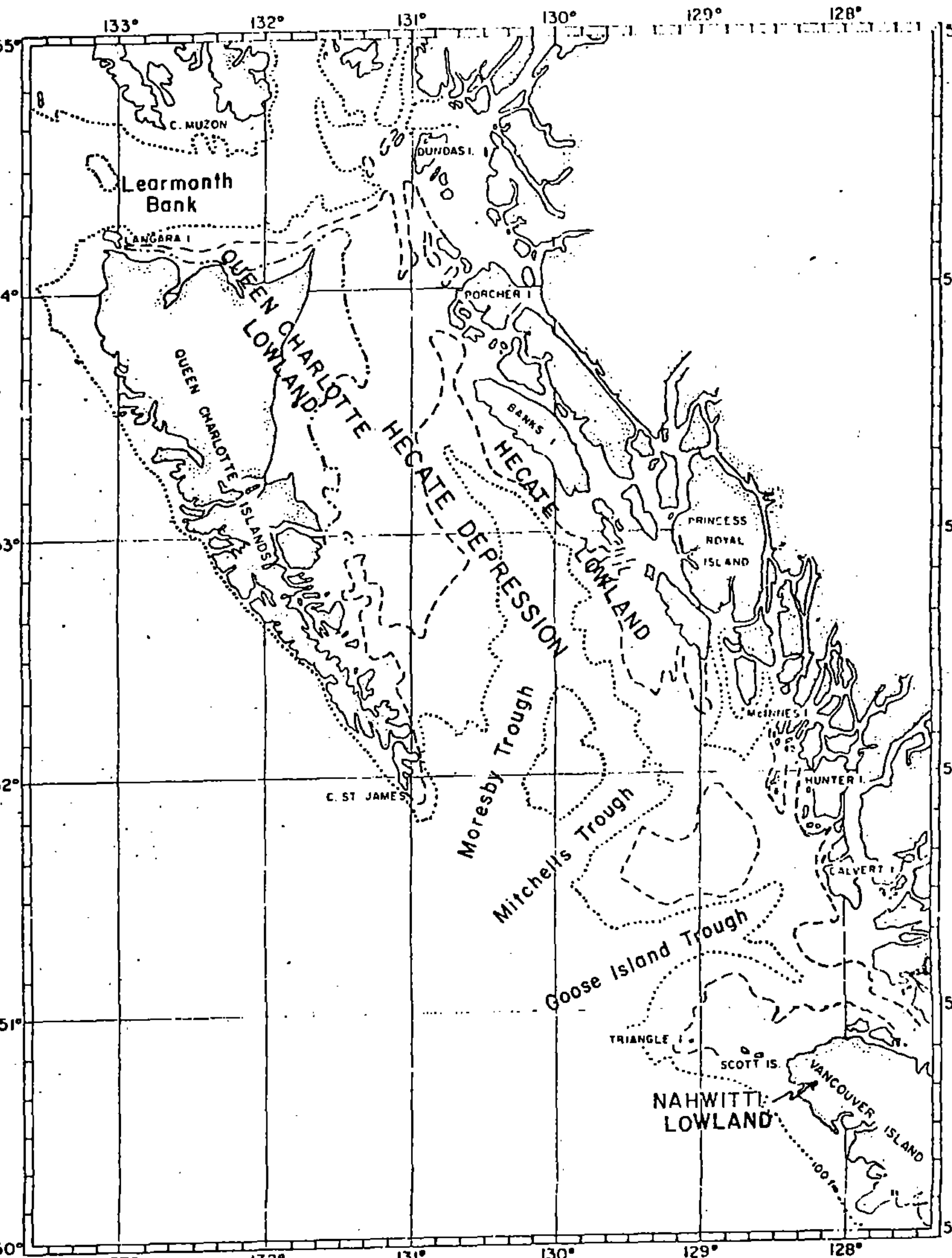


Fig. 1. Bathymetry of Hecate Strait and adjoining areas.
... 100 fm; ---- 50 fm; -··- 10 fm.

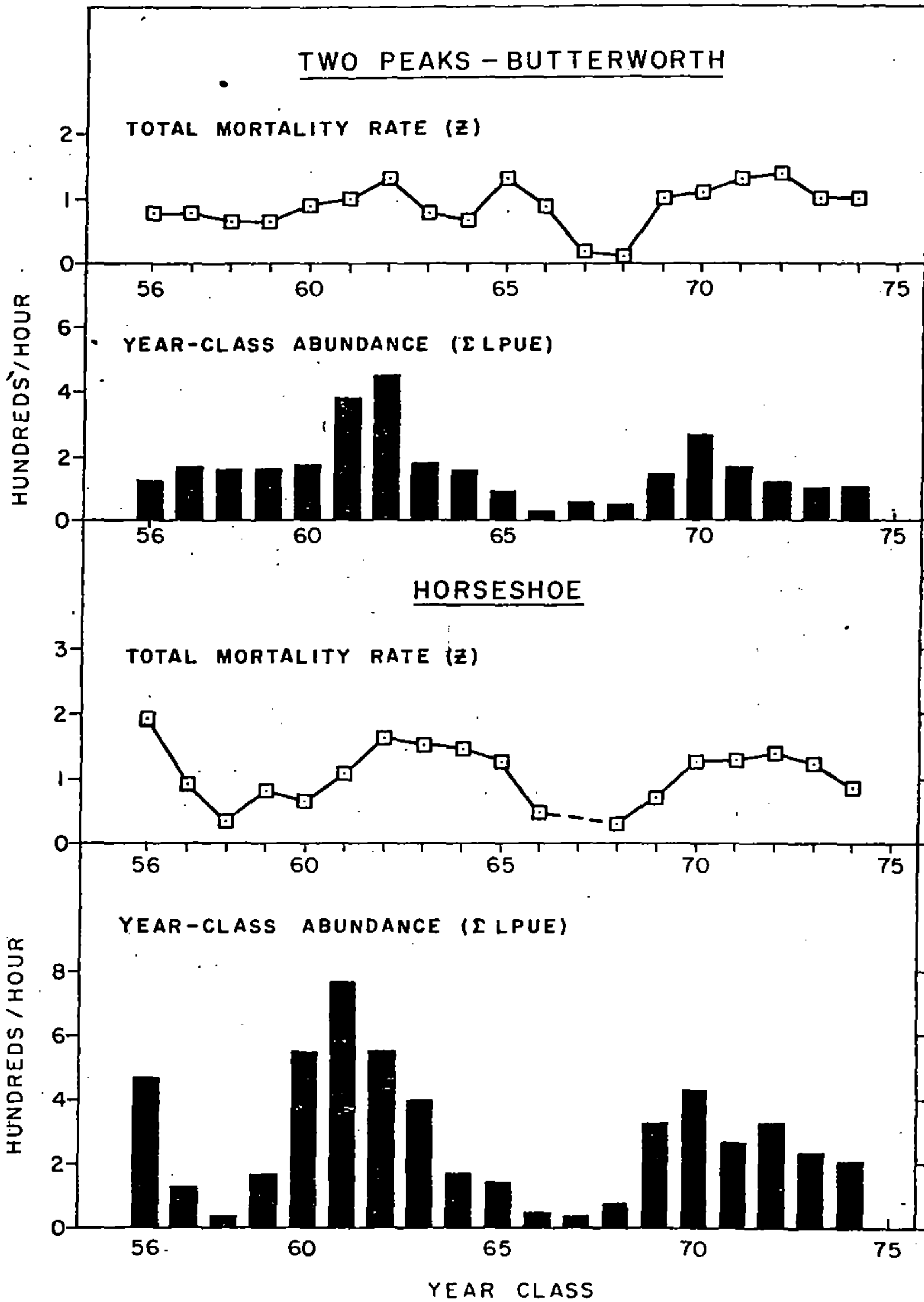


Fig. 2. Annual mortality rate and year-class abundance for Pacific cod on two grounds in Hecate Strait.

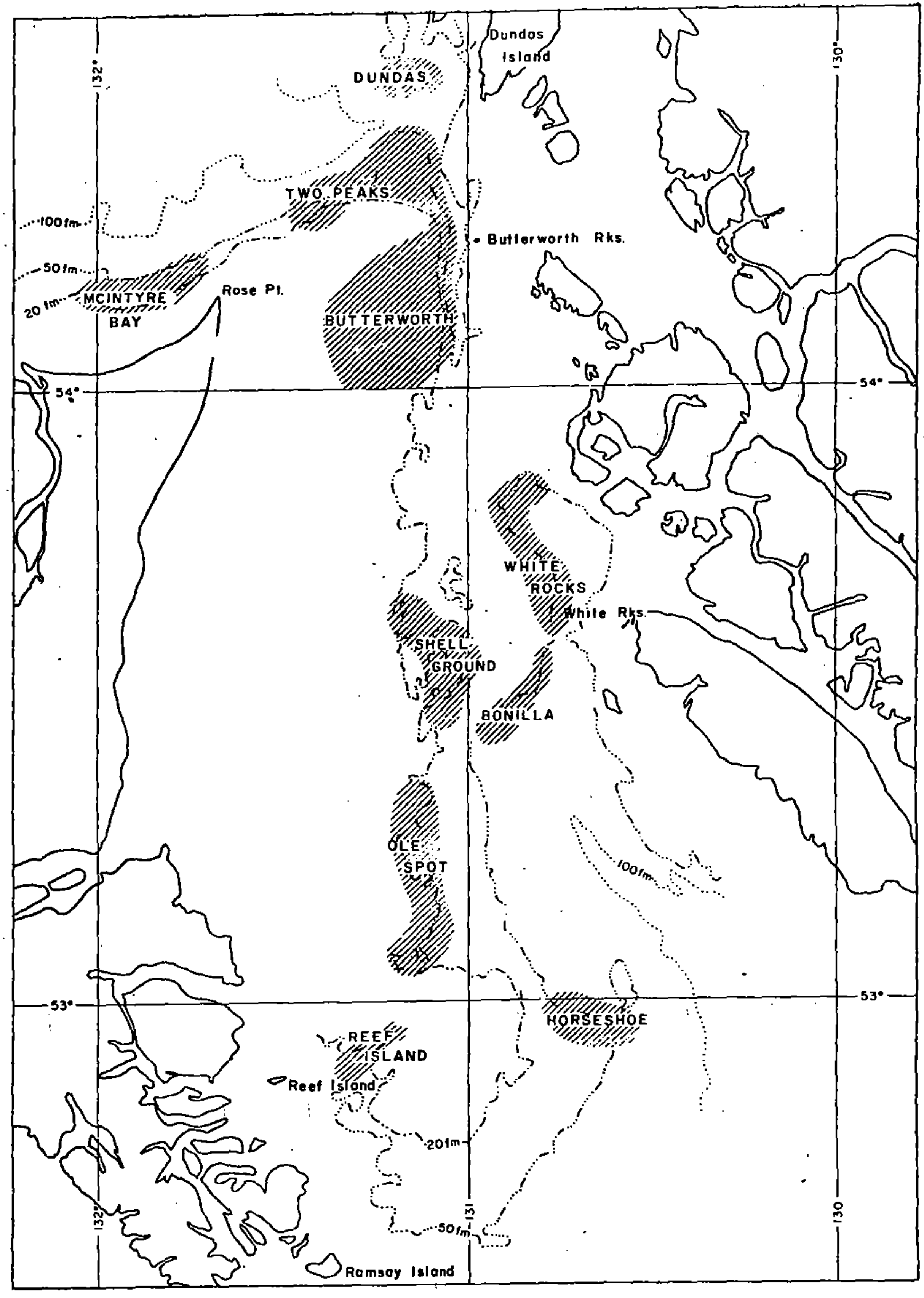


Fig. 3. Groundfish trawling grounds in Hecate Strait.

Appendix A.

I - GEOGRAPHY, CLIMATOLOGY, AND OCEANOGRAPHY OF HECATE STRAIT

INTRODUCTION

In this section the physical features, climatology, and our current knowledge of the oceanography of Hecate Strait are reviewed. This includes the geography, shoreline features, bathymetry, some aspects of the climate, and wave conditions. The oceanography includes a brief review of tides, tidal and non-tidal currents, surface temperature, and salinity features and anomalies, seasonal temperature and salinity structures, annual cycles and vertical distributions of temperature, salinity, density, and dissolved oxygen content. Although the major emphasis is directed to the features of Hecate Strait, some information on the adjoining areas, notably the coastal seaways of Queen Charlotte Sound and Dixon Entrance, is included, as conditions in these areas greatly affect the water masses and currents of Hecate Strait.

The main sources of information are those of Thomson (1981a), "The oceanography of the British Columbia coast", a very timely publication in the preparation of this section, and Dodimead (1980), "A general review of the oceanography of the Queen Charlotte Sound-Hecate Strait-Dixon Entrance region". In most cases the information has been extracted verbatim without reference, except in the figures. However, these and other sources of information are listed in the "Bibliography". Data sources are listed separately. Tabata (1980) has published an inventory of physical oceanographic information (data sources and reports) for the northern waters.

II - GEOGRAPHY

Hecate Strait is a major coastal seaway separating the islands outlining the mainland of British Columbia from the Queen Charlotte Islands (Fig. 1). It is bounded on the south by Queen Charlotte Sound and on the north by Dixon Entrance, which together form a continuous coastal seaway over the continental shelf of the northern British Columbia coast. It is the least exposed of the three seaways. At its southern entrance, between Cape St. James on the west and McInnes Island on the east, Hecate Strait is about 180 km (97 naut mi) wide. Its northern entrance is generally considered to be bounded by Rose Point on the west and Stephens Island on the east, a distance of about 56 km (30 naut mi). It encompasses an area of approximately 940×10^3 km^2 (274×10^3 naut mi^2). It is noted that for this report a small triangular area in Dixon Entrance coinciding with the boundaries of the statistical fisheries areas has been included as part of Hecate Strait. Similarly, the southern boundary is coincident with the boundaries of the statistical areas.

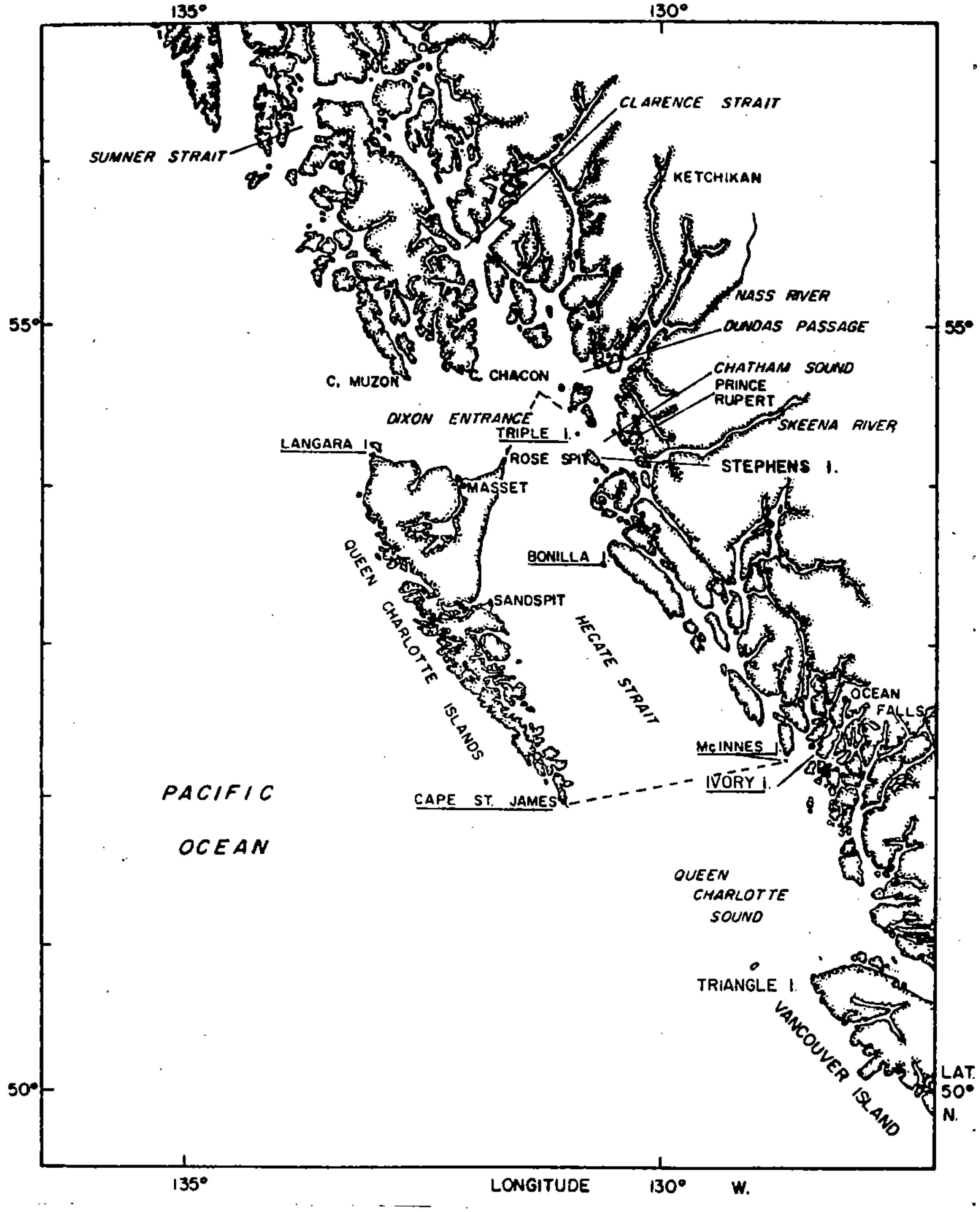


Fig. 1. Queen Charlotte Sound - Hecate Strait - Dixon Entrance Region (dashed lines are the boundaries of Hecate Strait for this report).

III - SHORELINE FEATURES

Hecate Strait (including Queen Charlotte Sound and Dixon Entrance) lies within the Hecate Depression, which includes the narrow, 20-50-km (11-27 naut mi) wide plain along the island-strewn mainland coast (the Hecate lowland), the low relief northeast corner of Graham Island (the Queen Charlotte lowland), and the rocky flatlands of northern Vancouver Island (the Nahwitti lowland) (Fig. 2). This coastline was covered by ice during the last ice age, emerging about 11,000 yr ago.

Within the Hecate lowland (mainland coast), the coastline is characterized by low rocky headlands interspersed with sand, gravel, and boulder beaches. The Skeena River, which enters these lowlands some 20 km (11 naut mi) south of Prince Rupert, has the second largest delta in British Columbia, and extends about 30 km (16 naut mi) to the west in Chatham Sound and adjoining channels.

The Queen Charlotte lowland has some of the most fascinating beach forms in British Columbia. The beach-type that extends form Virago Sound to Rose Spit on the north coast of Graham Island continues some 65 km (35 naut mi) south of Rose Spit, but with a foreshore steeper, narrower and of coarser sediment than along the north coast of Graham Island. Along its northeast coast sea cliffs range from 15-60 m (50-200 ft) in height and dunes are present 100-200 m (325-650 ft) inland of the backshore. Beach sediments are actively being moved by littoral processes, which carry them northward to Rose Spit. Sandspit, which curves for nearly 5.5 km (3 naut mi) halfway across the entrance to Skidegate Inlet, is another area of pronounced depositional feature. As with the gradual eroding beaches to the north, it suggests the presence of a net northward surface drift along the western shores of Hecate Strait. Along the east coast of Moresby Island steep rocky shores mainly of resistant crystalline rock are dominant.

IV - BATHYMETRY

Hecate Strait has the most regular bathymetry of the three seaways (Fig. 2). The axis of the Strait is a narrow 220-km (120 naut mi) long submarine canyon that hugs the mainland flank with depths that decrease from about 164 fm (300 m) at its southern extremity in Mitchells Trough to less than 50 fm (91 m) to the north. In the southwestern part of the Strait in Moresby Trough, maximum depths of 260 fm (475 m) occur. The northwestern side is a broad shallow area less than 10 fm (22 m) in depth, and consisting of glacial sands and gravel. In contrast, the water in the inside passages between the coastal islands and the mainland coast are deep, especially in the mainland fjords. Depths throughout the inside passages vary from 55 to 220 fm (100 to 400 m) and in the fjords the depths often exceed 330 fm (600 m).

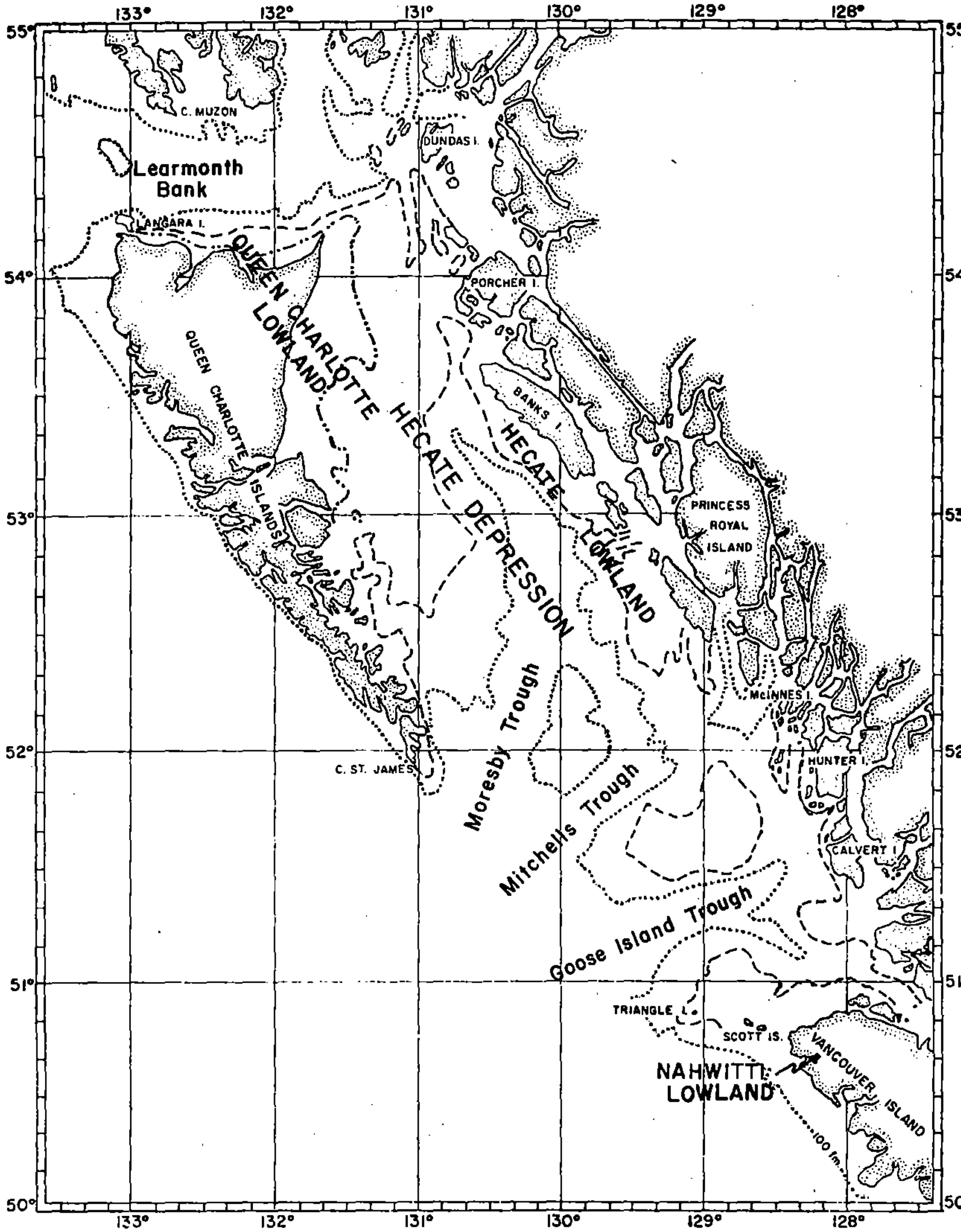


Fig. 2. Bathymetry of Hecate Strait and adjoining areas.
... 100 fm; ---- 50 fm; -·-- 10 fm.

V - WINDS

Wind conditions in the northern seaways are associated with the same semipermanent, huge-scale pressure systems that govern the oceanic wind regimes off the Pacific coast. The Aleutian Low pressure system, which is evident year-round (except in July), gradually increases in intensity from August until January; from August to December its center moves southeastward from the northern Bering Sea to the Gulf of Alaska but shifts abruptly to the western Aleutian Islands in January, after which the system progressively weakens and is no longer evident in July (Fig. 3). The eastern Pacific High pressure system, which is present year-round off the coasts of California and Baja California, reaches maximum intensity during June-August, at which time it encompasses the whole or most of the Gulf of Alaska. The combined pressure patterns produced by these two systems means that from late fall to early spring winds will be predominantly from southeast to southwest along the British Columbia coast as the air circulates anti-clockwise around the dominant Aleutian Low. Form May through September, the combined effect of a greatly weakened Aleutian Low and intensified North Pacific High results in a clockwise flow of air over the ocean. Coastal winds at this time are predominantly from the northwest.

Because of the channelling effect of the bordering mountains, winds in Hecate Strait commonly blow parallel to the coast, with the prevailing directions southeast-northwest. The frequency and intensity of southeasterly winds are greater to the north than to the south, whereas the frequency and intensity of northwesterlies are greater to the south than to the north.

In winter the southeast component is dominant (Fig. 4). In summer, at northern weather stations such as Sandspit and Prince Rupert, winds have a weak southeast component. However, at southern stations a strong northwest component is present at Cape St. James, but only a weak northwest component at McInnes Island.

The seasonal variability in direction and speeds in Hecate Strait are probably best indicated by wind observations at McInnes Island. Here, the largest mean speeds, about 20-30 mi/h (9-13 m/s), occur along the southeast and south components from October through April (Fig. 5). From June through August, mean speeds along these directions are about one-half the winter values, but are greater than the mean speeds along the northerly components which are about 3-8 mi/h (1.3-3.6 m/s). The speeds are relatively constant throughout the year along the northerly components. The percentage frequency of winds reflects their annual variability, relatively large values (about 20-30%) for the east and southwest components from October to April, and for the northwest component from May to October.

A marked drop in average wind speeds toward the shores, particularly the mainland shore, occurs as inferred from the frequency decrease toward the mainland shore of winds greater than 25 mi/h (Fig. 6 and 7).

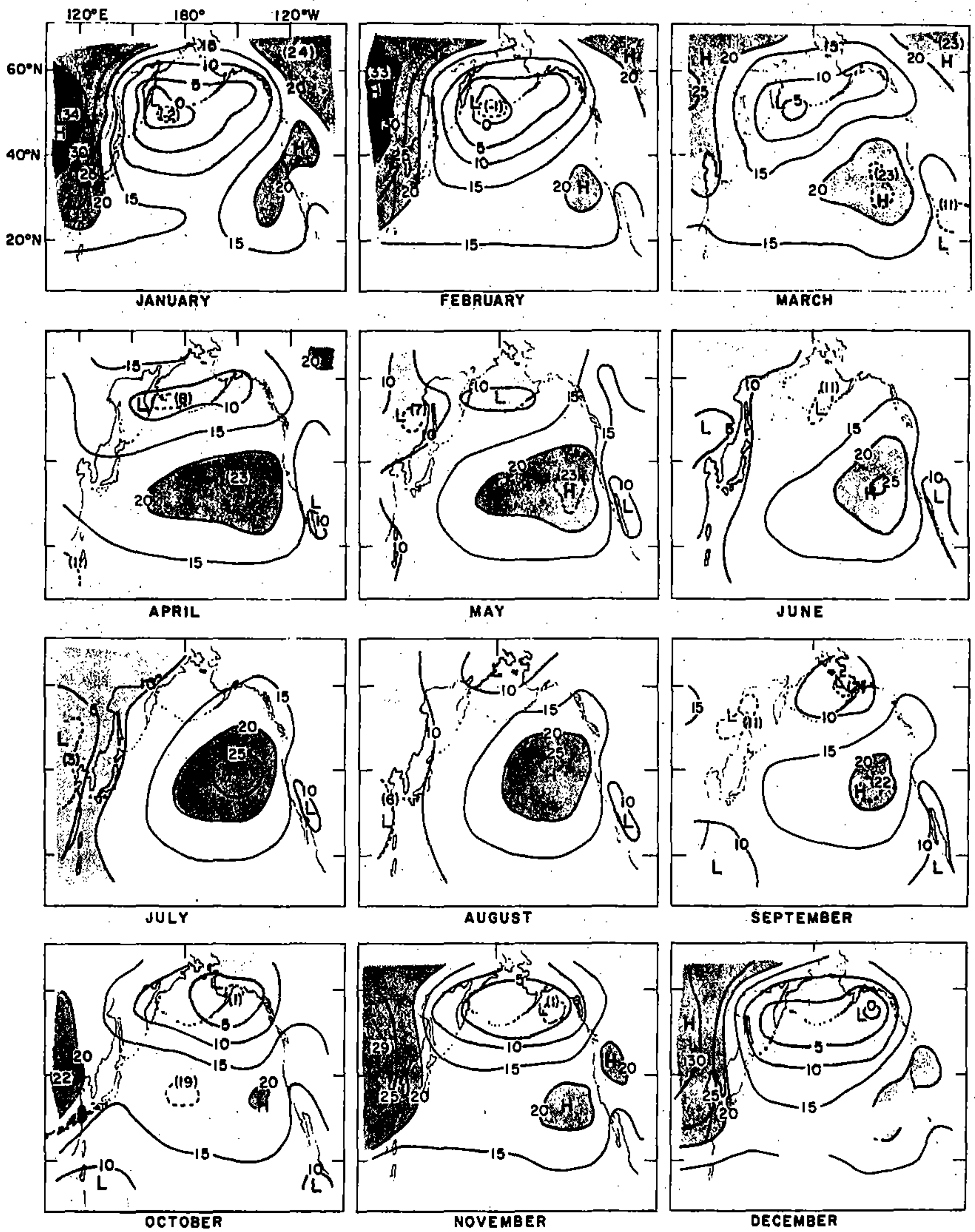


FIGURE 5. Monthly mean air pressure at sea level (value+10,000)/10=mb (based on U.S. National Climatic Center, Tape Data Family—11; 1951-70)(from Favorite et al. 1976).

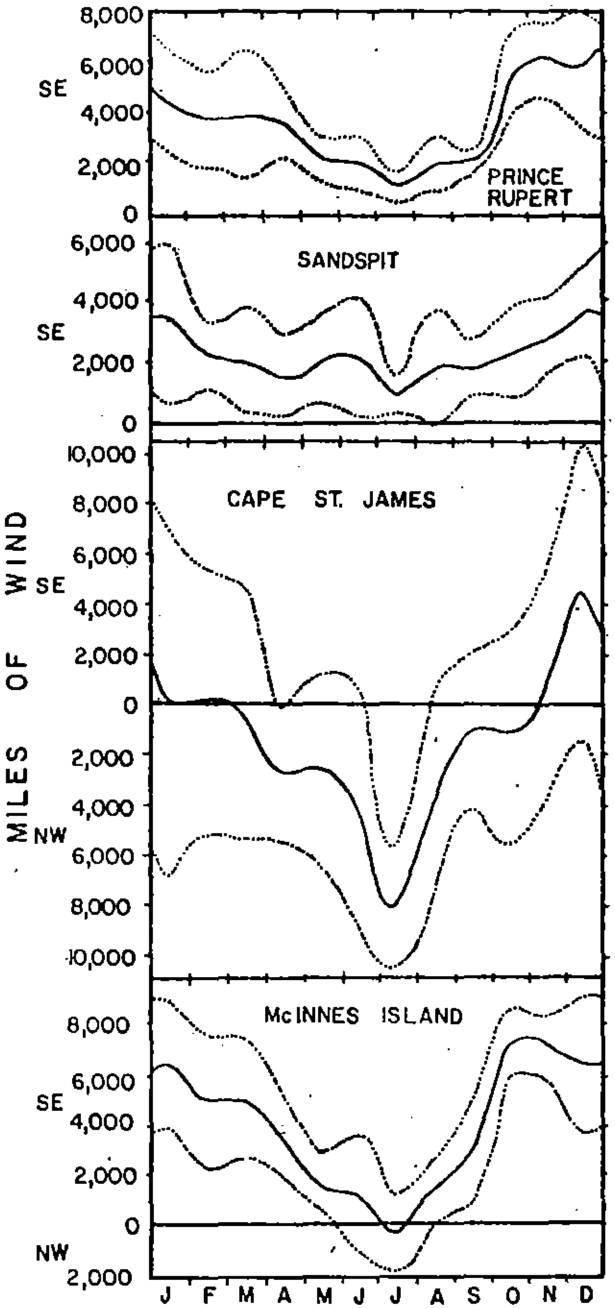


FIG. 4. Grand means and standard deviations of monthly total miles of wind resolved along the southeast axis at Prince Rupert, 1954 through 1962, Sandspit, 1955 through 1964, McInnes Island, 1955 through 1963, and Cape St. James, 1955 through 1963. (from Crean 1967)

	J	F	M	A	M	J	J	A	S	O	N	D	MEAN
N	3.5	4.1	3.4	3.6	3.6	3.8	4.2	3.3	3.8	3.3	3.9	3.5	3.7
NE	7.9	6.6	6.7	5.3	4.4	3.8	7.5	2.8	3.1	4.6	6.3	7.9	5.6
E	11.4	9.5	9.7	9.4	7.6	7.3	7.0	5.7	7.1	8.9	10.2	11.7	8.8
SE	25.5	24.3	22.5	21.7	14.9	13.3	12.3	14.1	16.5	27.8	23.8	26.4	19.8
S	28.7	27.0	23.2	20.7	15.1	14.2	11.4	14.1	18.3	23.2	27.2	28.6	21.0
SW	18.9	18.7	16.1	14.5	10.2	9.6	8.8	8.3	11.3	16.0	18.9	19.9	14.2
W	12.8	13.8	9.1	8.7	5.8	5.6	5.1	5.1	5.9	8.5	14.2	12.4	8.9
NW	8.1	7.8	8.0	8.3	8.0	8.1	7.9	6.7	7.4	6.9	8.0	9.4	7.9
MEAN SPEED	15.4	14.9	13.8	13.1	9.5	9.3	8.2	8.3	10.5	15.2	15.9	16.5	12.6

	J	F	M	A	M	J	J	A	S	O	N	D
N	6	7	7	8	8	7	8	8	11	5	6	5
NE	14	10	10	6	3	2	2	2	4	5	10	12
E	29	27	20	13	9	8	6	8	14	20	28	27
SE	19	18	18	15	11	10	10	14	16	25	25	22
S	12	15	17	21	22	21	18	21	20	20	12	13
SW	9	11	10	12	12	14	11	11	8	12	10	11
W	3	3	4	6	10	11	12	10	6	3	3	3
NW	7	8	13	18	23	26	31	24	20	10	6	7
CALM	1	1	1	1	2	1	2	2	2	0	0	0

Fig. 5. Long-term monthly means (1955-72) of wind speed (mi/hr) (upper plate) and of percentage frequency (lower plate) along 8 points of the compass, McInnes Island.

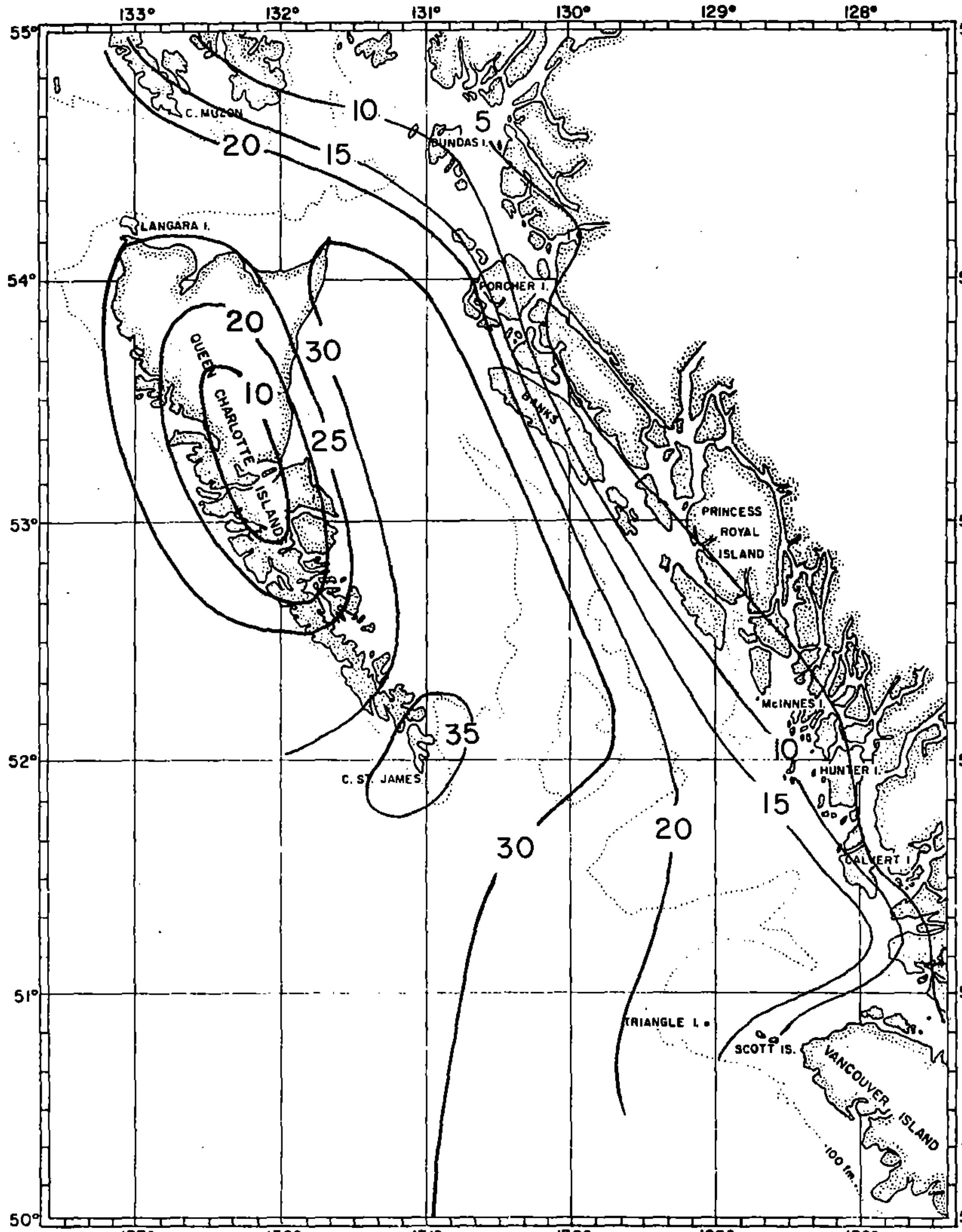


Fig. 6. Percentage frequency of winds greater than or equal to 25 m.p.h., October to April (from Faulkner and Schaefer 1978).

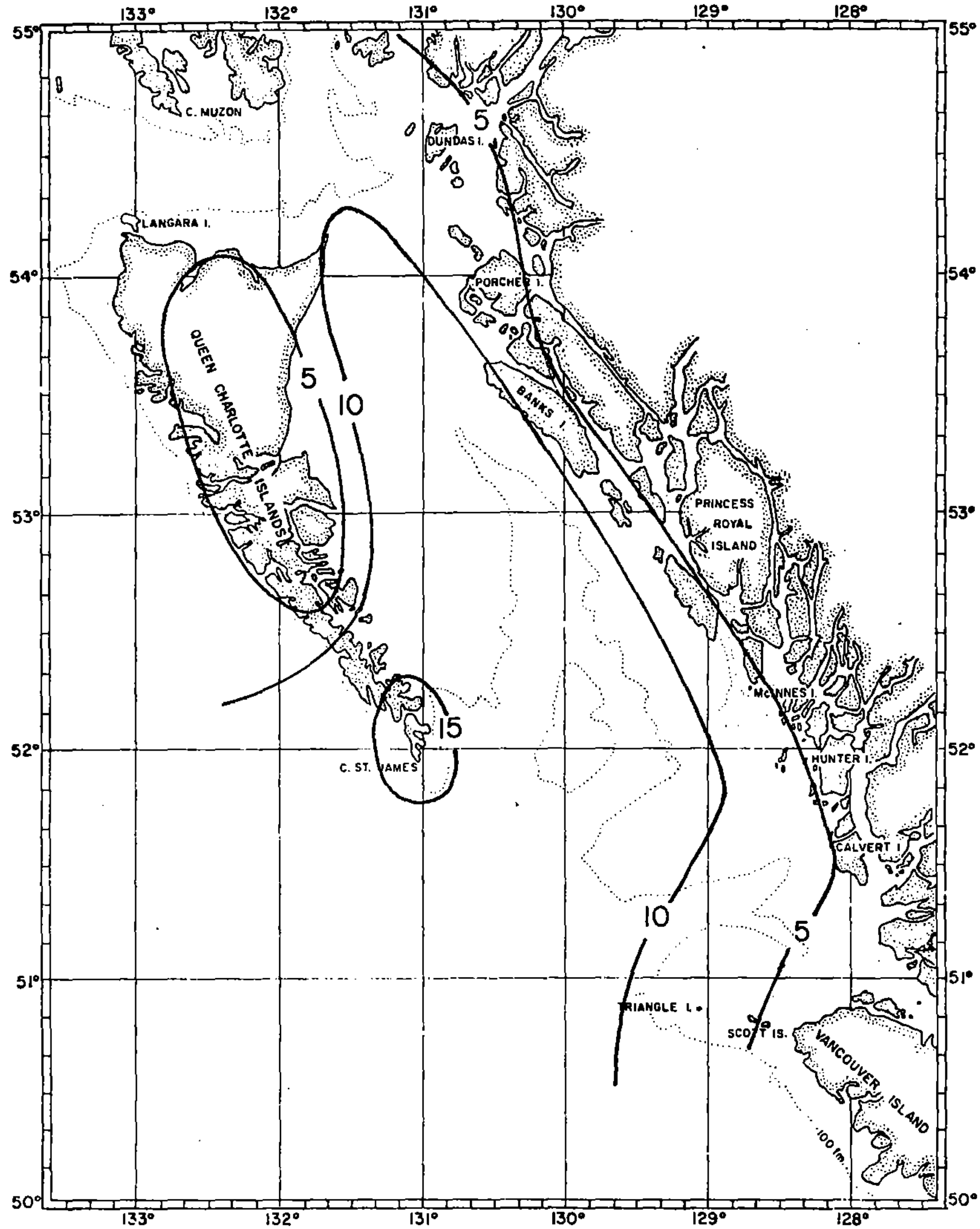


Fig. 7. Percentage frequency of winds greater than or equal to 25 m.p.h., May to September (from Faulkner and Schaefer 1978).

VI - FOG

Table 1 gives the seasonally average days of fog at four coastal weather stations bordering the waters of Queen Charlotte Sound, Hecate Strait, and Dixon Entrance. The percentage occurrence of sea fog is greater during summer (June through September) than during autumn or winter (October through February). Fog tends to be more prevalent over the seaward approaches to Queen Charlotte Sound and Dixon Entrance than over the mainland side or over Hecate Strait. However, there is nothing that resembles the persistent summer fogs of the exposed coast of Vancouver Island to the south.

The foggiest months are August and September at 10-15% of the time. Fog occurs less than 5% of the time from October through February, about 5% of the time in March and April, and around 10% during May, June, and July. Fresh winds that may accompany foggy conditions in summer may effectively lift the moisture to a very low deck of stratus clouds with a slight improvement of visibility but, in general, near zero visibilities are likely to persist for many days over wide areas of the seaway.

Table 1. Number of days of fog during 3-mo intervals at few locations on the northern coast (from Thomson 1981a).

Location	Jan-Mar	Apr-June	July-Sept	Oct-Dec
Prince Rupert	1	4	10	1
Cape St. James	5	7	11	7
Langara	1	3	6	1
Sandspit	2	2	2	2

VII - WAVES

Wave conditions are typically less severe in the coastal seaways than in the open ocean. Of the three major seaways average wave heights are least in Hecate Strait; in Queen Charlotte Sound they are somewhat higher than those in Dixon Entrance. Queen Charlotte Sound and the southern end of Hecate Strait are especially vulnerable to deep-sea waves from the southeast which, when aided by favouring winds, undergo little attenuation as they propogate northward. In addition, frontal systems are known to rapidly generate steep mountainous seas over the broad shoal area adjacent to the east coast of Graham Island.

On a seasonal basis, wave conditions are most severe in autumn and winter, and mildest in spring and summer. Hazardous wave heights in excess of 3.5 m (10 ft) occur on the average 20-30% of the time along the outer coast from October through January, but diminish in frequency to around 10% along the mainland side of the seaways. From February until March the frequency of seas over 3.5 m reduces to 15% on the outer coast and 5% on the mainland coast. By late spring the chance of encountering hazardous seas is less than 5%, a condition that prevails until late September when storms again begin to lash the coast with renewed vigour.

The suddenness at which extreme autumn wave conditions can arise is substantiated from observations made from the Drill Rig (SEDCO 135F) in 137 m (75 fm) of water off Cape St. James in 1968. Beginning in mid-October the rig was battered by heavy seas for 16 days, as one storm after another generated waves of 9-15 m (30-50 ft). Between storms seas never fell below 3 m (10 ft). On October 22, a rapidly moving storm with gusting winds of 41 m/s (80 kn) produced significant waves exceeding 20 m (65 ft). On at least one occasion, a wave close to 30.5 m (100 ft) was observed.

The most dangerous aspects is not the magnitude of the waves generated but the rapidity with which conditions change. At 1500 h on October 22 the seas were reported 3.0 m (10 ft) in height. Within 8 h the waves were 18.3 m (60 ft) in height (Fig. 8). Shortly after this, there was an even more rapid decrease in wave height.

VIII - TIDES

Tides in Hecate Strait are typical of the predominant tides along the Pacific coast of North America; they are mixed, predominantly semidiurnal (two highs and two lows per lunar day). They pass through tropic and equatorial sequences in alternate weeks. The large tidal ranges occur during tropic tides when the diurnal inequality is at its greatest. The inequality occurs principally in the height and time of succeeding low tides. The mean tide range, the difference between the heights of higher high water and lower low water at mean tide, increases from south to north. Shoaling effects cause the range of the semidiurnal tide to increase from about 2.4 m (8 ft) across the mouth of Queen Charlotte Sound to around 3 m (10 ft) midway along Hecate Strait, and from 2.4 m (8 ft) at the mouth of Dixon Entrance to 3.7 m (12 ft) along its eastern shore. Corresponding values for the mean tide are from 3 m (10 ft) at the entrance to Queen Charlotte Sound to 4.8 m (16 ft) midway along Hecate Strait and from about 3.5 m (11.5 ft) at the entrance to Dixon Entrance to 5 m (19.4 ft) at Prince Rupert. Tidal ranges over 7 m (23 ft) are encountered on large tides within the Skidegate Channel that separates Graham and Moresby islands and in the vicinity of Prince Rupert. There is an amplification of the mean range to as much as 4.9 m (16 ft) as it moves up the narrow inlets of the mainland coast.

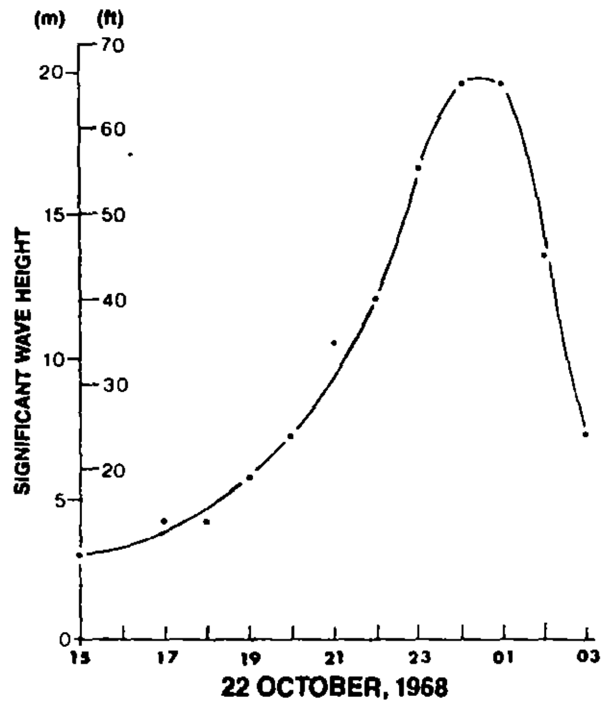


Fig. 8. Wave heights reported from SEDCO 135 F drilling rig anchored off Cape St. James in 137 m water (from Thomson 1981a).

The north-going flood tide in the offshore waters moves through Queen Charlotte Sound and along the mainland shores and meets the flood tide coming through Dixon Entrance in the northern part of Hecate Strait (Fig. 9). The confluence of the tides appears to be some 45-55 km (25-30 naut mi) farther north in winter than in summer. It takes about 30 min for the tide to reach the northern part of Hecate Strait from either of the two oceanic approaches, then the combined tide swings westward across the Strait, reaching the southeastern shores of Graham Island some 15 min later. A particular stage of the tide within the three seaways differs by at most 1 h (Fig. 9).

In addition to the daily and bi-weekly cycles in the tidal range, there are cyclic modulations that take place over long periods of time; monthly, semiannually, 8.8 yr, 18.6 yr and 20,940 yr.

IX - SEA LEVEL

Sea level is of considerable significance as an index to identifying variability in flow and in water structure. For example, the annual variability in the subsurface water masses in Queen Charlotte Sound appears to be responsible for a large part of the annual sea level oscillations observed at Prince Rupert. Also, below-average sea level in January indicates the absence of warm subsurface waters in Queen Charlotte Sound (and in Hecate Strait).

Monthly means of sea level (adjusted for atmospheric pressure) and anomalies clearly indicate an annual cycle with a marked variability in amplitude (Fig. 10). Abrupt changes in sea level usually occur in October-November, coincident with the onset of the strong southerly winds, and the values generally remain high at least through February. Highest annual values generally occur in December-January; lowest annual values from May through September.

The largest anomalies generally occur during the autumn-winter period (October through March). Years in which relatively high positive (high sea level) and negative (low sea level) anomalies were dominant during this 6-mo period are identified. Sea levels were generally low in 1946-47, 1948-49, 1949-50, 1950-51, 1951-52, 1955-56, 1956-57, 1961-62 and 1970-71. Large positive anomalies during October-March were dominant in 1953-54, 1954-55, 1957-58, 1960-61, 1963-64, 1967-68, 1968-69, 1969-70, 1972-73, 1977-78, 1979-80 and 1980-81. In the latter period anomalies were comparable to those observed in 1957-58, a period in which anomalously warm surface conditions prevailed along the Pacific coast.

Anomalies in summer are much smaller and generally less persistent than those in the autumn-winter period.

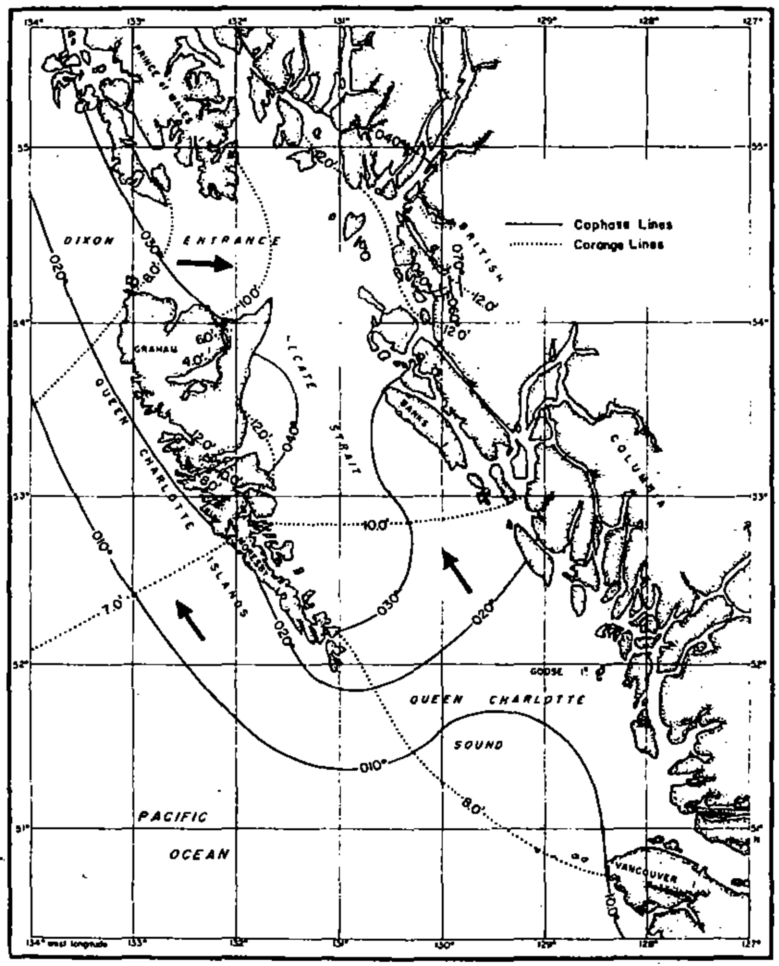


Fig. 9. Corange and cotidal values for semidiurnal tide. Tide range (dotted lines) in feet; tidal phase (solid line) in degrees. Difference of 29° corresponds to time difference of 1 hr. Arrows give direction of tide propagation (from Thomson 1981a).

