INTRODUCTION INTO AYSEN CHILE OF PACIFIC SALMON

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Review of Ecological Researches on Pacific Salmon Introduced into the Aysén Region, Southern Chile

By

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1. INTRODUCTION

Chileans have long dreamed of introducing salmon into their country. The dream has been doubly reinforced: first, by the successful introduction of several species of trout from Europe into Chile; and secondly, by the successes of the introduction of chinook salmon from California into New Zealand. Introductions of trouts and salmons into Chile began in the year 1905. The first shipments, from Hamburg (Germany), contained eyed eggs of brown (*Salmo trutta*), rainbow (*Salmo gairdneri*) and brook trout (*Salvelinus fontinalis*) and of Atlantic sálmon (*Salmo salar*). Subsequent shipments of coho (*Oncorhynchus kisutch*), chinook (*O. tschawytscha*), and sockeye salmon (*o. nerka)* eggs came from the United States (Joyner, 1980).

The introductions of trout were remarkable success. They adapted themselves to ecological niches left vacant by the devastation to freshwater life made by Pleistocene glacial advances, and spread to nearly every stream between central Chile and Cape Horn, a distance of over 2,500 km. However, all attempts at introducing salmon into Chile were not successful until 1980 (Joyner, 1980).

In 1969, Chilean interest in the introduction of Pacific salmon received a further stimulus from Japan. Field surveys were conducted in December 1969 for about one month by 4 Japasense experts and Chilean counterparts. Main rivers and lakes in the XIth (Aysén) and XIIth (Magallanes) Regions extending from 44°S to 56°S were surveyed on the potential of Chilean water resources to support the acclimatization and culture of Pacific salmon. The supplementary survey was conducted for 3 weeks in the XIth and XIIth Regions in February 1971.

After a wide search, the survey team concluded that the transplantation of salmon and trout into these regions would be possible, and they selected the Simpson River, the longest river in the XIth Region, to execute this project on the following reasons: (1) natural conditions of the Simpson River similar to those of some rivers in Hokkaido where chum salmon (*Oncorhynchus keta*) has been returning for spawning, and (2) suitable social conditions to conduct this project at an experimental stage. A site for a hatchery was selected on the Claro River near its junction with the Simpson River at the town of Coyhaique.

Initially, cherry salmon (or masu salmon) (*Oncorhynchus masou*) was selected to be transplanted, because: (1) effects of coastal oceanographic conditions on released fry and fingerings had been completely unknown, and (2) salmons having longer life in rivers were considered appropriate.

This project was started in November 1972 by receiving 150,000 eyed eggs of cherry salmon. About 85,000 fry was released in January 1973.

The target species was changed from cherry salmon to chum salmon from 1974, because (1) remarkable progress of chum salmon ranching project in Japan, (2) chum salmon was considered to be an appropriate species for the development of fishery industry in Chile, and (3) facility of egg supply in large quantity. Accordingly, the project of chum salmon ranching was started in full-scale from 1974.

At the beginning, the introduced eggs were hatched out at Coyhaique, and the fry had to be released just after the absorption of yalk sac, because of the poor facilities for maintaining and feeding the fry until 1976. Later, however, the hatchery facilities were improved, and then the fry, fingerings and juveniles could be released after feeding in some period. About

23.5 million fry, fingerings and juveniles were released in the period from 1973 to 1986. Most of the releases were chum salmon (21 millions).

So far, the returns have been few. Most of them came from a "delayed release" experiment. Recently, in June-July 1986, a total of 7 chum salmon of 5-6 kg returned to a small river in the XIIth Region. But the origin of the returns and its migration route are still unknown, although these salmon gave some clues for their behavior in the Southern Hemisphere.

In addition to the release of fingerings and juveniles, the activities of the present project included surveys and investigations of the natural conditions closely related to the releases and returns. The ecological and environmental study included field survey of the natural conditions (water quality, plankton and fishes) in the study area (rivers, fjords, channels and open sea), and behavior of released fingerings and juveniles, survey for returns, delayed releases, etc.

The results of these surveys have been published (1) as a series of Technical Reports (TR) and Informationl Briefs (IB) in English or Spanish by the present project (see "8. REFERENCES"), (2) annual reports of the present project in Japanese or Spanish, and (3) occasional unpublished reports in Japanese by Japanese experts. The present report summarizes these results and discussion in the field of ecological researches of the project.

References of TR or IB are indicated at the end of each paragraph or section in this report (e.g. "TR-5" indicates "Technical Report No. 5").

2. STUDY AREA

2 – 1. General View of the Aysén Region

The XIth Region (Aysén Region) is located between 43°39'S and 49°16'S. The coastal zone of this region is characterized by many islands, channels and fjords which exhibit typical features of past glacial activity (Map 1). There are also a lot of lakes of different sizes in islands and the continent. The West Wind Drift approaches the coast of the Chiloé and Chonos Archipelagos between 40°S and 44°S, and bifurcates into two currents, the northward Humboldt (Perú) Current and the southward Cape Horn Current (Barros, 1983). (TR-9)

2 – 2. Coyhaique Hatchery, Claro River and Simpson River

The Coyhaique Hatchery is located near the confluence of the Simpson River and the Claro River (one of tributaries of the Simpson River) and is about 80 km distant from the mouth of the Aysén River (Maps 5 and 6, Fig. 1). The Claro River is about 30 km long and the water is usually clear but sometimes becomes turbid by suspension of mud flown into the river by rain. A waterfall being 10 m high is located about 1,500 m upstream from the confluence. Salmon fry, fingerings and juveniles were released into the Claro River at a point 100 m upstream from the confluence. The river is about 15 m wide at the release point (outlet of the hatchery), and the river bed is covered with stones. A weir being 1 m high was built to supply water to the hatchery at 250 m upstream from the confluence. It is not possible for the released fish to go upstream beyond this weir. (TR-11)

The Simpson River, which is one of the longest rivers in southern Chile, originates from near the border to Argentine, and flows northwest to Aysén Fjord. This river is about 200 km long and 200-300 m wide at the lower reaches, where it is known as the Aysén River. The

Salto River, about 10 km long and 45 m wide at its mouth, runs into the passage of Ensenada Baja which is situated at the innermost part of Aysén Fjord (Maps 4 and 5). (TR-6).

2 – 3. Ensenada Baja

Ensenada Baja (45°27'S and 72°49'W) is a small bay (or inlet) connecting to Aysén Fjord with a narrow channel and is located at the innermost part of the fjord having a strong influence of freshwater from the Aysén (Simpson) River and other streams (Maps 4 and 5). This bay has a muddy bottom with a depth of 4-8 m at the center. (TR-5).

2 – 4. Aysén Fjord and Moraleda Channel

Aysén Fjord is about 60 km long and 2.5-6.5 km wide, and has a prolonged basin of a depth from 200 to 350 m (Map 3). Moraleda Channel is more broadly opened northward, with a depth of 50-200 m at most parts of the basin, and connected with several narrow paths to the Pacific Ocean on the west (Map 1). (IB-11).

3. NATURAL CONDITIONS OF THE STUDY AREA

3 – 1. Simpson River

(1) Air temperature

The air temperature was high in summer (December - March) being 17° - 18°C, and low in winter (July - September) being 3° - 7°C. (IB-3).

(2) Water temperature

The water temperature was high in summer (January - March) being about 15° - 18°C and low in autumn to winter (April - July) being 2° - 6°C. Seasonal variations of water temperature showed the similar pattern to the air temperature. (IB-3).

Water temperature was measured with an automatic recorder at Coyhaique Hatchery. Minimum, maximum and mean daily water temperature for every 10 days in 1982 is shown in Fig. 2. These were high in summer (July - January) being about 14° - 15°C in mean, and with a wide seasonal variation of 7° - 8°C to about 20°C. (TR-11).

(3) pH

The pH value was almost constant being 6.5 - 7.2 throughout the year. (IB-3).

(4) Dissolved oxygen

The dissolved oxygen was mostly 10 - 15 ppm and 83 - 123°/o in saturation. These values are appropriate for river fishes to live and for released salmon to migrate seawards. (IB-3).

(5) Aquatic insects

Surveys on aquatic insects were not undertaken in detail. The limited data showed that the abundance of insects were hight from spring (around December) to autumn (around April) and low in winter and early spring (July to November) (Figs. 3 and 4). Aquatic insects of the Simpson River consisted of Diptera, Ephemenoptera, Plecoptera and Tricoptera. Diptera and Ephemenoptera were dominant both in benthos and in drifts. (IB-3).

(6) Fishes

Nine (9) species were found in the Simpson River system (Table 1). Only 5 species were confined to freshwater throughout their life span: *Aplochiton zebra, Galaxias platei, Hatcheria macraei*, *Odontesthes bonariensis* (corrected as "*Austromenidia* sp." by Zama, personal communication in 1986) and *Percichthys trucha*, although sea-going juveniles of *A. zebra* and *G. platei* may also exist, and *O. bonariensis* is known to live also in estuarine waters in its native Argentine. Following 8 diadromous species reproduce in freshwater, but spend a certain period of their life in saline waters: *Geotria australis, Oncorhynchus keta, O. kisutch, Salmo gairdneri, S. trutta, Aplochiton marinus, A. taeniatus* and *Galaxias maculatus*. Both freshwater and sea-run forms of the *Salmo* species were found in the Simpson River system. The freshwater fish fauna is known to be poor in Chile, becoming gradually impoverished farther to the south, and is completely distinct from that of other parts of South America. (TR-9).

3 – 2. Fjord and Channel

The study area was divided into 3 sub-areas by surface salinity for convenience as follows (Map 3):

1) Fjord area (St. 1 - St. 4): The salinity was low and variable under a strong influence of freshwater inflow from rivers and a marked halocline.

2) Transitional area (St. 5, St. 6, St. 7 and St. 12):
Transitional water from Aysén Fjord (Fjord area) to Moraleda Channel (Channel area).

3) Channel area (remaining 8 stations): The salinity was high and relatively stable throughout the year.

In addition, the channel area was subdivided into 2 parts: northern (St. 9, St, 10, St. 15 and St. 16) and southern (St. 8, St. 11, St. 13 and St. 14). In southern Chile, a period of September to mid December is recognized as spring, mid December to March as summer, April to mid May as autumn and mid May to August as winter. The cruise in May 1981 was included in the category of autumn. (IB-11).

(1) Temperature (horizontal distribution)

The surface temperature of the fjord area varied seasonally from 6.2°C to 16.4°C, converging toward the channel area (Fig. 5). The summer temperature was higher in the fjord and transitional areas (approximately 13° - 16°C) than in the channel (12° - 14°C), while the winter temperature was reversed, measuring 6° - 7.5°C in the fjord and 9° - 9.5°C in the channel. The surface temperature was uniform from the fjord to the channel in spring and autumn. The temperature was relatively stable throughout the year in the channel, usually ranging from 9°C to 13°C, and no difference was found between the northern and southern parts. (IB-11).

(2) Temperature (vertical distribution)

In the fjord and transitional areas, there was a great seasonal variation in temperature in the surface layer (0-5 m layer, or sometimes 0-10 m layer) (Fig. 6). A pronounced thermocline was formed, particularly in summer and winter. The temperature below the thermocline was almost uniform being 9.5° - 12°C throughout the year. In summer, the temperature was higher in the surface layer in the subsurface one, but in winter the temperature in the surface layer was lower. There was a slight vertical difference in temperature in spring and autumn in the fjord and transitional areas. In the channel area, the temperature showed slight vertical changes throughout the year. The temperature tended to be uniform vertically in spring and autumn, but the stratification occurred in summer and winter in the whole area.

(3) Salinity (horizontal distribution)

The surface salinity varied widely from 2.3°/oo to 32.0°/oo in the fjord and transitional areas, usually less than 15°/oo in the former, and increased abruptly toward the channel (Fig. 5). The salinity in the fjord was lower in spring and summer than in autumn and winter. In the channel, the salinity was relatively stable, usually ranging between 27‰ and 32‰ throughout the year, and was a little lower in the southern part. (IB-11).

(4) **Salinity (vertical distribution)**

In the fjord, the salinity in the upper layer was low and very variable. The seasonal fluctuation became smaller toward the channel as in the case of the temperature (Fig. 7). A distinct halocline was formed in the upper layer of the fjord and transitional areas. The salinity increased to 27‰ or more below the halocline. In the channel, the salinity was almost homogeneous vertically. The salinity slightly decreased in spring and summer in the fjord. In the channel, the saline water (higher than 32‰) penetrated from north in the layer deeper than 25 m in these seasons, and in winter the water body of low salinity (lower than 30‰) was found to develop deeper. The salinity in the deep layer of the channel tended to decrease gradually from north to south throughout the year, particularly in spring and summer. (IB-11).

(5) **Transparency**

The transparency varied from 1.3 m to 15.5 m, usually 3-9 m in the fjord, and increased to 6 m or more toward the channel although there was a wide seasonal variation. The transparency in the channel had a regional difference: slightly lower at the southern stations than at the northern ones. In autumn and winter, the transparency was high in the whole areas. The transparency seemed to increase in proportion to the salinity. Generally, the low transparency (less than 4 m) was recorded when the salinity was below 13‰, while the high transparency (more than 10 m) was confined to the high salinity above 24‰. (IB-11).

(6) **Phytoplankton**

Seasonal changes of phytoplankton were examined monthly from February 1983 to February 1984 based on the samples taken at St. A in Ensenada Baja as shown in Map 4. (B-16).

Salinity and temperature ranged seasonally from 1.6‰ to 17.8‰ (average 4.3‰) and 5.9°C to 18.3°C (average 11.1°C), respectively (Fig. 8). The salinity of the surface waters of the lagoon was remarkably reduced by the discharge of the Aysén River flowing into Aysén Fjord. The highest salinity in June appears to be considerably related with the inflow of high saline water with tide. (IB-16).

The phytoplankton was composed of diatoms, dinoflagellates and euglenoids. The diatoms were dominant in number of species (more than 24 species) (Table 2). Most of these diatoms are known as brackish or freshwater species. *Skeletonema costatum, Nitzschia closterium* and *Prorocentrum micans,* etc. are known to be representatives of neritic and euryhaline forms. Therefore, this species composition suggests that this area is the estuarine type and the species reflects the influence of estuarine runoff.

The seasonal changes in density of phytoplankton is shown in Fig. 9. The major bloom of phytoplankton occurred twice; the first in February 1983 and the second in August 1983. The summer-autumn peak was more distinct than the late winter one. The late winter peak is likely to be linked with the early spring (probably September) bloom. This spring bloom was accomplished in the period of the temperature increase, while the summer-autumn bloom was found in the period of its decrease.

Diatoms were the most abundant group, accounting for 45.0% to 100% (average 89.5%) of total phytoplankton density. As to the seasonal changes of the 4 major diatoms, (1) *Skeletonema costatum* was the major species for maintaining high phytoplankton density in late winter, (2) *Chaetoceros* spp. and unidentified diatoms were closely related to the summer-autumn bloom, and (3) *S. costatum* seems to be an important species of the spring bloom together with *Melosira* sp. (*M. italica*) type. (IB-16).

(7) Zooplankton

Results of the survey on zooplankton in Aysén Fjord, Moraleda Channel and the Archipelago region was described in detail by Hirakawa *et al.* (1985) (TR-14) The abstracts and some main points are referred here.

1) Sampling stations and methods

a) Aysén Fjord (Map 3) – Zooplankton were collected at monthly intervals by vertical tows from near-bottom to the surface with a Norpac net at St. A in Ensenada Baja from June 1980 to December 1983 and at St. B in the estuary of the Aysén River from May 1980 to December 1981. Samplings at each station from St. 1 to St. 6 in the fjord were made once a season by vertical tows from 50 m depth to the surface with a Norpac net from November 1980 to January 1983.

b) Moraleda Channel (Map 3) – Samples were obtained at monthly intervals at St. C near Pto. Aguirre from April 1980 to October 1982 and once a season at each station from St. 7 to St. 16 (except St. 9) in the channel from November 1980 to January 1983. Vertical tows were made with a Norpac net from near-bottom to the surface at St. C and from 50 m depth to the surface at the other stations.

c) Archipelago region (Map 2) – During the cruise of the Research Vessel "Itzumi" in March 1982, zooplankton was collected by vertical tows from 200 m depth (at stations more than 200m deep) or near-bottom (at stations less than 200 m deep) to the surface with a Norpac net at 9 stations. (TR-14).

2) Results

The abundance of zooplankton showed seasonal changes having 2 peaks a year; the first in April-May and the second in September-November. However, the autumn peak in 1983 was not so remarkable as in the other years. The abundance of zooplankton at St. B and St. C increased in the period from late winter to summer.

Monthly changes in setting volume of zooplankton at 3 stations is shown in Fig. 10. Zooplankton in the subsurface layer was generally more abundant and more distinct in the seasonal changes than that in the surface layer. The abundance was high in November and/or December and April at St. 1 and St. 3 but was not so remarkable at St. 6 in autumn as at the other stations.

The average zooplankton wet weight was high in spring in the fjord (59.0 g wet wt/10^3 m^3), and in summer in the channel (345.2 g). High biomass in the fjord appeard to be built up by zooplankton, especially by copepods living mainly in the subsurface layer.

In the Archipelago region, the average biomass was 264 g wet wt/10^3 m^3. This value was higher than those in the western and central Bering Sea and off the southern coast of Hokkaido in autumn (Minoda, 1977; Furuhashi, 1980). Therefore, it is estimated that the highest zooplankton biomass in this region was not quantitatively less than in the Bering Sea and northern North Pacific in the period of the high productivity from spring to early summer.

The most abundant group in the upper layer of the fjord and channel and the Archipelago region was Copepoda, accounting for 57.7-87.5% of the total number of zooplankton in each season (Table 3). Euphausiacea eggs ocurred more predominantly next to Copepoda in summer in the channel, and were replaced by non-pelagic invertebrate larvae as well as Appendicularia and Hydromedusae in the Archipelago region (Table 3). Copepoda was abundantly distributed at 10-15 m depth, while non-pelagic invertebrate larvae were found mainly at the surface in the upper layer of the fjord.

Copepoda and non-pelagic invertebrate larvae (mostly Balanidae nauplii) were obtained abundantly in the period of the seasonal increases of zooplankton at St. A, St. B and St. C. Additionally, Cladocera and Appendicularia were also major constituents of zooplankton; the former in spring at St. A and the latter in late winter and early summer at St. C.

Fig. 11 shows seasonal averages in abundance of 8 major zooplankton in Aysén Fjord. Peaks in abundance of the mejor zooplankton were developed firstly in spring by *Calanus* copepodid (*C. chilensis* and *C. patagoniensis*) and Balanidae nauplii, and progressed toward autumn on the seasonal succession caused by the summer dominants (*Acartia tonsa* and cyphonautes larvae) and the summer-autumn dominant (*Paracalanus parvus*). The differences of seasonal peaks in these zooplankton probably contributes to maintain high zooplankton biomass from spring to summer in this fjord. Most of the major zooplankton of the channel basin was simultaneously abundant in summer (Fig. 12). The pattern of the seasonal occurrence was different from that in the fjord.

Of 5 major zooplankton in 45°-47°S in the Archipelago region, *C. chilensis, P. parvus, Oikopleura* spp. and Siphonophorae were abundant along the shore waters.

The zooplankton biomass in the fjord was high from spring to summer. The salmon fingerings and juveniles appeared to encounter sufficient quantity of food organisms continually during its offshore migration after the release from Ensenada Baja in September-November. Seasonal peaks in biomass shifted westward from Ensenada Baja to Moraleda Channel in warm seasons. The average zooplankton biomass in the channel was 7 times higher than in the fjord in summer. Therefore, the feeding conditions of the salmon in the channel is considered to be more suitable for their growth on the quantity of prey. Considering the regional distribution of zooplankton in the Archipelago region, the seasonal distribution of zooplankton biomass in Aysén Fjord and its environs appears to provide good feeding conditions adjusted to the growth of the released salmon (Fig. 13). (TR-14).

(8) **Fishes**

Zama and Cárdenas (1984) (TR-9) listed a total of 73 species of marine and freshwater fishes in 44 families from the XIth Region with detail descriptions of the species, geographical distribution in Chile, spawning seasons and good color pictures of the fishes. The abstracts and some main points of marine fishes area referred here.

Seventy-three (73) species of fishes in 44 families were listed from the XIth Region (Table 4). Sixty-eight (68) species were indigenous to the region; 5 sere exotic species: 4 salmonids and an atherinid *Odontesthes bonariensis.* Most species listed in TR-9 were marine fishes totalling 68 species in 43 families which occurred in the inland and open sea. One family included only 1.7 species on the average. A lot of families and a few species per family may be a characteristic of the marine fish fauna of this region. Compared with the coastal fish fauna around Concepción and Arauco (36° - 38°S) consisting of about 118 species in 59 families, the marine fish fauna of the XIth Region was poorer. The shoreline of the fjord and channel is generally steep slopes, and the coastal waters are strongly influenced by freshwater inflow from rivers, e.g. the salinity range was 2-17°/oo at the surface of Aysén Fjord and 27-32°/oo in Moraleda Channel. Algal and animal communities along the shore were poor and simple.

In addition, the shallow water fish fauna (less than 20 m in depth) in Aysén Fjord and Moraleda Channel seemed to be simple. These physical and biological conditions may prevent positive adaptation of fishes into the shallow waters in southern Chile.

Of the 73 species listed, the approximate spawning seasons of 26 species in the XIth Region are shown in Fig. 14 Seventeen (17) species had ripen gonads in spring; 13 in summer; 5 in autumn and 5 in winter. The spawning seasons of most species (19) were in spring and/or summer. (TR-9).

3 – 3. Open sea

The objectives of the field survey was to obtain basic data on abiotic and biotic conditions in the open sea off the Archipelago region. This area was considered to be one of the possible routes for offshore migration of releases and homing migration for returns.

(1) Temperature

Fig. 15 shows that the distribution of the surface temperature and salinity. The surface temperature of the open sea was higher than 14°C in the north of 46°S, and around 13° - 14°C in the south of 46°S and the coastal area of the Chonos Archipelago. The temperature of the inland area was less than 13°C.

The temperature was measured at 0, 50, 100 and 200 m deep. The temperature at 50 m deep ranged 11.0° - 13.5°C and was slightly low in the coastal area. The temperature of 100 and 200 m deep was 9.5° - 10.0°C and around 8.5° - 9.5°C, respectively. (TR-7).

(2) Salinity

The distribution of salinity in the surface layer is shown in Fig. 15. The salinity less than 33.0°/oo was prevailing in the whole area. The high salinity of 33.5°/o was recorded at an offshore station on 46°S. The salinity in the inland area was lower than 32.0°/oo.

The salinity at 50 m deep was 33.0 - 33.5°/oo in general, but the high salinity of 33.7 - 33.8°/oo was recorded at some offshore stations. The salinity of the inland area was less than 33.0°/oo . The salinity at 100 and 200 m deep was almost uniform in the offshore area around 34.0°/oo and 34.4 - 34.5°/oo , respectively. (TR-7).

(3) Plankton

Results of the surveys on plankton are described in the previous section "3 - 2. Fjord and Channel, (7) Zooplankton". (TR-14).

(4) Fishes

Fish catches by long line in the open sea was very poor. Only 3 specimens were caught by 8 operations. They were azulejo (*Prionace glauca*, Carcharhinidae), mero (*Polyprion yanezi*, Percichthyidae) and jurel (*Trachurus murphyi*, Carangidae). This result suggests that a relatively homogeneous water body is probably prevailing in the surface layer of this area in this period, and that fishing grounds are not formed in this area under these natural conditions. Consequently, the biomass of surface fish was probably poor in this period, and the poor catch was considered to be the reflection of the poor biomass.

Supplementary fishing operation by gill net in the inland area was made in the same period. The catches were 198 specimens in 19 species of fishes and 123 specimens in 3 species of crustaceans. The fishing efficiency was found to be high in the nets placed in the shallow water close to the shore. (TR-7 and others).

4. RELEASE, MIGRATION, FEEDING AND PREDATION

4 – 1. Release of Salmon Fry and Juveniles

A list of salmon releases is shown in Table 5. Initially, the hatchery facilities were poor, and the salmon had to be released at fry stage of 0.3-0.45 g just after the absorption of yalk sac in the year 1974 - 1977. (IB - 15 and unpublished data).

A feeding experiment was started in 1977, and 60,000 fry of about 1.8 g was released. Then, a full-scale feeding started from 1978 in better hatcheries. The majority of the releases weighed about 1.2 g in 1978, 2-5 g in 1979, 2.8-14 g in 1980, 5-18 g in 1981, 4-15 g in 1982, 5-19 g in 1983, 6-12 g in 1984 and 4-6 g in 1985. In recent years, an experiment of "delayed release" had been conducted. Some chums were reared to yearling or to subadult in sea cages before release, in order to shorten the ocean life to increase the possibility of the return.

Only chum salmon was reared in 1974 - 1980, but cherry salmon and pink salmon were introduced from 1981. Introduction of pink salmon were due to followings reasons; (1) almost all of pink salmon return in 2 years, shorter than chum salmon, and (2) this species is known to be relatively resistant to temperature fluctuation at early stages resulting healthier fry.

