Biological Reconnaissance of Yakoun River Estuary, Queen Charlotte Islands, and Results of a Trial Fertilization with Urea

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BIOLOGICAL RECONNAISSANCE OF YAKOUN RIVER ESTUARY, QUEEN CHARLOTTE ISLANDS, AND RESULTS OF A TRIAL FERTILIZATION WITH UREA

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ABSTRACT

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The structure of plankton, benthic algae and invertebrate, vascular plant and fish populations in the Yakoun River estuary were examined over a four month period in the spring and summer of 1980. An attempt was made to increase populations of salmonid food items by artificially fertilizing the estuary and stimulating production at the primary trophic level, based on the assumption that food availability was a significant limiting factor in the survival of juvenile pink salmon within this system. However, neither primary production nor nitrogen regeneration were appreciably accelerated following this fertilization. Mean phytoplankton production was 5.6 mg $C \cdot m^{-2} \cdot h^{-1}$ over Yakoun Bay during the study period. Mean production by benthic algae and by vascular plants was 120 mg $C \cdot m^{-2} \cdot h^{-1}$ and 200 mg $C \cdot m^{-2} \cdot h^{-1}$, respectively. Juvenile chum, chinook and coho salmon used the Yakoun estuary extensively from April to July. No catches of juvenile pink salmon were recorded. Analysis of the stomach contents of juvenile chum salmon revealed that harpacticoid copepods, particularly Tachidius discipes, were the most import food items in April and May. While harpacticoid copepods were the main food items in juvenile coho diets in April, dipteran pupae and adults had become the preferred food items by May and June. It appears unlikely that the fertilization of Yakoun Bay resulted in any appreciable enhancement of juvenile salmonid growth or survival.

RÉSUMÉ

Stockner, J.G. and C.D. Levings, (Editors). 1982. Biological reconnaissance of Yakoun River estuary, Queen Charlotte Islands, and results of a trial fertilization with urea. Can. Tech. Rep. Fish. Aquat. Sci. No. 1132: viii + 119 p.

Au printemps et en été 1980, on a étudié pendant quatre mois la structure des populations de plancton, d'algues et d'invertébrés benthiques, de plantes vasculaires et de poissons dans l'estuaire de la rivière Yakoun. On a tenté d'accroître les populations des espèces servant de nourriture aux salmonidés en fertilisant artificiellement l'estuaire et en stimulant la production au niveau tropique primaire. Cette expérience partait de l'hypothèse que la disponibilité de nourriture était un facteur limitatif important pour la survie du saumon rose juvénile dans ce système. Toutefois, ni la production primarie ni la régénération de l'azote ont été sensiblement accélérées par suite de cette fertilisation. La production moyenne de phytoplancton s'élevait à 5,6 mg $C.m^{-2}.h^{-1}$ dans la baie Yakoun pendant la période d'étude, tandis que celles d'algues benthiques et de plantes vasculaires atteignaient 120 mg $C.\ m^{-2}.h^{-1}$ et 200 mg $C.m^{-2}.h^{-1}$, respectivement. Les juvéniles des saumons kétas, quinnats et cohos ont beaucoup utilisé l'estuaire d'avril à juillet. Aucun saumon rose juvénile n'a été capturé. L'analyse des contenus stomacaux des saumons kétas juvéniles a révélé que les copéodes de la famille des Harpacticidés, surtout _Tachidius discipes_, constituaient les éléments les plus importants du régime en avril et mai. Quoique ces copépodes représentaient la principale nourriture des saumons cohos juvéniles en avril, les pupes et les adultes de Diptères devenaient les aliments préférés en mai et juin. Il semble peu probable que la fertilisation de la baie Yakoun ait entraîné une amélioration importante au niveau de la survie et de la croissance des saumons juvéniles.

Photo 1. DCGB tanker applying liquid urea fertilizer to Yakoun River estuary.

Photo 2. Aerial application of liquid urea fertilizer to Yakoun River estuary.

PREFACE

The results reported here have been abstracted from a comprehensive contractor's report presented by Beak Consultants Ltd., to the Department of Fisheries and Oceans, Pacific Region, in December 1980. The full report is not widely available and is difficult to circulate. With the valuable assistance of Ms. Pat Miller, the editors have considerably condensed the original report and here present data which are probably of most interest to the scientific community. Estuaries in northern British Columbia waters are relatively unknown and we feel that wider dissemination of the information gained from this study is warranted.

The following Beak personnel were responsible for particular sections of the study. In some instances they also helped design the research plan, but this most frequently was specified by the Scientific Authority, Dr. J.G. Stockner and his associates, Dr. C.D. Levings, Dr. M. Pomeroy and Mr. K. Stephens.

Topic	Person responsible
Vascular plants	A.I. Moody
Fish	K. Hyatt, R. Moody, K. Christensen
Invertebrates	
Benthic macrofauna	A. Gavin
Benthic meiofauna	C.J. Low
Zooplankton	V. MacDonald
Algae	
Phytoplankton	A. Carruthers
Benthic	J. Taylor
Oceanography	J. Stronach

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INTRODUCTION

The even-year pink salmon (Oncorhynchus gorbuscha) run of the Yakoun River is one of the largest in British Columbia, accounting for more than half of the total population of this species in the Queen Charlotte Islands (Brown and Musgrave 1979). Due to downward fluctuations in the size of the run in Masset Inlet (Wood, 1977) and, in particular, the Yakoun River (Walker 1970) it was felt that the pink salmon stocks were declining. Based on the assumption that food availability was a significant limiting factor in the survival of juvenile salmon within this system, it was hypothesized that the productivity of invertebrates used as food by young salmon might be indirectly increased by artificially fertilizing the estuary, and increasing production at the primary trophic level. As no data were available on juvenile salmonid use of the estuary nor on lower trophic levels, a preliminary study was undertaken on these topics in April to July of 1980, and the results of this work are presented here.

During the present study biological data were collected and oceanographic measurements were made in the Yakoun estuary for two months preceding and one month following a single application of (urea) fertilizer. The abundance and composition of phytoplankton, zooplankton, benthic algae and invertebrates, vascular plants and fish populations were documented. The number of juvenile pink salmon outmigrants from the Yakoun River was low, as 1980 was an "off" year for pinks. Chum salmon (Oncorhynchus keta) were more plentiful in 1980 and their fry were considered to have dietary habits most similar to pink salmon, so their distribution, growth rate and diet while resident in the Yakoun estuary were described in some detail.

DESCRIPTION OF THE STUDY AREA

The Queen Charlotte Islands are located between 52° and 54° north latitude along the British Columbia coast (Figure 1). Along their western shores, the islands constitute the edge of the continental shelf; along their eastern shores they can be thought of as an elevated part of the relatively shallow Hecate Strait. The dividing line between the Charlotte lowlands and the Skidegate plateau (Figure 1) passes through Masset Inlet. Thus, the eastern half of Masset Inlet is bounded by boggy lowlands while the western part is bounded by more mountainous terrain. The Yakoun River drains this eastern boggy area and represents approximately one-third of the drainage area of Masset Inlet. (Barber et al. 1975).

The Yakoun River discharge has been monitored by Water Survey of Canada for at least ten years. Figure 2 illustrates the river hydrograph for 1980. This river is primarily rain-fed and does not have pronounced snow-melt freshets. In the fall, winter and spring, there are large peaks in the flow rate; in summer flow rates are very low (Barber et al. 1975). The connection between Masset Inlet and the Pacific Ocean is via Masset Sound, a narrow (0.9 to 1.5 km), long (38 km), and shallow (22 m) channel (Barber et al. 1975). In the seaward approach to the Sound a threshold depth in the range of 4 to 6 m exists and at Cook Point the Sound is only 400 m wide. Masset Inlet has a surface area of approximately 220 km^2 and is between 3 and 100 m deep (Barber et al. 1975). Figure 3 illustrates the complicated bottom topography of Masset Inlet.

The climate of Masset Inlet (derived from data collected in Masset and Sandspit) is 'typical' of the Queen Charlotte Islands. The winters are mild and the summers are cool, with a mean temperature range of 5 to 10°C (Calder and Taylor 1968). For the ten year period from 1954 to 1964 Sandspit received approximately 32% of the astronomically possible hours of bright sunshine (Calder and Taylor 1968). Masset, with its northwest exposure, tends to be cloudier than other stations in the Queen Charlotte Islands, especially in June and July (Calder and Taylor 1968).

The Yakoun River flows into the eastern side of Masset Inlet through the tidal marsh and intertidal sand and mudflats of Yakoun Bay (Figure 4). The estuary occupies an area of approximately 4 km^2 and is cut by only one main river channel. At the upper end of Yakoun Bay this channel splits into two channels, which later rejoin upstream to create an island. There is an additional freshwater input, Coho Creek, which joins the main channel on the southeast side of Yakoun Bay (Figure 4). The average range of the tide at Port Clements is 2.16 m and except for the main channel, the bay is dry at low water and covered by only 0.5 to 1.5 m of water at high tide. The main river channel is approximately 1.5 m deep at low water. There is a gravel bar about halfway along the main channel and a double sand bar at its mouth. Within Yakoun Bay a number of large tree stumps have been left behind from flood events. A particularly distinctive feature of the Yakoun River is its high humic content, which leaves a brown stain throughout Masset Inlet.

METHODS AND MATERIALS

CIRCULATION

River discharge data were obtained from the Water Survey of Canada, which maintains a gauge near Port Clements, at the mouth of the Yakoun River (Environemnt Canada 1980). Salinity and temperature data were obtained using an Applied Microsystems CTD. The quoted accuracies of this system are ± 0.03 PPT salinity, ± 0.02°C and ± 0.1 m for depth. Water velocities were measured with an Endeco (Model 110) current meter, equipped with depth and temperature probes. Accuracies are quoted as ± 0.07 cm$\cdot$sec^{-1} for speed, ± 10° for direction, ± 0.61 m for depth and ± 0.5°C for temperature for this instrument. Drogue tracks were estimated by compass fixes using either a Sestral or a Silva Compass. The combination of compass and operator had an accuracy or approximately ± 5° per compass fix, resulting in a typical error of approximately 100 m in station position.

LIGHT

Continuous readings of total incident energy were obtained from Environment Canada, Atmospheric Environment Service (unpublished data), for Sandspit (53 km from the Yakoun estuary, Figure 2) for all days when productivity incubations were run. Sandspit is the only station on the Queen Charlotte Islands at which sunlight data are recorded. Surface insolation over the course of an entire day was measured in the Yakoun estuary on June 5 only.

The relative penetration of light through the water column at several pelagic offshore and river stations (Figure 5) was measured as photosynthetically active quanta; (400-700 nm) ($uE{\cdot}m^{-2}{\cdot}sec^{-1}$) with a Li-Cor light meter (Model 185A), equipped with a Li-Cor underwater quantum sensor (Li-192S), on April 23, as total energy ($Langleys{\cdot}h^{-1}$) on June 5 and 6, and as lux with a Montedoro-Whitney photometer (Model TC-5C) on June 28, 29 and 30. Blue, green and red colour filters were used with the illuminance meter on June 28, 29 and 30.

WATER CHEMISTRY

Station locations are shown in Figure 5. Prior to June 30, water chemistry samples were not collected at the same time as water samples for pelagic productivity. Instead, these samples were collected after the pelagic productivity bottles had been incubated for some time. This disparity in collection times was corrected on June 30 and subsequently, both water samples were collected on successive casts of a three litre Van Dorn bottle.

Ammonia, nitrite, nitrate, Kjeldahl nitrogen and total phosphorous concentrations, total alkalinity and conductivity were determined according to the standard methods of APHA (1976). Water collected for total phosphorus measurements was prefiltered through a 0.8 um glass fibre filter in the field. All water samples were frozen and stored for later analysis.

Ammonia was determined for unfiltered water by distillation followed by messlerization. Kjeldahl nitrogen in unfiltered water was determined by acid digestion of organic nitrogen to ammonia. The limits of detection for each of these components was 3.6 ug-at $N{\cdot}L^{-1}$. Water for nitrate and nitrite determinations was filtered through a 0.45 um Millipore filter. Nitrate was originally determined by the Brucine method (APHA 1976), which had a limit of detection of 3.6 ug-at N·L-1. However, it became necessary, as the season progressed and nitrate levels fell, to determine nitrate concentrations below this level and so the samples, which had been stored in sulfuric acid for up to five months at room temperature, were sent to the Lake Enrichment Program's Laboratory at the Pacific Biological Station in Nanaimo for analysis. The limit of detection for this analysis was approximately 0.1 ug-at $N{\cdot}L^{-1}$. Nitrite was determined through the formation of an azo-dye produced by the coupling of diazotized sulfanilic acid with naphthylamine hydrochloride. The detection limit for this procedure was 0.2 ug-at $N \cdot L^{-1}$.

Total phosphorus was measured using persulfate oxidation and asorbic acid colorimetry. The detection limit for this procedure was 0.3 ug-at $P \cdot L^{-1}$.

Prior to July 2 total alkalinity was not measured at the same time and location as ^{14}C productivity incubations were run. In order to estimate total and carbonate alkalinity values for use in the ^{14}C production calculations, measured alkalinity values were plotted against mean salinity values for a variety of sampling stations, depths and dates from April to July, 1980. (BEAK Figure 3.1.3-1, 1980). Predicted total alkalinities were corrected to carbonate alkalinities by extrapolating values from Strickland and Parsons' (1972) Table on Conversion of Total Alkalinity to Carbonate Alkalinity. The resulting estimated alkalinities are given in the (BEAK Report, Table 2.1.3-1, 1980). After July 2, alkalinity measurements were made at the same time and location as ^{14}C productivity incubations and these data were used in all production calculations.

SEDIMENT NUTRIENTS

Sediment from the top one centimeter of five intertidal stations located in a transect of Yakoun Bay (Figure 6) was removed immediately before (June 29) and two tidal inundations after fertilization (June 30, July 10). The sediment was frozen, returned to the lab and thawed. Fifty g of the wet sediment was shaken for one hour with 250 ml of distilled water to elutriate the interstitital nutrients. The elutriate was filtered through 0.45 um Millipore filters, frozen and sent to the Lake Enrichment Program's Laboratory, Nanaimo for determination of dissolved organic nitrogen (Kjeldahl N, ammonium N), nitrate and ammonium concentrations. Phosphate concentrations were also determined. Subsamples of sediment were oven-dried at 100°C for 48 hours, ground and redried for two hours to determine the moisture content of the sediment samples.

PHYTOPLANKTON

Primary production of phytoplankton was measured at several depths in the top five meters of the water column at pelagic stations located offshore of the tidal flats in Yakoun Bay (Figure 6). Unfiltered water samples collected in three liter van Dorn bottles were placed in 300 ml Pyrex BOD bottles and inoculated with radioactive ^{14}C bicarbonate (2.6 microcuries (approx. 96.2 kBq) on April 23, June 5, 26 and 28; 5.1 microcuries (approx. 188.7 kBq) on June 30, July 2 and 4). Two light bottles were suspended at each of four depths (0.25 m, 1 m, 2 m and 5 m) and one dark bottle was suspended at both 0.25 m and 5 m depths. All bottles were incubated for three to fours at midday (Strickland and Parsons 1972). (See BEAK, Appendix 1, 1980). Following incubation, subsamples (100 ml) were filtered through 0.45 um Millipore filters which were then placed in scintillation fluid consisting of 7.4 parts (by volume) Aquasol-2 to 1 part scintillation-grade phenethylamine. The amount of carbon dioxide present in the dark bottle, linearly interpolated to the correct depth, was subtracted from the mean carbon dioxide present in the light bottles. The difference in carbon dioxide represented the amount of particulate organic carbon produced by photosynthesis, or net photosynthesis (Strickland and Parsons 1972).

On April 23, 1 L water samples were filtered on 0.8 µm pore size glass fiber filters, frozen and stored for later chlorophyll a analysis using the method of Strickland and Parsons (1972). On June 26 to July 1, 0.45 µm Millipore filters were used; 0.4 µm Nuclepore filters were used on July 2 and 4. All samples were sent to the Lake Enrichment Program's Laboratory, Nanaimo for fluorometric chlorophyll analysis.

Phytoplankton were identified and enumerated in 100 ml samples fixed with Lugol's solution. Subsamples (25 mL) were settled overnight and two transects at 500X and 200X magnification were counted. At least two hundred cells were enumerated per subsample. Cell volumes were approximated by equating algal cells to geometric shapes of known volumes.

BENTHIC ALGAE

Primary production of benthic algae was determined at three (June 25, 27, 28 and 30, July 1 and 3) or four (June 6) replicate stations on the seaward fringe of the intertidal Z. marina community (Figure 6). The replicate benthic productivity measurements were made at a single site in order to minimize sampling variability due to substrate heterogenity. The Z. marina was chosen as the site of these measurements because it was possible to easily separate the algal mat from the underlying sediment and because the benthic algae within this community were more evenly distributed between replicate stations than were those in other intertidal habitats.

At each station, prior to June 30, sediment from the top one centimeter of two-5-cm^2 cores was placed separately in two series of light and dark bottles. In each case, sediment from the core was first combined with 600 ml of river water (filtered through a 10 µm Nitex screen), shaken and briefly settled. The elutriate containing unsettled sediment was then divided evenly between two 300 ml BOD light and dark bottles and a third bottle, for use in later chlorophyll a analysis. The suspension in each BOD bottle was brought up to volume with additional filtered river water, in order to exclude air bubbles, and inoculated with ^{14}C bicarbonate. This procedure yielded two series of light and dark bottles from each of the cores. The first series (A) were suspended at 0.25 m depth and the second series (B) were suspended at 1.0 m depth. The bottles were incubated for three to four hours at the original sampling location. The actual depths of incubation varied as the tide changed, and on many occasions both series were completely exposed during low tide (see Appendix 2). Filtered river water which did not contain sediment was placed in a single light bottle and incubated with the A series as a control. Following incubation, the amount of dissolved oxygen present in each bottle was determined according to the method of (Strickland and Parsons 1972). Sediment samples from the two cores collected in each replicate after June 29 were combined into one large slurry before being placed in the A and B series bottles.

Changes in the dissolved oxygen concentration were converted to carbon by assuming a photosynthetic quotient of 1.20. The two parameters that could be calculated were:

L - D = gross photosynthesis of sediment + filtered river water.
L - C = net photosynthesis of sediment (for A series only).

where L = light bottle O_2, D = dark bottle O_2, and C = control O_2.

Chlorophyll a in the top one centimeter of 5 cm^2 cores was determined in two cores taken at each of ten intertidal locations (Figure 7) on April 22 and May 17, and in one core at each station on May 18 and June 26. The top 3 mm of sediment within a single 0.0625m^2 quadrat was also removed from each station and preserved in formalin for subsequent enumeration of benthic diatoms and dry weight measurements on May 17 and June 26. Diatom valves were counted as described for phytoplankton after boiling a quarter sample in nitric acid and dichromate. Valve counts were halved to obtain cell numbers of both unicellular and filamentous diatoms. One quarter samples were microscopically inspected to provide an approximate estimate of the percentage contribution of non-diatoms to total algal volume. One half of the quadrat sample was dried at 100°C for 48 hours, ground and redried for two hours. Subsamples were weighed and ashed in a muffle furnace at 500°C for four hours to give ash free dry weight.

VASCULAR PLANTS

Although several techniques are available for determining net aboveground primary production of vascular plants, most are impractical for tidal marsh species. A widely accepted technique is to harvest the plants within a community in a series of randomly located quadrats, over a period of time, and then examine the relationship between live and dead standing crop increments (Smalley 1959 cited in Linthurst and Reimold 1978):

1. "If there is both an increase in the standing crop of living material and in the standing crop of dead biomass, then net production is the sum of these increases.

2. If both living and dead standing crop decreases, then production is assumed to be zero.

3. If the standing crop of living biomass increases and the standing crop of dead biomass decreases, production is equal to the increase in the living material.

4. If the amount of dead biomass increases and the amount of living biomass decreases, they are added and if the result is negative, production is assumed to be zero; if the result is positive, the resulting value is assumed to represent production."

While this method does account for the mortality of living material over a growing season, net annual aboveground production may still be underestimated as the amount of dead material (detritus) washed away during tidal inundations between sampling intervals is not considered.

Standing crop was determined using replicate quadrat (0.06 m^2) sampling in the major vascular plant communities located on both east and west sides of the Yakoun River. These communities consisted of stands of dominant plant species, including *Carex lyngbyei*, *Juncus arcticus*, *Zostera marina* (essentially monotypic stands), and a mixed community dominated by *Deschampsia caespitosa*. A total of ten replicate samples were collected for each community, five on each side of the river, on each sampling date.

Samples were collected at approximately monthly intervals from April to August. Quadrat locations were randomly chosen within the plant communities and all of the vegetation rooted within the quadrat (including all yellowing and standing dead material), was cut at ground level. In addition, all dead plant material found on the ground inside the quadrat was collected with the sample. The samples were bagged, labelled and frozen for shipment to the laboratory. In the lab the contents of each bag were thawed, rinsed to remove silt, and sorted into live and dead components. The live component included all of the current year's standing crop; the dead component consisted of detritus remaining from the previous season's growth. The samples were then placed into paper bags, dried at 105°C for 24 hours and weighed.

ZOOPLANKTON

Zooplankton were sampled at pelagic stations at the mouth of Yakoun Bay (Figure 5) by towing a SCOR plankton net (153 µm mesh) with a mouth diameter of 29 cm at a speed of approximately 0.5 $m \cdot sec^{-1}$, either horizontally or vertically (Table 1). Samples were preserved in 4% formalin-sucrose for subsequent identification and weighing. The dry weight of organic matter collected in net hauls was measured by filtering subsamples onto pre-weighed 0.45 µm Millipore filters and then drying them at 90°C for 24 hours.

BENTHIC INVERTEBRATES

Benthic meiofauna were sampled intertidally at low tide at nine stations on April 23 and at ten stations on May 18 and June 26 (Figure 7). The top 2 cm of sediment was removed from three 5 cm^2 cores in three replicates at each station and placed in a solution of formalin and Rose Bengal. Meiofauna were separated from sediments by repeated washings and decantation through a 45 µm sieve. All recognizable animals were enumerated according to major taxon. At least fifty harpacticoid copepods from each sample (numbers permitting) were identified to species.

Benthic macrofauna were collected in single sediment samples at three subtidal stations on April 23 (P1, P4, P6) and July 2 (P6, P8, P10) (Figure 5). A Ponar grab with a cross-sectional area of 0.052 m^2 was used. These samples were sieved through a 500 µm screen in the field and then preserved in formalin and Rose Bengal for later analysis. Macrofauna were also collected intertidally, during low tide, by removing the surface 3 cm of sediment in a single 0.06 m^2 quadrat, at each of ten stations (Figure 7). These samples were preserved in formalin with Rose Bengal. Macrofauna were sorted, identified and dried at 95°C for 48 hours. Mollusk shells were dissolved in 0.5N HCl before the organisms were dried.

FISH

Monthly surveys of fish were made in the Yakoun estuary from April to July. These surveys consisted of the following three components:

Beach seining

Fish were sampled in nearshore areas with a 10.0 m x 1.5 m beach seine of 13 mm stretched mesh. A standard area of approximately 100 m^2 was sampled on each occasion. Generally, netting efforts were synchronized to tidal stage and were conducted within two hours of low slack water during daylight hours. Captured fish were identified and enumerated prior to release; subsamples from selected stations were retained for detailed analysis. The locations of the fifteen beach seine stations sampled are shown in Figure 8.

Marsh tidal channel trapping

This component of the surveys examined juvenile salmonid and resident fish utilization of a tidal channel on the Yakoun estuary. The use of a beach seine net as a passive trap to sample fish populations has proven successful in other studies (Cain and Dean 1976; Levy et al. 1979). In this study, on each sampling occasion, a 13 mm stretch mesh net, 2.4 m deep, was placed across a tidal channel at the single site shown in Figure 8 at high tide and fastened to stakes on either bank. The net was checked approximately six hours later, at low tide, and the captured fish were identified to species, enumerated and released alive or immediately preserved in a 10% formalin solution.

Surface trawling

Spatial and temporal distributions of salmonid fry were monitored near the mouth of the Yakoun River and in Masset Inlet in this component of the surveys (Figure 9). A 6.1 m x 3.1 m Kodiak surface trawl, which tapered from 152 mm stretch mesh at the opening to 13 mm stretch mesh at the cod end was used. Due to failures in the sampling technique in April and May no fish were collected in those months. Catches of June and July trawling sessions were identified to species, enumerated, and preserved or released, depending on further analytical requirements. The duration of the tows was standarized at ten minutes.

Representative samples of fish collected in the beach seines and tidal channel traps on April 20 to 24, May 19 to 21 and June 30 were subjected to detailed stomach content analysis. (See BEAK, Appendices 9-12, 1980). Analysis included determination of fullness, state of digestion, identification of prey items to the lowest taxonomic level possible and the counting of prey items. Volumes of food items were determined by area coverage on a graduated grid after compression to a standard thickness of 1 mm. When numbers permitted, at least fifty harpacticoid copepods from the gut contents of chum salmon fry collected in April in the beach seines and in May in the beach seines and tidal channel traps (BEAK Appendix 13, 1980) were counted and identified to species.

FERTILIZATION

On June 29, during the afternoon low tide, the Yakoun estuary was aerially fertilized with 3402 kilograms of urea (46.6% nitrogen by weight). Since it was quite windy, a certain amount of the urea did not land in the intertidal target areas. Figure 10 shows the approximate locations of the fertilized sites.

RESULTS

PROPERTIES AND CIRCULATION

Masset Inlet

Very little seasonal salinity data have been collected in Masset Inlet. Figure 11 illustrates plots of vertical salinity sections taken along two transects, from Yakoun Bay to the entrance of Masset Sound, on April 22, 1980. The first transect was done at approximately mean sea level on an ebb tide; the second transect was done near low water (approximately 1.0 m above tidal datum) on a flood tide. Except near the river mouth, salinities ranged from 20.7 °/oo to 21.8 °/oo over Masset Inlet. After examining data that had been collected at a number of stations in Masset Inlet on July 20, 1952, Barber et al. (1975) concluded that salinities within the inlet ranged from 22 °/oo to 23.5 °/oo. They found that, in contrast, the waters in Dixon Entrance at the entrance to the sound had a range of salinities from 29.5 °/oo to 32.0 °/oo on that date. In a study done at Masset in 1948, the salinity varied only 1 to 2 °/oo over the year (Anon. 1948a, b).