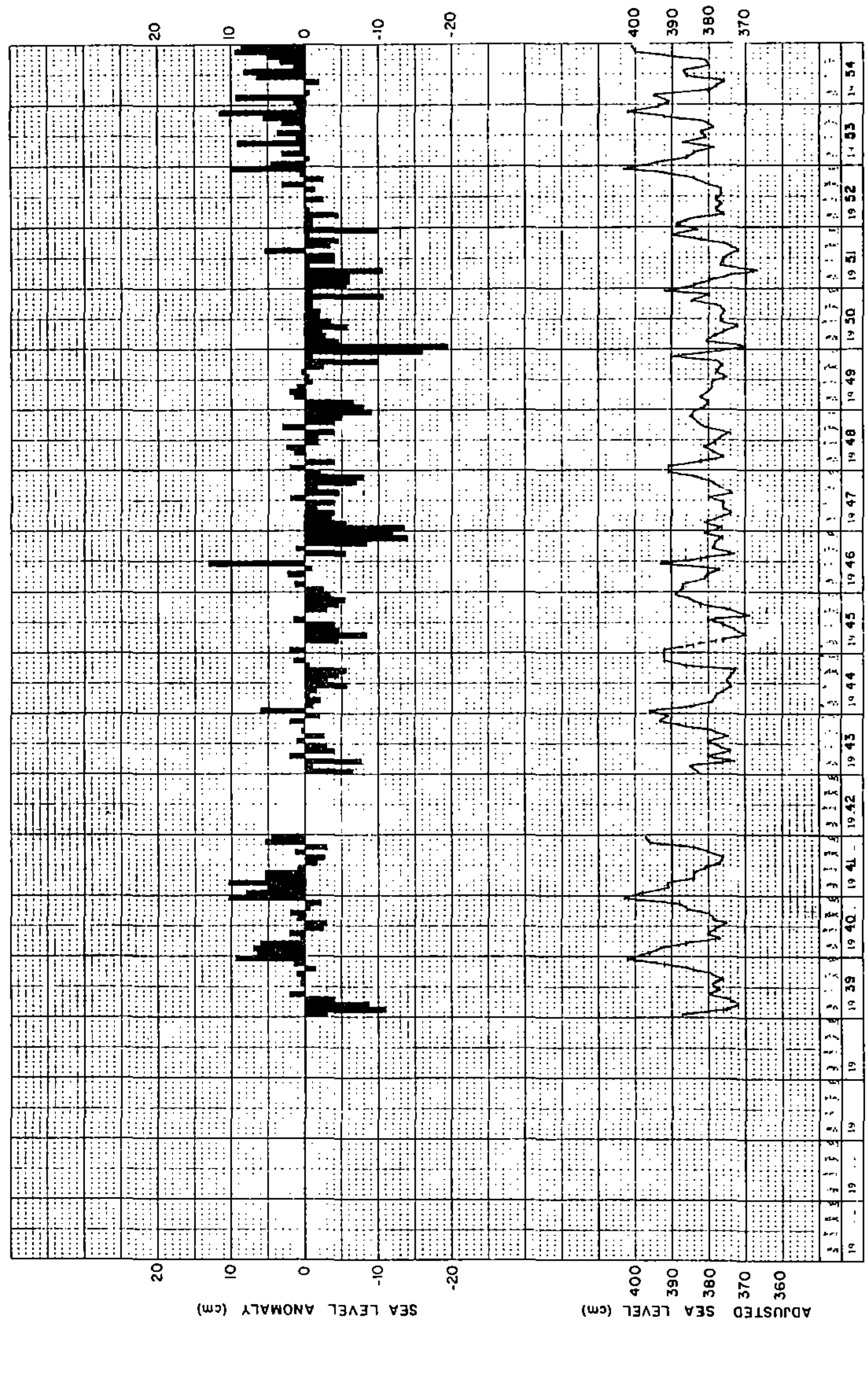
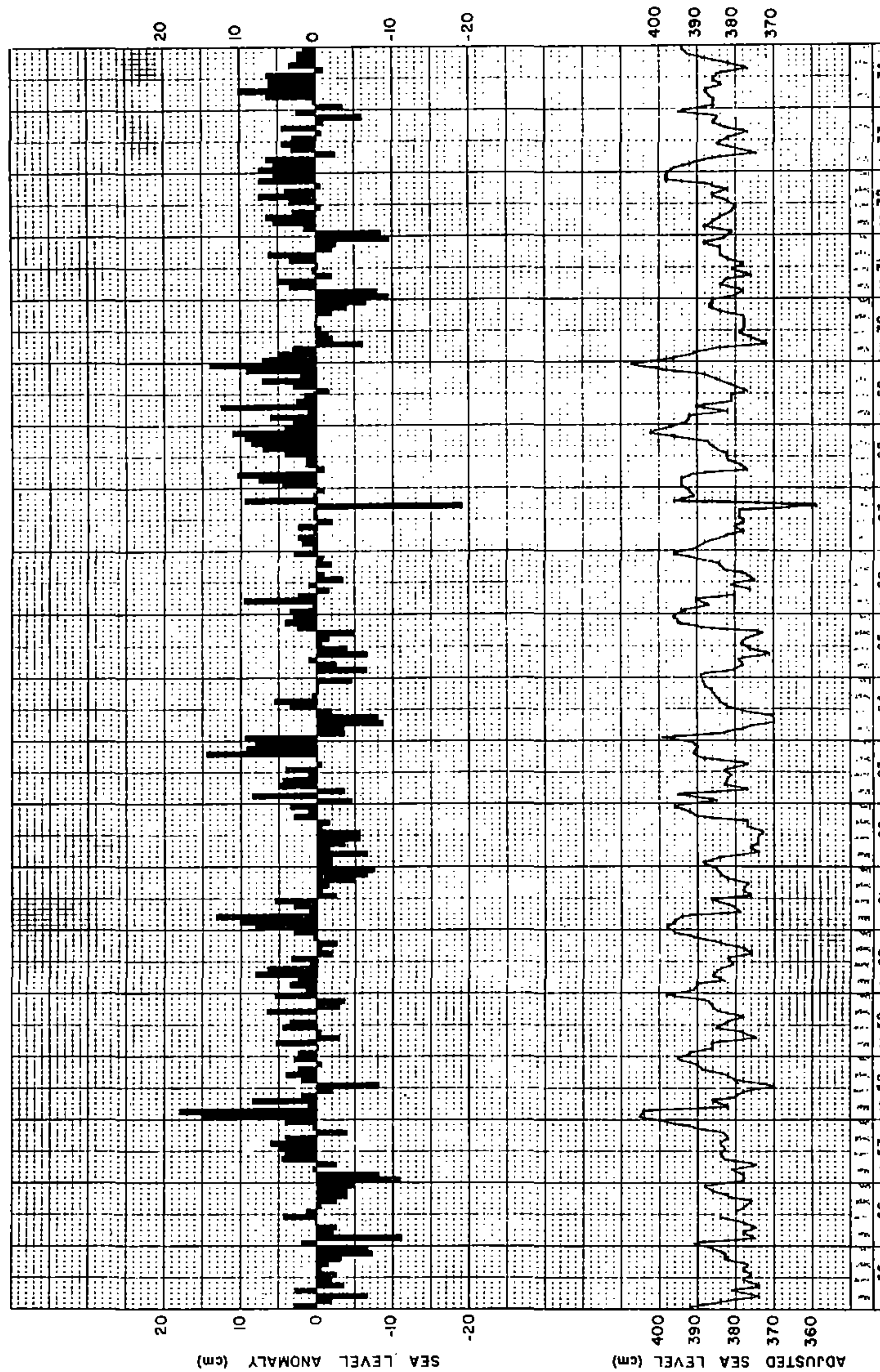


Fig. 10. Monthly means of sea level (adjusted for atmospheric pressure) and anomalies (solid bars) (monthly mean minus long-term monthly mean, 1946-1981) for Prince Rupert, 1939-81 (Contd.)


SEA LEVEL ANOMALY (cm)
20
10
0
-10
-20
ADJUSTED SEA LEVEL (cm)
400
390
380
370
360
19 55
56
19 57
19 58
19 59
19 60
19 61
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1964
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1973
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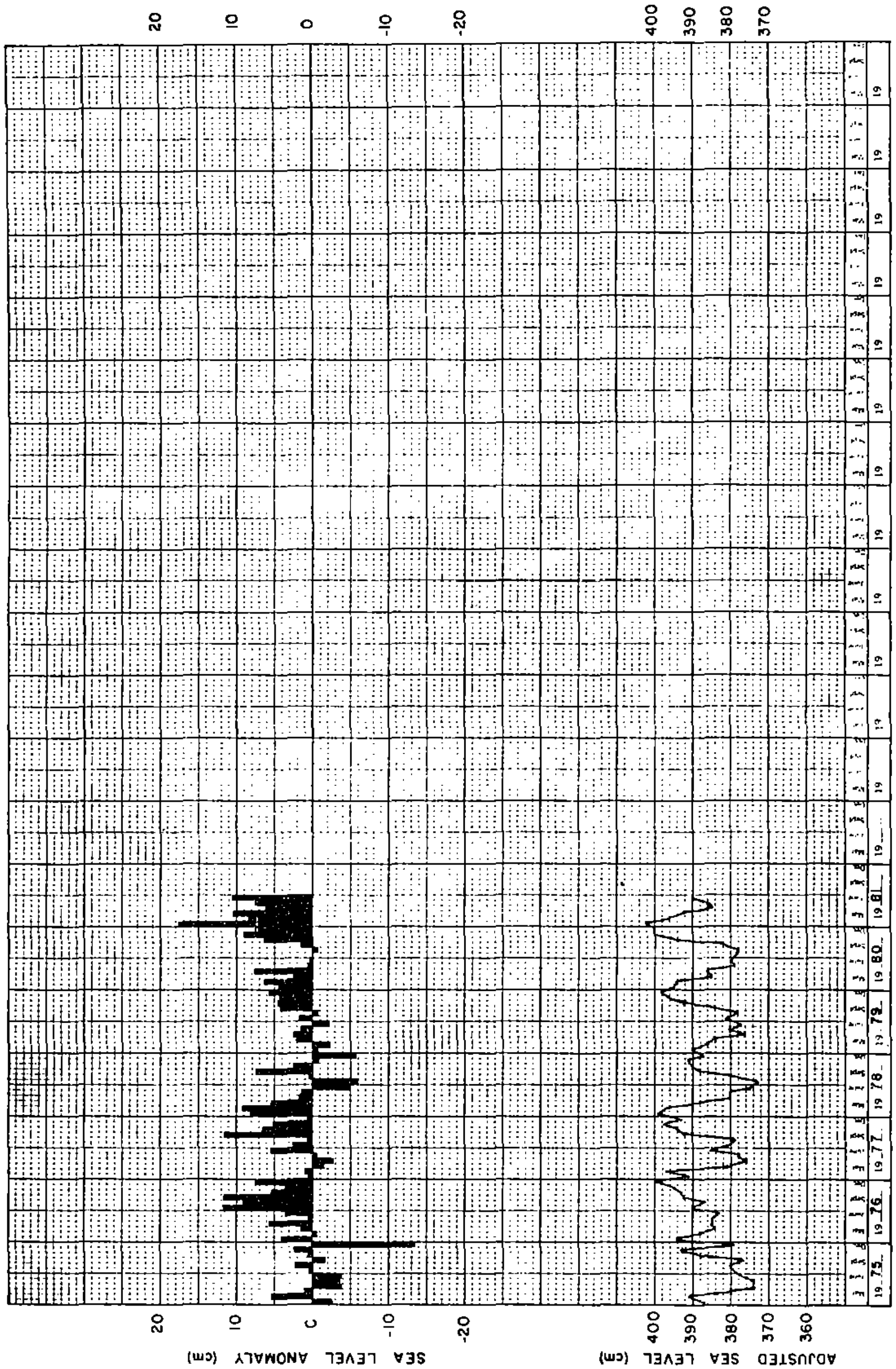
Fig. 10. (Cont'd).


SEA LEVEL ANOMALY (cm)
ADJUSTED SEA LEVEL (cm)
20
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19 80
19 81

Fig. 10. (Cont'd).

X - CIRCULATION

1. TIDAL CURRENTS

Surface water movements within the coastal seaways are dominated by the semidiurnal tidal streams that consistently undergo modification by the effect of wind, runoff, bathymetry, and shoreline configuration.

In the absence of vigorous winds or runoff, surface tidal currents within Queen Charlotte Sound and Hecate Strait generally consist of clockwise-rotary tidal streams that alter direction and speed in a regular manner over a cycle of about 12 1/2 h. The rotary nature of the tidal flow is best developed in the outer reaches of Queen Charlotte Sound where horizontal motions are comparatively unrestricted by land (Fig. 11). During spring tides, maximum speeds are of the order of 1 kn (50 cm/s) but decrease to around half this value during neap tides. Nearer the shore, the tidal ellipses generally become increasingly rectilinear (flow alternately in roughly opposite directions with slack water at each reversal in direction) with major axis aligned parallel to the trend of entrant channels. In most cases, the flow is accelerated as it negotiates the constricted mouths of these inland leading waterways. There are exceptions; it appears that tidal streams in the central portions of some broad openings that adjoin Queen Charlotte Sound retain their rotary nature because of the curvature of the shoreline and the splitting of the streams into still further channels.

In Hecate Strait near-surface tidal streams are elliptical to basically rectilinear due to restrictions on cross-strait flow by the valleylike bathymetry (Fig. 11). Other examples of semi-diurnal ellipses for the surface and other depths are provided form data observed hourly but only over a 50-h period at several locations in Hecate Strait (Fig. 12); whereas the former data were observed continuously over a period of several months. Some of the major features of the tidal motions in these data (Fig. 13) are:

(a) current motions at tidal frequencies were dominated by the semidiurnal component at all stations and depths. The amplitude of these currents exceeded 50 cm/s (Sta. 44); typical values were in the range of 23-35 cm/s. The semidiurnal components were generally two to four times greater than the diurnal components.

(b) semidiurnal currents at stations 43 and 44 were roughly aligned with the axis of Hecate Strait, whereas at station 42 the flow appeared to be oriented with the deep channel west of Banks Island. Similarly, the semidiurnal ellipses at I-1 and I-2 were aligned with the axis of the strait while at I-3 the orientation was approximately parallel to the deep channel.

(c) the semidiurnal currents consistently led the semidiurnal tides in the region; maximum flood (ebb) typically precedes local high (low) water by 1 1/2 to 6 h.

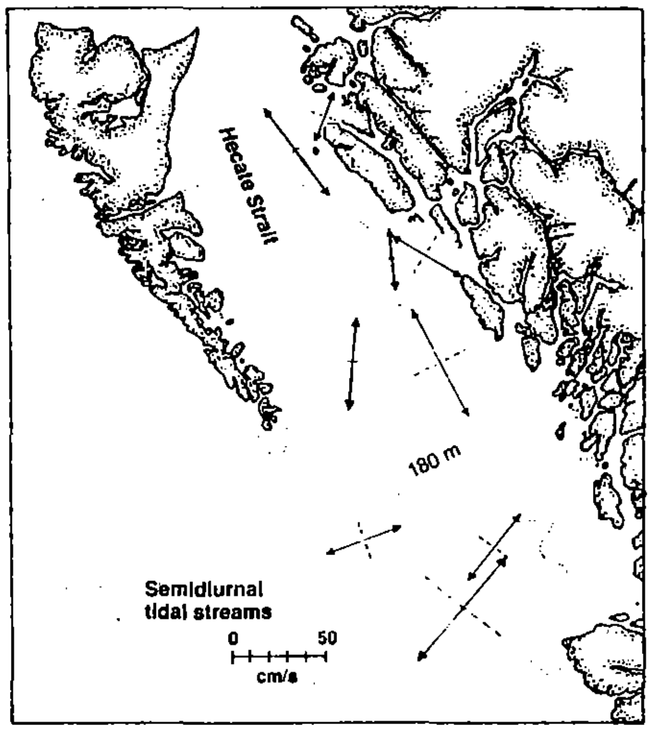


FIG. 11. Observed semidiurnal tidal streams at a depth of 15 m in Queen Charlotte Sound and Hecate Strait. Solid lines and arrows give orientations of major ebb and flood directions; broken lines at right angles give minor flow directions for rotary tidal currents. Scale measures speed relative to midpoint of each axis. (Courtesy S. Huggett).
(from Thomson 1981a)

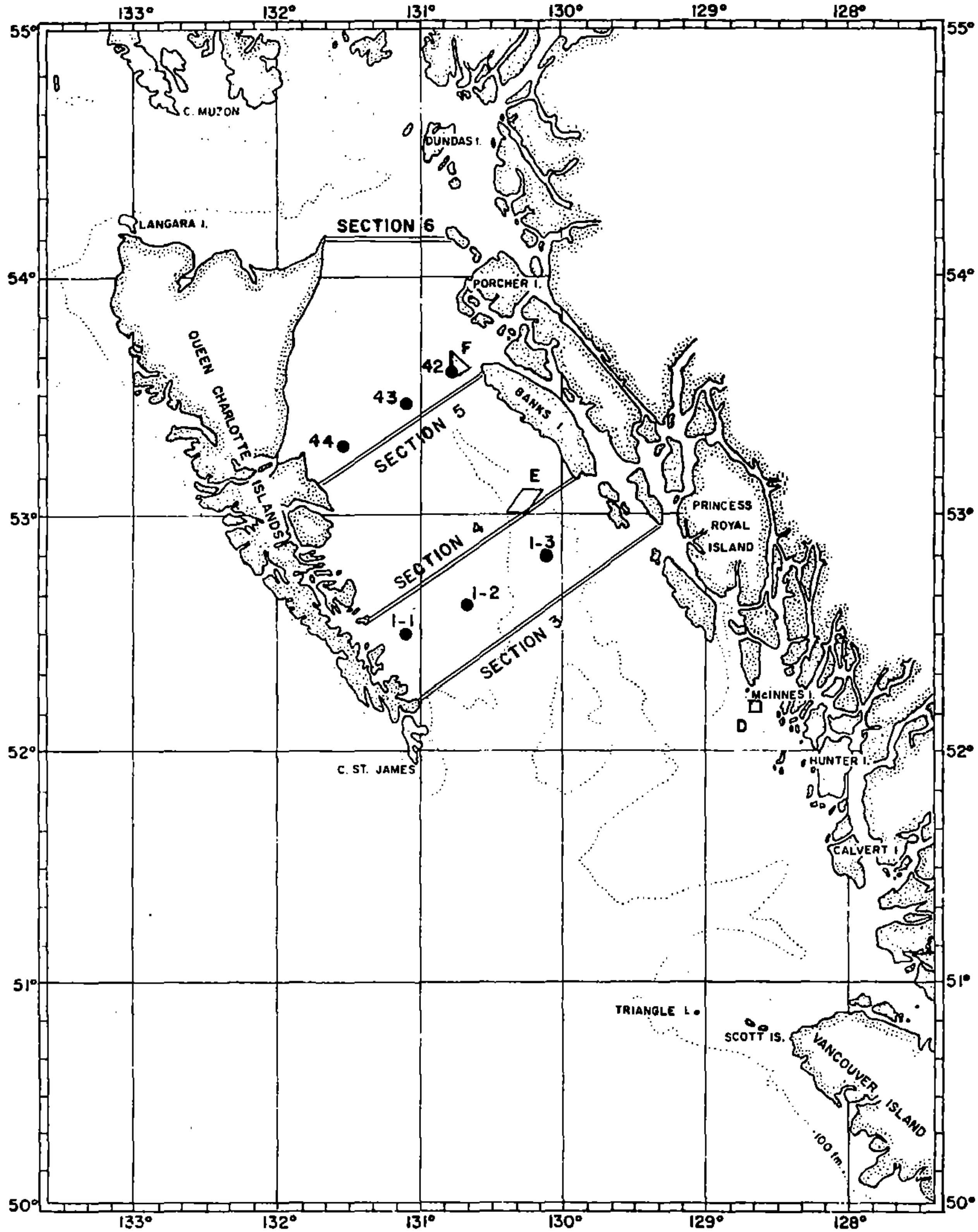


Fig. 12. Location of current meter observations, ● ; locations of observations showing annual cycles of temperature, salinity, density, dissolved oxygen content and temperature and salinity structures, D, E, F; and location of sections in Hecate Strait.

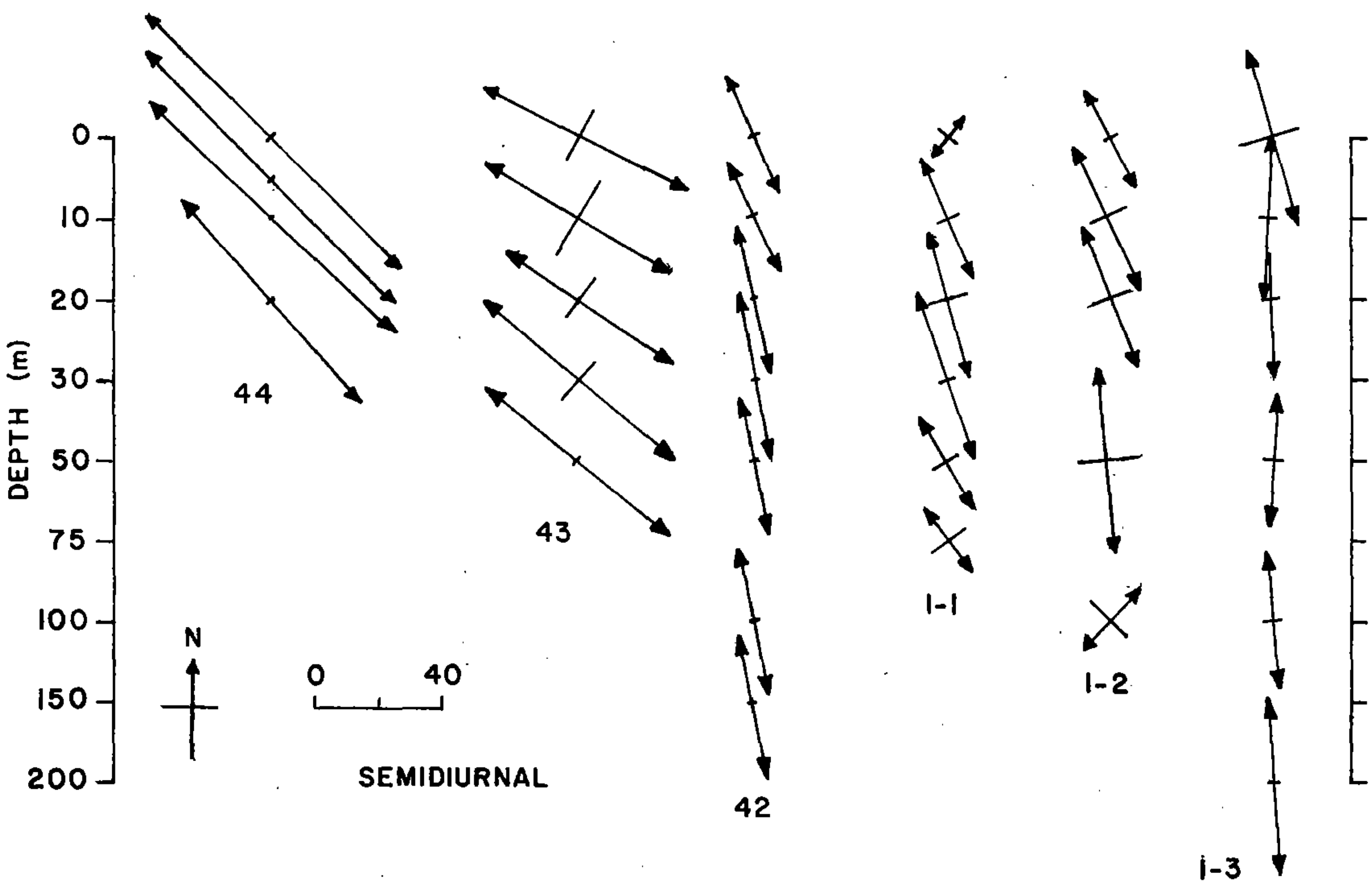


Fig. 13. Semidiurnal tidal current ellipses in Hecate Strait. The arrows give the orientation and magnitude of the major flood and ebb directions (from Thomson 1981b).

The times of particular stage of the current along the Hecate Strait (for example maximum ebb or flood) are progressively delayed from those at the seaward entrance to Queen Charlotte Sound, and reach a maximum delay of just about 2 h at the latitude of Banks Island (Fig. 14).

2. NONTIDAL CURRENTS

The nontidal components of the circulation are a result of wind and runoff. Because of the transient fluctuations in their patterns, the nontidal currents are often subject to rapid temporal and spatial variations. On a short term basis their predictability is almost nil. However, it is possible to define the major seasonal features related to the prevailing seasonal wind and runoff conditions.

(a) Estuarine Circulation

The features of the circulation and water stucture of a typical west coast inlet with a significant freshwater source at its head are well documented (Fig. 15). The main features are: a vertical structure consisting of an upper zone of brackish water, a halocline and a lower zone; a diluted upper zone that moves persistently seaward, with the surface salinity increasing as seawater is entrained from below; a compensatory intrusion of seawater below the halocline which maintains a lower zone of undiluted seawater.

From late spring to early summer large volumes of snow melt are discharged from the multitude of mainland coastal estuaries into the coastal seaways resulting in a measurable and highly variable estuarine circulation. It is most marked in Chatham Sound and Dixon Entrance because of the large discharges associated with the Nass and Skeena rivers. A significant estuarine circulation also occurs along the mainland coast and in Queen Charlotte Sound during this period.

b. Wind-drive Circulation (Ekman Transport)

The effects of wind along our outer coast generate two basic flow patterns (Fig. 16). Southeast winds produce a northward surface drift which is then deflected to the right by the earth's rotation. This in turn leads to a net onshore transport within the surface layer. Where the transport is blocked by the coast, as off the west coast of Vancouver Island, there is an onshore accumulation of surface water (convergence) and a depression of the near-shore isopycnals (downwelling) with a partial compensating offshore transport at depth. Resulting pressure gradients are then balanced by the establishment of a northward coastal current in the surface layer. If there is a relaxation of the winds, the piled up waters move seaward and the wind-driven current disappears. Under northwest winds, the surface Ekman transport is offshore (divergence), isopycnals rise near the coast (upwelling) with an onshore transport at depth, and the ensuing coastal current is southward.

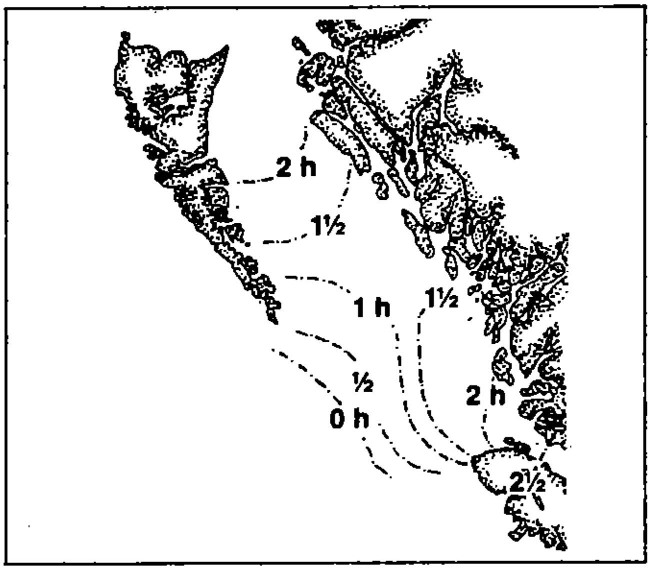


FIG. 14. Times of particular stage of tidal streams, relative to open coast. For example, off Banks Island maximum flood occurs 2 h after maximum flood at entrance to Queen Charlotte Sound. (Courtesy S. Huggett) (from Thomson 1981a).

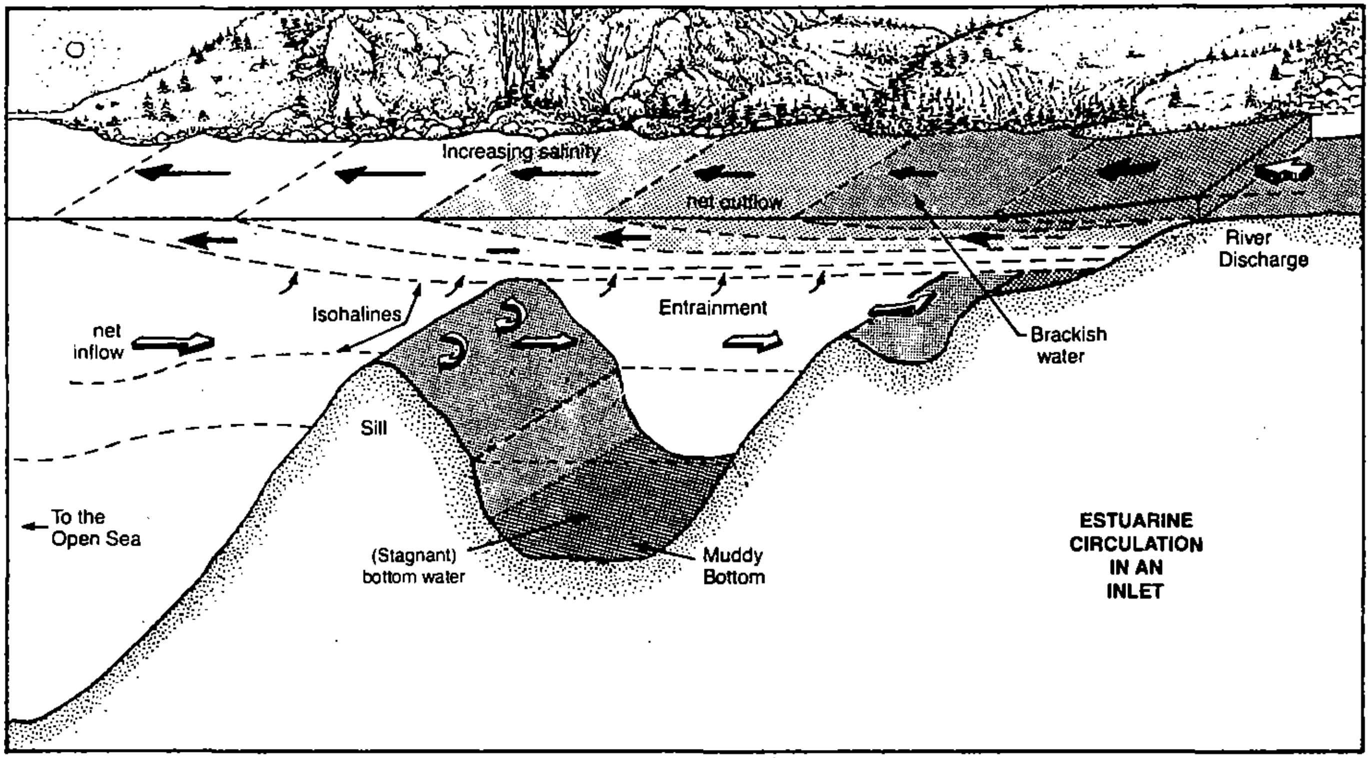


FIG. 15. Estuarine circulation in a typical British Columbia inlet. Salt water entrained and carried seaward by river outflow is replenished by a net inflow at depth. Sloping isohalines (lines of equal salinity) indicate a down-inlet increase in salinity in surface brackish layer. Turbulent mixing occurs in vicinity of sill (from Thomson 1981a).

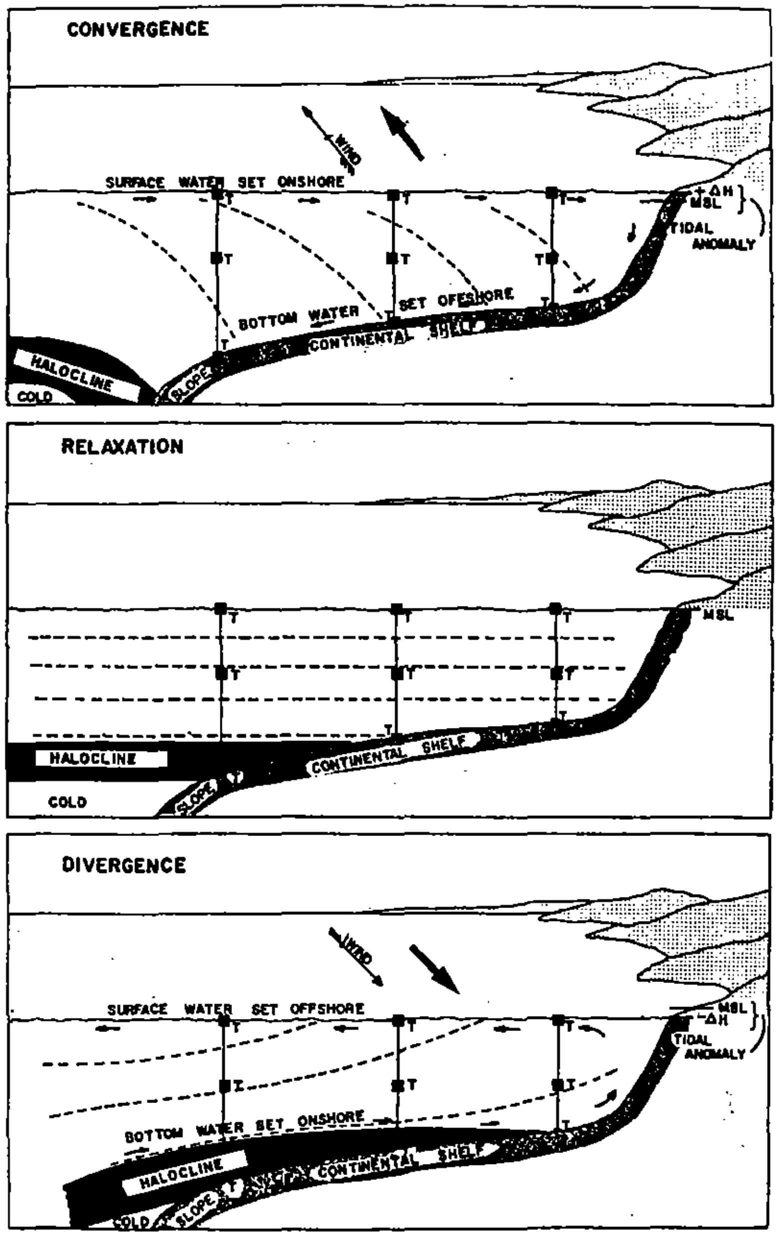


FIG. 16. Schematic of convergence, relaxation, and divergence situations off the west coast of Vancouver Island.

Indices reflecting the intensity of large scale wind-induced upwelling (offshore transport) and downwelling (onshore transport) are available for selected locations along the west coast of North America. They are based on calculations of the Ekman surface transport normal to the coast from atmospheric pressure data. The long-term mean (1948-76) values indicate that northward of San Francisco the season of indicated upwelling (offshore and southward transport) becomes progressively restricted (Table 2). In the vicinity of the British Columbia coast, the upwelling period extends from May through September at 48°N, 125°W, from May through August at 51°N, 131°W, and June through July at 54°N, 134°W. However the monthly values are small and decrease significantly from south to north, reflecing the south to north decrease in frequency and strength of northerly winds. Recently several studies have shown high correlations between these indices and year-class strengths of fish stocks off the coasts of Washington, Oregon, and California.

Ekman transport calculations off the northern British Columbia coast show that, like sea level, the largest transports and anomalies occur during the autumn-winter period (October-March) period are onshore, reflecting the prevailing southerly winds (Fig. 17).

Large anomalies for the October-March period are identified for comparison to sea level anomalies. Transports were relatively small in 1946-47, 1948-49, 1961-62, 1967-68, 1971-72. Relatively large onshore transports during this period prevailed in 1958-59, 1960-61, 1977-78, and in 1980-81. The transport in January 1981 was the largest recorded during the 1946-81 period at these locations.

Ekman transports are generally offshore in summer but are relatively small. Anomalies occur, but as with sea level, are less persistent than in autumn-winter. In June and July 1958 and 1978 offshore transports were relatively large.

c. Net (mean) surface and subsurface currents

The tidal current observations made at several locations and depths in Hecate Strait in May and September 1954 (Fig. 12) were also analyzed for net flows (Fig. 18). They show a considerable variation in current speed and direction with depth.

In late May, the net flow was neglible over the broad shallow bank adjacent to the east coast of Graham Island (station 44). These weak currents are not consistent with the presence of comparatively strong winds at the time of observations. The flow strengthened in the deep waters and was directed predominantly southward at station 42.

Mean speeds in excess of 25 cm/s were measured at near-surface depths with a definite cross-strait flow to the northeast in early September (I-1 and I-3). At station I-2 mean surface currents were southeast parallel to the axis of the Strait at speeds of about 25 cm/s. Winds may have affected the north-south variation in the near-surface currents at these locations. There was a sharp decrease in net speeds below 20 m depth. At stations I-1 and I-2 this was accompanied by a change in direction.

Table 2.—Mean monthly values of the indices for the 20-yr period, 1948-1967. Units are cubic meters per second per 100 m of coastline.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
60°N.149°W	-138	- 86	-46	-11	0	6	6	6	- 3	-26	-73	-109
60°N.146°W	-180	-103	-48	-12	- 2	6	5	3	- 9	-34	-94	-129
57°N.137°W	-212	117	-51	-24	-11	0	1	-6	-29	-88	-140	-163
54°N.134°W	- 97	- 68	-27	-20	-10	1	3	-1	-23	-62	- 98	- 91
51°N.131°W	- 64	- 36	-12	- 5	4	15	16	12	- 3	-40	- 58	- 57
48°N.125°W	- 90	- 47	-21	0	18	25	34	22	4	-39	- 88	-100
45°N.125°W	- 94	- 47	-15	9	34	48	74	50	16	-20	- 73	- 93
42°N.125°W	- 67	- 28	3	33	79	103	132	91	36	0	- 42	- 57
39°N.125°W	- 13	9	36	69	124	168	182	139	63	20	- 7	- 12
36°N.122°W	11	35	80	121	203	239	196	183	94	49	12	7
33°N.119°W	19	48	120	178	282	312	231	212	132	76	22	10
30°N.119°W	56	77	116	141	199	199	143	142	129	103	65	54
27°N.116°W	71	93	119	148	202	195	114	105	110	106	74	63
24°N.113°W	51	74	93	116	143	129	48	44	49	69	52	39
21°N.107°W	18	39	97	100	87	39	3	5	-14	-15	8	8

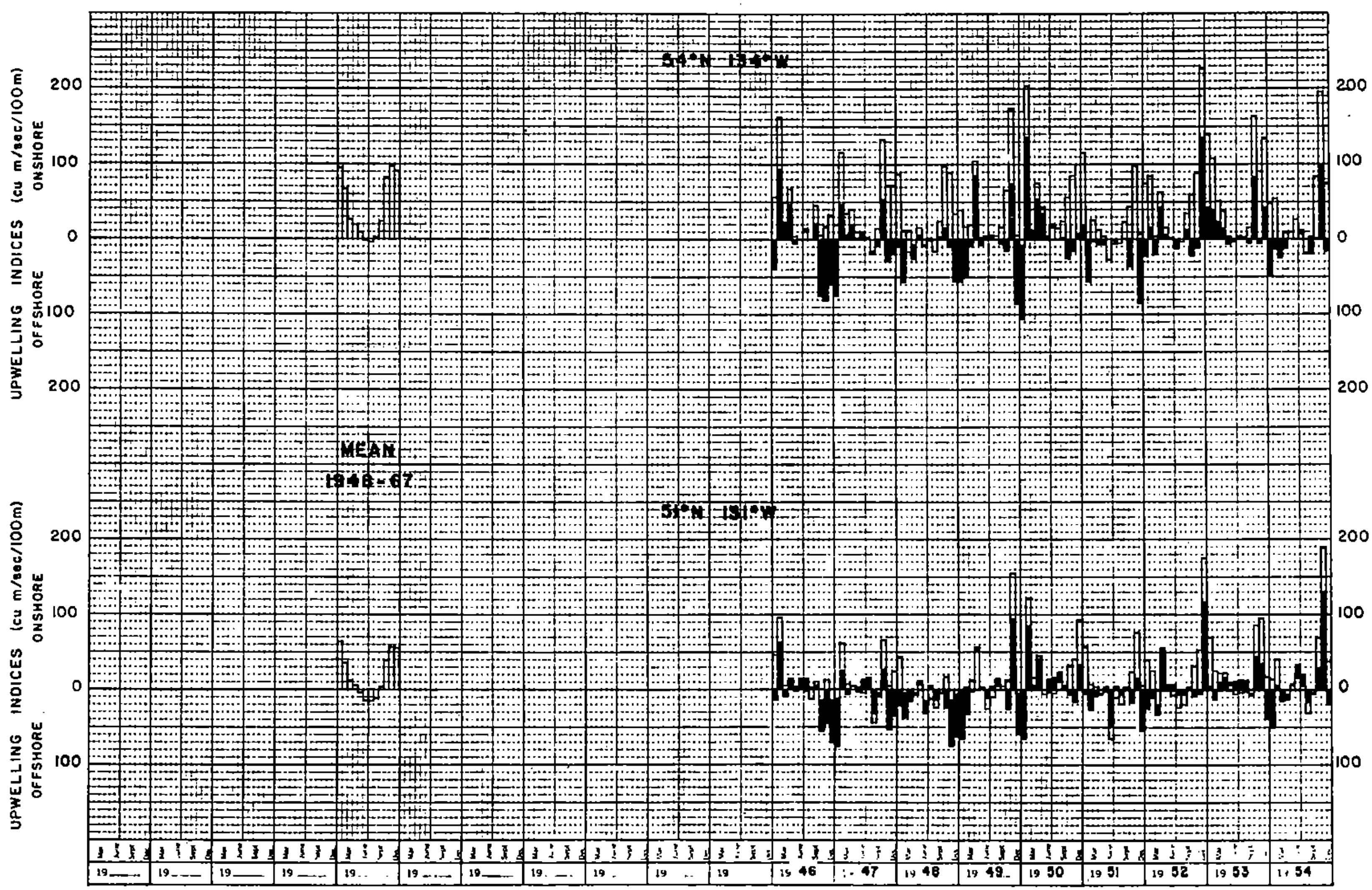


Fig. 17. Upwelling indices (onshore - offshore transport) and anomalies (solid bars) at 51°N, 131°W and 54°N, 134°W, 1946-81 (continued).

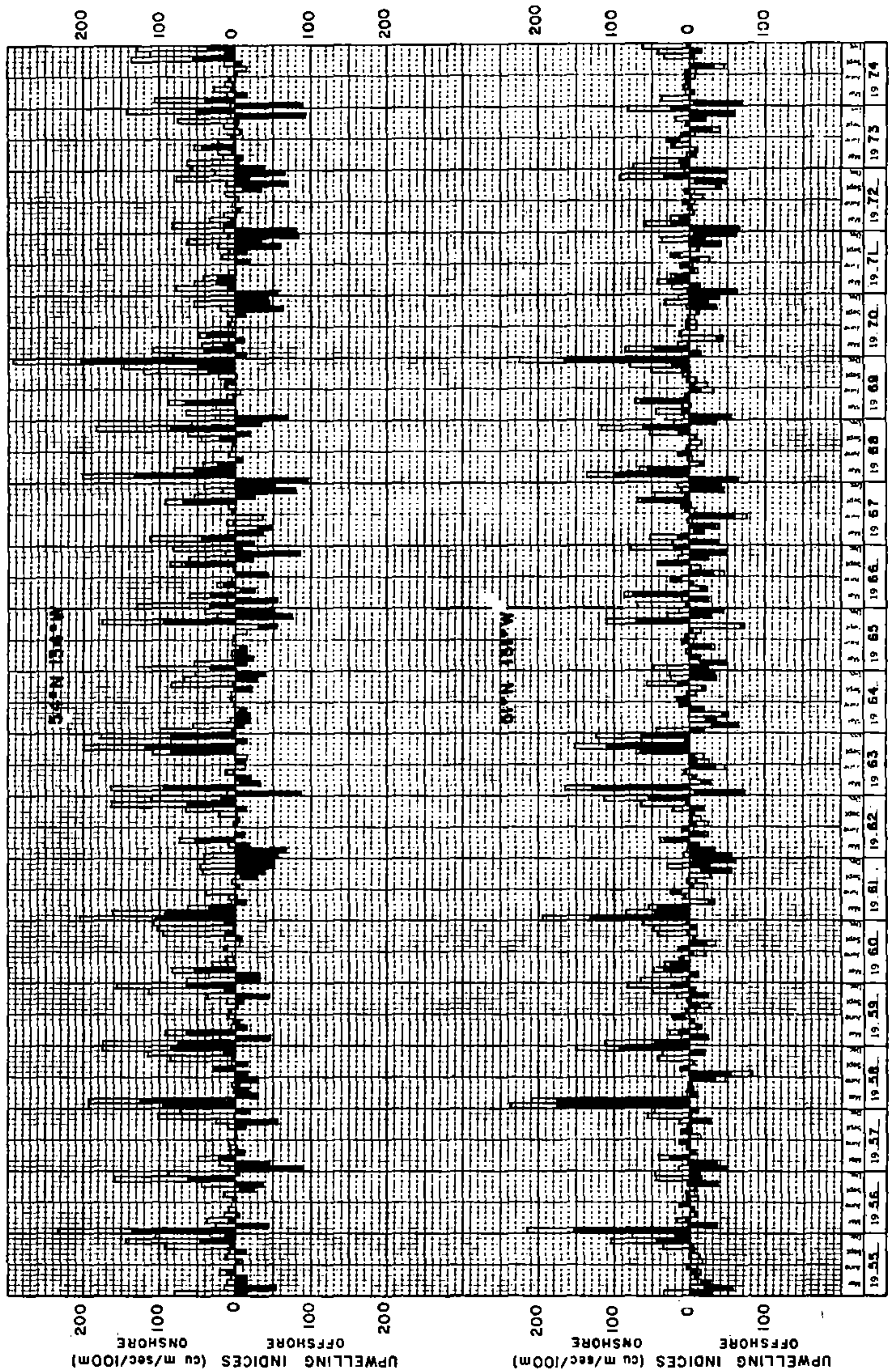


Fig. 17 (continued)

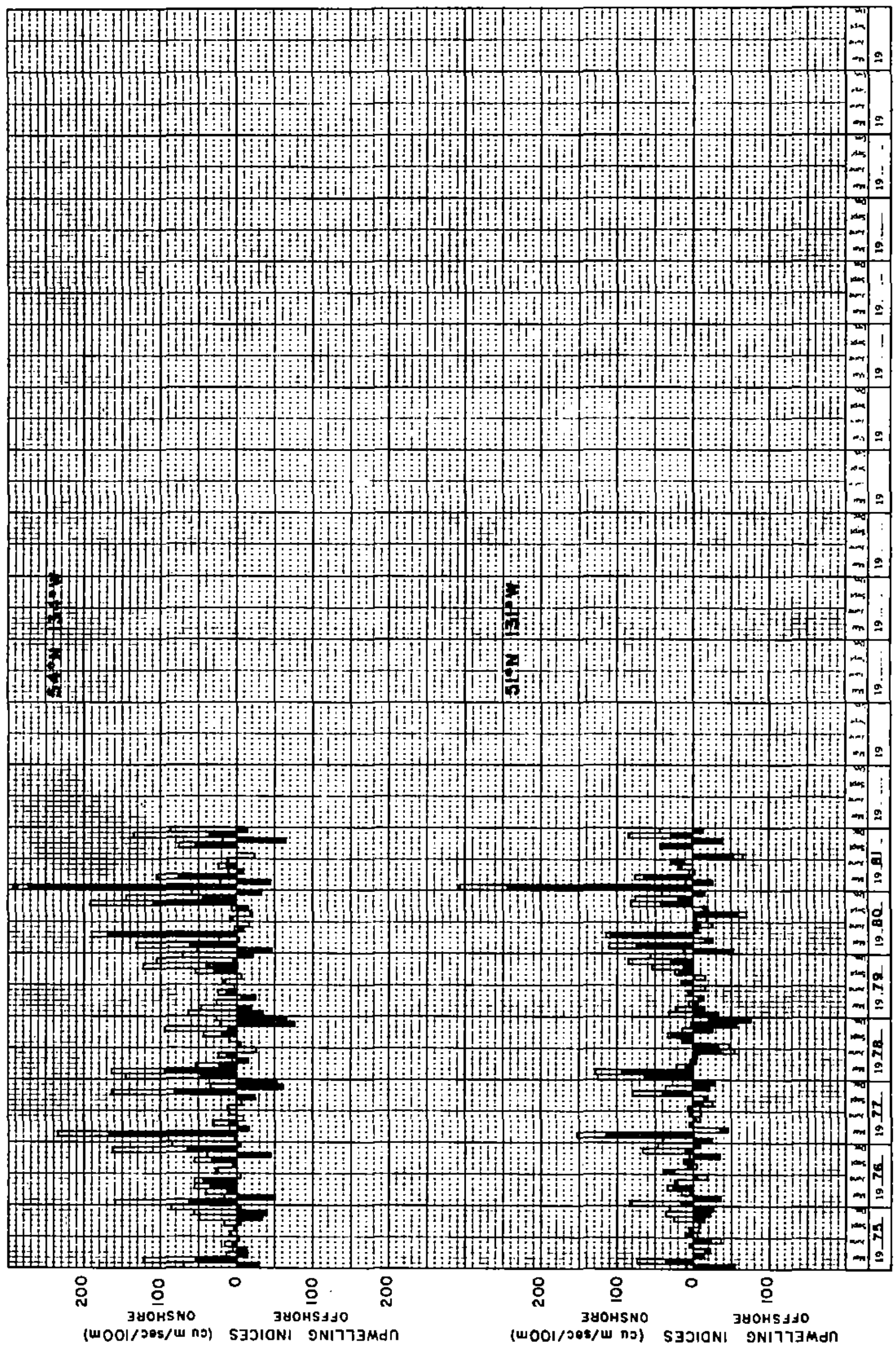


Fig. 17 (continued)

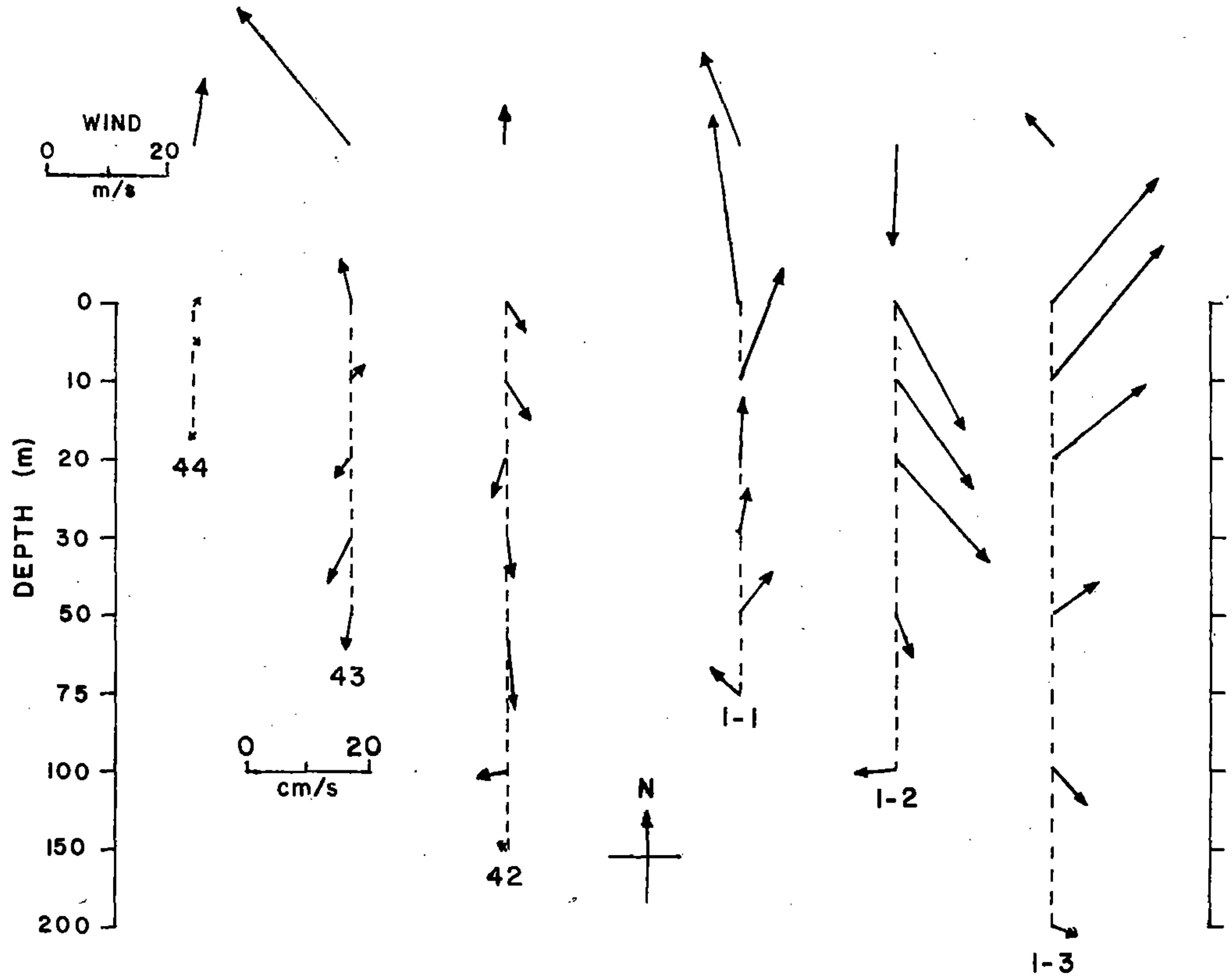


Fig. 18. Net (mean) currents in Hecate Strait (adapted from Thomson 1981b).

More recent data obtained and analyzed by the Institute of Ocean Sciences show that along the mainland side of Hecate Strait there is strong coherence between near-surface currents and wind directions. However, in mid-southern Hecate Strait there appears to be little coherence between wind and surface currents.

d. Features of the winter and summer surface flows

Data are inadequate to specifically define the surface flow patterns. However, two general seasonal patterns can be envisioned, reflecting the influence of the prevelant and strong southeast winds in winter and the relatively weak northwest winds and high runoff in summer.

(i) Winter surface flow

From November through February, southeast winds are the dominant influence on the surface currents; the relatively low freshwater discharge from the land appears to have a minor influence in this region. At the entrance to Queen Charlotte Sound surface waters are directed northward in the Sound and shoreward towards the mainland coast as a result of the persistent southeast winds coupled with the effect of the coriolis force (Fig. 19). Now aided by the direct action of these winds the surface waters then flow into Hecate Strait as a well-defined warm surface current. The flow continues northward into Dixon Entrance. At this point the strength of the wind appears to determine the flow paths. Under weak-to-moderately strong southeast winds, the flow is considered to continue northward across the eastern portion of Dixon Entrance into Clarence Strait. The remaining portion of Dixon Entrance will continue to be dominated by the tidal vortex that exists in central Dixon Entrance. If, on the other hand, the winds are strong, the northward transport of surface water through Hecate Strait will create a concentrated seaward flow around Cape Chacon and along the northern side of Dixon Entrance, in addition to the northerly set through Clarence Strait. The convergent situation that exists in Queen Charlotte Sound and Hecate Strait in this period results in a downward displacement of the isopycnals along the mainland side of these seaways. This implies an increased surface flow near the mainland coast.. In Queen Charlotte Sound there is an offshore movement of the subsurface waters which are replaced by warm, low-salinity waters. Typical speeds of the surface currents in mid-strait are presumably of the order of 3% of the wind speed averaged over several days.