Cherry salmon was introduced only in the first year of the project, as described in "1. INTRODUCTION", and reintroduced as a supplementary species of chum salmon. Cherry salmon has following life history; (1) this species remains 1-2 years in freshwater, then runs to the sea and returns in 1-2 years. (2) Some of them, mostly males, complete their life cycle in freshwater and reach maturity in 2 years.

The introduction of coho salmon was discussed. The characteristics of the species are: (1) freshwater life in the first year, and (2) short migration in the sea for 1-2 years. However, due to scant supply of eggs from Japan, this species was excluded in the selection of the target species. Later, coho salmon was experimentally introduced into Coyhaique Hatchery in 1983, as described in "4 - 6. Experimental Introduction of Coho Salmon".

The size of the released pink salmon in the major group was: 19 g in 1983, 1.3 - 2.2 g in 1984 - 1986. The released cherry salmons weighed 26-37 g in 1982, 21 g in 1983, 18-49 g in 1984 and 16 g in 1986. (unpublished data).

Concerning the cherry salmon, 200,000 eyed eggs were introduced at Coyhaique Hatchery in October 1981. They were hatched out and raised for 1 year. In October 1982, the juveniles were divided into 2 size groups. In November 1982, the juveniles of the smolted large-sized (37.2 g in mean weight) were released into the Claro River from the rearing pond of Coyhaique Hatchery. The small-sized group (n=9,000, 25.7 g in mean weight), 64°/o of which were parr type, were released into Don Poli Lake located 100 km south of Coyhaique for an experiment to settle the salmon of the land-locked type. (TR-11).

4 – 2. Migration of Released Salmon Juveniles

(1) Downstream migration in the river

Recapture trials of released juveniles (fingerings and juveniles) were made to study the seaward migration of salmon juveniles released into the Simpson River from Coyhaique Hatchery, pertaining following 4 groups: (1) 428,000 chum (4.87 g) released in September 1981, (2) 453,000 chum (6.06 g) in October 1981, (3) 275,000 chum (5.0 g) in February 1982, and (4) 810,000 chum (4.4 g) in October 1982. A total of 524 juveniles were recaptured ranging

28 - 268 specimens per trial. The results showed that the releases reached to the estuaries from 1 week (minority) to about 1 month (majority).

The condition factor [(body weight / folk length^3) X 1,000] was 7.9-10.3 at the time of release. The condition factor was almost stable with time progress during seaward migration, though the recapture data were limited. (Anon., 1984; and unpublished data).

Concerning the cherry salmon released in November 1982, trials to recapture released cherry salmon were conducted by cast-netting and angling in the period from November 1982 to December 1983. The total number of the recaptured salmon was 94 and they were captured near the hatchery up to 2,500 m downstream of the Simpson River. (TR - 11).

Some cherry salmon having developed gonads were recaptured in February - May 1983. The gonad index [(gonad weight / body weight) X 100] of these fish was 10.2 - 16.5. In December 1983, 5 cherry salmon (195 g and 24 cm FL on the average) were recaptured. (TR-11).

(2) Seaward migration in Aysén Fjord

1) Method

Recapture trials of salmon juveniles released into Aysén Fjord were made by gill nets and a purse seine in September - November in 1979 - 1983. A total of 89 juveniles were recaptured. (TR-12).

Data on the released juveniles pertaining to the present recapture study are shown in Table 6. Aysén Fjord was divided into 4 sections (I to IV) from the innermost part toward the mouth for convenience (Map 7).

The recapture of juveniles was carried out using 2 kinds of fishing gears, gill nets and a purse seine. The gill nets of 20-50 mm stretched mesh were used in September- November in 1979 - 1982. The purse seine was used in October-November 1982, and in October 1983.

The gill nets were set at 4 stations: St. A (Ensenada Baja), St. B (Punta Tortuga), St. C (Puerto Pérez) and St. D (Estero Manco) (Map 7). Both ends of the net was fixed in the bay at depths of 5-8 m at St. A. The net was extended off from the shore and the other end was anchored at depths of 10-30 m to the bottom at 3 other stations.

The purse seine was 10 m high, 126 m long and 13-28 mm stretched mesh, and operated by a 5-ton boat of 12 m long. The operation was made: (1) at 35 stations (Map 8A) in October-November 1982, and (2) at 51 stations (Map 8B) in October 1983. (TR-12).

2) Number, length and body weight of recaptured chum salmon

Within a few days after release, 12 specimens were recaptured by gill net at St. A in 1979. No chum salmon was caught in 1980, although the recapture trials were made at St. C and St. D. One fish was netted at St. C in 1981. Eleven (11) specimens were collected by the purse seine at 23 stations in 1982, and 65 fish were collected at 20 stations in all the sections of Aysén Fjord in 1983. Thus, a total of 89 released juveniles were recaptured in the fjord in 1979 - 1983.

The size of the recaptures was 7.3-13.0 cm in fork length, and 3.3-20.8 g in body weight. The size frequency distribution of the fish obtained by the purse seine is shown in Fig. 16. The variation of size of the recaptured fishes were not so wide. This suggests that the releases probably form schools of similar size group.

All the fish were captured on the north shore of Aysén Fjord in 1981 and 1982, while all (except 5 specimens at St. 30) were on the south shore in 1983. Juveniles released from Ensenada Baja probably migrated outward along both sides of the fjord. (TR - 12).

3) Condition factor of recaptured chum salmon

The condition factor [(body weight / fork length^3) X 1,000] of the recaptures ranged from 6.4 to 11.8. The condition factor tended to increase with the size of the fish, though there were a few exceptions, and there seems to be no big change in the condition factor of fish migrating through Aysén Fjord. (TR - 12).

4) Migration rate of releases

The majority of the recaptured fishes were released from Ensenada Baja. Based on the recapture data, the migration rate was calculated (Table 7). The migration rate is estimated to be 2.4-3.7 km/day, an average of 2.9 km/day. This result suggest that juvenile chum salmon migrate through Aysén Fjord at a rate of about 3 km/day. One fish was captured at St. C (49 km distant from Ensenada Baja) 3 days after the release in October 1981, then the migration rate was calculated to be 16.3 km/day. This rate was exceptionally high.

Kobayashi *et al.* (1965) and Mayama *et al.* (1982) observed that most chum fry migrated downstream at a rate of about 10 km/day. Juvenile chum released into the Simpson River ran down at 6-22 km/day. The outward migration rate of the chum through Aysén Fjord is estimated to be about 3 km/day. Kjelson *et al.* (1982) reported that chinook smolt (*Oncorhynchus tschawytscha*) passed through the estuary from Sacramento to San Francisco (U.S.A.) at 10-18 km/day. According to McDonald (1969) and Bakkala (1970), the schooling of chum fry became more distinct when they reached the sea. (TR-12).

4 – 3. Feeding Habits of Released Salmon Juveniles

(1) Simpson River.

Stomach contents of the recaptured chum salmon juveniles were examined. The stomach of juveniles was rarely empty. The composition of the stomach contents was: (1) 49% of Diptera, 28% of Ephemenoptera, 17% of Plecoptera and 6% of Tricoptera for the group released in September 1981, and (2) 46% of Diptera, 32% of Ephemenoptera, 14% of Plecoptera and 5% of Tricoptera for the group released in October 1981. The composition of stomach contents appeared to be the reflection of the fauna of the aquatic insects in the river. (IB-2).

Of 94 specimens of cherry salmon juveniles recaptured in the Simpson and Claro Rivers, stomach contents of 39 specimens (11 - 16 cm) collected in November 1982 to April 1983 were examined. Aquatic and terrestrial insects and others (mainly Gastropoda) were found in the stomach of the fish. Aquatic insects consisted of Diptera, Ephemenoptera, Plecoptera and Trichoptera. Diptera was the most dominant constituents, occupying 66% or more, except specimens collected in February 1983. The aquatic insects occupied about 50% in February 1983. The food composition in the stomach was similar to the species composition of drifting insects rather than that of benthic animals in the Simpson River. (TR - 11, IB - 3).

(2) Aysén Fjord

Stomach contents of recaptured chum salmon (n=89) were examined. Only 5 fish at St. A had empty stomach. The feeding index [(weight of stomach contents (g) / body weight (g)) X 100] of the released juveniles had a wide variation from 0.0 to 6.74, but most of them were in the range of 0.1 - 3.0. The feeding index showed no correlation with the size of the fish. The variation in feeding index was wide in Sections II - IV, but the feeding index of the fish in Section I was less than 2.0. Ensenada Baja was a small inlet of 2.3 km long and 0.9 km wide. Therefore, the food availability possibly decreased because of the release of salmon juveniles in large quantity. (TR-12).

The stomach contents of the recaptured juveniles were identified to the lowest possible taxonomical level and classified into 38 items (Table 8). The average number of prey organisms eaten per fish and the frequency of occurrence of food items are shown in Table 8. The number of food items was 10 in Section I, 22 in II, 28 in III and 28 in IV. Cladocera, Calanoida, Decapoda (Macrura, Anomura and Brachyura) larvae and terrestrial insects were found in the stomachs of the juveniles from all the sections. A considerable number of Cladocera (mainly *Podon leuckarti*) were eaten by the fish in Section I. Following species of Calanoida were dominant: *Calanoides patagoniensis, Calanus chilensis, Rhincalanus nasutus, Euchaeta* sp., *Metridia lucens* and *Drepanopus* sp. Macrura was mostly composed of Sergestidae larvae which occurred in all the sections. *Sprattus fuegensis* was the most dominant species among fish larvae preyed upon.

Cladocera, Harpacticoida, Balanidae larvae (Cirripedia), Decapoda larvae and Insecta are regarded as the main food in the innermost part of Aysén Fjord. Cladcera was most numerous in Sections I to III, and replaced by Calanoida in Section IV. Calanoida increased in both number and frequency of occurrence from Section I toward IV. Cladocera, Copepoda, Decapoda larvae and fish larvae were considered to be important food sources for chum salmon in Sections II-IV. Harpacticoida, Balanidae larvae and aquatic insects occurred in the inner 3 sections (I to III), while Euphausiacea, arrow worms (*Sagitta* spp.) and Appendicularia (*Oikopleura* spp.) were confined to the outer 2 Sections (III and IV) (Table 8). These changes in the food items seem to result from the difference in the fauna of food organisms corresponding with the salinity of Aysén Fjord.

The recaptured juveniles were divided into 3 size groups at intervals of 2 cm in fork length to analyze the utilization of food organisms by size group (Fig. 18). Calanoida, Insecta and arrow worms were more dominant in the small-sized groups of 7-11 cm long than the large-sized group of 11-13 cm long. Cladocera, Harpacticoida, Balanidae larvae and Decapoda larvae became increasingly dominant for the large fish. No correlation was detected between the size of fish and the size of prey. Large prey such as Euphausiacea, arrow worms and fish larvae were not dominant in large fish.

Crustaceans (such as Copepoda, Mysidacea, Amphipoda and Euphausiacea), Insecta and fish larvae are generally regarded as main food items for juvenile chum salmon staying in inshore waters (Bakkala, 1970; Okada and Taniguchi, 1971; Kobayashi, 1977; Healey, 1980; Seki *et al.*, 1981). But no Mysidacea was found in the stomach of the recaptured juveniles. Amphipoda and Euphausiacea were not dominant prey. *Calanus chilensis, Calanoides patagoniensis, Rhincalanus nasutus, Paracalanus parvus, Clausocalanus* spp. and *Metridia lucens* were dominant Copepoda in Aysén Fjord and contributed to the high biomass of zooplankton from spring to early summer (TR-14). The occurrence and abundance of these Copepoda in the stomachs of the recaptures are considered to be reflected by the natural conditions of the coopepod fauna in the fjord. In the surface of Aysén Fjord and Moraleda Channel, Brachyura larvae were abundant in spring and summer. But the Brachyura larvae appeared not to be an important food source for juvenile chum salmon. Terazaki *et al.* (1982) and Terazaki and Iwata (1983) studied feeding habits of chum salmon fry in the Otsuchi Bay, Japan, and reported that (1) chum salmon fry generally consumed food organisms that were abundant in their habitats, (2) electivities for harpacticoid copepods were high and positive, (3) electivities for *Acartia* spp., *Oithona* spp. and *Paracalanus parvus* were low and almost negative, and (4) electivities for crab and shrimp larvae were variable at sampling stations.

The feeding index [(weight of stomach contents / body weight) X 100] of juvenile chum salmon staying inshore is known to be around 1.0 - 5.0 (Kobayashi, 1977; Healey, 1980; Seki *et al.* 1981). The chum salmon in the present collection showed comparatively low values (0.1-3.0 for the majority). However, the fauna of food organisms in Aysén Fjord was abundant at least from spring to early summer, judging from the absence of the empty stomach (except for 5 fish from Ensenada Baja) and the zooplankton biomass in the fjord. (TR-12).

Hirakawa (1985) (IB-17) examined the feeding conditions of juvenile chum salmon, especially the relationship between the distribution of zooplankton and the composition of food items caught by the recaptured salmon juveniles.

Research cruises for recapturing released juveniles were carried out 4 times in Aysén Fjord and Moraleda Channel in September-October 1985.

The average zooplankton biomass by cruise was about 90-180 g wet wt/ 10^3 m^3 in the upper layer of the fjord and channel in spring, and was higher in the channel than in the fjord. The highest biomass predominantly consisted of Brachyura zoea and was recorded in the channel in early October. Of the major zooplankton, small-sized forms consisting of Balanidae nauplii, cyphonautes larvae and *Paracalanus parvus* were dominant in the inner and middle parts of the fjord. In the channel, medium-sized forms consisting of *Calanus* copepodids of *Calanus chilensis* and *Calanoides patagoniensis, Drepanopus forcipatus, Metridia lucens*, Brachyura zoea and *Oikopleura* spp. predominantly occurred together with Balanidae nauplii, *P. parvus* and *Acartia tonsa.* The composition of the major zooplankton in the channel was more diversified than that in the fjord.

The released juvenile chum salmon were recaptured at 8 stations in the fjord (15 fish) and at 2 stations in the channel (5 fish). This was the first record of the recapture in the channel. The juveniles in the fjord mainly fed on *Podon leuckarti*, Harpacticoida, Balanidae nauplii, Balanidae cypris, Gammaridea, Sergestidae larva, *Oikopleura* spp. and Insecta. Cyphonautes larvae and *A. tonsa* were dominant in the net samples, but rarely occurred in the diets of the juveniles. *P. parvus* was not found in the stomach contents. The major food prey in terms of volume were: (1) large-sized forms consisting of Gammaridea and Insecta in the fjord, and (2) Copepoda, Euphausiacea larva (furcilia), Callianassidae zoea and fish eggs in the channel. These Copepoda were medium- and large-sized forms consisting of *Calanus chilensis, Calanoides patagoniensis, Rhincalanus nasutus* and *Metridia lucens. A. tonsa,* Brachyura zoea and *Oikopleura* spp. were dominant in the net samples, but not major food for the juveniles.

The feeding index ranged from 0.9 to 6.8 (3.7 in mean) and nearly coincided with those (1.0-5.0) reported by Kobayashi (1977). But these values were higher than those of the recaptured salmon juveniles in Aysén Fjord (0.1-3.0). The results showed that zooplankton biomass increased from the fjord toward the channel during the period of outward migration of the released juveniles. (IB-17).

4 – 4. Feeding Habits of Other Fishes in Aysén Fjord

A total of 1,196 fishes belonging to 20 species in 15 families were collected in Aysén Fjord during the survey related to the outward migration of released salmon juveniles. (TR-12).

Of the 20 species collected, stomach contents of 16 species were examined. Most of the fishes were obtained in the middle part of Aysén Fjord. No salmon juveniles were found in the stomachs of the fishes. *Engraulis ringens, Macruronus magellanicus, Merluccius gayi* and *Normanichthys crockeri* had empty stomachs (the number of specimens was only one in each species). The stomach contents of the remaining 12 species were classified into 25 prey items in 9 higher taxonomic categories. The majority of *Odontesthes smitti* (=*Austromenidia smitti*, by Zama, personal communication in 1986) and *Sprattus fuegensis* had empty stomachs (69.2 and 53.9°/o, respectively). The ratio of fish having empty stomachs was less than 10°/o in *Eleginops maclovinus.* Omnivorousness was found in the 3 nototheniid species, *E. maclovinus, Notothenia longipes* and *N. tessellata.*

As shown in Fig. 19, crustaceans were very common foods for most of the fishes. Planktonic crustaceans such as Cladocera, Calanoida, Balanidae larvae and Decapoda larvae were eaten mainly by surface swimmers such as *S. fuegensis* and *O. smitti*. Benthic Cirripedia, Isopoda, Amphipoda and Brachyura were common foods for bottom dwellers such as *Salilota australis, Agonopsis chiloensis* and the 3 nototheniids. (TR-12).

4 – 5. Predation on Released Salmon Juveniles

(1) Predation during downstream migration in the river

Brown trout (*Salmo trutta*) was introduced into Chile from Germany in 1905, and settled in central and southern Chile (Golusda, 1927; Barros, 1961; MacCrimmon and Marshall, 1968). This trout was the most dominant species in the Simpson River system and commonly occurred in Aysén Fjord. (TR-6).

Brown trout and rainbow trout (*Salmo gairdneri*) had been considered to be potential predators on released salmon juveniles. The predation of these trouts on the releases had been recognized, however, no surveys have been conducted yet on the predation in the rivers.

Followings are results of surveys on some biological aspects of the wild brown trout in the Aysén and Salto Rivers, including the predation of the trout on released salmon. (TR-6).

Seventy-seven (77) brown trout were captured in the Aysén and Salto Rivers in March-June in 1980-1982. Most of them were on spawning runs from the fjord. Prespawning movement to upper streams appeared to be more active in March-April than in May-June. The trout ranged from 25.8 to 69.0 cm TL, having a mode at 55-60 cm in both male and female. Females were more abundant than males in the catch in both rivers, but there was no statistically significant difference from the 1:1 sex ratio. All of the small fish less than 41 cm TL and some of the large fish had immature gonads. Their gonad index (GI) was less than 0.56. Maturing males (GI: 2.50-5.78) decreased GI in March-April, while maturing females (GI:6.51-19.42) increased GI in March-May. Twenty-five (25) scale samples revealed that the fish (29.5-65.5 cm TL) had eges of 2-4 years and spent 1-2 complete years in freshwater. About 15 circuli were formed per year on the scales in their freshwater life in the first and second years. All the scales showed a sudden and remarkable increase in number of circuli and in width of radius when fish are presumed to have entered the fjord, but thereafter annual increment decreased gradually. The size of 2- and 3-year-old fishes at smolt migration was estimated to be about 12 and 17-18 cm TL, respectively. They appeared to become mature at the end of 3-4 years old at 40-45 cm TL. Fish, snails and squat-lobsters were main food items for the trout in the Aysén River, and fish was the commonest food for the trout in the Salto River. (TR-6).

(2) Predation in the fjord

The predation of fishes on salmon juveniles (chum and pink) released into Ensenada Baja from October 1980 to March 1984 was studied. (IB-8).

A total of 686 specimens consisting of the following 10 species were collected in Ensenada Baja, *Callorhynchus callorhynchus* (Callorhynchidae), *Oncorhynchus keta* (Salmonidae) (chum salmon), *Salmo gairdneri* (Salmonidae) (rainbow trout), *S. trutta* (Salmonidae) (brown trout), *Merluccius australis* (Merluccidae), *M. gayi* (Merluccidae), *Odontesthes smitti* (Atherinidae), *Eleginops maclovinus* (Nototheniidae), *Trachurus murphyi* (Carangidae) and *Stromasteus stellatus* (Stromateidae). *E. maclovinus, S. trutta* and *T. murphyi* occupied the majority (about 90°/o in number) of the catch. The former 2 species occurred in each sampling, meanwhile the latter was found only in March 1984. *O. keta* was caught by a gill net. All the *S. gairdneri*, except small specimens, were probably escaped fish from floating pens set in the same bay by another authority, Fundación Chile. The number and size of the collected fishes are summarized in Table 9.

A total of 703 chum and pink salmon juveniles were collected from 130 stomachs of 5 species: *S. trutta, M. australis, M. gayi, E. maclovinus* and *T. murphyi* (Table 10). Among these species, the predation by *S. trutta* was severe. Eighty (80) *S. trutta* preyed on 457 salmon juveniles (65.0°/o of the total). The smallest size of the predators was 16.0 cm SL for *E. maclovinus,* 22.2 cm for *S. trutta,* 33.7 cm for *M. gayi* (one specimen), 42.5 cm for *M. australis,* and 43.8 cm for *T. murphyi.* The maximum number of prey in one fish were 48 salmon in *T. murphyi,* 35 in *S. trutta,* 21 in *M. australis,* and 12 in *E. maclovinus.* The number of prey per fish was high in the fish of 40-50 cm in all the species, and was very low in the fish less than 35 cm.

Fig. 20 shows daily changes in numbers of preyed salmon juveniles after the release, and number of brown trout captured in Ensenada Baja. A lot of salmon were predated in 2-3 days after the release, and then the preyed salmon remarkably decreased in number. Before the release, 1-5 brown trout was captured daily in the bay in October 1982 and September 1983. After the release, the number of the daily catch abruptly increased up to 16 in 1982 and to 12 in 1983. The brown trout was possibly attracted into Ensenada Baja by the released salmons.

604,000 small chum juveniles (9.7-9.9 cm FL in mean) and 276,000 large ones (13.6 cm) were released in November 1981. After the release, 198 chum were obtained from the stomach of predators; 183 originating from the former group and 15 from the latter. These data suggests that smaller fish is more vulnerable to predation.

Concerning the fishes in Aysén Fjord, *S. trutta* and *E. maclovinus* were very common. *M. australis* frequently occurred in the fjord, though it was not abundant. *T. murphyi* usually migrated into the innermost part of Aysén Fjord in late summer (March) and autumn (April), and appeared at Puerto Pérez, near the mouth of the fjord, in spring (October and November). *M. gayi* was relatively rare in the fjord. Therefore, these 4 species (except *M. gayi*) are regarded as principal predators on released salmon juveniles in Aysén Fjord. *S. gairdneri, Macruronus magellanicus* (Merluccidae) and *Sebastes oculatus* (Scorpaenidae) occurred in the fjord. The were highly piscivorous and potential predators. (IB-8).

4 – 6. Experimental Introduction of Coho Salmon

163,000 eyed eggs of coho salmon were experimentally introduced into Coyhaique Hatchery from Llanquihue Piscicultura (a private hatchery) in the Xth Region in July 1983. The origin was a wild stock in Llanquihue Lake after escaping from the hatchery to the lake at a smolt stage. The introduced eggs were hatched out, reared by feeding and released into the following places; (1) into Claro and Simpson Rivers: 700 fish (73 g BW and 19 cm FL) in May 1985, and 700 fish (155 g and 24 cm) in November 1985, (2) into Las Torres Lake in the Cysnes River system: 22,500 fish (60 g and 18 cm) in March 1985, 10,000 (65 g and 18 cm) in April 1985, and 1,500 fish (73 g and 19 cm) in May 1985.

5. SURVEYS ON SALMON RETURNS

5 – 1. Ensenada Baja, Salto River and Simpson River

Gill nets were placed to capture returned salmons (1) in Ensenada Baja from mid March to late June in 1980 - 1984, (2) at the river mouth or slightly upstream from the river mouth of the Salto River from late March to late June in 1981 - 1984, (3) at Puerto Piedra, about 7 km upstream from the river mouth of the Simpson River (Aysén River) from mid March to mid June in 1980 - 1981. (Zama, unpublished; IB-15 and others).

A total of 68 chum (63 male and 5 female) were captured from April 17 to June 22, 1982. The size and the age were 41.5-61.0 cm TL, 565 - 2,759 g BW and 2+. Ten (10) were captured in the bay, 49 at the river mouth of the Pajarones Stream and 9 from the Salto River.

All of the captured salmon had rubbed snouts and worn caudal fins at both ends. These marks resulted from rearing in cages for a long period. These captures probably originated from a group (n=490, 1,145 g BW on the average) realeased into Ensenada Baja from January 26 to February 1, 1982, to reduce the overpopulation in cages. The released salmon appeared to stay around there. Some of them were found to go upstream of the Pajarones Stream. (The outlet of the Ensenada Baja Hatchery is located at the river mouth.) Besides, some other chum with nuptial coloration were caught by gill nets in the bay and the estuary of the Salto River.

The capture of 8 salmon with nuptial coloration at the estuary suggests that the upstream migration probably occurred in this river. However, capture trials for the upstreaming salmon were prevented from bushes along the riverside, a lot of trees fallen into the river and the swelling of the river with rain water in April-June.

Twelve (12) (5 male and 7 female) were captured from April 5 to October 2, 1983. The size and age were 41-57 cm TL, 1,040 - 1,975 g BW and 2+ or 3+. They possibly belonged to (1) the same group of the returns in 1982, or (2) another group (n=118, 1,063 g on the average) released into Ensenada Baja on April 19, 1983.

In 1984, 6 salmon (4 chum and 2 cherry) were captured (excluding cherry salmon of stream resident type). The capture record of chum are as follows; (1) male, 51 cm TL, 1,360 g, 2+, captured in Ensenada Baja in May, (2) male, 36 cm, 420 g, 2+, in Ensenada Baja in August, (3) sex unknown, 39 cm, 530 g (without viscera), 2+, in Bahía Acantil in October, and (4) female, 45 cm, 870 g, 2+, in Playa Blanca in December. Those of 2 cherry are (1) male, 40 cm, 630 g, 2+, in the Mañiguales River in April, and (2) female, 37 cm, 500 g, 1+, in Canal Costa in July.