Seasonal fluctuations of salinity in Masset Inlet may be attributed to river flow rates. For example, since river input is larger in April than it is in July, lower salinities could be expected to occur in Masset Inlet in the spring. Although the Yakoun River influence appears to be directly confined to an area within 1.5 km of the river mouth, the fresh water discharge results in the average salinity of Masset Inlet being in the low 20 °/oo's rather than in the 29.5 °/oo to 32.0 °/oo range which is typical of the waters in Dixon Entrance (Barber et al. 1975). Furthermore, the combination of tidal currents and wind currents mixes the water within the inlet so that it is practically vertically homogeneous. Although tidal currents are weak near Yakoun Bay, most days are windy (Calder and Taylor 1968) and consequently wind mixing may be considered to be a significant factor in the circulation of Masset Inlet.

It is possible to estimate the overall flushing rate of water through Masset Inlet. The inlet has a surface area of approximately 170 x 10^6 m^2, a mean depth of 37 m and thus, a volume of approximately 6.3 x 10^9 m^3. The average Yakoun River discharge for 1972 to 1979 was 31 $m^3 \cdot sec^{-1}$ (Environment Canada 1980), for a mean annual total discharge of 0.98 x 10^9

m^3. The volume of fresh water in Masset Inlet is about one-third of the total volume, or 2.0×10^9 m^3; the total freshwater input may be as much as three times the Yakoun River input or about 3.0×10^9 m^3 (Barber et al. 1975). The time scale for water renewal is given by the volume of fresh water present, divided by the annual fresh water supply rate, $(2.0 \times 10^9\ m^3)\cdot(3.0 \times 10^9\ m^3\cdot year^{-1})^{-1}$, or 243 days. Although this estimate is admittedly crude, a strong argument in its support is the high degree of homogeneity of the water in Masset Inlet - it appears that as fast as freshwater is added, it is incorporated into the entire Masset Inlet system, and so has no preferential pathway to the inlet. A preferential pathway would exist if a highly stratified surface layer existed over the entire estuary, and could flow out as a density current, as in a fjord-type estuary.

The tidal prism in Masset Inlet is about -

$$170 \times 10^6 \times 2.5m = 425 \times 10^6\ m^3.$$

It is interesting to compare the discharge of the Yakoun River over a tidal cycle with this figure:

Discharge $m^3\cdot s^{-1}$	River Volume Flux $(10^6\ m^3)$ Tidal $cycle^{-1}$	Percentage of tidal prism
20	0.864	0.2
50	2.16	0.5
100	4.32	1.0
200	8.64	2.0

It is clear that much more water must be circulating in Masset Inlet, to satisfy tidal requirements, than is supplied daily by the Yakoun River.

Assuming that salinity varies by 1 to $2^\circ/_{oo}$ in Masset depending on the season (Anon. 1948a, b), the salinity of the water moving through the sound into the inlet on a flood tide can be calculated. If the salinity in the inlet is initially $23^\circ/_{oo}$ and a change of $1^\circ/_{oo}$ occurs over a two month period, due to a mean freshwater influx of 100 $m^3\cdot sec^{-1}$, an approximate salt and volume balance can be computed:

$$Q_{flood} = 425 \times 10^6\ m^3\ \text{tidal cycle}^{-1}$$

$$Q_{rivers} = 4.3 \times 10^6\ m^3\ \text{tidal cycle}^{-1}$$

$$Q_{ebb} = Q_{flood} + Q_{rivers} = 429.3 \times 10^6\ m^3\ \text{tidal cycle}^{-1}$$

The rate of change of salt per tidal cycle is of the order

$$\frac{-1^\circ/_{oo}}{2\ \text{months}} \times \frac{1\ \text{month}}{60\ \text{tidal cycles}} \times 6.3 \times 10^9 m^3$$

$$= -52.5 \times \frac{10^6\ m^{3\circ}/_{oo}}{\text{tidal cycle}}$$

$$= Q_{flood}\ S_{flood} - Q_{ebb}\ S_{ebb}$$

$$= 425 \times 10^6 S_{flood} - 429.3 \times 10^6 \times 22.5 \quad m^{3}\,^{\circ}/_{oo}$$

tidal cycle

Thus, $S_{flood} = 22.6^{\circ}/_{oo}$.

If there had been no salinity change, so that S_{ebb} was $23^{\circ}/_{oo}$ then S_{flood} would be $23.1^{\circ}/_{oo}$. Therefore, it can be concluded that very small salinity differences between Masset Sound and Masset Inlet are required to balance the assumed annual salinity cycle of Masset Inlet, or to maintain an ambient $23^{\circ}/_{oo}$ salinity. Within Masset Sound then, salinities must increase from approximately $23^{\circ}/_{oo}$ at the Yakoun the Masset Inlet end, to approximately $23^{\circ}/_{oo}$ at the Yakoun Estuary end to approximately $30^{\circ}/_{oo}$ at the Dixon Entrance end.

The flushing calculations were based on the utilization of freshwater as a "tracer". The "point of application" of the freshwater is removed from the main circulation forces of Masset Inlet. Figure 12 illustrates the tidally induced residual circulation in the actual and in an idealized Masset Inlet (Barber 1980). Flushing would not be uniform for all regions of the inlet as there are obviously regions where the strength of the residual currents vary. The Yakoun River in fact flows into a region of weak residual currents.

Yakoun Bay

Salinity profiles in the region offshore of Yakoun Bay exhibited considerable variation in vertical structure in April (Fig. 11). On April 22, on an ebb tide, surface salinities ranged from $3.2^{\circ}/_{oo}$ at the station located at the river mouth to $20.8^{\circ}/_{oo}$ at a station located just offshore in Masset Inlet. At approximately mean low water on that day salinities ranged from $0.9^{\circ}/_{oo}$ at the river mouth to $30.0^{\circ}/_{oo}$ just offshore (BEAK Appendix 1, 1980). On May 18 at low water salinity values recorded at these locations ranged from $11.6^{\circ}/_{oo}$ at the river mouth to $19.5^{\circ}/_{oo}$ offshore. On July 2 and 4 salinity was measured within Yakoun Bay at high water. Surface salinities ranged from $8.5^{\circ}/_{oo}$ to $21.1^{\circ}/_{oo}$ within the main river channel. The salinities in the rest of the bay were quite uniform, ranging from 18.1 to $21.6^{\circ}/_{oo}$. The information gathered at Stations S44 to S53 on May 21 (plotted in the BEAK Report, Appendix 1, 1980) illustrates the presence of a salt wedge in the river at low flow times. In addition, the salinity profile measured at the location of the marsh tidal channel sampling station indicated that there is a wide range of salinities.

At the time of summer low river flows high salinity water ($23.0^{\circ}/_{oo}$) covered the entire marsh at high tide (July 9); at low tide low salinity water remained in the main channel ($4.0 - 6.0^{\circ}/_{oo}$ at a station located 2 km upstream from the delta edge at 1135 hours, June 25), and at the river mouth salinities were of the order $22^{\circ}/_{oo}$. The salt wedge on July 2 intruded approximately 2.5 km upstream of the confluence of the two arms of the main river channel.

Currents in the offshore area are small, seldom exceeding 30 $cm \cdot sec^{-1}$ and usually are 10 to 15 $cm \cdot sec^{-1}$. For reference purposes a 10 $cm \cdot sec^{-1}$ current results in a daily displacement of 0.86 km. The current meter observations are tabulated elsewhere (BEAK Appendix 2, 1980).

Based on drogue tracks, the direct influence of the Yakoun River on circulation in Yakoun Bay was confined to a limited area. If no wind was blowing, drogue observations indicated that the offshore area directly affected over one tidal cycle may be as small as 2 km^2. When a 15 knot wind is blowing, the affected area could increase to more than 10 km^2. The offshore area has a mean depth of approximately 10 m.

Using this information the dilution factors of the nutrients artificially added to Yakoun Bay can be estimated. If fertilizer is applied to the intertidal area at low tide and mixes with the water from the subsequent flood tide, a solution of concentration C, occupying a volume of

$$3.1\ km^2 \times 1.0\ m = 3.1 \times 10^6\ m^3$$

at high water will be created. This volume of solution will move out and mix with a wide range of possible volumes outside of Yakoun Bay on an ebb tide. Table 2 lists the estimated concentrations of the added nutrients after one tidal cycle.

There is obviously a large range of dilution ratios. The estimates shown in Table 2 are expected to be low; concentrations would likely be higher, principally because mixing may not proceed to as great a depth as indicated in the table.

In order to estimate the dilution rate of nutrients for period of time greater than one tidal cycle, river runoff conditions must be considered. From the river hydrograph data (Environment Canada 1980) there is an approximate volume of fresh water of

$$1\ km \times 4\ km \times 1\ m \times 1/2 = 2 \times 10^6\ m^3$$

in the offshore areas, where 1 m is the assumed mean depth and 1/2 is an estimate of the freshwater fraction. For a river flow of 70 $m^3 \cdot sec.^{-1}$ this volume of freshwater represents 0.33 days discharge. Thus, it appears that after one tidal cycle (0.5 days), it would be difficult to find any added nutrients, due to the efficiency with which density currents remove Yakoun River water from the bay and mix it with the other water masses.

If there were no wind effects, and the nutrients were not immediately taken up by bacteria, plankton, benthic algae or vascular plants, they could presumably be found for a few days, as the parcel of fertilized water would move on and off of the intertidal flats on Yakoun Bay with each tide. This water would also be expected to move eastward with the residual tidal circulation as in Figure 12a. According to the above model, it would take several days for the parcel to move out past the mouth of the bay, by which time wind and tidal mixing in that part of the system would have probably dispersed it. During periods of low river flow, however, the concentration of added nutrients could effectively drop to zero if there were appreciable winds.

LIGHT

Surface Insolation

A summary of the solar radiation data recorded by Environment Canada for Sandspit, on the days on which algal primary production was measured, is shown elsewhere (BEAK,1980; Table 3.1.2-1). Although there were some differences in the amount of sunshine received during this time, as is apparent in the comparison between insolation recorded at Sandspit and Yakoun Bay on June 5 (Figure 13), these differences were not considered to be significant and consequently, all productivity calculations were made using uncorrected Sandspit solar radiation data. During the week immediately preceding and the week following the fertilization of the estuary the pattern of sunny and cloudy days in Sandspit and in Yakoun Bay was very similar.

Light Extinction With Depth

Although differences in the extinction with depth at blue, green and red wavelengths were expected, due to the dark, turbid colour of the river water, no consistent pattern of light attentuation was observed in this study. Light levels decreased exponentially with depth; the extinction coefficient (k) ranged from 0.80 to 1.60 m^{-1} (mean 0.99 m^{-1}) for pelagic stations and from 0.96 to 1.88 m^{-1} (mean 1.30 m^{-1}) for river stations, reflecting the presence of the humic-stained water. A list of the vertical diffuse light extinctioncoefficients (k) measured at these stations is given elsewhere (BEAK, 1980).

NITROGEN AND PHOSPHORUS

Concentrations of nitrate, nitrite, ammonia, Kjeldahl nitrogen and total phosphorus found in water samples collected at river and pelagic stations in the Yakoun estuary are recorded in Table 3. The concentration of nitrate recorded at most pelagic stations varied from 4.0 to 7.1 ug-at $N \cdot L^{-1}$ during April and May. In June and July it varied from 0.5 to 3.8 ug-at $N \cdot L^{-1}$. There appeared to be no relationship between nitrate concentration and depth throughout the summer.

The apparent seasonal trend observed in the decrease in nitrate concentrations in water samples was not noted in other nutrients examined in this study. Nitrite concentrations remained below 0.3 ug-at $N \cdot L^{-1}$; Kjeldahl nitrogen concentrations ranged from below 3.6 to 21.0 ug-at $N \cdot L^{-1}$. Total phosphorus concentrations varied between 0.3 to 3.1 ug-at $P \cdot L^{-1}$. Subsurface peaks of Kjeldahl N and total phosphorus, although common, did not appear to be related to one another or with peak chlorophyll _a_ concentrations.

Organic nitrogen, as given roughly by Kjeldahl nitrogen, concentrations in the river water samples were no higher than in those collected offshore. Dissolved inorganic nitrogen was undetectable in the river water, even on April 23 when nitrate and nitrite were at their peak concentrations in offshore water. The concentration of ammonia in Yakoun Bay increased to high levels from below the limit of detection (3.6 ug-at $N \cdot L^{-1}$) on four occasions before fertilization and on four occasions after fertilization (Table 3).

SEDIMENT NUTRIENTS

Interstitial nutrient concentrations measured in sediments collected in the estuary on June 29 and 30 (before and after fertilization) are given in Table 4. Dissolved organic nitrogen (DON) and ammonia always represented more than 95% of the total interstitial nitrogen present in the sampled sediments; nitrate was always present in minute amounts. Prior to fertilization, interstitial nitrogen concentrations were highest at Station B15, located near the head of Yakoun Bay (Table 4). On June 30, the interstitial nitrogen concentration had decreased substantially at this station (Table 4). It is unlikely that a significant amount of fertilizer landed near Station B15, and this may partially account for this decrease. When all five sampling stations were statistically considered (Wilcoxin signed-rank test), nutrient concentrations were not significantly different on June 29 and June 30. However, ammonia concentrations did increase in the sediments at four out of five stations. At Station B11, ammonia levels increased by more than 800% following fertilization.

PHYTOPLANKTON

Chlorophyll a concentrations at pelagic stations in the Yakoun estuary varied little between April 23 and July 4, 1980. However, from June 26 to July 4, rapid changes in chlorophyll a concentrations did occur. When 0 to 5m depth integrals of chlorophyll a were averaged over all ten pelagic stations, values increased from 15 mg Chl a·m^{-2} on June 30 to 25 mg Chl a·m^{-2} on July 1, and than fell to 6 mg Chl a·m^{-2} on July 4. Chlorophyll concentrations measured at individual depths ranged from 0.72 to 6.89 mg Chl a·m^{-3} (mean = 3.21 mg chl a·m^{-3}) (BEAK, 1980; Tables 3.4.1-2,3.2.1-1).

Stockner et al. (1979) found mean annual chlorophyll a concentrations of 1.14 to 2.61 mg chl a·m^{-3} in the upper 25 m of pelagic stations located in the Strait of Georgia. Chlorophyll a ranged from 0.04 mg Chl a·m^{-3} at some stations in winter to 19.2 mg Chl a·m^{-3} during the spring phytoplankton bloom at the mouth of Howe Sound. However, these results cannot be readily compared to those measured in the present study because observations in the Yakoun estuary were made only over a period of four months, and at monthly intervals. For this reason it is not possible to know whether or not all phytoplankton blooms which occurred in Masset Inlet during the spring and summer of 1980 were sampled.

Depth profiles regularly showed high subsurface concentrations of chlorophyll a (BEAK, 1980; Appendix 3). For example, on July 1 when chlorophyll a peaked in the top 5 m of water at pelagic stations, chlorophyll a concentrations increased by 46% and 117% between 0 and 2 m depth at Stations P8 and P10, respectively (BEAK, 1980; Table 3.4.1-1). This increase was accompanied by greater cell numbers and total cell volumes at 2 m depth than at the surface (BEAK, 1980; Table 3.2.1-1).

Total phytoplankton cell numbers and cell volume greatly increased between May and June. There were no obvious between-station differences in cell numbers or volume at any sampling session. Average cell numbers for all pelagic stations and depths were 102 ± 19.2 cells·mL^{-1} (n=8) on May 20 and 21; by June 26/July 4 phytoplankton abundance had increased to 810 ± 71.7 cells·ml^{-1} (n=29) (BEAK Table 3.2.1-1, 1980). Cell volume increased from 5.3 ± 0.99 x 10^4 $\mu m^3 \cdot mL^{-1}$ (n=8) in May to 38.1 ± 3.73 x 10^4 $\mu m^3 \cdot mL^{-1}$ (n=29) in June/July. Unlike chlorophyll *a* concentrations, cell numbers and volumes were quite low. The lowest mean annual phytoplankton concentrations found by Stockner et al. (1979) in the northern part of the Strait of Georgia were 1216 cells·mL^{-1} and 6.51 x 10^5 $\mu m^3 \cdot mL^{-1}$. Seasonally, cell numbers ranged from 4 cells·mL^{-1} to 1.70 x 10^4 cells·mL^{-1}; cell volume ranged from 1.00 to 10^3 $\mu m^3 \cdot mL^{-1}$ to 3.46 x 10^7 $\mu m^3 \cdot mL^{-1}$ (Stockner et al. 1979).

Phytoplankton carbon present in the Yakoun estuary was estimated to between 3-20 µg C.L^{-1}, using the approximate conversion factor of 10^4 µm.mL^{-1} = 0.52 µg C.L^{-1} (Sheldon and Parsons 1967). This concentration is lower than the threshold carbon concentration at which zooplankton in the Strait of Georgia begin feeding (Parsons and LeBrasseur 1973).

The plankton samples collected at pelagic stations in May were dominated, in terms of cell numbers, by *Skeletonema costatum*, *Coscinodiscus lineatus*, *Thalassiosira decipiens* and *Gymnodinium* sp. (Appendix 2). *C. lineatus* and *T. decipiens* had the greatest cell volumes, owing totheir very large cell-size (Table 5). River stations, which were sampled for phytoplankton in May only, had a much different species composition than pelagic stations. The river stations were dominated by pennate diatoms such as *Navicula* sp., *Synedra* sp. and *Gomphonema* sp. Marine species such as *S.costatum*, *C.lineatus* and *T. decipiens* were present in the salt wedge at 1.5 to 2 m depth in the Yakoun River but absent at the surface where salinities were very low. (See BEAK, 1980; Table 3.2.1-1).

In June/July, the phytoplankton community included a large number of flagellated cells such as *Ochromonas* sp. and *Chroomonas* sp. The diatoms *Chaetoceros debilis* and *S. costatum* were dominant, in terms of cell numbers. Large-celled centric diatoms such as *C. debilis*, *Leptocylindrus danicus* and *Rhizosolenia setigera* were dominant in terms of total volume.

Primary production of phytoplankton estimated from ^{14}C fixation varied between 0 and 24.2 mg C·m^{-3}·h^{-1} at pelagic stations off the mouth of Yakoun Bay (BEAK, 1980; Table 3.4.1-1 and Appendix 3). Pronounced subsurface peaks in primary production were occasionally observed, the two most outstanding examples being at Station P6 on June 28 and June 30. These subsurface peaks did not, however, coincide with peak chlorophyll concentrations. When normalized to chlorophyll *a*, production varied between 0 and 6.4 mg C·mg Chl *a*·h^{-1}. The 0 - 5m integral of primary production was 20.3±3.1 mg C·m^{-2}·h^{-1} (mean ± S.E., n = 19) averaged over all stations and depths for which an integral could be calculated. On a daily basis this would represent roughly 20 x 12 = 240 mg C·m^{-2}.

Two approaches were adopted to determine if the fertilizer addition might have affected pelagic primary production. First a Photosynthesis vs.Irradiance curve was constructed for Yakoun phytoplankton for the period June 26 - July 4. This was done by taking irradiance at Sandspit during the time period ^{14}C bottles were incubated at Yakoun, then reducing this surface irradiance to a value representative of the depth of incubation (using an attenuation coefficient of 0.99 m^{-1}). Primary production at that time and depth was then normalized to the concentration of chlorophyll a present, and plotted vs. infrared irradiance (BEAK, 1980; Figure 3.4.1-1).

Because of the large scatter of points (due partly to the fact that Sandspit rather then Yakoun irradiances were used), it is difficult to distinguish the difference between the P vs. I response of phytoplankton before and after fertilization. Indeed, the highest observed assimilation index was 6.4 mg C·mg Chl $a^{-1}\cdot h^{-1}$ for Station P6, 2m depth, on June 28 before fertilization. Several post-fertilization photosynthetic rates were, however, higher than the pre-fertilization rates, except for the anomalous June 28 observation at P6. There was no conclusive evidence that fertilization increased primary production per unit of chlorophyll a.

The second approach was to examine the 0-5 m depth integral of primary production. (Daily production rates were estimated by scaling the measured ^{14}C fixation by the reciprocal of the fraction of total daylight insolation received at Sandspit during the incubation period, scaling factors ranged between 2.10 and 4.39. When plotted as an average for all pelagic stations, there was no short- or long-term trend evident (BEAK, 1980; Figure 3.4.1-2). Considering all sampled stations, there was no significant difference in 0-5 m integrated production between June 26-28 and June 30-July 4 (Wilcoxon two-sample test). To see if chlorophyll a levels or light conditions had any discernable effect on primary production, the association between 0-5 m depth integrals of production and chlorophyll a and between integrated production and daily insolation at Sandspit was tested (Kendall's coefficient of rank correlation). Neither association was statistically significant.

BENTHIC ALGAE

There appeared to be little relationship between percent algal cover, chlorophyll a concentrations and diatom cell numbers and volume at benthic stations in Yakoun Bay. Mean chlorophyll a concentrations were between 30 and 200 mg chl $a\cdot m^{-2}$ at nine out of ten stations (Table 6). At Station B3 in the Zostera beds, mean chlorophyll concentration was 417 mg chl $a\cdot m^{-2}$ on May 17 and 248 mg chl $a\cdot m^{-2}$ on June 26. On May 17, the three stations with the lowest chlorophyll concentrations also had the lowest diatom numbers and volume (BEAK, 1980; Table 3.2.1-6). However, on June 26 there was no relationship between chlorophyll a and diatom numbers or volume. This result may be partially due to the fact that only the top 3 mm of sediment was examined for cell numbers and volume, while chlorophyll a concentrations were determined in the top 1 cm.

When differences in chlorophyll a concentrations between April 22 and June 26 were calculated separately for the surface sediments collected at each station (Wilcoxon signed-rank test) there was no evidence that they varied significantly through the spring. However on a shorter time scale, there was some evidence that chlorophyll a at the benthic productivity stations in the Zostera fringe increased on the day following fertilization (BEAK, 1980; Fig. 3.2.1-1), but the sampling variability was great. The 30-200 mg chl $a\cdot m^{-2}$ typically found at Yakoun Bay is slightly higher but overlaps with the values of less than 100 mg chl $a\cdot m^{-2}$ found on the

Nanaimo delta (Naiman and Sibert 1979). The dark color of the Yakoun River and its sudden freshets may be responsible for limiting light penetration and so causing the low surface chlorophyll *a* levels observed on the Yakoun estuary. This may be particularly true of Station B5, which was located on a sand levee of the river where very low surface chlorophylls of 33 and 32 mg chl $a \cdot m^{-2}$ were measured on May 17 and June 26, respectively.

No consistent differences among sampling stations or sampling dates were observed in ash-free dry weights of sediment surface scrapings (Table 7). It was impossible to estimate the carbon biomass of benthic algae from sediment ash-free dry weights due to the large amount of detritus present.

Average total cell numbers of benthic diatoms for the ten intertidal stations were $3.1 \pm 0.62 \times 10^6$ $cells \cdot cm^{-2}$ on May 17,compared to $1.7 + 0.22 \times 10^6$ $cells \cdot m^{-2}$ on June 16 (BEAK Table 3.2.1-6 1980). Diatom volume was $1.1 \pm 0.29 \times 10^9$ $\mu m^3 \cdot cm^{-2}$ on May 17 and $0.6 \pm 0.22 \times 10^9$ $\mu m^3 \cdot cm^{-2}$ on June 26. This decrease in cell numbers was significant (P less than 0.024, Wilcoxon signed-rank test), but the decrease in total cell volume was not statistically significant. Station B5 on a sand levee had very low numbers of diatoms in both May and June, very low total cell volume in May and moderately low volume in June. No other site differences were obvious, even in species composition.

In May, *Achnanthes* sp., *Achnanthes hauckiana*, *Amphipleura rutilans*, *Nitzschia palea* and *Synedra fasciculata* dominated diatom numbers (BEAK Table 3.2.1-6, 1980). In terms of cell volume, *A. hauckiana A. rutilans*, *N. palea* and *S. fasciculata* were dominant (BEAK, Table 3.2.1-6, 1980). This pattern of dominance was still evident in June, except that *N. palea* had declined substantially in abundance and *Achnanthes* sp. was more prominent.

On several occasions the oxygen light-and-dark-bottle method used at Yakoun Bay gave anomalous results. Five of 38 productivity determinations were rejected, in 4 cases because the surface dark bottle had more O_2 in it after incubation than did the control bottle (implying that gross photosynthesis by phytoplankton in the added water was consuming O_2 and/or that sediment respiration was releasing O_2), and in one case because the light bottle had less O_2 than the dark bottle after incubation. In 2 of the remaining 33 determinations the surface light bottle O_2 was less than the control O_2, implying that net primary production of the sediment algae was negative. Appendix 2 lists the 33 determinations retained for further analysis.

VASCULAR PLANTS

The Yakoun estuary marsh can be segregated into several distinct communities, based on dominant vegetation, which increases in complexity and heterogeneity along the intertidal gradient from low to high zones. The plant communities and substrate types which were discernible from aerial photographs (BC 7864-225,1980) are mapped in Figure 14.

The two mixed grass communities, dominated by *Calamagrostis nutkaensis* and *Deschampsia caespitosa*, and located in the high intertidal marsh were not separable in the photographs and therefore were both mapped as "Grass". The "Grass" communities occupied ten hectares on the east side of the delta and thirty-eight hectares on a long sheltered fringe on the west side of the estuary. Common species included *C. nutkaensis*, *Bromus pacificus*, *Elymus hisutus*, *Agrostis palustris* and *Carex pluriflora*. This community was flooded only during extreme high tides and consequently most of the annual production was being directly incorporated back into the substrate. A heavy layer of decomposing plant material covered the soil surface in this zone.

A community dominated by a rush, *Juncus arcticus*, occurred just below the high marsh zone. This community was patchily distributed throughout the upper marsh areas and occupied a total of six hectares. It too is infrequently flooded, with the result that much of its production remains on the marsh for the entire growing season of the subsequent year.

The third plant community, located at a slightly lower tidal elevation than the *J. arcticus* community, was dominated by the grass *D. caespitosa*. Other common species present in this zone included *Festuca rubra*, *Agrostis exarata*, *Hordeum brachyantherum* and *Potentilla pacifica*. Accumulations of vegetation from this zone which occurs in winter and spring disappears following summer high tides.