(ii) Summer surface flow

In summer the combination of northwesterly winds and the moderately high coastal runoff which contributes to a significant estuarine circulation results in a variable and complex flow pattern (Fig. 20). In Queen Charlotte Sound the surface flow is predominantly west to northwest in part due to the existence of a divergent condition along the outer coast and in part due to an estuarine-type circulation originating at the mainland coast. These conditions result in an onshore movement of cold saline subsurface waters. There is also a northward surface flow along the mainland coast.

Along the western side of Hecate Strait a weak northward flow generally exists. This flow continues northward to Rose Spit, possibly

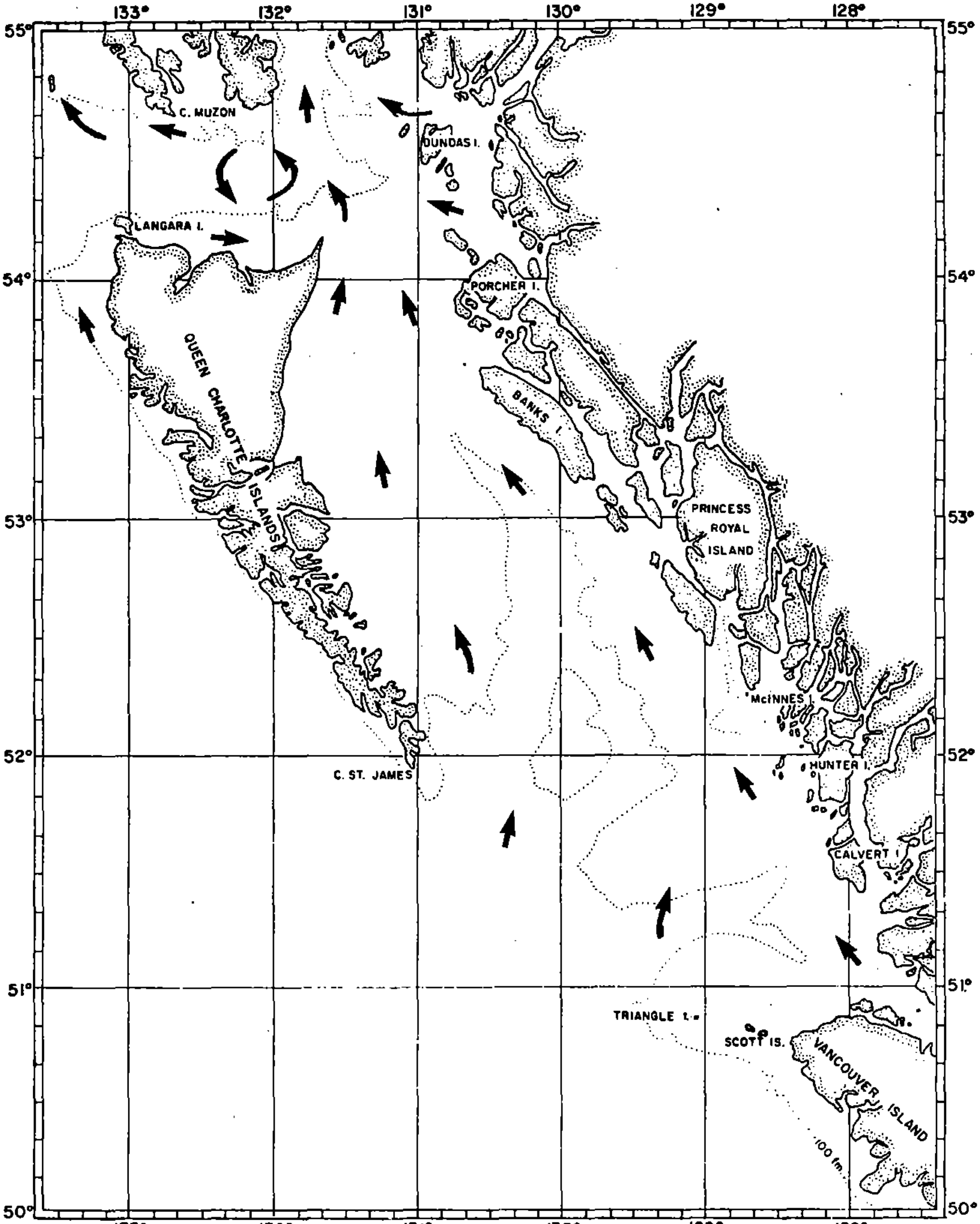


Fig. 19. A generalized winter surface flow pattern.

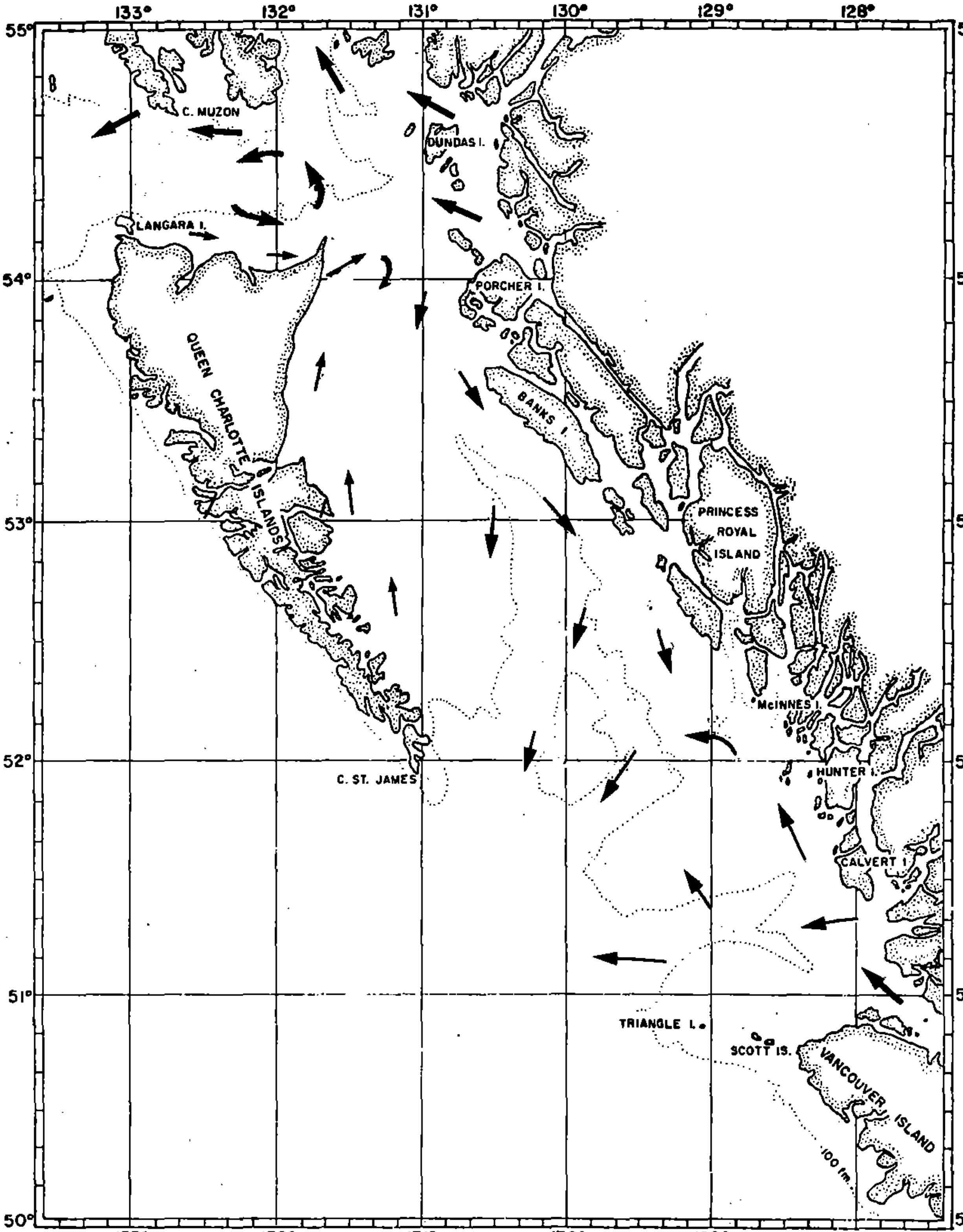


Fig. 20. A generalized summer surface flow pattern.

forming a small gyre. A southward flow originating along the mainland side of northern Hecate Strait partially contributes to the gyre, but mainly continues southward along the mainland side of Hecate Strait due to the northwesterly winds. These winds maintain a southward flow along the eastern shores of Hecate Strait. These waters, together with the northward flowing waters form Queen Charlotte Sound then move southwestward towards the open ocean.

In Chatham Sound and Dixon Entrance an estuarine-type flow is dominant in summer. On leaving Chatham Sound, the upper zone of dilute water moves in a generally northwesterly direction into the southern reaches of Clarence Strait and among the islands flanking the southeastern part of the Strait. A division of the flow occurs, part moving northward through Clarence Strait, and part southward around Cape Chacon into Dixon Entrance. On leaving the vicinity of Cape Chacon, the flow moving seaward through Dixon Entrance spreads southward from the northern shores into the west-central part of Dixon Entrance. This low-salinity water finds primary egress through the deep channel north of Learmouth Bank. The surface outflow is accompanied by subsurface inflow of cold saline waters in the lower zone.

Surface currents throughout the coastal seaways are generally considerably less than those encountered during winter.

XI - SURFACE TEMPERATURE AND SALINITY

The temperature and salinity of the surface waters along the British Columbia coast vary seasonally in accordance with the amount of incoming solar energy and the input of freshwater runoff. The latter has a marked regional variability.

1. SURFACE TEMPERATURES AT COASTAL LIGHT STATIONS

Annual temperature cycles at coastal light stations along the British Columbia coast show a minimum in February-March, and a maximum in August; the average is about 43-57°C (6-14°C) along the northern coast (Fig. 21).

Marked deviations occur from the average for a given month (Fig. 22). From 1937 to early 1945 there was a dominance of anomalously warm (positive anomaly) surface conditions particularly during the winter months (December-February). Warm winter conditions prevailed in 1937-37, for three consecutive winter periods, 1939-40, 1940-41, and 1941-42 and in 1943-44 and 1944-45. The warm winter conditions usually persisted until mid-summer, but the anomalies were generally less than those in winter. From 1946 to 1957 there was a dominance of cold surface conditions in winter - 1946-47, two consecutive winters in 1948-49, 1949-50, and again in 1955-56 and 1956-57. During this 11-yr period, there was only one summer period in which

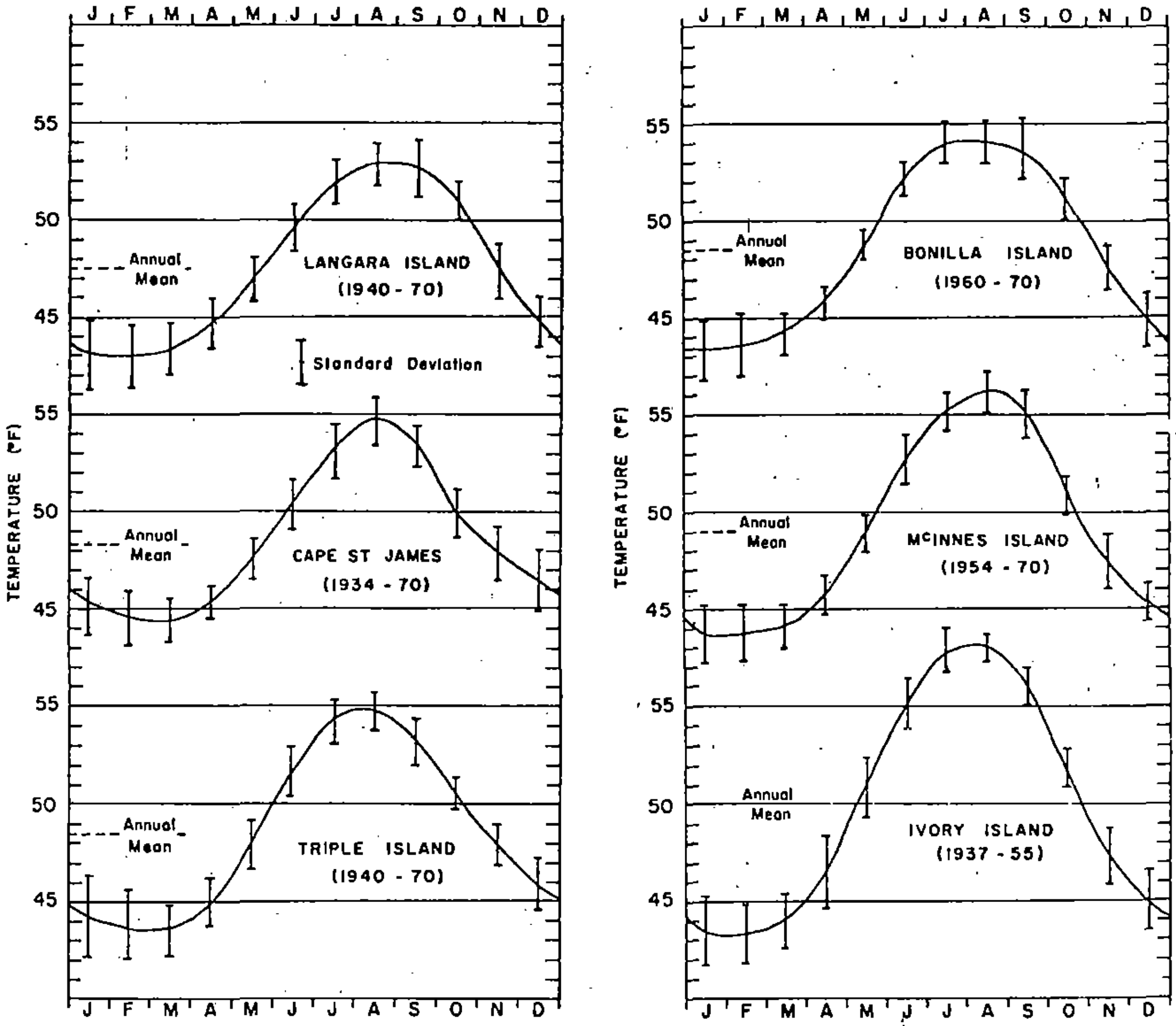


Fig. 21. Long-term monthly means and standard deviations of seasurface temperature at 6 lightstations located in the Queen Charlotte Sound - Hecate Strait - Dixon Entrance region.

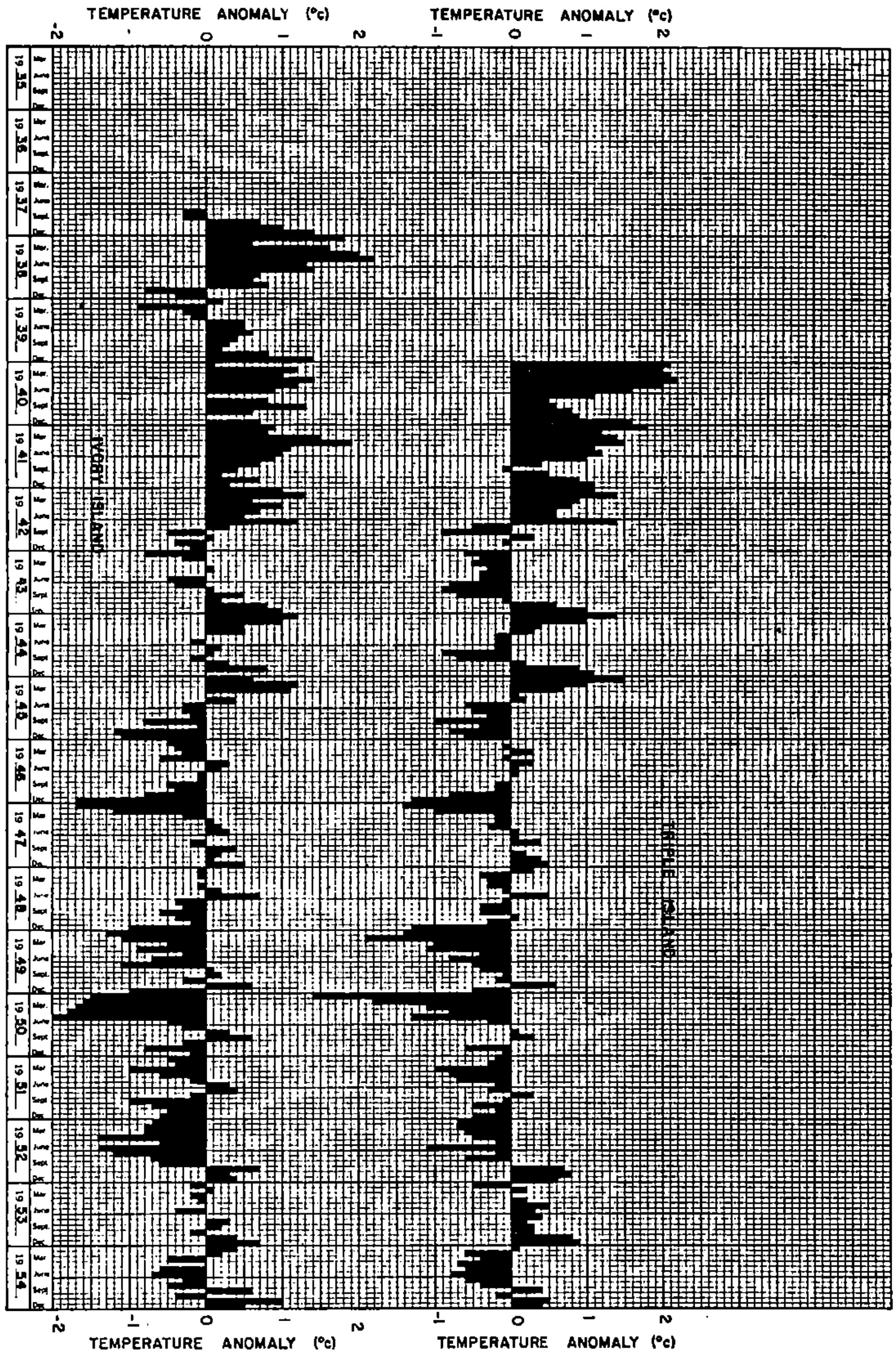


Fig. 22. Sea surface temperature anomalies at Triple Island, 1955-59; Bonilla Island, 1960-1981; Ivory Island, 1937-54; and McInnes Island, 1955-81. Plus anomaly-monthly mean temperature higher than long-term monthly mean.

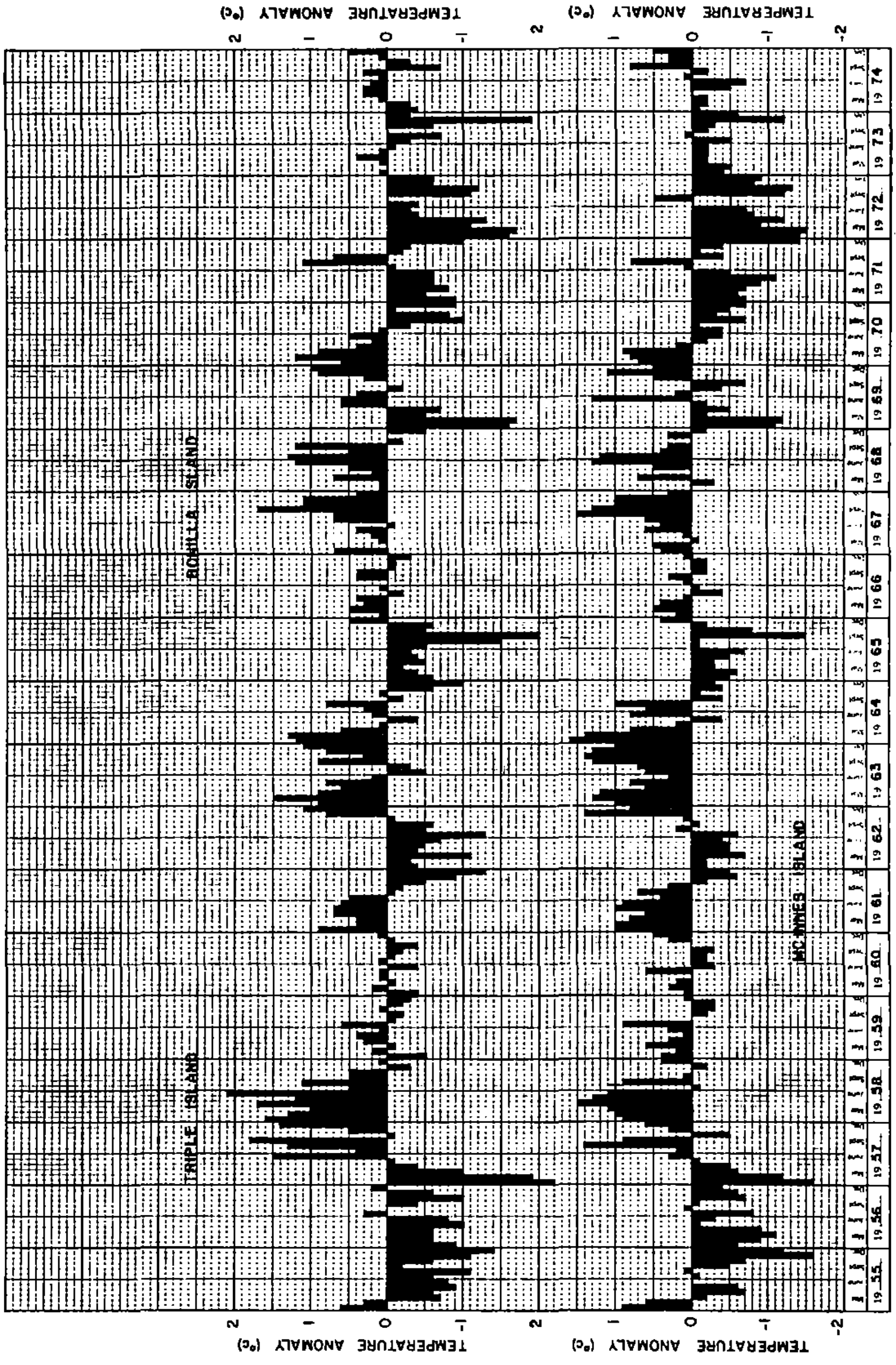


Fig. 22 (continued)

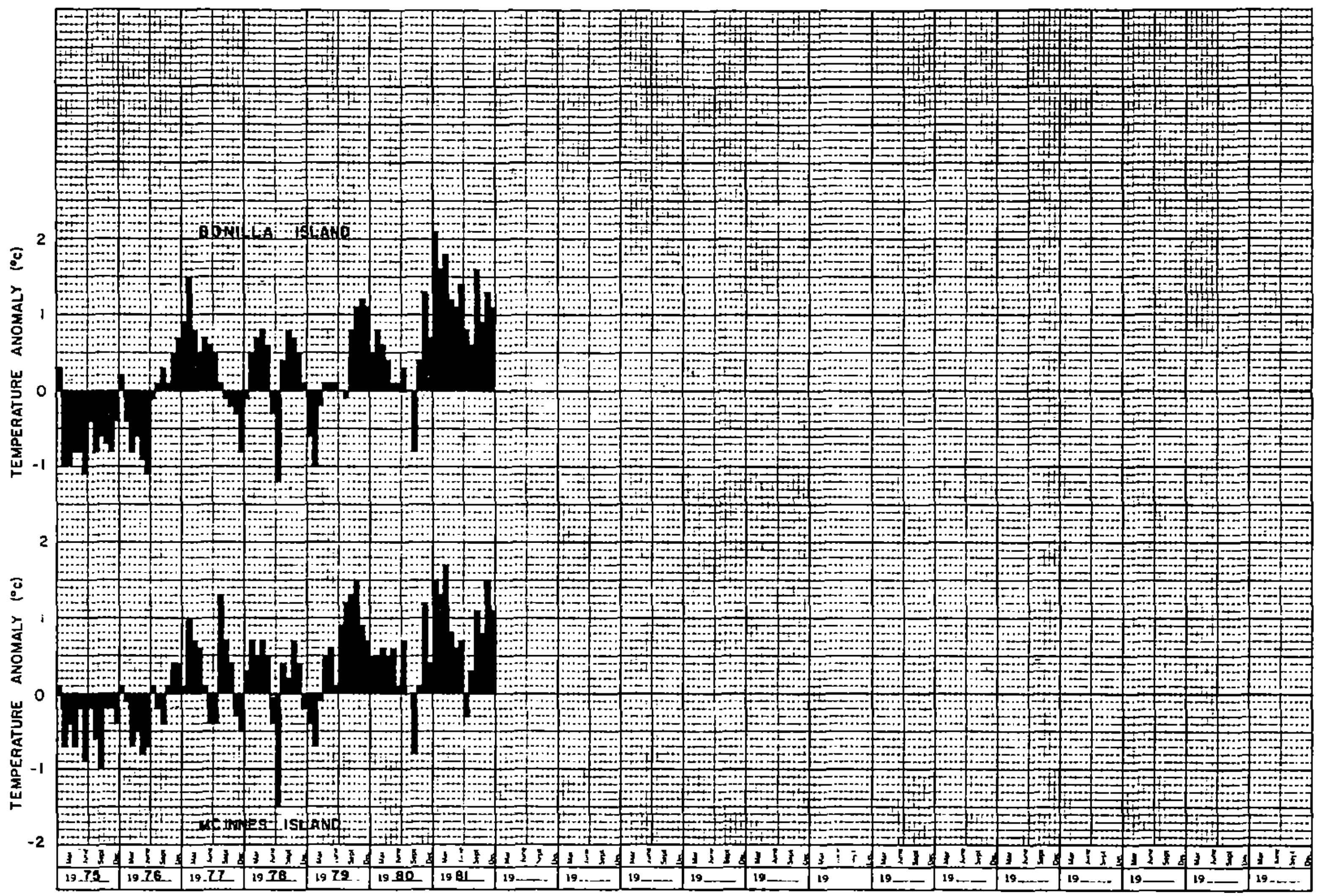


Fig. 22 (continued).

temperatures were relatively high, namely 1957. The anomalously warm conditions continued through most of 1958. The anomalously warm conditions in 1957-58 are well-documented for the eastern Pacific coast. Although surface conditions were variable from 1958 to mid-1970, the trend was towards warm conditions, winter 1962-63 generally continuing through 1963 into winter 1964. Warm conditions again prevailed in the latter half of 1967, mid-1968 and winter 1969-70. Cold conditions prevailed in winter 1961-62 through to September 1962, generally throughout 1965 and in early 1969. Cold conditions dominated from 1970 to mid-1976; 1970-71 (August through June), 1972-73 (September to February), generally throughout 1975 to mid-1976. From this period to the present, warm conditions generally prevailed. Conditions were particularly warm in the latter half of 1979 and early 1980, and again in the latter part of 1980 through 1981. During this 1980-81 period anomalies were generally as great as those observed in 1957-58.

Deviations of yearly averages from the long-term annual means indicate a marked overall cooling trend during the 1940-50 period (Fig. 23). This was followed by a warming trend from 1950-63, and a cooling one extending from 1963 through 1972. Following this a general warming trend exists, and will likely continue to 1983, after which another cooling trend should occur. Annual temperatures in 1981 were as high or higher than in 1958.

2. HORIZONTAL DISTRIBUTIONS OF TEMPERATURE

Examples of summer and winter surface distributions are shown in Fig. 24, 25, and 26. In summer tongues and cells are the dominant features (Fig. 24) reflecting the variability in flow patterns, mixing and upwelling processes. Temperatures range from about 9°C in southern Queen Charlotte Sound to 14.5°C in the central part of the Sound, from about 10 to 14°C in Hecate Strait, and from about 11.5-13°C in Dixon Entrance. Maximum temperatures in Dixon Entrance are about 1-1.5°C lower than those observed in Hecate Strait and in Queen Charlotte Sound.

In winter, relatively uniform temperature conditions prevail throughout most of the region; as in summer, temperatures in Dixon Entrance are about 1-1.5°C lower than those observed in Hecate Strait and Queen Charlotte Sound (Fig. 25 and 26). These examples are considered typical of average (Fig. 25) and of relatively cold (Fig. 26) surface conditions.

3. SURFACE SALINITIES AT COASTAL LIGHT STATIONS

Unlike the annual surface temperature cycle, the annual surface salinity cycles vary from station to station (Fig. 27). At Triple Island the minimum occurs in June-July reflecting the peak discharges of the Skeena and Nass rivers which usually occur in June. On the other hand, McInnes Island shows a salinity minimum in November, and is related to heavy local precipitation and runoff which are a maximum at this time of year. A secondary minimum is also indicated in July-August.

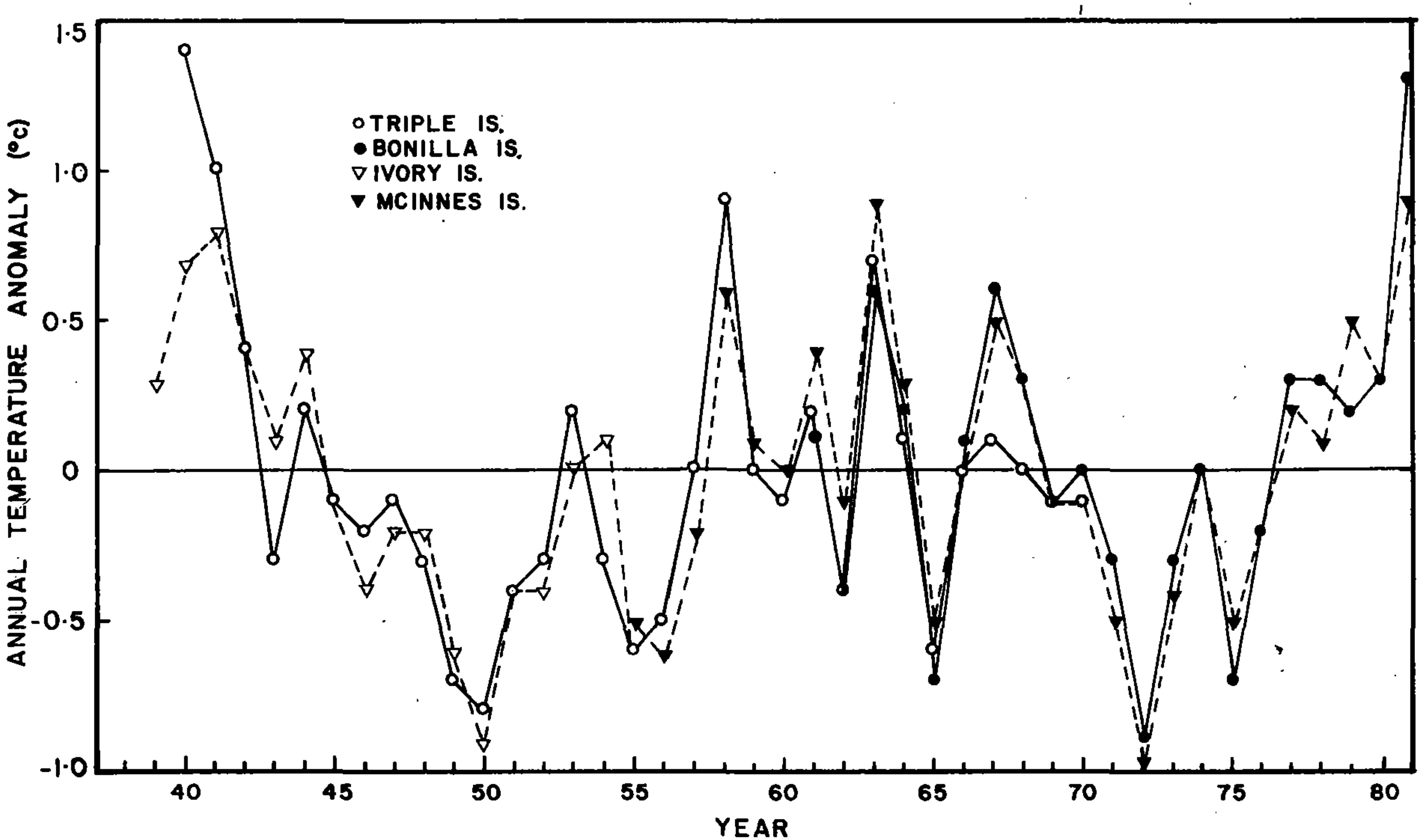


Fig. 23. Annual temperature anomalies. Plus anomaly-annual mean temperature higher than long-term annual mean.

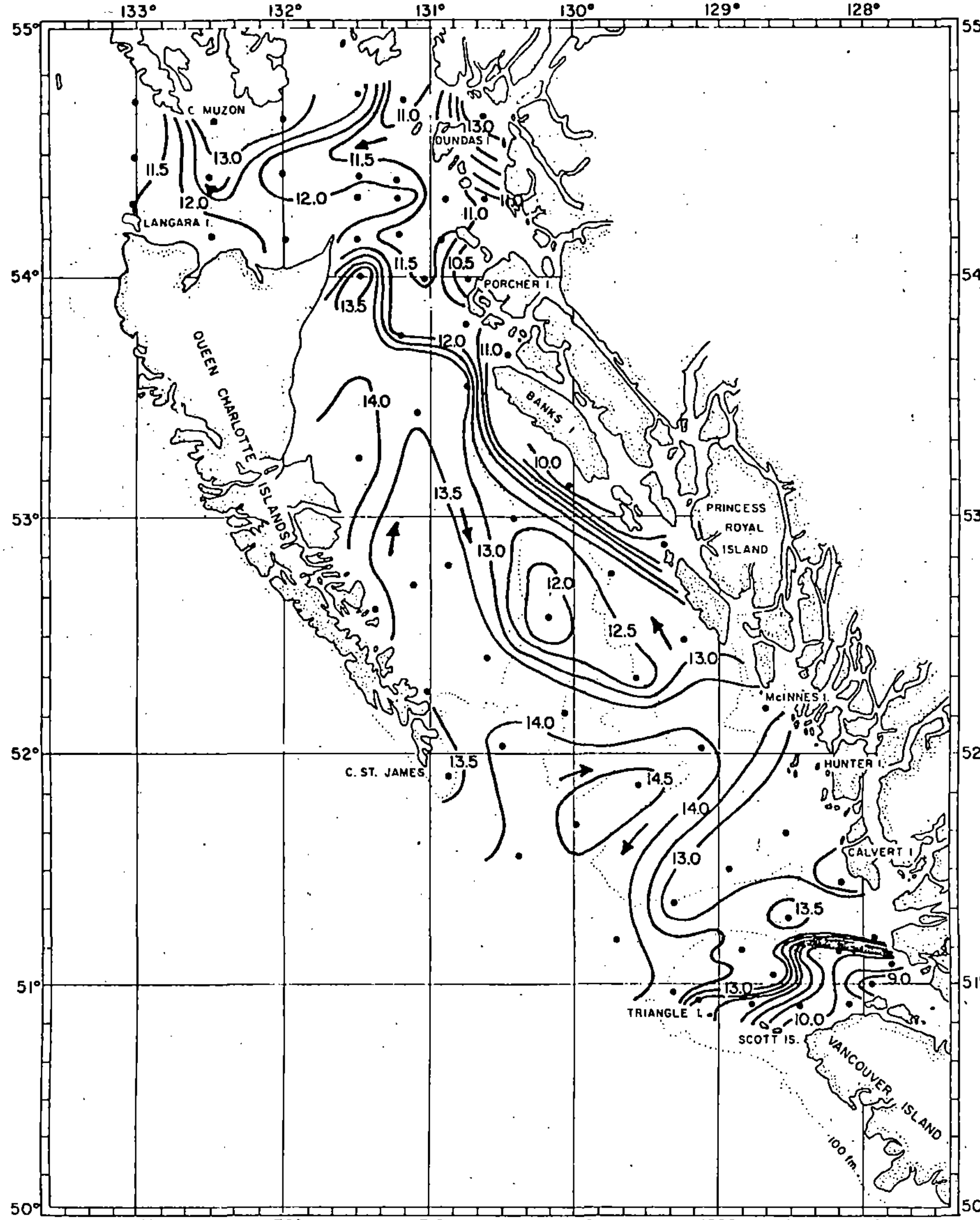


Fig. 24. Temperature (°C) distribution at 3 m depth, August 17-September 9, 1954 (arrows indicate direction of flow).

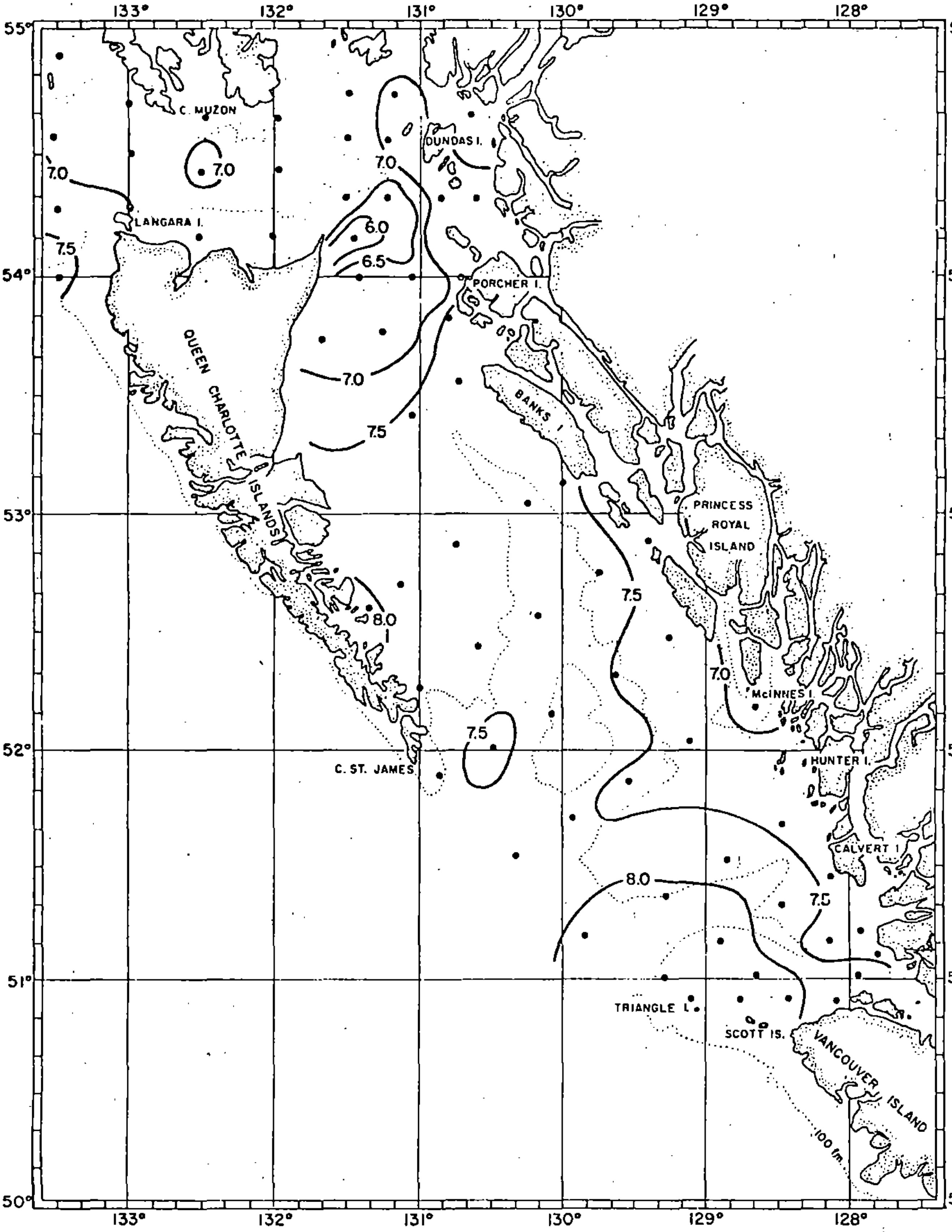


Fig. 25. Temperature (°C) distribution at 3 m depth, February 6-13, 1955.

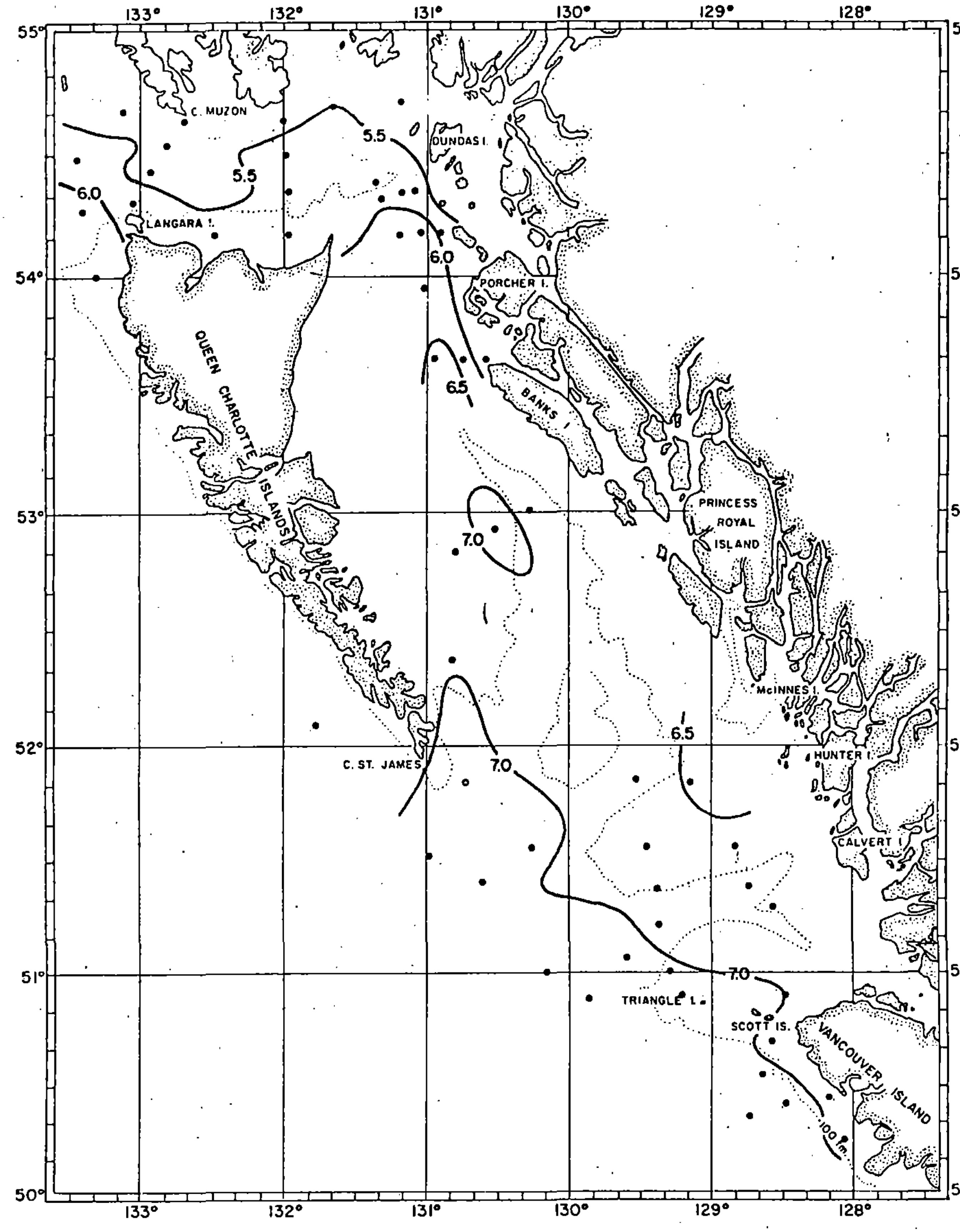


Fig. 26. Temperature (°C) distribution at 5 m depth, January 17-24, 1962.

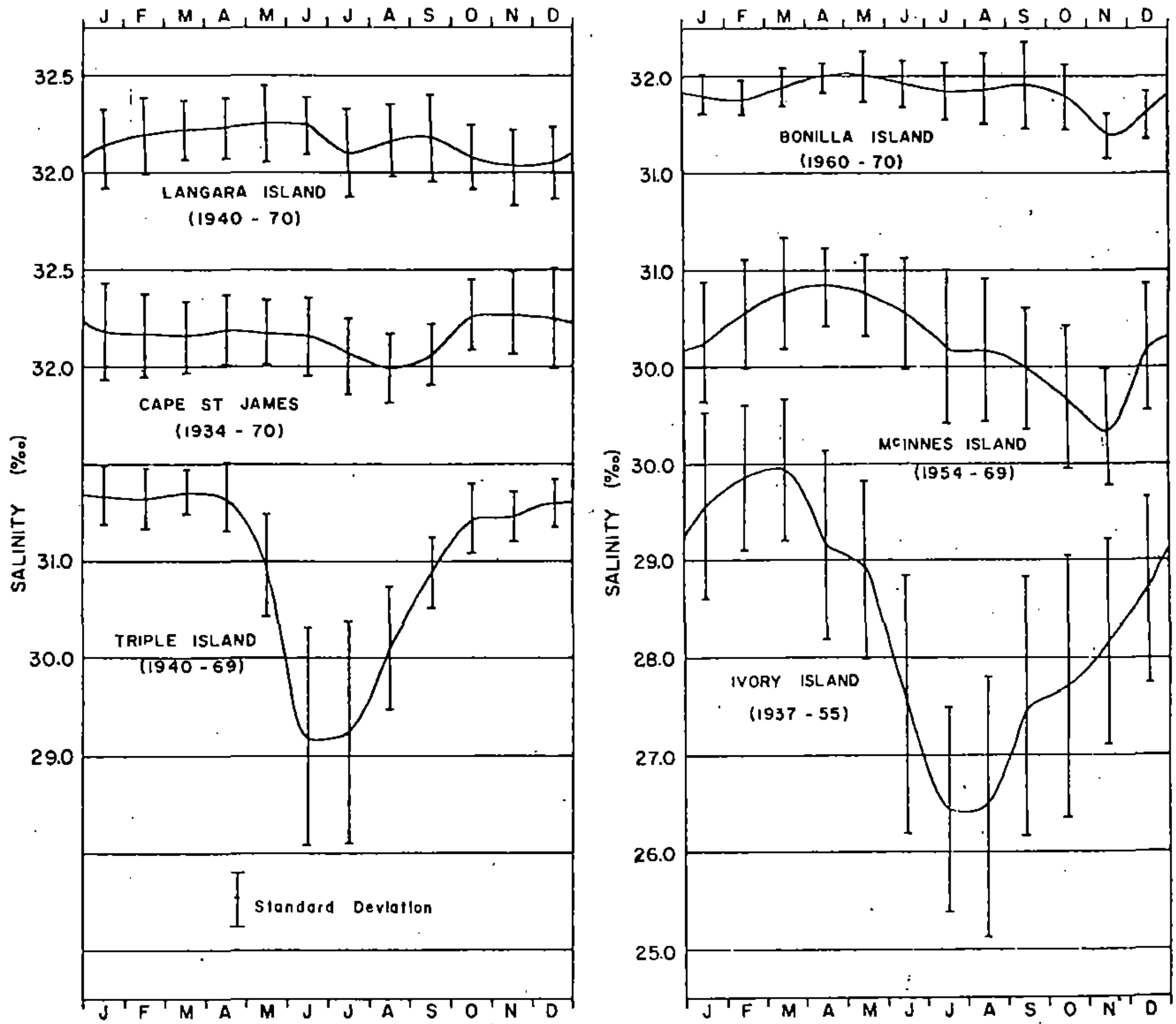


Fig. 27 Long-term monthly means and standard deviations of surface salinity at 6 lightstations located in the Queen Charlotte Sound - Hecate Strait - Dixon Entrance region.

Marked deviations occur from the long-term average for a given month (Fig. 28). Positive anomalies reflect high-salinity conditions, negative anomalies low-salinity conditions. The greatest variability and persistence of large anomalies is found at Ivory Island. At all stations, the largest anomalies generally occur in the June-July period, reflecting the influence and variability in freshwater discharge from snow-melt fed rivers such as the Skeena and Nass rivers to the north and the Bella Coola and Dean rivers to the south. At Triple Island there was a dominance of high-salinity conditions from mid-1940 to mid-1953. Low salinity conditions persisted during 1954 and 1955. From 1956 through to 1970 (termination of observations), conditions were variable. At McInnes Island high-salinity conditions prevailed from 1955 through 1965. This was followed by a period of predominantly low-salinity conditions, 1966-1975. Conditions in 1970 and early 1971 were anomalously low, and anomalously high to 1981.

Deviations of yearly averages from the long-term annual means indicate a general decrease in surface salinity (Fig. 29). Yearly deviations show some coherence between stations, but less than that for temperature. Also, there appears to be little coherence between temperature and salinity fluctuations.

4. HORIZONTAL DISTRIBUTIONS OF SALINITY

Examples of horizontal distributions of surface salinity for early and late summer (Fig. 30 and 31) and winter (Fig. 32) reflect the marked seasonal and spatial variations that occur throughout the region. In early July, the low-salinity water is confined to eastern Dixon Entrance, among the mainland coast of Hecate Strait, and Queen Charlotte Sound (Fig. 30). By late August this water has spread throughout Dixon Entrance (Fig. 31). In Hecate Strait, salinities are slightly lower than those in early summer, and a general cross-channel orientation of the isohalines occurs. In Queen Charlotte Sound, salinities are slightly higher but the tongue of low-salinity water has progressed seaward.

In winter and early spring salinities are relatively uniform throughout the region, with lowest salinities along the mainland coast (Fig. 32). The salinity range is relatively small, about 31.5-32‰.

XII - ANNUAL CYCLE OF TEMPERATURE, SALINITY, DENSITY, AND DISSOLVED OXYGEN CONTENT

The main features in the annual cycle are similar throughout the seaways (Fig. 33, 34, 35). In mid-summer (July-August), the dominant features of the vertical structures are the thin mixed or near-mixed surface layer, and underlying this layer, the relatively marked gradients associated with the thermocline, halocline, pycnocline, and oxycline. During this period these

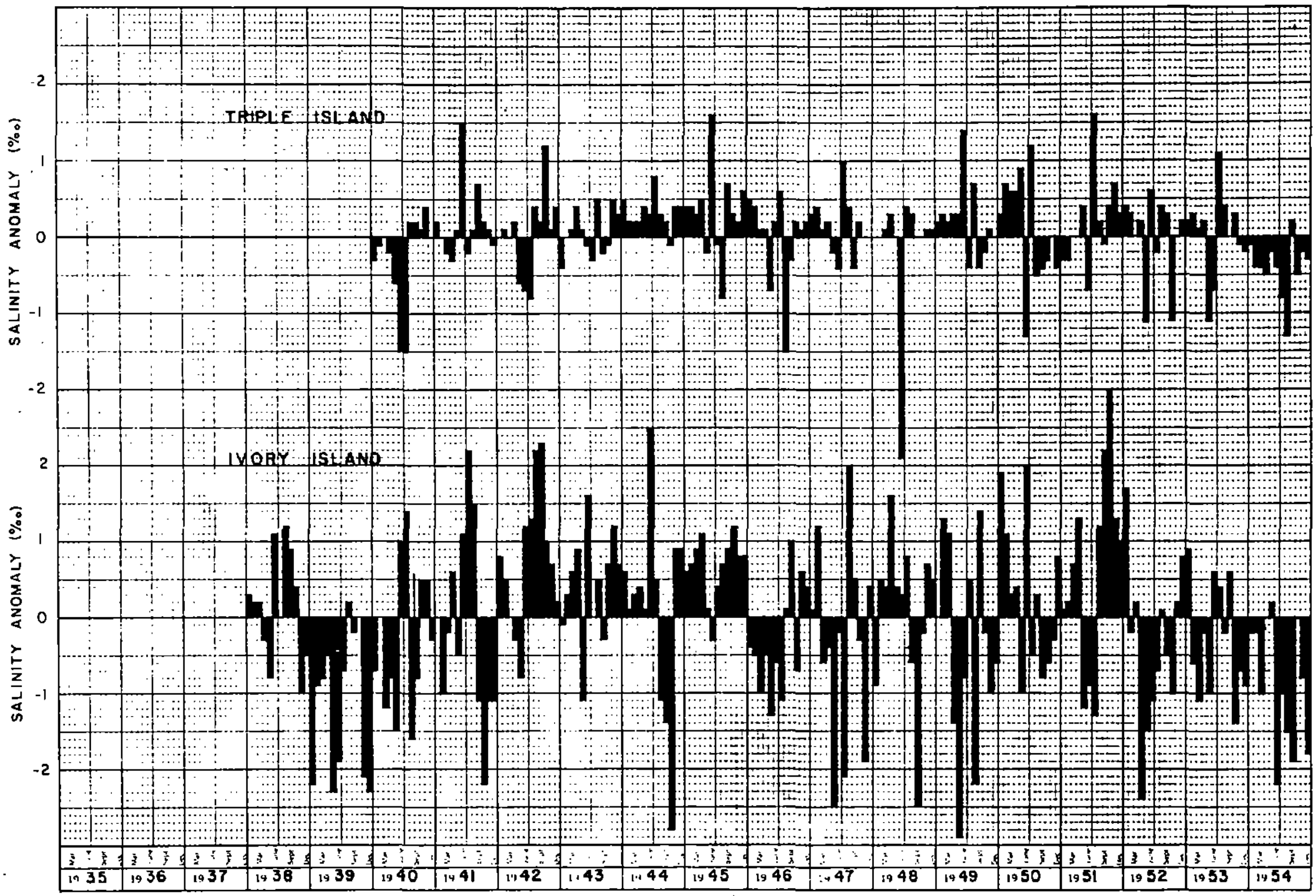


Fig. 28. Surface salinity anomalies at Triple Island, 1940-70; Bonilla Island, 1971-81; Ivory Island, 1938-54; and McInnes Island, 1955-81. Plus anomaly--monthly mean salinity greater than long-term mean.