The male chum of 51 cm TL captured in Ensenada Baja in May probably originated from KJ-81 (eyed eggs introduced from Japan in 1981). The maximum size of KJ-81 releases was 92.3 g (mean size of a group (n=6,000) released in February 1983), excluding marked releases (n=500) at Puerto Aguirre. Accordingly, it is considered that this salmon grew under natural conditions and reached maturity.

The male chum of 36 cm TL was caught by angling by a sport fisherman at the mouth of Ensenada Baja. This specimen probably originated from KJ-82 (eggs introduced in 1982) and was released at the size of 5-14 g in October 1983. This specimen probably also grew under natural conditions for one year.

There were no records of returns of salmon in 1985 in Ensenada Baja and other areas. (Zama, unpublished; and others).

Age designation

0+: Fish not passing the first winter (mid June – mid September), fry stage in the group transplanted from Japan to Chile.
1+: Fish in the first winter with additional growth in Chile.
2+: Fish in the second winter with additional growth of marine or freshwater life; jack salmon.
3+: Fish in the third winter with additional growth; adult salmon. (IB-15).

5 – 2. Aysén Fjord and Moraleda Channel

Coastal currents are swift and shore slopes are steep in most places in Aysén Fjord and Moraleda Channel. Fishing operations by floating gill nets were difficult under these conditions. However, recapture trials for returning salmon was conducted by gill nets at some places along the coastal area in Moraleda Channel and the mouth of Aysén Fjord in March 17-26, 1982. Another trials were made by gill nets at 3-5 stations in Aysén Fjord at monthly intervals in April - May 1984. But no salmon were captured in these trials. (Zama, unpublished).

5 – 3. Open Sea

Recapture trials of returning salmon were conducted by long line at open sea in the area of 44°08'S - 47°00'S, 74°37'W - 76°01'W in March 10-26, 1982. No salmon were captured by 8 operations. Due to bad weather during the survey, the fishing operation by gill nets was not conducted. It is known that the sea is rough in these areas in autumn-winter corresponding to the season of probable homing migration. (TR-7).

5 – 4. Salmon Returns in Other Area

In 1986, 7 chum (6 male and 1 female) were captured at a hatchery in the XIIth Region (Magallanes Region); 3 males (5.2-5.6 kg) and 1 female (5.7 kg) around May 28, 1 male (about 5-6 kg) on June 3, 1 male (5.2 kg) on June 10, and 1 male (5.2 kg) on June 12. This hatchery, Salmones Antártica Ltda, is located at 51°33'S, 73°45'W, near the mouth of a small river, Río Prat Chico, flowing into the middle part of a bay called Seno Ultima Esperanza. This bay is one of the branches of a big bay, Golfo Almirante Montt, connecting to the ocean through a narrow channel, Canal Morla Vicuña (Maps 9 and 10). This hatchery was constructed in 1983 and have been operating a project of coho salmon ranching. No other chum returns have been reported until now (August 1986). These 7 chum salmon are considered to have been trapped in the bay during the homing migration. (unpublished data).

5 – 5. Summary of Surveys on Salmon Returns

Most of the returning salmon in the XIth Region were captured from April to mid May. The capture of an immature salmon suggests that some salmon may stay in fjords after the release at juvenile and yearling stages. The chum returns in the XIIth Region suggests that some salmon probably went out to the open sea for feeding migration. There were no records of returns of pink salmon, except experimental release of large-sized pink salmon, though this salmon is known to return in shorter period than chum.

5 – 6. Experiments on Upstream Migration

Experiments on upstream migration by chum and pink salmons were made; (1) 162 mature male pink salmon (540 g on the average) and 118 mature male chum salmon (1,263 g on the average) were released in Aysén Fjord at a point about 7 km distant from the estuary of the Simpson River in April 1983. One pink salmon was recaptured at the estuary. A total of 25 chum were recaptured; 5 in Ensenada Baja and the Pajarones Stream, 1 in the Salto River and 19 in the Simpson River (6-49 km upstream from the estuary). (2) 154 mature male chum salmon (1,513 g) were released in Aysén Fjord at a point about 13 km distant from the estuary of the Simpson River in May 1983. A total of 25 fish were recaptured: 9 in Ensenada Baja and the Pajarones Stream and 16 in the Simpson River.

The chum and pink salmons used in these experiments hatched out in Coyhaique, were reared there for 3-6 months and then transferred to Ensenada Baja. Some of them (a group released in April) were then transferred to Puerto Aguirre for additional rearing for 6 months and then sent back to Ensenada Baja. The results suggest that returning places may not be fixed for salmons reared in several placas before the release. (Zama, unpublished).

5 – 7. Returns of Coho Salmon

The recapture data of coho salmon until June 1986 in Aysén Fjord, Ensenada Baja and the Simpson River are listed below.

January	1986	3 fish (108 - 475 g)
February	1986	4 fish (379 - 2,220 g)
March	1986	7 fish (347 - 1,780 g)
April	1986	14 fish (214 - 3,650 g)
May	1986	28 fish (630 - 2,600 g)
June	1986	2 fish (220 - 600 g)

Of the total 58 recaptures, 36 fish returned to Coyhaique Hatchery from April to June 1986, showing its peak from late April to early May as listed below.

Late	April	11 fish
Early	May	12 fish
Mid	May	4 fish
Late	May	9 fish
Early	June	0 fish
Mid	June	0 fish
Late	June	0 fish

Most of the coho salmon captured at Coyhaique were fully matured. The body weight of the returns measured 0.9-2.5 kg, and was smaller than normal returns of coho salmon (3-5 kg). The returns in small size is probably attributable to the long-term rearing in freshwater (20-28 months) before releasing. As the result of the rearing, their ocean life for feeding migration was shortened, and they reached maturity in small size. The spawning season of the holding stock (cage cultured fish in Ensenada Baja) from the same source was coincident with the period of the homing migration of the wild stock.

Of the captured coho salmon, one specimen was unusually big (3,650 g). This fish probably came from another source. Cage culture of coho salmon has been conducted by another organization (Fundación Chile) at Chacabuco located in the innermost of Aysén Fjord. In January 1986, one of the cage was damaged by an attack of a sea lion, and about 200 individuals of 3-year-old coho salmon were escaped. One big fish in our specimens was probably identified as one of these escaped salmon. The scale of this salmon also indicated its long cultured life.

The successful upstream migration of coho salmon for spawning may suggest that the Simpson River and the coastal environment are appropriate for the salmon to complete its life cycle. Therefore, it is considered to be feasible to establish fishery resources of coho salmon around these areas by salmon ranching. (Nagasawa, unpublished).

6. CONCLUDING REMARKS

6 – 1. Summary of Archievements

(1) Water quality

Surveys on water quality and oceanographical observations were conducted in Ensenada Baja, the Simpson River system, Aysén Fjord, Moraleda Channel, Elefantes Fjord (south to Moraleda Channel) and the open sea. These areas are the probable route in seaward migration for fry and juvenile salmon released at Coyhaique or Puerto Aysén and the possible route in homing migration to the mother river.

Changes of water temperature in the Claro River were considered to be slightly unfavorable in hatching and rearing at the Coyhaique Hatchery, however, no other negative factors for released juvenile salmons were detected in the water quality (temperature, salinity, pH and DO) of the rivers, estuary, fjord and channels. (TR-11; IB-3; IB-11).

(2) Plankton

Surveys on plankton were conducted at the same locations as in the water quality survey. The result showed that the zooplankton biomass was high in the fjord area in spring and its peak in abundance shifted from the fjord to the channel in summer. Accordingly, the release of salmon juveniles in spring (September-October) was considered to be suitable from the viewpoint of the food availability to the juveniles. (TR-14; IB-16).

(3) Fish fauna

Seventy-three (73) species of 44 families have been recorded in the Aysén Region including previous records. Fifty-eight (58) species of marine and freshwater fishes have been collected so far in the Aysén Region by the present project. Almost all the fishes were found in the fjord and the channel area. However, fishes were few in the coastal area in the fjord bacause of low salinity. Eighteen (18) species of fishes were collected in Ensenada Baja. Brown trout (*Salmo trutta*), róbalo (*Eleginops maclovinus*) and pejerrey (*Odontesthes smitti*) were common all the year round.

No studies have been undertaken on epipelagic fishes in the open sea of southern Chile where the introduced salmons possibly live. Moreover, there have been no records of the existence of epipelagic fishes in this area, corresponding to herrings and sauries in the North Pacific. This area may be devoid of competitors and lacking of available foods for the introduced salmons. (TR-7; TR-9; Zama, unpublished).

(4) Recapture of juvenile salmon

Juveniles released at the Coyhaique Hatchery were considered to reach to the estuary of the Aysén River (Simpson River) in 7-10 days on the average after the release. Recapture trials of the released juvenile salmon revealed that the juveniles released at Ensenada Baja reached to Moraleda Channel migrating along the coastal shores of the fjord at the speed of about 3 km/day. The migratory behavior beyond the channel has not been elucidated. (TR - 12; Anon., 1984).

(5) Feeding habit of juvenile salmon

Stomach contents of recaptured juvenile salmon were examined. Cladocera, Harpacticoida, Balanidae larvae, Decapoda larvae and Insecta were main components of food items of the juveniles recaptured in the inner part of the fjord. On the other hand,Copepoda, Euphausiacea, Decapoda larvae, and fish larvae were the main food items for the juveniles in the outer part of the fjord. The feeding index was 0.1-3.0 in most cases showing no correlation with fish size. These values were slightly lower than those in Japan, however, these feeding conditions both in the fjord and in the channel in the period from spring to autumn were considered favorable for the juveniles. (TR - 12; IB - 17).

(6) Predation on juvenile salmon

The predation on chum and pink salmon juveniles was severe in 2-3 days after the release, but the predation remarkably decreaced since then. The predatory fishes were brown trout (*Salmo trutta*), róbalo (*Eleginops maclovinus*), mackerel (*Trachurus murphyi*) and merluza (Merluccius spp.). The predation of brown trout was relatively violent to both chum and pink salmons released in Ensenada Baja. Most of juveniles seemed to reach the fjord in about 10 days at latest after the release in Ensenada Baja. (IB-8).

(7) Surveys on salmon returns

Chum salmon released after long-term rearing in floating pens in Ensenada Baja were confirmed to perform homing migration after possible feeding migration in the fjord for 3 - 5 months. These salmon were recaptured mainly in the period from early April to early May.

Besides, some immature chum salmon were caught in the fjord during their probable feeding migration. Two mature males were recaptured during their homing migration at the river mouth, but their behavioral patterns have not been elucidated as yet.

Recapture trials of returning salmon in the fjord, the channel and the open sea were not successuful.

Concerning other salmons, a few sea-run type immature and mature cherry salmon were recaptured. But there have been no records of recapture for pink salmon, except those released experimentally, though the pink salmon is known to return in younger age than the chum salmon. Their migratory behavior after the release is still unknown in our trials. (TR - 7; IB - 15; Zama, unpublished; and others).

6 – 2. Some Unsolved Points

(1) Behavior of salmons after release

It was confirmed that the released chum salmon migrated to the channel through the fjord. However, their behavior beyond the channel is still unknown whether they migrate to the open sea or stay in the inland sea (fjord and channel).

The recapture of an immature chum salmon at the mouth of Ensenada Baja suggests that some released juveniles remain in the inland sea. But the other record of the recapture of 2 mature males implies the possibility of their outward migration to the open sea. The mature chum returns in the XIIth Region suggest that some salmon probably migrated in the open sea to the south for feeding.

(2) Feeding conditions in the open sea

Epipelagic fishes are apparently lacking in the open sea off southern Chile. It suggests that the abundance of food organisms may not be sufficient for the introduced salmons to make feeding migration in the open sea. The krill resources are reportedly abundant in the Patagonian waters. However, data are lacking on the availability of krill to the salmon in the layer where they possibly migrate. (Anon. 1982; Zama, unpublished; Zama, 1985).

(3) Environment in the open sea

It is still unknown that marine environment and sea conditions are appropriate for the migration of the introduced salmons.

6 – 3. Some Possible Factors for Homing Migration

Followings are some of main factors and reasonings related to homing migration of the introduced salmons.

(1) Oceanic structure

The oceanic structure offshore of southern Chile is significantly different from those in the North Pacific.

A westward skin current approaches from northwest to the Aysén offshore zone (43° - 44°S) and bifurcates into a north and south current. The Cape Horn Current, the southward current, is considered to be a water body suitable for introduced salmons to migrate. However, this current does not form a circular flow, but is running one-way to the Argentine waters. Besides, this current has little seasonal variations of water temperature. Eddies and counter currents exist in the area between the bifurcated currents and the continent. Therefore, salmons are possibly able to settle and grow in these area, as in the chinook salmon introduced into the New Zealand waters, though the establishment of large-scale resources of salmons may not be expected.

A wide upwelling of low temperature is prevailing in the area between the northward Humbolt Current (Perú Current) and the continent. Accordingly, it may not be possible for the released salmon juvenile to be flown away northward by the Humbolt Current to tropical areas. (Zama, unpublished; Zama, 1985).

(2) Predation

1) Predation in rivers

The Coyhaique Hatchery is distant about 80 km from the estuary of the Simpson River. The predation of brown trout and rainbow trout on released juvenile salmons was recorded. But a large number of the juveniles presumably reached the river mouth.

Following countermeasures have been undertaken to reduce the predation in rivers; (1) release of juvenile salmons from the Ensenada Baja Hatchery located at the river mouth of the Simpson River, and (2) release of larger juveniles having higher swimming capability. (Anon., 1984; Zama, 1985).

2) Predation in Ensenada Baja

A large number of juvenile salmon were predated in 2-3 days after the realease. Number of preyed salmon remarkably decreased after that, and most of the released salmon probably migrated beyond Ensenada Baja in 7-10 days after the release. Smaller juveniles were proved to be more vulnerable to predators than larger ones, because of less swimming capability.

Following countermeasures were undertaken to reduce the predation and to increase the survival rate of the released juveniles in Ensenada Baja; (1) capture of brown trout and other possible predators during the releasing periods, and (2) release of larger juveniles having higher swimming capability. (IB-8; Anon., 1984).

(3) Number of released juveniles

The possibility of homing migration may be raised by releasing more juveniles. However, the present facilities are operated almost in full capacity physically and financially (Zama, 1985).

(4) Release of healthy fingerings or juveniles

After the improvement of the hatcheries and rearing facilities, the rearing conditions have been remarkably improved keeping high hatching and survival rate (90°/o) and the good condition factor (8-10) have been maintained. Consequently, it is considered that juveniles (fingerings or juveniles) have been apparently released in good conditions. The effects of long-term and overwintering rearing on the juveniles has not been studied, however, the possibility of physiological malfunction of the juveniles by the rearing may be very low. (Zama, 1985).

(5) Homing ability in the Southern Hemisphere

Experiments on the "delayed release" of chum salmon proved that (1) the Japanese chum salmon held homing ability to go back to the released point, and (2) the Simpson River was appropriate as the mother river for the introduced chum salmon. It is also demonstrated that the chinook salmon introduced into New Zealand and Chile and coho salmon into Chile held their homing ability to go back to mother rivers. (Zama, 1985).

(6) Difference of seasons

The four seasons are reversed between the Northern and Southern Hemispheres. It is proved that the chum salmon introduced from the Northern Hemisphere (Japan) into the Southern Hemisphere (Chile) was able to adjust the difference of the season by shortening half year of its life-span, based on the rearing experiment of the chum salmon until maturity in floating pens in sea water. (TR - 16; Zama, 1985).

(7) Influence of magnetic fields and the sun on homing migration

There have been some doubts that the homing instinct may be disturbed by the transplantation from the Northern to the Southern Hemisphere in case that the salmon may sense the magnetic fields and/or utilize sun compasses. Anadromous salmonids introduced from the Northern Hemisphere such as brown trout, rainbow trout, coho salmon and chinook salmon have been already settled in Chile. Athough the chum salmon is known to migrate more extensively than the above-mentioned salmonids, the settlement of these salmonids may negate the influence of the magnetic fields and the orientation using the sun compass on the homing migration of the introduced salmons. (Machidori, 1983).

(8) Upstream migration to other rivers

There remains a possibility of the upstream migration of the chum salmon to other rivers than the Simpson River, because the coastline of the XIth Region (Aysén Region) is very complicated. It is generally known that chum salmon returning to the mother river is more abundant than the salmon going up to other rivers in their homing migration, considering smiliar cases in fjords in Alaska and Canada. (Zama, 1985).

However, 7 chum salmon of 5-6 kg returned to southern Chile, not to the mother river, but to a small river in the XIIth Region in June-July 1986. These salmons are supposed to have been trapped in a small bay during their homing migration. Studies on the returns have just started, and results of the studies will be published elsewhere. (Unpublished).

6 – 4. Concluding Remarks

The present project has been executed for 14 years from 1973 up to present with objectives of settlement of Pacific salmons in southern Chile. The following investigations and trials have been undertaken to reach the goal: development and improvement of transportation techniques of eyed eggs and juveniles, improvement of hatching and rearing techniques, improvement of releasing techniques (suitable time and period, suitable releasing point, suitable size of fry, fingerings or juveniles for releasing), environmental studies (water quality, plankton, fishes) in rivers, fjords, channels and the open sea, trials to recapture the released juvenile and possible homing adults, etc. However, it is regrettable to note that the expected homing migration has not been realized in spite of these efforts.

For the past 14 years, various kinds of surveys and investigations have been undertaken to obtain data and to solve many problems. Even though, a few unsolved points still exist: (1) sea conditions and oceanic structure of the South Pacific, especially the sea area around 45°S, (2) migration routes and mechanisms of the salmon after the release until homing, (3) ability for homing migration, and (4) feeding conditions of the salmon in the open sea. It is almost impossible to solve these problems relating to the open sea. Therefore, various kind of trials have been conducted to testify them indirectly judging from the presence or absence of the homing migration by releasing juvenile salmon in different ways. In fact, a lot of experiments have been planned and performed, but successful results have not been produced as yet. At present, it is thought that these points may be the biggest and insuperable problems.

Salmonids are known to have a freshwater origin and to evolve their lives to expand their habitat zone to the sea. Several migration types are known among them. Cherry salmon makes a short migration in the sea, but also is able to complete its whole life cycle in freshwater (rivers and lakes). Coho salmon and pink salmon make a short migration in the offshore area. On the other hand, chum salmon and sockeye salmon have a long life in the ocean through an extensive migration.

It was confirmed that coho salmon and chinook salmon performed homing migration in Chile, and salmon ranching projects of these species already started. Cherry salmon is probably able to return home after feeding migration offshore of southern Chile or to settle in rivers and lakes, and has a potential of establishment of the resources.

The Chilean coast extends 4,000 km north to south, and the offshore area of southern Chile is rich with abundant resources of subantarctic fishes. This area is very extended and has potentials of holding a large quantity of fishery resources. Salmonids have several migration types as metioned above. In the future, these factors shall be considered for further development strategy of introduction of salmons. The Chilean waters still have great potentials for the establishment of salmon resources.

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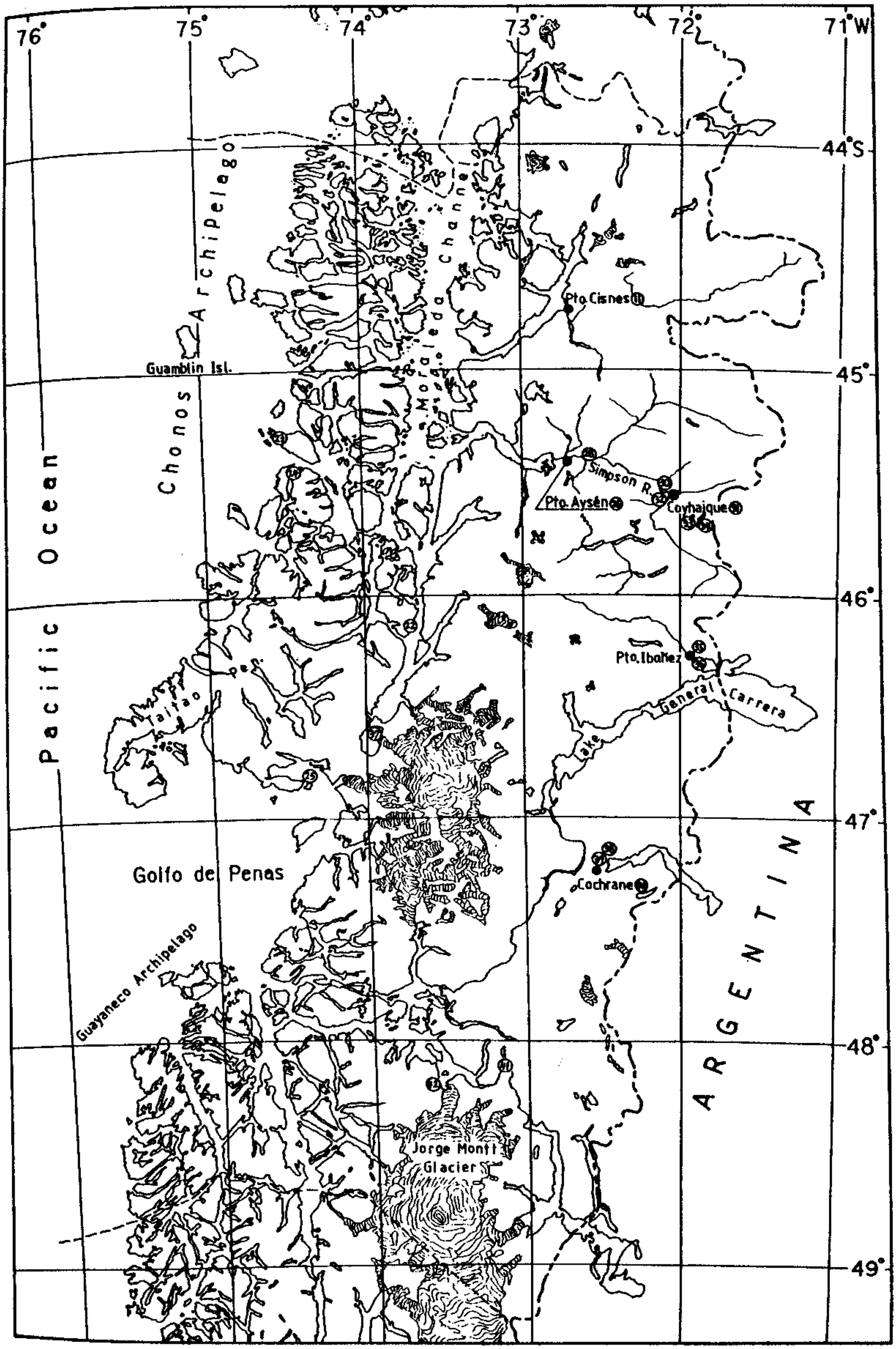
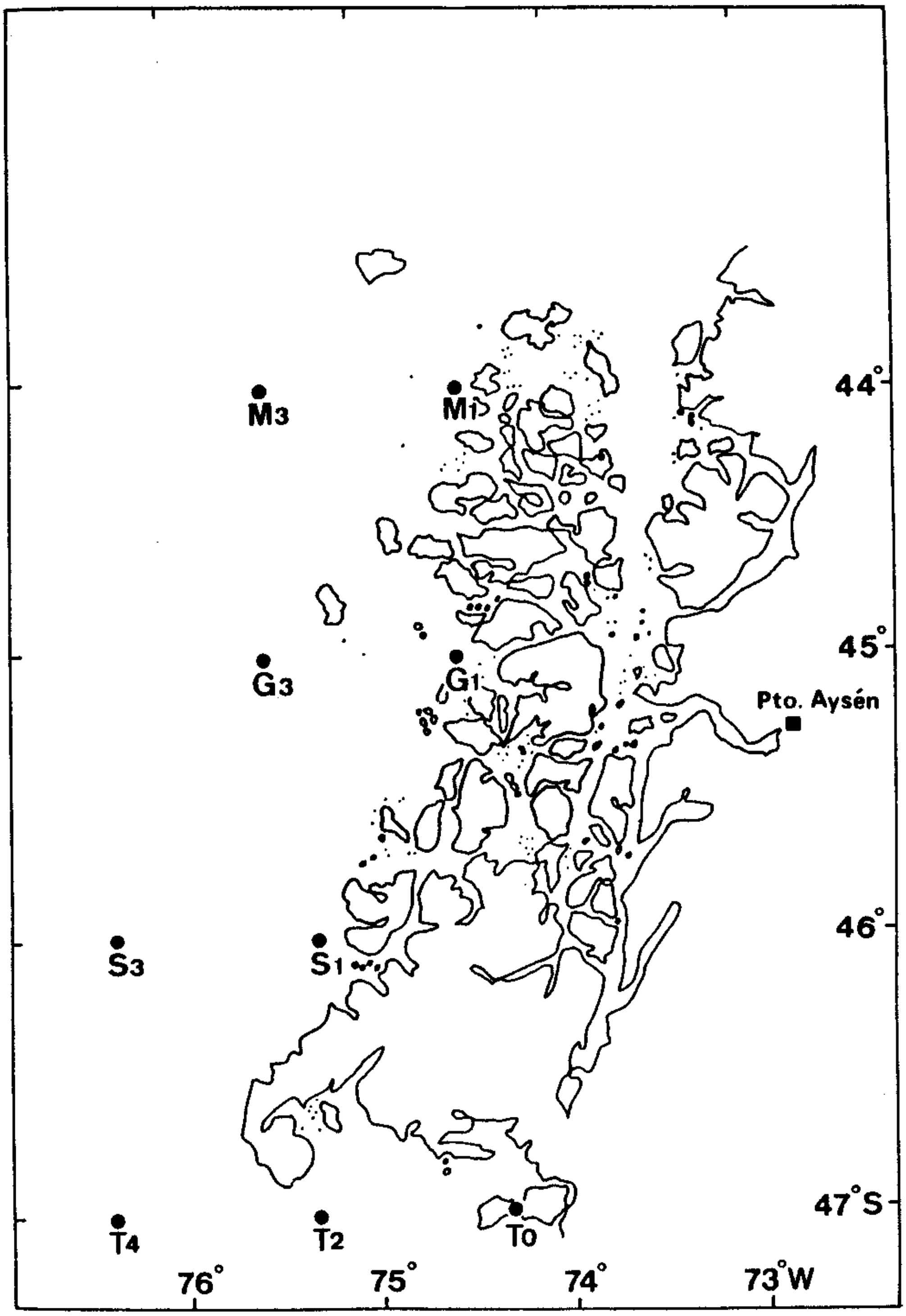
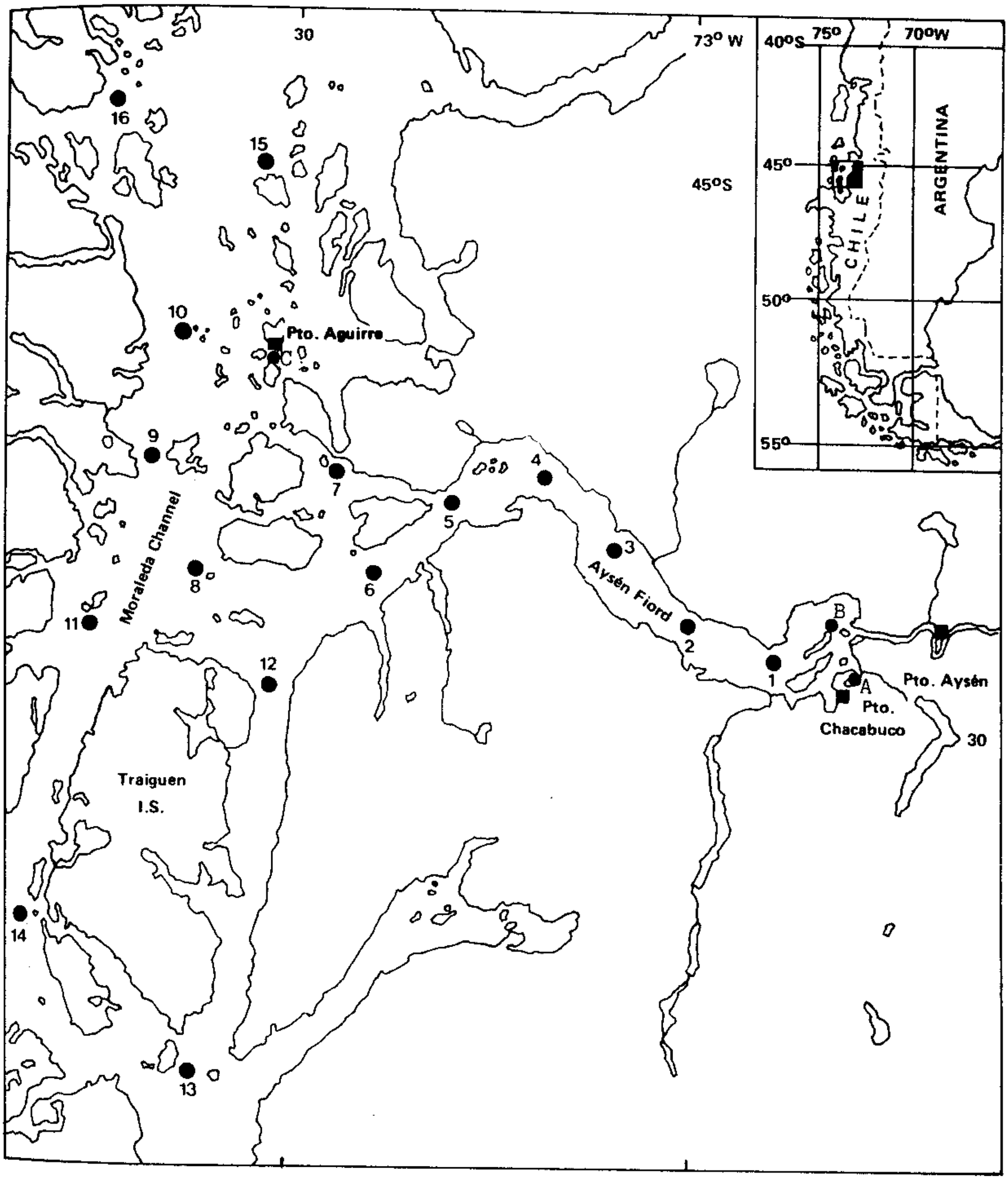