At an elevation approximately 30 cm below the *D. caespitosa* community was an almost monotypic stand of *Carex lyngbyei*. In the Yakoun estuary this plant displays the two distinct growth forms that have been previously described for it in other areas (Levings and Moody 1976: Squamish estuary; Eilers 1975; Nehalem estuary, Oregon). The *Carex* zone was flooded at virtually every high tide and most of the previous year's growth was exported into the rest of the estuary by early summer. *C. lyngbyei* occupied fourteen hectares on the east side and six hectares on the west side of the estuary.

Plants which were much more limited in distribution included *Glaux maritima*, found in sparse stands, usually on coarse sand substrate, and *Cotula coronopifolia*, found mainly in areas of compact silt by Coho Creek (Figure 14). Total coverage by these two species was little more than one hectare. *Triglochin maritima* was also present on less than three hectares. These plants were not evaluated for biomass because of their limited distribution and relatively small standing crop.

Eight-six hectares of the intertidal zone in Yakoun Bay were occupied by short, dense *Zostera marina* plants with blades about 20 cm long and 2-3 mm wide. Peak biomass occurred in June in this community with a standing crop of 90-100 $g \cdot m^{-2}$. These intertidal plants appeared to grow larger and to become more sparsely distributed with increasing depth. In the lower reaches of the tidal channels and at the extreme outer edge of the estuary, there were extensive subtidal beds of *Z. marina* which grew up to a meter or more in length and had blade widths of up to 1.0 cm. Although these beds could be observed during very low tides their complete extent could not be mapped. Attempts at mapping the subtidal beds from a low flying Beaver aircraft during extremely low tides, and with the aid of a 35 mm colour infrared film, failed due to heavy cloud cover and the dark humic colouration of the river which effectively obscured the beds. However, indirect evidence of their large extent was noted on days in which surface trawling took place when eelgrass was incidently collected in the trawls, at depths of up to 3 m, across portions of Masset Inlet. *Z. marina* can, on this basis, be presumed to occupy sizeable portions of the shallows in Masset Inlet.

Ruppia maritima and *Z. marina* also grew along the marsh drainage courses and shallow river channels of Yakoun Bay. As in the rest of the bay, *Z. marina* became more abundant and lush with increasing depth in these waterways.

The biomass increments of the plant communities dominated by *D. caespitosa*, *J. arcticus*, *C. lyngbyei* and *Z. marina* were measured in April, May, June and August. These communities were chosen for detailed study because they appeared to contribute the most organic material to the estuarine system.

Table 8 shows the changes in live and dead standing crops, between sides of the estuary within communities, and among the four communities during the spring and summer. Since the standing crops of the *J. arcticus* and the *Z. marina* communities were larger in June than in August it was assumed that peak biomass occurred sometime in June or July. As of August 1, the standing crops of the *C. lyngbyei* and the *D. caespitosa* communities were still increasing.

In Yakoun Bay the *C. lyngbyei* community had a larger "peak" biomass (Table 8) than did any of the other marsh communities. Although the "peak" live standing crops of the *D. caespitosa* (427-487 g dry $wt \cdot m^{-2}$), and the *J. arcticus* (844-580 g dry $wt \cdot m^{-2}$) communities were approximately the same as that of the short form of *C. lyngbyei* (504 g dry $wt \cdot m^{-2}$) the "peak" live standing crop of the tall form was approximately 30% larger (844 g dry $wt \cdot m^{-2}$). The t-test for differences between standing crop means showed no significant difference between sites for *C. lyngbyei* in April, but the significant differences gradually increased in May and June until August, when the tall form on the east side of the estuary had reached a height of one m, twice that of the short form on the west side.

Figures 15 to 18 illustrate the seasonal changes in standing crop in each of the four plant communities. Significant differences in mean live standing crop between the *D. caespitosa* communities on the east and west sides of the delta were measured on all sampling dates except July 31, (Figure 16). The *J. arcticus* community underwent a pattern of growth and decline similar to that of the *D. caespitosa* community on the delta's west side (Figures 16 and 17). No significant differences between mean live standing crop on either side of the delta were found on any sampling date. This also applies to the intertidal *Z. marina* community where no significant differences in mean live standing crop between growing sites was observed (Figure 18). The "peak" live standing crops of the *D. caespitosa*, *J. arcticus* and *C. lyngbyei* communities appeared to be at least fourfold greater than that of the intertidal *Z. marina* community (Table 8). However, although the eelgrass plants underwent a seasonal increase and decline in biomass, similar to the other marsh species, their above-ground phytomass had not been completely shed during the previous fall and winter. For this reason it was difficult to compare the "peak" standing crop of this community with that of the other communities. In addition, the losses in measurable standing crop which occurred throughout the study period as plants died and the dead material (detritus) was washed away were probably of the greatest significance in the _Z. marina_ community as it was much more subject to tidal inundation. Although decaying plant material was not found in this community dead eelgrass leaves were found scattered over large portions of the upper marsh in early spring.

The dry weight variability among the replicates containing detritus was very high and is probably indicative of the differences in the degree of tidal inundation, the strength of river flow and species characteristics. Plant fragments were often "wind-rowed" or swept into conformations that made replicate sampling difficult.

Assuming a growing season 1200 hours long and a conversion factor of 50% between dry weight (organic matter) and carbon it is possible to calculate the weight of carbon produced per square meter per hour in the Yakoun marsh:

	$g\ C \cdot m^{-2} \cdot h^{-1}$
C. lyngbyei (tall)	0.34
C. lyngbyei (short)	0.20
D. caespitosa	0.17
J. arcticus	0.24
Z. marina	0.20
TOTAL	0.97

ZOOPLANKTON

Zooplankton density increased at least thirtyfold between April 23 and July 2 at pelagic stations located at the mouth of Yakoun Bay (Table 9). Mean zooplankton numbers ranged from 360 ± $34 \cdot m^{-3}$ (n=3) on April 23, to 6,000 ± $1,200 \cdot m^{-3}$ (n=4) on May 20, and to 14,000 ± $2,300 \cdot m^{-3}$ on July 2, however this increase cannot be solely attributed to an increase in zooplankton biomass because a considerable amount of detritus was also often captured in the net. For example, at Station P4 on April 23, the total dry weight was more than twice that measured at the other two stations due only to the large amount of detritus that was captured in the net (Table 9).

Cirripedia nauplii dominated the zooplankton community, in terms of numbers, at all stations throughout the study period. Following the large increase in numbers of these nauplii in May there was a corresponding increase in the number of cypris larvae in July. In May and July, copepod nauplii and copepodites were abundant at all stations, and the cladoceran _Evadne tergestina_ was very common at some stations. The zooplankton species composition among stations on any single sampling date appeared to be quite uniform.

BENTHIC INVERTEBRATES

Meiofauna

The meiofaunal composition of three replicates from each of ten intertidal stations is summarized in Table 10. No trends in total numbers over time were apparent (BEAK, 1980; Table 3.3.2-3). Over all stations and dates the average total number of meiofauna was 3.38 ± 1.96 x 10^6 individuals·m^{-2}. The total number of meiofauna was extremely variable among stations and sampling dates. Stations located in the same habitat often had very different meiofauna populations. Stations B5, located on a sand levee, had consistently low numbers of meiofauna.

Nematodes were numerically the most important, comprising 45% of the total numbers averaged over all stations and dates (range 26-69%). Harpacticoids averaged 12% (range = 0-37%) of the total numbers. *Huntemannia jadensis*, *Microarthridion littorale* and an unidentified member of the Family Ectinosomatidae were generally the most abundant harpacticoids.

Macrofauna

Considerable differences were found in the density of macrofauna collected at subtidal and intertidal stations (Table 11). Total numbers of macrofauna per unit area were about one order of magnitude greater in the intertidal stations than they were in the subtidal stations. Macrofaunal dry weight per unit area was significantly higher (<0.05) at intertidal stations compared to subtidal locations in April. However, no significant differences in dry weight could be established for the late June - early July sampling. Neither intertidal or subtidal macrofauna numbers or dry weight changed between April 23 and the latter sampling period.

The species composition of subtidal and intertidal sediment samples was also quite different. Polychaetes comprised an average of 58% and 80% of total subtidal macrofauna on April 23 and July 2, respectively, but they comprised only 16% and 4% of intertidal macrofauna on those dates. Bivalves were an important component of the subtidal macrofauna.

The intertidal stations were more difficult to characterize taxonomically. Abundant taxa were unevenly distributed among the ten stations and in no case were high numbers of a single species confined to one habitat type. This patchy distribution among stations is evident in the fact that only two taxa (*Cumella vulgaris* and *Corophium salmonis* on April 23; *C. vulgaris* and harpacticoids on June 26) comprised more than 10% of the total numbers averaged over all stations, yet several taxa dominated the macrofaunal community at individual stations. For example, enchytraeid oligochaetes made up 55% of the total macrofauna at Station B9 on April 23, but only 5% of the total numbers when all stations were considered together. These isolated concentrations were ephemeral; only Station B3 in the *Z. marina* beds had large numbers and dry weight of macrofauna in both April and June. Other stations showed no appreciable differences.

FISH

Seasonal Abundance

A total of twenty-one species of fish were collected during the beach seining, tidal channel trapping and surface trawling operations (Tables 12, 13 and 14). Appendix 3 lists the common and the scientific names of the fish obtained. Both marine and estuarine species capable of tolerating a range of salinities occurred in the study area. Juvenile chinook, coho and chum salmon and staghorn sculpins were the most consistently collected species in the nearshore environments (Table 12). Coho fry were the most abundant species taken in beach seines in April. However, by May chum fry dominated these catches. Staghorn sculpins were common throughout the study area and became the most conspicuous component of the fish fauna by June. A similar pattern wasevident in salmon fry and staghorn sculpin abundance in the tidal channels over the same period (Table 13). A difference was apparent for coho fry, however, as this species was predominant both in the April and May channel catches but only in the April beach seine catches. A school of shiner perch was trapped at the tidal channel site in June and consequently this species was more numerous than even the ubiquitous staghorn sculpin on that sampling occasion.

As indicated by beach seine (Table 12) and tidal channel trapping (Table 13) data, seasonal changes in juvenile salmon abundance on the estuary were similar for catches of both sampling methods. No juvenile salmon were caught in the surface trawls in Masset Inlet in June and July.

Chinook were present on the Yakoun estuary in low numbers over the entire study period; abundance declined steadily from April to July.

Attempts to collect pink salmon fry in the mainstem river and estuary areas were unsuccessful. High water levels in the river in April, 1980 (Figure 11) prevented the installation of fyke nets and inclined plane traps to intercept downstream pink salmon migrants in the Yakoun River. Tidal channel trapping and beach seining have proven to be efficient methods for sampling pink salmon fry in other systems and yet both methods failed to yield even one pink on the Yakoun estuary from April to July, 1980.

Chum fry were present on the estuary during the entire study period, however, numbers of chum fry were highest during the May sampling session. An order of magnitude difference was observed between chum fry numbers in April and May (Tables 12 and 13). In the absence of more frequent catch information over the study period it is reasonable to assume that maximum chum fry populations on the Yakoun estuary occurred in May.

Occurrence of sockeye and coho fry in catches on the estuary Tables 12 and 13) is of particular interest as both species generally do not migrate downstream after emergence from the spawning beds but rather remain in fresh water for periods of one to two years. Of the five juvenile sockeye collected in April, four were underyearlings. The average fork length of these fry was 28.0 (±2.70 S.D.) mm. Juvenile sockeye were not collected on the Yakoun estuary during subsequent sampling sessions and it is highly probable that the fry collected in April were washed downstream to the estuary by the heavy river discharges observed during the first two weeks of April.

Spatial Distribution

Juvenile chinook and sockeye were caught at the tidal channel trap site and at both mainstem and side channel beach seine sites. Staghorn sculpins were similarly ubiquitous. Chum salmon fry were present on the estuary in low numbers in April; while only one fry was trapped at the tidal channel site, 22 of the 23 fry netted by beach seines in April were collected at Station 1 to 4. It appears that chum fry were using major side channels in preference to the main river channel or to small tidal channels higher in the marsh. By May chum fry were much more numerous and were well represented in all three habitat types when sampled.

While a few coho fry were caught at beach seine stations along the mainstem Yakoun in April and May, most coho fry were collected in the Coho Creek tidal channels. The data from the tidal channel trapping operation (Table 13) reflect the distributions of juvenile salmonids on the upper marshes at high tide because the net was drawn across the tidal channel at high water. In contrast the beach seine data (Table 12) were collected near low water and hence indicate fish distributions at low tide. Coho fry were found at the upper estuary at high tide and along the lower reaches of Coho Creek (beach seine Stations 1 to 4) at low tide indicating a tendency to remain in fresh water over the tidal cycle.

On May 21, 1980, 134 coho and 16 chum fry were trapped at the tidal channel site. When the net was dropped at high tide, salinities to 18$^{o}/_{oo}$ near the bottom thus a wide range of salinities were available to the fry captured in the tidal channel during that tidal cycle.

A total of twenty Kodiak surface trawls were made off the Yakoun estuary and near the mouth of Masset Inlet in June and July, 1980. Catch data are reported in Table 14. The results of two trawling sessions near the mouth of the Yakoun River were very similar. Eight fish species were collected in the June trawls, seven in the July trawls. A total of only eighty-five individuals were caught in the over two hours of combined trawling effort at this site (Table 14).

In contrast, the offshore trawl transect conducted in July near the outlet of Masset Inlet yielded more fish and a total of thirteen species. Only six of the fourteen species gathered from the July transects were common to both locations; furthermore, an inverse relationship in abundance was apparent between these species at the two transect locations.

Pacific sandlance and shiner perch were the most abundant species in the offshore trawls. Both species are known to form schools in offshore waters and it is likely that complete schools were collected by the surface trawl net in Masset Inlet.

Size, growth and residency of juvenile salmon

Length and weight for juvenile chum, coho and chinook salmon collected on the Yakoun estuary in 1980 are shown in Table 15 and 16. Appendix figures 1 and 2 show length-weight relationships for chum and coho. All three species of fry collected (chum, coho and chinook) showed increases in average size over the study period. Size increases over time were more pronounced for chinook and coho than for chum fry.

As only a few chinook fry and smolts were collected during the study these results should be interpreted with caution. The average sizes for chinook smolts during the same period decreased. This likely reflects recruitment of smaller smolts to the estuary during May.

Coho fry collected on the Yakoun estuary exhibited the greatest apparent increase in size over the study period. Average fry weight doubled between April and May and doubled again between the May and June sampling sessions. As the sampling sessions were approximately the same interval apart (4 weeks) these results indicate that recently emergent fry were probably not being recruited into the coho fry population or the estuary and that coho residencies were on the order of weeks to months.

Chum fry showed the smallest increase in average size between April and May samples. Average length increased by 4.0 mm and average weight by 0.3 g over the one month interval. It appears reasonable to assume the chum fry stay in the Yakoun estuary for periods of days and weeks on the basis of these capture and change in size data.

FEEDING

A total of 266 chum, coho and chinook fry and chinook smolts captured in beach seines and the marsh tidal channel trap were subjected to detailed stomach content analyses. In order to identify the importance of the various food items to the diets of juvenile salmon, three measures of abundance were used: number (N), percent number (%N) and frequency of occurrence (FO). This information was determined for all of the stomachs examined and is presented elsewhere (BEAK, 1980; Appendices 9 - 11. Volumes of food items were determined for a subsample of 78 juvenile salmon stomachs.

Percent volume and an Index of Relative Importance IRI) (%N + %V x FO) were also calculated for each food item in the gut content of fish in the subsample. The completed information for juvenile salmon subjected to the more detailed analyses is presented elsewhere (Beak, 1980; Appendix 12). Comparison of Appendices 9 through 11 and 12 in the latter report show only minor differences between the stomach contents of the sample of 262 fish and the subsample of 78 fish.

Chinook

The diets of chinook fry and smolts collected in April and May were examined, but widely different sample sizes limit the usefulness of the information gathered. Insects were the dominant food items for chinook fry in April (BEAK, 1980; Appendix 12). In May the gammarid amphipod

Corophium sp. was used most heavily by fry less than 50 mm in length. Juvenile chinook greater than 50 mm in length fed predominantly on Corophium sp. in April, but insects, especially dipterans became more important by May. The chinook juveniles trapped in the tidal channel in April appeared to have different diets from those of the beach seine stations in that Cumella vulgaris, a crustacean, was the most important food item. Nematodes were important parts of the diets of all chinook juveniles over 50mm in length but were absent from the smaller size class.

Coho

The percent number and percent volume of major food items found in the gut contents of coho fry from the Yakoun estuary are shown in Figure 23. Coho fry used a variety of food items while present on the estuary from April to June. In terms of overall importance the major food items consumed by juvenile coho were insects, gammaridean amphipods and harpacticoid copepods.

In April harpacticoid copepods constituted more than half of the total number of food items selected and yet represented less than 10 percent of the total volume. They were found in 70 percent of the stomachs analyzed and were the most important item in the diet in April. One month later harpacticoids accounted for 2 percent of the total numbers and less than 1 percent of the total volume of organisms taken as food. Relative importance was less than one-tenth of that the previous month. A similar, but less dramatic, decline was apparent for Collembola. Coho fry from the tidal channel in June contained neither harpacticoids nor Collembola, however, this may reflect the spatial as much as the temporal distribution of these prey organisms. On the Yakoun estuary coho fry seem to undergo pronounced changes in diets with time. Such seasonal changes in diet may reflect seasonal changes in average size, abundance or species composition of preferred food items or of the predators themselves.

Chum

The composition of major food items found in the stomach content of chum fry from the Yakoun estuary are presented in Figure 21. In terms of occurrence of taxa, chum fry diets were similar to coho diets. In terms of importance of various food items there are marked differences between the two.

Harpacticoid copepods were by far the most important food items for chum fry from both tidal channel and beach seine locations and both the April and May sampling sessions. Insects constituted almost all of the remaining stomach contents for both locations and periods.

Harpacticoids represented 84 percent of the number and 33 percent of the volume of stomach contents of chum fry collected by beach seines in April. Comparable figures for May were 93 percent and 13 percent, respectively. Harpacticoids constituted 73 percent by numbers and 12 percent by volume of total food items consumed by chum caught at the tidal channel trap site. It appears that larger harpacticoids were selected in April while more and smaller individuals were used as food in May.

Detailed identifications of harpacticoid copepods were performed for 24 chum fry gathered in April and May. Harpacticoids were randomly selected and identified to the species level. Complete results are contained in Table 17. Tachidius discipes was the dominant harpacticoid in the diets of chum fry caught by beach seine in both April and May, however, its relative importance in terms of percent composition declined by half (64 to 29 percent) from April to May.

A comparison of the tidal channel and beach seine samples in May reveals a selective preference for different harpacticoids at the two locations. In terms of importance to chum fry as food items the following organisms dominated the May tidal channel fry stomachs; Tisbe sp. (24.6%) T. discipes (22.3%) and Mesochra pygmaea (18.9%). Fry caught by beach seine in May, however, made extensive use of T. discipes (29.1%) Amphiascus minutus (23.0%) and Stenhelia asetosa 15.9%).

Harpacticoids generally comprised about 10%, by numbers, of the meiofauna on the estuary (range 0 - 37%) and yet consistently represented the most important taxon in the diets of chum fry. In addition those harpacticoids identified from chum stomachs (Table 15) were not numerically important components of the harpacticoid fauna at the intertidal sampling stations (Table 10). Tachidius discipes and Stenhelia asetosa were the only species which ever represented more than 10% of the harpacticoid fauna found in chum fry stomachs. Chum fry on the Yakoun estuary appear to prey upon relatively rare members of the harpacticoid fauna.

Kodiak surface trawls in Masset Inlet and off the Yakoun estuary were also intended to gather information on the distributions of juvenile salmon and their potential predators. No salmon fry or smolts were collected by trawl net but a number of other species including sculpins, shiner perch, sand, rock and English sole and starry flounders, were caught. The stomach contents of three staghorn and two buffalo sculpins and ten shiner perch were examined but no salmonids were found.

DISCUSSION

PRIMARY PRODUCTION FROM VARIOUS SOURCES

The net primary production of phytoplankton, benthic algae, and vascular plants can be roughly estimated for Yakoun Bay. For phytoplankton, mean production in the top 1 m of the water column (pelagic stations, June 26 - July 4) was 5.6 ± 0.66 mg $C \cdot m^{-3} \cdot hr^{-1}$ (mean $\pm$ S.E., n = 35). Assuming an average water depth of 1 m over the intertidal zone during the day, 5.6 mg $C \cdot m^{-2} \cdot h^{-1}$, or 18 kg. $C \cdot h^{-1}$ over a submerged area of 313 hectares would be produced. The net primary production by benthic algae was estimated to be about 0.12 g $C \cdot m^{-2} \cdot h^{-1}$ for 85% of the intertidal area, or scaled up to the total submerged area of 313 hectares, 380 kg $C \cdot h^{-1}$. Average net production by marsh plants was approximately

0.24 g $C \cdot m^{-2} \cdot h^{-1}$ over an area of 74.5 hectares (179 kg $C \cdot h^{-1}$). The inaccuracy of these estimates is such that the true value could lie anywhere within a factor of 2 or 3 of each estimate. It is clear, however, that phytoplankton production was a relatively insignificant source of carbon for the Yakoun Bay ecosystem.

Vascular plant production is of indirect utility to salmon fry because it serves as an input to the detrital component of the food web. The amphipod Eogammarus confervicolus, an important consumer on the Squamish River delta (but not abundant at Yakoun), cannot utilize C. lyngbyei unless the plant tissues are decomposed (Pomeroy 1977). The live tissue of benthic algae may either be directly grazed by invertebrtes or it may die and also enter the detrital food chain. In this study there was no observed increase in benthic algal standing crop despite rapid primary production, and thus a considerable influx of carbon into higher trophic levels could have occurred (an unknown fraction could also have been exported from Yakoun Bay during tidal exchange and periods of river flushing. Pomeroy (1977) and Pomeroy and Levings (1980) found that amphipods fed preferentially on the phaeophyte Pylaiella sp. and the chlorophyte Entermorpha sp. Sharp (1980) and Chang and Parsons (1975) demonstrated that the amphipods E.confervicolus and Anisogammarus pugettensis could grow to maturity on diets of macroalgae or diatoms. Mixed populations of harpacticoids collected from the Nanaimo River estuary assimilated heterotrophically-derived carbon at a rate roughly 8 - 10 times faster than they assimilated autotrophic carbon (Brown and Sibert 1977; Sibert et al. 1977). These references demonstrate that there is a large estuarine community of consumers able to assimilate both living algal tissue and detritus.

There are differences in the timing at which detrital and living tissue enter higher trophic levels. Naiman and Sibert (1979) conclude that although Zostera marina grows over the summer it is mainly available to consumers from December through February when it decomposes. Marsh grasses are mainly exported to the mudflat on high tides in spring after the fall and winter dieback. Epibenthic algae are a readily available food source throughout the year (Pomeroy, 1977).

JUVENILE SALMONID USE OF THE ESTUARY

Four of the five species of Pacific salmon likely use the estuary of the Yakoun system to varying degrees. Pink fry were not collected from the study area in 1980 but are reported to make limited use of estuaries elsewhere (Bailey et al. 1975; Andersen et al. 1982; Parker 1971; Levy et al. 1979), as are coho fry (Mason 1975) which use the upper portions of the Yakoun estuary as rearing habitat. The anomalous occurrence of sockeye fry on the estuary is possibly explained by high river flows in early April of 1980. Chinook fry and smolts are present throughout the estuary but never constitute a significant portion of the fish fauna in terms of numbers. Chum fry appear well distributed on the estuary in both time and space and attain their highest numbers in May. On the basis of limited information residency periods of salmon fry on the Yakoun estuary are similar to other areas (e.g. Levy et al. 1979; Healey, 1980).

Analyses of stomach contents of juvenile salmon collected on the estuary from April to June revealed that young salmon exhibit varying dependencies upon estuarine food organisms. Juvenile chinook on the Yakoun estuary feed predominantly on insects, especially Dipterans, and the epibenthic amphipod Corophium sp. Coho fry use harpacticoid copepods as a primary food source in the early spring but use insects, particularly Dipterans, extensively by May and into June. Chum fry exhibit an almost total dependency on harpacticoids during their entire period of estuarine residency. Harpacticoid species selected as major food items by chum fry generally constitute only minor components of the harpacticoid fauna which in turn represents a minor part of the total benthic meiofauna.

Small staghorn sculpins are present in high numbers throughout the Yakoun estuary and are the most important non-salmonid species on the estuary. Larger staghorn sculpins reside in the offshore water of Masset Inlet and so, probably, do other potential predators of juvenile salmon although no evidence of salmon fry predation was found in 1980. Furthermore, no juvenile salmon were collected in the offshore waters of Masset Inlet despite extensive surface trawling efforts.

FERTILIZER-INDUCED MODIFICATIONS

No increases in nitrogen levels or primary production were observed following the aerial fertilization of Yakoun Bay with urea on June 29. It was expected that the urea could either be removed tidally to deeper water offshore, directly absorbed by benthic algae, phytoplankton or vascular plants within Yakoun Bay, or that it would undergo bacterial degradation, thus stimulating the detrital food chain and resulting in the remineralization of nitrogen.

Regarding the tidal removal of urea from Yakoun Bay, increased concentrations of Kjeldahl N at the bay's mouth were not found after fertilization. This implies that either urea was quickly assimilated by the Yakoun ecosystem or that the added urea was rapidly diluted to negligible concentrations during tidal inundation. Valiela et al. (1973) found that the ebbing tide carried away 6 to 20% of nitrogen applied as sewage sludge to salt marsh plots, but Chalmers et al. (1976; cited in Kistritz 1978) found that half of sludge nitrogen was removed from study plots via tidal flow. The fraction exported per tidal cycle from Yakoun is unknown, but whatever its magnitude it would be rapidly mixed through the water column.

Due to the presence of fresh northwest winds during the aerial fertilization of the bay, it is estimated that only about 80% of the urea fell on the estuary, this means that since urea is 46.6% nitrogen by weight, less than 1.27×10^3 kg of nitrogen was added.