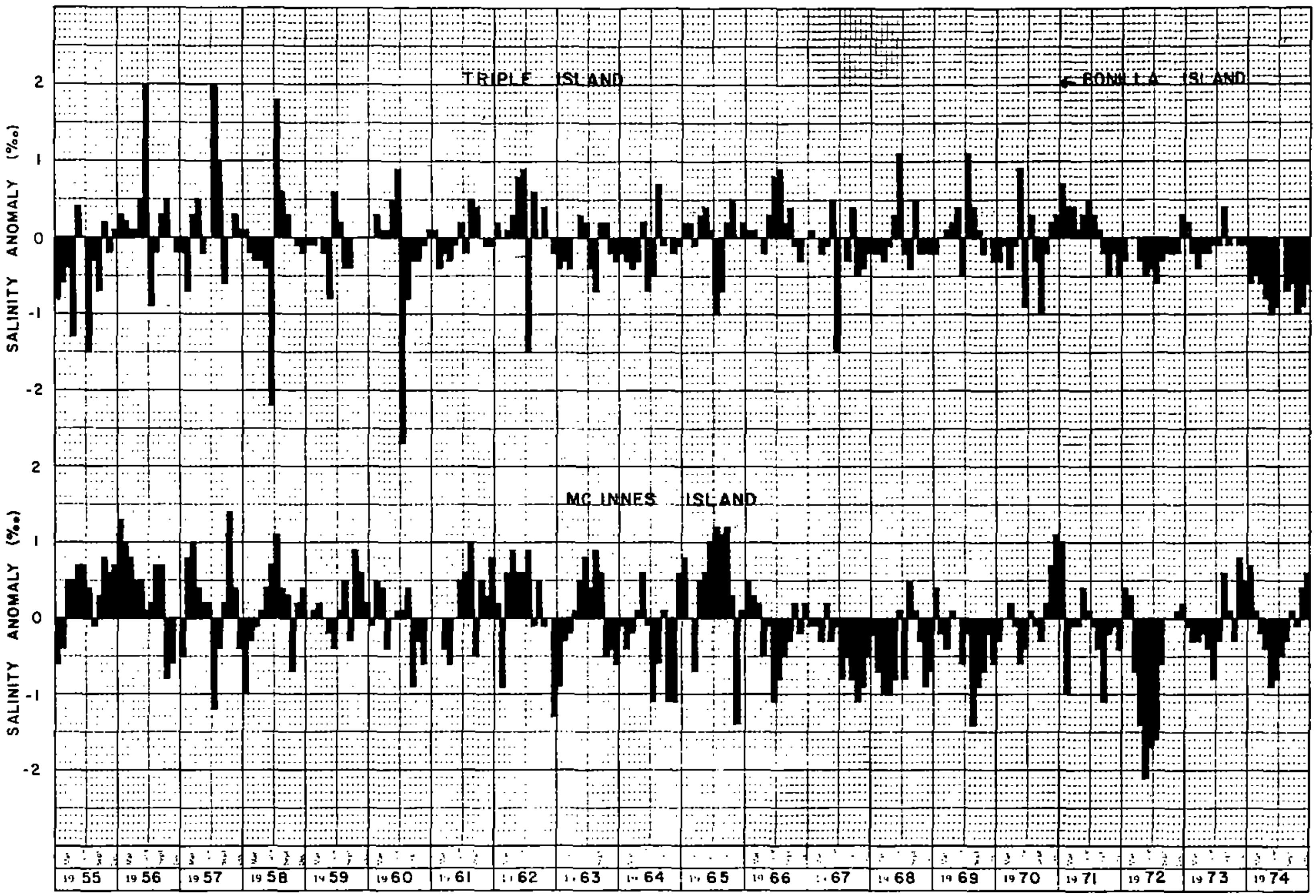

TRIPLE ISLAND
BONILLA ISLAND
MC INNES ISLAND
SALINITY ANOMALY (‰)
SALINITY ANOMALY (‰)
2
1
0
-1
-2
1955
1956
1957
1958
1959
1960
61
62
63
64
65
1966
67
68
1969
1970
1971
1972
1973
1974

Fig. 28 (cont'd)

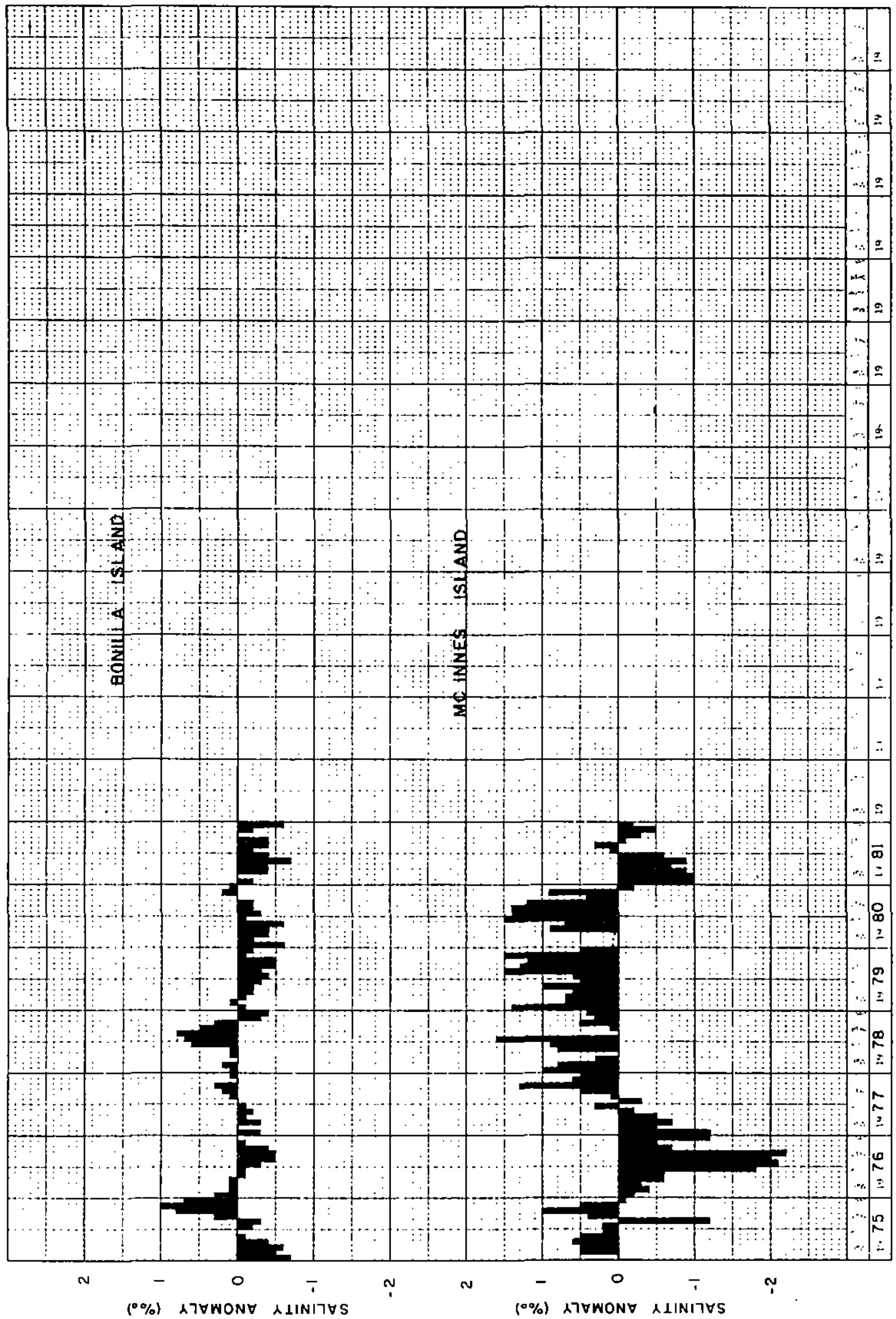

BONILLA ISLAND
MC INNES ISLAND
SALINITY ANOMALY (‰)
SALINITY ANOMALY (‰)
2
1
0
-1
-2
75
76
77
78
79
80
81

Fig. 28 (cont'd)

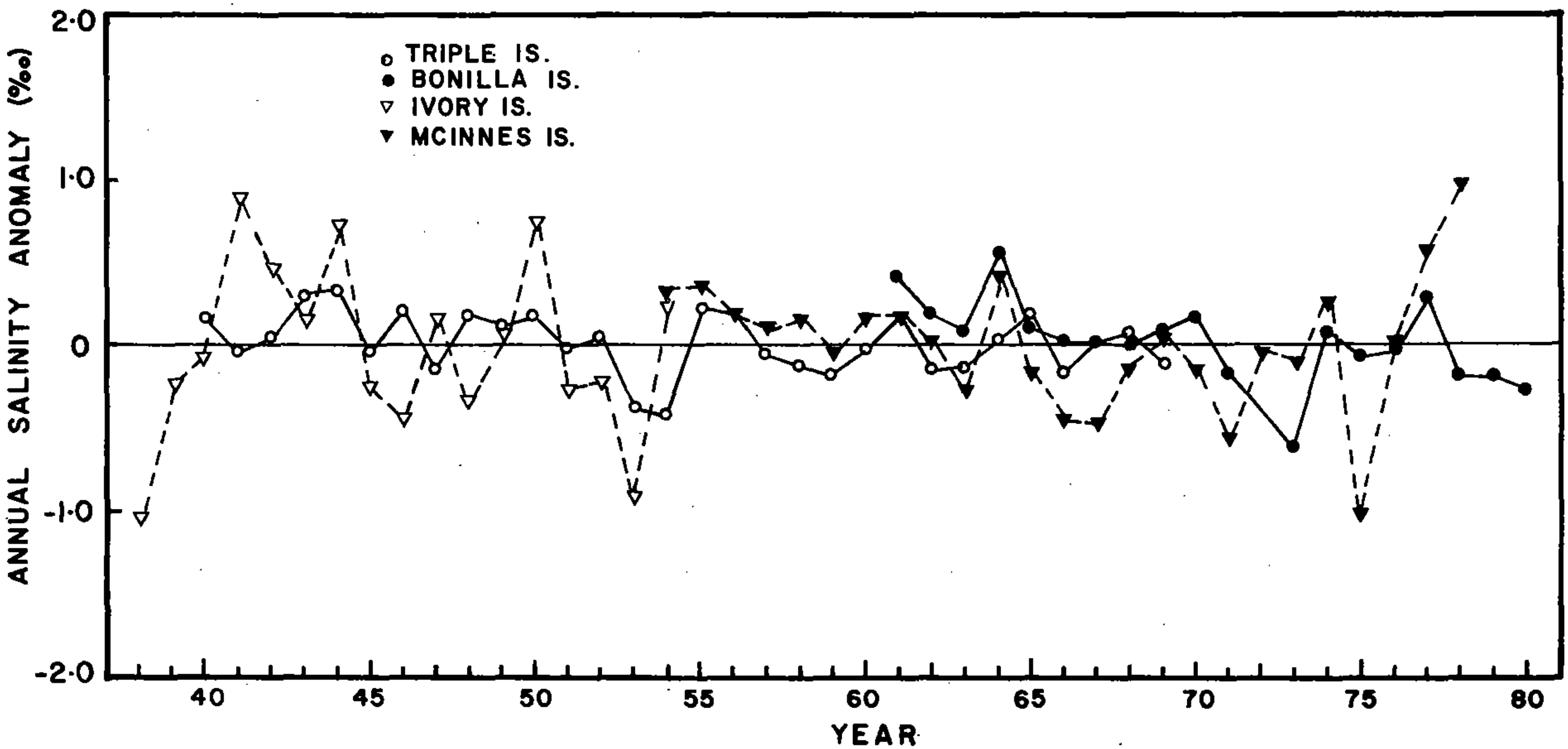


Fig. 29. Annual surface salinity anomalies. Plus anomaly-annual mean salinity greater than annual long-term mean.

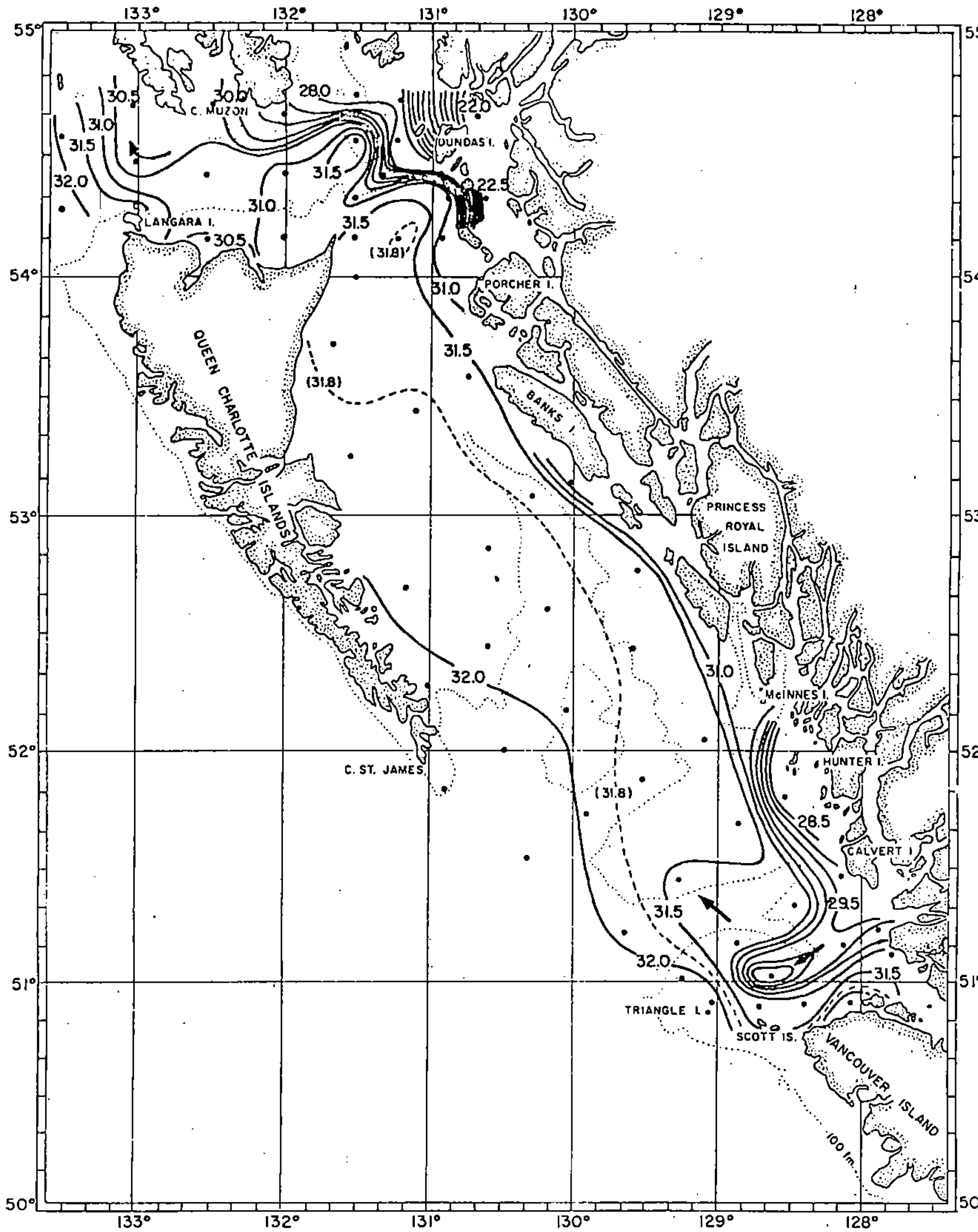


Fig. 30. Salinity (‰) distribution at 3 m depth, June 29-July 22, 1954 (arrows indicate direction of flow).

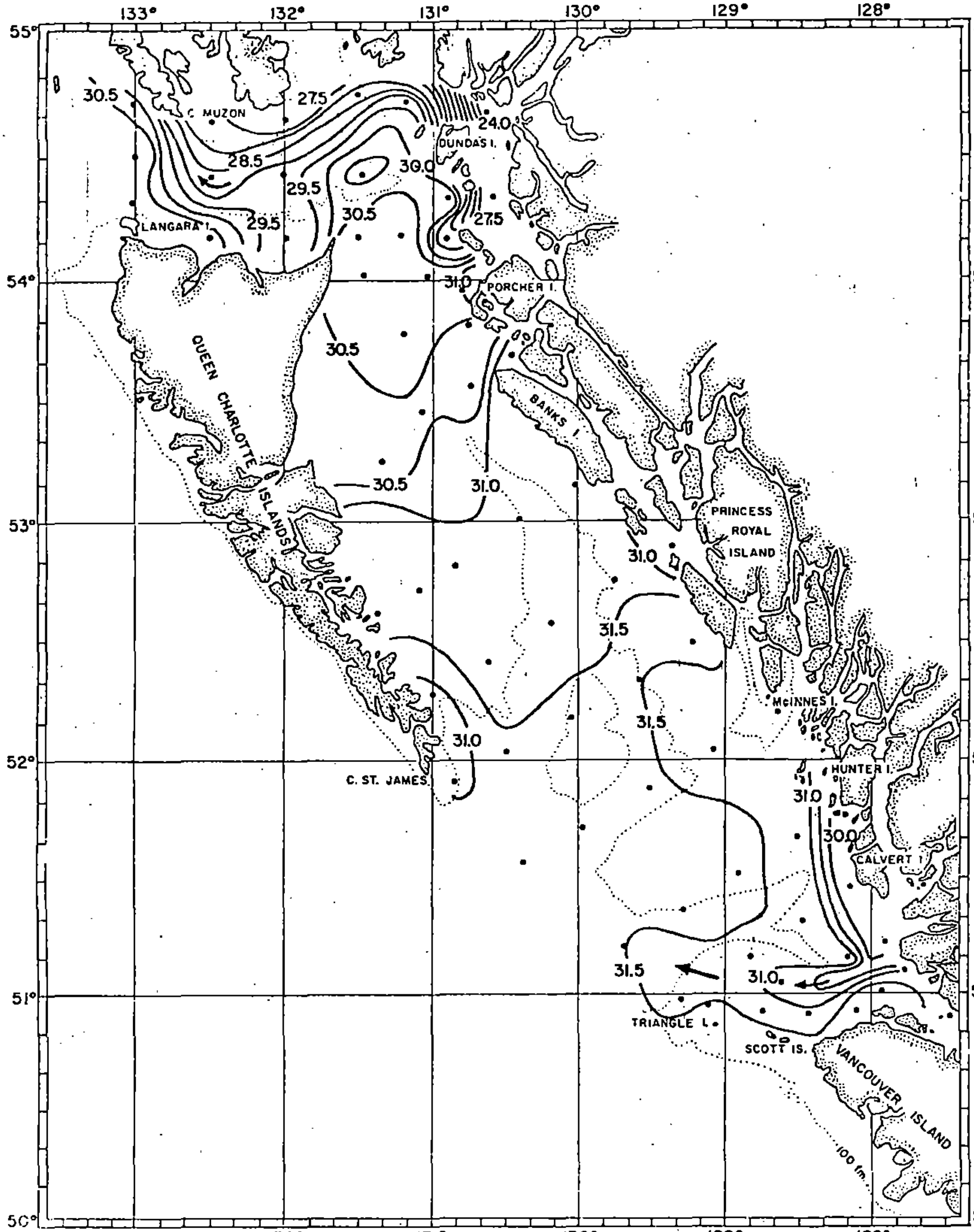


Fig. 31. Salinity (‰) distribution at 3 m depth, August 17-September 9, 1954 (arrows indicate direction of flow).

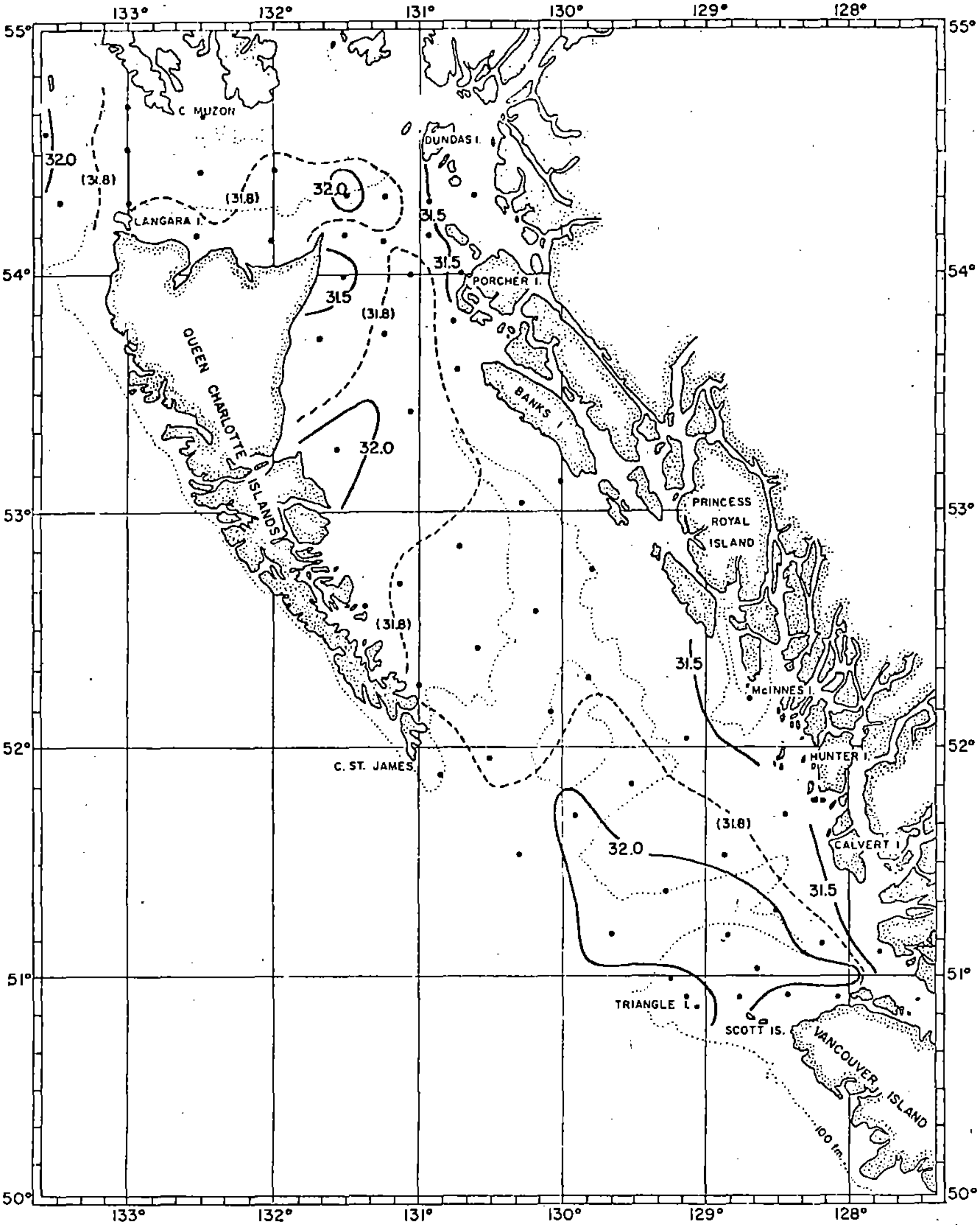


Fig. 32. Salinity (‰) distribution at 3 m depth, April 14-18, 1955.

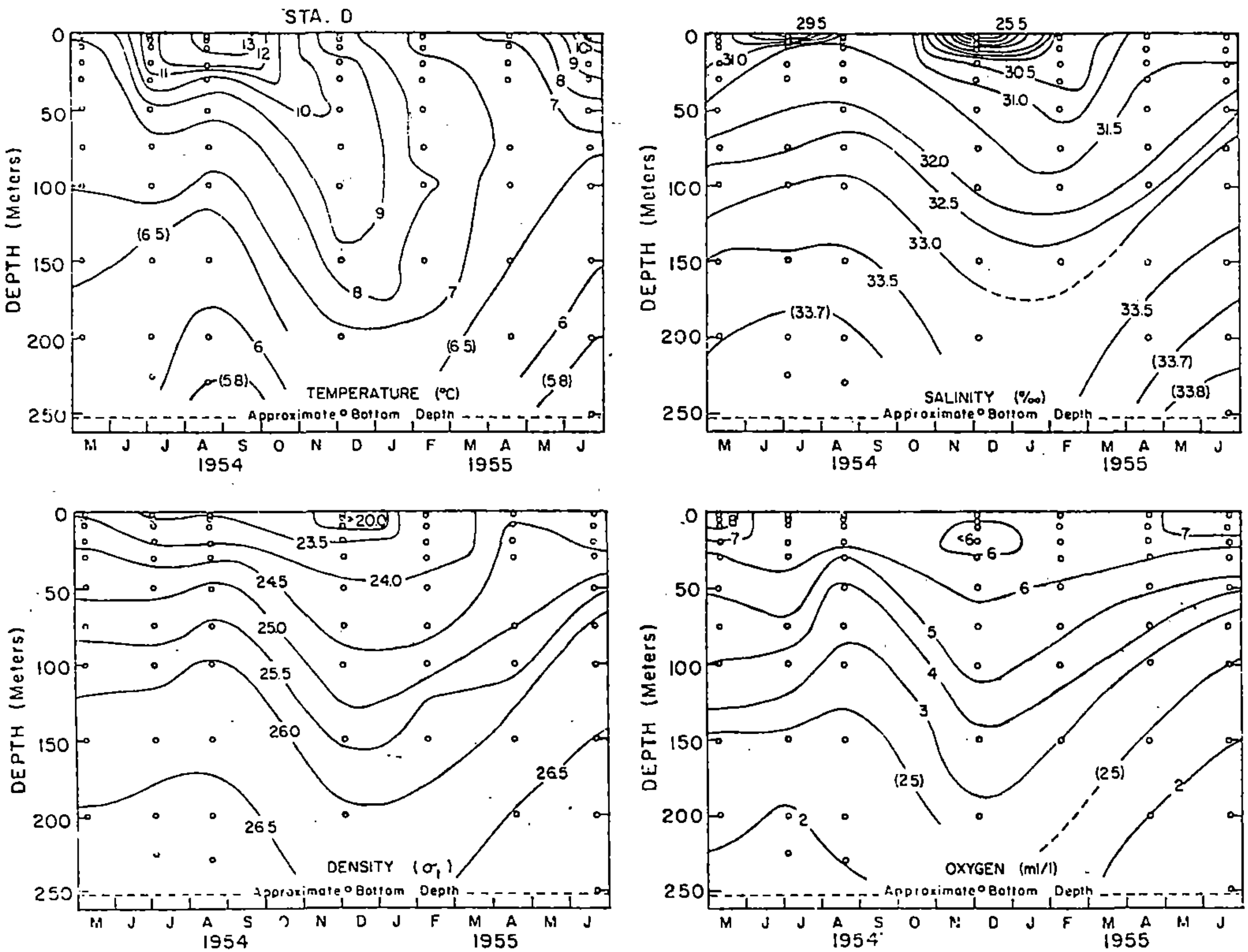


Fig. 33. Annual cycle of temperature, salinity, density and dissolved oxygen content at Station D in Queen Charlotte Sound, 1954-55.

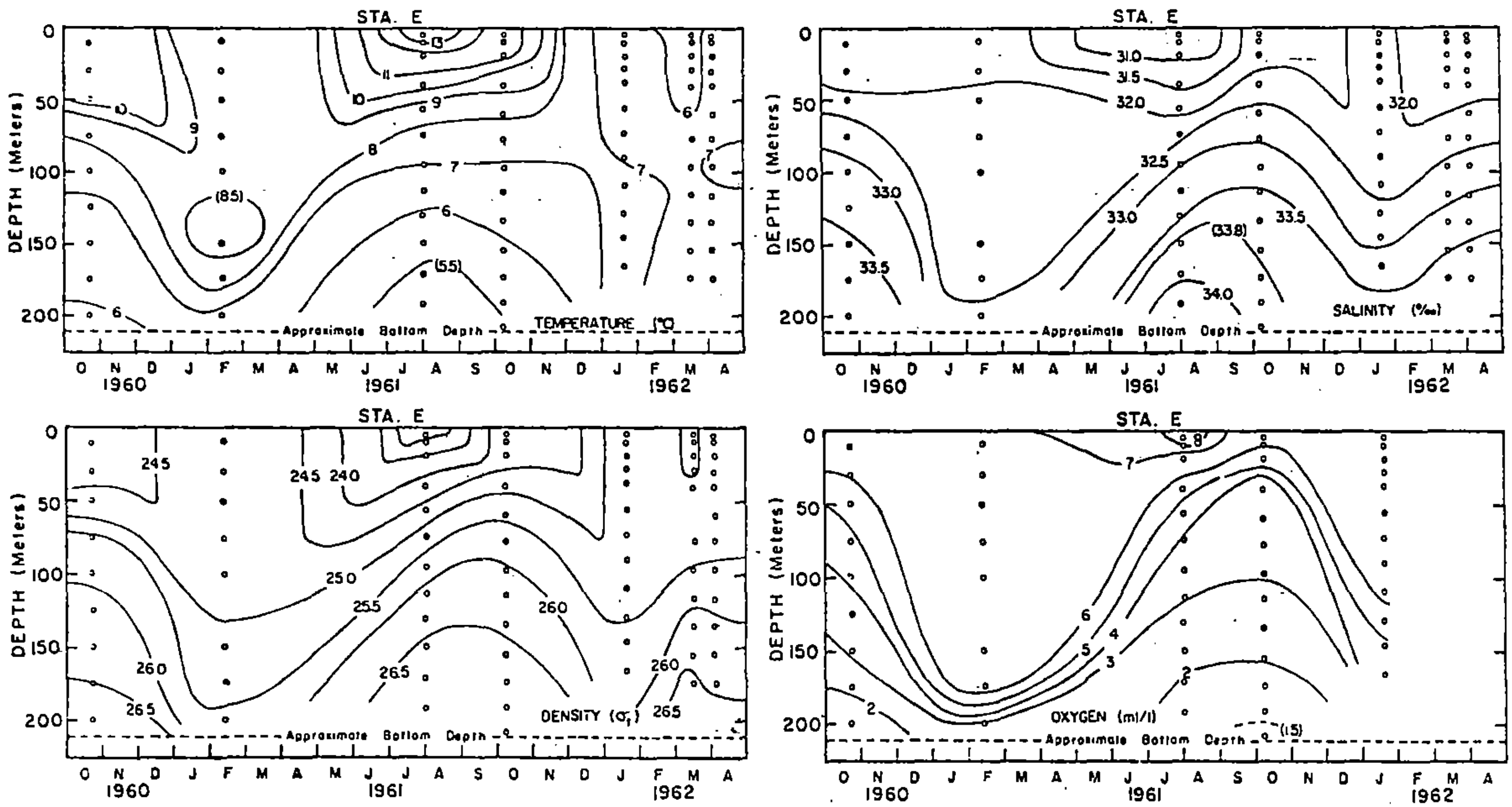


Fig. 34. Annual cycle of temperature, salinity, density and dissolved oxygen content at Station E in Hecate Strait, 1960-62.

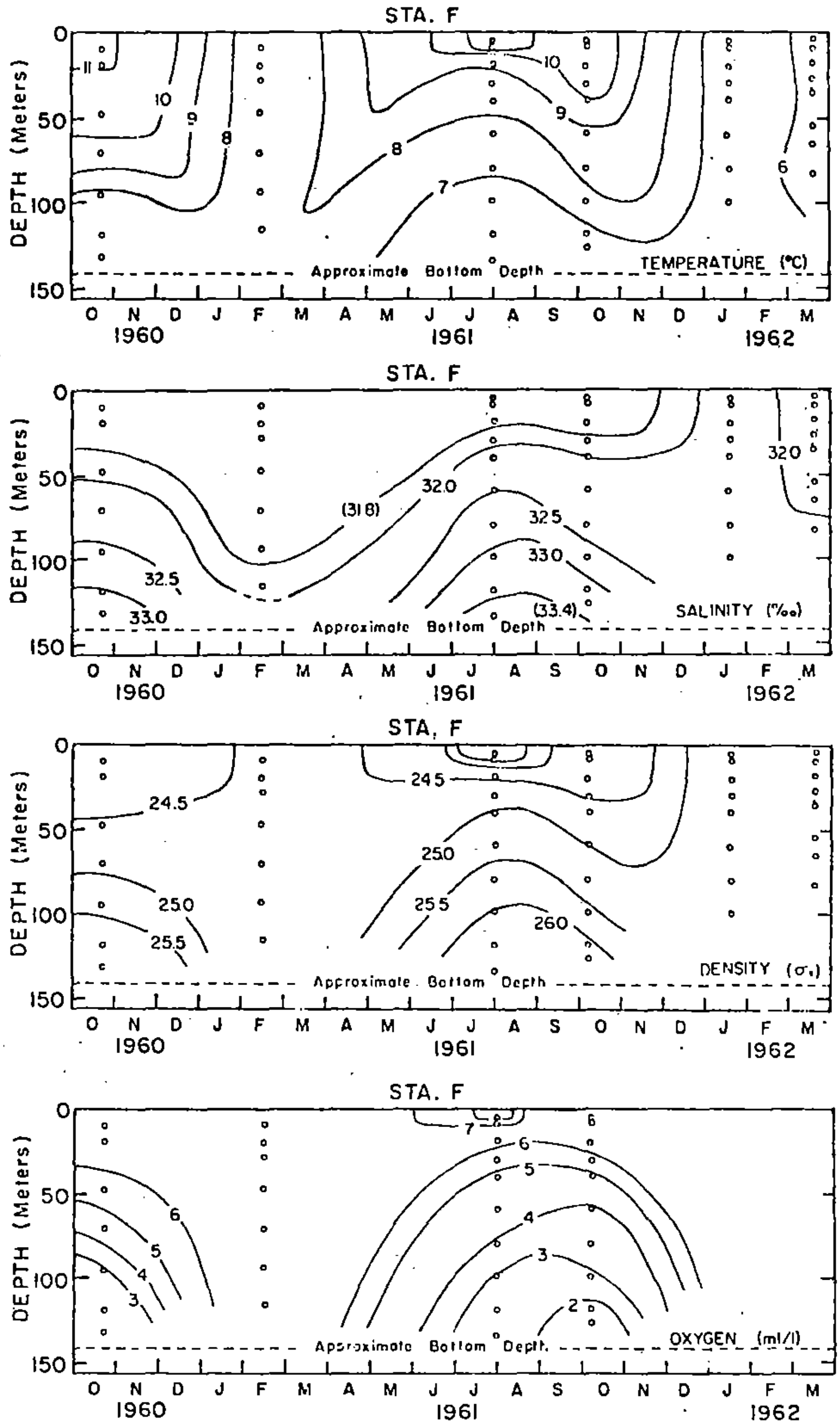


Fig. 35. Annual cycle of temperature, salinity, density and dissolved oxygen content at Station F in Hecate Strait, 1960-62.

gradients are at their minimum depth. Below them the waters are of relatively low temperature and dissolved oxygen content, and of high salinity and density. These features are defined as "summer" conditions.

Coincident with the development of the generally strong and persistent southerly winds of autumn and early winter (October-December), marked changes occur throughout the water column. The surface layer thickens; the thermocline, halocline, pycnocline, and oxycline are displaced downward, and appear to reach their maximum depth in December-January. By this time the subsurface waters, those beneath the gradients, have been replaced by waters of relatively high temperature and dissolved oxygen content and of low salinity and density. Also, during this period, erosion of the summer thermocline continues because of surface cooling and convective and wind-induced mixing. These surface processes continue through February until late March-early April. During this period the thermocline disappears and temperatures decrease, and near-isothermal conditions may extend to depths of 150-200 m. However, the vertical gradients of salinity, density, and dissolved oxygen remain, but are considerably deeper than those observed in mid-summer. In the shallower areas, marked vertical gradients may occur in the near-bottom waters (e.g. Fig. 34 - dissolved oxygen). Temperature inversions are common features during late winter. These features are defined as "winter" conditions.

With the relaxation of southerly winds in spring, the surface waters which have accumulated along the mainland coast move seaward, and there is a compensating movement of subsurface oceanic water shoreward. As a result, the subsurface waters are replaced by waters of relatively low temperature and dissolved oxygen content and of relatively high salinity and density. There is also an upward displacement of the vertical gradients of salinity, density, and dissolved oxygen, marking the return to summer conditions.

In these figures the isolines have been drawn to indicate relatively gradual changes between the extremes of "summer" and "winter" conditions. However, because of the marked variability in the onset, strength, and duration of the seasonal winds, considered to be the prime factor related to the occurrence of these conditions, it is reasonable to assume that variations in the onset and duration of the change probably occur. Strong southerly winds usually commence about mid-October, and remain relatively strong through December. Therefore the change to "winter" conditions will generally occur during this period. However, the relaxation of these winds is extremely variable, and may occur at any time from late winter to late spring; also, the relaxation process may be gradual or relatively abrupt within this time frame. Therefore, it follows that the subsurface conditions could change accordingly; the return to "summer" conditions may be abrupt or gradual and may occur at any time from late winter through late spring. The data for 1954 indicate a relatively late and abrupt change to "summer" conditions, between May and early July 1954.

Another feature evidence in these data is the variability that can occur in "winter" conditions. The deepening of the isolines appears to have been less in winter 1961-62 than in winter 1960-61 (Fig. 34). Also, by late winter (January-February), temperatures throughout the water column were lower in the winter of 1962 (January) than that of 1961 (February). Several factors were associated with the relatively cold conditions in winter 1961-62; monthly means of sea level and zonal Ekman were relatively low as has been noted previously, and monthly means of air temperature at McInnes Island were between 0.8 and 2.5°C lower in the winter of 1961-62 than in that of 1960-61.

XIII - SEASONAL TEMPERATURE AND SALINITY STRUCTURES

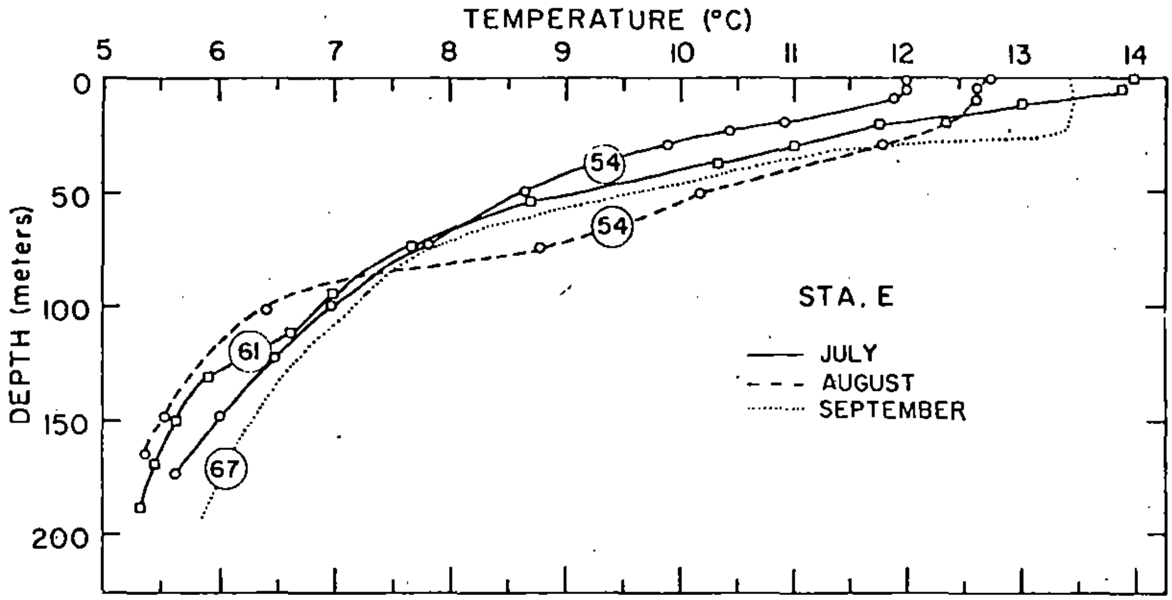
Vertical temperature and salinity structures considered representative of the deeper waters of Hecate Strait are illustrated in Fig. 36, 37, 38, and 39.

In July-September, the distinctive features of the temperature and salinity structures are the thin mixed or near-mixed surface layer and the marked thermocline and halocline (Fig. 36). In the absence of surface mixing, the thermocline and halocline will extend to the surface. The thermocline extends from near-surface to about 100-125 m. The magnitude of the thermocline is dependent upon the degree of surface heating and mixing and is about 6-8°C. The halocline extends from near-surface to depths of 125-150 m. The upper portions of the thermocline and halocline are generally coincident in depth, but the lower limit of the halocline appears to be deeper than that of the thermocline. The magnitude of the halocline is dependent upon the freshwater input, and therefore varies with location, but is about 2-3‰. During this period, the thermocline and halocline are at their minimum depth. Below these gradients temperature decreases, and salinity increases, slightly with depth; temperatures are low and salinities high throughout most of the water column.

In October-December the dominant processes and their sequence are considered to be: surface cooling (primarily through conduction and evaporation), wind-induced and convective mixing, onshore transport of the surface layer accompanied by an accumulation and downward displacement of these waters along the mainland side, and offshore transport at depth resulting in a displacement of subsurface waters to seaward. These processes are reflected by changes in the structures. The initial changes are the thickening of the surface mixed layer and the downward displacement of the thermocline and halocline in late October (Fig. 37). These result in large changes in temperature and salinity at intermediate depths (75-100 m). By November-December, the subsurface waters have been replaced and are now relatively warm and of low salinity.

During late winter (January-March) the cooling, mixing, and advective processes continue. The main features are the near-isothermal conditions to depths of 150-200 m and the relatively large temperature inversions common at depth (Fig. 38).

In April-June, mixing and surface cooling are replaced by surface heating and dilution. Also, there is a relaxation in southerly winds; this is accompanied by an offshore movement of surface waters, and a compensating onshore flow of subsurface waters. These processes result in the development of the summer thermocline, an increase in the magnitude of the halocline, a



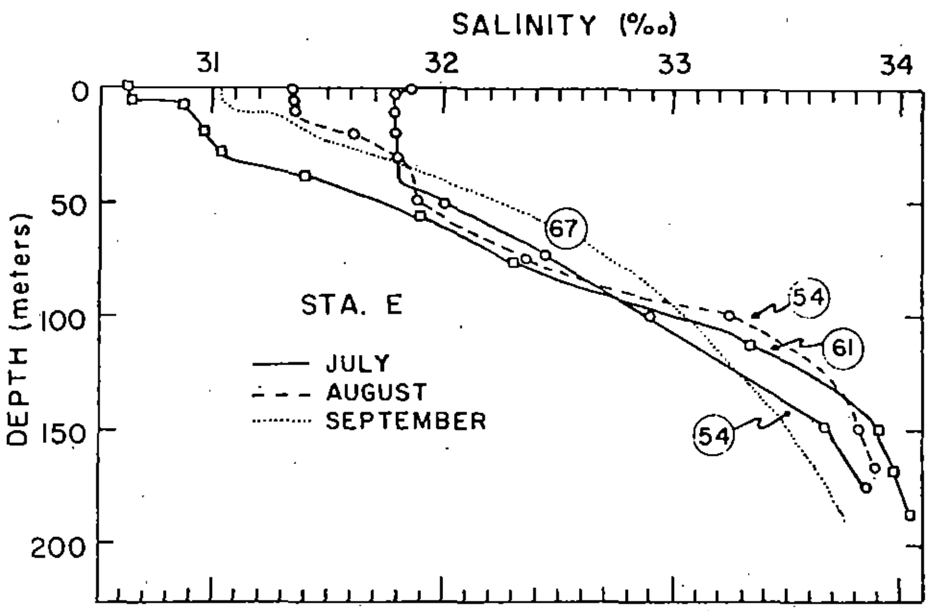


Fig. 36. Temperature and salinity structures at Station E in Hecate Strait, July-September.

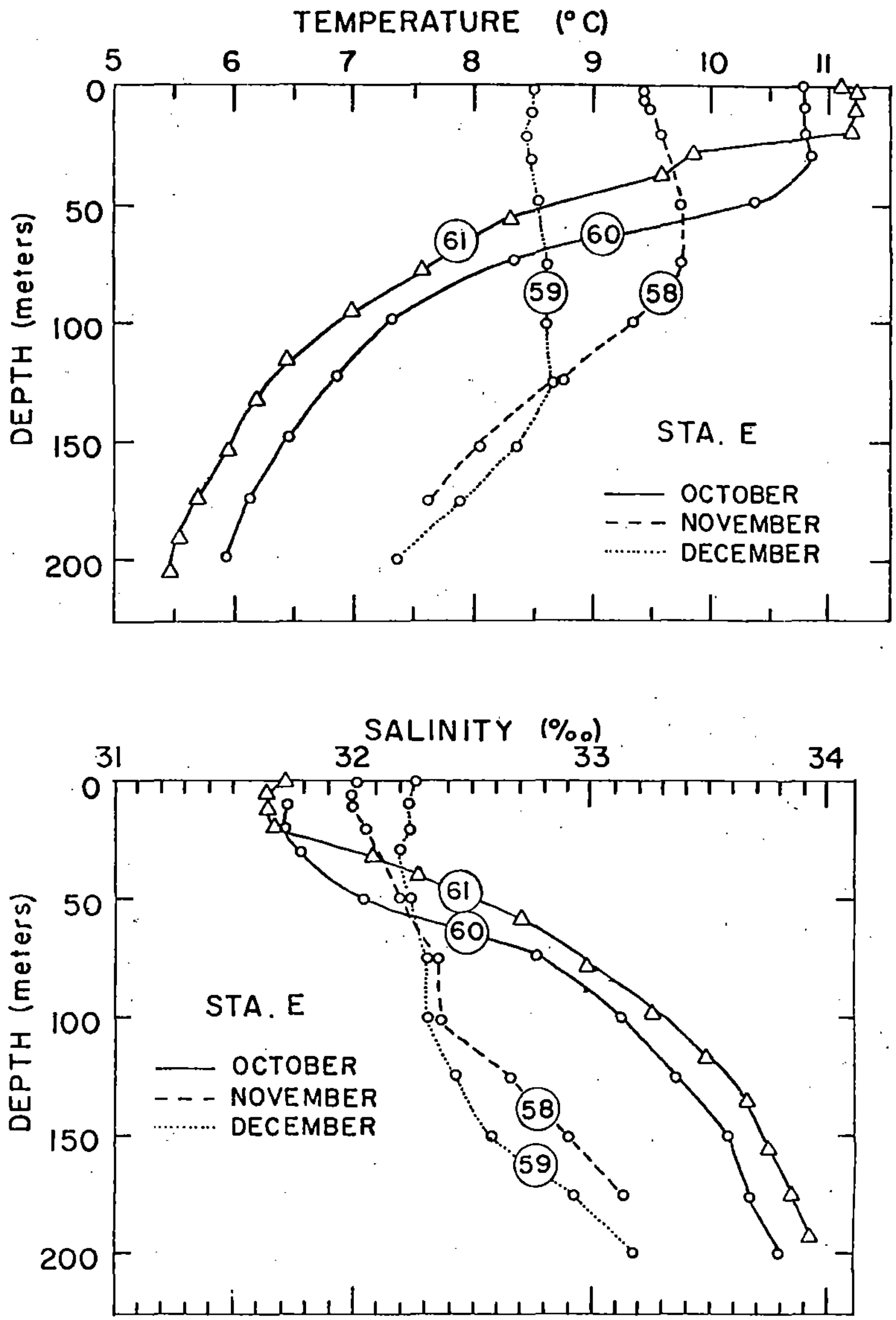


Fig. 37. Temperature and salinity structures at Station E in Hecate Strait, October-December.

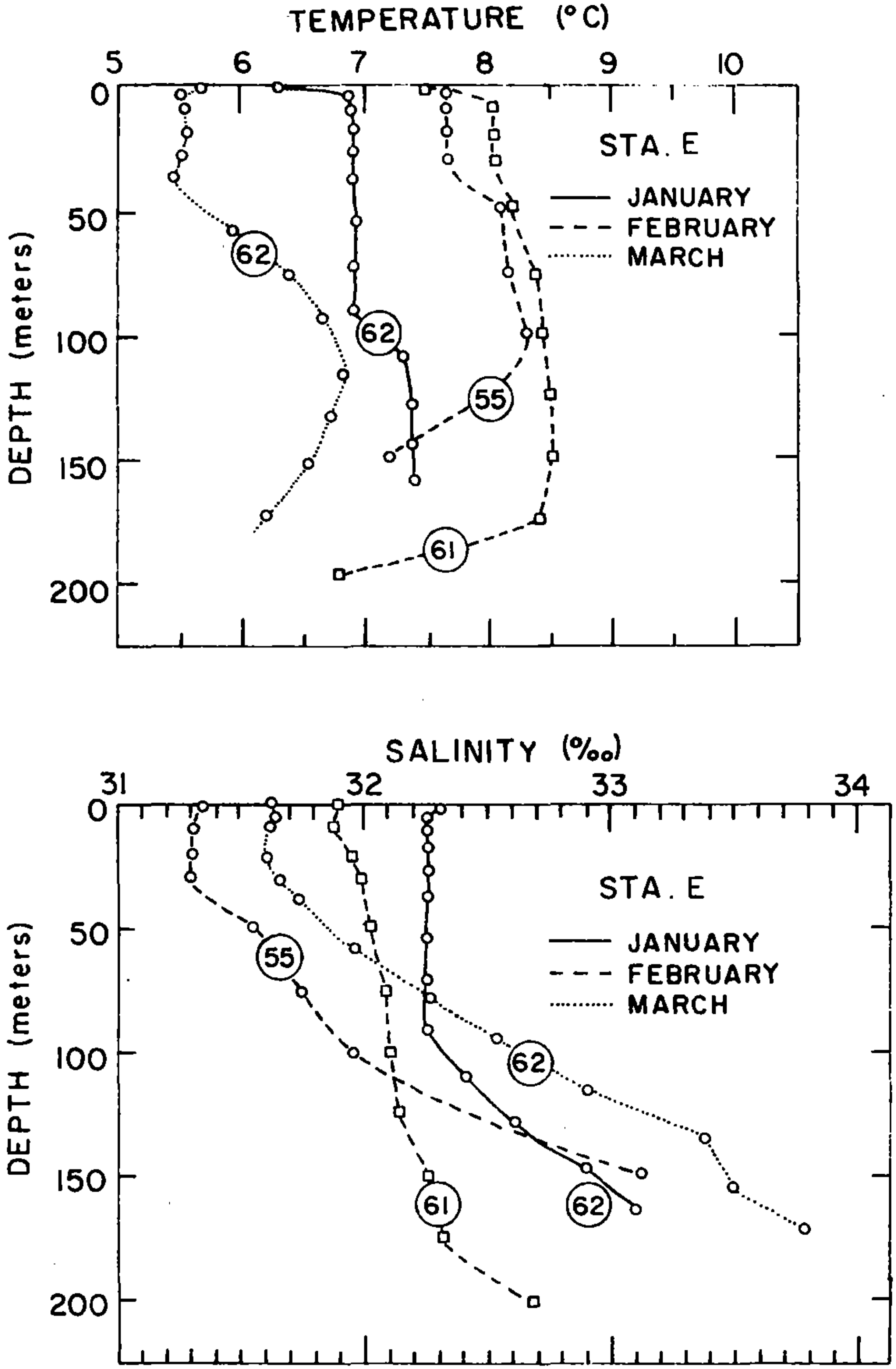


Fig. 38. Temperature and salinity structures at Station E in Hecate Strait, January-March.

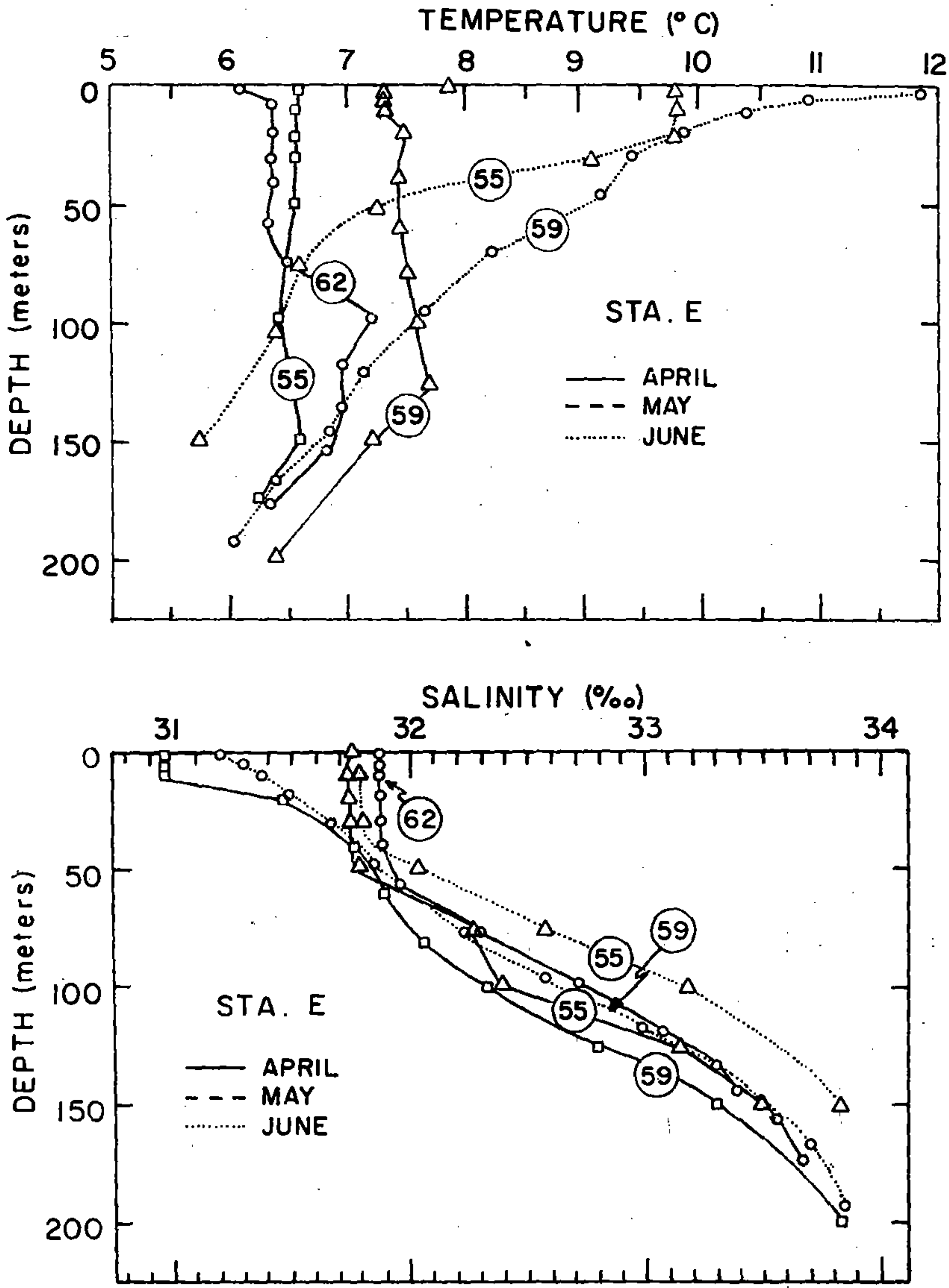


Fig. 39. Temperature and salinity structures at Station E in Hecate Strait. April-June.

decrease in the depth of the halocline and a re-entry of relatively cold and saline subsurface waters (Fig. 39), marking the return to "summer" conditions. During this period, both "summer" and "winter" conditions may occur.