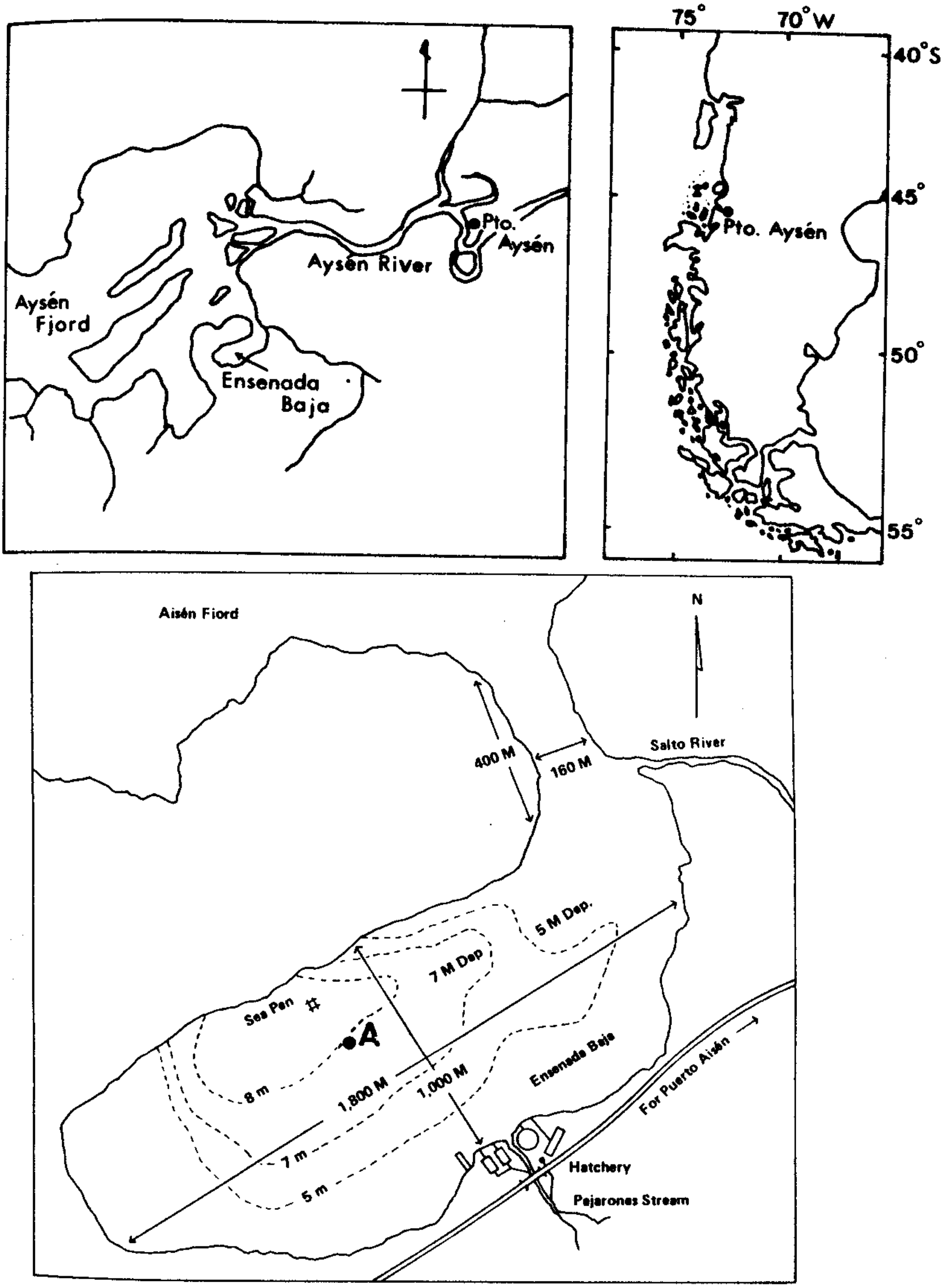
Map 1. Map of the XIth Region (Aysén Region) showing the study area of ecological researches on the introduction of Pacific salmon.



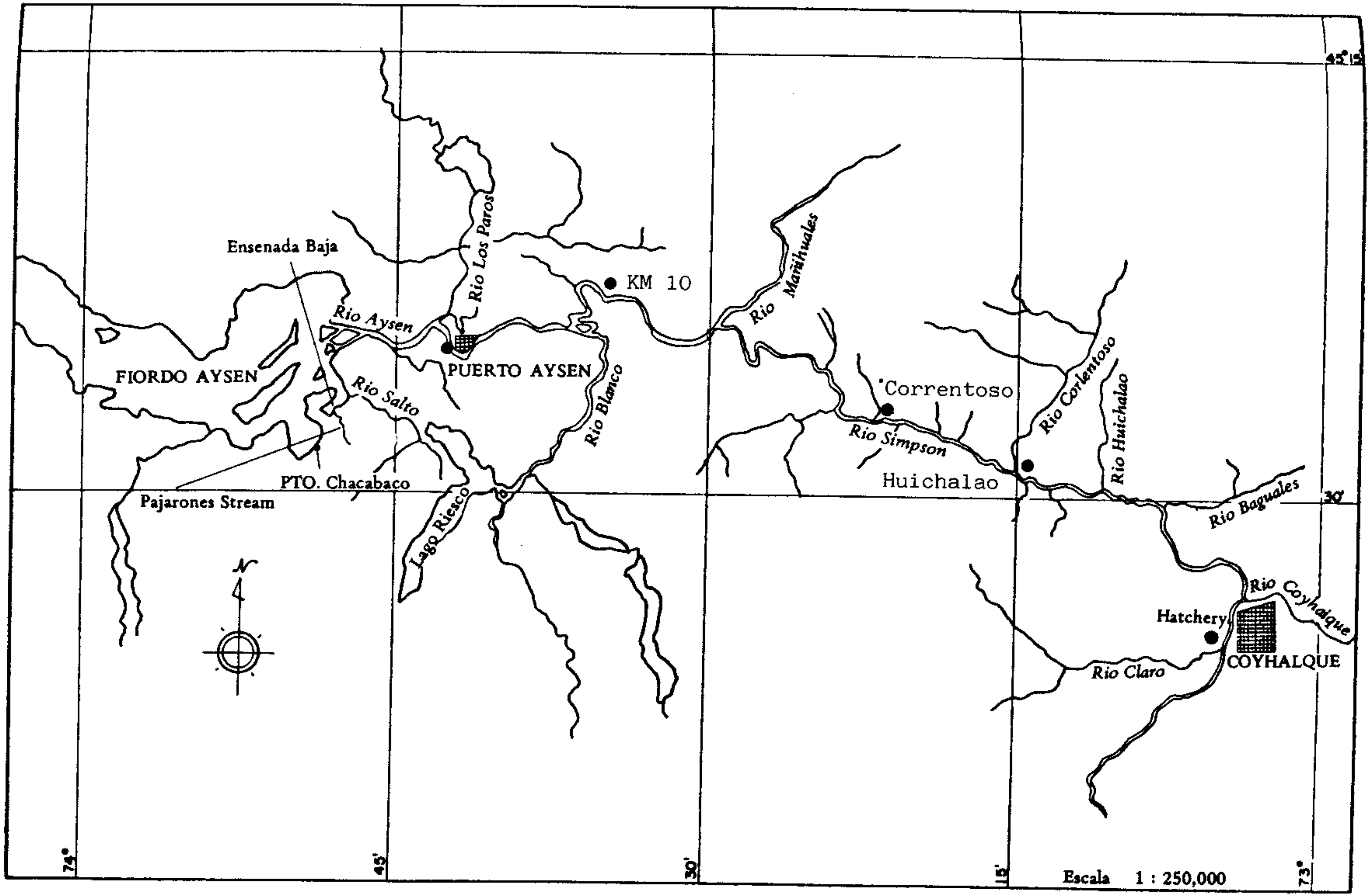
Map 2. Map of the Archipelago region showing the location of sampling stations.



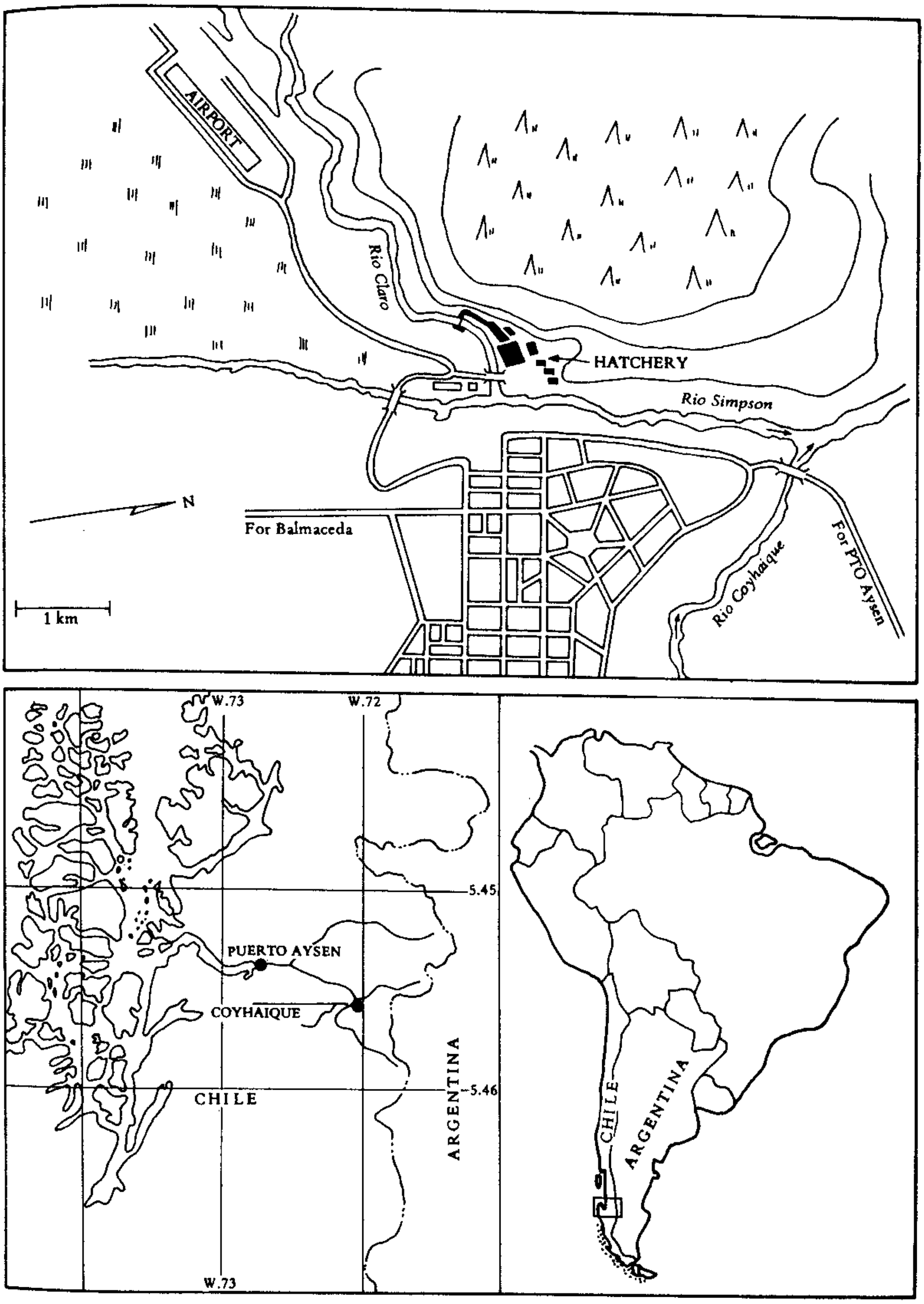
Map 3. Location map of sampling stations in Aysén Fjord and Moraleda Channel.



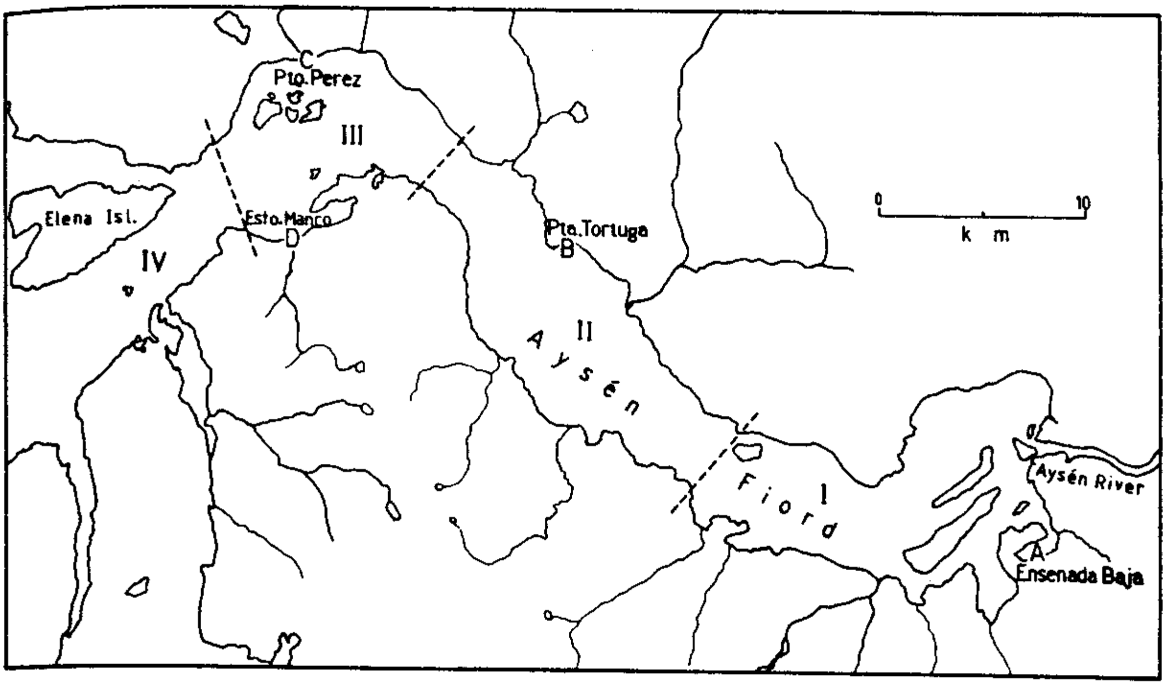
Map 4. Location map of Station A in Ensenada Baja.



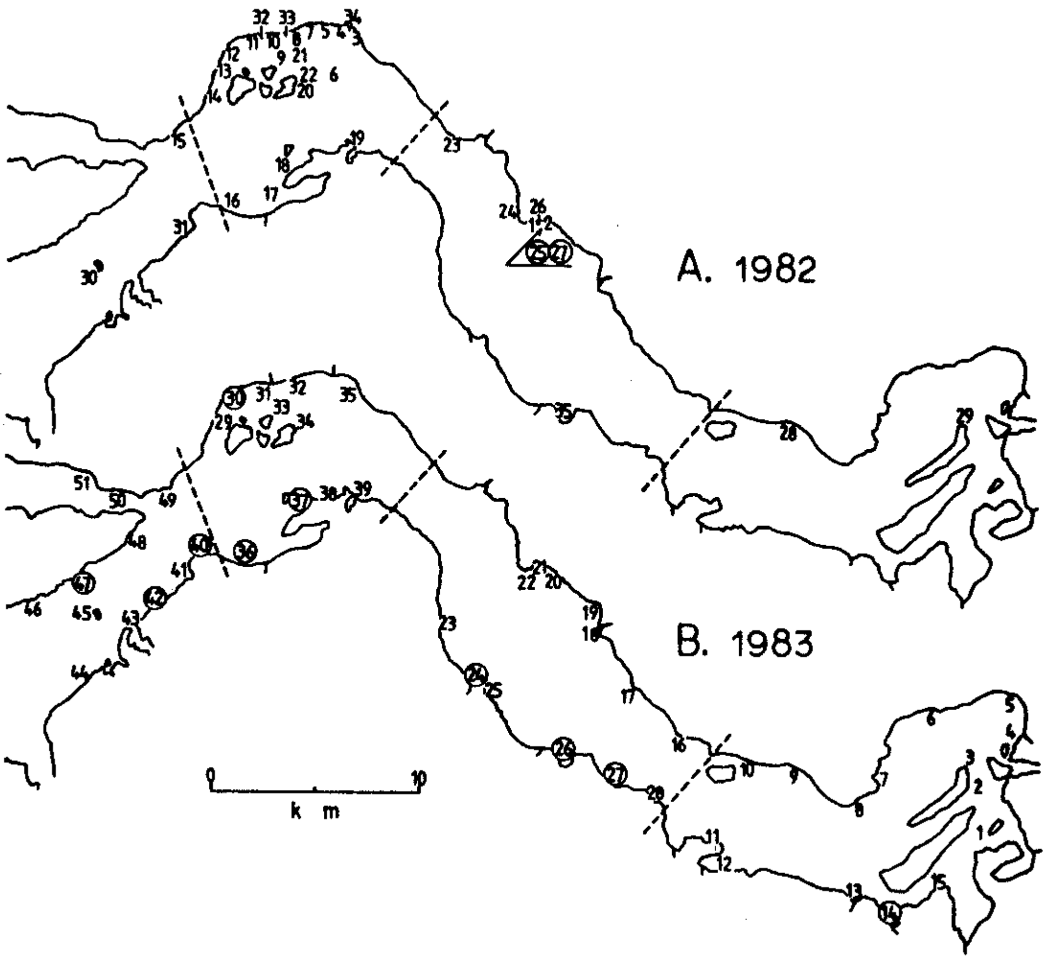
Map 5. Map of the Simpson River system, Salto River, Pajarones Stream, and locations of sampling stations and Coyhaique Hatchery.



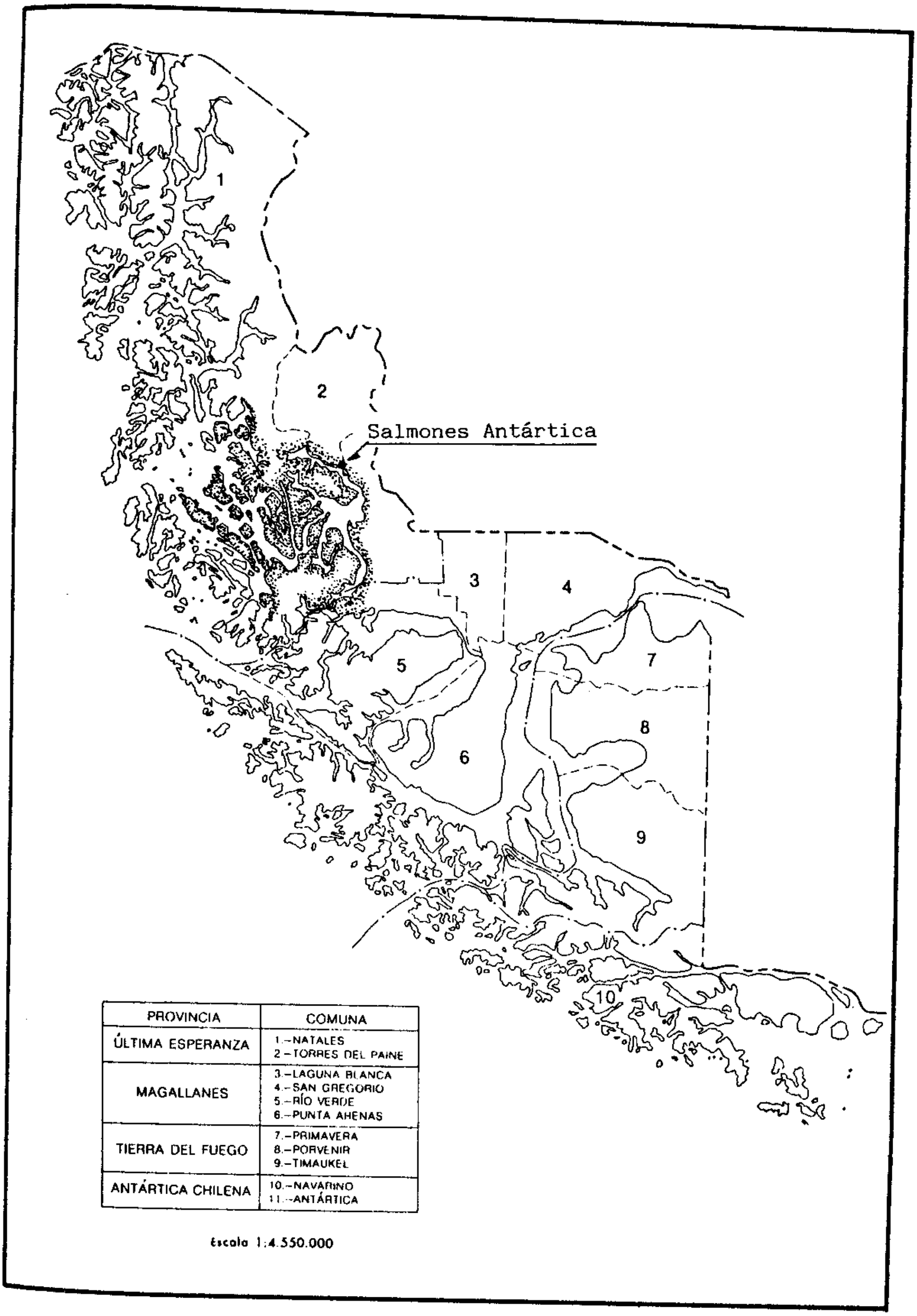
Map 6. Location map of Coyhaique Hatchery.