Assuming first that all of the urea stayed within the intertidal zone, but was mixed around by the two tidal inundations occurring between fertilizer application and sediment sampling, and that the area affected was thus about 200 hectares (somewhat less than the intertidal area), the expected increase in sediment nitrogen would be:

$$1.27 \times 10^6 g\ N \times \frac{1\ g\text{-atom}}{14\ g} \times 10^6\ \frac{\mu g\text{-atom}}{g\text{-atom}} \times \frac{1}{200 \times 10^8\ cm^2}$$

$$= 4.53\ \mu g\text{-at}\ N \cdot Cm^{-2}$$

Assuming that this nitrogen influx was confined to the top centimetre of sediment having a density of 2 g dry wt$\cdot$cm^{-3} an increase of 2.3 µg at N$\cdot$g^{-1} dry wt of sediment would be expected. This increase would be indistinguishable from the natural variability of sediment nitrogen. If one assumes instead that urea was confined to a strip about 1 km in length and 200 m wide, an increase of 23 µg-at N$\cdot$g^{-1}dry wt of sediment is expected. This increase is similar to the average increase of 33 µg-at $NH_3N\cdot g^{-1}$ dry wt observed in the four benthic stations B11-14, excluding Station B15 high in the intertidal where ammonium decreased after fertilization.

Alternatively, if one assumed that over two tidal cycles the urea went entirely into overlying water, it would mix into a volume of about

$$300 \text{ hectares} \times 1 \text{ m} = 3 \times 10^6 \text{m}^3$$

resulting in a concentration of 30 µg-at N$\cdot$L^{-1}. When mixed into the estuary this would be diluted by a factor of between 0.05 and 0.31. A conservative estimate of the dilution factor is 0.1, giving a level of 3 µg-at N$\cdot$L^{-1} offshore. However, no ammonia values above the limit of detection (3.6 µg-at N$\cdot$L^{-1}) were observed on June 30 or July 1 (bacterial decomposition of organic nitrogen releases ammonia) (Hollibaugh 1978). With regard to offshore dilution, it is of interest to note that 7 grapefruit were launched at about the seaward limit of the fertilized area July 2. On July 3, 3 grapefruit were found about 1 km offshore of the delta front. This, and the observation that debris collected along the front suggest that the horizontal extent of water movements (0.86 km) was correctly estimated. It is, however, likely that estimates of vertical mixing are high. Thus, if the urea moved off the estuary, its concentration would perhaps be higher than 3 µg-at N$\cdot$L^{-1}.

We therefore conclude that the added urea was likely taken up by the sediment, but the inherent variability of sediment ammonia concentrations makes a firm conclusion impossible.

It is interesting to compare the potential elevation of sediment nitrogen by fertilization of 4.5 - 45 µg-at N$\cdot$cm^{-2} to other nitrogen sources normally present in the Yakoun estuary. One source is the background rate of nitrogen remineralization in sediment. Pamatmat (1968) found that community respiration over an annual cycle at False Bay, San Juan Island, averaged 22 mL $O_2\cdot m^{-2}\cdot h^{-1}$. Oxygen consumption in undisturbed sediment covered with well-aerated water is significantly correlated with temperature, whereas differences in community structure are of secondary importance in affecting benthic respiration (Hargrave 1969). Pamatmat's observed respiration rate is typical of a sediment temperature of 12°C, which seems reasonable for Yakoun sediments in spring. Adopting this community respiration rate of 22 mL $O_2\cdot m^{-2}\cdot hr^{-1}$ for Yakoun results in an expected ammonia regeneration rate (Rowe et al. 1975) of 0.16 µg-at N$\cdot$cm$^{-2}\cdot$d^{-1}. Therefore, background nitrogen remineralization would have to proceed for at least 30 days to equal the fertilizer addition. Another natural source of nitrogen at Yakoun is rainfall. The average nitrogen concentration in rainfall at a forest ecosystem in the Southern Applachians was 7.8 µM NO_3^- and 1.2 µM NH_3 (Swank and Henderson 1976); Junge (1958) gives an average concentration of 10 µM NH_3 in coastal rainfall in a number of countries. Assuming a concentration of 20 µg-at N . L^{-1} in rainfall, and taking the annual mean precipitation of 126 cm for the years 1941-1970 at Sandspit (Environment Canada, Atmospheric Environment Service), gives an annual input of 2.5 µg-at $N \cdot cm^{-2} \cdot d^{-1}$, obviously an insignificant source of nitrogen at Yakoun Bay. The final natural source of nitrogen to be considered here is the Yakoun River. Because Kjeldahl N was at approximately the same concentration in river water and offshore water, the Yakoun River will be a significant supplier of organic nitrogen only when its discharge exceeds 60 $m^3 \cdot sec^{-1}$ so that its contribution over a tidal cycle exceeds that provided by the influx of offshore water. Inorganic nitrogen was below the limit of detection in river water which is not surprising when one compares the results of Naiman and Sibert (1978) for the Nanaimo River. They found a peak nitrate concentration of 15.3 µM in January, but from April throughNovember nitrate was below 3.6 µM. Ammonia remained at levels of 1.3 - 3.0 µM from January to May in the Nanaimo River, dropping to less than 0.7 µM at other times.

There was no evidence of increased photosynthetic activity by epibenthic algae or phytoplankton after fertilization, and only a hint of a transient increase of benthic chlorophyll a one day after fertilization. The fact that primary production was not noticeably accelerated suggests that the transient increase in benthic chlorophyll a was coincidental. Did urea enter the detrital food chain? It was mentioned earlier that bacterial decomposition of organic nitrogen would be expected to release ammonia, and in four out of five benthic stations ammonia concentration increased in the sediment after fertilization. Sporadic increases in ammonia in offshore water were observed both before and after fertilization (Table 4). Pomeroy (1977) noted that ammonia in surface water adjacent to the Squamish delta was highest in May. This could have been a consequence of vigorous bacterial degradation of particulate detritus tidally removed from the upper intertidal. For salt marshes on the eastern U.S. coast, the export of ammonia, when it occurs, seems to occur during relatively short (1-2 or 3 month) periods (Nixon 1980).

The data gathered during the spring and early summer at Yakoun Bay revealed no impact of fertilization on primary production. There was, however, indirect evidence that some of the added urea was microbially degraded to ammonia in surface sediment.

FOOD CHAINS LEADING TO JUVENILE SALMON

On April 23 mean nitrate concentrations at river and pelagic stations in the Yakoun estuary were 5.8 µg-at $N \cdot L^{-1}$. By May 20 mean nitrate concentrations at these stations had fallen to 3.6 µg-at N . L^{-1} (Table 3). After that date nitrate concentrations continued to decrease and ranged from 2.2 µg-at $N \cdot L^{-1}$ on June 26 to 1.1 µg-at $N \cdot L^{-1}$ on July 1, two days after fertilization (Table 3). In contrast, total dissolved phosphorus concentrations showed no such seasonal decline and fluctuated between 0.3 and 1.2 µg-at $P \cdot L^{-1}$ throughout the study period. It is possible that despite a high demand for phosphorus within the Yakoun estuary enough of this nutrient could be regenerated that plant growth did not suffer. It is probable that if any nutrient limited plant growth within this ecosystem, it was nitrogen. Valiela and Teal (1974) concluded that nitrogen was more important than phosphorus in limiting the growth of east coast salt marsh vegetation.

If inorganic nitrogen and phosphorus were removed from the water in the classic Redfield ration of 16·1 by atoms; (Spencer 1975); then

$$0.3\ \mu\text{g-at P}\cdot\text{L}^{-1} \times 16 \text{ atoms N}\cdot\text{L}^{-1} \text{ atom P} \\ = 4.8\ \mu\text{g-at N}\cdot\text{L}^{-1}$$

would be the nitrogen level required to utilize the minimum existing phosphorus supply in the Yakoun estuary. Between May 21 and July 4 measured nitrate concentrations never exceeded 3.8 μg-at N·L^{-1}, indicating that nitrogen might have indeed been limiting during this time. nitrogen concentrations may have been much greater than this (Table 3).

In addition, it is possible that a large proportion of the total phosphorus may have been organic (Strickland and Austin 1960) and consequently not immediately available to algae and vascular plants. It is not possible to conclude, for these reasons, whether or not nitrogen or phosphorus limits plant growth at Yakoun Bay.

It was also possible that light limited plant growth, but again the results of this study permit no firm conclusion. Although there is some evidence that the phytoplankton were specially adapted to the low-light environment within the water column, and that the net production of phytoplankton, benthic algae and vascular plants was not unduly low at Yakoun, it is not known whether more light would have stimulated primary production.

For the sake of argument, let us assume that nitrogen limits primary production in the spring when salmon fry enter the Yakoun estuary. What would be the likely response of the lower trophic levels to an addition of urea at this time? Either bacteria or algae could directly absorb the added urea. Thayer (1974) has suggested that heterotrophic bacteria will compete with algae for a source of nitrogen when metabolizing large quantities of compounds with large C/N ratios. A large amount of presumably nitrogen-depleted detritus is present during spring on the Yakoun delta (Figure 20). Remsen et al. (1972) found that phytoplankton were responsible for the major part of urea decomposition in two estuaries in Georgia. Hollibaugh (1978), Carpenter et al. (1972) and Mitamura and Saijo (1975) found that urea was not degraded by marine heterotrophs, although urea-decomposing bacteria are present in marine environments (Zobell 1946). The uptake of urea would be expected to be rapid regardless of whether or not heterotrophs were responsible. Elevated ammonia concentrations were observed in Yakoun sediments the day following fertilization, suggesting that the urea may have been mineralized without a substrate oxidation by natural estuarine plankton after an artifical increase in amino acid concentration; Hollibaugh (1978) found that 52 to 132 hours were required for natural coastal plankton to mineralize half of the nitrogen added as amino acids.

Remineralized nitrogen could also enhance benthic algal or phytoplankton production, although this effect was not observed in the Yakoun estuary. LeBrasseur et al. (1978) measured the ^{14}C uptake of phytoplankton in the upper 10m of Great Central Lake on four days following fertilization with inorganic nitrogen. They found elevated production two days after fertilization and peak production on the third day. There is no reason to suppose that the response of benthic algae or phytoplankton,(if it occurs), to elevated ammonia would be any slower at Yakoun. Assuming no immigration from neighbouring areas, no significant increase in herbivore biomass in response to enhanced primary production could occur in shorter than the turnover time of the herbivore population. (Turnover time is defined as the ratio of average biomass during a period of time over the production in that period.) Meiofauna in general have a turnover time of about 5 to 6 weeks (McIntyre 1964; Gerlach 1971). Thus if the enhancement of meiobenthic herbivores is to coincide with the period of residence of salmon fry on the delta, fertilizer must be applied at least 1 1/2 months prior to the arrival of the fry.

Regarding herbivorous zooplankton, it is uncertain whether their production could be further stimulated by increasing phytoplankton productivity in Yakoun Bay. Between April 23 and July 2 average zooplankton numbers increased from 360 to 14,000 individuals $\cdot m^3$ at stations offshore of the Yakoun delta. This represents a mean specific growth rate of 0.052 day^{-1} in zooplankton numbers over 70 days. In comparison, LeBrasseur et al. (1978) found that a fivefold increase in primary production during years that Great Central lake was fertilized resulted in zooplankton biomass increasing at a rate of 0.018 d^{-1}, 45% of biomass increase is substantially lower than that which occurred naturally in zooplankton numbers at Yakoun Bay. Given the rapidity of increase in numbers, it is difficult to provide any assurance that fertilization would accelerate this increase.

Although numerous experiments have been conducted to assess the effects of fertilizer applications on marsh species, no studies have been conducted with those plant species occuring as dominant components of the Yakoun estuary. Studies which have dealt with Spartina alterniflora, a species which forms the dominant component of Atlantic coast marshes, have concluded that the plant responds favourably to nitrogen enrichment. The species occurs in tall and short growth forms as does C.lyngbyei, and fertilization seems to stimulate the short form into yields close to that of the tall form. Mendelssohn (1979) found that interstitial water nitrate levels were extremely low in all Spartina habitats; however, the nitrate levels were significantly higher where the tall form occurred as opposed to where the short form occurred. The tall form is found adjacent to channels, as is the tall form of C.lyngbyei. The same study found the major channels had higher nitrate levels than the adjacent marsh sediments. It was postulated that as the water floods from the creeks into the adjacent meadows, the nitrates are used by other organisms thus reducing the nitrate supply available to the high marshes.

Interstitial water ammonium concentrations in marshes are generally one or two orders of magnitude greater than marsh nitrate concentrations and considerably higher than estuarine water ammonium levels. It has been concluded that marshes are net exporters of ammonium into the surrounding waters (Mendelssohn 1979), and that the major source of this ammonium is the organic detritus in the marsh. In the high marsh areas, where the short form of Spartina occurred, the ammonium concentrations were six times that of low marsh areas. Mendelssohn (1979) suggested that this was a result of poor drainage in the high marsh allowing the ammonium to remain in situ. Apparently these high ammonium by the *Spartina*; enrichment with sewage sludge (Valiela et al. 1973) and with urea (Valiela and Teal, 1974) significantly increased yields in the high marsh areas. The ammonium content of sediment water was found to decrease from spring to fall (Valiela and Teal, 1974). Plots which were repeatedly treated with urea showed a great increase in the concentration of NH_4, and this difference was maintained over the winter period. In addition the yield of the marsh species was doubled (Valiela and Teal, 1974). In contrast, in a Baltic coast area Tyler (1967) found a significant growth response to fertilization of *Juncus* sp. marshes by ammonium and no effect from nitrate fertilization.

From the aforementioned studies it can be concluded that fertilization is a potentially successful method of enhancing marsh production. However, the type of fertilizer to be used and the individual species responses need to be explored further before any conclusions can be made. If *C.lyngbyei* behaves in a manner similar to *S.alterniflora* it may be possible to stimulate the short form to produce yields comparable to the very productive tall form. However, as Valiela and Teal (1974) found, the response of the plants may not occur until the following growing season. As a result of this delayed response, the plants would not be contributing significant amounts of detritus until the end of the growing season. Therefore salmon fry would not benefit from this form of enhancement until about two years after the onset of the program. Nevertheless, in light of the conclusions concerning the benthic and pelagic algal production, it appears that the detrital food chain is a more likely choice for the possibility of enhancement.

The potential benefits of fertilization upon eelgrass beds are difficult to determine as this study was originally not designed to test such effect; hence we can only speculate. The role of *Z. marina* as a "phosphorus pump" is well known and has been described extensively in the literature (McRoy et al. 1970; McRoy et al. 1973). *Z. marina* takes up column; the same process may apply to nitrogen. Short (1975) suggested the *Z. marina* may be opportunistic in its choice of nutrients, absorbing nitrogen from the water column or from sediment, wherever the levels are higher. However, it has also been found that contrary to other seagrasses such as *Thalassia* sp. which occurs in tropical waters, the rate of nitrogen fixation around *Z. marina* roots is very low (Patriquin and Knowles 1972) or negligible (McRoy et al. 1973).

Seagrasses may be nitrogen limited. Patriquin (1972) found that *Thalassia* sp. was limited by nitrogen. Following fertilizer experiments in a Scottish sea loch, Raymont (1947) found extremely heavy sea grass growth. In Alaska, where the production of *Z. marina* was calculated to be 10g dry $wt \cdot m^{-2} \cdot d^{-1}$, McRoy et al. (1973) concluded that the nitrogen requirement for this level of production was 200-300 mg $N \cdot m^{-2} \cdot d^{-1}$.

The question of whether or not eelgrass production could be enhanced by fertilization may be dealt with in light of the above conclusions. The expected background remineralization of nitrogen was calculated as 0.16 ug-at $N \cdot cm^{-2} \cdot d^{-1}$ or 22.41 mg $N \cdot m^{-2} \cdot d^{-1}$. The proposed range of fertilizer was 4.5-45 ug-at $N \cdot cm^{-2}$ or the equivalent of 630-6300 mg $N \cdot m^{-2}$ depending on the area over which the fertilizer was spread. It therefore appears likely that eelgrass production could be enhanced and that the fertilization was of an order sufficient to do so, at least over a short time span. Since Z. marina can absorb nutrients directly from the water column, there exists a strong possibility that the fertilizer which was mixed into the estuarine water was absorbed directly by the extensive submergent beds of eelgrass at the front of the estuary. The intertidal eelgrass may have absorbed the fertilizer from the sediment as well as the water column. This may explain why significant changes in nutrient concentrations were not detected in the water following

When considering the foregoing discussion concerning the possibility of enhancing algal and marsh production, it is apparent that eelgrass probably offers the greatest potential for enhancement. There already exist large beds of eelgrass both in the Yakoun estuary and in Masset Inlet. The eelgrass can absorb the nutrients directly either from sediments or water and the turnover rate of this plant is relatively rapid.Leaves and portions of leaves are lost continually although the plant is never denuded, even in winter. McRoy et al. (1973) found Z. marina to be extremely productive in Alaska and concluded that there was at least a twofold turnover in a year. With the continued shedding of material, Z. marina is a steady source of food for detritivores. Because there would be no lag time as in the marsh response it would conceivably be possible to fertilize and to achieve a detrital response in the same year. However, it would be much more likely to achieve a response, especially at the second trophic level, the year following fertilization.

RESPONSES OF JUVENILE SALMON TO FERTILIZATION

It is extremely unlikely that the fertilization of the Yakoun marsh affected juvenile salmon production on the estuary. Chinook and chum juveniles fed heavily on estuarine organisms (Figures 20 and 21; Table 15), particularly harpacticoid copepods, and thus appear to be the most plausible beneficiaries of fertilization of the estuary. However, there was no indication that these food organisms were in such short supply as to limit fry and smolt survival on the estuary. Nor is there any evidence that either the amount of nutritional content of food material limits the overall production of these benthic invertebrates.

Macro- and meiofauna numbers on the Yakoun estuary exhibited extreme variability between replicates, stations and sampling dates and estimated based on the data gathered during this study. Levy and Northcote (1982) estimate that juvenile chinook reside on the Fraser River estuary for weeks to months, chum for days or weeks, and pinks for hours or days. Similar periods of residence are apparent for the Yakoun estuary.

If population levels and residency periods could be determined for the various species of salmon on the Yakoun estuary and in offshore waters, and if the key trophic interrelationships could be determined and accurately measured, then the cost/benefit of fertilization could be estimated in terms of enhanced salmon production. Although it appears unlikely at the present time, that fertilization of Yakoun Bay or Masset Inlet, in order to achieve enhanced primary and secondary production, will result in any measurable enhancement of juvenile pink salmon growth or survival it is possible that through further studies, estuarine fertilization may still prove to be an effective tool for salmon enhancement

SUMMARY

The size of the large even-year pink salmon run of the Yakoun River on Queen Charlotte Island in British Columbia has been declining during recent years. Based on the assumption that food availability was a significant limiting factor in the survival of juvenile salmon within this system, an attempt was made to increase populations of salmonid food items by artifically fertilizing the estuary and stimulating production at the primary trophic level.

The structure of plankton, benthic algae and invertebrate, vascular marsh plant and fish populations in the Yakoun estuary and Masset Inlet were examined over a four month period in the spring and summer of 1980. Standing crop and primary production were measured in the phytoplankton, benthic algae and vascular plant communities. Water circulation, salinity, light attentuation and nutrient concentration measurements were also made. Nitrogen levels in Yakoun Bay declined from April to June. Since flushing of Masset Inlet is slow, very little nitrogen can be supplied by the waters of Dixon Entrance and because of light and climate restrictions, vegetative production may be limited at certain times of the year. It was felt that nitrogen was the most probable limiting factor to plant growth and production at all trophic levels in the Yakoun estuary.

An extensive sampling program took place one week before and one week after the aerial application of approximately 3402 kg of urea to the intertidal region of Yakoun Bay on June 29. However, the only recorded impact of the fertilization was an increase in ammonia concentrations in the interstitial water of sediment in four out of five intertidal stations. It is unlikely that this ammonia was derived from the microbial decomposition of the added urea. Neither phytoplankton or benthic algal production noticeably accelerated following fertilization. Mean phytoplankton production over Yakoun Bay during the study period was 5.6 mg $C \cdot m^{-2} \cdot hr^{-1}$. Production by benthic algae and by vascular plants was 120 production values are not low in comparison to those measured in other estuaries in British Columbia.

Juvenile chum, chinook and coho salmon, and staghorn sculpins use the Yakoun estuary extensively from April to July. However, no pink salmon were captured in the beach seines, marsh tidal channel traps or surface trawling components of the fish population survey. Seasonal abundances and residencies of the other salmon species were similar to those recorded in other estuaries. Analysis of the stomach contents of juvenile chum salmon, which are believed to have dietary habits similar to pink salmon, revealed that harpacticoid copepods, particularly *Tachidius discipes*, were the most

important food items in April and May. In contrast, coho fry seemed to undergo more pronounced changes in diet with time. While harpacticoid copepods were the main food items in coho diets in April, Dipteran pupae and adults had become the preferred food items by May and June.

Although it appears unlikely that fertilization of Yakoun Bay will result in any appreciable enhancement of juvenile pink salmon growth or survival it is possible that through further studies, estuarine fertilization may still prove to be an effective tool for salmon enhancement.

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Table 1. Zooplankton sampling characteristics at pelagic stations in the Yakoun River estuary, April to July 1980.

DATE	STATION	COMMENTS				
		Type of tow	# Replicates/station	Distance towed (m)	Depth (m)	Volume filtered (m^3)
April 23	1,4,6	Horizontal	1	80	2.0	5.2
May 20	1,2	Horizontal	1	90	2.0	6.2
	4,7	Vertical	3	-	0-10.5	2.1
July 2	6	Vertical	3	-	0-10.5	0.70
	8	Vertical	3	-	0- 8.0	0.54
	10	Vertical	3	-	0- 5.0	0.33

Table 2. Estimated concentrations of nutrients added to the Yakoun River estuary after one tidal cycle.

Condition	Surface area (km^2)	Depth (m)	Volume (10^6 m^3)	Concentration (C)
Spring: High River Flow, no wind (April 22)	5	3	15	0.21
Spring: High River Flow, Wind (based on high salinities, April 23)	5	5	25	0.12
Summer: Off-Estuary Wind (May 18)	6	10	60	0.05
Summer: Low Flow (June 27)	2	5	10	0.31

Table 3. Nutrient concentrations at Yakoun River (R) and offshore (P) stations, 1980.

Date P	Station	Depth (m)	NO_3-N	NO_2-N	NH_4-N	Kjeldahl N	Total
			--	ug-atoms N·L^{-1}		--	
April 23	P1	1	7.1	0.3	LD[a]	15.	0.74
	P4	1	4.3	0.3	LD	12.	0.97
		5	7.1	0.3	LD	LD	1.3
	P6	1	5.7	0.3	LD	LD	1.0
		5	7.1	0.2	LD	LD	1.0
	R8	0	3.6	LD	LD	9.3	0.42
May 20	P1	0	6.0	LD	LD	7.9	0.74
		1.5	4.6	LD	LD	5.7	0.81
	P2	0	4.0	LD	LD	6.4	0.65
		1.5	5.2	LD	LD	11.	0.84
	P4	0	-	LD	LD	5.7	0.81
		2	1.9	LD	LD	LD	0.77
		5	1.9	LD	LD	LD	0.84
	P7	2	1.9	LD	LD	3.6	0.74
May 21	R1	0	0.9	LD	LD	5.7	0.52
		1.5	1.9	LD	LD	5.7	0.32
	R3	0	1.6	LD	LD	6.4	0.48
	R4	0	1.6	LD	LD	5.7	0.74
		2	2.4	LD	LD	4.3	0.36
June 26	P6	0	3.8	LD	LD	7.1	0.34
		1	2.6	0.3	LD	6.4	0.38
		2	1.6	0.3	LD	7.9	0.41
	P8	0	1.1	LD	LD	LD	0.34
		1	-	LD	4.3	6.4	0.34
		2	2.4	LD	LD	8.6	0.38
		5	2.6	0.3	LD	6.4	0.47
June 28	P6	0	1.1	LD	LD	9.3	1.19
		1	1.4	LD	5.7	12.1	0.88
		2	1.6	LD	7.1	10.7	0.88
		5	1.9	LD	LD	8.6	0.72
	P8	0	1.1	LD	LD	7.1	0.75
		1	1.9	LD	LD	7.9	1.03
		2	1.2	LD	5.7	10.7	0.59
		5	2.6	LD	LD	16.4	0.97
June 30	P6	0	1.1	LD	LD	16.4	0.31
		1	1.0	LD	LD	4.3	0.59
		2	-	LD	LD	5.0	0.59
		5	-	LD	LD	37.1	0.63
	P8	0	2.4	LD	LD	8.6	0.31
		1	2.0	LD	LD	6.4	0.47
		2	1.1	LD	LD	10.7	0.69
		5	1.0	LD	LD	6.4	0.34
	P9	0	1.6	LD	LD	9.3	0.53
		1	2.3	LD	LD	7.9	0.69
		2	2.1	LD	LD	11.4	0.66
		5	1.9	LD	LD	10.0	0.97

Table 3. (Cont'd)

Date P	Station	Depth (m)	NO$_3$-N	NO$_2$-N	NH$_4$-N	Kjeldahl N	Total
				-- ug-atoms N·L^{-1} --			
June 30 Continued	R4	0	1.5	LD	LD	10.7	0.47
		1	1.6	LD	LD	15.7	0.75
	R7	0	1.3	LD	LD	15.0	LD
		1	1.0	LD	LD	17.1	0.81
July 1	P6	0	1.1	LD	LD	7.9	0.29
		1	0.9	LD	LD	7.1	0.32
		2	0.9	LD	LD	13.	0.32
		5	1.2	LD	LD	8.6	0.29
	P8	0	1.1	LD	LD	16.	0.32
		1	1.0	LD	LD	21.	0.39
		2	1.3	LD	LD	7.1	0.29
		5	0.8	LD	LD	6.4	0.48
	P10	0	1.4	LD	LD	7.1	0.36
		1	0.6	LD	LD	7.9	0.42
		2	1.6	LD	LD	16.	0.39
		5	2.3	LD	LD	17.	0.55
	R4	0	0.8	LD	LD	16.	0.65
		1	0.5	LD	LD	21.	0.42
	R7	0	2.0	LD	LD	21.	0.61
		1	1.1	LD	LD	7.9	0.74
July 2	P6	0	2.4	LD	LD	5.0	0.77
		1	1.2	LD	LD	7.1	0.71
		2	1.2	LD	LD	5.0	0.65
		5	1.9	LD	LD	6.4	0.71
	P8	0	0.8	LD	LD	4.3	0.65
		1	2.2	0.2	LD	10.	1.2
		2	3.1	LD	15.	8.6	0.68
		5	2.4	LD	LD	6.4	0.87
	P10	0	2.8	0.2	4.3	7.9	0.94
		1	1.8	LD	LD	6.4	1.1
		2	0.9	0.2	3.6	9.3	0.84
		5	2.4	0.2	LD	8.6	0.65
July 4	P6	0	1.6	LD	LD	5.7	0.45
		1	1.4	LD	LD	5.7	0.48
		2	1.2	LD	LD	5.0	0.52
		5	1.1	LD	LD	5.7	0.55
	P8	0	1.1	LD	LD	8.6	0.61
		1	2.4	LD	LD	5.0	0.32
		2	1.1	LD	LD	10.	0.36
		5	1.5	LD	LD	10.	0.32
	P10	0	3.0	LD	5.0	20.	0.61
		1	1.6	LD	LD	11.	0.68
		2	1.4	LD	LD	LD	0.39
		5	1.4	0.2	LD	11.	0.52

[a] Concentration less that limit of detection (3.6 ug-N.L^{-1} for ammonium and Kjeldahl N; 0.2 ug-N.L^{-1} for nitrite).