The near-isothermal feature of the temperature structure in late winter is of considerable significance, as surface conditions in this period generally reflect the subsurface conditions to depths of 150-200 m. Thus, the anomalies in the long-term records of sea surface temperature at the light stations are considered to reflect corresponding anomalies in the subsurface waters to at least these depths, in these areas, during late winter. It follows that, since there generally appears to be good coherence between sea level at Prince Rupert, zonal Ekman transport and sea-surface temperature anomalies, any or all of these can be used as indices of subsurface temperature conditions during late winter in Queen Charlotte Sound and Hecate Strait.

A schematic diagram indicating the approximate overall annual range and the range of "summer" and "winter" conditions for the subsurface waters (those below 125 m) in Queen Charlotte Sound and Hecate Strait is presented in Fig. 40. The overall range in temperature is about 3.5°C at 125 m, decreasing to about 1.3°C at 30 m depth. Similarly, the salinity range decreases from about 1.8‰ at 125 m to 0.3‰ at 300 m depth. Incidently, the figure also shows the large variability in temperature and salinity characteristic of depths between the surface and 125 m.

XIV - VERTICAL SECTIONS OF TEMPERATURE, SALINITY, DENSITY, AND DISSOLVED OXYGEN CONTENT

Data to show the seasonal and spatial distribution of properties with depth are limited. The best data set is that for 1954-55. The locations of the sections are shown in Fig. 12, and the distributions are shown in Fig. 41 to 57. These reflect to some degree the seasonal sequence of events and the spatial variability that may occur.

In these data the subsurface waters were of lower temperature and dissolved oxygen content and of higher salinity and density in July and August than those in May, with the extreme of "summer" conditions occurring in July in southern Hecate Strait (Fig. 41-45) and in August in central Hecate Strait (Fig. 46-50). In July, the isolines at depths between 50 and 150 m generally sloped slightly downward toward the eastern shore, while in August they appeared to slope upward. This indicates an upwelling or divergent condition along the eastern shoreline in August, which would be accompanied by a southward flow. This is opposite to the convergent condition and northward flow inferred from the slight downward slope of the isohalines in July. These two conditions are reflected in the Ekman transport data; in July 1954 the transport was onshore (divergence), but in August it was offshore (divergence).

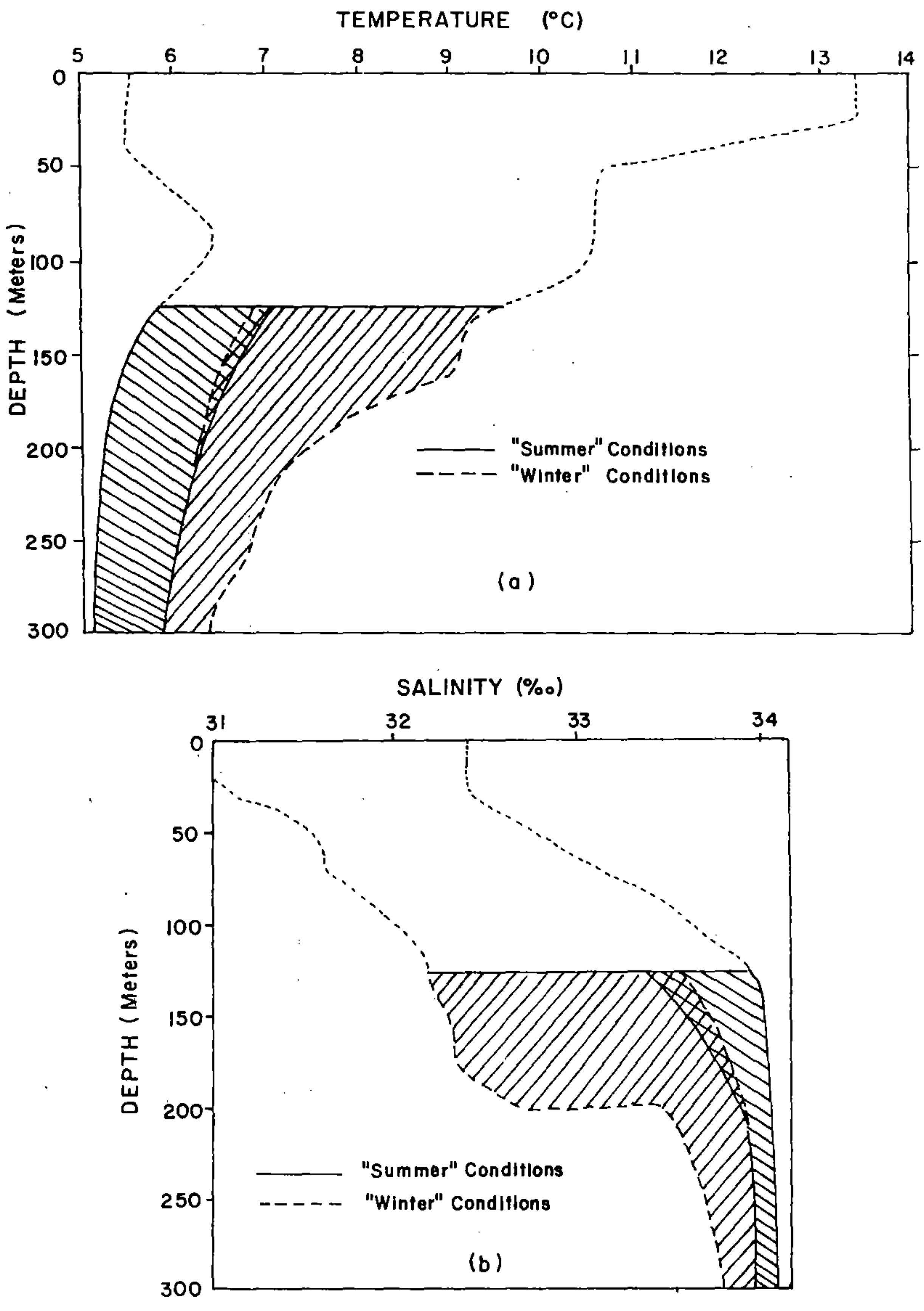


Fig. 40. Approximate ranges of "summer" and "winter" (a) temperature and (b) salinity conditions in the subsurface waters of Queen Charlotte Sound and Hecate Strait.

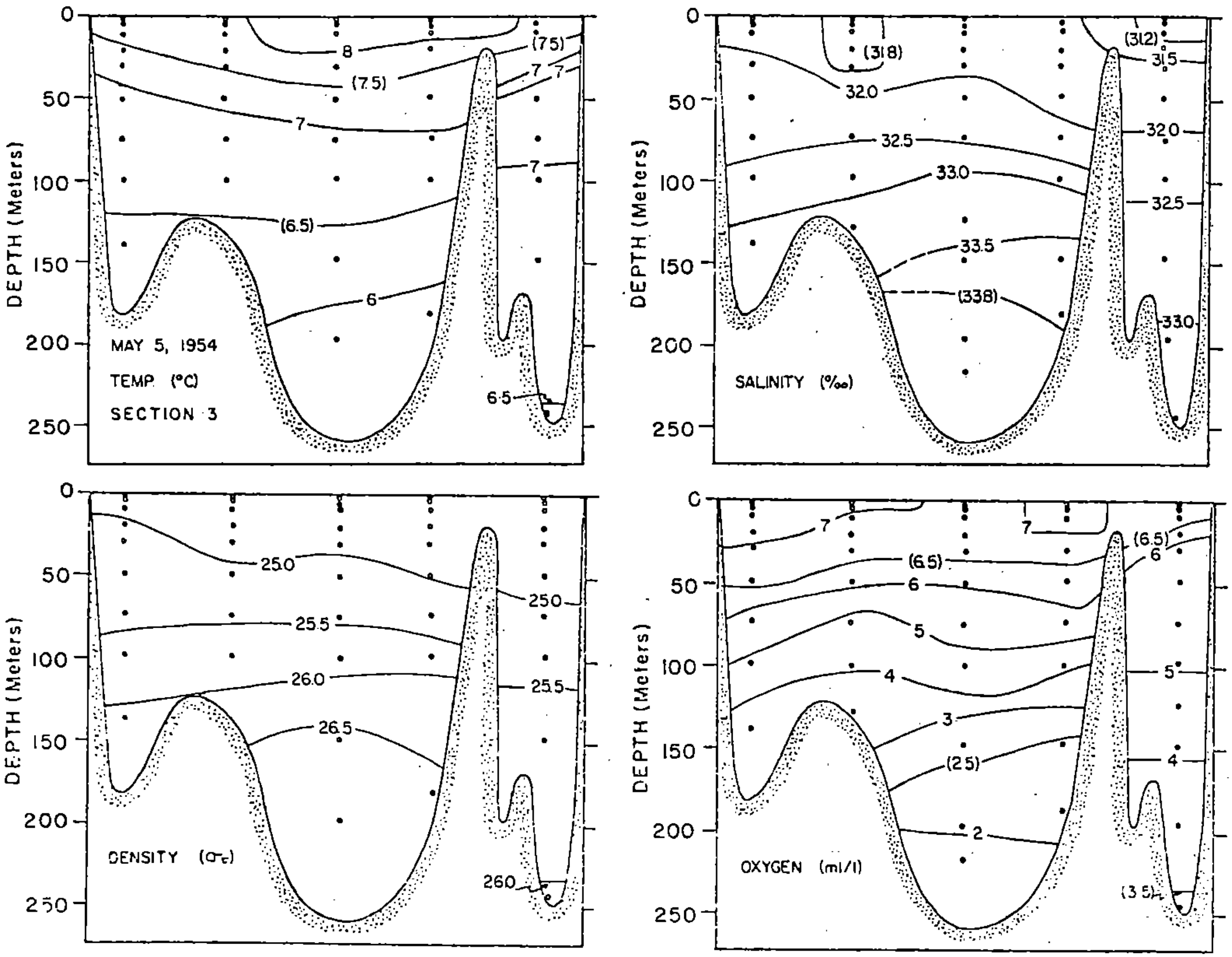


Fig. 41. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, May 5, 1954

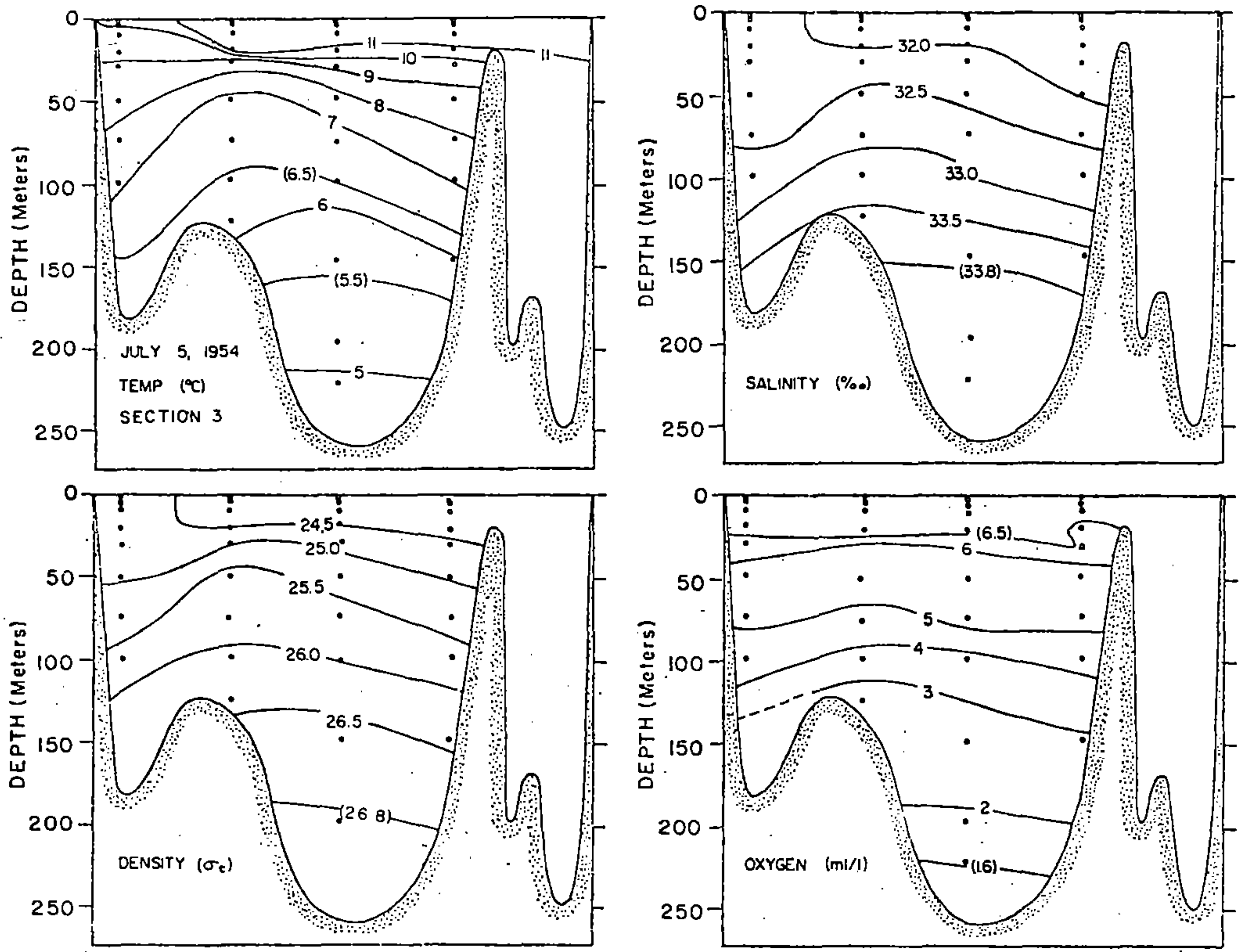


Fig. 42. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, July 5, 1954.

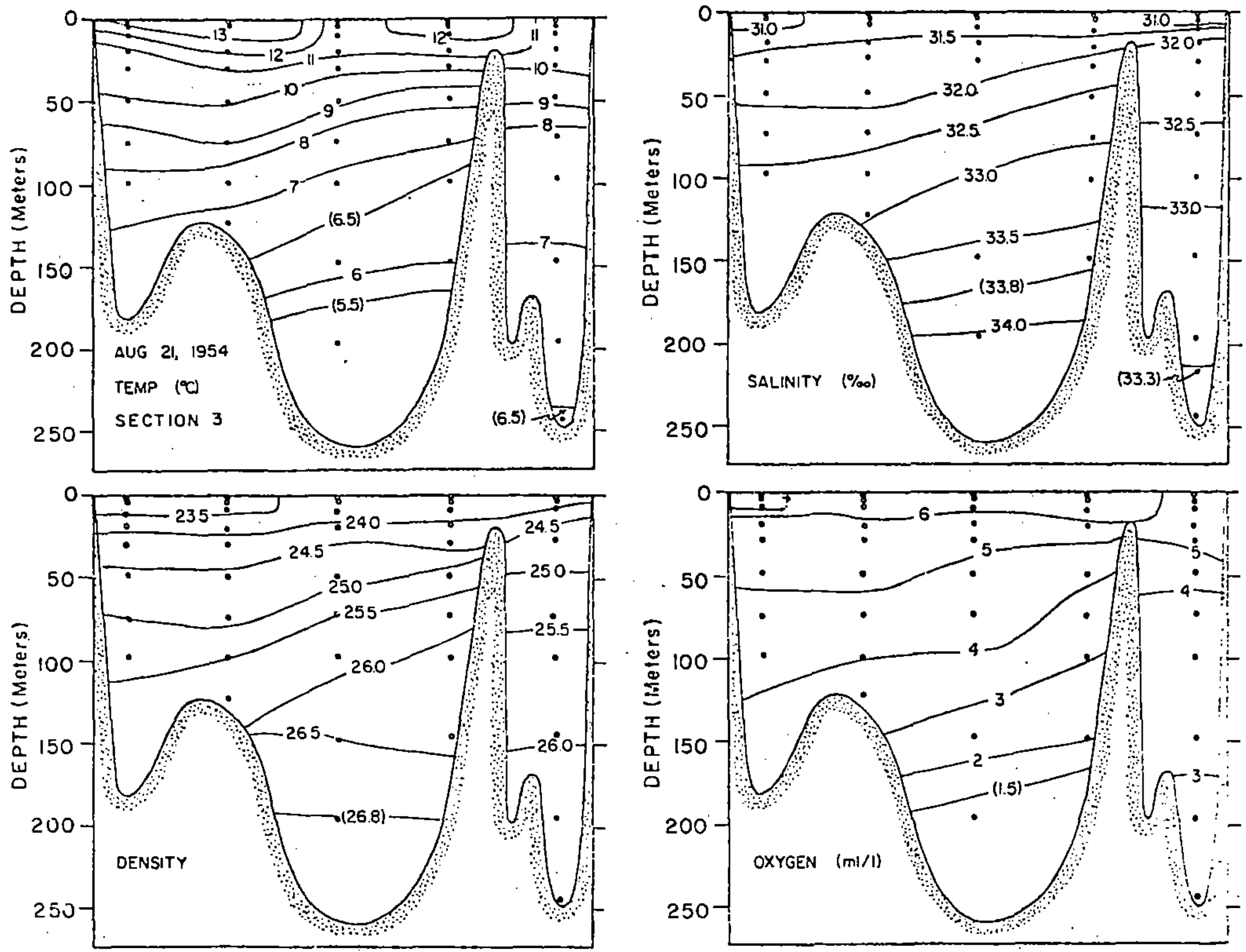


Fig. 43. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, August 21, 1954.

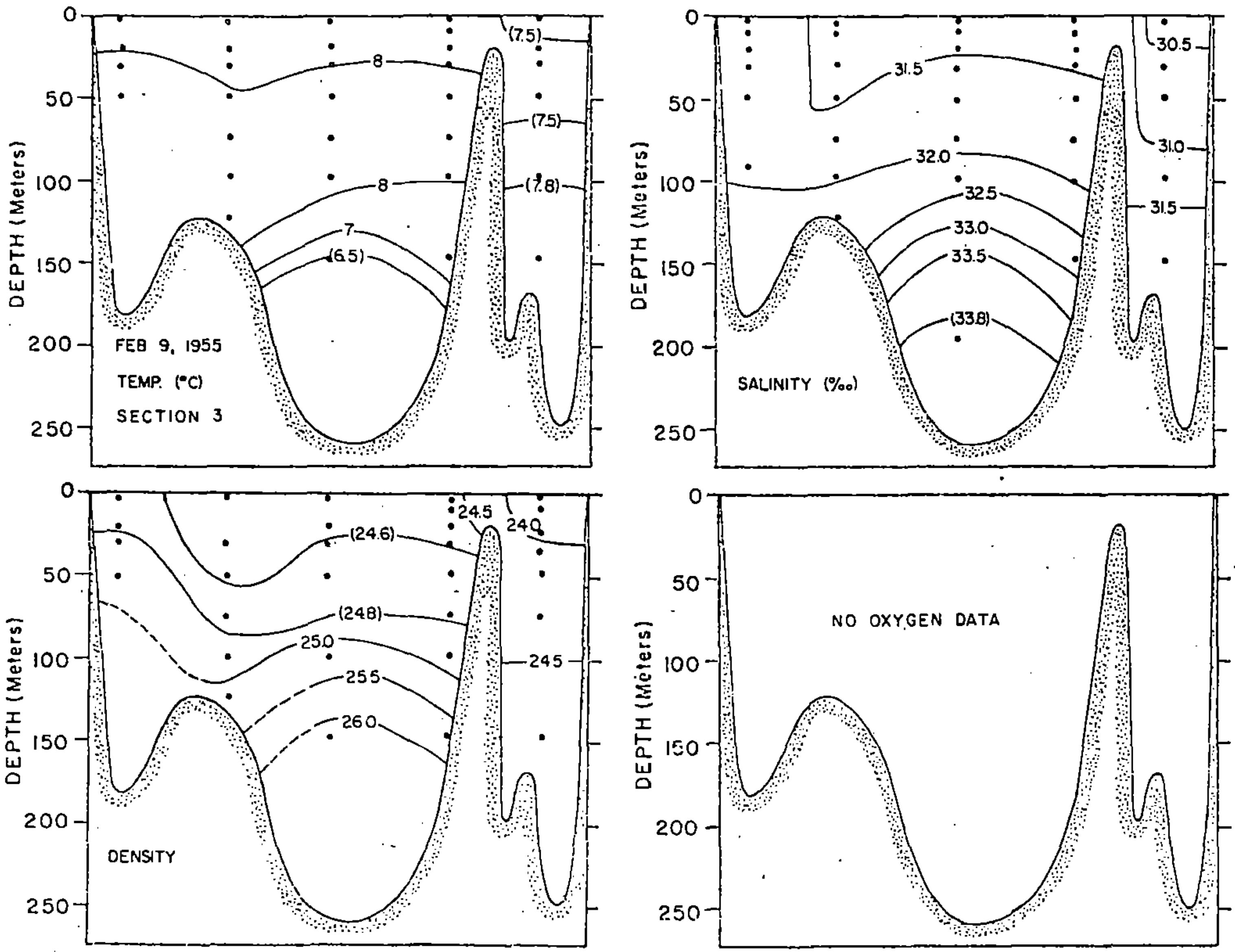


Fig. 44. Vertical sections of temperature, salinity and density in Hecate Strait, February 9, 1955.

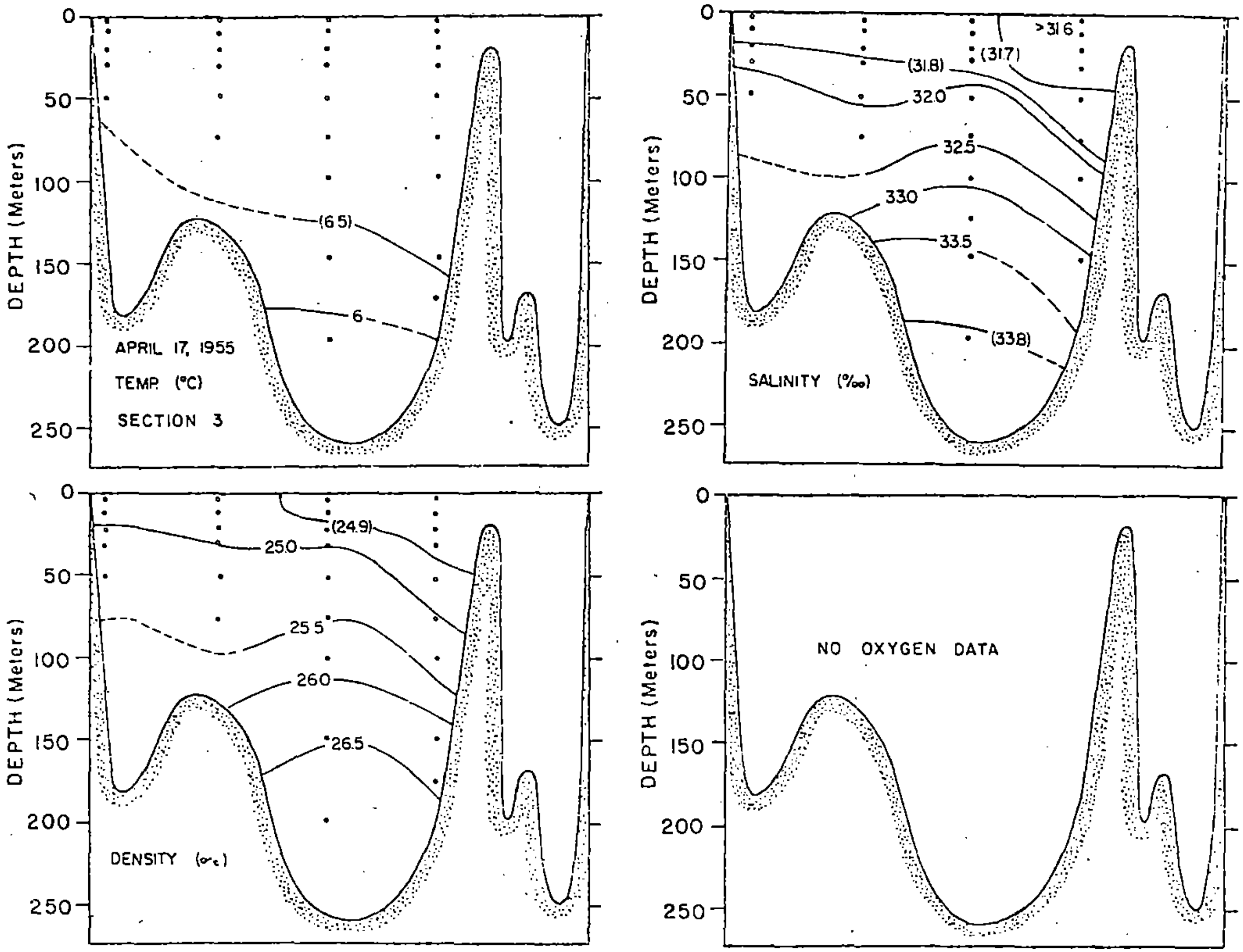


Fig. 45. Vertical sections of temperature, salinity and density in Hecate Strait, April 17, 1955.

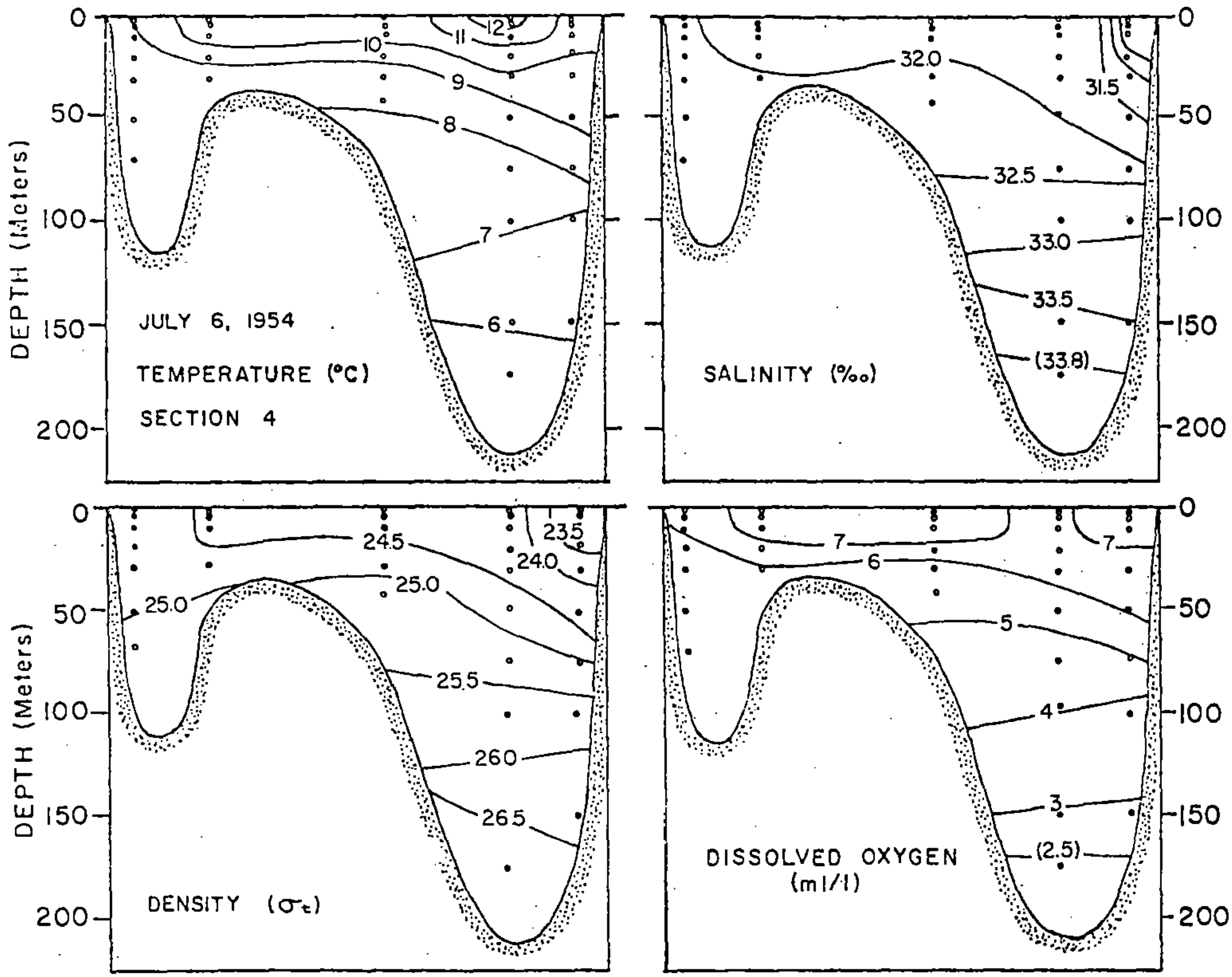


Fig. 46. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, July 6, 1954.

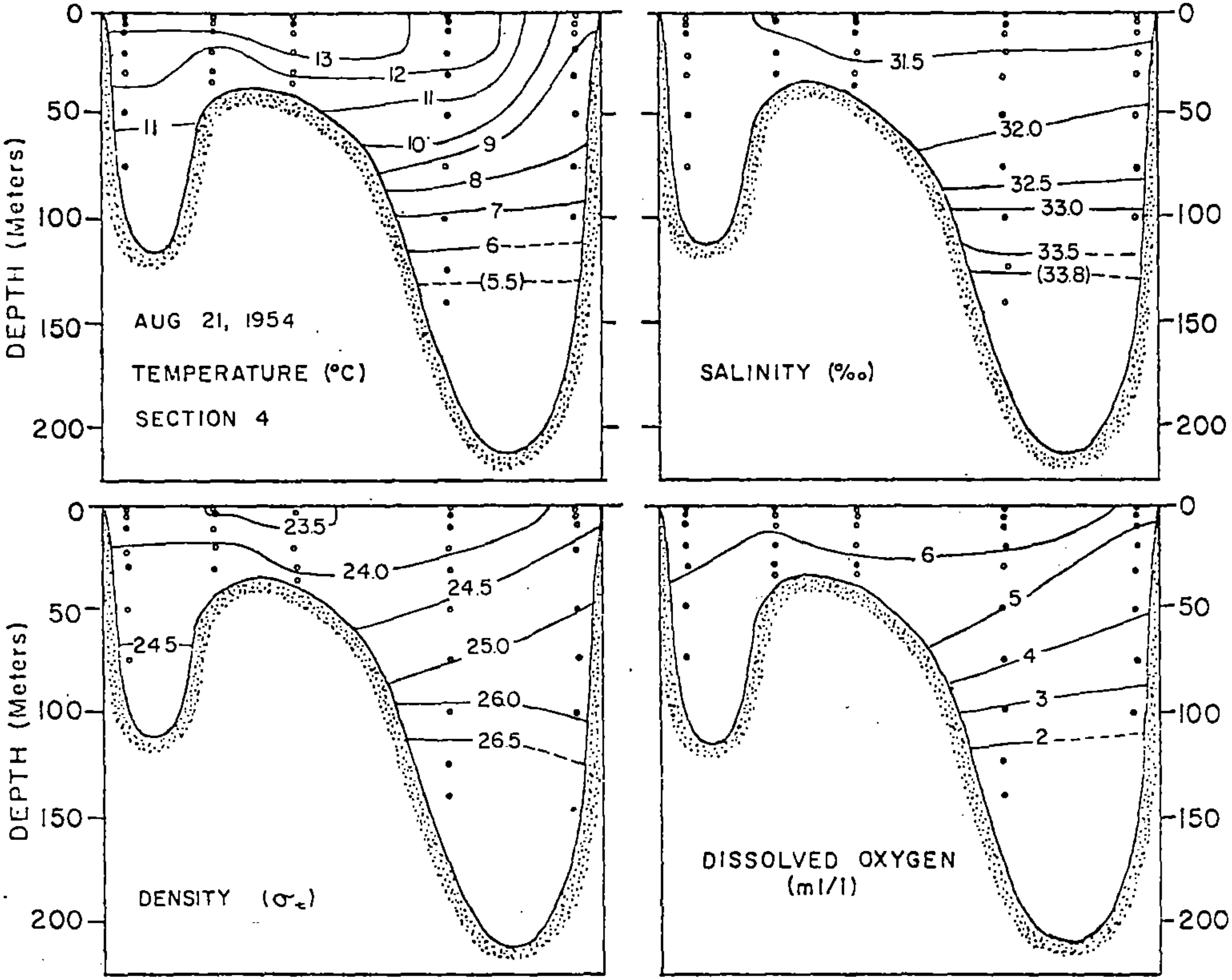


Fig. 47. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, August 21, 1954.

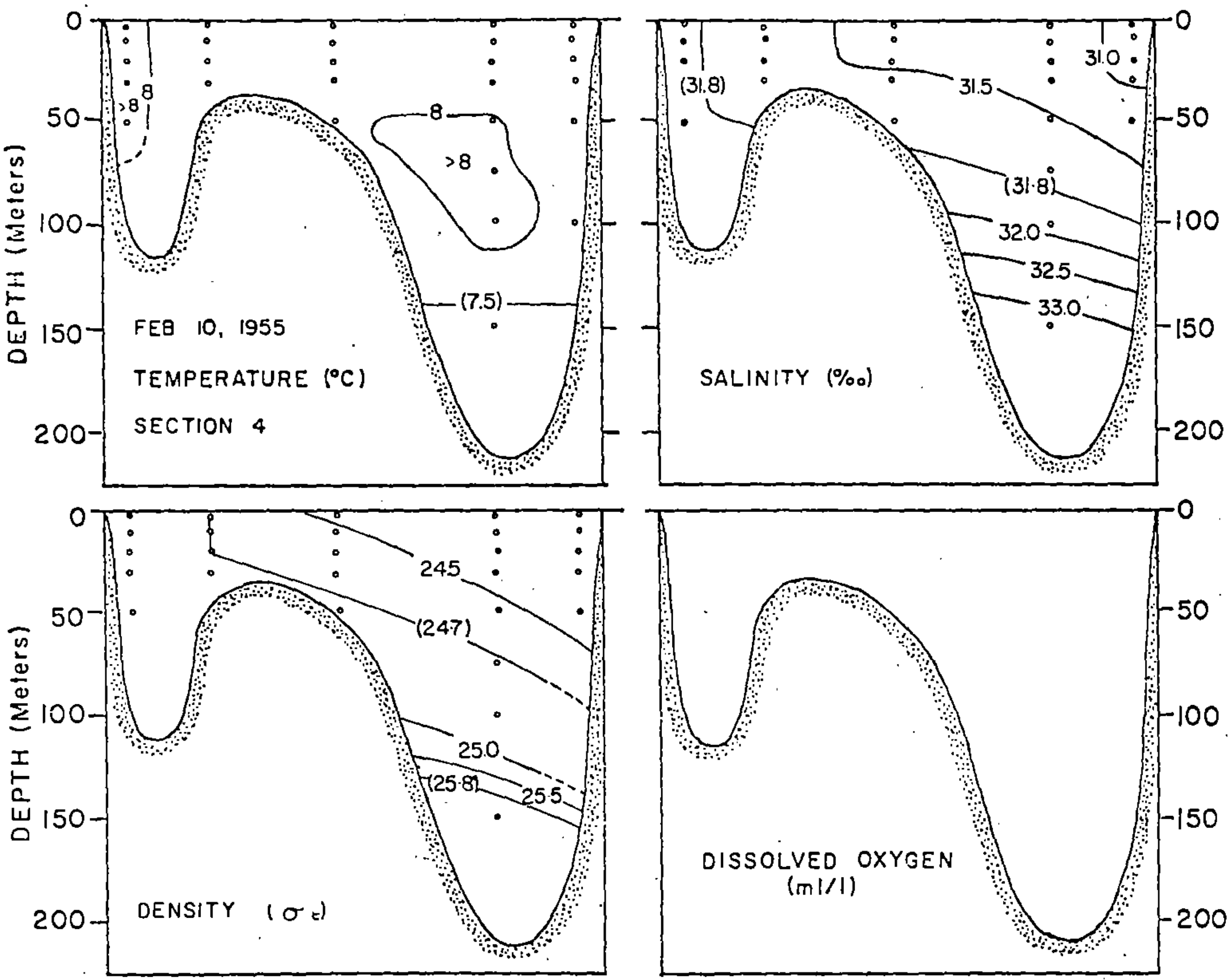


Fig. 48. Vertical sections of temperature, salinity and density in Hecate Strait, February 10, 1955.

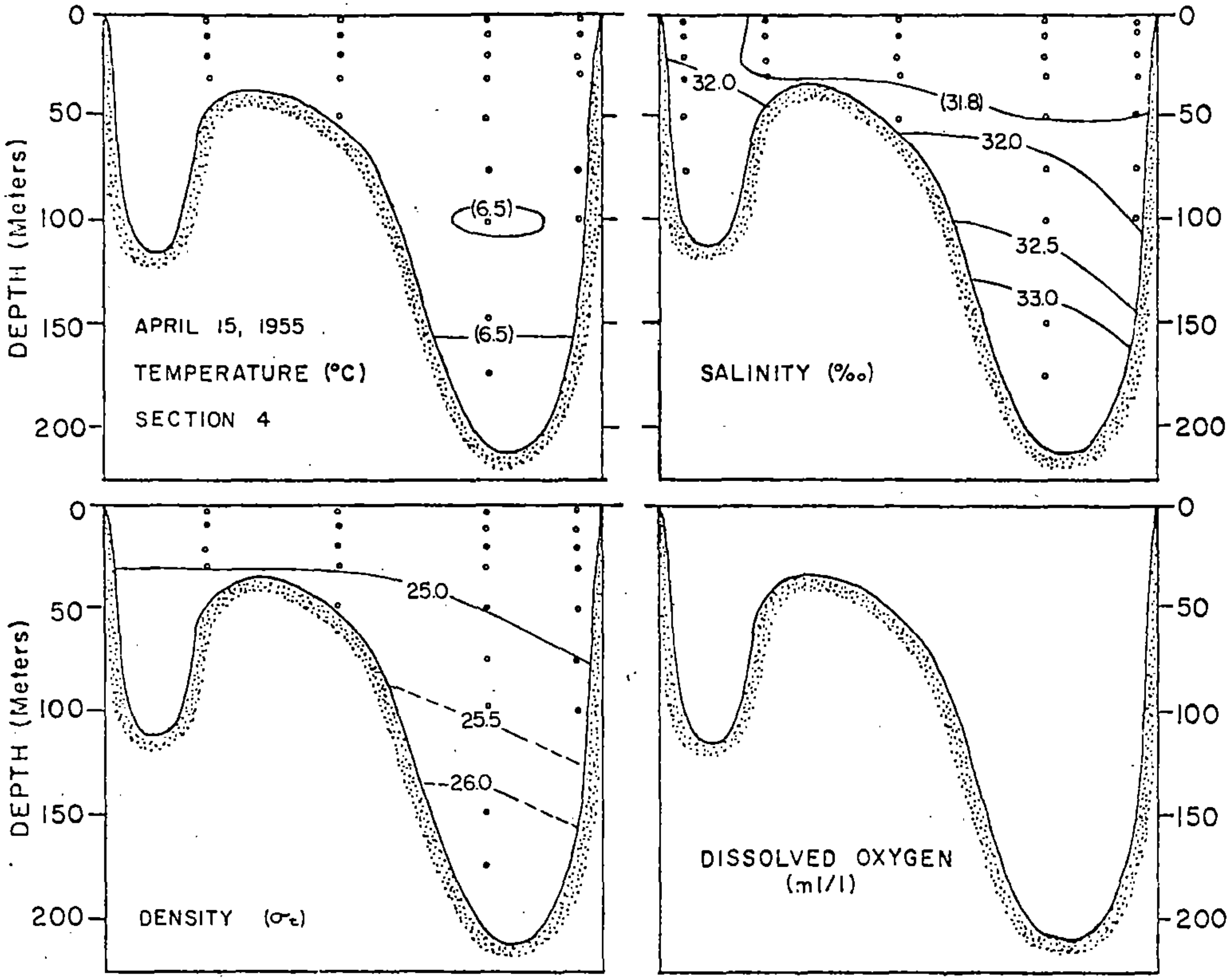


Fig. 49. Vertical sections of temperature, salinity and density in Hecate Strait, April 15, 1955.

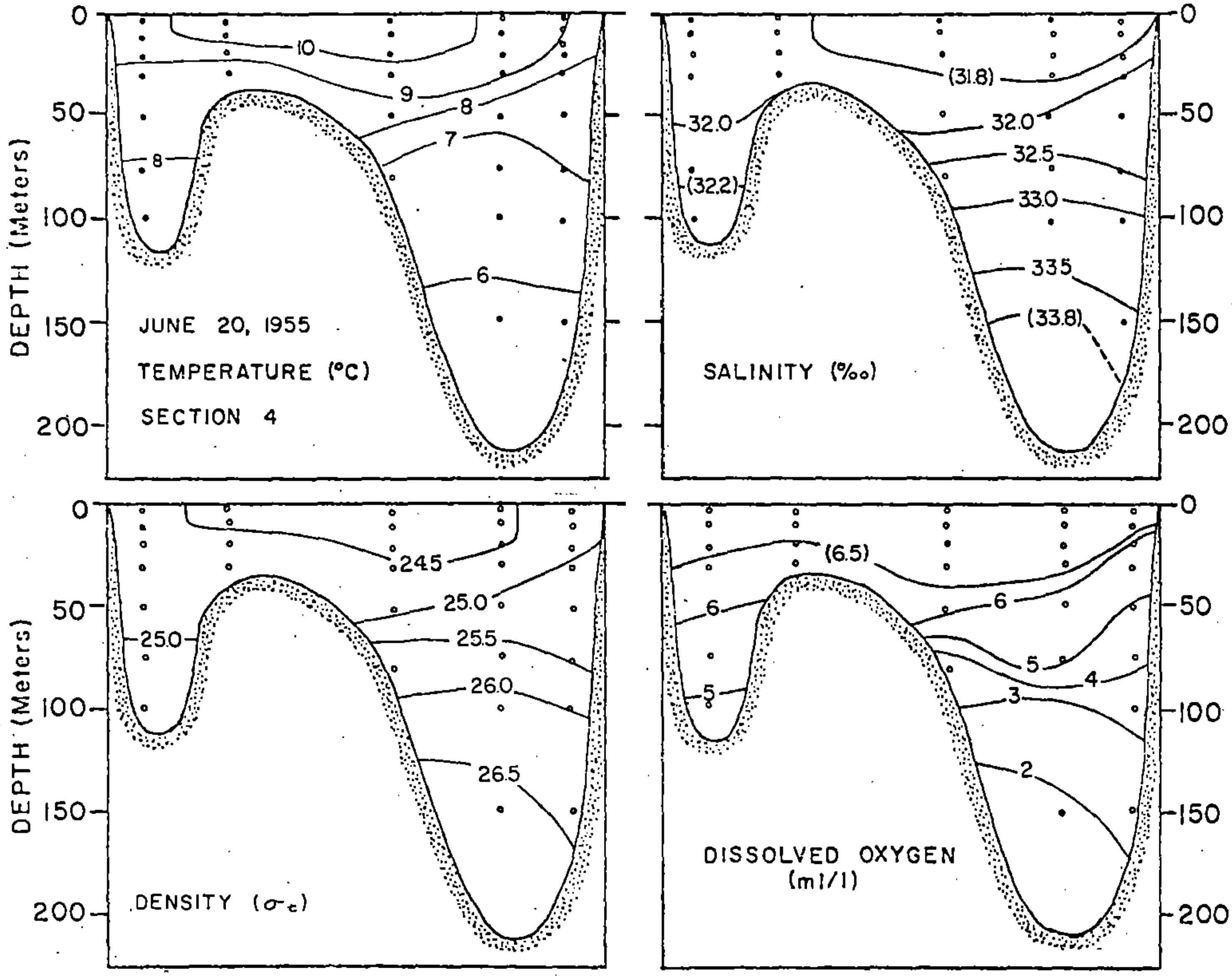


Fig. 50. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, June 20, 1955.

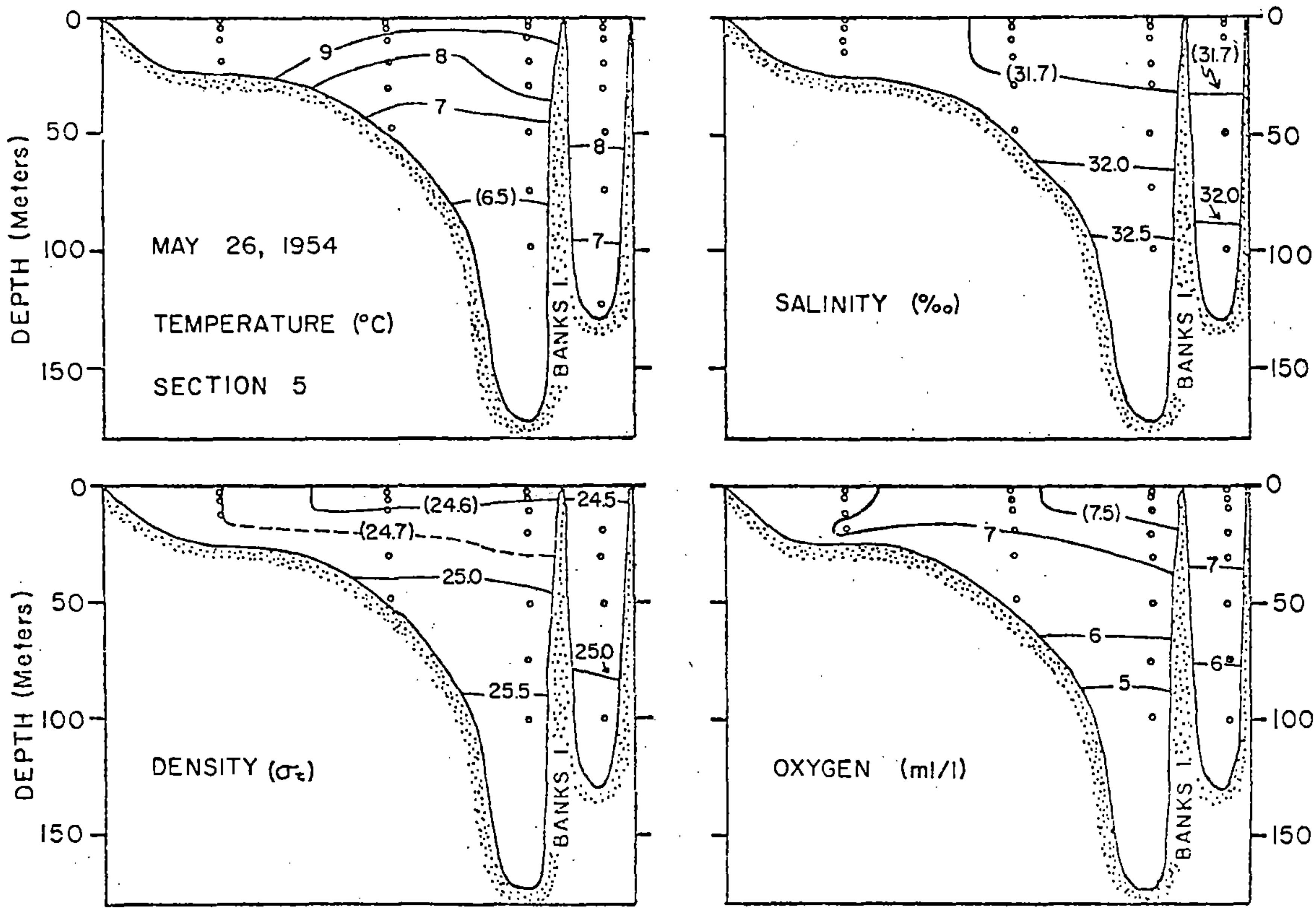


Fig. 51. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, May 26, 1954.

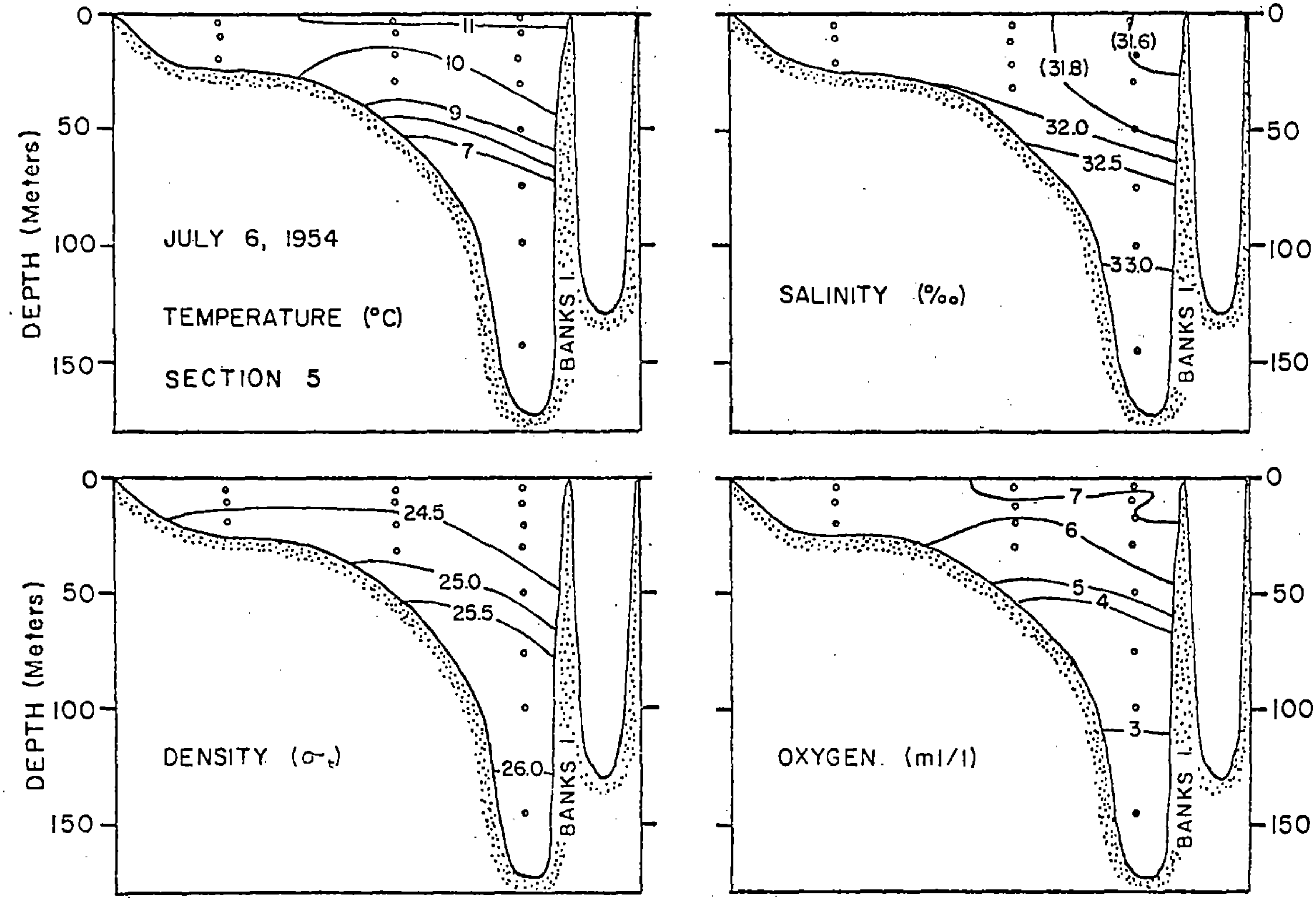


Fig. 52. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, July 6, 1954.