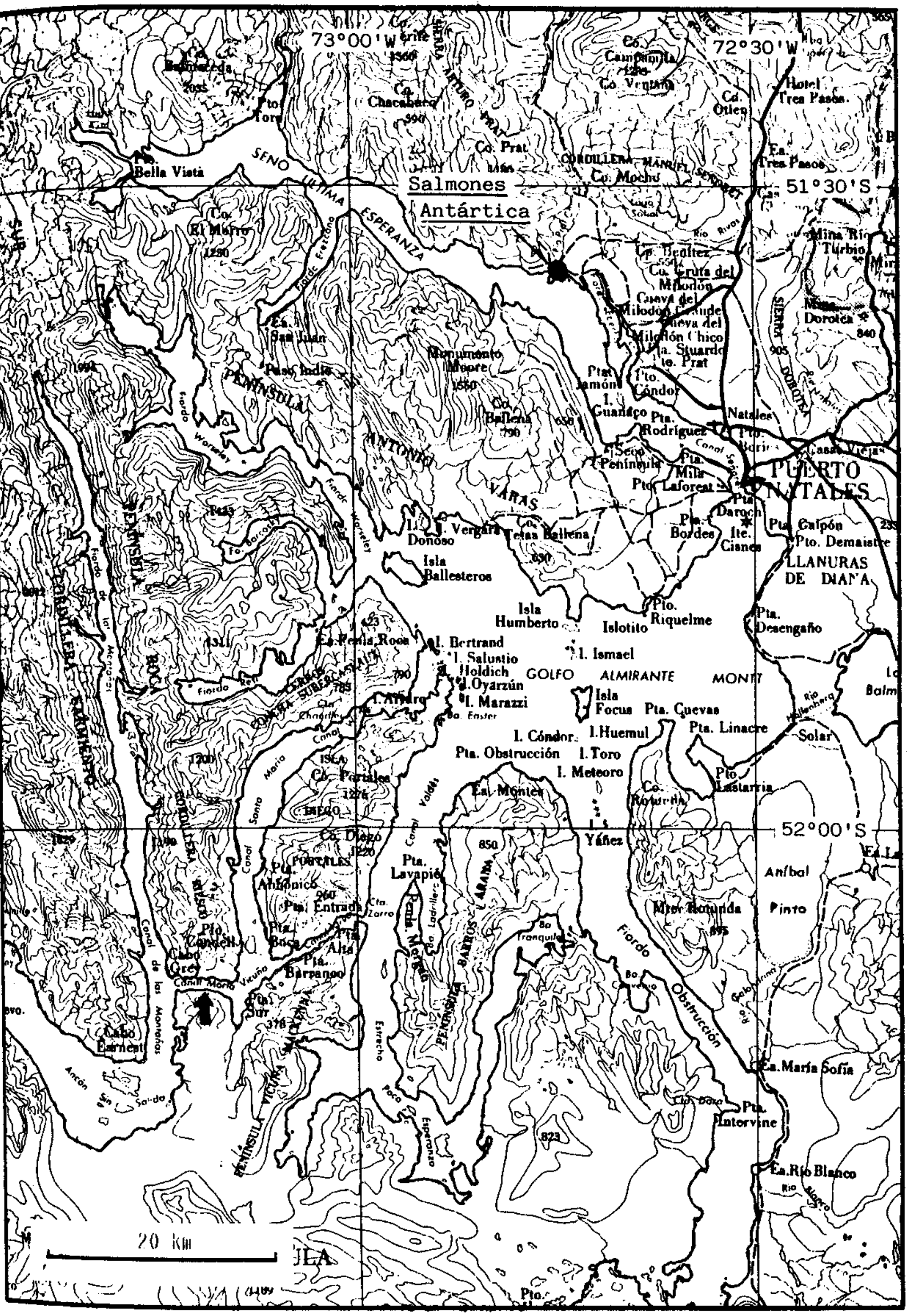
Map 7. Map of Aysén Fjord showing 4 sections (I - IV) of the fjord and sampling stations (A - D) for recapture trials of juvenile chum salmon by gill nets in 1979 - 1982.



Map 8. Map of Aysén Fjord showing sampling stations for recapture trials of juvenile chum salmon by purse seine in 1979 - 1982.



Map 9. Map of the XIIth Region (Magallanes Region) showing the location of Salmones Antártica.



Map 10. Map of Golfo Almirante Montt, Seno Ultima Esperanza and the location of Salmones Antártica.

Table 1. Freshwater fishes of the Simpson River system

Scientific name	Local name	Family
Geotria australis	Lamprea de bolsa	Petromyzonidae
Salmo gairdneri	Trucha arco iris	Salmonidae
S. trutta	Trucha fario	Salmonidae
Aplochiton taeniatus	Peladilla	Aplochitonidae
A. zebra	Peladilla	Aplochitonidae
Galaxias maculatus	Puye	Galaxiidae
G. platei	Puye	Galaxiidae
Hatcheria macraei	Bagrecito	Trychomycteridae
Eleginops maclovinus	Róbalo	Nototheniidae

Table 2. List of phytoplankton species in Ensenada Baja collected from February 1983 to February 1984

BACILLARIOPHYCEAE
- CENTRALES
  - *Skeletonema costatum*
  - *Thalassiosira* spp.
  - *Rhizosolenia delicatula*
  - *Chaetoceros* spp.
  - o *Melosira* sp. (*M. italica* type)
  - o *Melosira* sp.
  - o *Cyclotella* spp.
- PENNALES
  - *Nitzschia closterium*
  - o *Nitzschia* sp. (*N. acicularis* type)
  - o *Nitzschia* sp. (*N. palea* type)
  - o *Nitzschia* spp.
  - o *Fragilaria* spp.
  - o *Asterionella formosa*
  - o *Synedra ulna*
  - o *Ceratoneis arcus*
  - o *Cocconeis* spp.
  - o *Diploneis* spp.
  - o *Navicula* spp.
  - o *Gomphonema* spp.
  - o *Amphora* spp.
  - o *Cymbella sinuata*
  - o *Cymbella* spp.
  - o *Eunotia* sp.
  - o unidentified diatoms

DIONOPHYCEAE
- Prorocentrales
  - *Prorocentrum micans*
- Peridiniales
  - *Heterocaps triquetra*
  - *Peridinium* sp.

EUGLENOPHYCEAE
- unidentified Eugelenoida

Table 3. Seasonal changes in relative abundance of dominant zooplankton in Aysén Fjord, Moraleda Channel and the Archipelago region

Area	Zooplankton	Spring	Summer	Autumn	Winter
Fiord					
	Copepoda	70.1	57.7	79.5	66.7
	Non-pelagic invertebrate larvae	19.6	21.8	15.4	26.8
	Cladocera	4.8	5.8	+	0
	Decapoda larvae	2.4	+	+	0
	Euphausiacea egg and larvae	+	1.5	1.9	0
	Hydromedusae	+	4.9	+	+
	Appendicularia	+	3.5	+	+
	Fish egg and larvae	1.3	+	+	+
	Others	+	3.2	1.6	5.6
Channel					
	Copepoda	73.3	59.3	74.8	87.5
	Non-pelagic invertebrate larvae	11.5	6.1	19.5	6.5
	Cladocera	+	+	0	0
	Decapoda larvae	5.5	1.4	+	+
	Euphausiacea egg and larvae	1.9	15.9	+	+
	Hydromedusae	4.0	10.1	4.0	+
	Appendicularia	1.3	+	+	+
	Fish egg and larvae	2.1	5.5	0	+
	Others	+	+	1.2	4.3
Archipelago region					
	Copepoda	NO DATA	NO DATA	78.1	NO DATA
	Non-pelagic invertebrate larvae			1.9	
	Cladocera			0	
	Decapoda larvae			+	
	Euphausiacea egg and larvae			3.4	
	Hydromedusae			6.8	
	Appendicularia			7.9	
	Fish egg and larvae			+	
	Others			1.5	

+ ;less than 1%

Table 4a. Fish fauna and their geographical distribution in the XIth Region (1)

Species	Inland and open seas				River and lake		
	AF	M-E	MC	OC	SR	LS	OS
1. *Geotria australis*	+				+		
2. *Halaelurus bivius*	+	+	+				
3. *H. canescens*			+				
4. *Prionace glauca*				+			
5. *Centroscyllium granulosum*		+	+	+			
6. *Etmopterus paessleri*			+				
7. *Squalus acanthias*	+	+					
8. *Raja chilensis*		+					
9. *Callorhynchus callorhynchus*	+	+					
10. *Sprattus fuegensis*	+	+					
11. *Engraulis ringens*	+	+					
12. *Oncorhynchus keta*	+						
13. *O. kisutch*	+						
14. *Salmo gairdneri*	+	+			+		
15. *S. trutta*	+				+		
16. *Aplochiton marinus*							+
17. *A. taeniatus*			+		+		
18. *A. zebra*				+*	+		+
19. *Galaxias maculatus*	+	+	+	+	+		
20. *G. platei*					+		+
21. *Hatcheria macraei*					+		
22. *Gymnoscopelus nicholsi*				+			
23. *Physiculus marginatus*			+				
24. *Salilota australis*	+	+	+				
25. *Micromesistius australis*	+	+		+			
26. *Macruronus magellanicus*	+	+					
27. *Merluccius australis*	+	+		+			
28. *M. gayi*	+	+		+			
29. *Coelorinchus fasciatus*			+	+			
30. *C. patagoniae*			+	+			
31. *Cataetyx messieri*			+				
32. *Genypterus blacodes*	+	+					
33. *G. chilensis*		+					
34. *Echiodon cryomargarites*				+			
35. *Austrolycus depressiceps*		+		+		+	
36. *Melanostigma gelatinosum*				+			

(continued)

* From Port Otway according to Thompson (1916), who did not noted whether specimens were obtained from the fresh water or from the sea.

Table 4b. Fish fauna and their geographical distribution in the XIth Region (2)

Species	Inland and open seas				River and lake		
	AF	M-E	MC	OC	SR	LS	OS
37. *Scomberesox saurus scombroides*				+			
38. *Odontesthes bonariensis*							+
39. *O. smitti*	+	+					
40. *Leptonotus blainvilleanus*	+	+		+			
41. *Sebastes oculatus*	+	+	+				
42. *Congiopodus peruvianus*		+		+			
43. *Normanichtys crockeri*	+	+					
44. *Agonopsis chiloensis*	+			+			
45. *Careproctus crassus*		+					
46. *Percichthys trucha*							+
47. *Polyprion oxygeneios*		+		+			
48. *Prolatilus jugularis*	+	+					
49. *Trachurus murphyi*	+	+		+			
50. *Mugiloides chilensis*		+					
51. *Cottoperca gobio*	+	+		+			
52. *Eleginops maclovinus*	+	+	+		+	+	
53. *Notothenia brevicauda*	+	+	+				
54. *N. cornucola*		+					+
55. *N. longipes*	+	+					+
56. *N. tessellata*	+	+					+
57. *Harpagifer bispinis*			+				+
58. *Calliclinus geniguttatus*	+	+					
59. *Myxodes cristatus*		+					
60. *M. viridis*		+					
61. *Hypsoblennius sordidus*		+					
62. *Ophiogobius jenynsi*		+		+			
63. *Thyrsites atun*				+			
64. *Allothunnus fallai*	+						
65. *Scomber japonicus*	+						
66. *Seriolella porosa*	+						
67. *Stromateus stellatus*	+	+					
68. *Gobiesox marmoratus*		+		+			
69. *Hippoglossina macrops*	+						
70. *H. mystacium*				+			
71. *Mancopsetta milfordi*				+			
72. *Paralichthys microps*	+	+					
73. *Thysanopsetta naresi*				+			

Data are based on the present records and those shown in the synonymy in the text. The mouth of the Salto River is included in the category of Aysén Fiord; Baker and Martínez Channels in the Mesier Channel. AF, Aysén Fiord; M-E, Moraleda Channel to Elefantes Fiord; MC, Mesier Channel; OC, oceanic and coastal waters; SR, Simpson River system; LS, Lagoon San Rafael; OS, others (south of 46° S).

Tabla 5a. List of salmon releases by the present project (1)

Year	Month	Species	Number of releases	Size of releases BW (g)	Size of releases FL (cm)	Place of release*
1973	Jan.	Cherry	85,000	0.24	2.8	SiR
1974	May	Chum	645,000	0.33	3.2	SiR
1975	Jan.	Chum	900,000	0.44	3.5	SiR
	May	Chum	800,000	0.35	3.3	SiR
		TOTAL	1,700,000			
1976	Jan.	Chum	976,000	0.45	3.5	SiR
	May	Chum	756,000	0.37	3.5	SiR
	May	Chum	80,000	0.35	3.5	SaR
		TOTAL	1,812,000			
1977	Jan.	Chum	820,000	0.33	3.4	SiR
	May	Chum	1,461,000	0.35	3.7	SiR
	Sept.	Chum	50,000	1.82	5.9	SiR
	Oct.	Chum	10,000	1.82	5.9	SaR
		TOTAL	2,341,000			
1978	Jan.	Chum	228,000	0.30	3.5	SaR
	Fab.	Chum	1,500,000	1.24	5.4	SiR
		TOTAL	1,728,000			
1979	Aug.	Chum	282,000	2.00	6.6	SiR
	Oct.	Chum	253,000	3.11	7.7	SiR
	Oct.	Chum	123,000	3.40	8.0	EB
	Nov.	Chum	97,000	4.66	8.4	EB
	Dec.	Chum	40,000	16.00	12.2	EB
		TOTAL	795,000			
1980	Sept.	Chum	484,000	2.81	7.0	SiR
	Sept.	Chum	178,000	9.26	11.1	EB
	Oct.	Chum	449,000	5.54	8.9	SiR
	Oct.	Chum	83,000	8.26	10.9	EB
	Oct.	Chum	363,000	14.09	12.6	EB
	Dec.	Chum	101,000	79.98		EB
		TOTAL	1,658,000			

* SiR : Simpson River
SaR : Salto River
EB : Ensenada Baja

Table 5b. List of salmon releases by the present project (2)

Year	Month	Species	Number of releases	Size of releases BW(g)	Size of releases FL(cm)	Place of release*
1981	Feb.-Apr.	Chum	400	193.0	–	EB
	May	Chum	1,700	279.0	31.3	EB
	Aug.	Chum	900	330.0	32.6	EB
	Sept.	Chum	428,000	4.87	7.7	SiR
	Sept.	Chum	553,000	11.50	11.4	EB
	Oct.	Chum	453,000	6.06	9.0	SiR
	Oct.	Chum	262,000	5.41	9.0	EB
	Nov.	Chum	604,000	6.77	9.8	EB
	Nov.	Chum	276,000	18.20	13.6	EB
		TOTAL	2,579,000			
1982	Jan.	Chum	490	1,145.0	46.0	EB
	Jan.	Chum	7,700	28.9	14.9	PA
	Jan.	Chum	7,700	40.5	17.1	EB
	Feb.	Chum	275,000	5.0	8.5	SiR
	Mar.	Chum	3,200	105.0	23.3	EB
	Mar.	Chum	3,200	157.0	24.4	PA
	Oct.	Chum	810,000	4.4	8.2	SiR
	Oct.	Chum	181,000	6.5	9.3	EB
	Oct.	Chum	457,000	15.4	12.1	EB
	Oct.	Chum	35,000	27.0	14.5	PA
	Nov.	Cherry	22,000	37.2	15.2	SiR
	Nov.	Cherry	9,000	25.7	13.3	DP
	Dec.	Pink	1,350	195.6	25.0	EB
		TOTAL	1,812,640			
1983	Jan.	Chum	41,000	85.6	19.8	EB
	Feb.	Chum	6,000	92.3	20.0	EB
	Feb.	Chum	500	202.0	25.6	PA
	Feb.	Chum	100	1,028.0	43.1	PA
	Apr.	Chum	118	1,063.0	48.5	EB
	Apr.	Pink	221	350-540	31-34	EB
	May	Chum	154	1,513.0	47.5	EB
	July	Chum	170	889.0	41.9	EB
	July	Pink	155,000	18.8	12.9	EB
	Sept.	Chum	895,000	4.8	8.2	SiR
	Oct.	Chum	901,000	13.7	11.7	EB
	Oct.	Chum	390,000	6.0	9.0	EB
	Oct.	Chum	497,000	5.0	8.4	EB
	Nov.	Cherry	57,000	21.0	12.8	SiR
	Dec.	Chum (C)	31,000	3.0	7.1	SiR
	Dec.	Pink (C)	700	3.4	7.4	EB
		TOTAL	2,974,963			

* SiR : Simpson River
SaR : Salto River
EB : Ensenada Baja
PA : Puerto Aguirre
DP : Don Poli Lake
(C) : Chilean origin

Table 5c. List of salmon releases by the present project (3)

Year	Month	Species	Number of releases**	Size of releases BW(g)	FL(cm)	Place of release*
1984	Jan.	Cherry	3,000	43.0	15.7	DP
	Jan.	Cherry	7,000	43.0	15.7	SiR
	Jan.	Cherry	3,000	49.0	15.8	PC
	Feb.	Pink	20,000	0.35	–	EB
	Mar.	Pink	259,000	1.37	6.3	EB
	Nov.	Chum	615,500	11.5	11.1	EB
	Nov.	Chum	402,000	6.5	9.4	SiR
	Nov.	Cherry	26,300	18.3	12.3	SiR
		TOTAL	1,335,800			
1985	Apr.	Pink	716,000	2.2	7.3	EB
	Aug.	Chum	682,000	5.2	8.4	SiR
	Aug.	Chum	900,000	3.7	7.5	SiR
	Aug.	Chum	695,000	4.2	7.9	SiR
	Sept.	Chum	162,000	5.8	8.6	LPR
		TOTAL	3,155,000			
1986	Feb.	Chum	35,300	51.6	18.6	LP
	Mar.	Pink	850,000	1.3	5.8	EB
	Mar.	Cherry	8,600	15.5	11.2	FL
	Mar.	Cherry	7,000	15.5	11.2	DP
		TOTAL	900,900			

* DP : Don Poli Lake
EB : Ensenada Baja
FL : Frío Lake
LP : Los Palos Lake
LPR Los Palos River
PC : Puerto Cisnes
SiR : Simpson River

** The total number of releases until July 1986 is:
(1) Chum : 21,292,000
(2) Pink : 2,002,000
(3) Cherry : 228,000
(4) Grand total : 23,522,000

(after JICA report (1984) by an evaluation mission headed by Mr. Shirahata, and supplemented by unpublished recent data until July 1986).

Table 6. Origin of released salmon used for recapture trials in 1979 - 1983

Date of release	Place of release	Number released	Mean size at release		Rearing facility
			Length (SD)	Weight (SD)	
Nov. 24, 1979	Ensenada Baja	25,000	8.6 TL	5.1	Pond to floating pen
Oct. 22, 1980	Coyhaique	449,000	8.9 FL	5.5	Pond
Oct. 26, 1980	Ensenada Baja	83,000	10.9 TL	8.4	Pond
Oct. 27, 1980	Ensenada Baja	363,000	12.6 TL	14.1	Pond to floating pen
Sep. 7, 1981	Coyhaique	428,000	7.7 FL	4.9	Pond
Sep. 12, 1981	Ensenada Baja	553,000	11.4 FL (± 1.1)	11.5 (± 4.5)	Pond to floating pen
Oct. 15, 1982	Coyhaique	810,000	8.2 FL	4.4	Pond
Oct. 22, 1982	Ensenada Baja	457,000	12.1 FL (± 1.0)	15.4 (± 3.8)	Pond to floating pen
Oct. 22, 1982	Ensenada Baja	181,000	9.3 FL (± 0.8)	6.5 (± 1.5)	Pond
Sep. 20, 1983	Coyhaique	895,000	8.2 FL	4.8	Pond
Oct. 1, 1983	Ensenada Baja	497,000	8.4 FL (± 0.7)	5.0 (± 1.1)	Pond
Oct. 1, 1983	Ensenada Baja	390,000	9.0 FL (± 0.7)	6.0 (± 1.2)	Pond to floating pen
Oct. 1, 1983	Ensenada Baja	901,000	11.7 FL (± 1.1)	13.7 (± 4.0)	Pond to floating pen

Table 7. Migration rates of released juvenile chum salmon in Aysén Fjord from Ensenada Baja

Date of release	Date of collection	No. of days after release	Station	Distance from Ensenada Baja (km)	Migration rate per day (km)
1981					
Oct. 12	Oct. 15	3	C	49	16.3
1982					
Oct. 22	Oct. 31	9	25 & 27	33	3.7
1983					
Oct. 1	Oct. 5	4	14	9	2.3
Oct. 1	Oct. 11	10	24	32	3.2
Oct. 1	Oct. 11	10	26	27	2.7
Oct. 1	Oct. 11	10	27	25	2.5
Oct. 1	Oct. 18	17	30	51	3.0
Oct. 1	Oct. 18	17	36	49	2.9
Oct. 1	Oct. 18	17	37	47	2.8
Oct. 1	Oct. 21	20	40	51	2.6
Oct. 1	Oct. 21	20	42	55	2.8
Oct. 1	Oct. 21	20	47	58	2.9

Table 8. Stomach contents of juvenile chum salmon recaptured in Aysén Fjord in 1979 - 1983

Section	I	II	III	IV	I - IV
No. of fish examined	18	31	12	20	81
Total no. of preys	13461	871	1238	873	16443
Average no. of preys per stomach	748	28	103	44	203
POLYCHAETA					
Syllidae juvenile			+ (1)		+(1)
CLADOCERA					
Podon leuckarti	719.9(6)	16.6(14)	60.4(9)	0.1(1)	175.3(30)
CALANOIDA					
Acartia tonsa			0.4(4)	+(1)	+(5)
Aetideus armatus				+(1)	+(1)
Calanoides patagoniensis			14.6(9)	1.9(7)	2.6(16)
Calanus chilensis		0.1(3)	0.5(4)	7.0(10)	1.8(17)
Calanus sp.		+(1)		+(1)	+(2)
Candacia cheirura			+(1)	0.2(3)	+(4)
Drepanopus sp.			2.6(5)	0.6(5)	0.5(10)
Euchaeta sp.				7.7(3)	1.9(3)
Metridia lucens			2.3(4)	3.1(7)	1.1(11)
Paracalanus parvus		+(1)			+(1)
Rhincalanus nasutus		+(2)	0.2(2)	8.0(6)	2.0(10)
Calanoida spp.	0.2(1)	0.2(4)	7.7(7)	0.7(4)	1.4(16)
HARPACTICOIDA					
Harpacticoida sp.	0.7(5)	0.9(7)	0.2(2)		0.5(14)
CIRRIPEDIA					
Balanidae cypris	22.4(6)	1.4(6)	1.6(4)		5.7(16)
Cirripedia (cirri)		+(1)	+(1)		+(2)
AMPHIPODA					
Gammaridea spp.		0.3(7)			+(7)
Hyperiidae spp.				0.2(3)	+(3)
EUPHAUSIACEA					
Euphausiidae larvae			+(1)	2.0(13)	0.5(14)
MACRURA					
Sergestes larvae	0.3(2)	3.3(11)	3.8(7)	1.0(9)	2.1(29)
Macrura mysis			+(1)	0.1(1)	+(2)
ANOMURA					
Munida zoea		+(1)	0.2(2)	1.6(9)	0.4(12)
Callianassidae zoea				+(1)	+(1)
Porcellanidae zoea	0.5(1)	+(1)	0.3(4)		0.2(6)
BRACHYURA					
Atelecyclidae zoea	1.8(4)	0.5(3)	1.1(4)		0.7(11)
Brachyura zoea	0.7(2)	0.3(4)	0.7(2)	0.2(3)	0.4(11)
Brachyura megalopa			+(1)	1.4(5)	0.4(6)
INSECTA					
Chironomidae larvae	0.1(2)	+(1)			+(3)
Aquatic insects		0.2(4)	0.2(2)		+(6)
Terrestrial insects	1.3(6)	2.5(8)	0.4(3)	0.4(4)	1.4(21)
SAGITTOIDEA					
Sagitta sp.			0.3(2)	1.0(4)	0.3(6)
APPENDICULARIA					
Oikopleura sp.			+(1)	0.6(3)	0.2(4)
PISCES					
Fish eggs				0.2(1)	+(1)
Sprattus fuegensis larvae		1.0(7)	3.3(8)	5.3(11)	2.2(26)
Galaxias maculatus larvae		+(2)		+(1)	+(3)
Eleginops maclovinus larvae		0.1(3)	0.5(2)	0.2(3)	0.2(8)
Fish larvae		0.5(11)	1.5(6)	0.3(3)	0.5(20)
Number of prey items	10	22	28	28	38
Total occurrence of preys	35	102	99	123	359

Average number of prey organisms per stomach and frequency of occurrences are shown in parentheses. +: less than 0.1.