Table 4. Interstitial dissolved nutrient concentrations in Yakoun Bay sediments before and after fertilization, 1980.
June 29: Benthic (B) Stations sampled immediately before fertilization.
June 30: Benthic Stations sampled two tidal inundations after fertilization.

Nutrient	Station	June 29	June 30
DON[a]	B11	4.61	2.26
	B12	0.93	18.43
	B13	10.37	9.42
	B14	4.15	13.36
	B15	33.69	28.81
NO_3^-	B11	0.15	0.16
	B12	0.15	0.12
	B13	0.92	0.10
	B14	0.20	0.27
	B15	0.13	0.26
NH_3	B11	11.42	102.00
	B12	10.02	39.70
	B13	7.23	8.03
	B14	11.84	23.82
	B15	37.54	21.96
Phosphorus	B11	0.25	0.027
	B12	0.89	0.068
	B13	0.75	0.58
	B14	0.42	0.45
	B15	0.33	0.71

[a] DON includes all dissolved forms of nitrogen except NO_3^- and NH_3.

Table 5. Cell volumes of phytoplankton and benthic diatoms in the Yakoun River estuary, April - July, 1980.

Taxon	um^3.cell^{-1}
Bacillariophyceae	
Centrales	
Bacteriastrum sp.	1300
Chaetoceros sp.	300
C. danicus	300
C. debilis	300
C. decipiens	340-430
C. gracilis	320-340
C. simplex	340
Coscinodiscus lineatus	1300-3300
Cyclotella sp.	420-50
Ditylum brightwellii	22000
Leptocylindrus danicus	3250
Melosira varians	1600
Rhizosolenia setigera	15000
Skeletonema costatum	70
Thalassiosira sp.	900-3200
T. decipiens	1800-2800
Pennales	
Achnanthes sp.	40-80
A. laukiana	170
A. minutissima	80
Amphipleura rutilans	400
Amphora coffaeaformis	220
Anomoeoneis vitreae	280
Asterionella sp.	120
Cocconeis sp.	250
C. placentula	510
Cymbella ventricosa	300
Diatoma hiemale	600
Diploneis sp.	200-400
D. decipiens	500
D. pseudovalis	500
Fragillaria sp.	160-390
Gomphonema sp.	150
Gyrosigma spencerii	3500-4300
Licmophora abbreviata	2000
Meridion circulare	300
Navicula sp.	300
Navicula sp. A	140
Navicula sp. B	300
N. radiosa	480
N. salinarum	600

Table 5. (Cont'd)

Taxon	$\mu m^3.cell^{-1}$
Pennales (cont'd)	
N. pseudoscutriformis	200-520
N. tripunctata	800-950
Neidium sp.	960
Nitzschia sp.	400-800
Nitzschia sp. A	160
Nitzschia sp. B	700
N. acicularis	290
N. closterium	70
N. dissipata	600
N. frustulum	80-180
N. hantzschia	480
N. linearis	2400
N. longissima	160
N. palea	400
N. seriata	2500
Pleurosigma sp.	1200
Rhoicosphenia curvata	260
Rhopalodia musculus	800
Surirella sp.	1000
S. ovata	600
Synedra sp.	1200
S. angustata	1100
S. fasciculata	1200
Tabellaria	
T. fenestrata	900
T. flocculosa	500
Chrysophyceae	
Cryptomonas sp.	180-220
Chroomonas sp.	20-70
Distephanus speculum	400-500
Etreptia sp.	650
Ochromonas sp.	20
Dinophyceae	
Gymnodinium sp.	90-600
Gyrodinium sp.	800-1000
Ciliata	
Mesodinium sp.	800

Table 6. Mean chlorophyll *a* concentrations ($mg \cdot m^{-2}$) in surface sediment from several intertidal habitats of the Yakoun River estuary, April to June 1980.

Substrate station	mean chlorophyll *a* ($mg \cdot m^{-2}$ ± S.E.)		
	April 22 (n=2)	May 17 (n=2)	June 26 (n=1)
Z. marina			
B3	134 (31)	417 (9)	248
B4	95 (30)	46 (10)	112
B10		192 (24)	176
Silt			
B1	158 (0.4)	160 (3)	175
B2	96 (2)	193 (3)	83
Silty ponds near *C. lyngbyei*			
B7	199 (102)	179 (12)	94
B8	97 (16)	141 (51)	166
B9	98 (25)	190 (1)	190
Sand			
B5	98 (9)	33 (5)	32
Fine gravel			
B6	97 (n=1)	129 (15)	194

Table 7. Dry weights and ash-free weights (g·m^{-2}) of benthic algae and substrate in the top 3 mm of sediment at ten intertidal stations in the Yakoun River Estuary, April to June 1980.

	April 23		May 17		June 26	
Station	DW(g.m^{-2})	AFDW(g.m^{-2})	DW(g.m^{-2})	AFDW(g.m^{-2})	DW(g.m^{-2})	AFDW(g.m^{-2})
B1	5620	51.8	5390	42.9	5770	63.7
B2	5420	62.4	6330	92.8	5330	27.2
B3	5460	63.4	5470	65.0	5600	246.0
B4	5100	105.0	5590	46.7	4740	37.8
B5	5160	32.6	5720	35.8	5420	26.6
B6	5240	23.0	6620	81.3	5600	49.0
B7	4900	30.7	5540	48.0	5580	52.5
B8	5120	22.4	5070	51.5	5390	87.7
B9	5290	70.4	6090	72.6	5510	110.0
B10	-	-	5960	83.5	6110	117.0

Table 8. Mean live standing crop and dead biomass increments (g dry wt.m^{-2})(±S.D.) measured in the four major marsh communities of the Yukoun River estuary, April to August, 1980. A total of ten replicates were collected in each community, five on either side of the estuary, for each sampling date.

Date	Species	Site	Live Biomass (g dry wt.m^{-2}±S.D.)	Live Increment (g dry wt.m^{-2})	Dead Biomass (g dry wt.m^{-2}±S.D.)	Dead Increment (g dry wt.m^{-2})
April 22	*C. lyngbyei*	E	33.3 (11.4)	-	6.0 (1.8)	-
		W	21.9 (5.7)	-	5.8 (1.4)	-
May 17		E	143.0 (39.3)	109.7	-	
-6.6						
		W	75.1 (39.1)	53.2	-	
-5.8						
June 26		E	706.8 (113.4)	563.8	-	-
		W	384.9 (184.6)	309.8	-	-
August 1		E	844.2 (143.3)	137.4	-	-
		W	504.0 (115.8)	119.1	-	-
April 22	*D. caespitosa*	E	31.1 (7.3)	-	221.5 (34.0)	-
			81.8 (32.6)	-	634.2 (255.7)	-
May 17		E	36.1 (16.2)	5.0	150.5 (39.4)	-71.0
		W	116.5 (47.5)	34.7	393.7 (142.1)	-240.5
June 26		E	261.0 (84.1)	224.9	157.8 (74.8)	7.3
		W	486.9 (20.7)	370.4	304.0 (77.0)	-89.7
August 1		E	427.8 (37.0)	166.3	106.9 (66.2)	-50.9
		W	428.3 (54.2)	-58.6	240.4 (157.6)	-63.6
April 22	*J. arcticus*	E	67.6 (23.0)	-	367.4 (113.2)	-
		W	77.2 (11.8)	-	307.1 (98.3)	-
May 17		E	168.0 (37.2)	100.4	261.3 (112.2)	-106.1
		W	189.8 (10.5)	112.6	391.8 (112.5)	84.7
June 26		E	488.3 (127.7)	320.3	421.6 (83.1)	160.3
		W	580.3 (152.8)	390.5	348.7 (212.3)	-43.1
August 1		E	482.8 (38.7)	-5.5	180.7 (91.0)	-240.9
		W	437.5 (190.7)	-142.8	302.9 (175.5)	-45.8
April 22	*Z. marina*	E	56.8 (24.5)	-	-	-
		W	43.5 (19.1)	-	-	-
May 17		E	61.7 (24.1)	4.9	-	-
		W	35.1 (10.7)	-8.4	-	-
June 26		E	61.7 (24.1)	4.9	-	-
		W	100.6 (18.9)	65.5	-	-
August 1		E	78.0 (15.8)	-11.8	-	-
		W	68.0 (18.0)	-32.6	-	-

Table 9. Abundance (number·m^{-3}) of dominant zooplankton at stations in the Yakoun estuary, 1980. Taxa listed are those accounting for >5% of particular samples. The dry weights (mg·m^{-3}) of total samples are also shown.

	April 23			May 20				July 2		
Taxa	P1	P4	P6	P1	P2	P4	P7	P6	P8	P10
Actinotroch larvae	-	18	25	-	-	-				
Cirrepedia nauplii	197	161	175	2021	495	811	795	9912	1587	5508
Copepoda nauplii	-	-	-	627	259	3785	4134	-	1120	1224
copepodites 1-2	22	-	21	3066	850	946	1431	840	1494	1530
copepodites 3-5	-	-	-	-	-	-	-	-	747	-
Evadne (*tergestina*)	-	-	-	-	378	-	-	-	1587	2448
Gastropod veligers	-	-	-	487	-	-	-	-	-	1530
Littorina sp.	-	-	-	-	-	-	-	2016	-	-
Oikopleura (*dioica*)	-	-	-	-	-	-	-	1008	840	918
Paracalanus parvus	-	-	33	-	-	-	-	-	-	-
Polychaete larvae	-	18	-	-	-	-	477	-	-	-
Pseudocalanus minutus	-	-	29	-	-	-	-	-	-	-
Sagittus elegans	-	21	25	-	-	-	-	-	-	-
Scaphocalanus (*echinatus*)	-	-	21	-	-	-	-	-	-	-
Zooplankton and detritus dry wt. (mg·m^{-3})	5.0	11.3	2.5	5.4	3.4	7.4	7.4	46.8	39.2	39.0

Table 10. Mean numbers (±S.D.) of dominant meiofauna and harpacticoids per sample at ten intertidal stations in the Yakoun River estuary, April to June, 1980. A total of three replicates per station were made on April 23, May 18, and June 26. Meiofauna were collected in the top 2 cm of sediment of 5 cm^2 cores and separated by washing the sediment through a 0.45 um sieve. Only numbers representing 5% or more of the total meiofauna sample are shown.

	MEAN TOTAL NUMBER									
	STATION									
A. Meiofauna	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Nematodaa	749(73)	766(137)	935(742)	999(742)	292(196)	504(162)	548(182)	1049(347)	665(422)	1029(102)
Oligochaeta	124(126)	109(154)	-	125(177)	56(71)	39(55)	21(30)	205(207)	175(208)	272(272)
Ostracoda	214(124)	517(186)	318(62)	365(175)	189(143)	295(50)	268(104)	522(338)	629(600)	275(275)
Copepoda Nauplii & copepodids	140(140)	101(84)	-	-	682(965)	206(292)	-	-	490(347)	-
Harpacticoida	348(99)	478(191)	227(17)	478(150)	68(53)	230(116)	299(73)	318(184)	284(80)	505(16)
Mean total number $Sample^{-1}$	1604(255)	2075(326)	1539(11)	2270(1298)	752(501)	1151(88)	1197(348)	2036(384)	1830(896)	2519(47)
Mean total number m^{-2} ($x10^8$)	3.21	4.15	3.08	4.54	1.50	2.30	2.39	4.07	3.66	5.04

	MEAN TOTAL NUMBER									
	STATION									
B. Harpacticoids	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Unidentified Juveniles	19	-	-	-	-	-	-	-	-	30
Unidentified Diosaccidae	18	-	-	111	8	-	-	-	-	-
Unidentified Ectinosomatidae	152	165	82	89	6	46	86	-	30	56
<u>Huntmania jadensis</u>	-	106	-	77	13	-	84	53	40	218
<u>Microarthridion littorale</u>	53	-	-	82	-	-	-	-	-	59
<u>Nannopus palustris</u>	-	-	-	-	-	-	-	21	-	-
<u>Schizopera knabeni</u>	-	-	-	-	-	-	—	10	-	-
<u>Stenhelia (asetosa)</u>	48	-	-	-	10	15	-	53	-	140
<u>Stenocaris sp.</u>	-	-	-	-	-	-	-	14	-	-
<u>Tachidius discipes</u>	-	-	-	-	6	-	-	-	-	-
Cylindropsyllidae	-	-	-	-	-	-	23	-	31	
Mean total number of Harpacticoids. Sample^{-1}	345	647	220	392	55	250	311	178	307	581
Mean total number of Harpactcoids m^{-2} (x106)	0.70	1.32	0.45	0.8	0.11	0.51	0.63	0.36	0.63	1.18

Table 11. Numbers of dominant macrofauna at subtidal and intertidal stations in the Yakoun River estuary, April to July, 1980. Subtidal samples were collected in a Ponar grab with a cross-sectional area of 0.05 m^2. Intertidal samples were collected in the top 3 cm of sediment in 0.06 m^2 quadrats. Only numbers representing 5% or more of the total macrofauna $\cdot m^{-2}$ are shown.

	Total Numbers							
	April 23				June 26	July 2		
Taxa	Subtidal P1	P4	P6	Intertidal B1-B9 (mean)	Intertidal B1-B10 (mean)	Subtidal P6	P8	P10
Nematoda	-	96	-	-	736	-	-	-
Phoronida								
Juveniles	-	173	113	-	-	-	-	-
Annelida								
Oligochaeta								
Juveniles	-	-	-	-	1104	-	-	-
Polychaeta								
Aricidea minuta	-	-	-	-	-	1125	167	123
Fabricia oregonica	-	-	-	1323	-	-	-	-
Glycinde picta	346	132	-	-	-	-	250	148
Haploscoloplos pugettensis	216	320	113	-	-	660	167	123
Mediomastus capensis	-	132	-	-	-	-	-	-
Myriochele heiri	-	56	-	-	-	-	-	-
Nephtys juveniles	1260	-	56	-	-	-	-	-
Nephtys cornuta	-	-	-	-	-	349	111	283

Table 11. Cont'd.

	April 23			June 26		July 2		
Taxa	Subtidal P1	P4	P6	Intertidal B1-B9 (mean)	Intertidal B1-B10 (mean)	Subtidal P6	P8	P10
Prionospio steenstrupi	1332	-	56	-	-	-	-	74
Terebellides stroemi	-	150	113	-	-	-	278	86
Tharyx parvus	-	-	-	-	-	-	153	-
Harpacticoida	-	-	-	-	2208	-	-	-
Cumacea								
Cumella Vulgaris	-	-	-	5670	3358	-	-	-
Amphipoda								
Corophium salmonis	-	94	-	2835	-	-	-	-
Gammaroidea juveniles	-	-	-	-	614	-	-	-
Bivalvia								
Axinopsida serricata	-	113	56	-	-	854	-	-
Mysella tumida	-	-	-	1701	-	-	-	-
Psephidia lordii		226	282	-	-	-	83	172
Total Numbers $\cdot m^{-2}$	3600	1880	1130	18900	12300	3880	1390	1230
Dry weight $(g \cdot m^{-2})$	0.17	0.56	3.07	4.19	3.94	6.93	2.08	0.72

Table 12. Total number of fish caught at 15 beach seine stations on the Yakoun River estuary, April to July, 1980. Catch Per Unit Effort (CPUE) is also shown for each sample month. See Appendix 3 for abbreviations.

		NUMBER OF FISH CAUGHT								
Station	Date	CHUM	COHO	CHIN	SOCK	SHSC	STFL	TSSB	PPFH	CRGN
1	20/04/80	2	35	4	2	10	-	-	-	-
2	"	1	10	-	-	12	-	-	-	-
3	"	19	91	1	-	16	-	-	-	-
4	"	-	-	-	-	2	-	-	-	-
5	"	-	-	1	-	2	-	-	-	-
6	"	-	-	-	-	-	1	-	-	-
7	"	-	-	-	1	-	-	-	-	-
8	"	-	19	-	-	-	-	-	-	-
9	"	-	1	-	-	-	-	-	-	-
10	ns[a]									
11	20/04/80	-	1	-	1	-	-	-	-	-
12	"	-	-	-	-	1	-	-	-	-
13	21/04/80	1	2	-	-	6	-	-	-	-
14	"	-	1	-	-	-	-	-	-	-
15	"	-	-	-	-	1	1	-	-	-
TOTALS		23	160	6	4	50	2	0	0	0
CPUE		1.6	11.4	0.42	0.28	3.6	0.14	0	0	0
1	21/05/80	-	7	1	-	7	-	-	-	-
2	"	9	4	2	-	-	-	-	-	-
3	"	25	4	2	-	21	-	-	-	-
4	"	2	18	-	-	5	-	-	-	-
5	"	-	-	-	-	24	-	-	-	-
6	"	-	-	1	-	3	-	-	-	-
7	"	85	22	-	-	3	-	-	-	-
8	"	-	-	-	-	56	-	-	-	-
9	"	9	19	1	-	51	-	-	-	-
10	"	3	1	-	-	25	-	-	-	-
11	"	29	-	4	-	25	-	-	-	-
12	ns[a]									
13	ns[a]									
14	ns[a]									
15	ns[a]									
TOTALS		162	75	11	0	210	0	0	0	0
CPUE		14.7	6.8	1.0	0	19.0	0	0	0	0

Table 12 (Cont'd)

		NUMBER OF FISH CAUGHT								
Station	Date	CHUM	COHO	CHIN	SOCK	SHSC	STFL	TSSB	PPFH	CRGN
1	02/07/80	-	-	-	-	80	-	5	-	-
2	"	-	1	-	-	108	-	-	-	-
3	"	-	-	-	-	94	-	-	-	-
4	"	-	-	-	-	17	2	-	-	-
5	"	-	-	-	-	2	1	-	-	-
6	"	-	-	-	-	35	1	-	-	-
7	"	-	-	-	-	-	-	-	-	-
8	"	-	-	-	-	158	-	-	-	-
9	"	-	-	-	-	2	-	-	-	-
10	"					-				
11	"	-	-	-	-	25	-	-	-	-
12	"	-	-	-	-	18	-	-	-	-
13	01/07/80	-	-	-	-	23	-	1	1	1
14	"	-	-	1	-	8	-	-	-	-
15	"	-	-	-	-	15	1	-	-	-
TOTALS		0	1	1	0	585	5	6	1	1
CPUE		0	0.067	0.067	0	39.0	0.33	0.40	0.067	0.067

[a] ns - indicates not sampled.

Table 13. Total number of fish caught in a marsh tidal channel trap on the Yakoun River estuary, April to July 1980. See Appendix 3 for abbreviations.

	NUMBER OF FISH CAUGHT							
DATE	CHUM	COHO	CHIN	SOCK	STHD	DOLY	SHSC	SHSP
24/04/80	1	95	2	1	-	1	15	-
19/05/80	5	100	2	-	-	-	23	-
20/05/80	13	57	-	-	-	-	24	-
21/05/80	16	134	-	-	-	-	15	-
30/06/80	-	1	-	-	1	-	68	-
01/07/80	-	3	-	-	-	-	-	-
02/07/80	-	-	-	-	-	-	-	64
TOTALS	35	390	4	1	1	1	145	64

Table 14. Total numbers of fish caught in surface trawls in the Yakoun River estuary (June 29 and July 31) and in Masset Inlet (July 31), 1980. All trawls were of approximately ten minutes duration. Catch per unit effort (CPUE) for these sampling dates are also shown. See Appendix 3 for abbreviations.

	NUMBER OF FISH CAUGHT												
TRAWL	SALA	TUBE	SLSC	BFSC	TSSB	RKSL	SHSC	SPSN	ENSL	CRGN	SDSL	PPFH	STFL
Yakoun Estuary 29/06/80													
1	1	-		1	1	-	-	-	-	-	-	-	-
2	1	1		-	-	-	1	-	-	1	-	-	-
3	-	-		-	-	-	-	-	-	-	-	-	1
4	-	-		-	-	-	-	-	-	-	-	-	-
5	-	-		-	2	-	-	-	-	-	-	-	-
6	-	-		-	2	-	-	-	-	-	-	-	-
TOTALS	2	1	0	1	5	0	1	0	0	1	0	0	1
CPUE	0.33	0.17	0	0.17	0.83	0	0.17	0	0	0.17	0	0	0.17

Table 14. (cont'd)

TRAWL		SALA	TUBE	SLSC	SHSP	BFSC	TSSB	RKSL	SHSC	SPSN	ENSL	CRGN	SDSL	PPFH	EULA
						NUMBER OF FISH CAUGHT									
Masset Inlet 31/07/80															
1		-	-	-	-	-	-	-	-	-	-	-	-	-	1
2		-	-	-	-	-	-	-	-	-	-	-	-	2	-
3		3640[a]	-	-	-	-	-	-	1	-	-	-	-	-	-
4		3690[a]	-	-	-	-	-	1	-	-	-	-	-	-	-
5		1060[a]	10	4	-	-	-	2	1	1	-	2	1	3	-
6		54	8	3	57	-	-	-	-	-	-	-	-	-	-
7		17	6		2	1	-	1	-	-	2	3	-	-	-
TOTALS	8461	24	7	59	1	0	4	2	1	2	5	1	5	1	
CPUE	1209	3.4	1.0	8.4	0.14	0	0.57	0.28	0.14	0.28	0.71	0.14	0.71	0.14	
Yakoun Estuary 31/07/80															
8		-	1	-	-	-	-	1	-	-	1	2	-	-	-
9		-	-	-	-	-	-	-	-	-	-	-	-	6	1
10		-	-	-	-	-	-	-	-	-	-	-	-	6	-
11		-	-	-	-	-	3	-	-	-	-	-	-	12	20
12		-	-	-	-	-	1	-	-	-	-	-	-	5	6
13		-	-	-	-	-	-	-	-	-	-	-	-	6	5
14		-	-	-	-	-	-	-	-	-	-	-	-	2	-
TOTAL		0	1	0	0	0	4	1	0	0	1	2	0	37	32
CPUE		0	0.14	0	0	0	0.57	0.14	0	0	0.14	0.28	0	5.3	4.6

[a] Estimated by subsampling.

Table 15. Mean lengths (mm) and standard deviations of juvenile salmon taken at the Yakoun estuary 1980. Data are from beach and tidal creek samples. Numbers in square brackets indicate sample sizes.

Date	Coho	Chum	Chinook fry	Chinook smolts
April	37.1 (0.48) [n = 76]	42.0 (0.68) [n = 15]	40.4 (0.67) [n = 5]	80.5 (6.35) [n = 15]
May	44.3 (0.99) [n = 65]	46.0 (0.89) [n = 67]	46.0 (1.08) [n = 2]	69.0 (4.11) [n = 2]
June	57.2 (2.22) [n = 5]	n.c.[a]	n.c.	n.c.

[a] indicates none caught.

Table 16. Mean weights (g) and standard deviations of juvenile salmon taken at the Yakoun estuary in 1980. Data are from beach and tidal creek samples. Numbers in square brackets indicate sample sizes.

Date	Coho	Chum	Chinook fry	Chinook smolts
April	0.48 (0.06) [n = 76]	0.69 (0.14) [n = 15]	0.67 (0.04) [n = 5]	6.35 (1.31) [n = 15]
May	0.99 (0.23) [n = 65]	0.89 (0.28) [n = 67]	1.08 (0.11) [n = 2]	4.11 (2.00) [n = 2]
June	2.22 (0.68) [n = 5]	n.c.[a]	n.c.	n.c.

[a] indicates none caught.

Table 17. Composition of harpacticoid copepods found in gut contents of 24 chum fry (*Oncorhynchus keta*) caught in beach seines (April 20 and May 21) and marsh tidal channel traps (May 19 to 21) 1980, on the Yakoun estuary.

	April							May							May									
	Beach Seine							Beach Seine							Tidal Channel Trap									
FRY NUMBER	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	10
Ectinosomatidae			1					2		2				2	1			12		1				2
Amphiascus minutus				7	2	6		22		5	5	16	22	10		1							8	
Heterolaophonte discophora			1					1																
Huntemannia jadensis					1	2	2		2		1				8	3	7	1	4	5	1	2		1
Mesochra pygmea				1	5	2		8		1	1	1	2	14	6	9	18	2	1	7	1		5	17
Mesochra juvenile?					1												4			1	1			2
Microarthridion littorale			2	5	1	1	2				2	2				1	1		2				6	
Nannopus palustris								8	2	4	2	1	3											
Nannopus juvenile?											1													
Schizopera knabeni			3		2	3		3	3	2	1	6	2	2	1	1	4		2	2	2	1	8	4
Stenhalia asetosa			5	1	3	12	3	4	1		23	12	10	5	2		1	1				2	1	
Stenhalia juvenile?				1							1													
Tachidius discipes	50	38	15	26	33	9	1	8	30	30	7	7	10	9	10	12	13	2	9	8	13	3	5	3
Tisbe sp.				1				2	4	2		2	2	3	4	12	1	1	6	1	29	11	15	6
Nitocra sp.										5	1										1		1	
Halicyclops sp.			5	8	2	2			1		2		1	1		1		1	1		2			1
Onychocamptus mohammed																	1			1				1
Diosaccidae			2									1								1				
Cyclopoid copepods									1															
Calanoid copepods														1										
Dactylopodia sp.																	3							
TOTAL HARPACTICOIDS IDENTIFIED FROM STOMACH CONTENTS	50	38	34	50	50	37	8	50	50	49	49	49	50	50	32	41	50	20	25	27	50	19	49	37

Table 18. Estimation of net annual aboveground primary production in the four major marsh communities of the Yakoun River estuary, 1980, using the Smalley (1959, in Linthurst and Reimold 1978) method. E indicates East side of the estuary, W indicates West side.