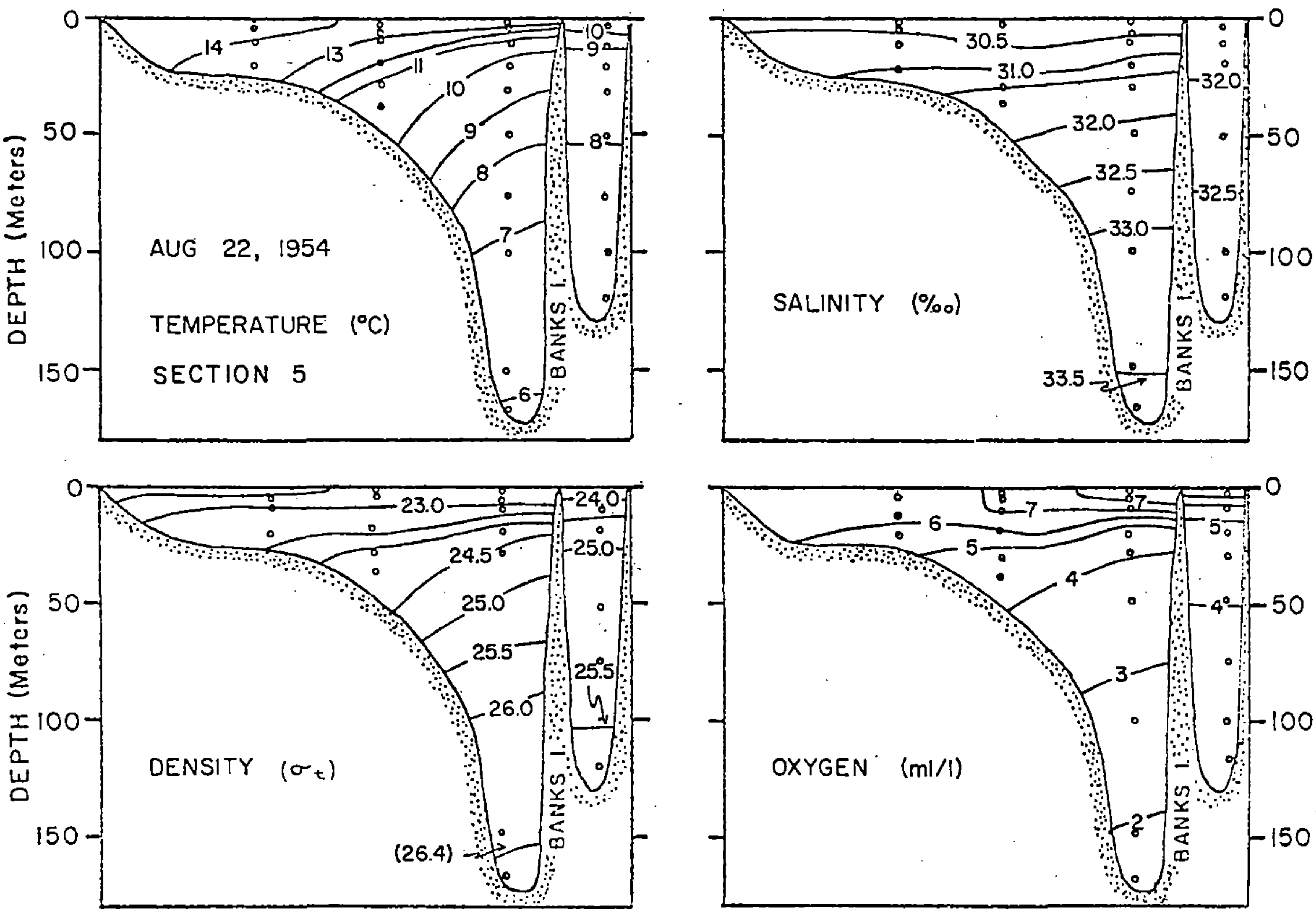


Fig. 53. Vertical sections of temperature, salinity, density and dissolved oxygen content in Hecate Strait, August 22, 1954.

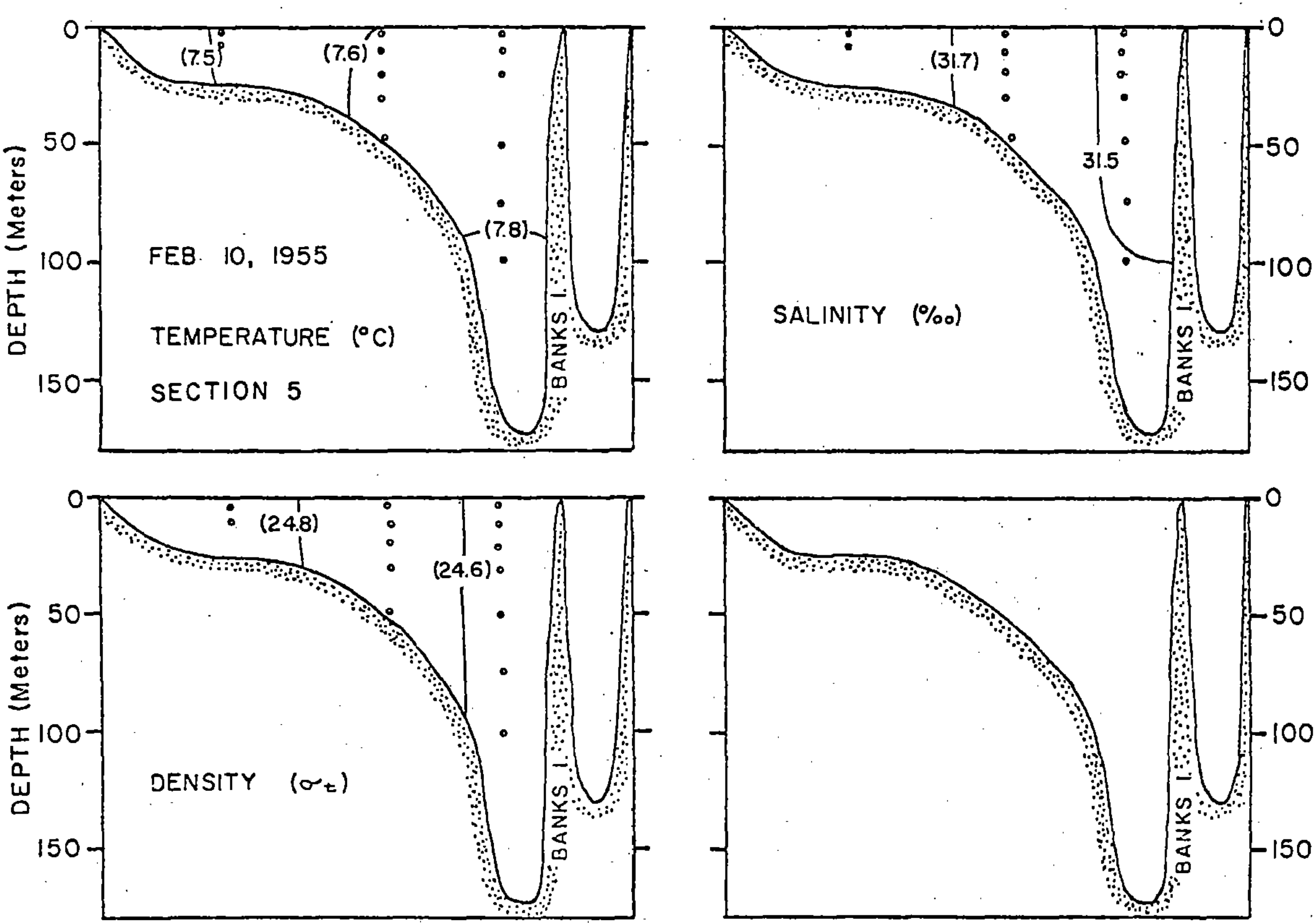


Fig. 54. Vertical sections of temperature, salinity and density in Hecate Strait, February 10, 1955.

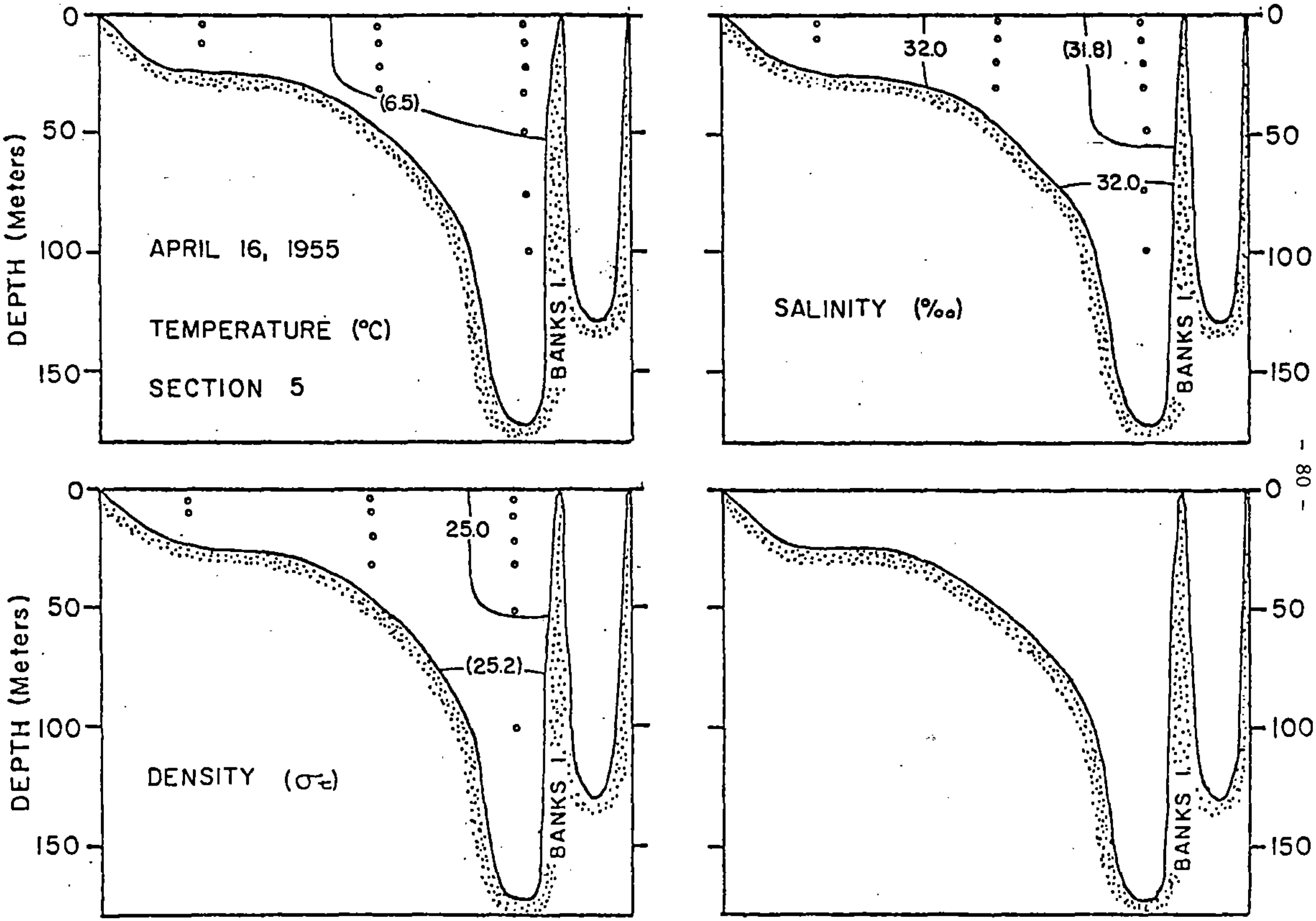


Fig. 55. Vertical sections of temperature, salinity and density in Hecate Strait. April 16, 1955.

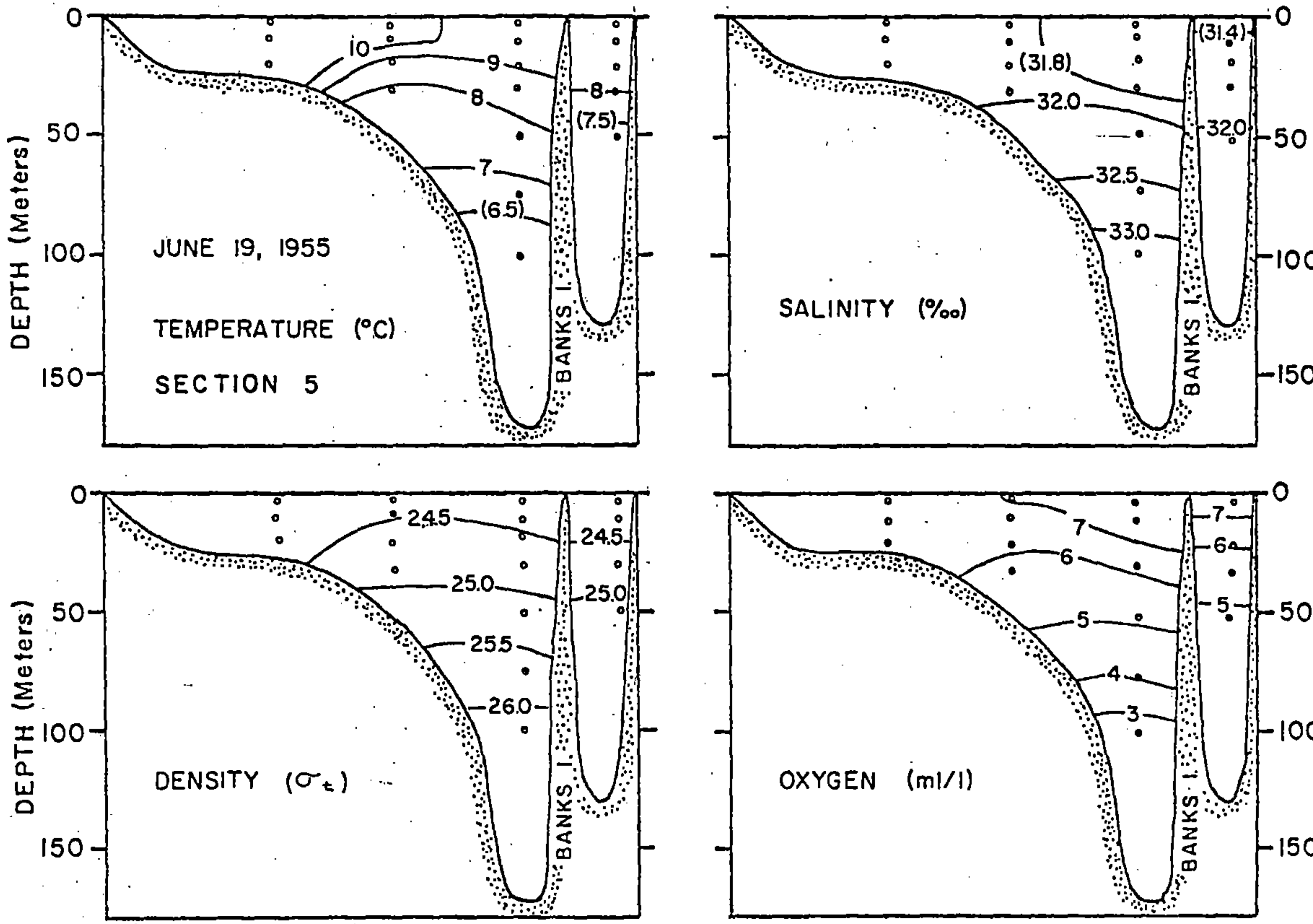


Fig. 56. Vertical sections of temperature, salinity, density and dissolved oxygen content. June 19, 1955.

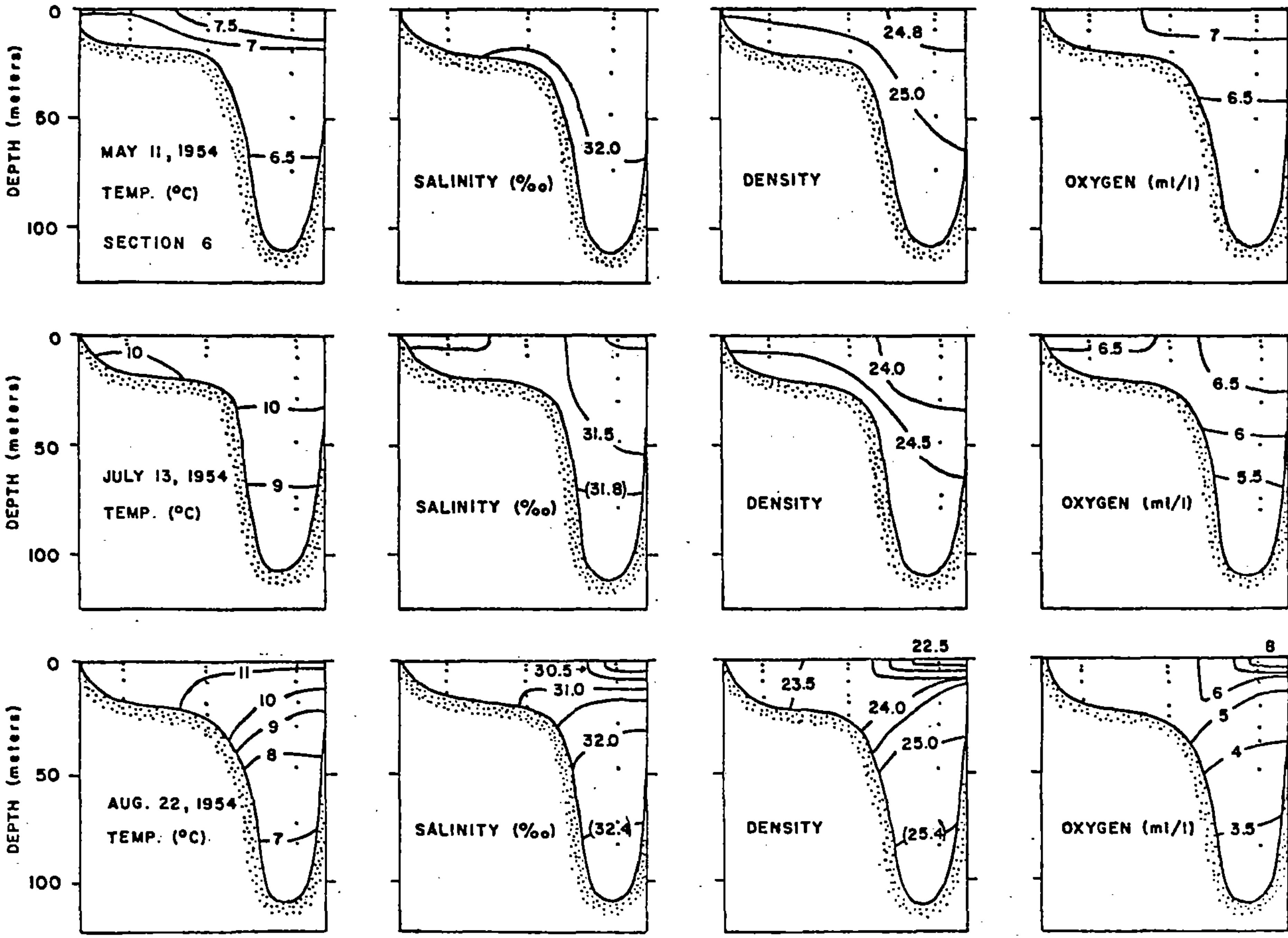


Fig. 57. Vertical sections of temperature, salinity, density and dissolved oxygen content. May 1954-June 1955.

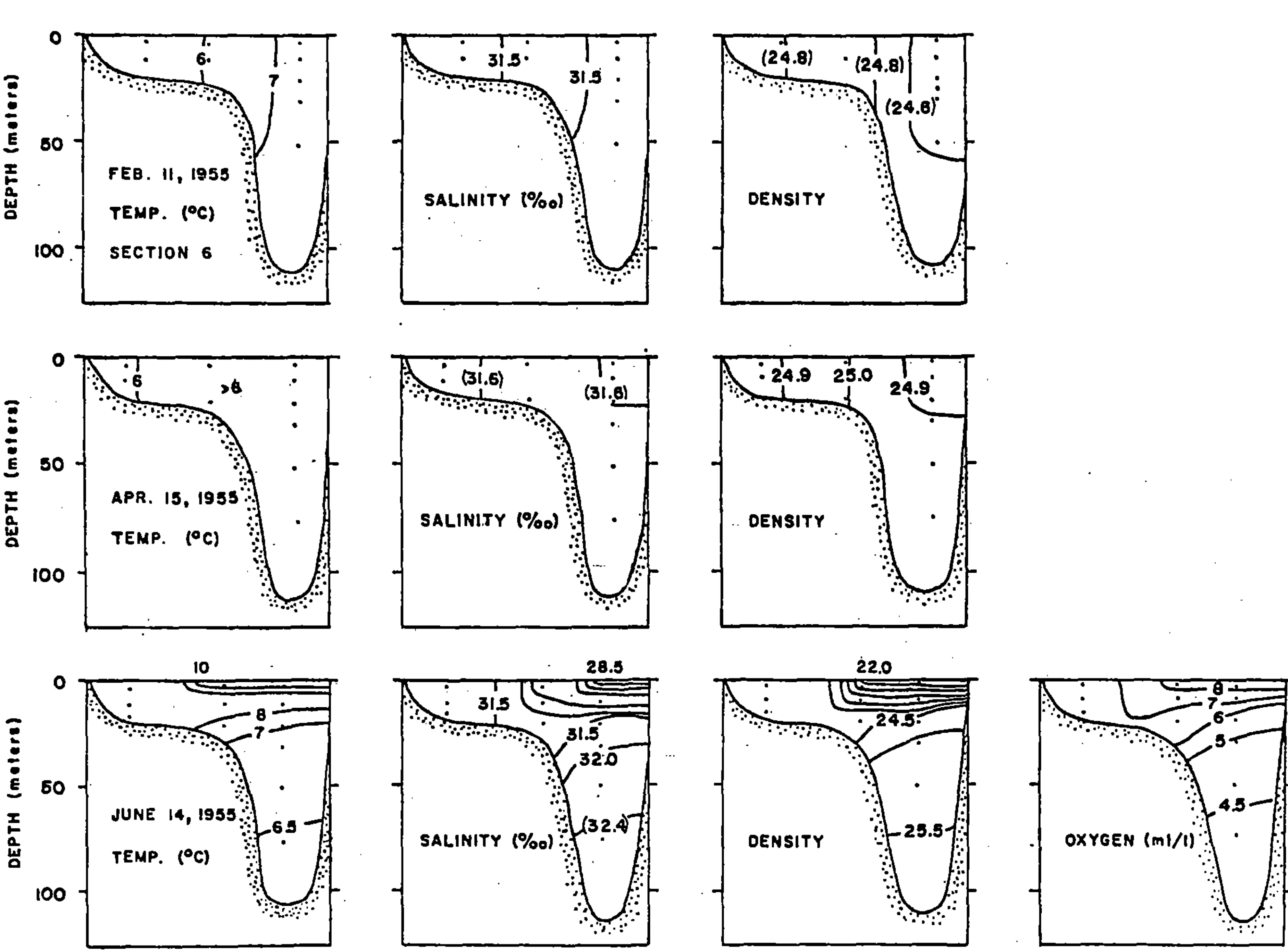

DEPTH (meters)
0
50
100
FEB. 11, 1955
TEMP. (°C)
SECTION 6
6
7
SALINITY (‰)
31.5
31.5
DENSITY
(24.8)
(24.8)
(24.8)
APR. 15, 1955
TEMP. (°C)
6
>6
SALINITY (‰)
(31.6)
(31.6)
DENSITY
24.9
25.0
24.9
JUNE 14, 1955
TEMP. (°C)
10
8
7
6.5
SALINITY (‰)
28.5
31.5
31.5
32.0
(32.4)
DENSITY
22.0
24.5
25.5
OXYGEN (ml/l)
8
7
6
5
4.5

Fig. 57. (cont'd).

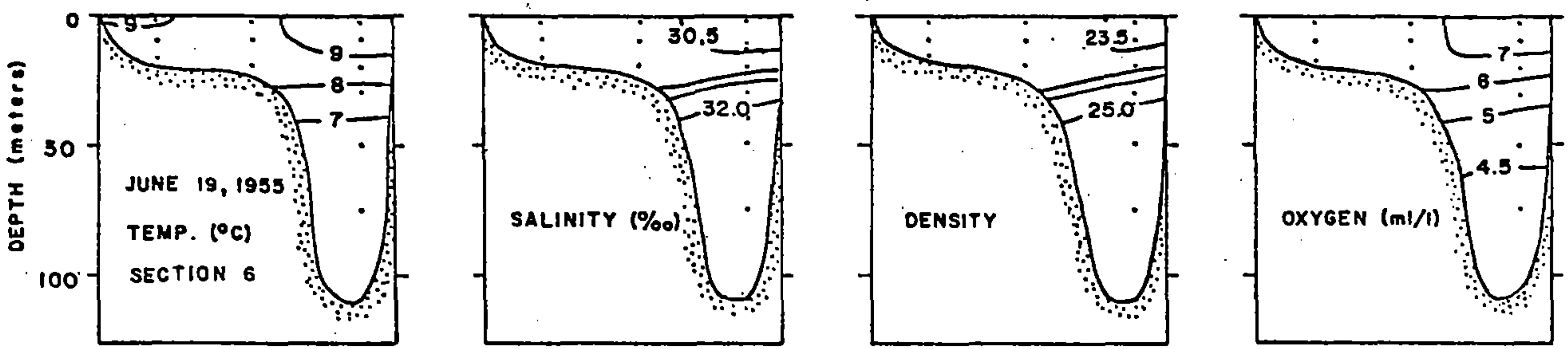

DEPTH (meters)
0
50
100
9
9
8
7
JUNE 19, 1955
TEMP. (°C)
SECTION 6
30.5
32.0
SALINITY (‰)
23.5
25.0
DENSITY
7
6
5
4.5
OXYGEN (ml/l)

Fig. 57. (cont'd).

The deepening of the isolines near the mainland coast in February and April 1955 (Fig. 44, 45, 48, 49) reflects a relatively strong northward flow that is characteristic of the winter months.

A dominant feature is the absence of any appreciable gradients in the relatively shallow waters on the western side of northern Hecate Strait throughout the year (Fig. 51-57). Other significant features are the high temperatures and dissolved oxygen content and low salinities and densities of the bottom water in northern Hecate Strait in July as compared to those for other periods (Fig. 57), opposite to conditions to the south. Another feature is the marked changes that can occur in the near-surface layer over a relatively short period (5 days) (Fig. 57).

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- Appendix B.

Catch and Escapement

Salmon in Hecate Strait and adjacent areas have been exploited commercially since the turn of the century. However, reliable catch and escapement data became available only since 1951. Catch of all species from 1951 to 1979 ranged from 1.8 million to 10.8 million pieces, with pink and sockeye being the most abundant (Table 1). Landings from this area comprise 12 to 38 percent (average 21%) of the B.C. total. Specifically Table 2 shows, on average, more than 35% of the even-year pink, 20% of the odd-year pink, 20% of the chum, 17% of the sockeye, 13% of the coho and 11% of the chinook landed in B.C. came from this area. However, the number of fish caught in Hecate Strait itself (mostly by troll gear) amounts to less than 5% of the B.C. total landings of coho and chinook combined. Landings of pink, chum and sockeye in Hecate Strait are negligible because these species are caught almost exclusively by net fisheries conducted in more sheltered waters adjacent to Hecate Strait.

Escapement to the 260 or so spawning streams around Hecate Strait ranged from 1.2 million to 6.5 million (Table 3). Except coho and chinook, the relative abundance of fish caught in a statistical area more or less reflect the relative production from that area. This is shown in the following sections which describe in more detail the fishery, catch and escapement of each species in the four statistical areas concerned.

(i) Chinook. Catches were fairly stable at around 70,000 pieces per year until the early 1960s (Table 1). Since 1962, landings increased steadily to a peak of 230,000 pieces in 1972 and started to decline sharply to a catch of 100,000 pieces in 1979. Trolling along shorelines and more open waters in Hecate Strait accounts for more than 70% of the total landings. Net catches are mostly incidental to fisheries targetting on other salmon species in more sheltered waters of Areas 4, 5, and 6. Increasing catches in Area 2E since 1969 and decreasing catches in Area 5 since 1972 are due to changes in trolling effort rather than changes in local production. Generally it is difficult to relate chinook catches (especially by troll gear) to local productions. For example, Fig. 1 shows very few or no chinook spawn in Areas 2E and 5, yet catches reached more than 40,000 pieces in some years for both areas. Ocean tagging in the early 1950s and coded wire tagging of juveniles in recent years have shown that chinook migrate over a wide range of areas during their life at sea and become vulnerable to fishing along the coast of Alaska, B.C., Washington and Oregon. Analysis of CWT data is underway and will provide clues as to the origins of chinook caught in the study area.

Spawning occurs in less than 50 streams and tributaries in Areas 4 and 5. Escapement in recent years has been declining in both areas and is believed to be due to a combination of habitat deterioration and overfishing by Alaska and local troll fisheries.

(ii) Coho. No significant trend is observed in coho landings from 1951 to 1979. Catches have been quite variable ranging from 160,000 to 1 million pieces (Table 1). Although very few net fisheries are directed at coho, more than half of the landings are caught incidentally to other salmon net fisheries. Trolling is still important in Areas 2E and 5 which contribute more than 80% and 65% of the landings in these areas, respectively (Fig. 2). It is generally believed that coho at sea range closer to their spawning streams than do chinook, but the origins of most troll-caught fish remain unknown.

Coho spawn in a wide variety of streams, creeks, tributaries and headwaters of many rivers. More than 70 streams in Area 2E, 75 streams in Area 4, 35 streams in Area 5 and 50 streams in Area 6 are known to have regular coho spawning populations. Because of their scattered geographical distribution, accurate escapement estimates are difficult to obtain. Estimates made by fishery officers showed a sharp decline of spawners since 1963 (especially in Areas 4 and 6) (Fig. 2) but the effect of lower escapement on recruitment is uncertain because of the difficulties in assigning troll-caught fish to their streams (or areas) of origin.

(iii) Chum. Catches were highly variable due to fluctuations in local abundances. Landings declined sharply in the 1950s due to overfishing. Stringent conservation measures in the early 1960s brought the stocks back to 1951 levels and catches fluctuated at around 600,000 fish until 1973 when a sharp decline occurred and catches remained at low levels up to the present (Fig. 3). Troll catches for this species are negligible and net catches more or less represent local abundances except in Area 5 where catches may include fish destined to spawn in adjacent areas. It has only been recognized recently that chums are the most unproductive salmon species in B.C. Optimal exploitation rates are estimated to be as low as 30% for some stocks. Escapements have been depleted severely in recent years especially in Areas 2E and 6 due to overfishing and mixed fishery problems with pink salmon.

(iv) Pinks. This is the most abundant species in the study area. Catches from 1951 to 1979 ranged from 600,000 to 8 million pieces. Even-year pinks are significantly more abundant than odd-year pinks especially in Areas 2E and 6. Landings in even years contribute from 17% to over 50% of the total B.C. pink catches with Area 6 contributing more than half of the pink catches in this area. Catches fluctuated at around 2.5 million fish in the 1950s, increased sharply to around 6 million in the 1960s, peaked at 8 million in 1972 and declined sharply to less than 3 million in the last few years. Odd-year pinks showed a steady decline from an average catch of 2 million pieces in the early 1960s to around 1 million in the 1970s (Fig. 4).

Trolling may produce more than half a million fish in years of exceptional abundances, otherwise troll catches are negligible. Little is known about the migration routes and fleet movement patterns especially among the islands in Areas 5 and 6. Escapements in each area have more or less paralleled catches although some of the large seine fisheries (especially in Areas 5 and 6) may intercept fish migrating to another area. Spawning takes place in more than 250 coastal streams and tributaries of large river systems around Hecate Strait.

(v) Sockeye. The Skeena River in Area 4 is the predominant sockeye producer in the study area. Catch, escapement and stock-recruitment dynamics have been described in detail by Shepard and Withler (1958), Ricker (1968) and Ricker and Smith (1975). Briefly, catches dropped drastically from over a million fish before 1955 to less than 200,000 in 1955 and the following years. The 1951 Babine River landslide effectively blocked most of the spawners from reaching the spawning grounds for 2 years. Recovery began slowly in the early 1960s, and together with the spawning channels built in the early 1970s, total stock sizes have recovered close to historical levels in the late 1970s (Fig. 5). However, the stock composition has changed predominantly to enhanced stocks while wild stocks (especially those lake systems other than the Babine) are being decimated. Traditionally, catches have been taken by gillnet fisheries close to the river mouth and troll catches are negligible. Catches in Areas 5 and 6 are mostly from local stocks which amount to less than 100,000 fish in most years.

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YEAR	COHO	SOCKEYE	PINK	CHUM	CHINOOK	TOTAL
51	565100	839100	1924700	917000	87700	4333600
52	437400	1445100	4651700	219700	123200	6877100
53	221700	827500	688300	379100	102100	2218700
54	351800	743700	1890900	842500	71700	3900600
55	345600	287000	2619200	147000	61900	3460700
56	459100	263300	2875700	239500	58500	3896100
57	362100	337800	2773300	380800	51600	3905600
58	314000	801700	2886000	426900	76800	4505400
59	261900	313800	1122600	70900	75300	1844500
60	291300	294400	1609600	185200	84500	2465000
61	351800	1059800	3061500	243600	59500	4776200
62	587300	688900	7783200	402100	102100	9563600
63	684100	303300	2814000	391200	114200	4306800
64	866600	1049100	4276100	945600	143400	7280800
65	727500	508400	1801500	300500	141400	3479300
66	1021600	788200	7666000	555200	144800	10175800
67	322200	1165600	590600	515700	140900	2735000
68	939600	928300	5728600	1021700	158100	8776300
69	233800	620300	586400	150400	139800	1730700
70	507300	769900	6137200	755100	129700	8299200
71	362100	950900	1352900	441200	152000	3259100
72	758900	853100	7985600	990200	227800	10815600
73	372000	1407000	1182000	709000	157000	3827000
74	328600	1458700	1251900	394800	165200	3599200
75	166000	540000	921000	54000	150000	1831000
76	372000	688000	2859000	89000	136000	4144000
77	191000	922000	2149000	325000	92000	3679000
78	374000	501000	3730000	443000	93000	5141000
79	256000	1340000	1517000	160000	100000	3373000

TABLE 1. CATCH IN PIECES BY SPECIES (AREA 2E,4,5,6)

YEAR	COHO	SOCKEYE	PINK	CHUM	CHINOOK	TOTAL
51	0.14	0.19	0.16	0.16	0.11	0.16
52	0.16	0.30	0.41	0.09	0.14	0.31
53	0.08	0.14	0.06	0.08	0.10	0.09
54	0.14	0.11	0.35	0.14	0.08	0.18
55	0.12	0.10	0.23	0.09	0.07	0.18
56	0.16	0.08	0.39	0.10	0.06	0.23
57	0.12	0.11	0.25	0.16	0.06	0.19
58	0.11	0.07	0.42	0.13	0.07	0.17
59	0.09	0.10	0.17	0.03	0.08	0.12
60	0.14	0.10	0.39	0.10	0.11	0.21
61	0.11	0.23	0.37	0.20	0.09	0.26
62	0.16	0.20	0.33	0.27	0.14	0.29
63	0.20	0.15	0.23	0.27	0.14	0.22
64	0.21	0.29	0.44	0.42	0.15	0.35
65	0.16	0.17	0.35	0.47	0.14	0.25
66	0.19	0.20	0.44	0.42	0.12	0.35
67	0.10	0.17	0.06	0.46	0.13	0.13
68	0.18	0.15	0.29	0.33	0.15	0.25
69	0.10	0.15	0.23	0.11	0.13	0.15
70	0.15	0.19	0.45	0.21	0.11	0.32
71	0.08	0.15	0.16	0.35	0.10	0.15
72	0.24	0.24	0.56	0.16	0.15	0.38
73	0.11	0.19	0.18	0.11	0.11	0.15
74	0.09	0.20	0.17	0.18	0.12	0.17
75	0.07	0.24	0.20	0.05	0.11	0.16
76	0.11	0.14	0.28	0.05	0.09	0.19
77	0.06	0.15	0.21	0.30	0.06	0.16
78	0.11	0.07	0.36	0.15	0.07	0.20
79	0.07	0.24	0.13	0.19	0.08	0.14
AVERAGE	0.13	0.17	0.29	0.20	0.11	0.21

TABLE 2. PROPORTION OF B.C. CATHCES LANDED IN THE STUDY AREA

YEAR	COHO	SOCKEYE	PINK	CHUM	CHINOOK	TOTAL
51	348808	372529	1162831	883575	26405	2794148
52	233279	556839	2798975	721475	24875	4335443
53	193010	849018	461650	387175	47825	1938678
54	272385	718676	946520	527570	55325	2520476
55	292885	174922	598250	146250	61525	1273832
56	477190	478201	1130781	209100	52200	2347472
57	271820	629490	1209725	337600	59675	2508310
58	275960	940513	1392775	430145	66600	3105993
59	174475	942767	1940734	75043	98950	3231969
60	197129	381615	1357228	359668	36652	2332292
61	307402	1093677	2541075	282687	28400	4253241
62	235172	759853	4817300	656125	50800	6519250
63	302034	931830	2677975	500033	65600	4477472
64	375934	996507	3496095	747430	45975	5661941
65	342305	750010	1967660	384580	40490	3485045
66	403205	580359	2741694	775657	57983	4558898
67	216511	748533	781082	634650	50415	2431191
68	300240	722193	3819808	720434	42925	5605600
69	202610	743829	1101315	267972	41262	2356988
70	236650	748125	2649335	320040	34825	3988975
71	172249	922375	1600642	453232	42175	3190673
72	182736	731626	3738512	506050	33405	5192329
73	139245	914383	1545290	536626	53220	3188764
74	114130	810946	1466701	425822	43376	2860975
75	146340	918872	2351845	172263	26254	3615574
76	146220	782897	2597513	234080	21308	3782018
77	133980	1002795	1222069	289953	34918	2683715
78	114997	461250	1842963	206453	30764	2656427
79	88700	1163240	1033435	105460	26422	2417257

TABLE 3. ESCAPEMENT IN PIECES BY SPECIES (AREA 2E,4,5,6)

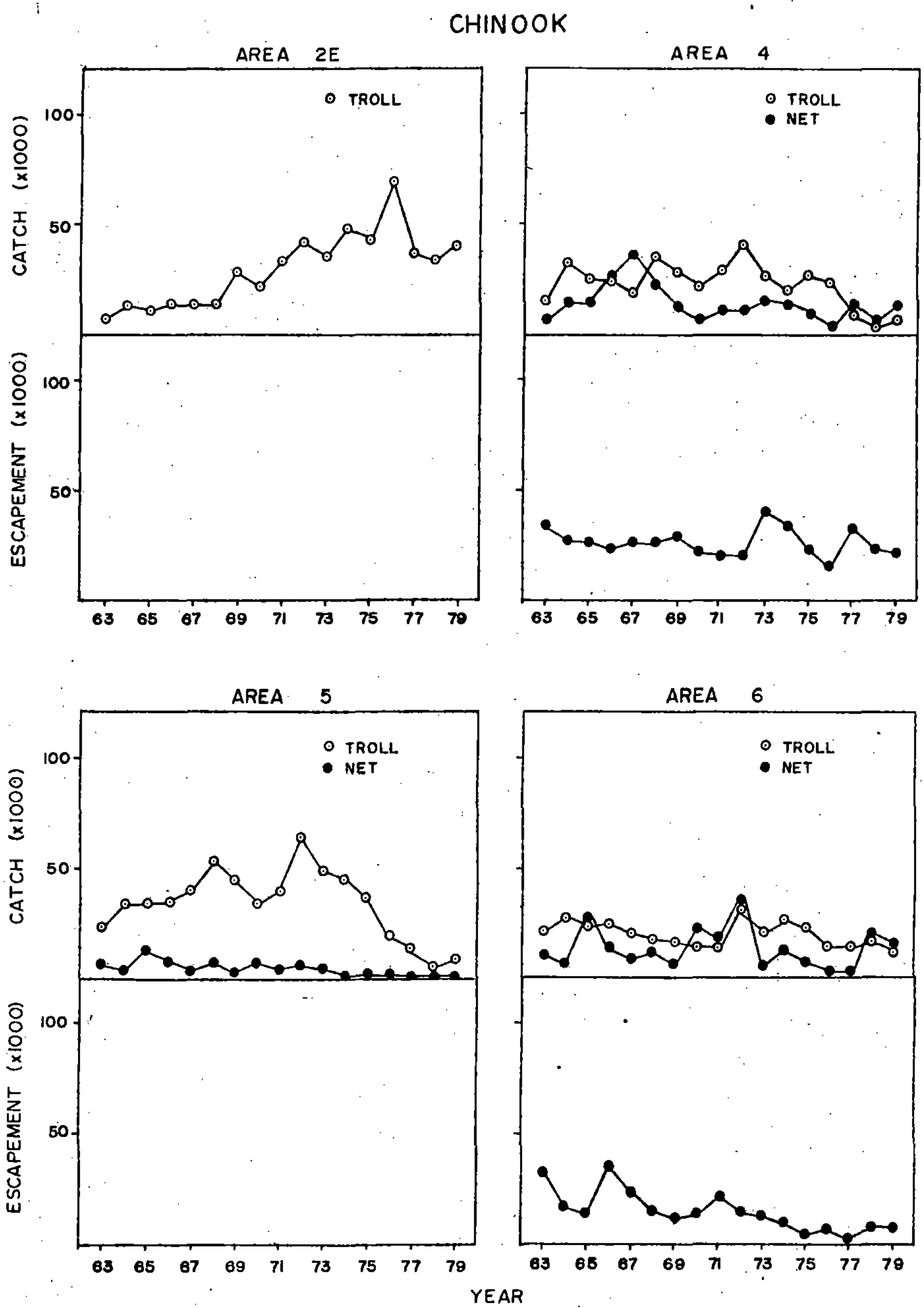

CHINOOK
AREA 2E
TROLL
AREA 4
TROLL
NET
AREA 5
TROLL
NET
AREA 6
TROLL
NET
CATCH (x1000)
ESCAPEMENT (x1000)
100
50
63
65
67
69
71
73
75
77
79
YEAR

FIG 1

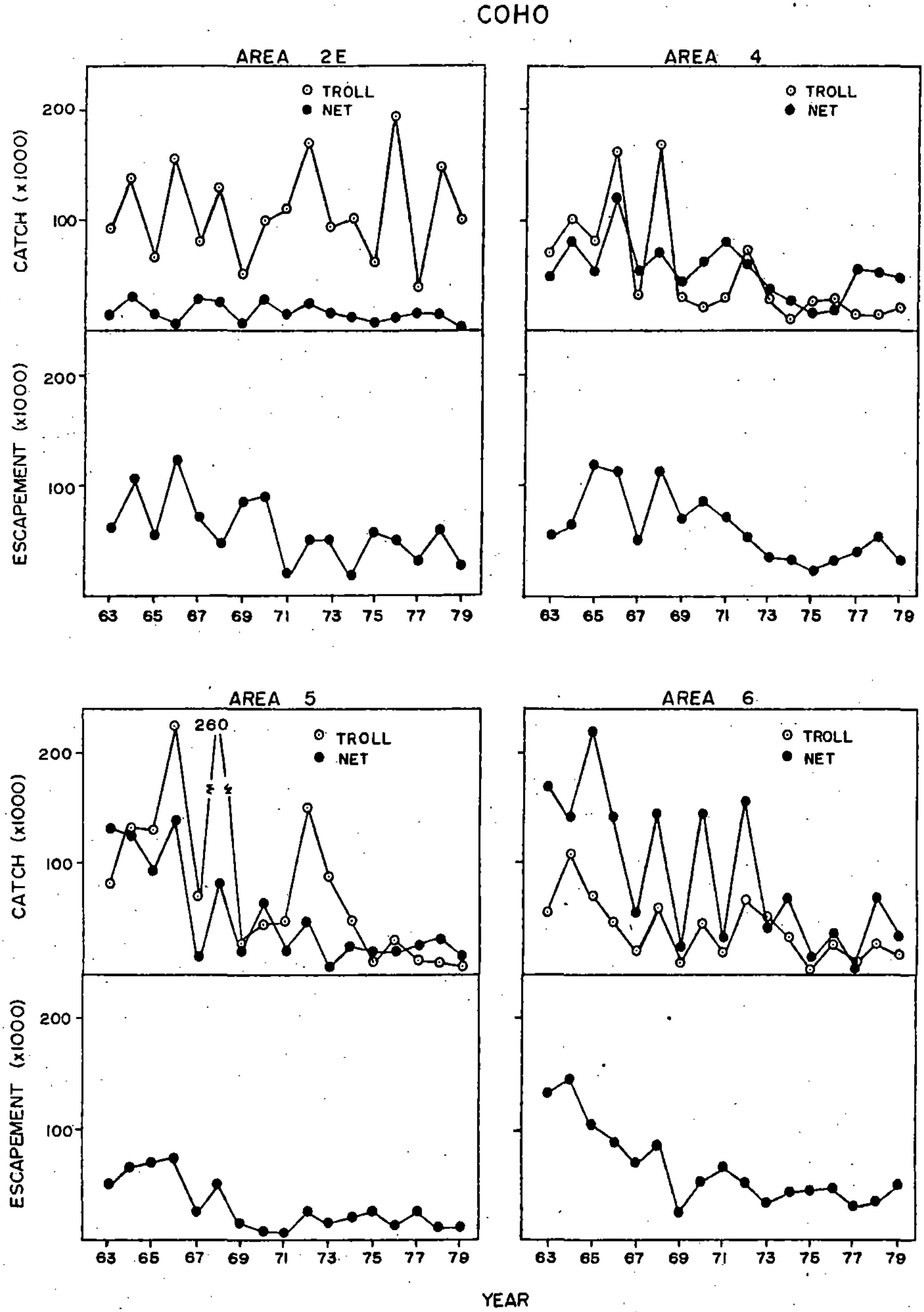

COHO
AREA 2E
AREA 4
AREA 5
AREA 6
TROLL
NET
260
CATCH (x1000)
ESCAPEMENT (x1000)
200
100
63
65
67
69
71
73
75
77
79
YEAR

FIG. 2

CHUM

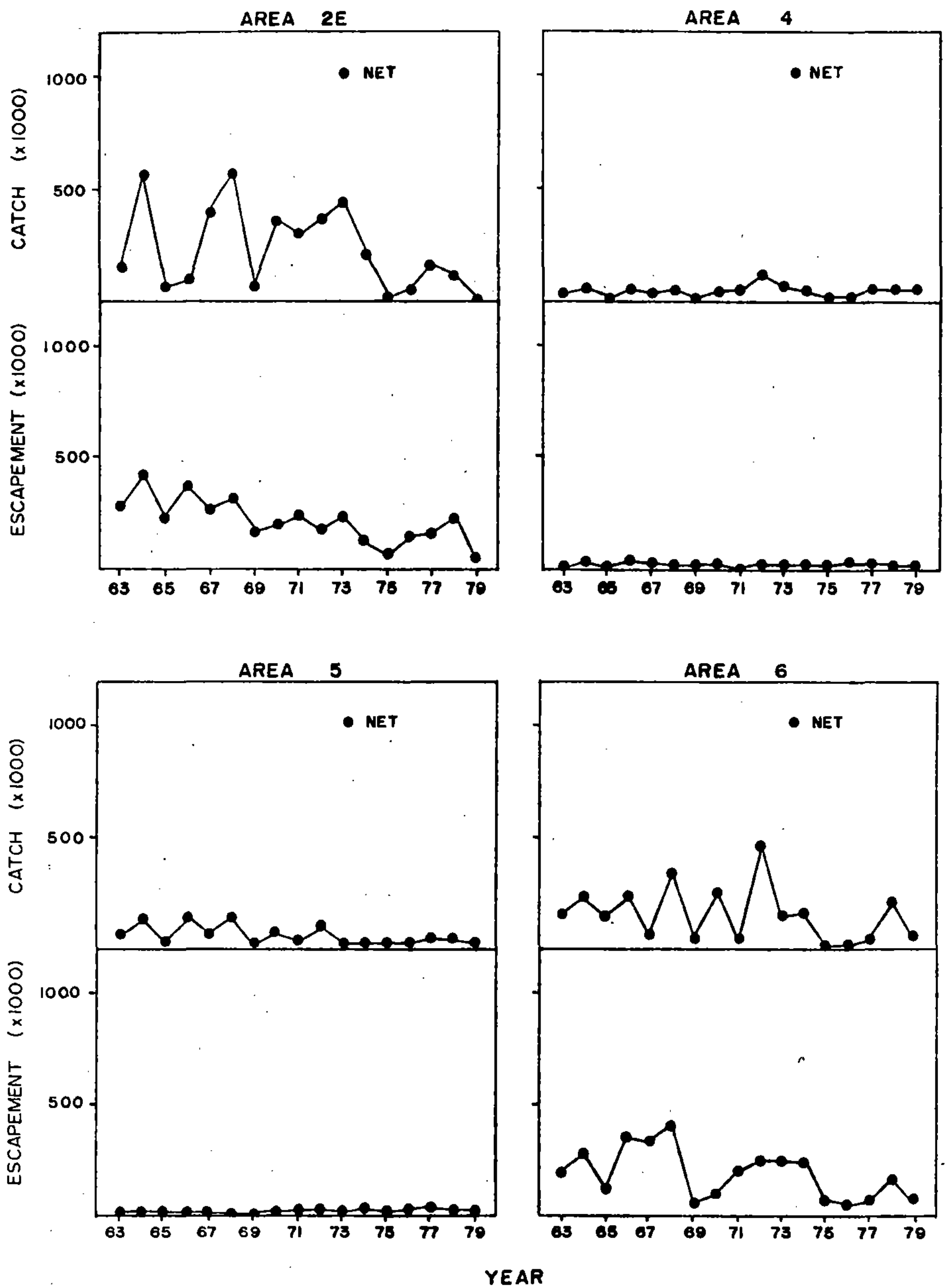
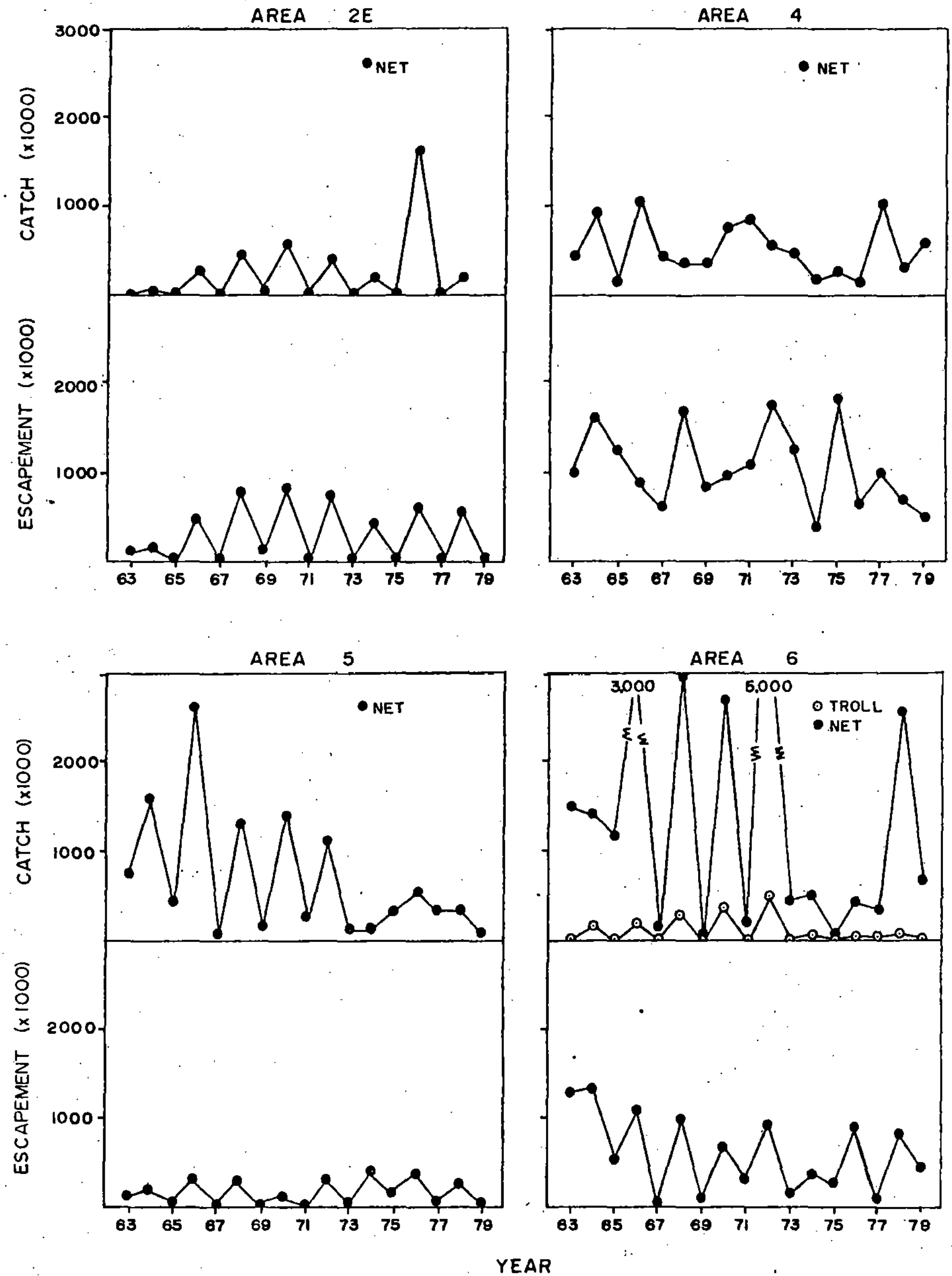

AREA 2E
AREA 4
AREA 5
AREA 6
NET
CATCH (x1000)
ESCAPEMENT (x1000)
1000
500
63
65
67
69
71
73
75
77
79
YEAR

Fig. 3

PINK



AREA 2E
AREA 4
AREA 5
AREA 6
NET
TROLL
3,000
5,000
CATCH (x1000)
ESCAPEMENT (x1000)
3000
2000
1000
63
65
67
69
71
73
75
77
79
YEAR

Fig. 4

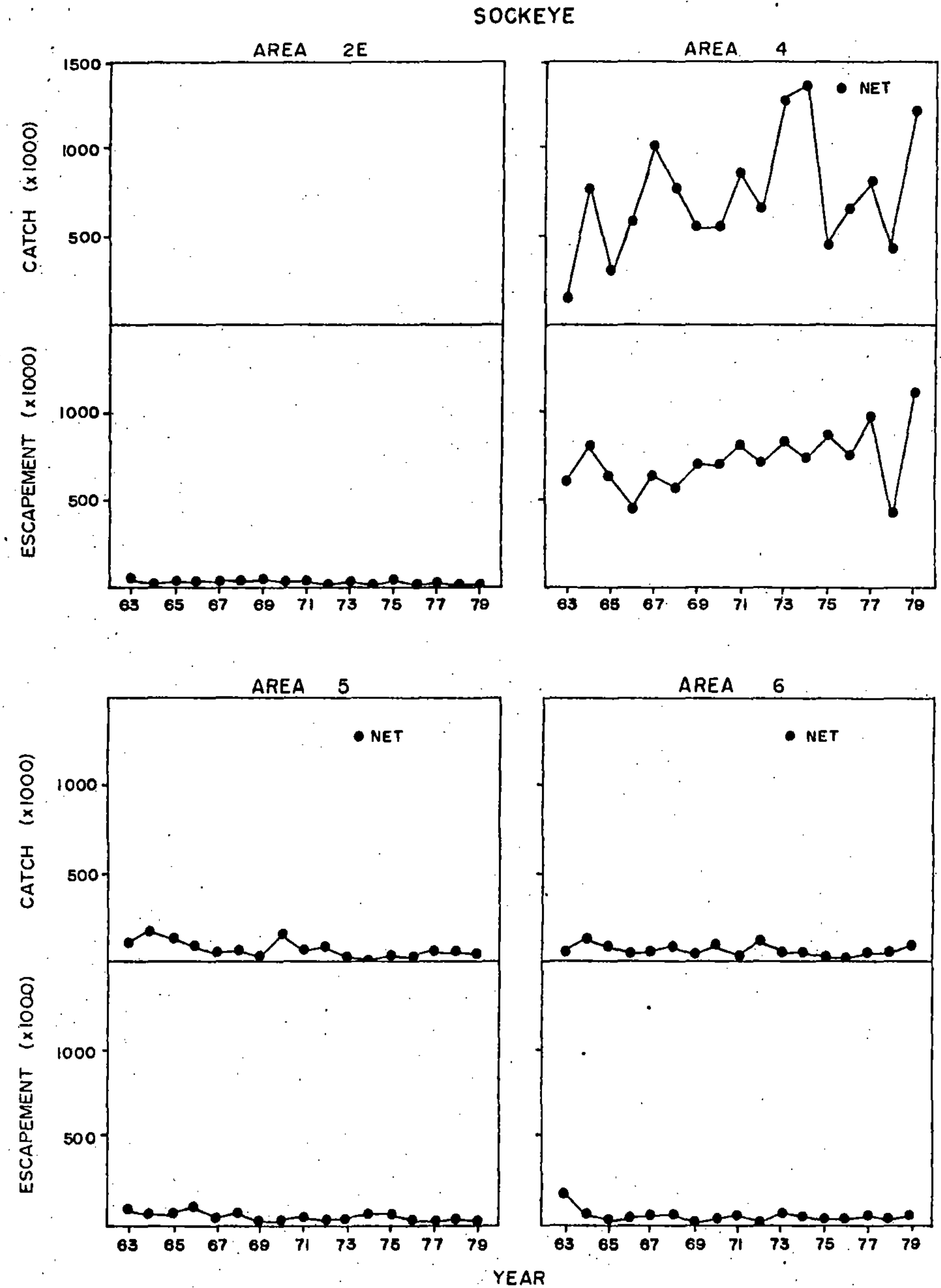

SOCKEYE
AREA 2E
AREA 4
AREA 5
AREA 6
NET
CATCH (x1000)
ESCAPEMENT (x1000)
1500
1000
500
63
65
67
69
71
73
75
77
79
YEAR

Fig. 5

Appendix C.