Table 9. Number and size of fishes collected in Ensenada Baja from October 1980 to March 1984

Species	No. of fishes collected	Total length (cm)	Standard length (cm)	Body weight (g)
C. callorhynchus	1	75.7	–	2260
O. keta	18	31.0 - 54.7	28.3 - 47.5	220 - 1720
S. gairdneri	19	29.1 - 61.0	24.4 - 53.5	220 - 2750
S. trutta	226	21.5 - 69.7	18.2 - 61.5	100 - 3680
M. australis	17	47.0 - 81.0	42.5 - 78.8	855 - 3570
M. gayi	1	34.1	33.7	250.
O. smitti	16	29.3 - 31.6	25.0 - 27.4	200 - 300
E. maclovinus	279	11.3 - 56.1	16.0 - 48.9	60 - 1730
T. murphyi	103	48.5 - 64.2	42.8 - 55.0	930 - 2000
S. stellatus	6	25.6 - 31.6	20.4 - 27.0	225 - 540

Table 10. Predators on juvenile chum salmon released in Ensenada Baja

Species	Oct. 23 to Nov. 3, 1980	Nov. 7 to 20, 1981	Oct. 18 to Nov. 6, 1982	Sept. 27 to Oct. 17, 1983	Mar. 20 to 26, 1984	TOTAL
S. trutta	8 (22)	21 (185)	22 (81)	27 (166)	2 (3)	80 (457)
M. australis				7 (48)		7 (48)
M. gayi	1 (1)					
E. maclovinus	20 (27)	2 (13)	2 (6)	12 (51)		36 (97)
T. murphyi					6 (100)	6 (100)
TOTAL	29 (50)	23 (198)	24 (87)	46 (265)	8 (103)	130 (703)

Numbers of predators and young salmon eaten (in parentheses) during each investigation.

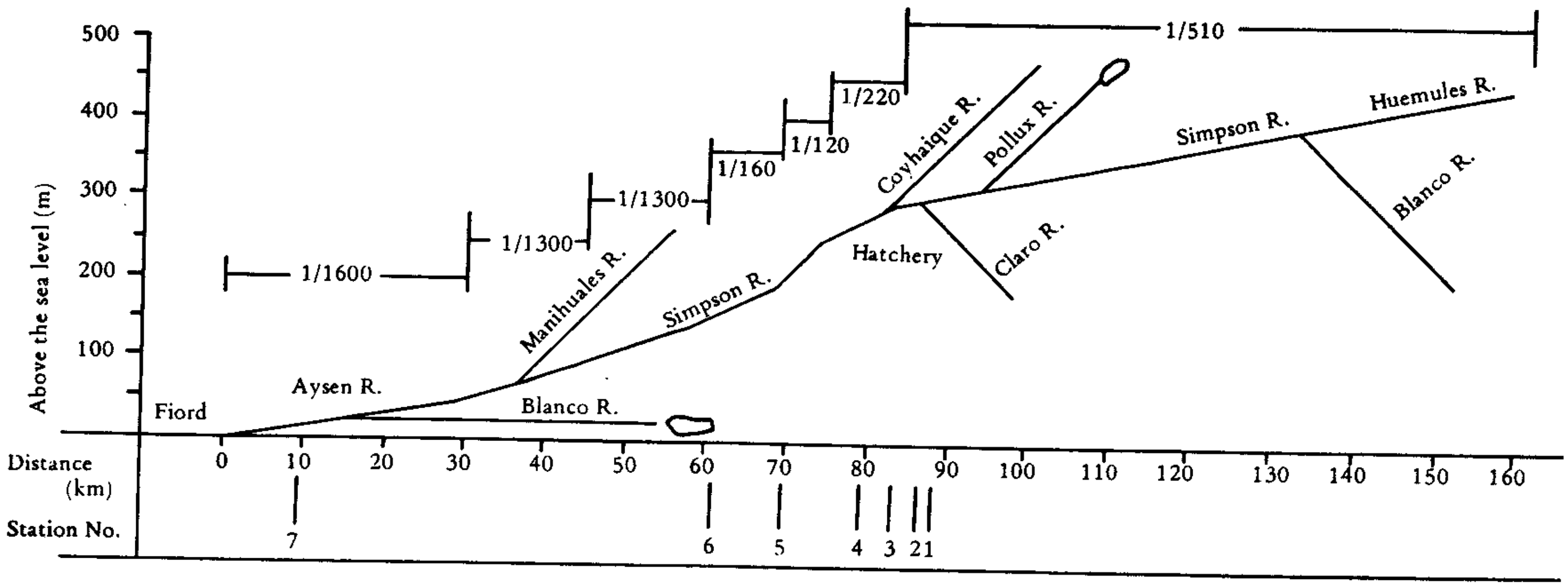


Fig. 1. Schematic drawing of the Sympson River system showing gradients and height above the sea level.

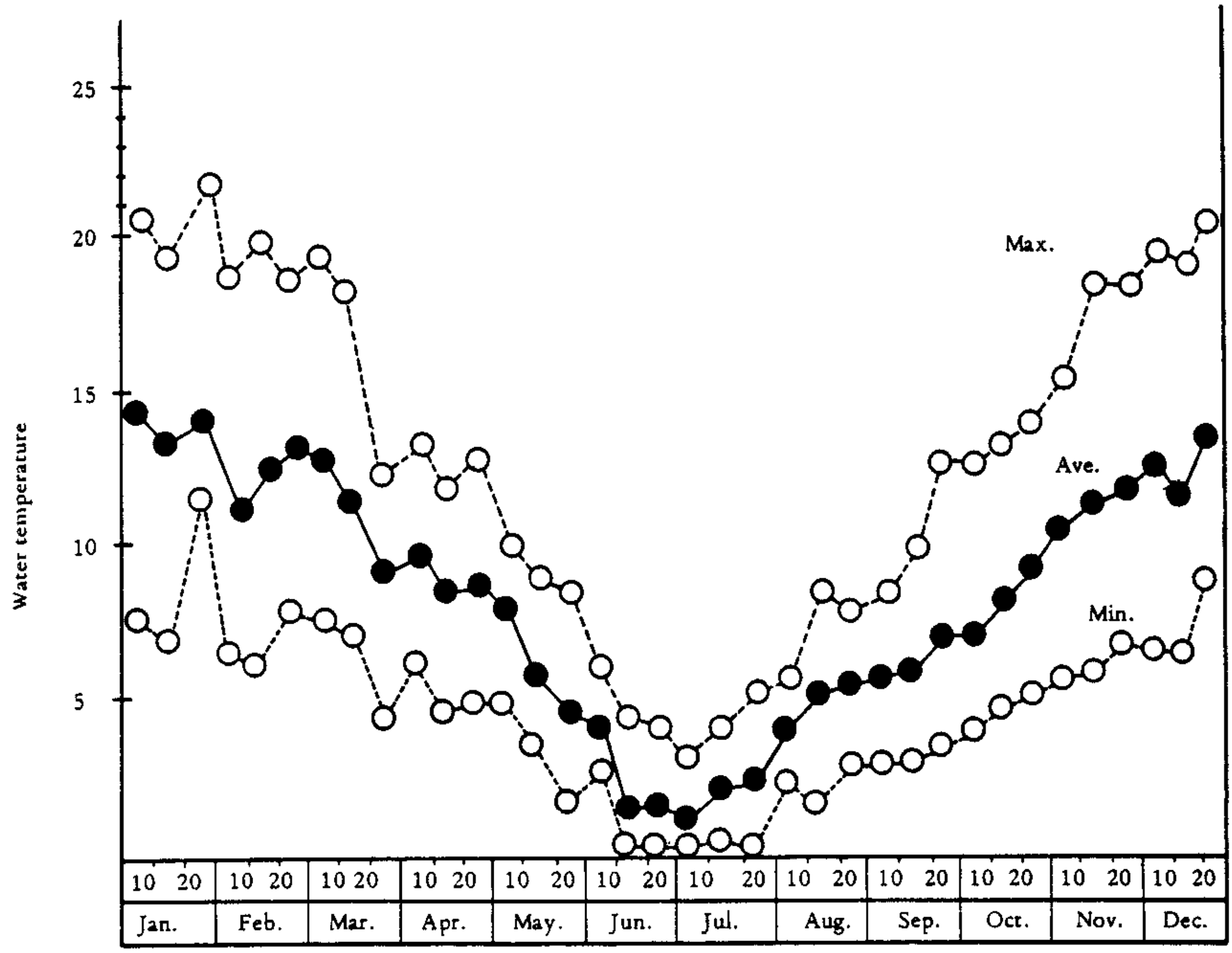


Fig. 2. Seasonal fluctuation of water temperature at Coyhaique Hatchery in 1982 (The average, maximum and minimum of the daily temperature for every 10 days).

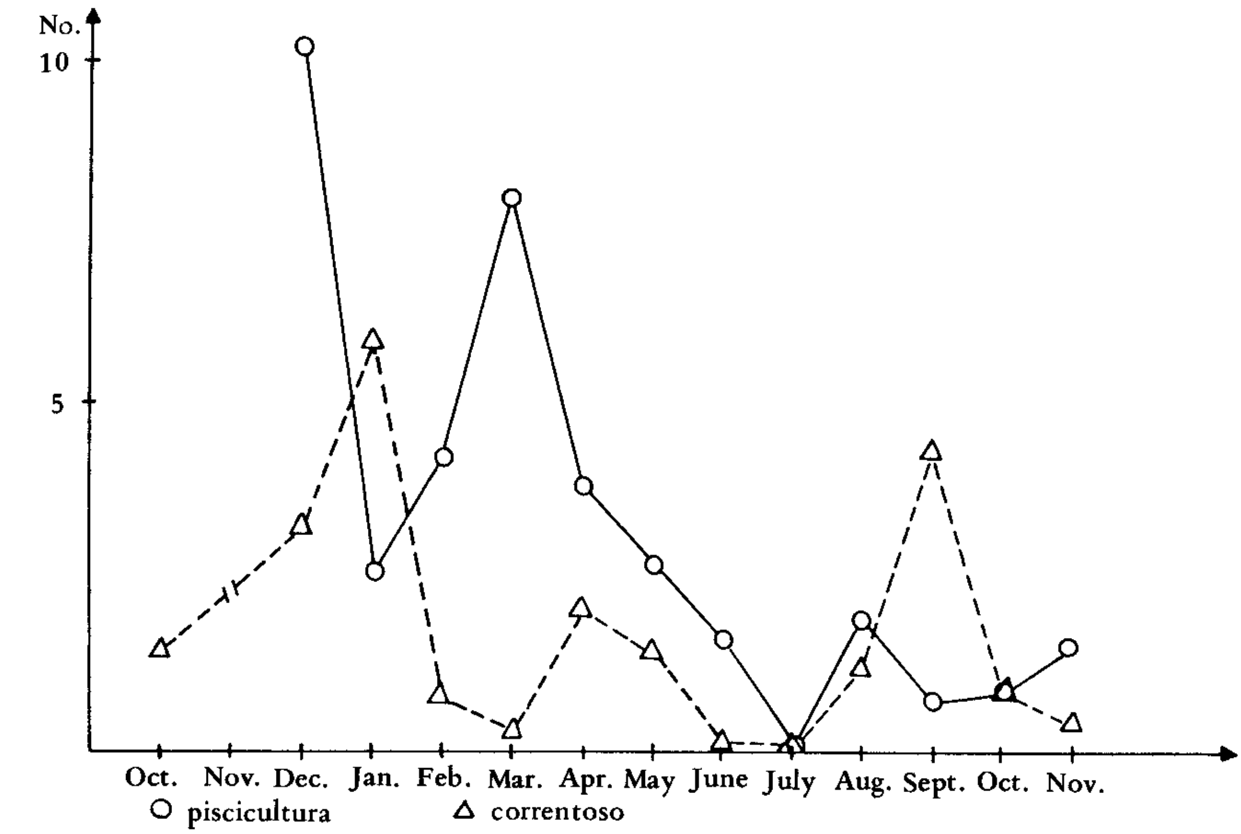


Fig. 3. Number of aquatic insects (drift) per m^3 at 2 stations in the Simpson River from October 1980 to November 1981.

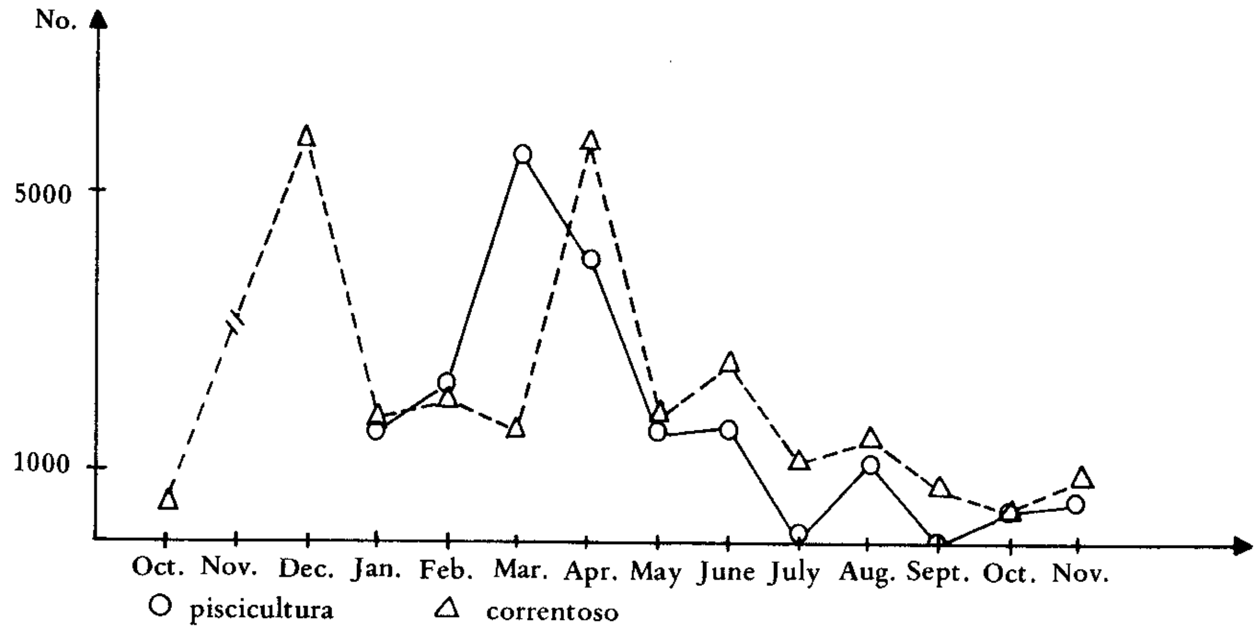


Fig. 4. Number of aquatic insects (benthos) per m^2 at 2 stations in the Simpson River from October 1980 to November 1981.

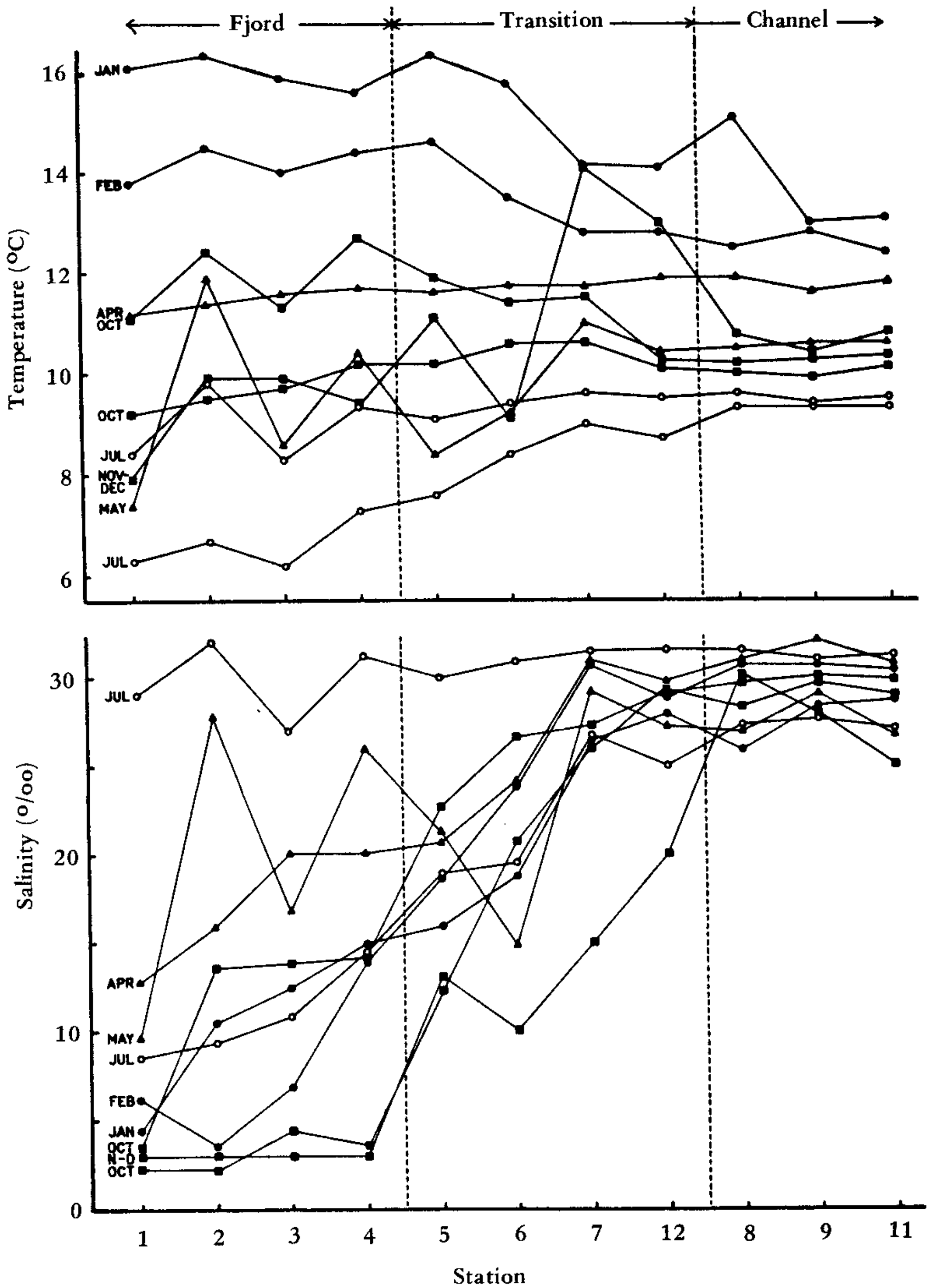


Fig. 5. Horizontal distribution and seasonal fluctuation of surface water temperature and salinity in Aysén Fjord, the transitional area and Moraleda channel.

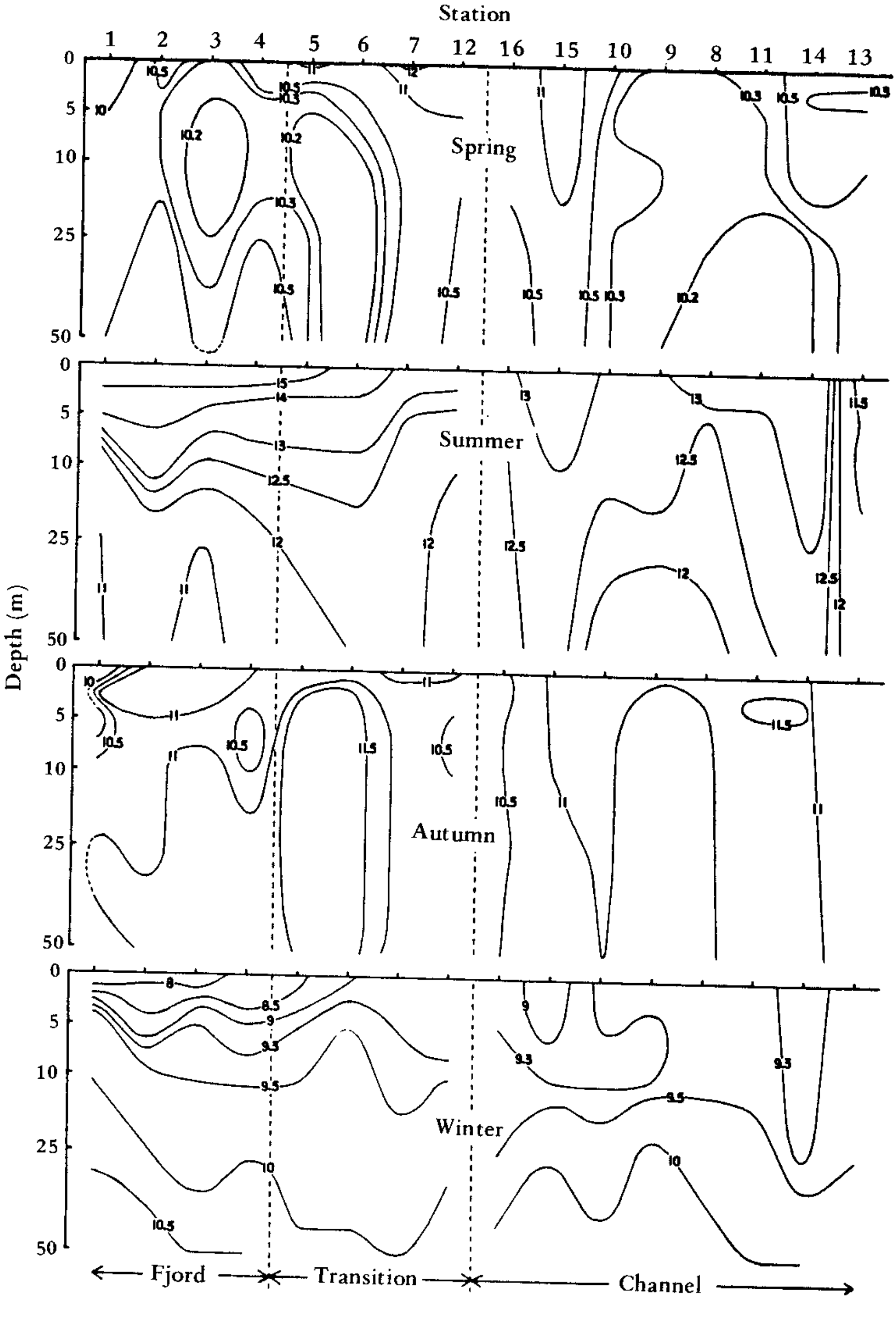


Fig. 6. Horizontal and vertical isothermal chart in 0 - 50 m layer by season in Aysén Fjord, the transitional area and Moraleda Channel.