Community	Net production per sample interval (g dry wt.m^{-2})			
	April-May	May-June	June-August	NAPP (g dry wt·m^{-2})
C. lyngbyei				
E	109.7	563.8	137.4	810.9
W	53.2	309.8	119.1	482.1
D. caespitosa				
E	5.0	232.0	166.3	403.5
W	34.7	370.4	0	405.1
J. articus				
E	100.4	480.6	0	581.0
W	197.3	390.5	0	587.8
Z. marina				
E	4.9	28.1	0	33.0
W	0	65.5	0	65.5

Appendix 1. Pelagic primary production (mgC·m^{-3}·h^{-1}), chlorophyll *a* (mg·m^{-3}) and assimilation index (mgC·mg^{-1} chl *a*·h^{-1}).

Date	Station	Incubation period (Local time)	Depth (m)	Chlorophyll *a* (mg·m^{-3})	Primary production (mgC·m^{3}·h^{-1})	Assimilation index (mgC·mg^{-1} chl *a*·h^{-1})
April 23	P1	1130-1545	0[a]	2.6	0.10	0.04
			1	6.4	1.16	0.18
			2	7.7	0.94	0.12
	P3	1300-1710	0	-	4.61	-
			1		2.32	-
			2	-	0.57	-
			5	-	0.	-
			10	-	0.	-
	P4	1215-1615	1	6.7	1.22	0.18
			2	7.7	0.60	0.08
			3	6.6	0.82	0.12
June 5	P1	1145-1545	0	-	6.00	-
			1	-	8.18	-
			2	-	1.93	-
			3	-	1.21	-
	P2	1115-1515	0	-	5.47	-
			0.5	-	7.23	-
			1	-	6.99	-
			2	-	4.45	-
			3	-	1.56	-
			5	-	1.58	-
			7	-	0.94	-
	P3	1100-1500	0	-	9.23	-
			0.5	-	11.2	-
			1	etc.	11.1	-
			2		4.07	-
			3		2.07	-
			5		1.04	etc.
			7		0.48	
	P4	1200-1600	0		12.5	
			0.5		10.7	
			1		8.13	
			2		4.21	
			3		2.33	
			5		0.14	
			7		0.	
June 26	P6	1020-1420	0	1.17	3.13	2.68
			1	3.73	4.35	1.17
			2	3.16	1.66	0.53
			5	1.84	0.92	0.50

Appendix 1. (cont'd)

Date	Station	Incubation period (Local time)	Depth (m)	Chlorophyll a ($mg \cdot m^{-3}$)	Primary production ($mgC \cdot m^{-3} \cdot h^{-1}$)	Assimiliation index ($mgC.mg^{-1}$ chl a$\cdot h^{-1}$)
	P8	1035-1435	0	3.87	5.81	1.50
			1	2.36	3.45	1.46
			2	2.41	1.35	0.56
			5	1.52	0.	0.
	P9	1045-1445	0	3.38	-	-
			1	4.00	2.58	0.64
			2	1.63	1.01	0.62
			5	3.20	0.	0.
June 28	P6	1058-1458	0	1.58	2.09	1.32
			1	2.24	6.21	2.77
			2	3.78	24.2	6.40
			5	4.88	1.84	0.38
	P8	1125-1525	0	-	4.08	-
			1	-	3.75	-
			2	-	1.91	-
			5	-	2.06	-
	P9	1120-1520	0	1.46	3.09	2.12
			1	1.40	3.79	2.71
			2	1.41	2.27	1.61
			5	3.60	2.80	0.78
June 30	P6	1045-1445	0	2.23	3.30	1.48
			1	3.32	6.82	2.06
			2	3.37	15.1	4.48
			5	4.78	3.66	0.77
	P8	1025-1425	0	1.91	2.16	1.13
			1	1.99	2.05	1.03
			2	1.85	1.66	0.90
			5	6.57	3.16	0.48
	P9	1020-1420	0	1.70	2.44	1.43
			1	1.59	2.68	1.69
			2	1.49	3.38	2.27
			5	3.32	1.99	0.60
July 1	P6	1120-1505	0	3.65	5.32	1.46
			1	3.51	8.79	2.51
			2	3.75	4.36	1.16
			5	5.30	0.82	0.15
	P8	1050-1450	0	4.36	10.3	2.36
			1	4.92	6.42	1.31
			2	6.38	4.73	0.74
			5	6.42	1.28	0.20

Appendix 1. (cont'd)

Date	Station	Incubation period (Local time)	Depth (m)	Chlorophyll a ($mg \cdot m^{-3}$)	Primary production ($mgC \cdot m^{-3} \cdot h^{-1}$)	Assimiliation index ($mgC \cdot mg^{-1}$ chl a$\cdot h^{-1}$)
	P10	1045-1445	0	3.18	19.1	6.00
			1	6.47	15.7	2.43
			2	6.89	9.71	1.41
			5	4.31	1.25	0.29
July 2	P6	1100-1500	0	1.54	7.81	5.07
			1	1.77	7.09	4.00
			2	3.70	5.64	1.52
			5	3.42	0.93	0.27
	P8	1040-1440	0	2.52	9.72	3.86
			1	2.85	10.2	3.58
			2	3.60	6.18	1.72
			5	5.48	0.93	0.17
	P10	1035-1435	0	3.77	-	-
			1	3.75	8.28	2.21
			2	3.56	6.33	1.78
			5	4.12	0.81	0.20
July 4	P6	1130-1530	0	1.33	5.82	4.38
			1	1.38	5.39	3.90
			2	0.98	5.10	5.21
			5	1.42	-	-
	P8	1045-1445	0	0.91	3.76	4.13
			1	0.94	3.20	3.41
			2	1.48	3.60	3.79
			5	0.72	0.43	0.43
	P10	1045-1445	0	0.80	1.98	2.47
			1	0.93	3.07	3.30
			2	0.90	2.98	3.31
			5	2.38	2.20	0.92

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*Depths recorded as 0m represent surface samples incubated at 0.25m depth.

Appendix 2. (cont'd).

Date	Station	Incubation Period in	Incubation Period out	Water Height[a] (m) in	Water Height[a] (m) out	Depth	Chlorophyll a $mg \cdot m^{-2}$	Gross primary[b] production $(mgC \cdot m^{-2}h^{-1})$	Gross primary[b] production $(mgC \cdot mgchl\ a^{-1} \cdot h^{-1})$	Net primary[c] production $(mgC \cdot m^{-2} \cdot h^{-1})$	Net primary[c] production $(mgC \cdot mgchl\ a \cdot h^{-1})$
June 30	1	1245	1545	0.0	0.0	A0.25	295	597	2.0	279	0.9
						B1.0	"[d]	526	1.8	---	---
	2	1245	1545	0.0	0.0	A0.25	168	534	3.2	215	1.3
						B1.0	"	542	3.2	---	---
July 1	1	1230	1530	0.2	0.0	A0.25	97	--	--	---	---
	2	1230	1530	0.2	0.0	A0.25	102	39.8	0.4	8.0	0.1
						B1.0	"	23.9	0.2	---	---
	3	1230	1530	0.2	0.0	A0.25	71	119	1.7	-39.8	0.06
						B1.0	"	112	1.6	---	---
July 3	1	1200	1600	1.1	0.0	A0.25	61	173	2.8	83.6	1.4
						B1.0	"	155	2.5	---	---
	2	1200	1600	1.1	0.0	A0.25	56	--	--	---	---
						B1.0	"	125	2.2	---	---
	3	1200	1600	1.1	0.0	A0.25	56	53.8	1.0	17.9	0.3
						B1.0	"	102	1.8	---	---

[a] As predicted for Port Clements, assuming benthic stations were at a tidal height of 0.3m.

[b] Gross primary production of benthic algae + filtered sea water.

[c] Net production of benthic algae only.

[d] (") indicates that two cores were mixed prior to dispensing subsamples into bottles. In this case, chlorophyll was determined only once on a mixed subsample. On June 6, 25 and 27, sediment from two cores was placed separately in replicate series A and B; therefore chlorophyll was separately determined for A and B.

Appendix 2. Primary production, chlorophyll *a*, and assimilation indices of intertidal benthic algae in the *Zostera marina* fringe of the Yakoun estuary, June to July, 1980.

Date	Station	Incubation period in	Incubation period out	Water height[a] (m) in	Water height[a] (m) out	Depth	Chlorophyll *a* $mg \cdot m^{-2}$	Gross primary[b] production $(mgC \cdot m^{-2} h^{-1})$	Gross primary[b] production $(mgC \cdot mg chl \cdot a^{-1} \cdot h^{-1})$	Net primary[c] production $(mgC \cdot m^{-2} \cdot h^{-1})$	Net primary[c] production $(mgC \cdot mg chl\ a^{-1} \cdot h^{-1})$
June 6	1	1120	1520	1.3	0.7	B1.0	46	208	4.5	---	---
	2	1135	1535	1.4	0.6	A0.25	52	222	4.3	165	3.2
						B1.0	22	115	5.2	---	---
	3	1150	1550	1.4	0.5	A0.25	45	222	5.0	143	3.2
						B1.0	45	179	4.0	---	---
	4	1200	1600	1.4	0.4	A0.25	15	129	8.8	72	4.9
						B1.0	20	136	6.8	---	---
June 25	1	1130	1430	0.0	0.8	A0.25	--	898	--	698	---
						B1.0	--	688	--	---	---
	2	1145	1445	0.0	0.9	A0.25	--	306	--	268	---
						B1.0	--	249	--	---	---
	3	1200	1500	0.1	1.0	B1.0	--	502	--	---	---
June 27	1	1110	1555	0.0	1.0	B1.0	61	235	3.9	---	---
	2	1125	1555	0.0	1.0	B1.0	73	229	3.1	---	---
	3	1145	1555	0.0	1.0	B1.0	76	218	2.9	---	---
June 28	1	1115	1515	0.0	0.4	A0.25	66	95.6	1.4	77.7	1.2
	2	1115	1515	0.0	0.4	A0.25	--	29.9	--	-53.8	---
						B1.0	--	35.8	--	---	---
	3	1115	1515	0.0	0.4	A0.25	--	95.6	--	---	---
						B1.0	--	77.7	--	---	---

APPENDIX 3. Common scientific and abbreviated names of fish caught in beach sienes, tidal channel traps and surface trawls in the Yakoun River estuary and Masset Inlet, April to July, 1980.

Scientific name	Common name	Abbreviation
Ammodytes hexapterus	Pacific Sundlance	SALA
Aulorhynchus flavidus	Tubesnout	TUBE
Blepsias cirrhosus	Silverspotted Sculpin	SLSC
Cymatogaster aggregata	Shiner Perch	SHSP
Enophrys bison	Buffalo Sculpin	BFSC
Gasterostereus aculeatus	Threespine Stickleback	TSSB
Lepidopsetta bilineata	Rock Sole	RKSL
Leptocottus armatus	Slipskin Snailfish	WPSN
Oncorhynchus keta	Chum Salmon	CHUM
Oncorhynchus ukisutch	Coho Salmon	COHO
Oncorhynchus nerka	Sockeye Salmon	SOCK
Oncorhynchus tshawytscha	Chinook Salmon	CHIN
Parophrys vetulus	English Sole	ENSL
Pholis laeta	Crescent Gunnel	CRGN
Platichthys stellatus	Starry Flounder	STFL
Psettichthys melanostictus	Sand Sole	SDSL
Salmo gairdneri	Steelhead Trout	STHD
Salvelinus malma	Dolly Varden	DOLY
Syngnathus griseolineatus	Bay Pipefish	PPFH
Thaleichthys pacificus	Eulachon	EULA

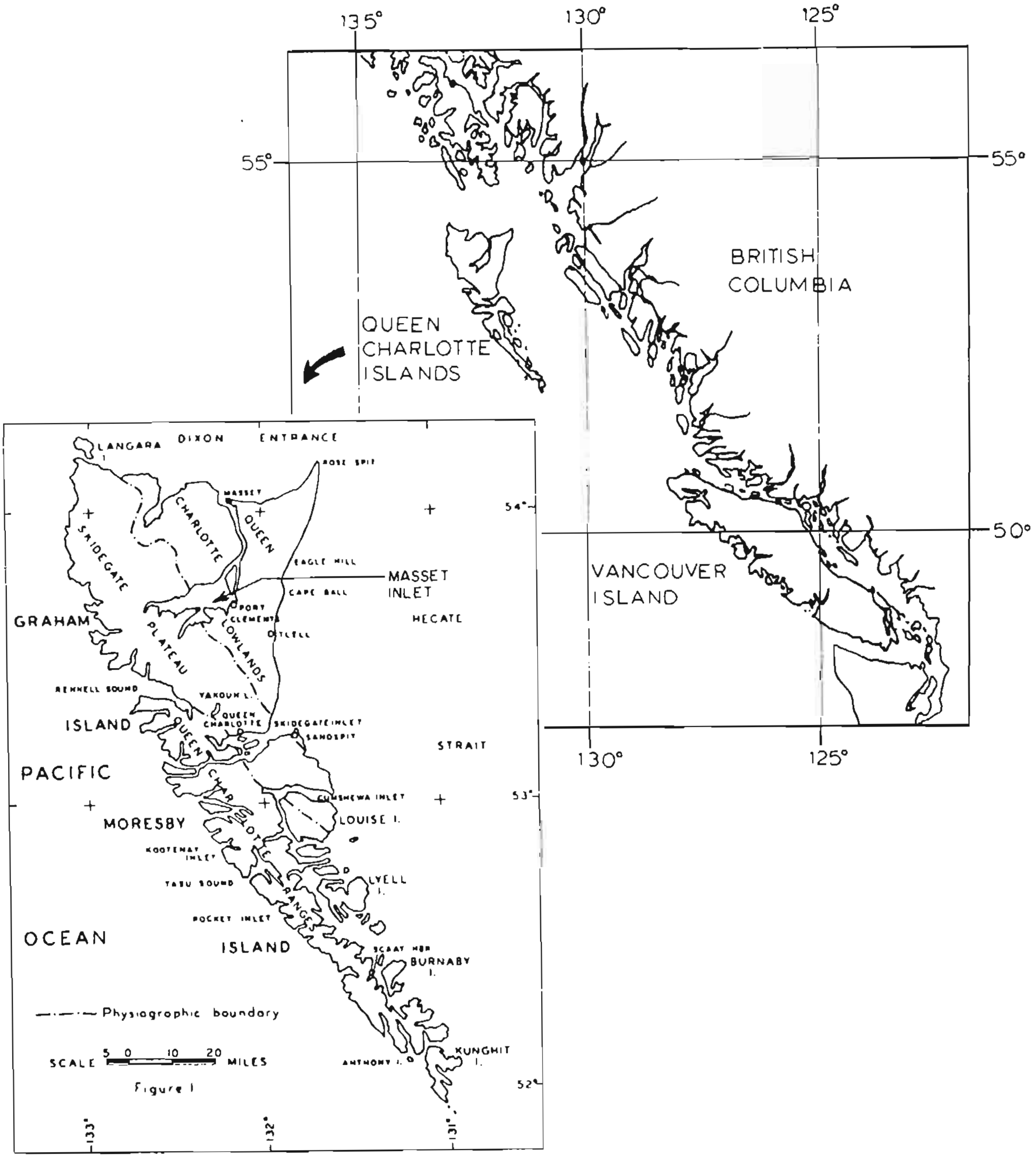


Figure 1. Chart of the British Columbia coast showing the location of the Queen Charlotte Islands. Inset - map of the Queen Charlotte Islands and Masset Inlet. (From: Sutherland Brown and Nasmith, 1962).

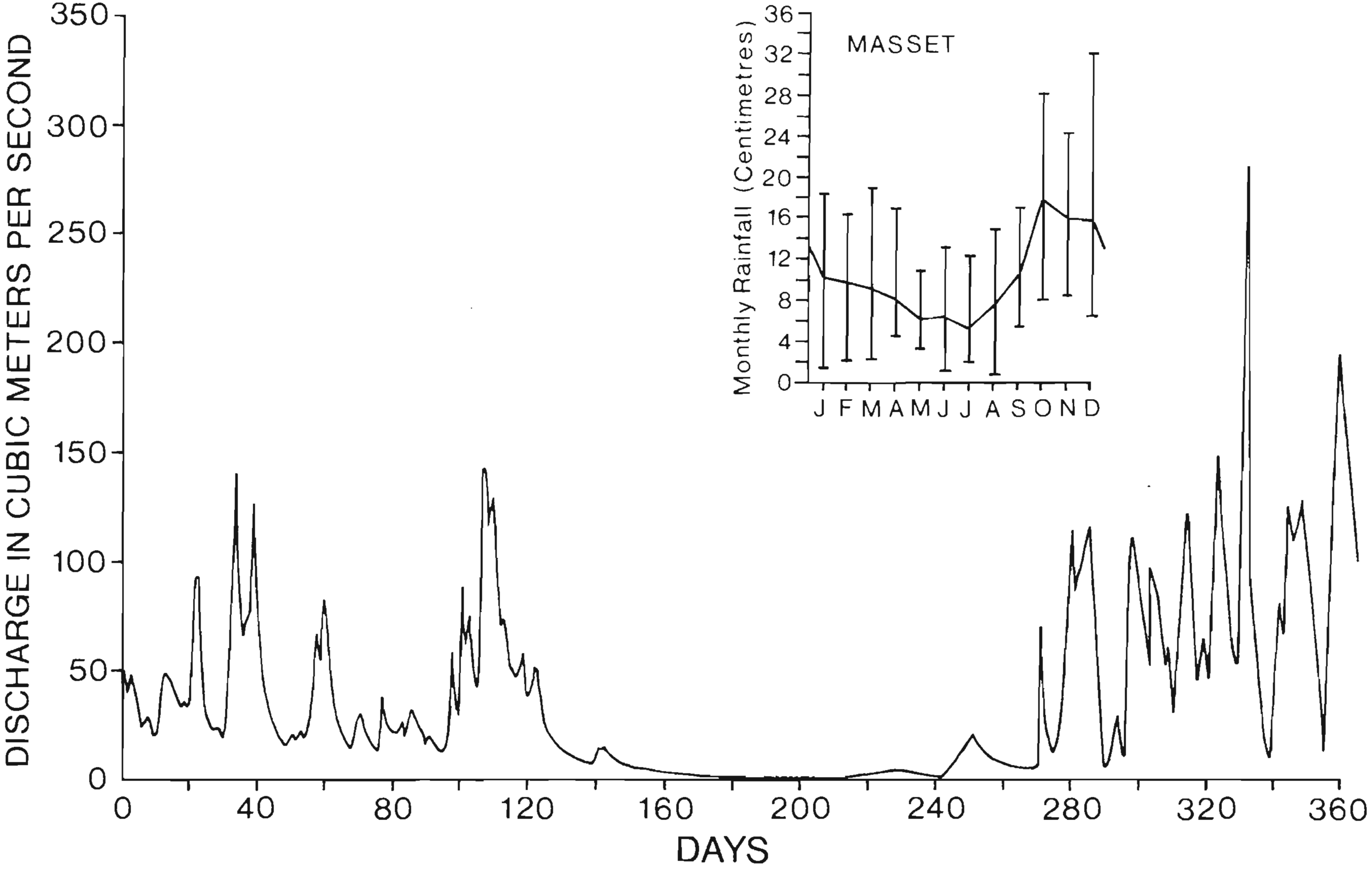


Figure 2. Hydrograph of the Yakoun River, showing discharge rate ($m^3 \cdot sec^{-1}$) during 1980. Discharge data was collected daily at Water Survey of Canada station No. 08-OA002, near Port Clements. Inset shows monthly rainfall (cm) received at Masset, derived from data collected from 1915-1948 and adjusted to 1947-1963. (Adapted from: Calder and Tay lor 1968.)

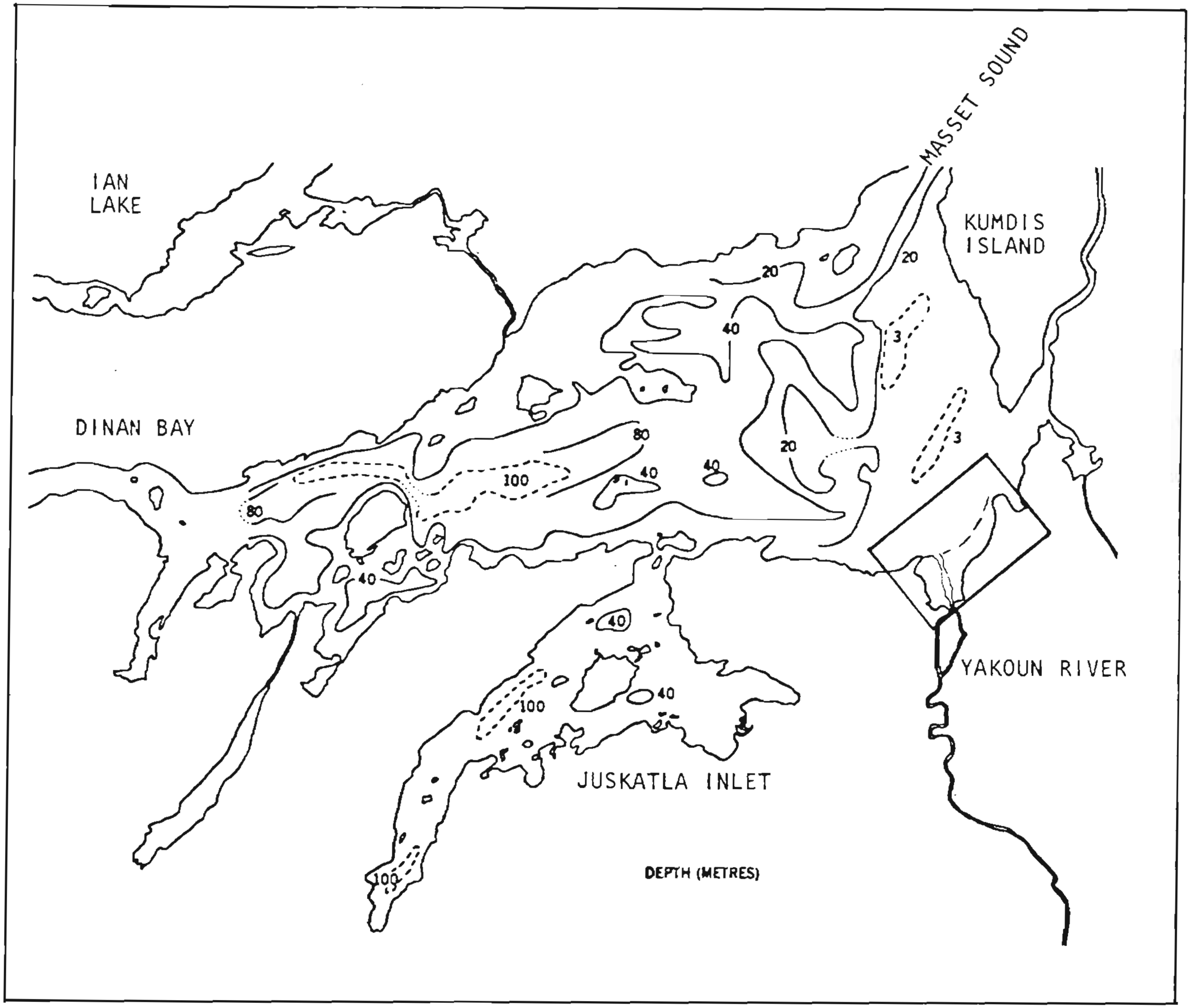


Figure 3. Chart of Masset Inlet showing depth contours (metres). From: Barber et al. 1975). The area described by the rectangle is enlarged in Figure 4.

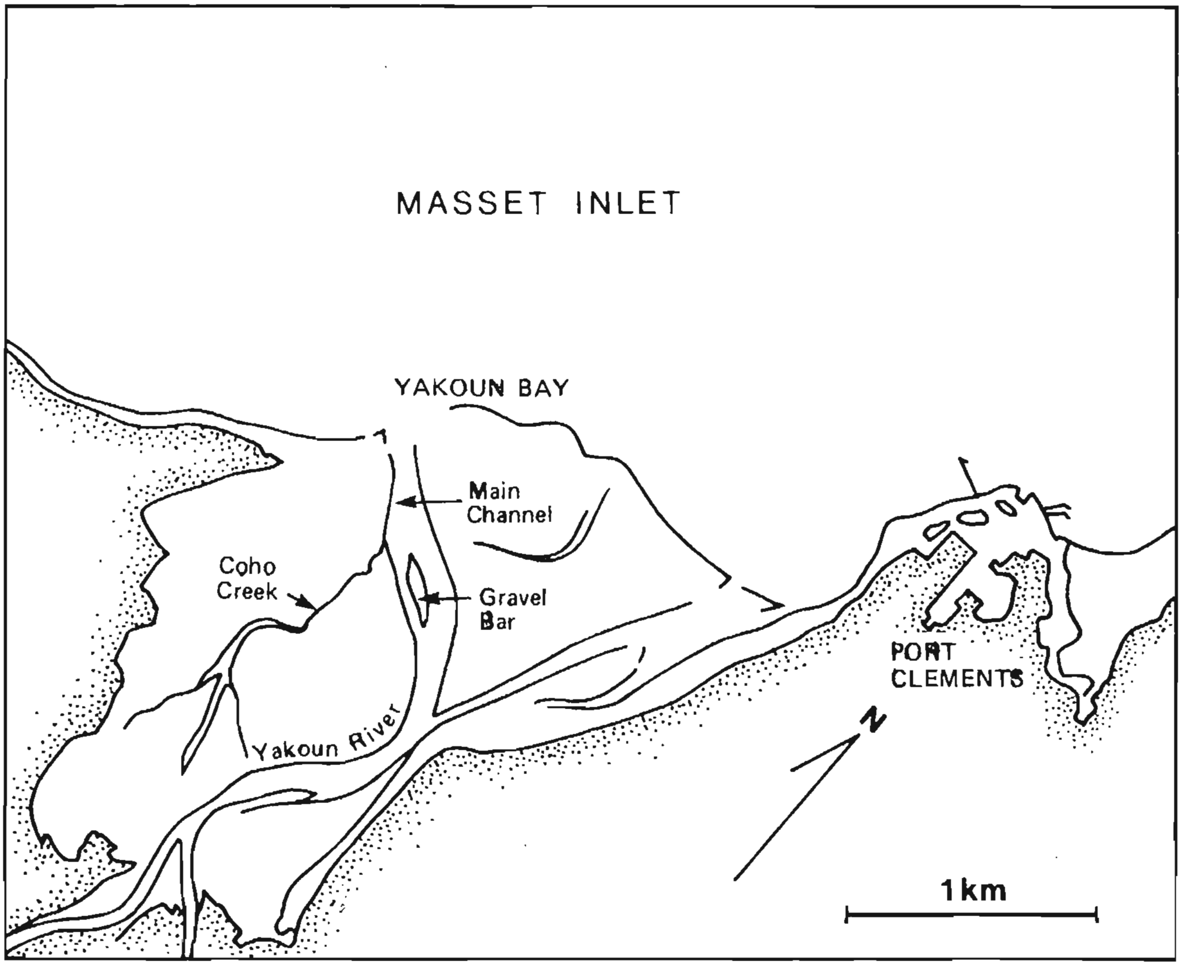


Figure 4. Map of Yakoun Bay, drawn from aerial photograph (BC 7864-225, 1980), indicating some place names and geographical landmarks.