Juveniles

There have been no studies directed specifically at assessing the importance of Hecate Strait as a feeding area or migration route for juvenile salmon. Some information can be gleaned from observations made incidentally to other projects regarding time of entry into the Strait, period of residence, feeding, behaviour and growth.

The likely times and sizes at entry by sockeye, pink and chum juveniles can be inferred from observation of the departure times of seaward migrants from streams and coastal areas bordering Hecate Strait, Dixon Entrance and Queen Charlotte Sound (Manzer 1956, Manzer and Shepard 1962, Parker 1968, 1971). Information on growth, food habits and seasonal residence can be pieced together from observations by LeBrasseur and Parker (1964), Taylor (1970), Taylor et al. (1970a, b, c, d). Hart and Dell (1978) and the Fisheries Research Institute (1969). Other information, as yet unpublished, may be available from the Fisheries Research Institute (FRI) of the University of Washington.

We have been unable to find any information, except by inference from coastal studies, regarding the important question of the stock origins of young salmon in the Strait.

In the following sections we will attempt to construct, by species, as much as possible of the life history of juvenile salmon in Hecate Strait.

(i) Chinooks. We have been been unable to find any reference from which to infer the times at which chinook juveniles enter the Strait during their first year of sea life. It is possible that the time of entry is quite variable because the two juvenile life history types ("stream" and "ocean") are quite different in size at first entering salt water. Stream-type chinook juveniles spend one year in fresh water before going to sea and hence are larger, while the ocean-type spend only a few months in fresh water after emergence and are smaller.

The earliest recorded seasonal observation of abundant young chinook in the Strait is July 20 (in 1968) (FRI 1969). At that time 13 juveniles caught by purse seine, tagged and released off Browning Entrance averaged 21.5 cm. In 1969, in a herring trawl survey during the period September 15-October 1, several juvenile chinooks were caught in southern Hecate Strait (Taylor et al. 1970a). Seven ocean-type juveniles averaged 27.6 cm and 11 stream-type averaged 30.0 cm. Stomach contents consisted mainly of euphausiids and sandlance. (Ten immature chinooks that had spent one or more years at sea also were taken during this survey.) Similar trawl surveys carried out later in the winter of 1969-70 (Nov. 24-Dec. 10, Jan. 26-Feb. 10) produced no juvenile chinooks; an early spring survey from April 7-23 produced 5 juveniles which might have entered the Strait in the previous summer. They averaged 41.7 cm and were feeding on euphausiids, herring and sandlance (Taylor et al. 1970b, c, d). The lack of young chinooks in winter catches doesn't mean that they were absent during the winter - winter trawling usually was directed at deep, schooled targets identified by echo sounder.

(ii) Coho. The time of entry of juvenile coho into Hecate Strait in their first year of sea life is unknown. Parker (1968) found that coho accompanied and fed on pink fry as they migrated seaward along Burke Channel from the Bella Coola River. The pink fry, and presumably the coho smolts, arrived at the confluence of Burke and Fisher channels and Fitzhugh Sound (within the outer islands fringing Queen Charlotte Sound) about June 1. Hence it seems likely that many of the coho would have proceeded from among the islands into the Sound during June and early July. It is likely that a comparable migration schedule would apply to young coho entering Hecate Strait.

The earliest seasonal catches of abundant juvenile coho were made on July 20 and 21 (in 1968). Sixty-five coho in their first summer at sea were taken by purse seine, tagged, and released off Browning Entrance. Their average length was 22.9 cm. A purse seine set on August 8 in the same year produced 3 coho suitable for tagging whose average length was 30.7 cm (FRI 1969). The average length of 6 coho taken by herring trawl during September 15-October 1 in 1969 was 27.8 cm (Taylor et al. 1970a). No juvenile coho were caught in herring trawls during the winter and early spring of 1969-70, in hauls that were usually made in deep water and not directed at salmon.

(iii) Chums. Parker (1971) reports that Bella Coola chum fry entered coastal waters in company with pink fry from March to May with a peak in late April. Their length at that time was about 3.8 cm, which must approximate the size of young chums entering Hecate Strait coastal waters directly, as would be the case on the east coast of the Queen Charlotte Islands.

We have found no record of their sizes during the first 2 months at sea. Chums were present in Chatham Sound in 1955 from early June until the first half of July, by which time they were abundant in Beaver Pass. By early August, no chums were caught on the beaches of Chatham Sound and only a few were taken in Ogden Channel. By the end of August they were taken only in Caamano Pass, in eastern Dixon Entrance (Manzer 1956, Manzer and Shepard 1962). From the distribution of catches in and around Chatham Sound it appears that chums were leaving the Sound to enter Dixon Entrance and Hecate Strait from mid-June until early August. (In a parallel survey in Queen Charlotte Strait in the same year, the time of departure into Queen Charlotte Sound appeared to coincide roughly with that at Chatham Sound [Manzer 1956]).

In the Hecate Strait herring trawl survey from July 19-30, 1969 no juvenile chums were caught, although 6 young pinks were caught in the same period (Taylor 1970). FRI reports tagging 6 chum juveniles caught by purse seine off Browning Entrance on July 20 and 21, 1968. Their average length was 18.0 cm. A purse seine set on August 8, 1968, produced 4 chums whose average length at tagging was 20.3 cm (FRI 1969). During the herring trawl survey from September 15-October 1, 1969, fifty chum juveniles were taken in 10 hauls (28 contained none). They averaged 21.6 cm and had been feeding mainly on euphausiids. Catches were greatest in southwestern and north-eastern Hecate Strait. All were taken in surface hauls in the early morning or late evening (Taylor et al. 1970a).

In a series of 10 experimental trawl hauls in Hecate Strait, November 3-14, 1963 LeBrasseur and Barner (1964) report catching 142 age 0 chum salmon averaging 21.0 cm and weighing 85 g. The 2 largest catches were made in northern Hecate Strait in the vicinity of 53°54' × 130°53', west of Porcher Island. The stomach contents were mostly unidentifiable except for some squid remains. Most stomachs were empty in morning catches. Comparing catches from various depths and at different times suggested that the juveniles tended to be near surface during the night, sounding before dawn and rising after daybreak. During the day they appeared to remain at mid-depths (below pinks), rising to the surface at dusk.

Two chums were caught during the herring trawl survey of November 24-December 10, 1969, in southeast Hecate Strait. No chums were taken in the trawl surveys of January 26-February 10 and April 7-23, 1970 (Taylor et al. 1970 b, c, d). These surveys were directed mainly at deep targets.

(iv) Pinks. In a 1955 survey of juvenile salmon in Chatham Sound, pink fry were present on all beaches sampled during the first 2 weeks of June. Later in June fewer were caught along the outer ring of islands but some were taken over deep water outside Prescott Island. During July the numbers around the islands decreased further except in Beaver Pass. By mid-August young pinks were no longer available along the beaches; some were caught in Browning Entrance and Hecate Strait, one-half to 4 mi from land. In September some were caught in Dixon Entrance 6-12 mi southwest of Zayas Island. The pattern of catches in and around Chatham Sound suggests that pink juveniles were entering Dixon Entrance and Hecate Strait from late June until mid-August (Manzer 1956, Manzer and Shepard 1962). (In a similar survey in Queen Charlotte Strait, it appeared that pinks had left the Strait for Queen Charlotte Sound by mid-August.) During the period of residence in and around Chatham Sound, the juveniles fed heavily on copepods and Oikopleura (Manzer 1969). We have no record of the size of juveniles at the time of entry into Hecate Strait, but must assume that it would be variable because the period of leaving the coastal islands appears to quite protracted (Parker [1968] reports that Bella Coola pink fry entering the sea averaged 3.5 cm).

In 1968 two pinks were tagged from a purse seine set off Browning Entrance on July 21. They averaged 18.4 cm (FRI 1969). Six juveniles caught in the 1969 herring trawl survey in south central Hecate Strait on July 27 averaged 13.8 cm (Taylor 1970). Fifty-two juveniles tagged from a purse seine set off Browning Entrance on August 8, 1968, averaged 18.0 cm (FRI 1969). During the herring trawl survey from September 15-October 1, 1969, 131 pinks were caught in 13 hauls out of a total of 37 in the Strait. Their average length was 20.9 cm. Areas of concentration during this cruise were in southwestern Hecate Strait centred on 52°45' × 131°00', in west central

Hecate Strait off Banks Island, and in north central Hecate Strait off Browning Entrance. Almost all hauls containing pinks were surface tows made at dawn or dusk (Taylor et al. 1970a).

In 10 sets of an experimentaltrawl, made mostly in northeastern Hecate Strait, LeBrasseur and Barner report catching 241 pink juveniles from November 3-14, 1963. They measured 20.0 cm and weighed 67.8 g on average. They were caught most often at the surface both day and night. Stomach contents were greatest during the day, and all were full. One-third of the stomachs of those caught at night were empty. Food consisted of euphausiids, amphipods and copepods (one catch on the Horseshoe Grounds produced stomachs containing Limacina).

No pinks were caught in herring trawl surveys during the winter and early spring of 1969-70 (Taylor et al. 1970b, c, d).

(v) Sockeye. In the 1955 survey of juvenile salmon in Chatham Sound, sockeye were present in the Skeena River mouth and on the beaches in the first 2 weeks of June. Thereafter catches declined and none were taken after mid-July. Apparently the sockeye entered Dixon Entrance and Hecate Strait mainly during June and July (Manzer 1956, Manzer and Shepard 1962). (In the Queen Charlotte Strait survey of the same year, some sockeye were found over deep water as late as early September). During their stay in Chatham Sound the sockeye had fed on copepods, larvacea and some small fish.

Six sockeye tagged from seine sets off Browning Entrance on July 20 and 21, 1968, averaged 18.0 cm. In a later set (August 8) in the same area, 42 tagged juveniles averaged 19.9 cm (FRK 1969). The 1969 Hecate herring trawl survey from September 15-October 1 produced 10 juveniles whose average length was 19.5 cm. They had been feeding mostly on euphausiids (Taylor et al. 1970a). Six sockeye were caught in trawl tows between November 4 and 15, 1963 in northern Hecate Strait. Their sizes and stomach contents were not recorded (LeBrasseur and Barner 1964). Herring trawl surveys during the winter and early spring of 1969-70 produced no juvenile sockeye (Taylor et al. 1970b, c, d).

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1970c. The British Columbia offshore herring survey, 1969-70. Report on cruises SK70-1,-2, and-3. Fish. Res. Board Can. Tech. Rep. 190: 47 p.

1970d. The British Columbia offshore herring survey, 1969-70. Report on cruises SK70-4,-5,-6, and-7. Fish. Res. Board Can. Tech. Rep. 213: 75 p.

Appendix D.

Destinations of post-juvenile salmon in Hecate Strait

Most salmon taggings in and around Hecate Strait have not been directed exclusively at determining the origins of salmon in the Strait itself. Some have been carried out to assess the proportions of salmon in Canadian catches which had originated in either U.S. or Canadian waters, as in the Dixon Entrance-Hecate Strait taggings of the 1960's. Others were designed to determine the migration routes and times of passage of local stocks passing through fisheries adjacent to spawning rivers, e.g., the chum taggings among the islands on the east coast of Moresby Island (Dickson 1971, 1975) and those of sockeye and pinks in and around Chatham Sound (Aro and McDonald 1968). Other minor taggings of older salmon were made incidentally to catching and tagging of juveniles, as in those done by the Fisheries Research Institute in the 1960's for the International North Pacific Fisheries Commission.

For the purposes of this report we have identified only those taggings which were carried out in the open waters of the Strait, i.e. eastward of Graham Island and the islands off Moresby Island, and westward of the islands adjacent to the mainland of Areas 4, 5 and 6. These taggings are shown in Tables 1 to 6. The list of source references following Table 1 applies to all Tables 1 through 6.

Because fishing and stream recovery efforts vary from area to area and season to season the proportions of recoveries of tagged salmon in different fishing and spawning areas must be used with caution in assessing the abundances of various stocks in the Strait. They may however be used to assess the range of stocks from which the Hecate Strait populations are derived.

(i) Chinooks. Of the 558 chinooks tagged in the Strait, 56 have been recovered. As can be seen from Table 1, the recoveries range from S.E. Alaska through many B.C. fishing areas and as far south as Oregon (probably the Columbia River). The recoveries suggest that in their southward migration chinooks pass either to the eastward of Vancouver Island (Area 12) or westward (Areas 23-27) to the two major southern producers, the Fraser (Areas 28, 29) and Columbia rivers.

(ii) Coho. Of the 2005 coho tagged in Hecate Strait, 320 have been recovered (Table 2). The recoveries suggest a range of stock origins from S.E. Alaska to southern British Columbia, but most appear to originate from northern and central B.C. coast rivers (Areas 3-9). Their migration from the Strait to southern B.C. appears to favour the route through Johnstone Strait (Areas 12, 13) rather than the west coast of Vancouver Island (Areas 27, 23), although recoveries are too few to be certain.

(iii) Chums. Recoveries from the few chums tagged in Hecate Strait range from S.E. Alaska to southern Johnstone Strait (Area 13) (Table 3). Recoveries within B.C. have been confined mostly to northern and central B.C. fishing areas (Areas 3-7).

(iv) Even-year pinks. Of the 10,467 even-year pinks tagged in Hecate Strait, 3021 (29%) have been recovered over an area ranging from S.E. Alaska to southern B.C. (Table 4). A high proportion of the recoveries (774 or 26%) were made in S.E. Alaska, while the bulk of the remainder were made in northern and central B.C. coastal areas (Areas 3-9). The 26 recoveries in Area 12 suggest that some even-year pinks from Johnstone Strait stocks also approach their spawning grounds through Hecate Strait. (Even-year stocks in the Gulf of Georgia are minimal or absent.)

(v) Odd-year pinks. Few (48) odd-year pinks have been tagged in Hecate Strait (Table 5). The few recoveries (10) came from Areas 3 and 4 on the B.C. north coast and Areas 11, 12, 20 and Washington State to the south. The more southerly recoveries probably represent individuals from the abundant Gulf of Georgia (including Fraser River) and Puget Sound odd-year stocks.

The numbers tagged and recovered are insufficient to determine whether or not S.E. Alaska odd-year stocks are present in Hecate Strait.

(vi) Sockeye. Only a few sockeye have been tagged in Hecate Strait (Table 6). Of a total of 10 recoveries, one was recovered in S.E. Alaska, the others in northern and central coast fishing Areas (3-9).

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Table / . Summary of tagging and recovery of chinook salmon caught in Hecate Strait. Tagging sites include only those in the open waters of Hecate Strait (the outer portions of Areas 4, 5, 6 and 2E). PS = purse seine, LL = longline, TR = troll, FW = freshwater, M = marine.

	1930		1966[a]		1967[a]		1968[a]		1968[b]		1968[c]		1968[d]		Totals	
References	1		2,3,4,5		2,3,4,5,6		3,4,5,7		3,4,5,7		3,4,5,7		3,4,5,7			
Number tagged	182		12		98		148		9		104		5		558	
Capture gear	TR		PS		TR		TR		TR		TR		TR			
Number recovered	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M
Alaska		1		1	1							2			1	4
British Columbia																
- Area 3		1														1
- Area 4								1			1	1			1	2
- Area 5								3		1		1				5
- Area 6								2								2
- Area 7								1								1
- Area 9		1										1				2
- Area 12						2		2								4
- Area 23		1														1
- Area 24						2										2
- Area 25														1		1
- Area 26		1						1								2
- Area 27								1								1
- Area 28		1														1
- Area 29		1							1		2				3	1
Unknown												1				1
British Columbia Total	0	6	0	0	0	4	0	11	1	1	3	4	0	1	4	27
Washington	1	1			1							2			2	3
Columbia River	6					1	5				2				13	1
Oregon					1										1	
Total	7	8	0	1	3	5	5	11	1	1	5	8	0	1	21	35

[a] Vicinity of Browning Entrance.
[b] Western Hecate Strait (Area 2E).
[c] Northeastern Hecate Strait (Area 5).
[d] Southeastern Hecate Strait (Area 6).

Table 2 . Summary of tagging and recovery of coho salmon caught in Hecate Strait. Tagging sites include only those in the open waters of Hecate Strait (the outer portions of Areas 4, 5, 6 and 2E). PS = purse seine, LL = longline, TR = troll, FW = freshwater, M = marine.

	1930		1962		1966		1966[a]		1967[a]		1968[a]		1968[b]		1968[c]		1968[d]		Totals	
References	8		9,10		9,10		2,3,4,5		2,3,4,5,6		3,4,5,7		3,4,5,7		3,4,5,7		3,4,5,7			
Number tagged	540		1		5		47		169		521		222		434		66		2005	
Capture gear	TR		LL		LL		PS		TR		TR		TR		TR		TR			
Number recovered	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M
Alaska								1				5		5		4		2		16
British Columbia																				
- Area 1												3		1		3				7
- Area 2		1												2		2				5
- Area 3		3								1		11				11				26
- Area 4	2	2					6	3	1	7	1	11		3		6			13	32
- Area 5	1	9						6				24		9		28			1	76
- Area 6		2							1	1	2	25		7		27			3	62
- Area 7		2										10		3		10		1		26
- Area 8	1	7										12	1			11			2	30
- Area 9		3								1		1		2		2				9
- Area 10										2						1				3
- Area 11																1				1
- Area 12																5				5
- Area 13																2				2
- Area 18												1								1
- Area 23		1																		1
- Area 27														1						1
Unknown		2										2		2		2				8
British Columbia Total	4	32	0	0	0	0	6	9	2	12	3	100	1	30	3	111	0	1	19	295
Total	4	32	0	0	0	0	6	10	2	12	3	105	1	35	3	115	0	3	19	311

[a] Vicinity of Browning Entrance.

[b] Western Hecate Strait (Area 2E).

[c] Northeastern Hecate Strait (Area 5).

[d] Southeastern Hecate Strait (Area 6).

Table 3 . Summary of tagging and recovery of chum salmon caught in Hecate Strait. Tagging sites include only those in the open waters of Hecate Strait (the outer portions of Areas 4, 5, 6 and 2E). PS = purse seine, LL = longline, TR = troll, FW = freshwater, M = marine.

	1962		1966[a]		1967[b]		1967[a]		1968[a]		1968[c]		1968[d]		Totals	
References	9,10		2,3,4,5		9,10		2,3,4,5,6		3,4,5,7		3,4,5,7		10,11,12,13			
Number tagged	1		?		4		?		6		10		2		23+	
Capture gear	LL		PS		LL		TR		TR		TR		PS			
Number recovered	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M
Alaska				2						2				1		5
British Columbia																
- Area 1														1		1
- Area 3				2						1		1				4
- Area 4				1		1										2
- Area 5										1						1
- Area 7										1						1
- Area 13										1						1
B.C. Total	0	0	0	3	0	1	0	0	0	4	0	1	0	1	0	10
Total	0	0	0	5	0	1	0	0	0	6	0	1	0	2	0	15

[a] Vicinity of Browning Entrance.

[b] Southeastern Hecate Strait (INPFC Area W3052).

[c] Northeastern Hecate Strait (Area 5).

[d] INPFC Area 3552 only.

Table 4. Summary of tagging and recovery of even-year pink salmon caught in Hecate Strait. Tagging sites include only those in the open waters of Hecate Strait (the outer portions of Areas 4, 5, 6 and 2E). PS = purse seine, LL = longline, TR = troll, FW = freshwater, M = marine.

	1962		1966		1966[a]		1966[a]		1968[b]		1968[c]		1968[d]		1968[e]		Totals	
References	9,10		9,10		2,3,4,5		3,4,5,7		3,4,5,7		3,4,5,7		3,4,5,7		10,11,12,13			
Number tagged	30		128		602		3498		476		4577		1097		59		10,467	
Capture gear	LL		LL		PS		TR		TR		TR		TR		PS			
Number recovered	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M
Alaska		1	1	20		75		584		24		40	1	24		4	2	772
British Columbia																		
- Area 1				1				15		1		6		2		1		26
- Area 2								8				5		2				15
- Area 3		1			3	29		298		9		50		16		7	3	410
- Area 4				3	6	34	31	444		24	8	47	3	21		7	48	580
- Area 5				1		9		218		19		114		50				411
- Area 6				1		3	1	215		18	2	180	1	87			4	504
- Area 7		1				1		17		2		10		11				42
- Area 8		1				3	1	16		6		25	1	52			2	103
- Area 9								3		1		6		9				19
- Area 10												2		2				4
- Area 11												1		2				3
- Area 12				1				6		3	1	9		7			1	26
- Area 20										1		1						2
- Area 29												2						2
Unknown						1		27		2	1	6		5			1	41
B.C. Total	0	3	0	7	9	80	33	1267	0	86	12	464	5	266	0	15	59	2188
Total	0	4	1	27	9	155	33	1851	0	110	12	504	6	290	0	19	61	2960

[a] Vicinity of Browning Entrance.

[b] Western Hecate Strait (Area 2E).

[c] Northeastern Hecate Strait (Area 5).

[d] Southeastern Hecate Strait (Area 6).

[e] INPFC Area 3552.

Table 5 . Summary of tagging and recovery of odd-year pink salmon caught in Hecate Strait. Tagging sites include only those in the open waters of Hecate Strait (the outer portions of Areas 4, 5, 6 and 2E). PS = purse seine, LL = longline, TR = troll, FW = freshwater, M = marine.

	1967[a]		1967[b]		Totals	
References	9,10		2,3,4,5,6			
Number tagged	10		38		48	
Capture gear	LL		TR			
Number recovered	FW	M	FW	M	FW	M
British Columbia						
- Area 3				1		1
- Area 4				4		4
- Area 11		1				1
- Area 12		1		1		2
- Area 20		1				1
British Columbia Total	0	3	0	6	0	9
Washington		1				1
Total	0	4	0	6	0	10

[a] INPFC Area W3052.

[b] Vicinity of Browning Entrance.

Table 6 . Summary of tagging and recovery of sockeye salmon caught in Hecate Strait. Tagging sites include only those in the open waters of Hecate Strait (the outer portions of Areas 4, 5, 6 and 2E). PS = purse seine, LL = longline, TR = troll, FW = freshwater, M = marine.

	1966[a]		1966[b]		1967[c]		1967[b]		1968[b]		1968[d]		1968[e]		Totals	
References	9,10		2,3,4,5		9,10		2,3,4,5		3,4,5,7		3,4,5,7		10,11,12,13			
Number tagged	1		?		4		?		4		8		1		18+	
Capture gear	LL		PS		LL		TR		TR		TR		PS			
Number recovered	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M	FW	M
Alaska																1
British Columbia																
- Area 3				1												1
- Area 4				3		1										4
- Area 5				2												2
- Area 6				1												1
- Area 9				1												1
B.C. Total	0	0	0	8	0	1	0	0	0	0	0	0	0	0	0	9
Total	0	0	0	8	0	1	0	0	0	1	0	0	0	0	0	10

[a] INPFC Areas W3552 and W3052.

[b] Vicinity of Browning Entrance.

[c] INPFC Area W3052.

[d] Northeastern Hecate Strait (Area 5).

[e] INPFC Area W3552.

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Appendix E.

GROUNDFISH IN HECATE STRAIT

INTRODUCTION

Hecate Strait is the most productive region for groundfish in the waters of western Canada. Trawling accounts for most of the landings, but a modest setline fishery exists for halibut. Total all-species landings were 15,380 t in 1979 and 16,074 t in 1980. Principal species landed during 1979 and 1980 were Pacific cod (30.6 and 28.3%), Pacific ocean perch (1.7 and 12.9%), walleye pollock (11.7 and 6.8%), Pacific halibut (9.6 and 10.8%), Other rockfish (9.5 and 7.3%), and rock sole (8.5 and 6.1%) (Table 1). In addition to the species listed in Table 1, other groundfish species of some importance include: butter sole (Isopsetta isolepis); ratfish (Hydrolagus colliei); sandlance (Ammodytes hexapterus); and soupfin shark (Galeorhinus zyopterus). Butter sole and soupfin shark landings were appreciable in the 1940s, but demand has subsequently decreased substantially. Butter sole demand is low because of its low percent fillet yield. Soupfin shark were sought for their vitamin A-rich livers, a market which disappeared in the early 1950s due to the development of synthetic vitamin A. Ratfish are allegedly abundant in the Hecate Strait and represent a potential, but never realized, source of quality oil and human food. Sandlance is one of the two major forage species (the other is herring) in Hecate Strait for such important predators as Pacific cod, Pacific halibut, salmon and rock sole.

Following are capsule accounts of the more important groundfish species in Hecate Strait. An extensive bibliography has been prepared on 3 x 5 cards, but is not attached to this preliminary report.

Table 1. Total landings in round weight (t) of groundfish from Hecate Strait (Area 5C + 5D), by species, in 1979 and 1980.

Species		1979		1980	
Common name	Scientific name	(t)	%	(t)	%
Arrowtooth flounder	*Atheresthes stomias*	1,528	9.9	1,014	6.3
Dover sole	*Microstomus pacificus*	633	4.1	606	3.8
English sole	*Parophrys vetulus*	863	5.6	994	6.2
Pacific halibut	*Hippoglossus stenolepis*	1,480	9.6	1,730	10.8
Petrale sole	*Eopsetta jordani*	39	0.3	33	0.2
Rex sole	*Glyptocephalus zachirus*	190	1.2	123	0.8
Rock sole	*Lepidopsetta bilineata*	1,314	8.5	976	6.1
Starry flounder	*Platichthys stellatus*	277	1.8	79	0.5
Other flounders	-	4	T	23	0.1
Pacific ocean perch	*Sebastes alutus*	268	1.7	2,079	12.9
Other rockfish	*Sebastes* & *Sebastolobus* sp.	1,466	9.5	1,175	7.3
Lingcod	*Ophiodon elongatus*	159	1.0	246	1.5
Pacific cod	*Gadus macrocephalus*	4,700	30.6	4,555	28.3
Pacific hake	*Merluccius productus*	-	-	1	T
Sablefish	*Anoplopoma fimbria*	235	1.5	320	2.0
Walleye pollock	*Theragra chalcogramma*	1,804	11.7	1,085	6.8
Spiny dogfish	*Squalus acanthias*	108	0.7	405	2.5
Misc. species	-	149	1.0	230	1.4
Animal food	-	135	0.9	159	1.0
Reduction	-	27	0.2	242	1.5
Total		15,380	99.8	16,074	100.0
% trawl-caught		89		87	

Sources: See attached page

SOURCES OF STATISTICS

HALIBUT

INPFC. 1980. Annual Report 1979. International Pacific Halibut Commission. 43 p.

__________ 1981. Annual Report 1980. International Pacific Halibut Commission. 49 p.

Note. Statistics presented as net weight (eviscerated, head off). Converted to round weight with the formula: RW = 1.33 NW

OTHER GROUNDFISH SPECIES

Smith, J. E. 1980. Catch and effort statistics of the Canadian groundfish fishery on the Pacific Coast in 1979. Can. TEch. Rep. Fish. Aquat. Sci. 961: 90 p.

_____________ 1981. Catch and effort statistics of the Canadian groundfish fishery on the Pacific Coast in 1980. Can. Tech. Rep. Fish. Aquat. Sci. 1032: 90 p.

ARROWTOOTH FLOUNDER (*Atheresthes stomias*)

1. Bibliography:

   See attached.

2. Unpublished studies and/or work in progress:

   (a) Annual trawl survey to determine abundance of juveniles.

3. Description of fisheries:

   Trawl only. Landings variable (Trace-1,300 t/y during 1977-80), due to variable demand for mink food and relatively poor keeping quality of the fillets sold for human consumption. Abundant resource. Estimated biomass in June 1980 was 33,000-53,000 t. Since 1972 primarily a food fish. Importance could escalate with decline of other species (stocks).

4, Description of Biology:

   Spawning season "winter". Eggs and larvae pelagic. Growth is fairly rapid: 9 cm at age 1; 20 cm at age 2; 45 cm at age 8; 60 cm at age 14. Ubiquitous distribution by depth and area. Diet probably piscivorous.

5. Desirable research programs:

   (a) Distribution and abundance.
   (b) Life history.
   (c) Inter-species relationships.

BUTTER SOLE (*Isopsetta isolepis*)

1. Bibliography:

(see attached).

2. Unpublished studies and/or work in progress:

Nil.

3. Description of fisheries:

Trawl only. Landings small (0-600 t/y) due to low fillet yield and variable demand as mink food.

4. Description of biology:

Spawning season is March-April. Only known spawning area is Skidegate Inlet. Eggs are non-adhesive, transparent, spherical (diam. = 1.031 mm), and lack an oil globule. Specific gravity is 1.021, and are demersal in Skidegate Inlet. Growth rate varies with sex, region, season and year class. Females reach 30 cm FL at age 5 or 6, and males reach 30 cm at age 6 or 7. Oldest recorded female was age 11 (35 cm), and the oldest males were age 10 (34-39 cm). Diet includes worms, shrimp, sand dollars, and young herring. Size (age) stratified by depth, directly. Summer migration to shallow water; winter migration to deep water. Only mature fish migrate to spawning area in Skidegate Inlet.

5. Desirable research programs:

(a) Distribution and abundance.

DOVER SOLE (Microstomus pacificus)

1. Bibliography (see attached)

2. Unpublished studies, etc.:

Dover sole tagging experiment at Dundas area 1979. Recoveries to date include west coast of Queen Charlotte Islands (Jan.-Mar.) and S. Hecate Strait gullies (late summer).

3. Fishery:

Summer trawl fishery in Hecate Strait (Dundas-Two Peaks) produces ≈700-800 t annually (since 1970). Dover sole become unavailable to the trawl fleet during Dec.-April. Spawning migrations to deepwater (200-600 fm) have been documented off California and Oregon. Commercial landings primarily fish age 4-20 y.

4. Biology:

Spawning takes place from January-April with peak period in March in deepwater (200-600 fm). Dover sole eggs are non-adhesive and pelagic. The larval life of this species may be prolonged for periods as long as one year. This characteristic has important bearing on this species' distribution. Nursery areas have not been located in Hecate Strait, but juveniles (age 0-4) have not been found with adults on the main fishing grounds (Two Peaks-Dundas; 30-80 fm). Occasionally, juveniles are encountered during Hecate Strait trawl survey at depths of 10-20 fm. Adults are found, in summer, on mud bottom at depths 30-80 fm. Winter spawning concentrations occupy a depth range of 200-600 fm.

5. Desirable research:

Ichthyoplankton surveys of west coast Queen Charlottes, Queen Charlotte Sound and Hecate Strait (Feb.-April).

Oceanographic data collection for North Hecate Strait to relate to time of westward migration to deepwater spawning areas.

ENGLISH SOLE (*Parophrys vetulus*)

1. Bibliography (see attached).

2. Unpublished studies, etc.

Annual trawl survey to estimate abundance of juvenile age classes and their contribution to selected fisheries in terms of recruitment.

3. Fisheries.

Trawl fishery. Landings 500-1000 t annually. Level of recruitment has a major influence on English sole fishery production in Hecate Strait. Fishery supported mainly by age 4-10 fish (predominately females by weight).

4. Biology.

Spawning season prolonged between September-May with peak spawning February-April. Major spawning areas have not been located but probably encompass areas S.W. of Banks Island at depths >100 fm. Eggs are non-adhesive and pelagic. Larvae are probably pelagic for 6-10 weeks. Major nursery areas for English sole (age 1-3) occur in waters 10-20 fm adjacent to Graham Island.

Juveniles above age 3 are found in deeper water (≥40 fm) with the adults. Strong year-classes historically include: 1942, 1951, 1956, 1958, 1959, 1974, 1975 (based on commercial catch-at-age data).

5. Desirable research.

(a) Monitoring of oceanographic features in Hecate Strait such as temperature, currents, bottom characteristics.
(b) annual ichthyoplankton surveys of Hecate Strait with regard to this species.
(c) Inter-species relationships (juvenile English sole and dogfish on Dogfish Bank).
(d) Validate age determination methods.

PACIFIC HALIBUT (Hippoglossus stenolepis)

1. Bibliography:

(See attached).

2. Unpublished studies and/or work in progress:

(a) Estimating discard at sea by domestic trawlers.
(b) Improving age determination methods (in conjunction with IPHC).

3. Description of fisheries:

Setline only (by regulation). Research and management conducted through Canada-U.S. Convention, by International Pacific Halibut Commission. U.S. vessels excluded from Canadian 200-mile zone after 1978. Canadian vessels excluded from U.S. 200-mile zone after 1980. Canadian halibut landings from Hecate Strait were 1,113-1,301 t/y during 1978-80.

4. Description of biology:

Spawning season is November-January. Nearest spawning area is west coast of Queen Charlotte Islands. Fertilization is external, in 150-225 fm. Eggs large, spherical (3.0-3.5 mm diam.). Eggs and larvae pelagic, and generally drift northward at ca. 100 fm. Juveniles settle on bottom in shallow water. General migration to deeper water as they grow older. Recruitment age to setline fishery is 5-7. Most recruits to Hecate Strait are thought to have migrated from the Gulf of Alaska. Growth fairly rapid: 9 cm at age 1; 57 cm ag age 5; 91 cm at age 10, and 125 cm at age 15. Females grow faster than males. Females mature at age 8-16, and males much younger. Fecundity is 500,000-4,000,000 eggs/female.

5. Desirable research programs:

(a) Continue ongoing projects (see 2 above)

PETRALE SOLE (*Eopsetta jordani*)

1. Bibliography

(See attached).

2. Unpublished studies and/or work in progress:

Nil.

3. Description of fisheries:

Trawl only. Minor in Hecate Strait, except when favourable climatic conditions produces several consecutive abundant year classes. Centre of commercial abundance lies well south of British Columbia.

4. Description of biology:

Spawning season is late winter-early spring. Fertilziation external. Egg pelagic (diam. = 1.3 mm). Incubation period (in laboratory) is 8-9 days at 7° C. Growth moderate and differs by sex. Males reach 30 cm at age 3, 40 cm at age 7, and 50 cm at ca. 22+. Females reach 32 cm at age 3, 42 cm at age 7, and 60 cm at age 22. Fifty percent maturity level is 38 cm (age 7) for males and 44 cm (age 8) for females. Fecundity is 400,000 eggs at 42 cm and 1,200,000 eggs at 57 cm. Diet is variable, but most important items are sandlance, herring, euphausids, and shrimp. Migrations are extensive geographically and bathymetrically. Major spawning ground off West Vancouver Island located in 200-300 fm of water. Spring-summer residence of these fish is the continental shelf northward to Hecate Strait.

5. Desirable research programs:

Nil.

ROCK SOLE (Lepidopsetta bilineata)

1. Bibliography (see attached).

2. Unpublished studies, etc:

Annual trawl survey to estimate abundance of juvenile age classes and their contribution to selected fisheries in terms of recruitment.

3. Fisheries:

Trawl fishery. Landings 500-1000 t annually. Level of recruitment has a major influence on rock sole fishery production in Hecate Strait. Fishery supported mainly by age 4-9 fish.

4. Biology:

Main spawning season is March-April, but a fall spawning has been reported. Spawning area of Reef Island-Cumshewa important to rock sole production in middle Hecate Strait. Eggs are demersal and adhesive. Growth rate varies with sex and year-class. Rock sole spend 1-3 mo in the pelagic stage before settling out. Juveniles age 1 and above are found on or near the main grounds with the adults (15-35 fm). Strong year-classes historically include 1942, 1947, 1955, 1969 and 1974 (based on commercial catch-at-age).

5. Desirable research:

(a) monitoring of oceanographic features in Hecate Strait such as temperatures, current, etc.
(b) annual ichthyoplankton surveys of Hecate Strait with regard to this species.
(c) validate age determination.

PACIFIC OCEAN PERCH (Sebastes alutus)

1. Bibliography (see attached).

2. Unpublished studies:

A biomass survey of S. alutus in Moresby Gully, lower Hecate Strait was conducted in 1981. A study of the reproductive biology of this stock and others in Queen Charlotte Sound will be initiated in late 1982.

3. Fisheries:

A major fishery for S. alutus was established in Moresby Gully in 1980 when 2100 t were removed. This harvest increased to approximately 2300 t in 1981. The stock is characterized by a large component of older fish (>25 y) and is assumed to be at or near its virgin biomass level.

4. Biology:

If Hecate Strait S. alutus resembles stocks from further south in B. C., mating takes place in late fall or early winter. The release of the free-swimming larvae occurs from February to April as the adults reach the deepest point in their winter migration down the continental slope to depths of 275-450 m.

The larvae are assumed to be pelagic for a portion of their first year of life then adopt a benthic habitat.

S. alutus is characterized by: slow growth; a prolonged period of sexual immaturity (11-13 y); an even longer time to become fully recruited to the fishery (13-15 y); an extended life span in which an age of 50-60 y is not uncommon; and a natural mortality rate which is probably less than 5% per year.

5. Desirable research:

(a) additional biomass studies in Moresby Gully on 3-4 year intervals to follow stock dynamics.

ROCKFISH (Sebastes spp.)

1. Bibliography (see attached).

2. Unpublished studies:

None.

3. Fisheries:

The fishery for rockfishes in Hecate Strait has only attained significant landings in recent years (1975-1980). *Sebastes brevispinis*, *S. pinniger*, and *S. flavidus* have been the primary contributors towards a total production during this period of between 400 and 1250 t.

Landings of rockfish were traditionally incidental to those of other species, but since 1978 the effort directly targetting on rockfish has increased substantially. As a result, total allowable catches have been adjusted to permit development of the fishery under somewhat controlled conditions.

4. Biology:

The biological features of the rockfish species in Hecate Strait are not well known. The rockfishes, as with Pacific ocean perch, are characterised by: slow growth; a prolonged period of immaturity; delayed recruitment; and an extended life span.

As a group, rockfishes occupy a wide range of depths but as indivual species occupy more restricted ranges from intermediate depths on the continental shelf (70-150 m) to the upper continental slope (180-460 m). They are considered to be non-migratory although some species/stocks appear to undergo seasonal depth migrations.

Timing of spawning varies considerably among areas and species but the majority release their larvae sometime between January and May. To date, no nursery areas have been identified however juvenile rockfishes of several species have been found in some areas along the continental shelf and in certain bays and inlets.

5. Desirable research:

(a) An ichthyoplankton study in Hecate Strait to characterize the importance of the area as a nursery and to examine the potential of such a survey for recruitment prediction.
(b) A detailed oceanographic study of Hecate Strait and Moresby Gully.

PACIFIC COD (Gadus macrocephalus)

1. Bibliography:

(See attached)

2. Unpublished studies and/or work in progress:

(a) Stock assessment--ongoing project.
(b) Validate age determination methods
(c) Predict year-class abundance
(d) Determine cause(s) of fluctuations in year-class abundance.

3. Description of fisheries:

Trawl only. During 1950-80, annual Canada-U.S. landings have ranged from 1,000 to 9,000 t, without trend. U. S. landings were negligible after 1967. No other nation participates. Substantial fluctuations in abundance, which are currently thought to be due to natural causes, at least for the period prior to 1975.

4. Description of biology:

Spawning season January-March. Fertilization external. Egg is adhesive and demersal. Fry shoal close to bottom. Incubation is 17 days at 5°C. Growth is rapid and life is short. Mean length is 23 cm at age 1, 44 cm at age 2. Maximum length is about 94 cm and age 9. Most are mature at age 3, and all at age 4. Commercial landings are primarily ages 2-5. Fecundity is 1.2 million eggs at 60 cm; 3.3 million eggs at 78 cm. Negligible emigration from, or immigration to Hecate Strait, according to tagging experiments. Intra-regional migration variable with respect to size (age), year-class abundance, and ground.

5. Desirable research programs:

(a) Distribution and behaviour
(b) Predator-prey relationships
(c) Early life history

PACIFIC SANDLANCE (Ammodytes hexapterus)

1. Bibliography:

Nil.

2. Unpublished studies and/or work in progress:

(a) Incidence in stomachs of trawl-caught Pacific cod and rock sole landed in B. C.
(b) Compilation of bibliography on studies elsewhere.
(c) Diet of Rhinocerus Auklet chicks on Lucy Island (with Dr. K. Vermeer, Canadian Wildlife Service)

3. Description of fisheries:

Nil. Sandlance is important as prey for a number of marine animals, including whales, salmon, Pacific cod, lingcod, rock sole, and petrale sole. Year-class abundance is thought to fluctuate substantially.

4. Description of biology:

No taxonomic or biological studies have been undertaken in B. C. waters. In the East and West Atlantic Ocean and West Pacific Ocean, 2-3 species have been identified in each region. Life history similar to Pacific cod--rapid growth and short life. Spawning in winter. Fertilization external. Egg adhesive and demersal.

5. Desirable research programs:

(a) Taxonomy
(b) Distribution, abundance and behaviour
(c) Age determination and growth
(d) Life history
(e) Predator-prey relationships.

SABLEFISH (Anoplopoma fimbria)

1. Bibliography:

(See attached)

2. Unpublished studies and/or work in progress:

(a) Distribution, migration patterns and abundance of juvenile sablefish in Hecate Strait and Queen Charlotte Sound;
(b) Factors affecting larval survival and strong year classes of sablefish--Hecate Strait-Queen Charlotte Sound.

3. Description of fisheries:

None.

4. Description of biology:

Sablefish (Anoplopoma fimbria), often called blackcod, is a member of the skilfish family. It is found from northern Mexico along the continental shelf to the Bering Sea and to the northeast coast of Japan. The largest concentrations are found from Queen Charlotte Sound to the Shumagin Islands in the Aleutian chain.

Spawning occurs during December and January in offshore shelf areas at depths exceeding 400 m. Because eggs and larvae develop in midwater offshore areas, the success of a year-class depends on a number of biotic and abiotic oceanographic conditions. Hence, the fishery is supported by infrequent but very strong year-classes that occur only when conditions are favourable. The 1977 year-class for example, is extremely strong and is thought to be the result of anomolous oceanographic conditions, specifically strong onshore drift, that occurred in 1977.

During the spring and fall young-of-the-year move to inshore areas growing up to 25 cm that year. The juveniles remain inshore feeding on a host of organisms including herring, pollock, euphausids and shrimp. Hecate Strait is an important nursery area for.young sablefish.

Age and length at 50% maturity is 4-7 and 5 y, and 50 and 52 cm for males and females, respectively. Sablefish mature and undergo extensive migrations offshore where they become available to the fishery. The adults reside offshore at depths of 200-1000 m, although they have been found as deep as 2700 m. Sablefish average 24 years of age but 40-50 years of age is not uncommon. Females grow as large as 110 cm while fewer than 1% of males are larger than 70 cm. Sablefish are opportunistic feeders and the impact of feeding on other commercially important species is unknown.

5. Desirable research programs:

(a) Continue to monitor distribution and abundance of juvenile sablefish and determine impact of strong year-classes on other commercially important species;
(b) Early life history.

WALLEYE POLLOCK (<u>Theragra chalcogramma</u>)

1. <u>Bibliography</u>:

(See attached)

2. <u>Unpublished studies and/or work in progress</u>:

(a) Factors affecting recruitment of walleye pollock in Hecate Strait;
(b) Delineation of walleye pollock stocks in Dixon Entrance-Hecate Strait.

3. <u>Description of fisheries</u>:

Since 1976, roe and food fisheries for walleye pollock (<u>Theragra chalcogramma</u>) have developed in Hecate Strait. The food fishery, which began to grow in 1976, was the result of a Canadian demand for fish fillets. Landings occur through the second, third and fourth quarters of the year and are part of a multispecies bottom trawl fishery. The food fishery peaked in 1978 with 1178 t landed and has declined to 464 t landed in 1981 (see Table 1).

The roe fishery began experimentally in 1978 in an attempt to capture a portion of the substantial Japanese roe market. Landings occur through the first quarter of the year and are largely midwater trawl. The roe fishery peaked in 1979 with 712 t landed and has declined to 48 t landed in 1980 (see Table 1). This decline has been attributed to the decrease in average size, the high incidence of immature pollock and the decrease in the abundance and/or availability of adults.

4. <u>Description of biology</u>:

Spawning occurs just after the second week in February in Hecate Strait. Each female carries from 199,000 (at 32 cm) to 996,000 (at 49 cm) eggs and releases them midwater where they develop. Egg and larval surveys indicate that pollock larvae are present throughout Hecate Strait with the majority of spawning occurring on the northwest side, east of Dogfish Bank. It should be noted some spawn found in Hecate Strait is thought to originate in Dixon Entrance with the large migratory stock known to be present there during February-March.

Juveniles are found in midwater offshore areas of Hecate Strait and occasionally in shallow subtidal locations. The young tend not to school with older or younger age-groups or with fish of a different length. The growth of juveniles over the first two years is identical coastwide with pollock at 12 mo reaching 13-15 cm and at 24 mo reaching 32-33 cm. Rapid growth continues until the onset of spawning at 3-5 y at which time the fish are available to the fishery. Because of their midwater offshore habit, juveniles are often taken incidentally by trawl fisheries.

Adult walleye pollock are abundant in the midwater in northern Hecate Strait and Dixon Entrance. They experience a high rate of mortality (0.3-0.9 in Dixon Entrance) with the oldest individuals aged to date by fin ray techniques attaining 11 and 12 y or age, male and female, respectively. Females grow faster than males after age 3 and may reach a maximum of 64 cm while males may reach up to 61 cm. The diet of adult pollock is comprised of pelagic and semi-pelagic animals including euphausids, amphipods, shrimp, hake and pollock eggs, eulachon and sandlance. There is evidence of limited cannibalism. Pollock fall prey to dogfish, lingcod, hake, rockfish, lamprey, fur seals and a variety of sea birds.

5. <u>Desirable research programs</u>:

(a) Distribution and migration--in particular is the Dixon Entrance stock.
(b) Age validation.
(c) Predator-prey relationships.

RATFISH (*Hydrolagus colliei*)

1. Bibliography:

(see attached).

2. Published studies and/or work in progress:

Nil.

3. Description of fisheries:

Nil. Potential source of quality lubricant (liver oil) and vitamin A, and flesh for human consumption. Allegedly abundant in Hecate Strait. However, low reproduction rate strongly suggests low fishing rate for long-term sustainable yield.

4. Description of biology (No studies in Hecate Strait):

Fertilization internal. Eggs incubate externally in egg cases deposited on bottom. Egg-laying occurs year-round, but more common in later summer and early autumn. Incubation time unknown. "Birth" occurs at ca. 64 mm TL. Males mature at ca. 36 cm TL and females at 45 cm TL. Maximum size is ca. 97 cm. No method for age determination. Distribution ubiquitous, geographically and bathymetrically. Principal prey are clams, crabs and fish (including ratfish and flatfish). Principal predators are soupfin shark, Pacific halibut, and spiny dogfish.

5. Desirable research program:

(a) Distribution and behaviour.
(b) Predator-prey relationships.
(c) Life history.
(d) Age determination.

SOUPFIN SHARK (Galeorhinus zyopterus)

1. Bibliography:

(See attached).

2. Unpublished studies an/or work in progress:

Nil.

3. Description of fisheries:

None since 1949 due to collapse of liver (Vitamin A) fishery.

4. Description of biology:

Viviparous. 6-52 pups/female; ca. 35 cm at birth. Gestation about 12 months. Diet piscivorous--pilchard, anchovy, salmon, rockfish viviparous perch, and squid. Extensive seasonal migration--spring off southern California and summer-autumn in Hecate Strait. Males mature at 140-170 cm; females at 170-190 cm.

5. Desirable research programs:

Nil.

SPINY DOGFISH (Squalus acanthias)

1. Bibliography:

(See attached).

2. Unpublished studies and/or work in progress:

(a) Observations on the biology of spiny dogfish in Hecate Strait, August 1977 and June 1978--in prep.
(b) Food and feeding of spiny dogfish in Hecate Strait, August 1977 and June 1978--in prep.
(c) Age at first maturity.
(d) Age validation.
(e) Distribution.

3. Description of fisheries:

As the result of a high demand for Vitamin A extracted from dogfish livers, a coastwide fishery for dogfish existed from 1941 to 1950. A sunken gillnet fishery in Hecate Strait accounted for 22% of the total Canadian catch in 1944 and 30% in 1945 with the highest catch of 1.5 million lb landed in 1945. Intensive fishing over a four-year period resulted in a decline of roughly 75% with over 46 million lb harvested over the five-year history of the fishery. The decline was probably the combined result of fishing in Hecate Strait and fishing on the same stocks in southern areas at that point of their migration. The development of synthetic Vitamin A led to the sudden collapse of the fishery.

No commercial fishery for dogfish exists in Hecate Strait at the present time although incidental trawl catches of 3.78 and 23.71 t were landed in Areas 5C and 5D, respectively in 1981. Discards of dogfish in the same areas for the same time period amounted to 131.81 and 315.03 t, again respectively.

4. Description of biology:

The spiny dogfish (Squalus acanthias) is indigenous to north temperate waters of both the Atlantic and Pacific oceans. Preliminary tagging studies indicate that the stock present in Hecate Strait is part of a migratory stock ranging from Dixon Entrance to southern Oregon, excluding separate stocks found in Georgia Strait and Puget Sound.

Dogfish "pups" are born alive between October and January after a long gestation period of 20-22 mo. The newborn pups are 24-30 cm in length and feed on planktonic organisms. The juveniles grow relatively rapidly over the first five years to a length of 40 cm and until the age of 15 y they inhabit the upper layers of the water column, separate from the deeper dwelling adults. The length at maturity coastwide is 72 cm and 93.5 cm for males and females, respectively. Preliminary estimates of age at first maturity fall between 11 and 17 y of age for males and between 20 and 34 y of age for females.

The adult dogfish is an opportunistic feeder and, although considered a nuisance, no evidence exists to relate dogfish predation to the variation in stock size experienced by any other commercially important species. Dogfish live in excess of 60 y and attain lengths of 99 cm for males, and 124 cm for females. The offshore stock exhibits southerly movement in the fall and winter months and northerly movement in the spring and summer months.

5. Desirable research programs:

(a) Impact of dogfish predation on other (commercially important) species;
(b) Abundance estimates.

Appendix F.

HECATE STRAIT HERRING POPULATIONS

Herring populations in the Hecate Strait study area have been identified by tagging during the reduction fisheries. The tagging effort in Hecate Strait fluctuated widely between 1937 and 1954 as the emphasis of this coastwide program was directed at the more southerly populations. In 1957 and 1958 there was a major tagging effort in Hecate Strait and in 1964 there were major taggings in the Queen Charlotte Islands. Generally, fish were tagged near the spawning grounds in March and April and the tags were recovered during the winter (October to February) reduction fisheries. In later years there were some summer reduction fisheries (June to September) and there was summer tagging in 1957. Summaries of tagging results were published by Stevenson in 1954 and Taylor in 1964 and 1973. For the years 1936 to 1957, detailed results are found in the annual reports of the B.C. Fisheries Department. The year-round distribution of herring in Hecate Strait is documented for the period of July 1969 to April 1970 in cruise reports by Taylor (Technical Reports #174, 177, 183, 190, and 213). Fisheries Research Branch publications prior to 1977 have been summarized by Hourston (MS Rep. 1427).

Six populations were defined for Hecate Strait. The biological basis for some of the definitions are unclear and, from year to year, large fluctuations in discreteness are detailed in the annual reports. These are probably more a function of the time and place of the fisheries than changes in population integrity. Because the reduction seine fisheries were confined mostly to nearshore waters and inlets, there is little information on the migratory movements of these populations and there is no recorded information on the movement of pre-adults.

The populations (see Fig. 1) and what is know, or suspected, of their movements can be summarized as follows:

North Coast Queen Charlotte Islands population

This population occupies at, or near, spawning the north coast of Graham Island between Cape Knox and Rose Point with the boundaries extending northward to Dixon Entrance. The basis for this stock definition are not clear but it is probably based on the age composition of these fish, the geographically and temporarily isolated spawnings in Naden Harbour, and some tagging. Whether the stocks that spawn in Naden Harbour reside in Dixon Entrance during the summer is largely unknown but herring have been observed and fished in McIntryre Bay in summer and through to the late fall. Herring tagged on the north coast of the Charlottes have been reovered in the North Coast summer reduction fishery, suggesting that some of these fish move across Hecate Strait in the summer.