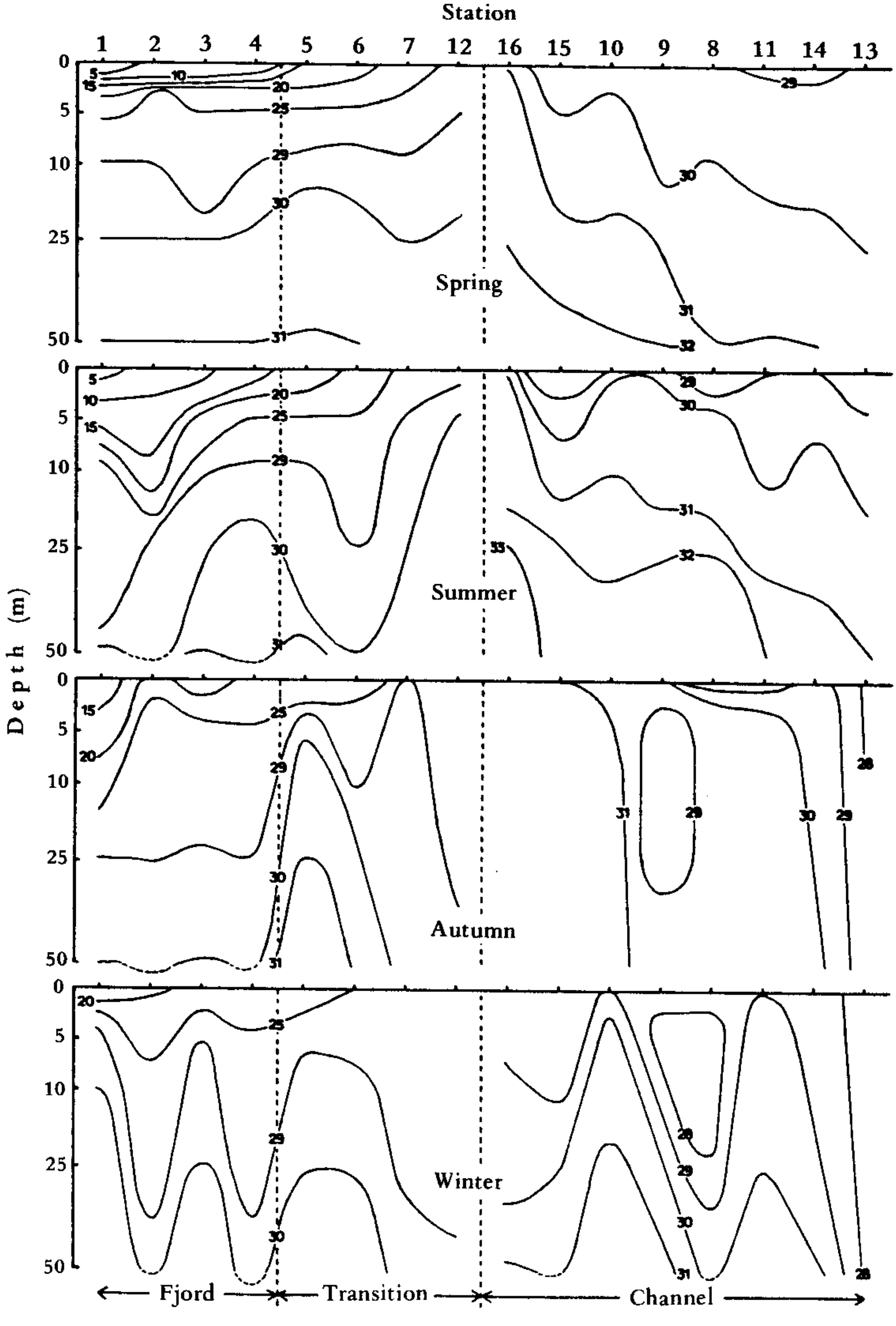


Fig. 7. Horizontal and vertical isohaline chart in 0 - 50 m layer by season in Aysén Fjord, the transitional area and Moraleda Channel.

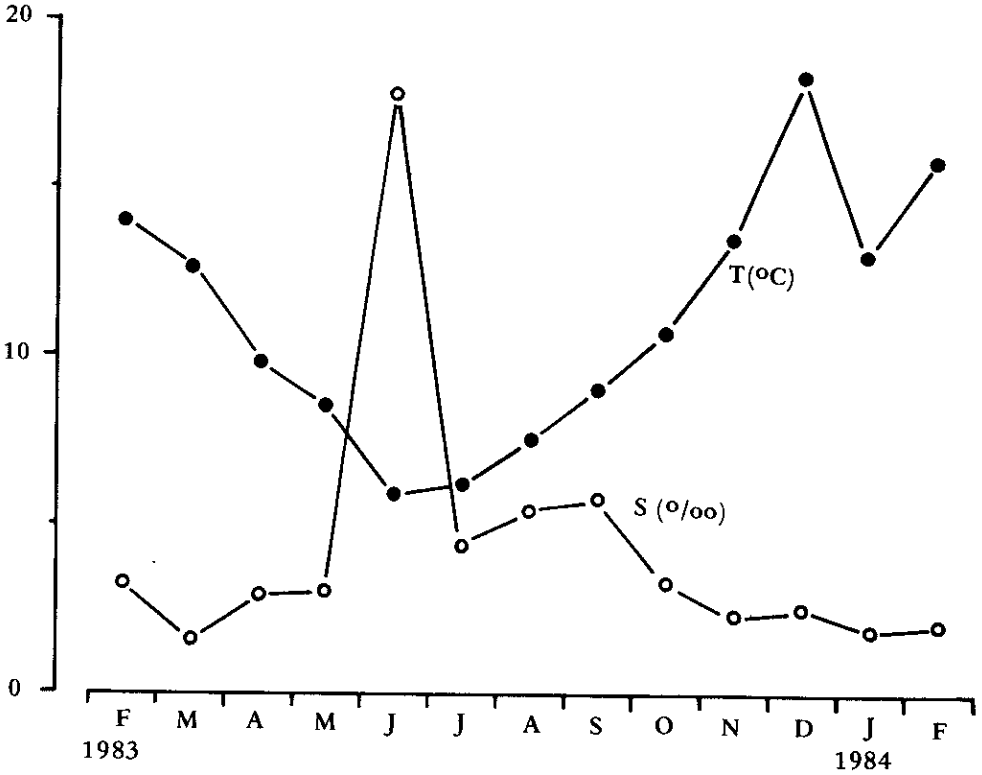


Fig. 8. Seasonal changes of surface temperature and salinity at Station A in Ensenada Baja from February 1983 to February 1984.

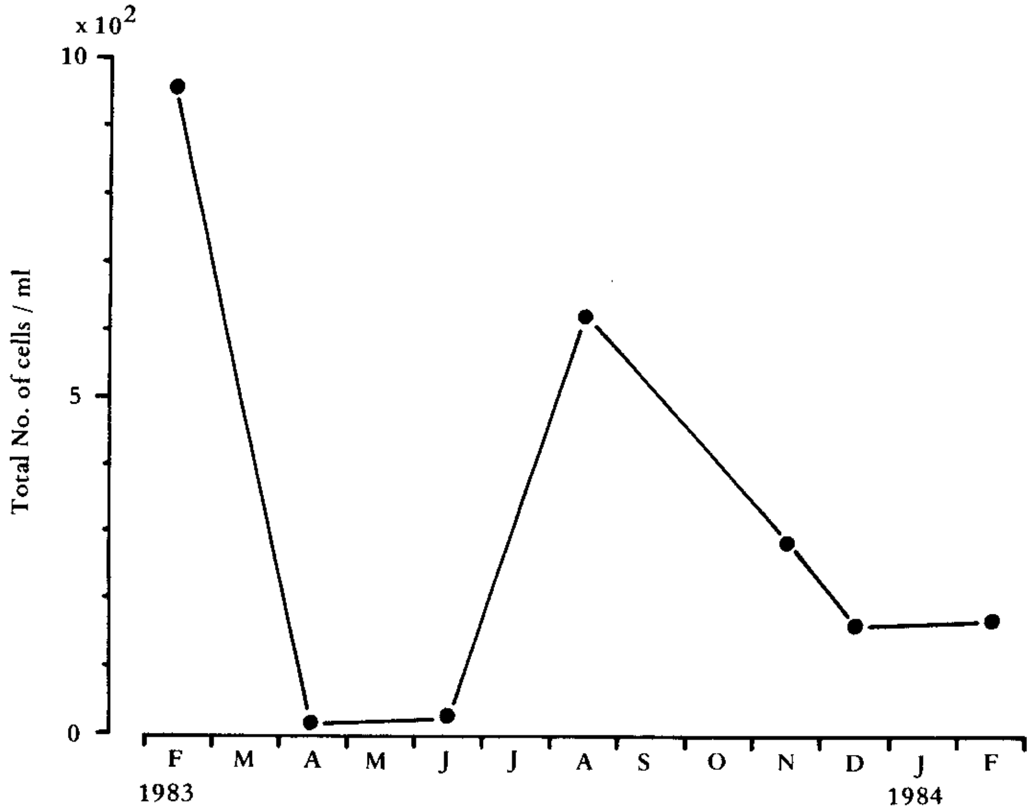


Fig. 9. Seasonal changes in phytoplankton density at Station A in Ensenada Baja from February 1983 to February 1984.

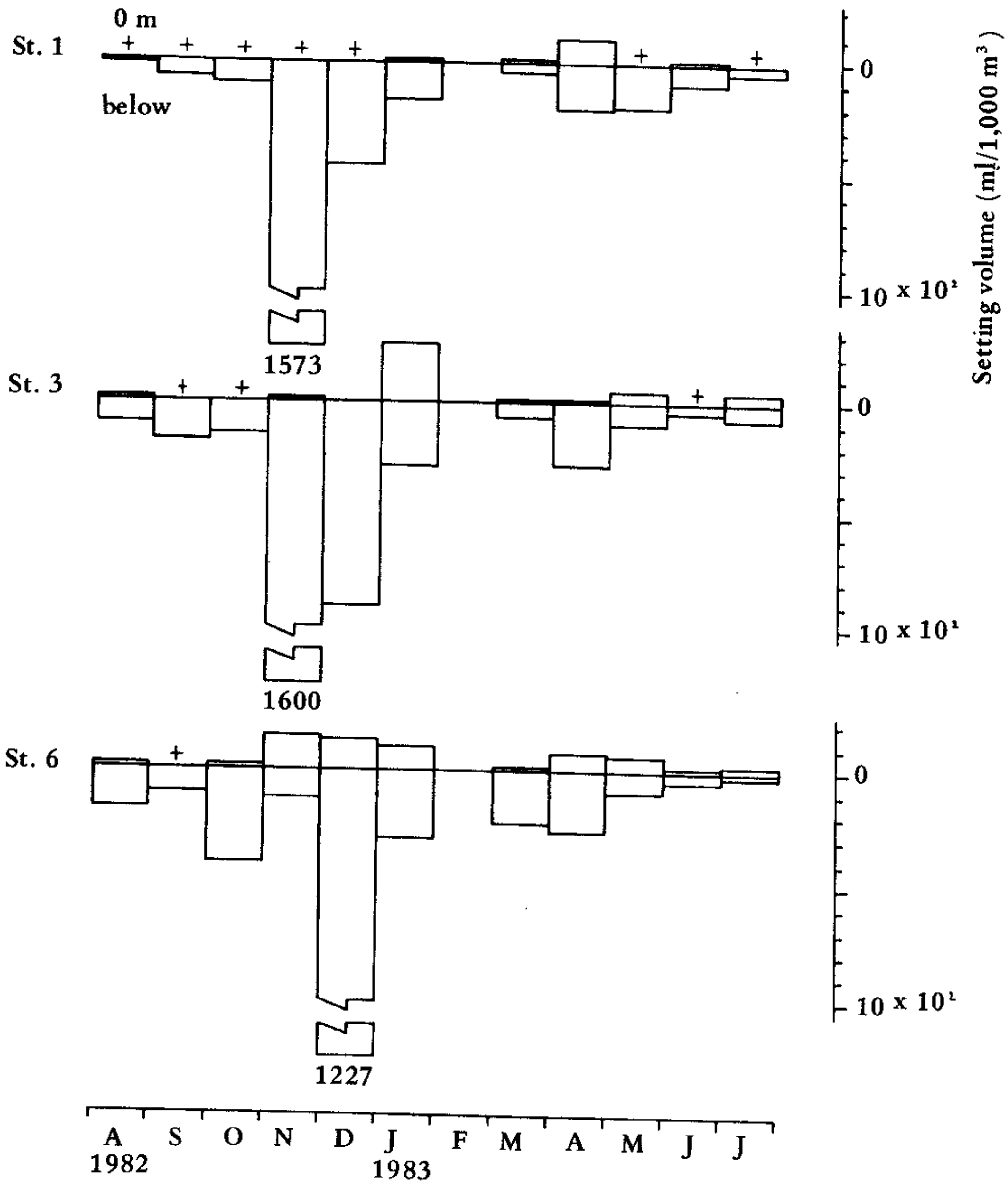


Fig. 10. Monthly changes in setting volume of zooplankton by station by layer in Aysén Fjord from August 1982 to July 1983.

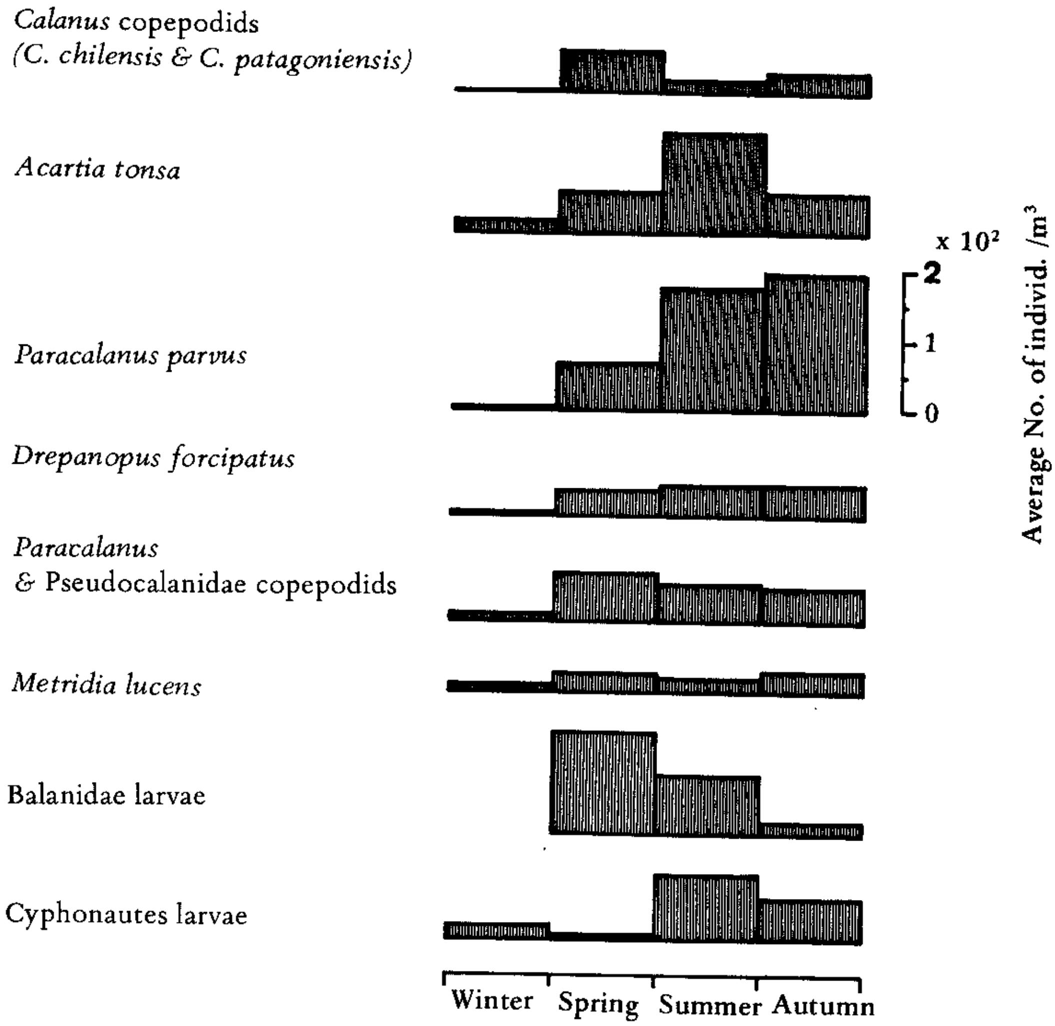


Fig. 11. Seasonal abundance of 8 major zooplankton in Aysén Fjord.

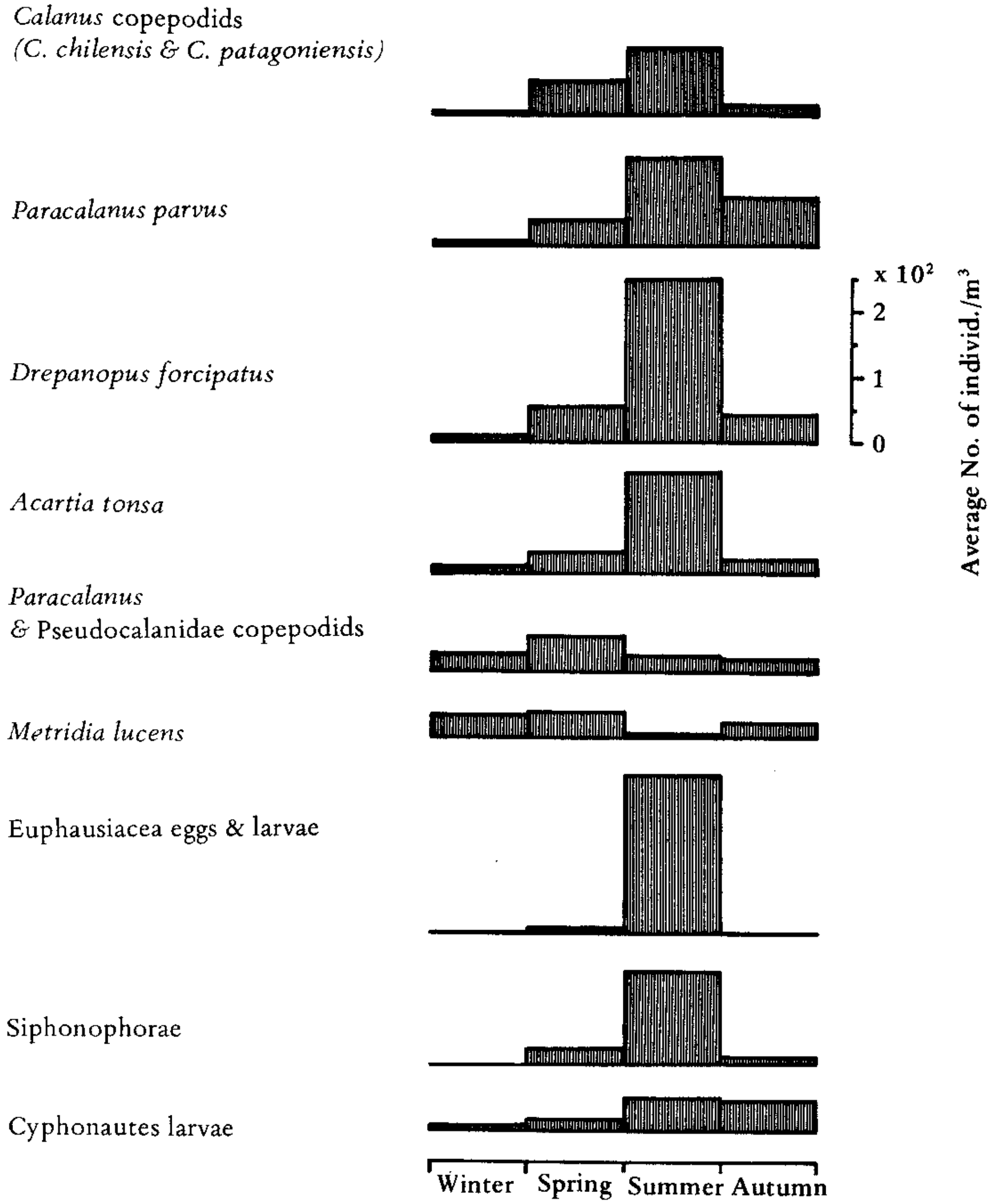


Fig. 12. Seasonal abundance of 9 major zooplankton in Moraleda Channel.

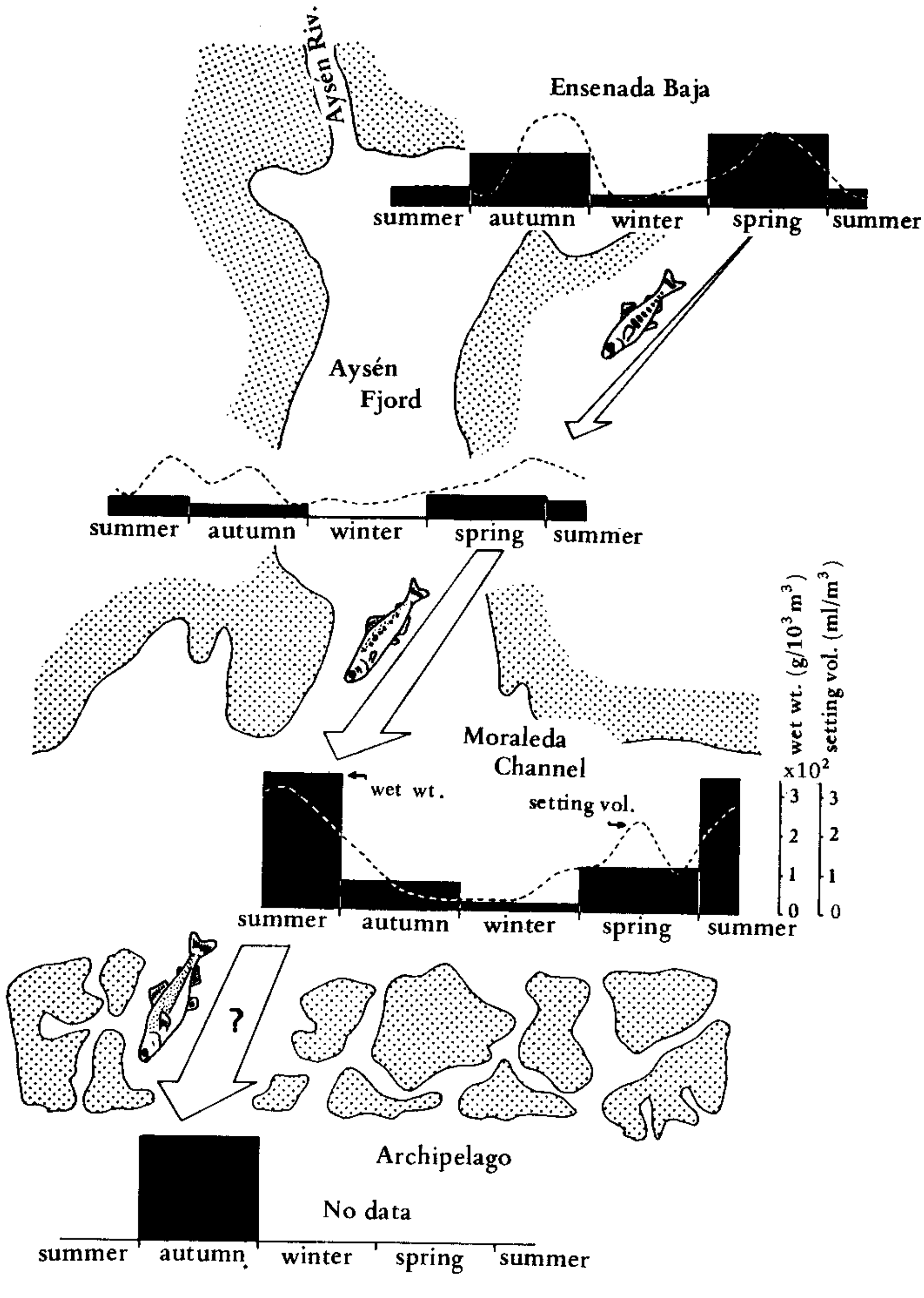


Fig. 13. Schematic diagrams showing seasonal changes in zooplankton biomass and the migration route of released juvenile salmon with growth from Ensenada Baja to the Archipelago region.

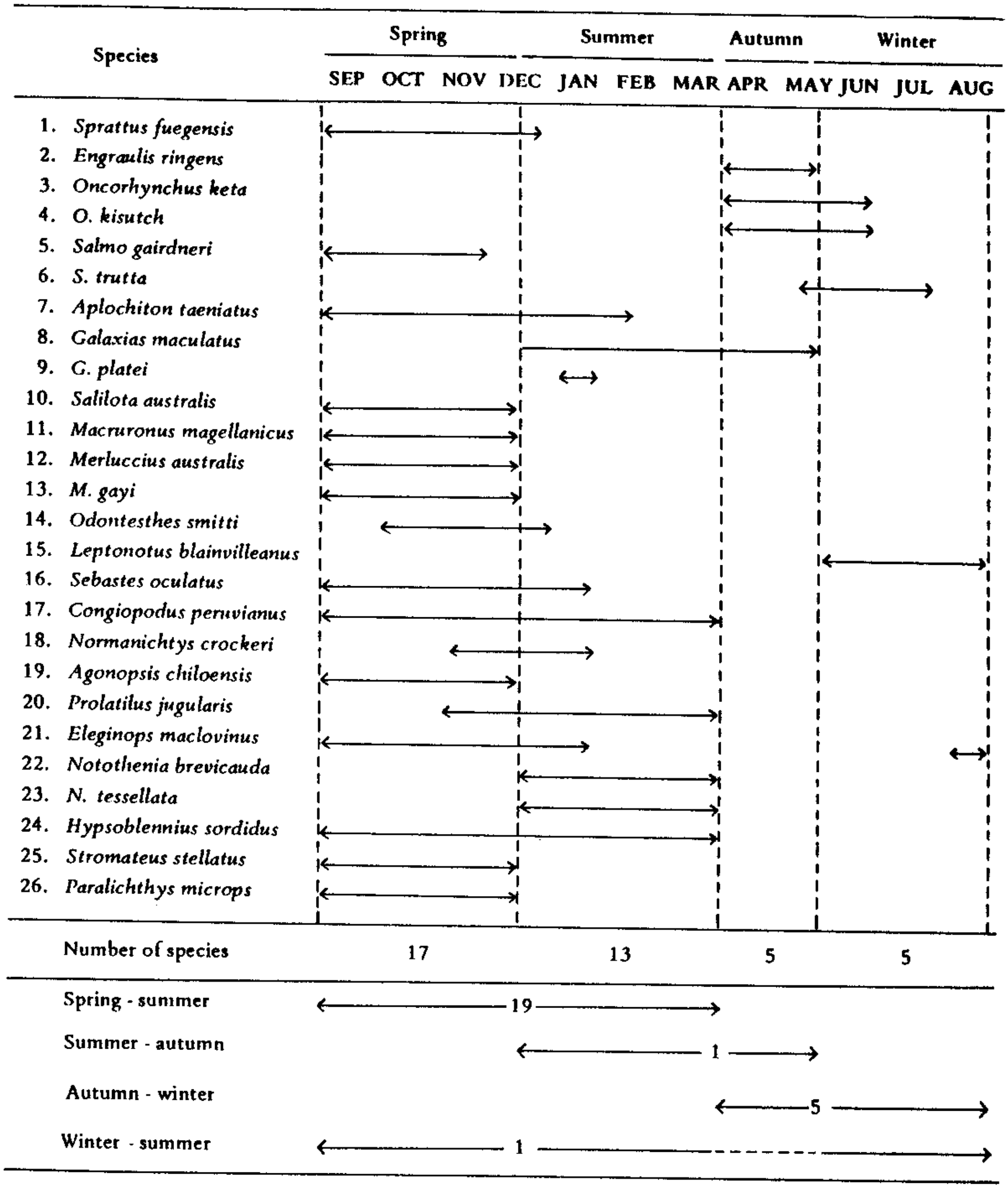


Fig. 14. Spawning season of fishes living in the XIth Region.