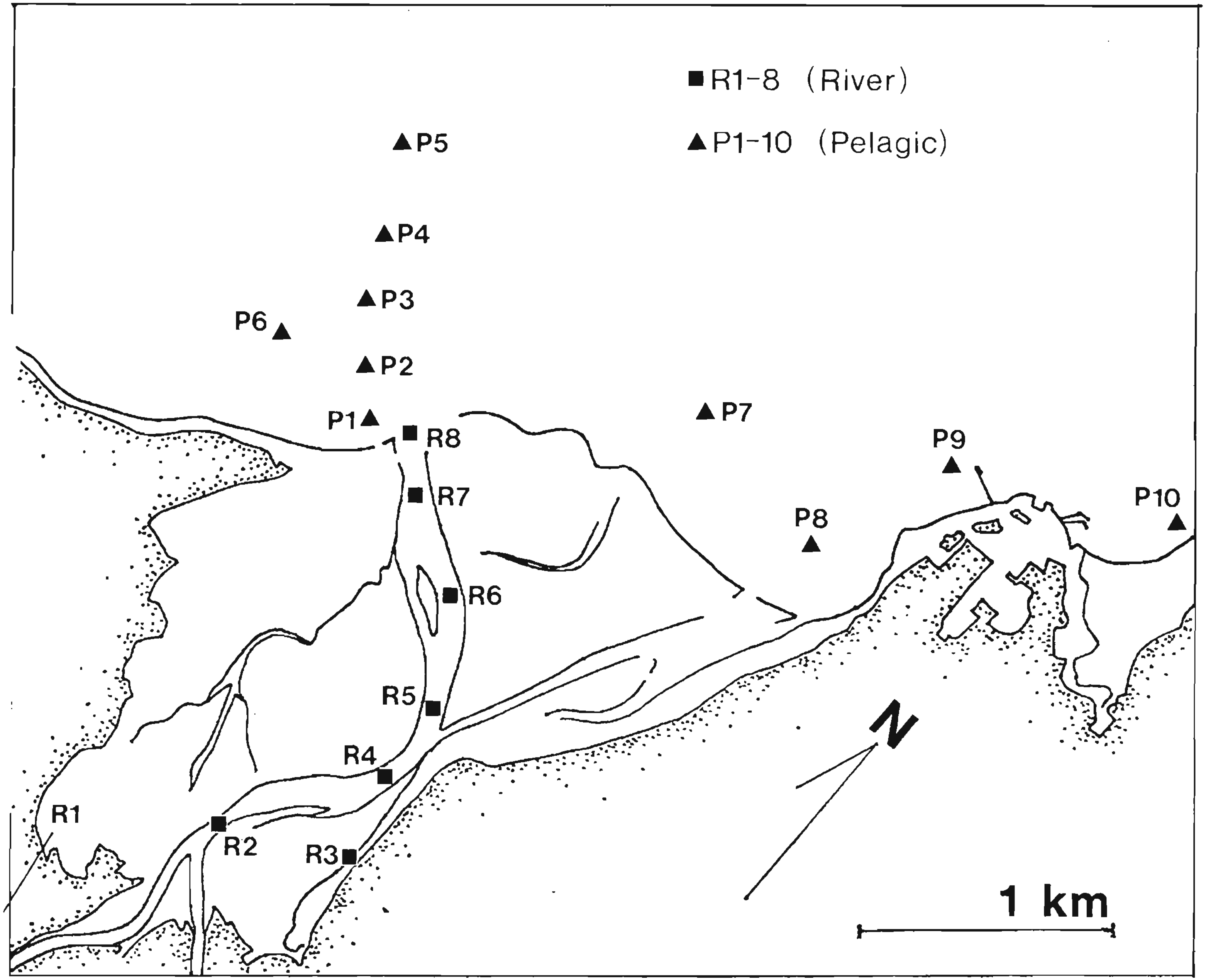


Figure 5. Pelagic and River sampling station locations in the Yakoun River estuary, April to July, 1980. Water chemistry, phytoplankton, chlorophyll a, zooplankton and subtidal macrofaunal samples were collected at these stations.

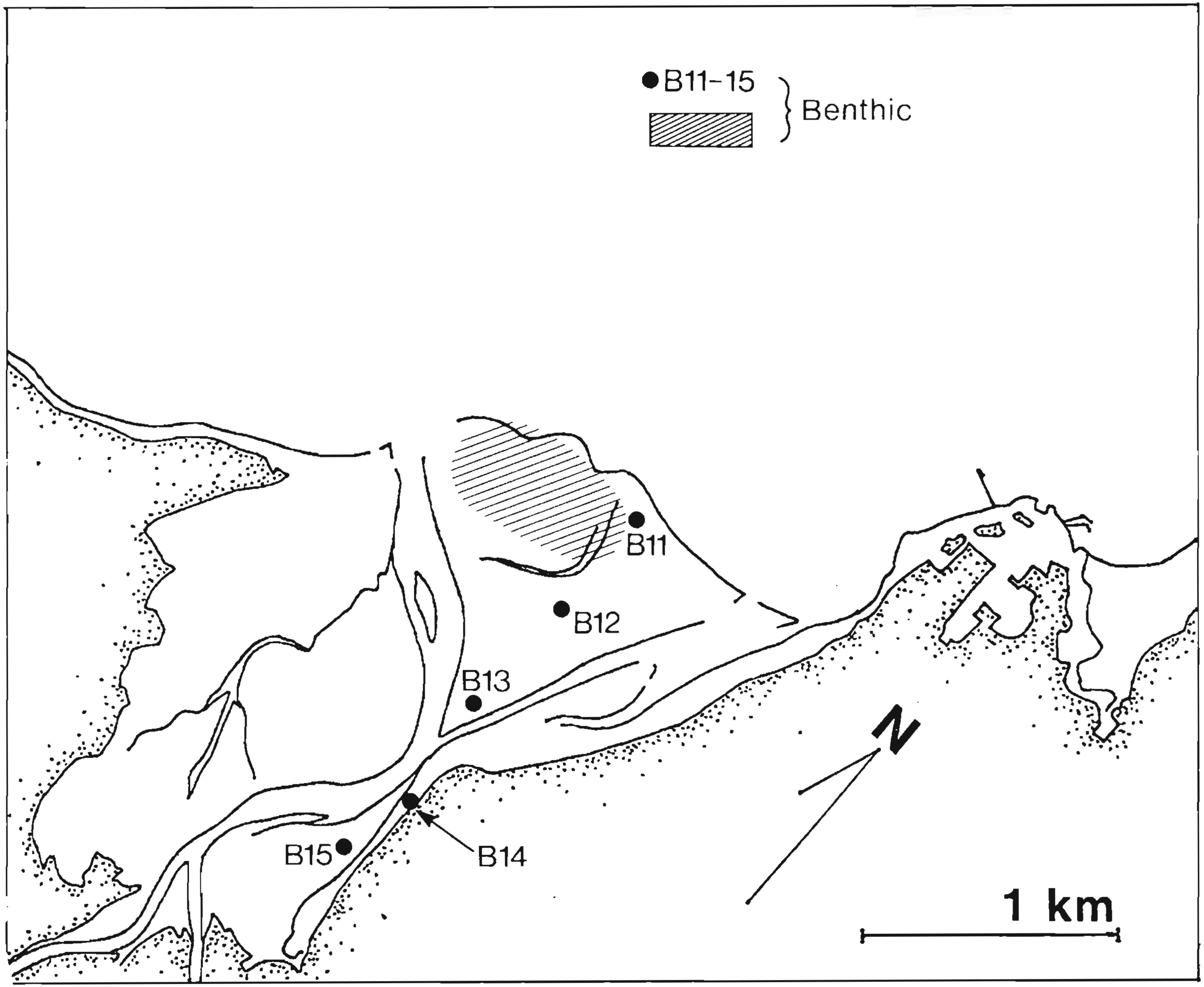


Figure 6. Sediment nutrient sampling station locations in the Yakoun River estuary, April to July, 1980. Samples used in the determination of benthic algal productivity were collected within the shaded zone.

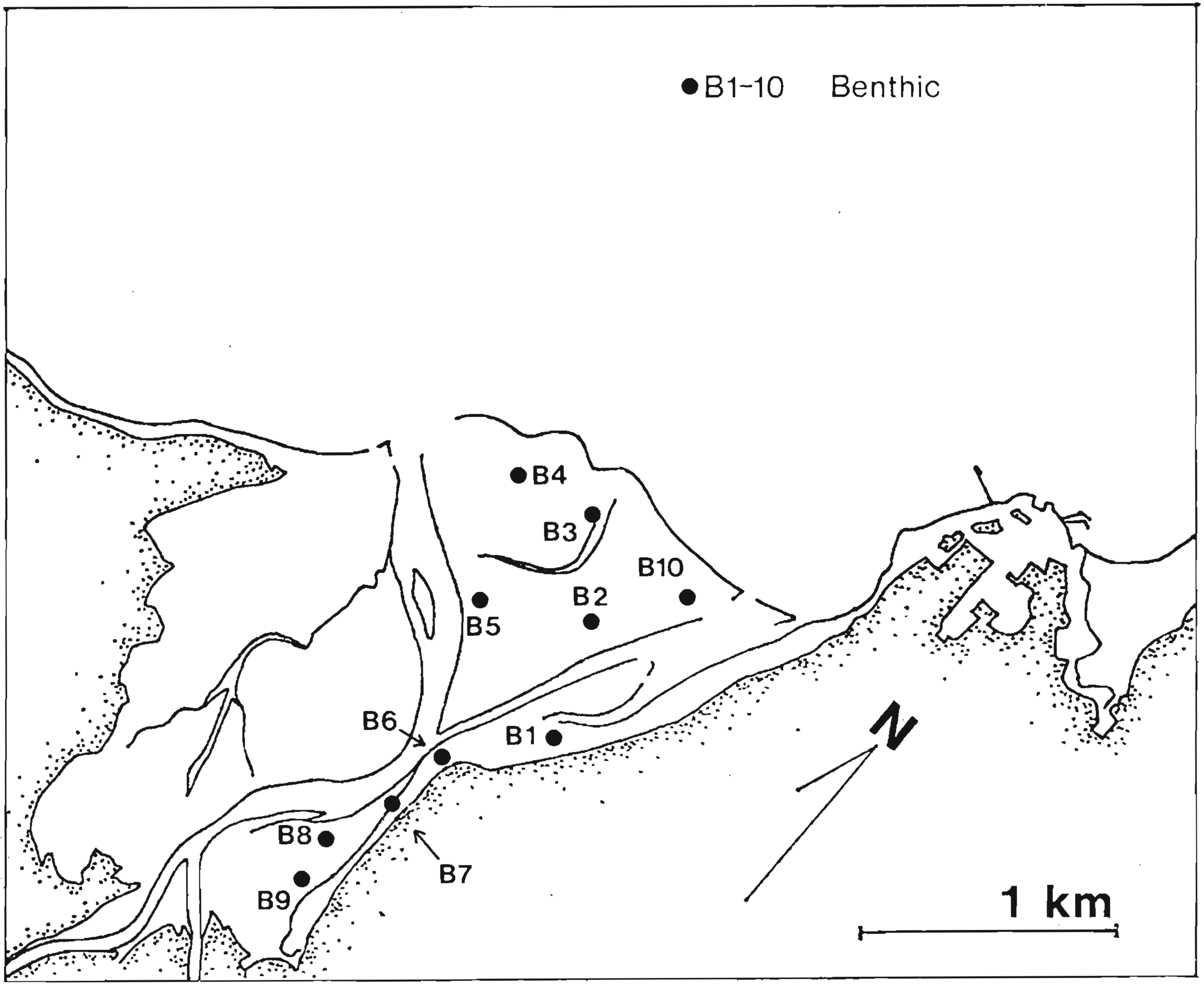


Figure 7. Benthic intertidal sampling station locations in the Yakoun River estuary, April to July, 1980. Benthic algae, chlorophyll a, meiofauna and macrofauna samples were collected at these stations.

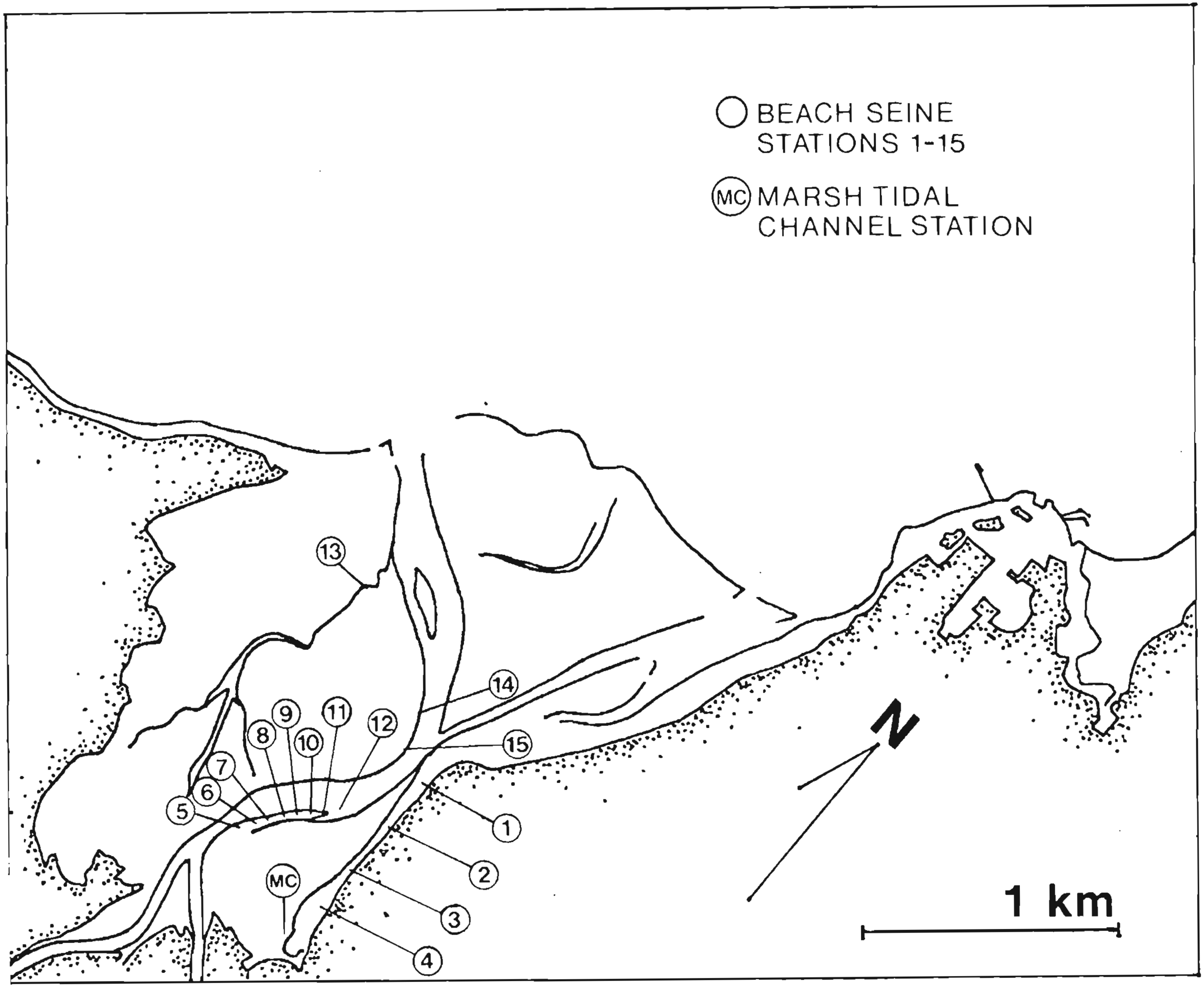


Figure 8. Beach seine and marsh tidal channel sampling station locations in the Yakoun River estuary, April to July, 1980. Juvenile salmonids and resident fish species were collected at these stations.

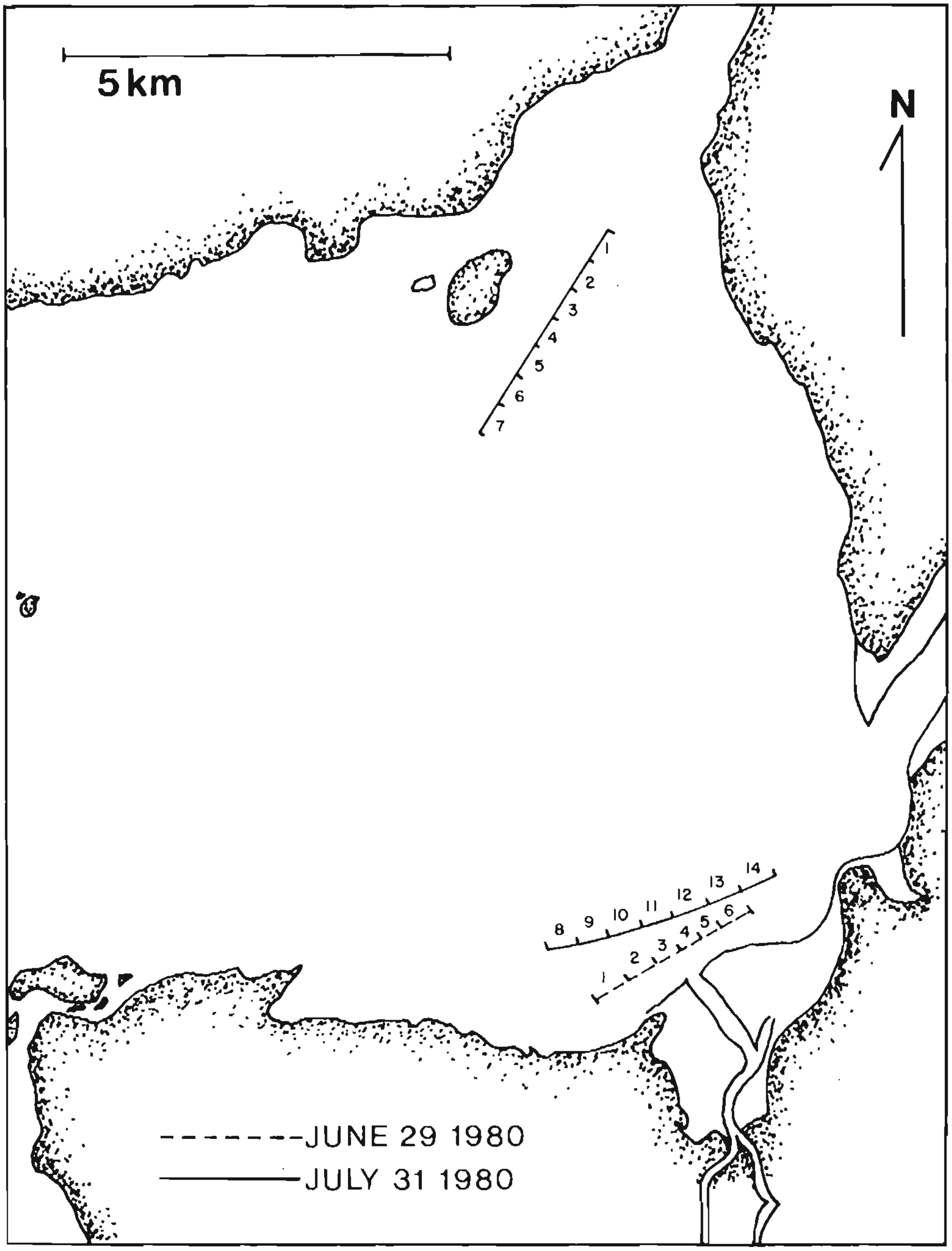


Figure 9. Surface trawl station locations in Masset Inlet, June 29 and July 31, 1980.

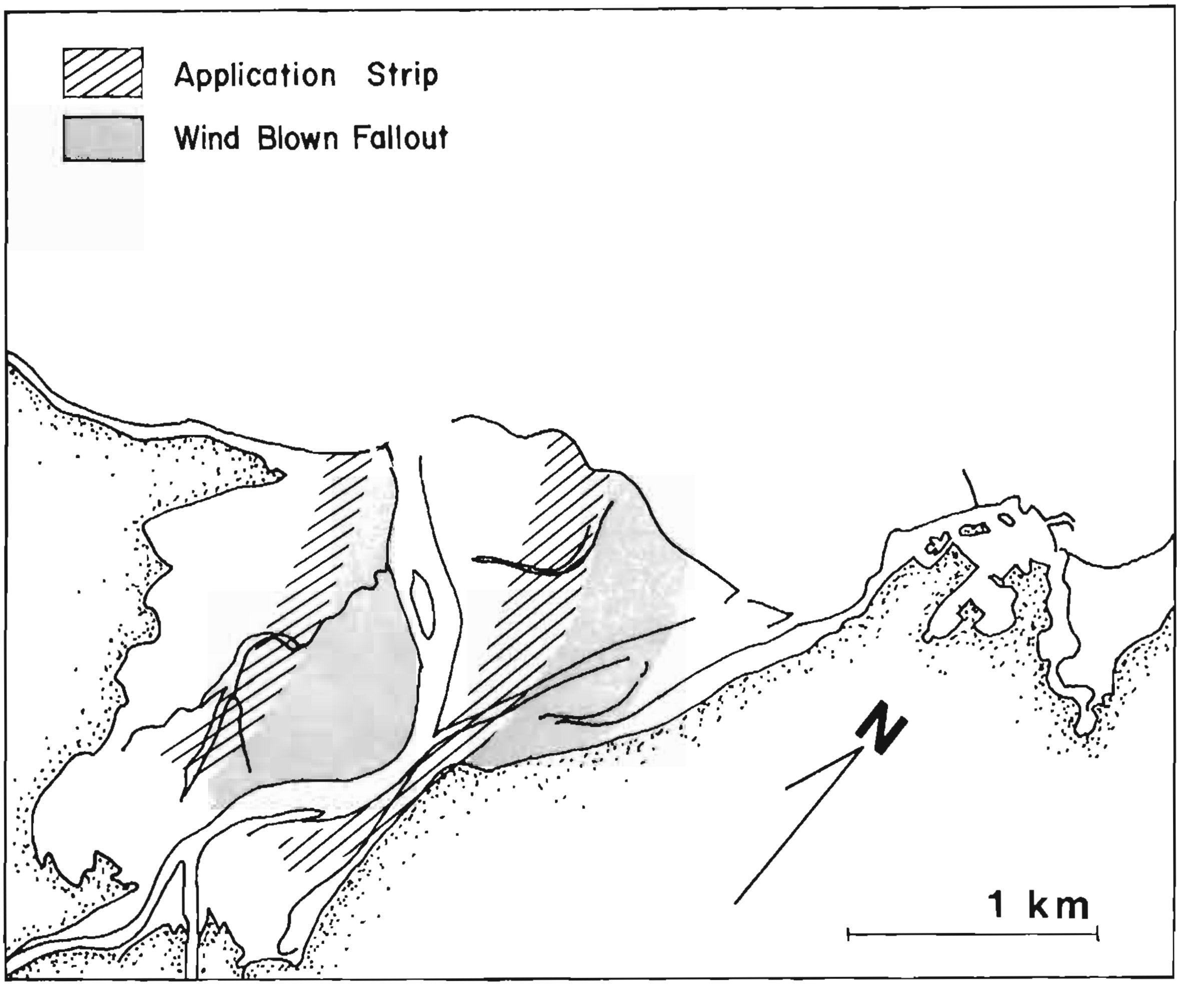


Figure 10. Intertidal areas within Yakoun Bay which were aerially fertilized with urea, June 29,1980, during afternoon low tide.