West Coast Queen Charlotte Islands population

Some very limited tagging provided evidence that herring that spawn in the major bays and inlets of the west coast of the Queen Charlottes between Flamingo Inlet and Cape Knox form a separate population. The migratory movements of these fish largely are unknown and tag recoveries have been mostly in the area of tagging. For some years, substantial recoveries were made from the lower east coast of the Charlottes winter reduction fishery, in the lower central coast winter fishery and in the north coast summer fishery. This would suggest that some of the fish belonging to this population migrate across Hecate Strait in the interval between spawning seasons.

Upper East Coast Queen Charlotte Islands population

This population consists mostly of the late spawners of Skidegate Inlet. There is some evidence that this is a non-migratory population, as opposed to the mostly migratory population of the lower east coast of the Charlottes. It is suspected that these fish are found during non-spawning periods in the main inlets of the central part of the Charlottes (Skidegate Inlet, Cumshewa Inlet and Laskuk Bay) and in Hecate Strait off the entrances to these inlets. There are consistent reports of large aggregations of 2-yr old fish in, and off, the entrance to Cumshewa Inlet throughout the year and these may be Skidegate Inlet spawners. There is also some evidence, from summer tagging, that some Skidegate Inlet spawners occupy the northern part of Hecate Strait in the summer.

Lower East Coast Queen Charlotte Islands population

This population comprises those fish spawning between Flamingo Inlet on the lower west coast of Moresby Island and Cumshewa Inlet. The center of the reduction fishery was Skincuttle Inlet and the lower portions of Juan Perez Sound. Fish tagged here during spawning have been recovered on the west coast of the Charlottes, the lower east coast of the Charlottes and the lower central coast winter reduction fisheries, and the north coast and upper central coast summer reduction fisheries. The fish in this population therefore appear to migrate across Hecate Strait to disperse along the mainland coastline as well as up the west coast of the Charlottes.

Northern (North Coast) population

Fish that presently spawn in Port Simpson and Big Bay and spawned up to the 1960's near Metlakatla and those that spawn on the shorelines of Porcher Island and the more southern portions of Area 5 (Principe Channel) form the Northern population. Fish that spawn north of Kitkatla Inlet appear to migrate to Browning Entrance while fish that spawn in Kitkatla Inlet and further south move to the upper and lower central coast during their migration. Fish that spawn in Port Simpson may also move north to Portland Inlet and into Dixon Entrance and northern Hecate Strait.

Upper Central population

The upper central population consists of both migratory and non-migratory stocks. Before the collapse of the reduction fishery, the non-migratory stocks were estimated to be of considerable magnitude but presently they are a small fraction of the total population.

The migratory fish exploited during the reduction fishery in Laredo and Caamano Sound spawned on the west shore of Princess Royal Island, with the center of spawning in and near Kitasu Bay. On their migratory movements these fish are thought to approach the upper central coast from or through Milbanke Sound. They appear to spend the summer in Queen Charlotte Sound and there may be considerable intermingling with the lower central coast population. There also appears to be considerable emigration, in some years, to the northern population.

The non-migratory stocks spawn in the mainland inlets of Area 6 and are also found there at other times of the year. Up to six non-migratory stocks have been described prior to their collapse in the 1960's. Whether all or part of these still exist is unknown. Taylor (1964) describes these non-migratory stocks in detail.

SPAWNING TIMES AND LOCATIONS

Pacific herring spawn at 14 major locations in Hecate Strait (Fig. 2). Information on the distribution and timing of herring spawning along the entire coast has been collected annually by Fisheries Officers since the early 1930's. The data summarized in Table 1 considers the 1942-79 period, and is more reliable than the earlier records which were limited to a few areas. In general, the median spawning time for herring in Hecate Strait occurs between April 4 to April 30. The two exceptions are Naden Harbour, which receives the earliest spawning, and Skidegate where spawning is late (averaging mid-May).

Herring usually spawn when the water temperature has warmed to 7-8°C. The incubation period is temperature dependent and averages between 10-15 days at normal temperatures. Little is known about the subsequent drift of the larvae in Hecate Strait during their early life history.

DISTRIBUTION

Figures 3-6 summarize the distribution of herring in Hecate Strait during mid-July 1969 to late April 1970 (technical reports 174, 177, 183, 190, 213). In general it seems that there are some areas where herring "hold" during the fall and winter months (if these fish behave like those in the Strait of Georgia the winter distribution can differ markedly from the summer distribution).

Sampling data indicate that offshore herring consist of a variety of age and size frequencies, including young-of-the-year fish (aged as 0+). It is interesting that the size and age can vary so much between catches made in the same general area at the same time (Table 2).

As a cautionary note the age designation system is not always consistent between reports. For example, the fish designated as age 0+ in

Table 2 represent fish in their first year of life and according to the convention currently used by RSB would be classified as age 1.

LANDINGS AND YEAR-CLASS STRENTH

Hourston (1980: RAPP. P.-U. REUN. CONS. INT. EXPLOR. MER. 177) has documented the history of the B.C. herring fishery. Briefly, the meal and oil reduction industry was introduced in 1935 and continued until 1967/68, when the fishery was closed early because the stocks showed symptoms of over-fishing. Only the traditional fisheries for local food and bait were permitted for the next 4 years. The roe fishery was introduced in 1971 and expanded over the next 7 years. This change in the nature of the fishery in Hecate Strait (see Fig. 7) is reflected in the landings which are summarized in Table 3.

Analysis of age composition data indicates that the 1951, 1958, 1961, 1968, and 1977 year-classes were strong.

CURRENT HERRING RESEARCH IN HECATE STRAIT

There are currently two research oriented studies in progress in Hecate Strait, one dealing with herring spawn and the other with stock identification.

Herring spawn research

Personnel of what is now the F.S.B. of the D.F.O. have conducted herring spawn surveys in Hecate Strait since 1950 for most major spawnings, and, in some areas, since the 1930's. The data from these surveys has been used as an index of the size of the spawning population. In the 1970's research activities dealing with herring spawn surveys were initiated at PBS.

The vegetation on major herring spawning grounds has been or will be mapped from aerial photographs for Cumshewa Inlet (year of photography - 1979), Skincuttle Inlet (year of scheduled photography - 1982), Chatham Sound (year of photography - 1980), and Kitkatla Inlet (year of photography - 1980).

Surveys were conducted and samples were collected by SCUBA divers on the east coast of the Queen Charlottes in 1981 and the central and north coast in 1977 to relate the number of eggs deposited to observable parameters.

Diving surveys of herring spawn to supplement F.S.B. conducted surveys were made on the north coast in 1979, 1980, and 1981, in the central coast in 1980 and on the east coast of the Queen Charlottes in 1981. For 1982 to 1984, diving surveys of spawn with sampling are planned for the north coast.

Stock identification by tagging

In 1980, a coastwide program for stock identification by tagging was initiated. In 1980 and 1981, herring were tagged at spawning in most of Hecate Strait and in 1980, herring were tagged in the late fall in Browning Entrance. Because of small fisheries, low tag returns, and cuts in funding, the tagging in the Queen Charlotte Islands and the central coast have been suspended. For 1982 to 1984, tagging is to continue for the north coast to examine the stock relationships of fish in the Browning Entrance food and bait fishery, the Kitkatla roe fishery, and the spawn-on-kelp and other ponding fisheries in the area.

Table 1. Location and timing (median time) of herring spawning at sites bordering on Hecate Strait. (From Hourston, A. S., 1980, Canadian Industry Report, Fish. and Aquat. Sci. No. 118.)

North coast			East coast Queen Charlotte Is.		
Location	Section	Median time	Location	Section	Median time
Port Simpson	33	Apr. 8	Skidegate Inlet	22	May 15
Big Bay	42	Apr. 5	Cumshewa Inlet	23	Apr. 28
Malacca Passage	43	Apr. 17	Laskeek Bay	24	Apr. 16
Edye Passage	44	Apr. 4	Skincuttle Inlet	25	Apr. 7
Kitkatla Channel	52	Apr. 10			
Anger Island	53	Apr. 30	Naden Harbour	12	Mar. 14
Foul Bay	54	Apr. 5			
Surf Inlet	66	Apr. 11			
Kitasu Bay	67	Apr. 4			

TABLE 2.

FRB TECH. REP. 213 (1970) pp 44 cruise: SK-70-5 APR. 7-23/70

Area of concentration		Set number SK-70-5-	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
			Age - years completed + additional growth											
Northern Hecate Strait	% age composition	3	-	-	41.89	32.84	21.69	1.96	1.42	0.13	0.03	0.03		
		4	-	-	12.92	44.57	27.95	7.63	5.57	0.86	0.35	0.16		
		17	-	-	2.66	44.69	25.42	14.92	8.47	1.86	0.99	0.88		0.10
		20	-	-	2.12	42.65	23.04	15.49	10.16	2.37	1.08	0.95	0.92	0.22
		21	-	-	2.82	40.25	22.68	16.29	10.63	2.93	1.31	2.63	0.36	0.10
		22	-	-	2.44	34.97	27.15	18.40	10.61	3.33	1.58	1.24	0.28	
	Average		-	-	10.81	40.00	24.66	12.62	7.81	1.91	0.89	0.98	0.26	0.07
	Average length		-	-	167.1	192.7	197.1	218.0	214.5	223.6	228.4	244.7	(257.4)	(259.0)
	Standard deviation		-	-	9.81	13.42	18.34	15.03	18.69	19.77	12.80	18.78	(18.14)	-
	Standard error		-	-	0.69	0.49	0.85	0.97	1.53	[illegible].28	3.12	4.36	(8.16)	-
Central Hecate Strait	% age composition	23	-	-	1.27	11.79	36.92	37.88	7.97	1.69	-	2.22	0.32	-
	Average length		-	-	(187.3)	209.0	222.3	230.3	242.3	(259.6)		(251.7)	(262.0)	
	Standard deviation				-	9.33	9.61	10.92	15.89	(15.22)		(8.28)	-	
	Standard error				-	1.53	0.89	1.09	3.36	(7.14)		(3.13)	-	

Table 3. Herring catch in Hecate Strait. Catch in short tons; year is 2nd year of season where season runs from July 1-June 30.

Year	Catch (tons)
51	55764.53
52	86699.22
53	2055.81
54	63647.82
55	45680.91
56	103891.30
57	67830.05
58	20840.97
59	32207.28
60	24595.71
61	59768.26
62	52144.63
63	88516.73
64	62491.06
65	97939.26
66	41349.79
67	13102.53
68	2861.35
69	789.60
70	368.82
71	5711.25
72	5412.63
73	8782.15
74	12147.07
75	11379.73
76	18389.11
77	15737.82
78	21083.05
79	13822.11
80	6898.60
81	11537.26

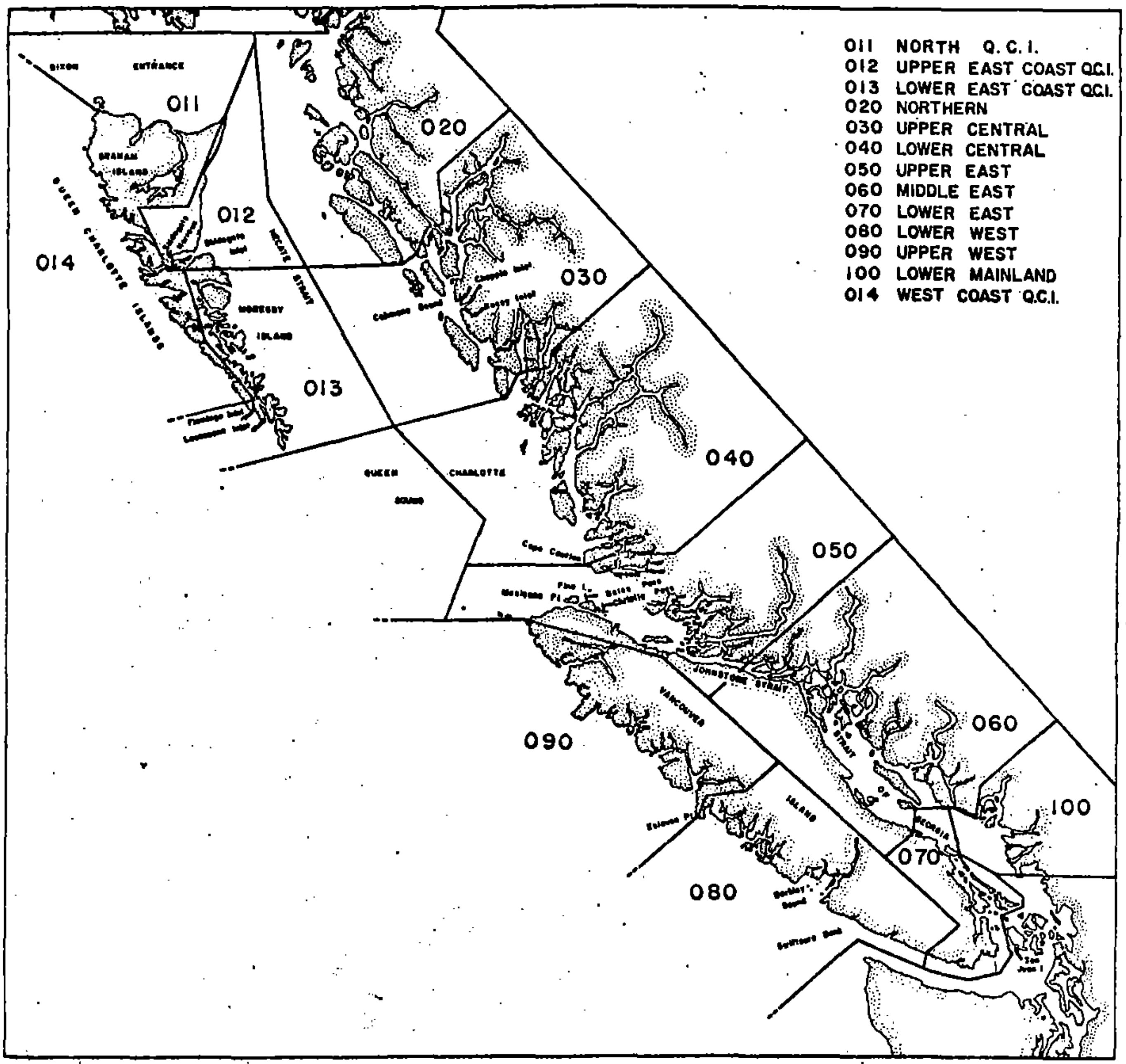

Fig. 1. The coast of British Columbia showing major herring populations by code number. (FROM TAYLOR, 1973).

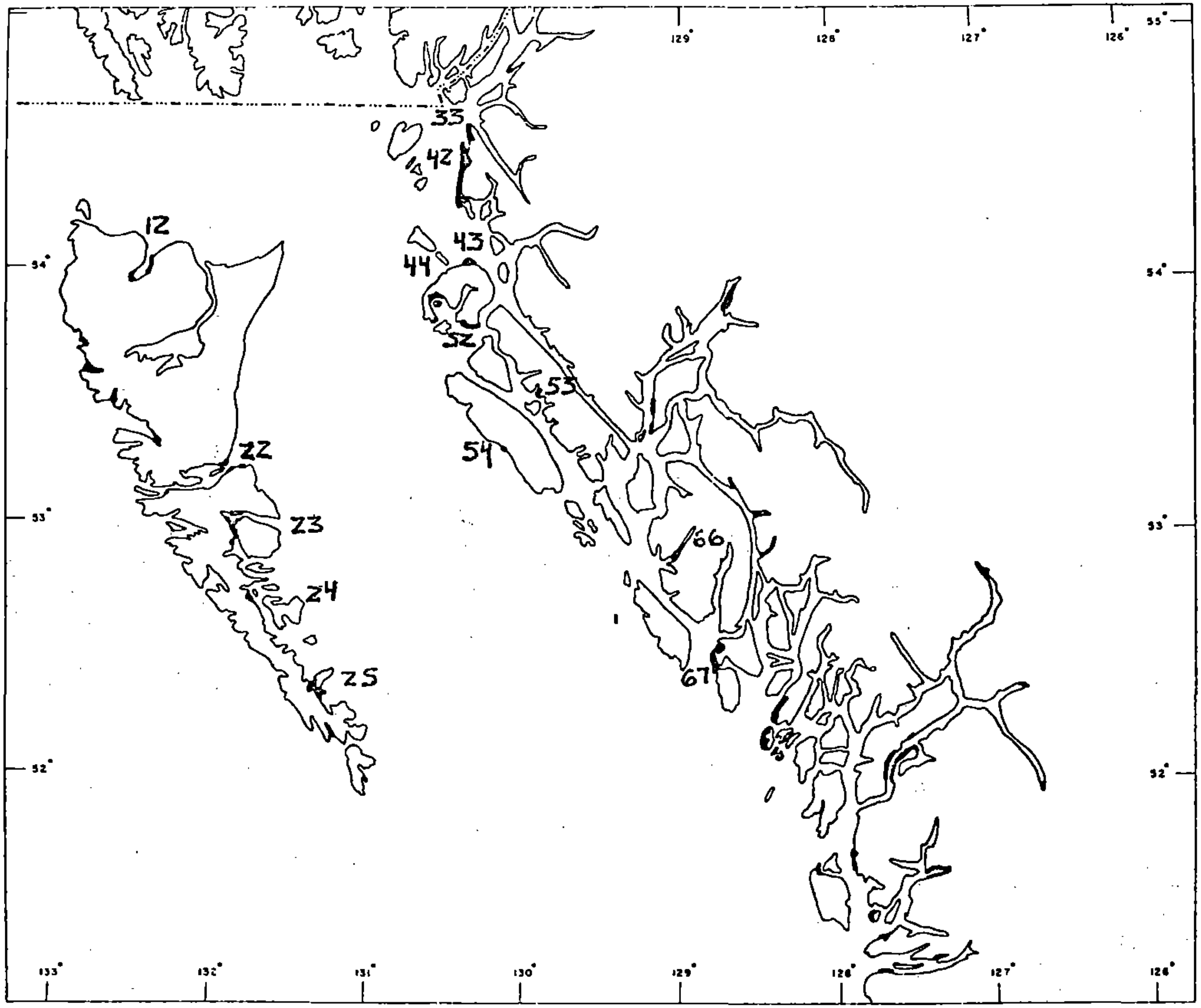

Fig. 2. Herring spawning grounds in northern British Columbia.

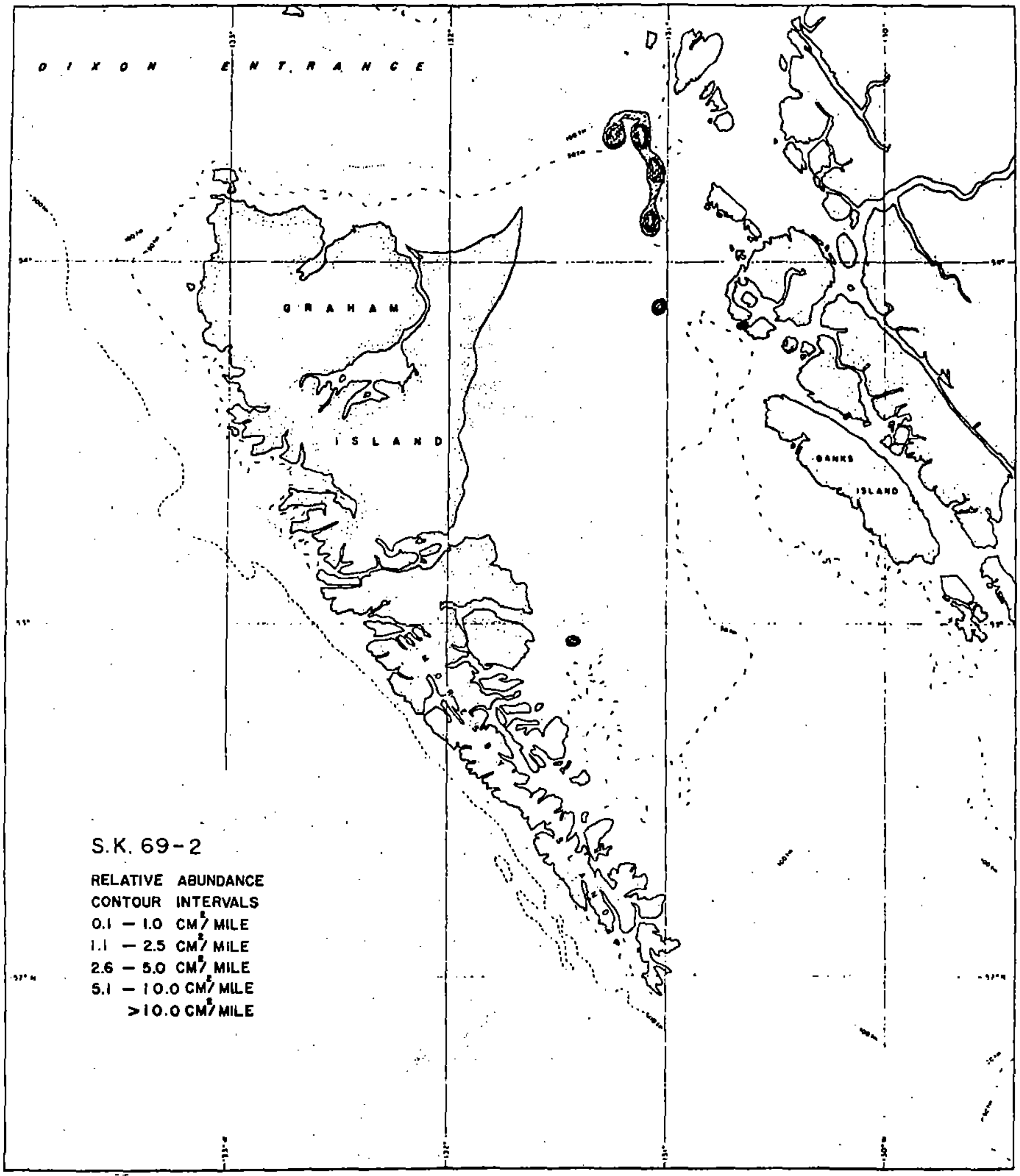

Fig. 8. Areas of concentration of herring, Cruise SK-69-2, Hecate Strait.

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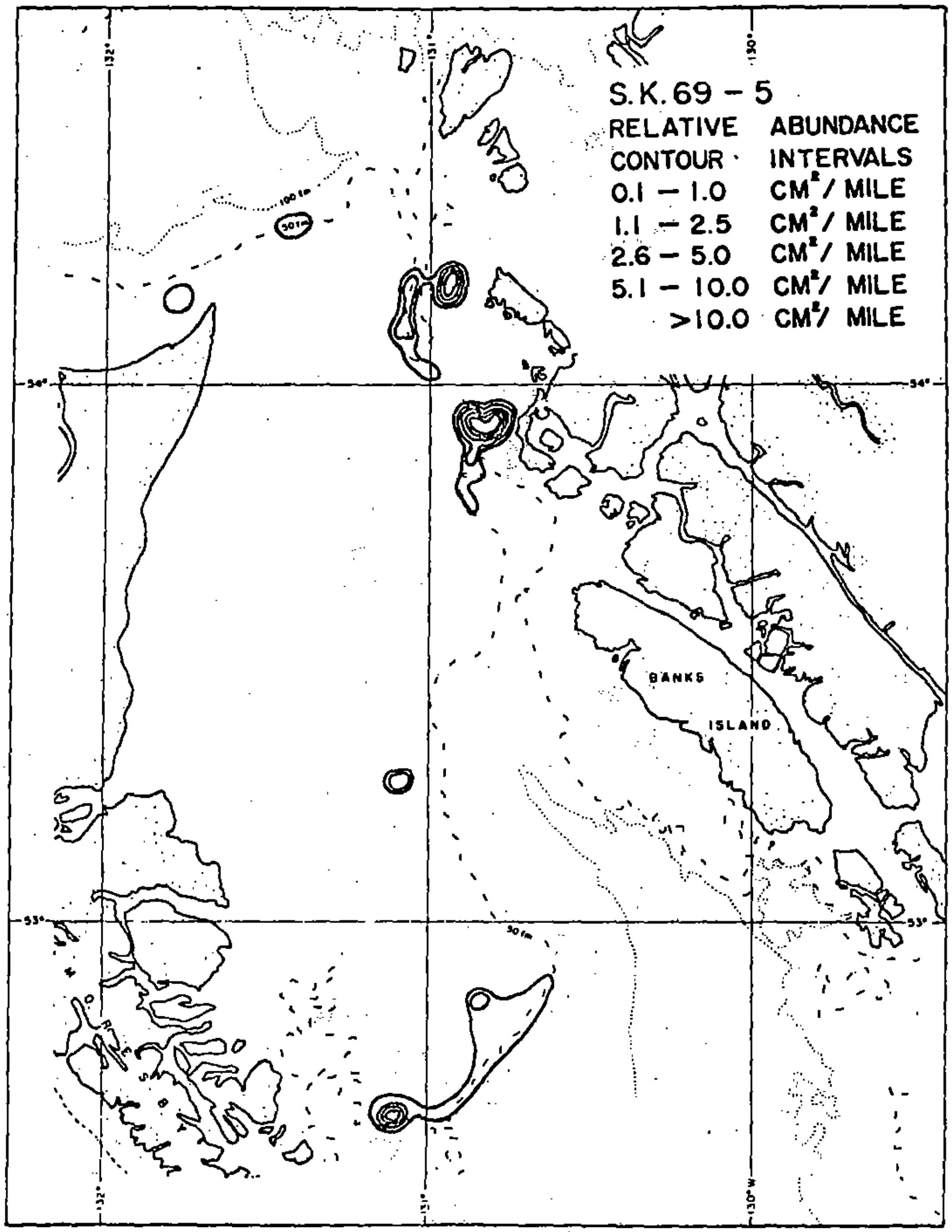


3b.
Fig. 8. Herring concentrations on Cruise SK 69-5, Hecate Strait, September 15-October 1, 1969.

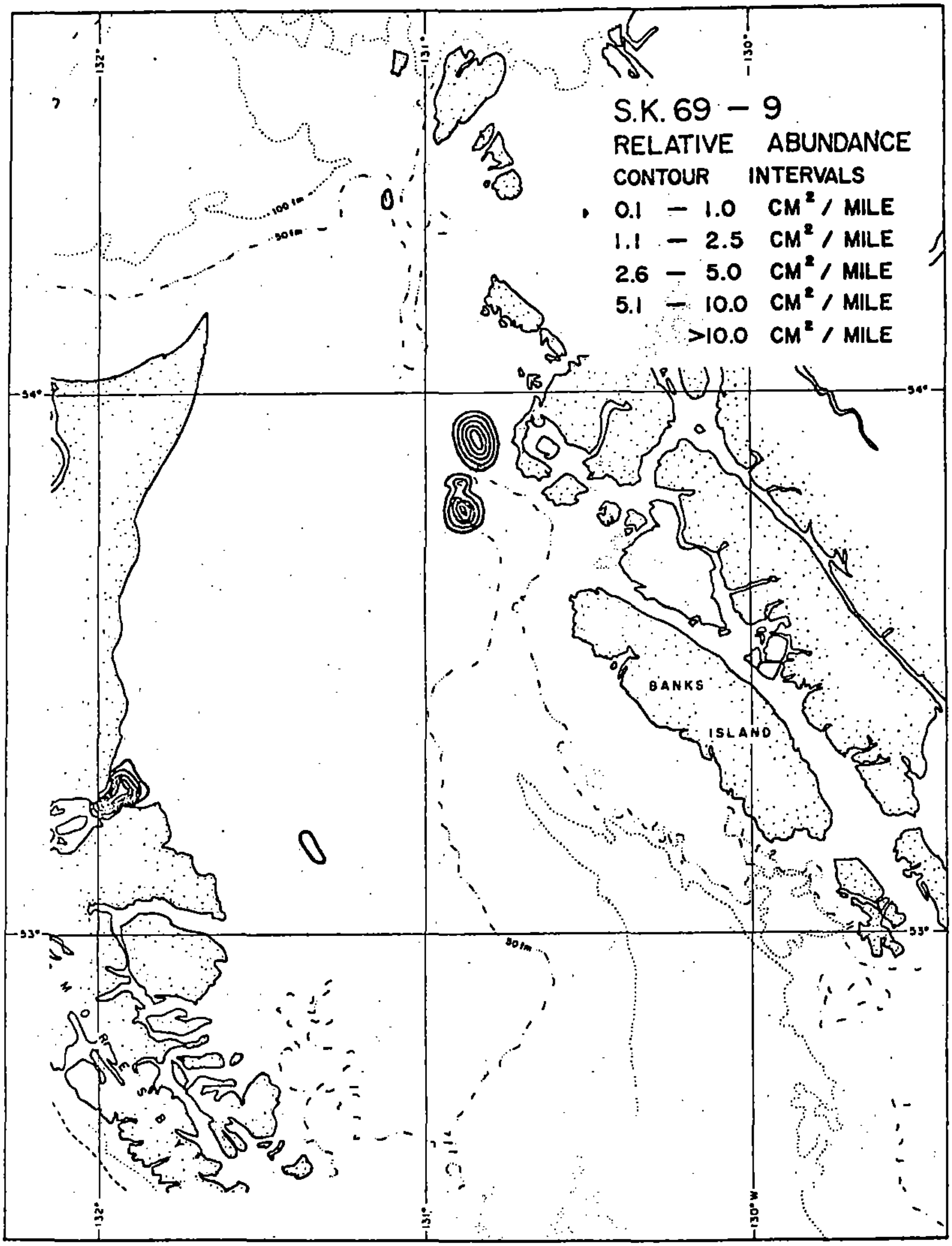


Fig. ~~8~~ 4. Herring concentrations on Cruise SK 69-9, Hecate Strait, November 24-December 10, 1969.

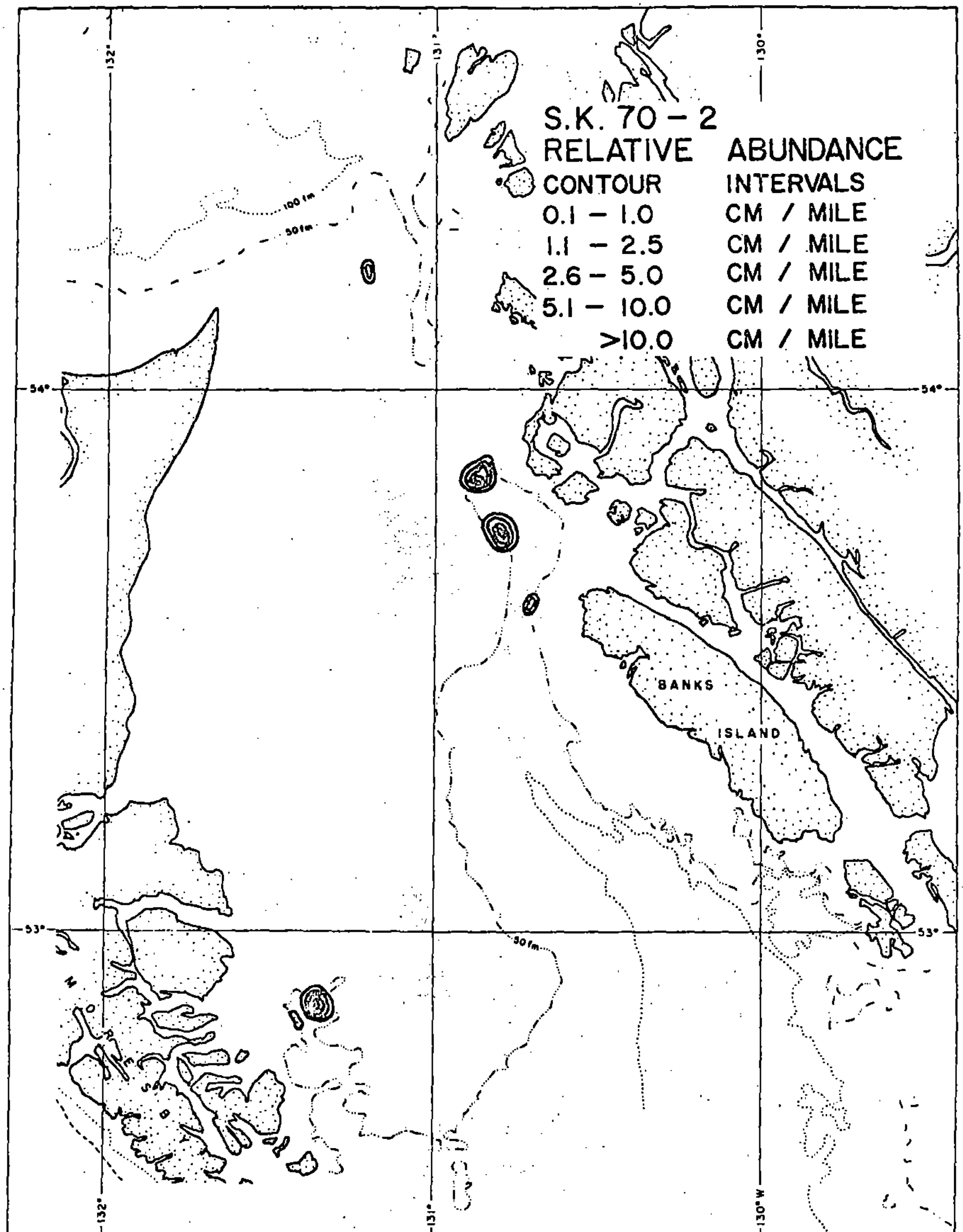


Fig. 8. Herring concentrations on Cruise SK 70-2, Hecate Strait, January 26-February 10, 1970.

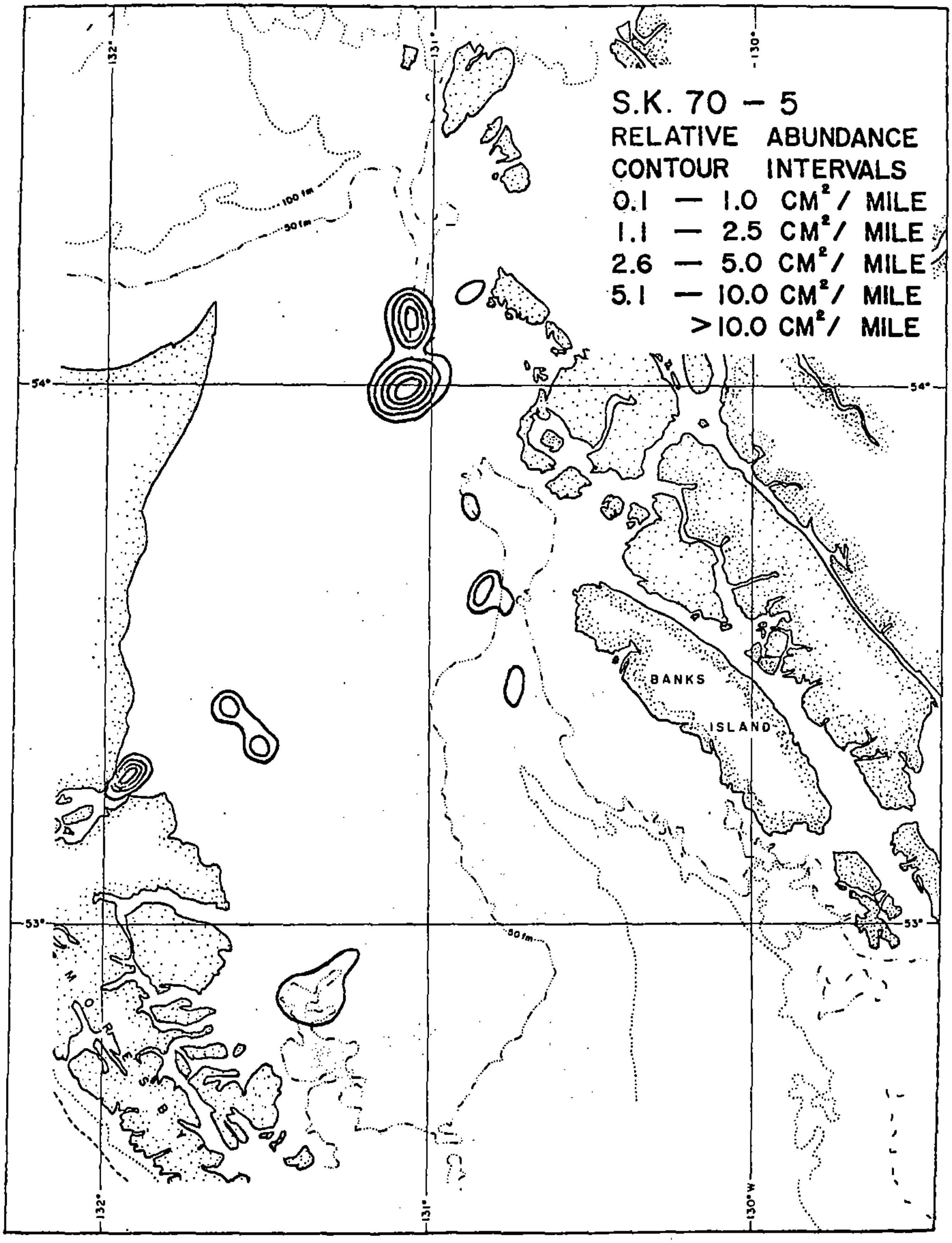
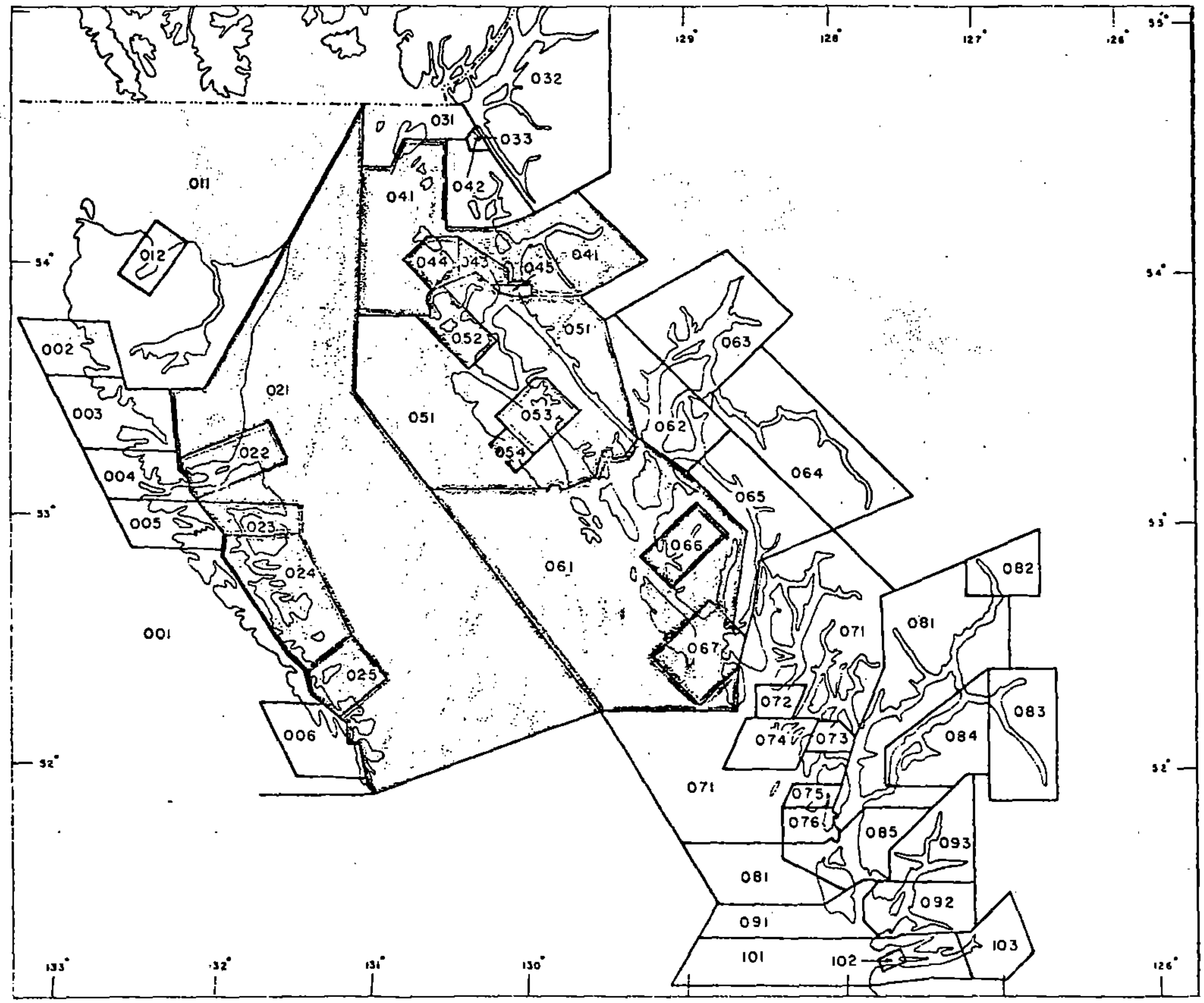


Fig. 11. Herring concentration on cruise SK 70-5, Hecate Strait, Apr. 7-23, 1970



-Area included in Hecate Strait catch is coloured in red.

Fig. 7. Herring sections in northern British Columbia.

Appendix G.

COMMERCIAL INVERTEBRATE POPULATIONS IN HECATE STRAIT

HISTORICAL PERSPECTIVE

The only long-term invertebrate fishery in Hecate Strait is for Dungeness crab (Fig. 1). There are no commercial trap or trawl fisheries for shrimp, and abalone have been extensively exploited in B.C. only since the mid-1970s. Other mollusc species in Hecate Strait are exploited only on a recreational or subsistence basis.

SPECIES CHARACTERISTICS

1. Crab

The crab fishery in Hecate Strait has been in a depressed state for the past decade. The cause remains unexplained. There has been no active research program in this area since the early 1970s, but earlier studies by Terry Butler (in preparation) provide a description of species' biology.

Mating occurs from May-September in the shallow water (9-27 m) east of Graham Island and eggs are extruded about October. The main location of berried females is unknown, but it is likely they move to deeper waters (36-90 m). Hatching occurs prior to mating in early spring, and the spatial distribution of larvae is also unknown. Moulting from the megalops to the juvenile crab stage occurs around September. Juvenile crabs are most abundant in shallow subtidal areas among vegetation and surface debris.

Yearling crabs remain close to shore but as they age, they move gradually to deeper waters. The preferred habitat is a firm sand bottom, especially on ridges. Maturity is reached at age 3 and they are recruited to the fishery at age 4.

Tagging studies indicate movement of juvenile and adult crabs from McIntyre Bay (Dixon Entrance) to Hecate Strait, with significantly less movement in the opposite direction. Factors affecting year-class strength are unknown, but above-average year-classes prior to 1965 were 1947, 1953, 1959, and 1962.

2. Shrimp

The only data base for shrimp stocks in Hecate Strait comesfrom a series of exploratory trap (5) and trawl (4) surveys, conducted mostly in the 1970s. Trap survey results were somewhat inconclusive because bad weather and lightweight gear made fishing difficult and possibly ineffective.

Trawl surveys indicated that, while most tows yielded small quantities of at least one commercial species, the potential for a commercial trawl fishery would probably be restricted to a low quantity, high quality fishery for sidestripe shrimp.

The trap surveys have resulted in a new, rapidly expanding trap fishery for prawns in the mainland inlets adjacent to Hecate Strait (areas 5 and 6). Inlets on the west coast of Hecate Strait have yet to be exploited, although their yield will likely be less because of their smaller size.

All shrimp are protandrous hermaphrodites, i.e. being mature males when young and mature females after age 3 or 4. Prawns are exploited with both traps and trawls, whereas other shrimp species are exploited solely with trawls. What constitutes a stock is not well defined, although each major inlet is generally managed separately.

3. Abalone

Populations of abalone have been surveyed on the east coast of Moresby Island in the late 1970s, and an extensive fishery is established on both sides of Hecate Strait (except off Graham Island). Abalone are found in moderately sheltered habitats but vary greatly in abundance between areas. Parameters influencing abundance are not well understood, and the contagious distribution makes it difficult to estimate total stock size. Growth has been measured in several tagging experiments and by population length-frequency analyses. Growth rate, unlike abundance, appears related to food availability.

Juvenile location and abundance is even less predictable in part due to suggested year-class variability. Abalone spawning may not occur every year, and larval and juvenile survival is site-specific.

4. Geoducs

Geoducs in Hecate Strait have not been studied, although an unpublished cursory resource survey of selected locations was undertaken in 1978 by the Marine Resources Branch. Major stocks are known to exist around the outer mainland islands of Queen Charlotte Sound (Area 7), and so it would seem likely that geoduc concentrations may occur in Hecate Strait as well.

Studies on southern stocks indicate that young geoducs grow quickly for their first decade, after which growth slows significantly. They become sexually mature at about age 4 and recruit to the fishery about age 6. Populations presently being exploited appear to have an average age of 30-50 yr with some individuals being > 150 years old. Recruitment rates are unknown. Maximum density is at about 20 m depth, and average densities in commercial beds are often about $10/m^2$. The species is very contagiously distributed.

The spatial and temporal distributions of larvae, and the timing of spawning have not been studied in B.C. Factors influencing recruitment are unknown.

5. Other clams

Information on intertidal clam distribution (mostly butter and littleneck) in the Principe Channel-Prince Rupert area and on some of the islands in Hecate Strait is presently being analyzed. Recruitment appears to have been relatively consistent on most beds surveyed, but because of extensive species distribution, overall year-class strengths for the whole region are difficult to determine.

FUTURE RESEARCH RECOMMENDATIONS

The study of the population dynamics of invertebrate species is made difficult by contagious distributions and limited species' mobility, which result in site-specific population parameters. The general lack of knowledge of the factors influencing reproduction and recruitment make it difficult to evaluate optimal levels of fishing and the impact of alternate management regimes. Acceptable stock recruitment models do not exist for most invertebrate species.

With shrimp and geoducs, significant undiscovered concentrations of commercial quantities likely exist, and so some exploratory activity by either research vessels or the private sector should be supported. With all species, studies of the distribution and biologies of the various life stages should be emphasized.

Specific research recommendations

Specific research recommendations include:

1. Re-establishment of population studies of recruited crab stocks

2. Characterization of the biology and fecundity of female crabs. Their relatively smaller size largely excludes them from the commercial crab fishery, and hence little data on them is routinely collected.

3. Determination of the importance of Hecate Strait to adult shrimp stocks in adjacent inlets. This might initially be achieved by studying larval distribution patterns, as this stage is passively affected by water currents.

4. Evaluation of the regional effects of alternate management strategies (e.g. closed refuges, effort limitations, variable size restrictions) on abalone abundance and recruitment.

5. Determination of the impact of harvesting on juvenile geoduc survival in north coast environments.

6. Evaluation of geoducs as a tool to indicate the frequency of significant environmental events. Their longevity and the presence of annual growth rings may allow some characterization of the environmental conditions which favour exceptional year-classes.

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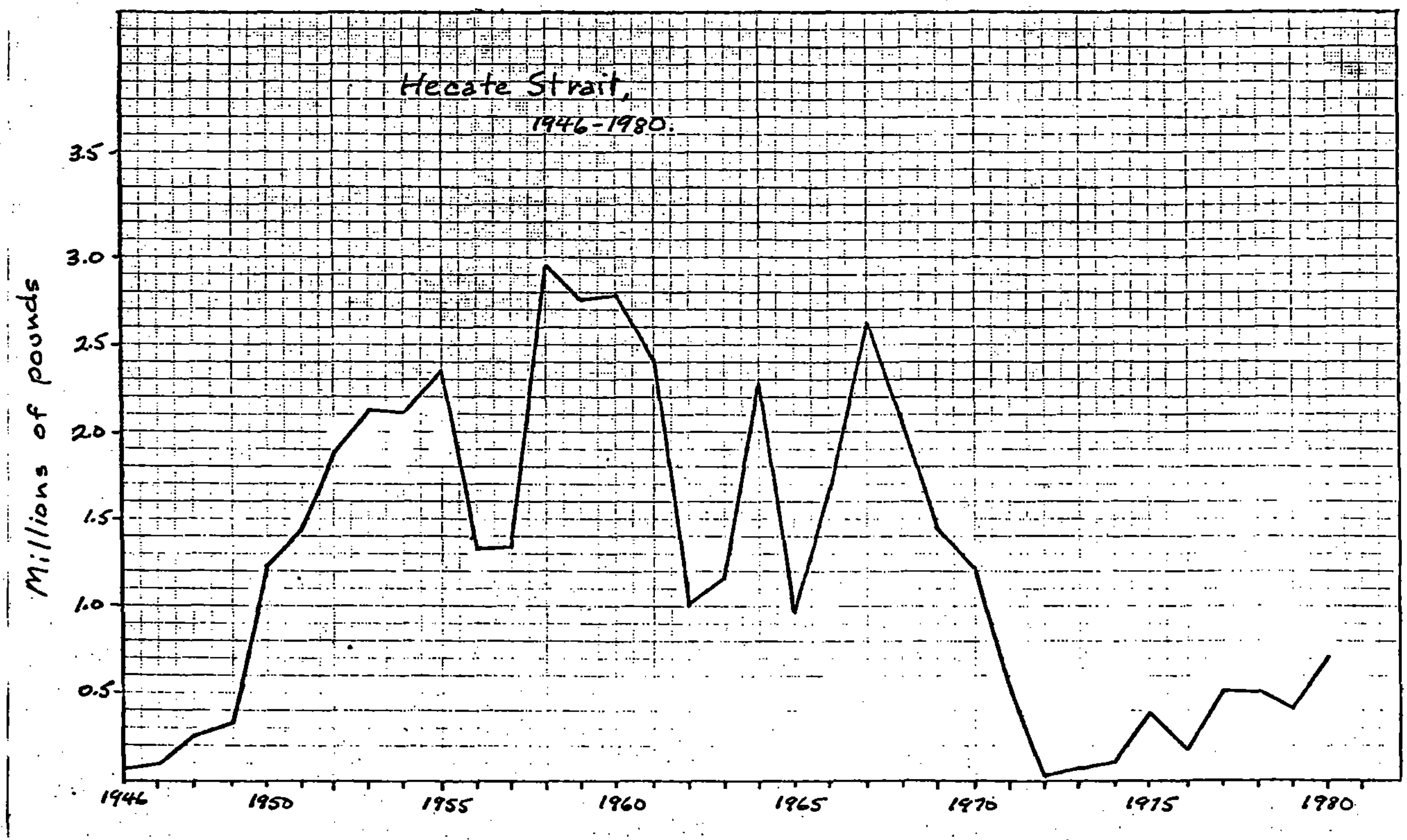

Fig. 1. Annual landings of crab in Hecate Strait.

APPENDIX H.

GOVERNMENT OF CANADA GOUVERNEMENT du CANADA
Fisheries and Oceans Pêches et Océans

INSTITUTE OF OCEAN SCIENCES
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9860 WEST SAANICH ROAD
SIDNEY, BRITISH COLUMBIA
CANADA V8L 4B2

Your file Votre référence

Our file Notre référence

April 13, 1982

File: 5715-1

Dr. R.J. Beamish
Director, Resource Services Branch
Pacific Biological Station
P.O. Box 100
Nanaimo, B.C.
V9R 5K6

Dear Dick:

Certainly Ralph can contribute to the development of the program in Hecate Strait and I have asked him to talk to Jamieson.

Past and present IOS research activities in Queen Charlotte Sound-Hecate Strait can be summarized as follows:

(i) Summer 1977 - Tides and Currents/Offshore Oceanography had several moored current meters in Queen Charlotte Sound and carried out a limited CTD survey. The main scientific result was that inertial oscillations (period about 15 hours) dominated the current meter records, were coherent over distances of several hundred kilometers, were forced by passing storms and were responsible for much of the mixed layer deepening. Rick Thomson has recently reported on these findings in Nanaimo.

(ii) Fall 1981 - Coastal Zone and Tides and Currents put in several moorings again in Queen Charlotte Sound. The Coastal Zone moorings, on the outer edge of the Sound, are part of SUPERCODE, a cooperative program with moorings extending from Baja California to Alaska, the aim of which is to look for propagation of coherent events along the coast. Correlation of similar propagating events at periods around five years with B.C. salmon statistics has been demonstrated by Mysak, Hsieh and Parsons (in press).

(iii) Spring, 1982 - Offshore Oceanography and Tides and Currents plan to intensify their efforts in Queen Charlotte Sound, especially around the edges of banks in the central Sound. Plans for work in Hecate Strait have been delayed because of budgeting and shiptime constraints.

The Ocean Ecology group plans to start work in the area in summer 1983 with three possible areas we will focus on initially:

(i) -the edges of the banks in central Queen Charlotte Sound where IOS work will start in 1982. Formation of fronts in these areas is possible but no evidence exists so far.

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Dr. R.J. Beamish
Pacific Biological Station
Nanaimo, B.C.

April 13, 1982

(ii) -around the islands and passages in Queen Charlotte Strait. Tidal mixing fronts and/or an estuarine outflow analogous to that of Juan de Fuca Strait are possible which could cause enhanced planktonic production. Some evidence of enhanced biomass was obtained during Tim Parsons' ship-of-opportunity program.

(iii) -on and at the edges of the shallow banks in Hecate Strait. We have no idea of planktonic biomass or productivity in these areas. Conceivably biomass could get washed out of the Strait before blooms can occur, cf. Juan de Fuca Strait. A plus of the area is that most of it should be well-mixed making underway sampling (via our own ships or ships-of-opportunity) feasible. A minus is that winds and waves may funnel down the Strait and the shallow depths will certainly steepen surface waves. The area is rumoured to be a difficult place to work.

We feel that it would be unwise to start a large scale survey of the area hoping to spot "hot spots", as it is twenty times as the area we studied off Vancouver Island. To assist us in zeroing in on one of these three (or other) areas, we hope this year to do a search of satellite imagery for the area co-operatively with Offshore and Ocean Information, under contract to Seakem. In addition, some ship-of-opportunity program would be desirable in Hecate Strait.

It seems to me you are beginning to get a fairly good grasp on what you would like to see done in Northern B.C. waters. As soon as you are ready, I think it would be useful for us to sit down together and discuss the overall programs of both laboratories on the Northern B.C. coast over the next 3-4 years.

Yours sincerely,

C.R. Mann
Director-General

crm/bp

cc Dr. R. Brinkhurst