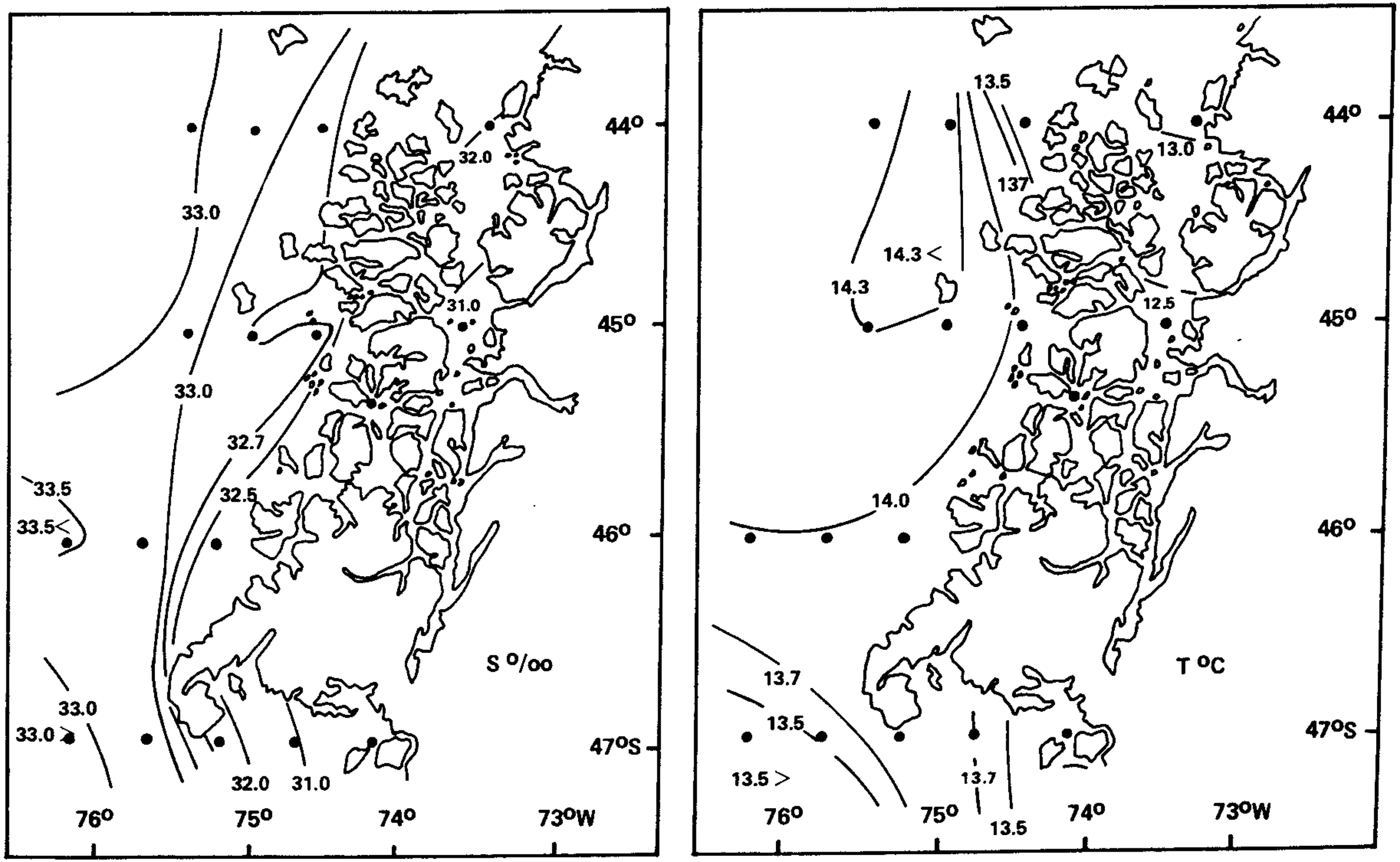


Fig. 15. Isohaline and isothermal charts in the surface of the Archipelago region in March 10 - 15, 1982.

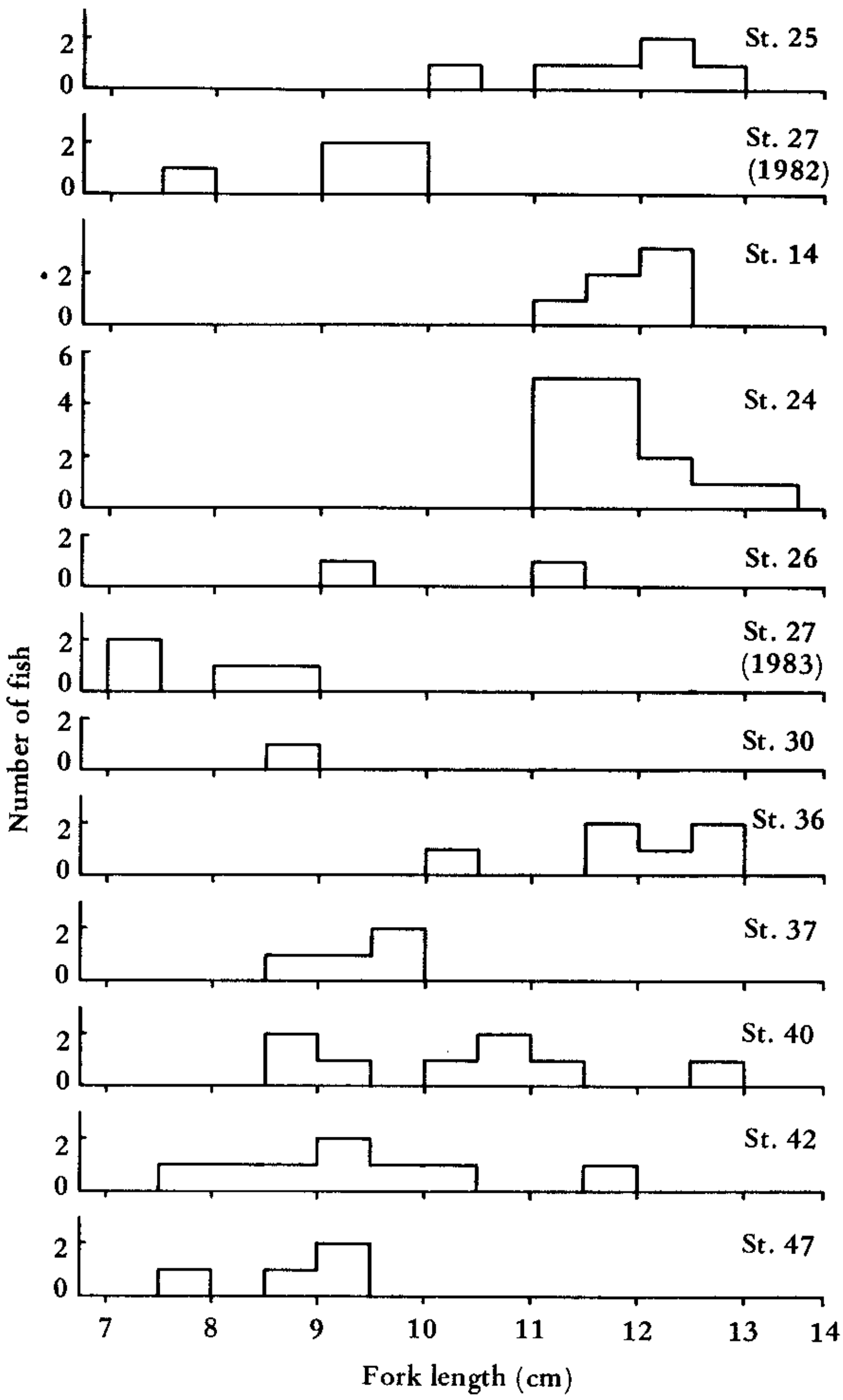


Fig. 16. Size frequency distribution of juvenile chum salmon recaptured by station in Aysén Fjord in 1982 - 1983.

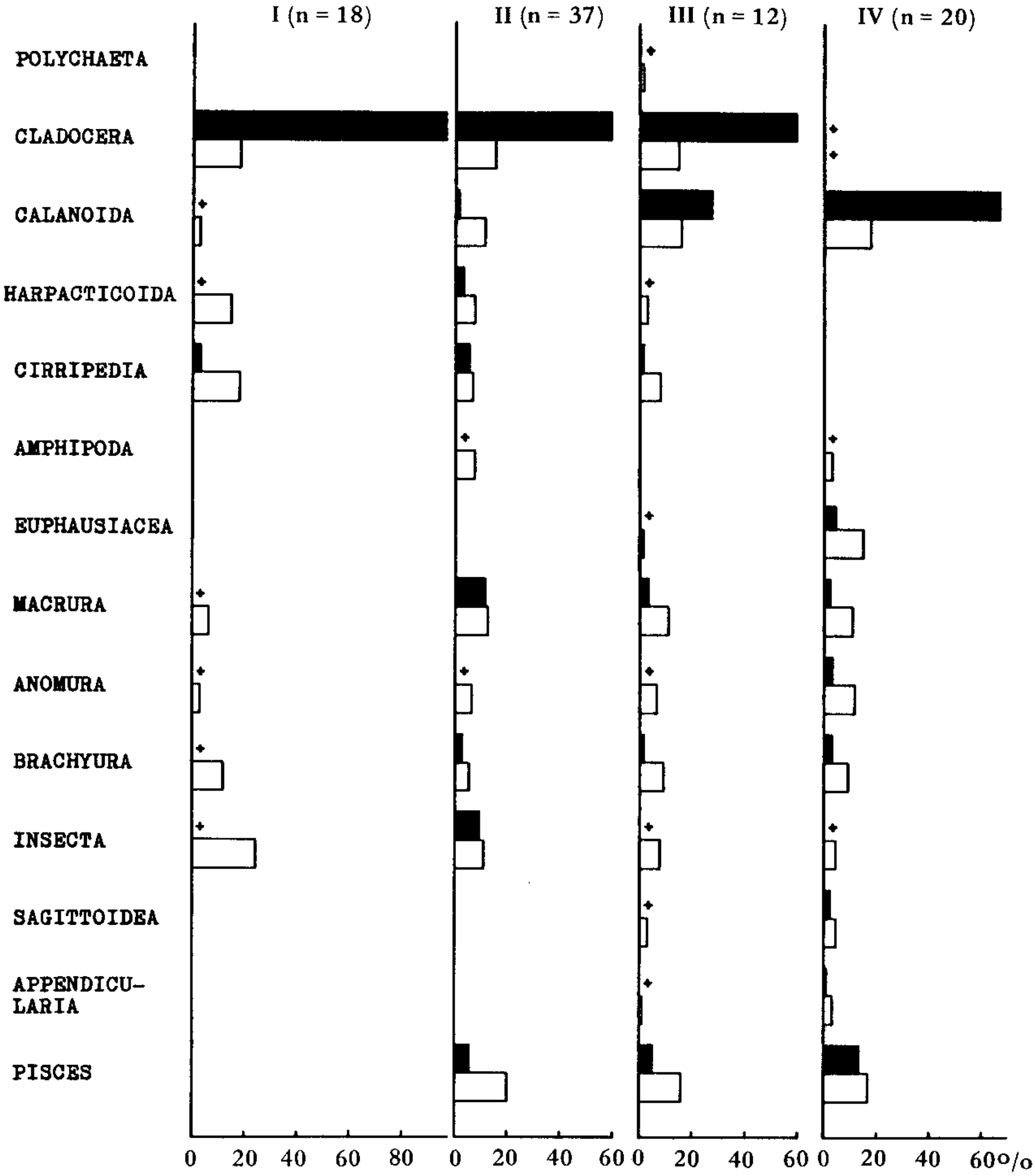


Fig. 17. Stomach contents of recaptured juvenile chum salmon by animal group by section in Aysén Fjord in 1979 - 1983. Black and white bars indicate the composition of prey and the frequency of occurrence in the juveniles, respectively. +: less than 1%, n: number of fish examined.

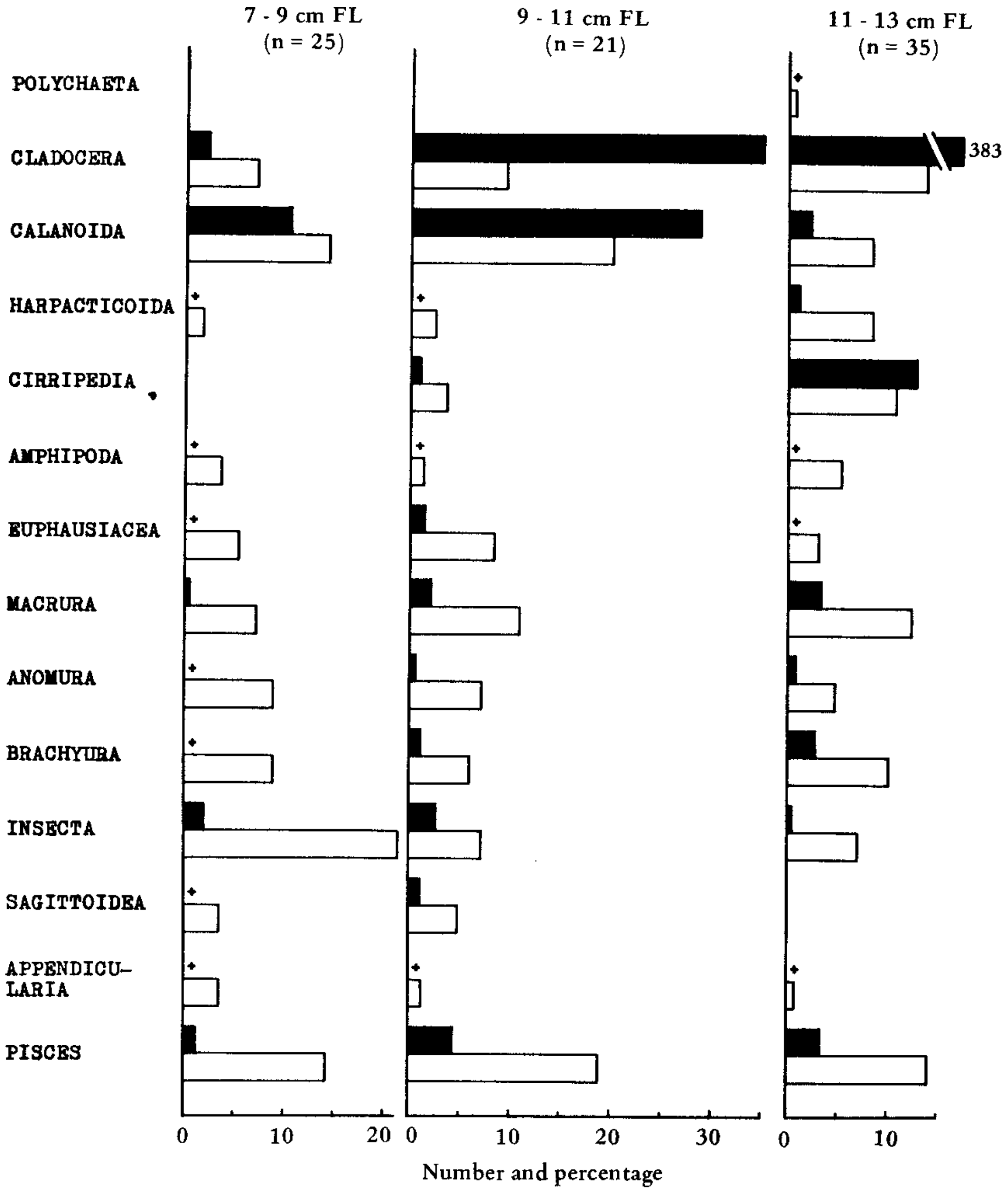


Fig. 18. Stomach contents of recaptured juvenile chum salmon by animal group by size of juvenile in Aysén Fjord in 1979 - 1983. Black and white bars indicate the average number of prey organisms per fish and frequency of occurrence in the juveniles in percentage, respectively. +: less than 1%, n: number of fish examined.

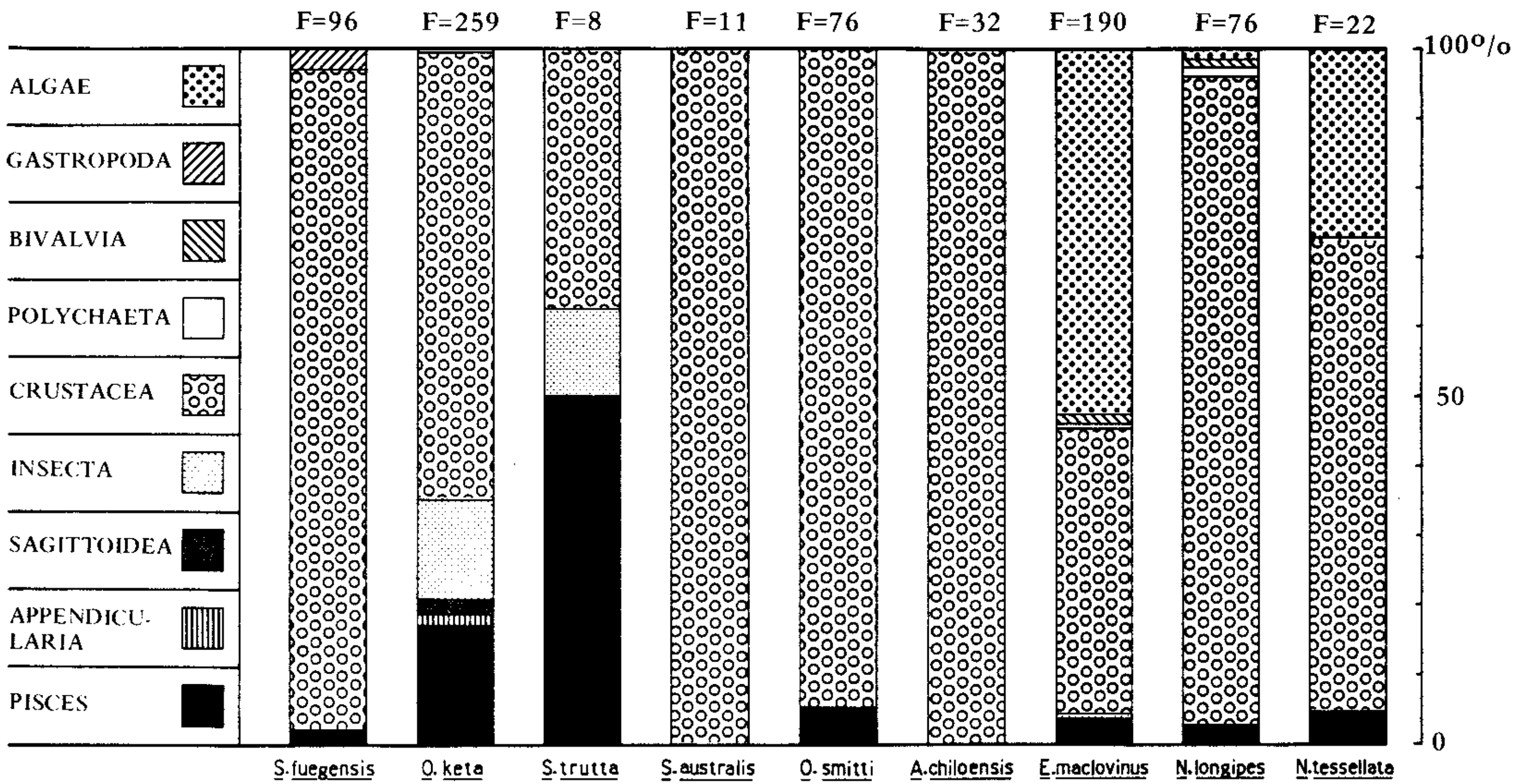


Fig. 19. Stomach contents of 9 common fishes in Aysén Fjord collected in 1979 - 1983. The composition is shown by the frequency of occurrence in fish. F: number of fish examined except fishes having empty stomach.

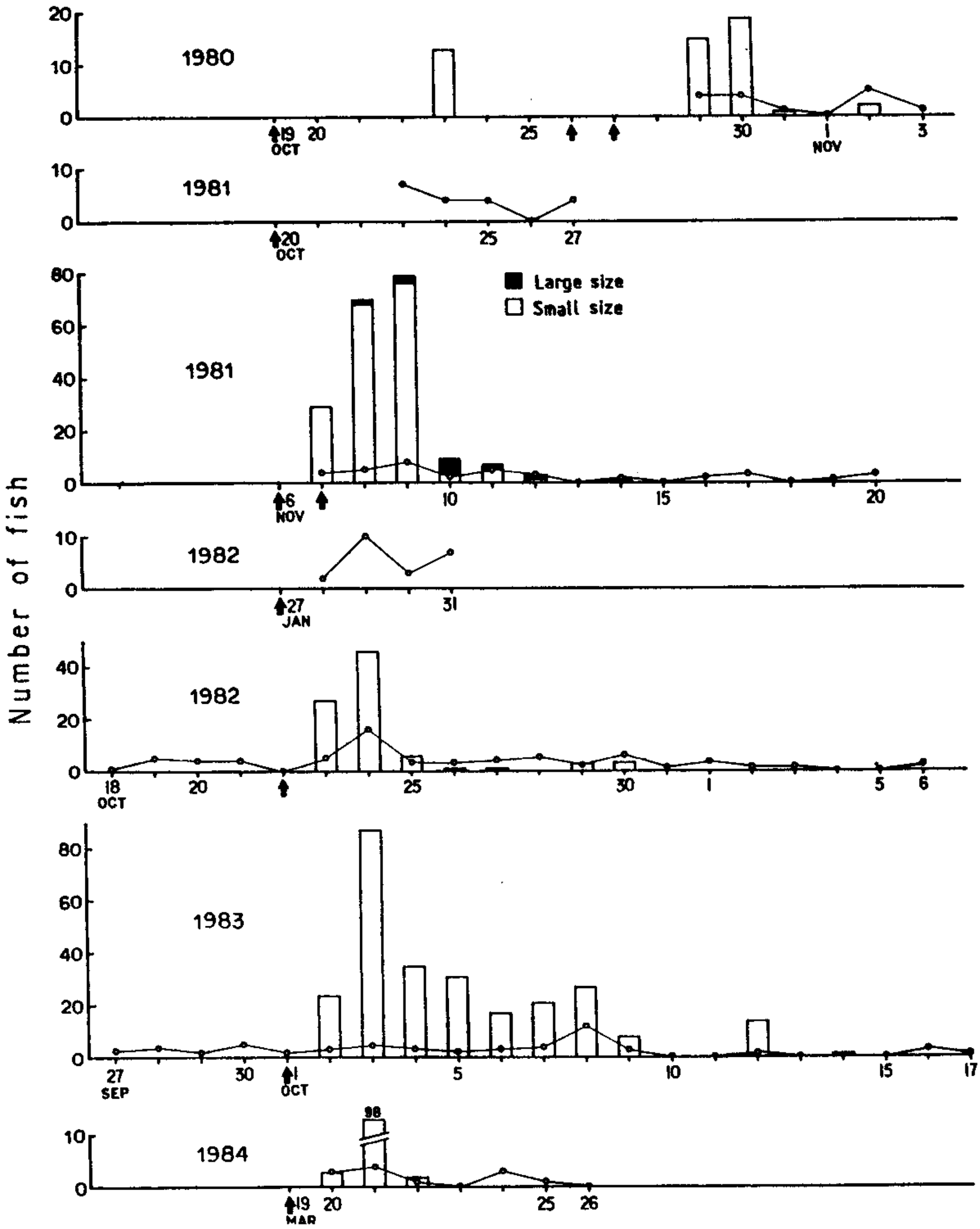


Fig. 20. Number of preyed salmon juveniles per day after the release and the daily catch of brown trout in Ensenada Baja. Arrows indicate the date of the releases.