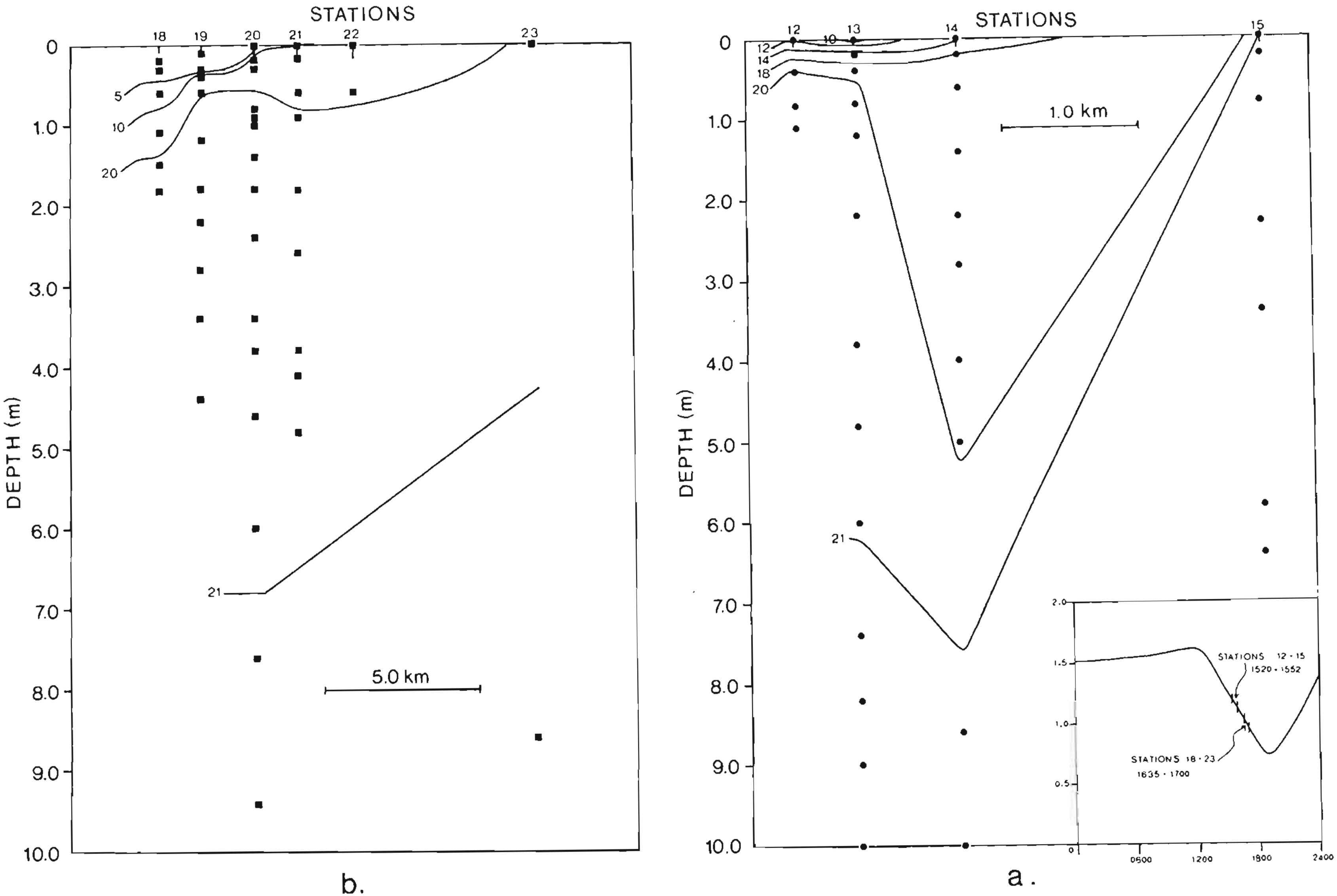


Figure 11. Vertical salinity (ppt) transect from the mouth of the Yakoun River towards the entrance of Masset Sound, April 22, 1980.
a) Salinity measurements at stations 12, 13, 14, 15, and 16. (1520 to 1552 h)
b) Salinity measurements at stations 18, 19 20, 21, 22, and 23. (1635 to 1700 h)
Inset shows tidal fluctuation at Port Clements on this date.

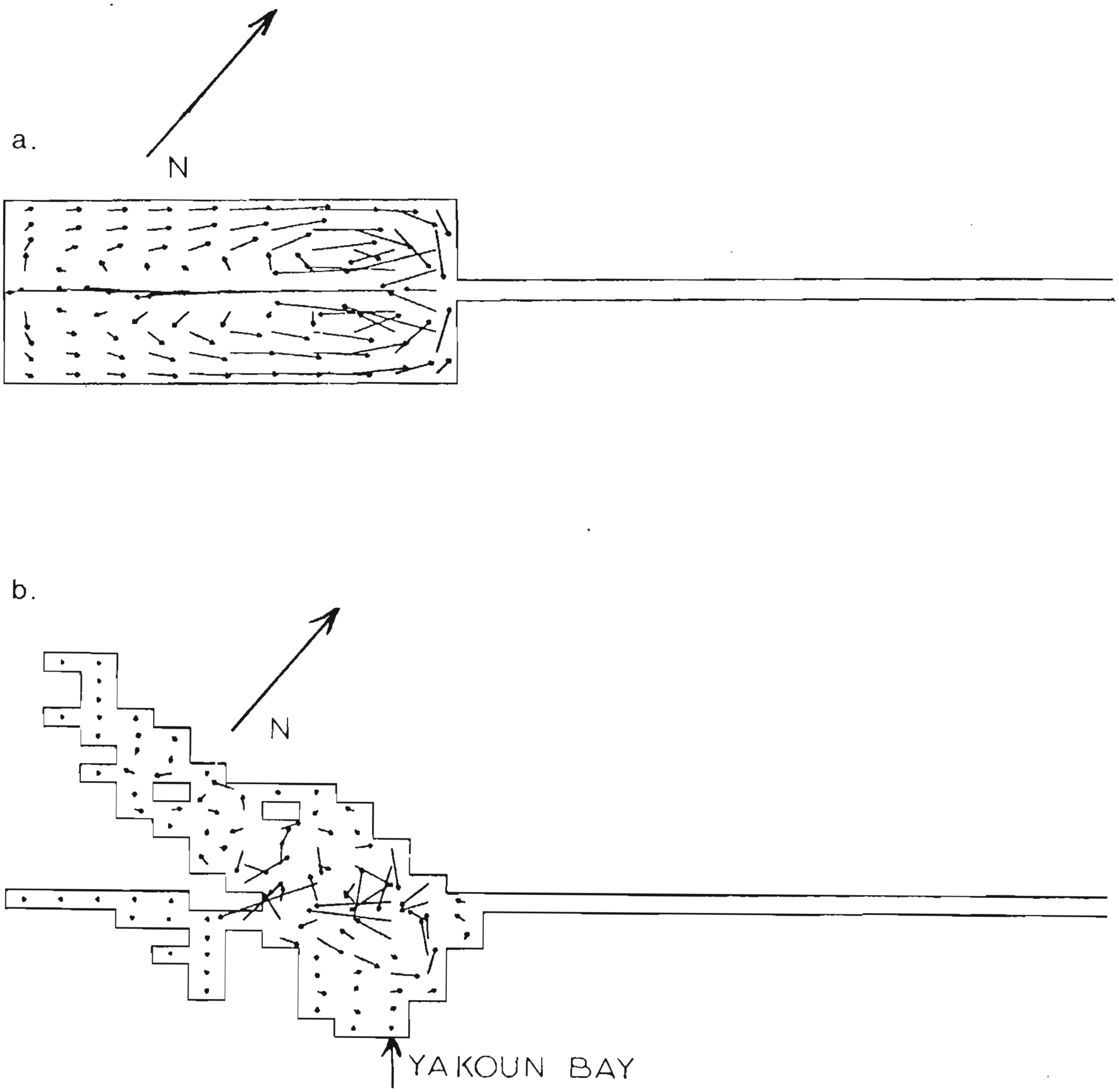


Figure 12. Residual tidal circulation in -

a) an idealized Masset Inlet and

b) Masset Inlet

(From: Barber 1980).

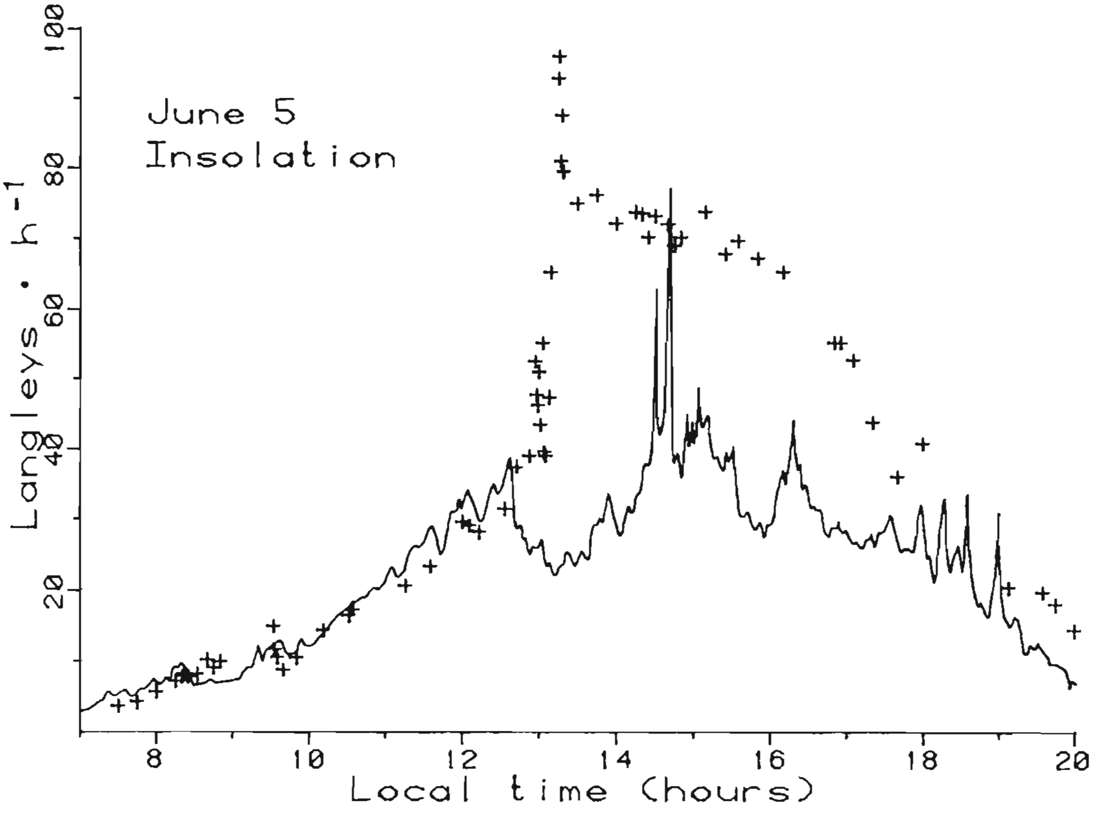


Figure 13. Comparison of insolation (Langleys$\cdot$h^{-1}) received at Yakoun Bay (+) and Sandspit (-) on June 5, 1980. Insolation is plotted as surface irradiance. Sandspit data recorded by the Atmospheric Environment Service, Environment Canada.

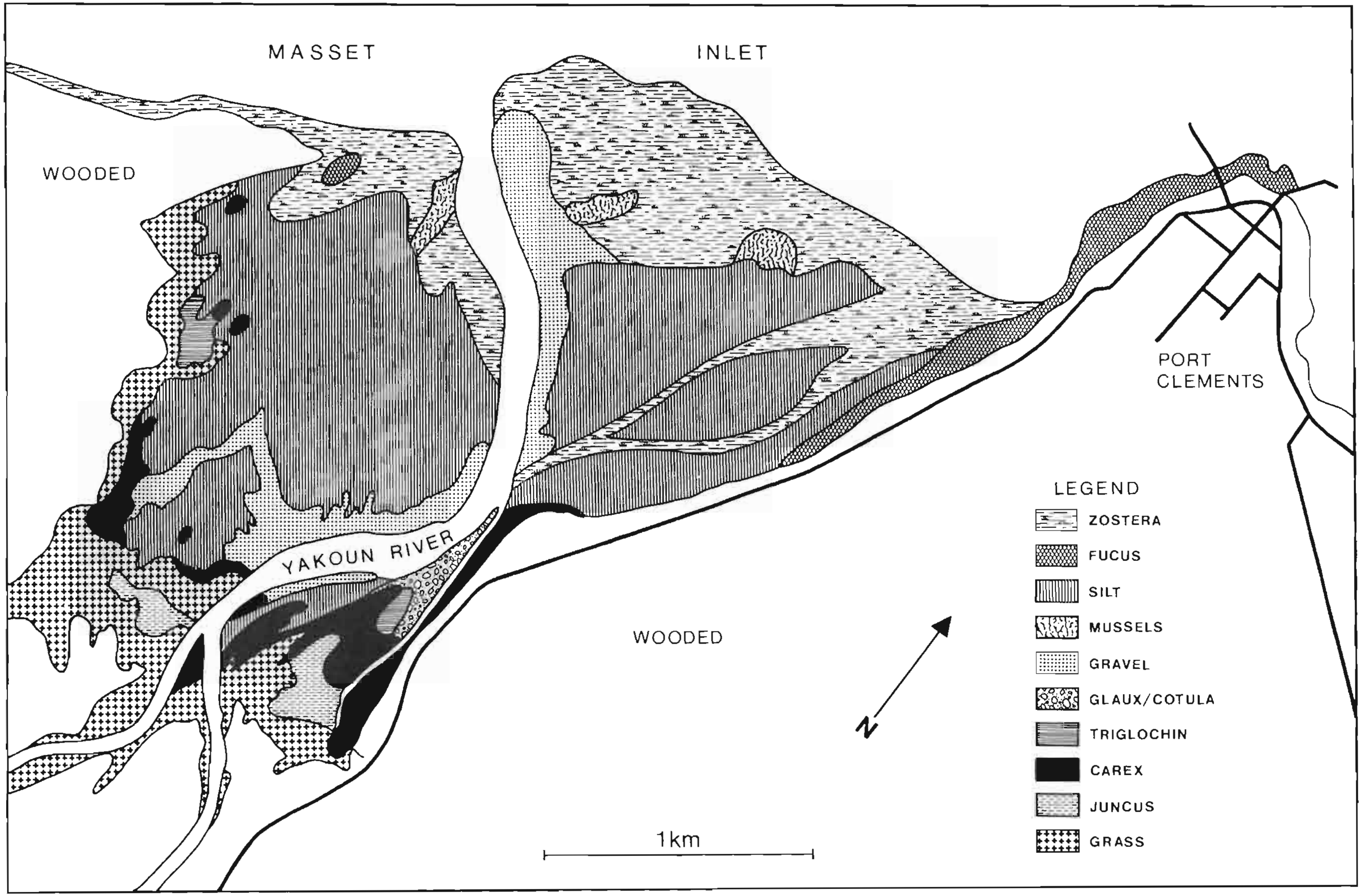


Figure 14. Major plant communities and substrate types in the Yakoun River estuary, 1980. Adapted from aerial photographs (BC 7864-225).

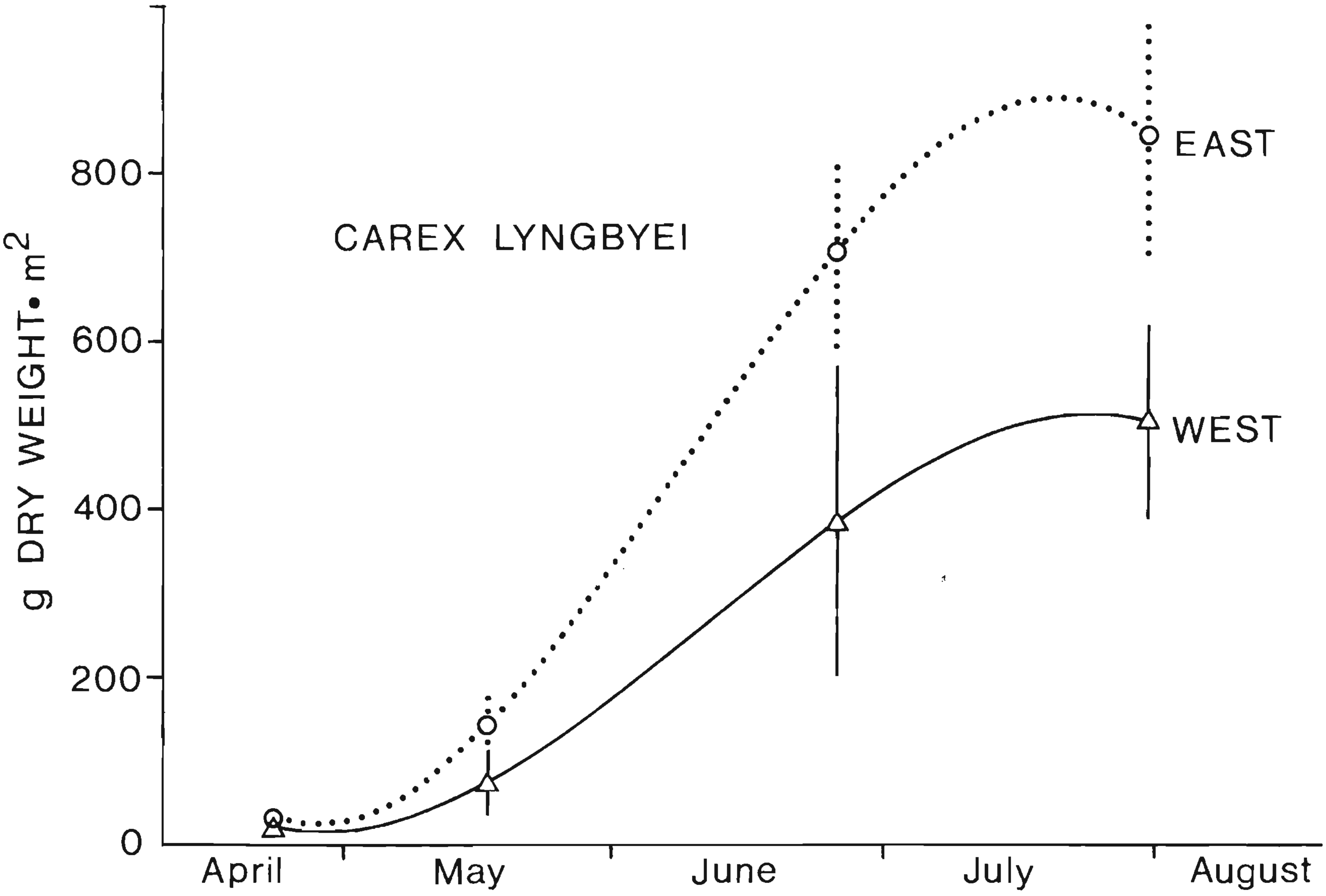


Figure 15. Seasonal changes in the mean live standing crop (g dry wt.·m^{-2}) of _Carex lyngbyei_ on the east and west sides of the Yakoun River estuary, April to August, 1980. Vertical lines indicate the standard deviation of each mean.

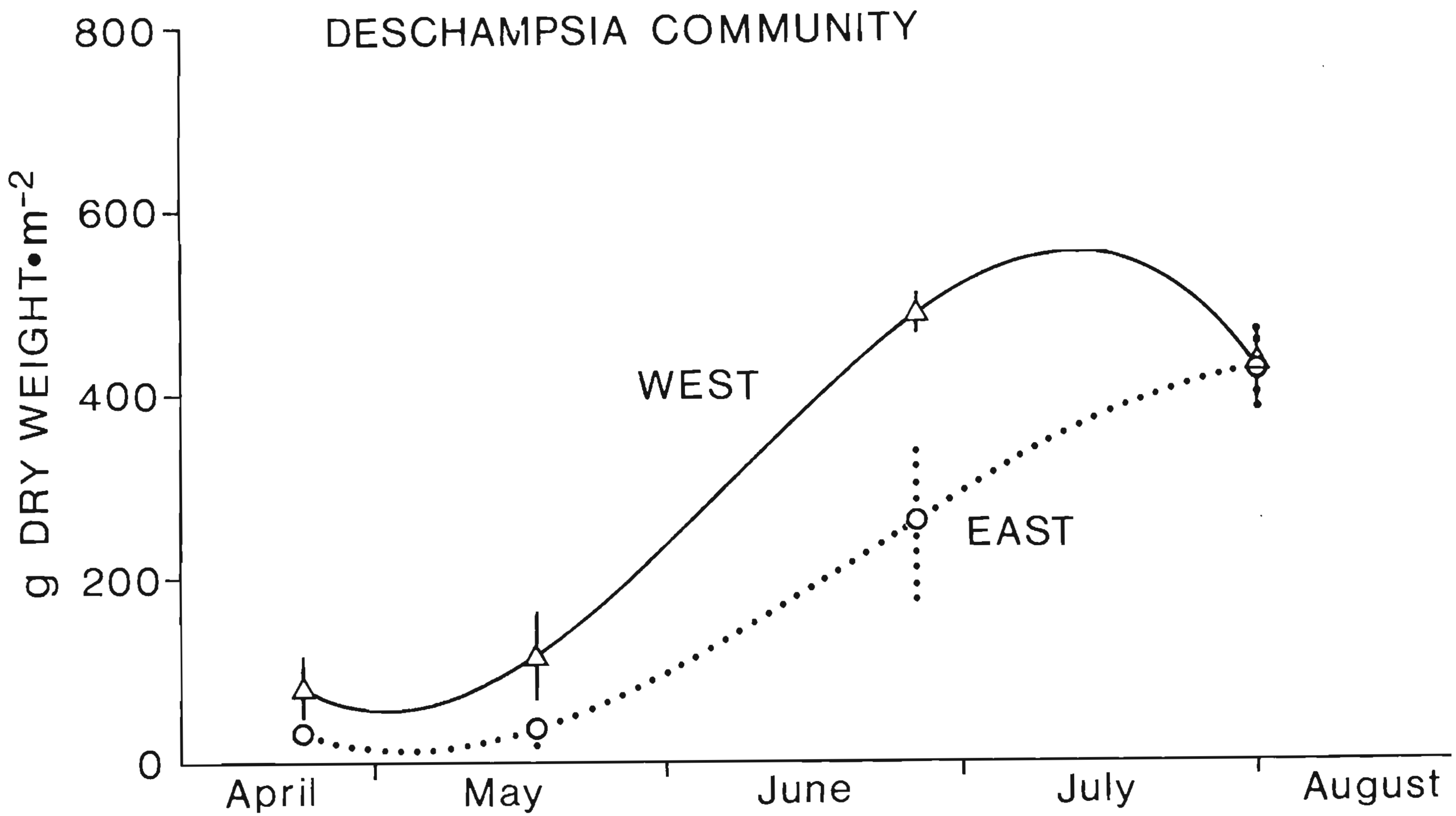


Figure 16. Seasonal changes in the mean live standing crop (g dry wt.$\cdot$m^{-2}) of <u>Deschampsia caespitosa</u> on the east and west sides of the Yakoun River estuary, April to August, 1980. Plants were harvested in five 0.0625 m^2 randomly selected quadrats on each side of the estuary at monthly intervals. All samples were dried at 105°C for 24 hours. Vertical lines indicate the standard deviation of each mean.

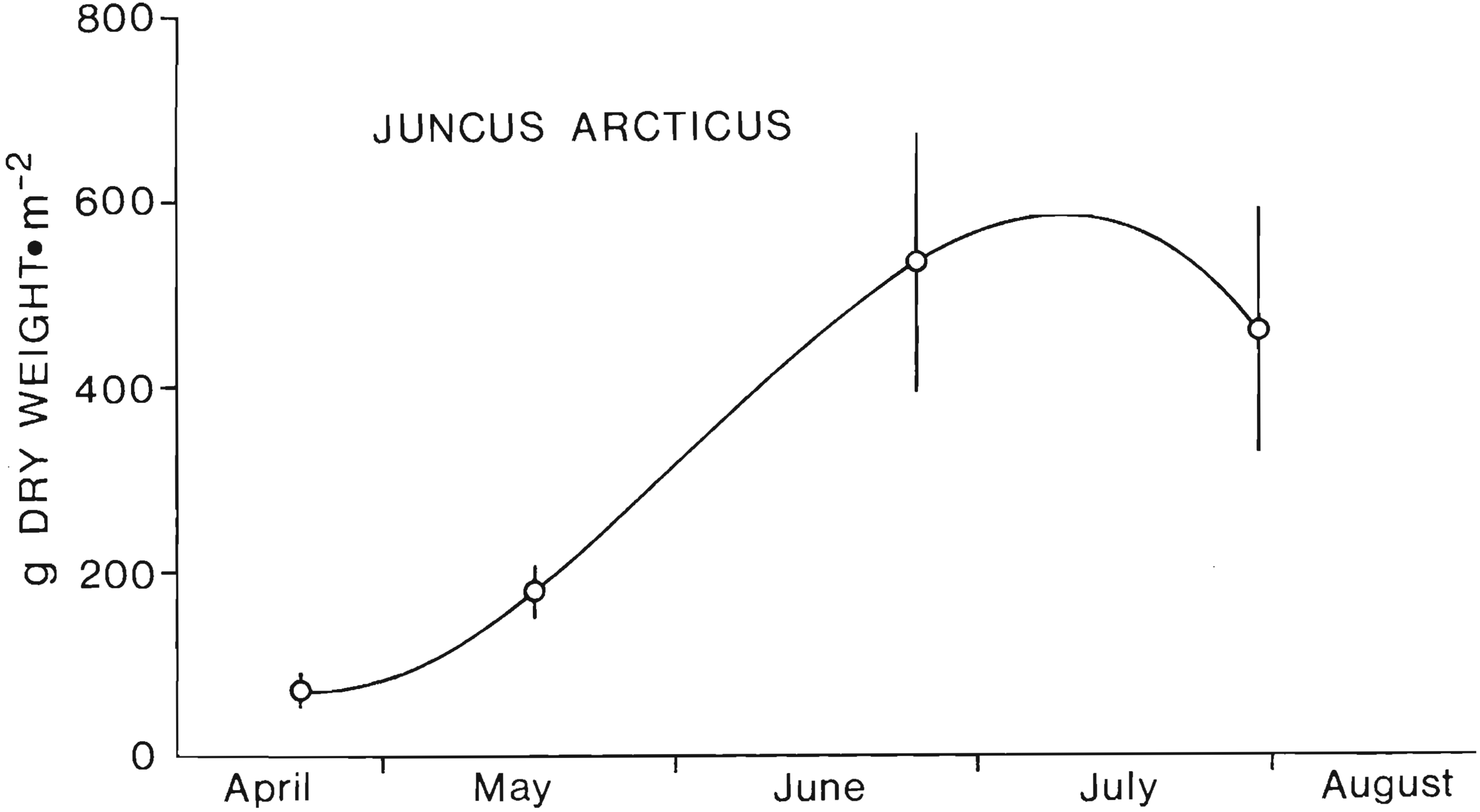


Figure 17. Seasonal changes in the mean live standing crop (g dry wt.·m^{-2}) of _Juncus arcticus_ on the east and west sides of the Yakoun River estuary, April to August, 1980. Plants were harvested in five 0.0625 m^{2} randomly selected quadrats on each side of the estuary at monthly intervals. All samples were dried at 105°C for 24 hours. Vertical lines indicate the standard deviation of each mean.

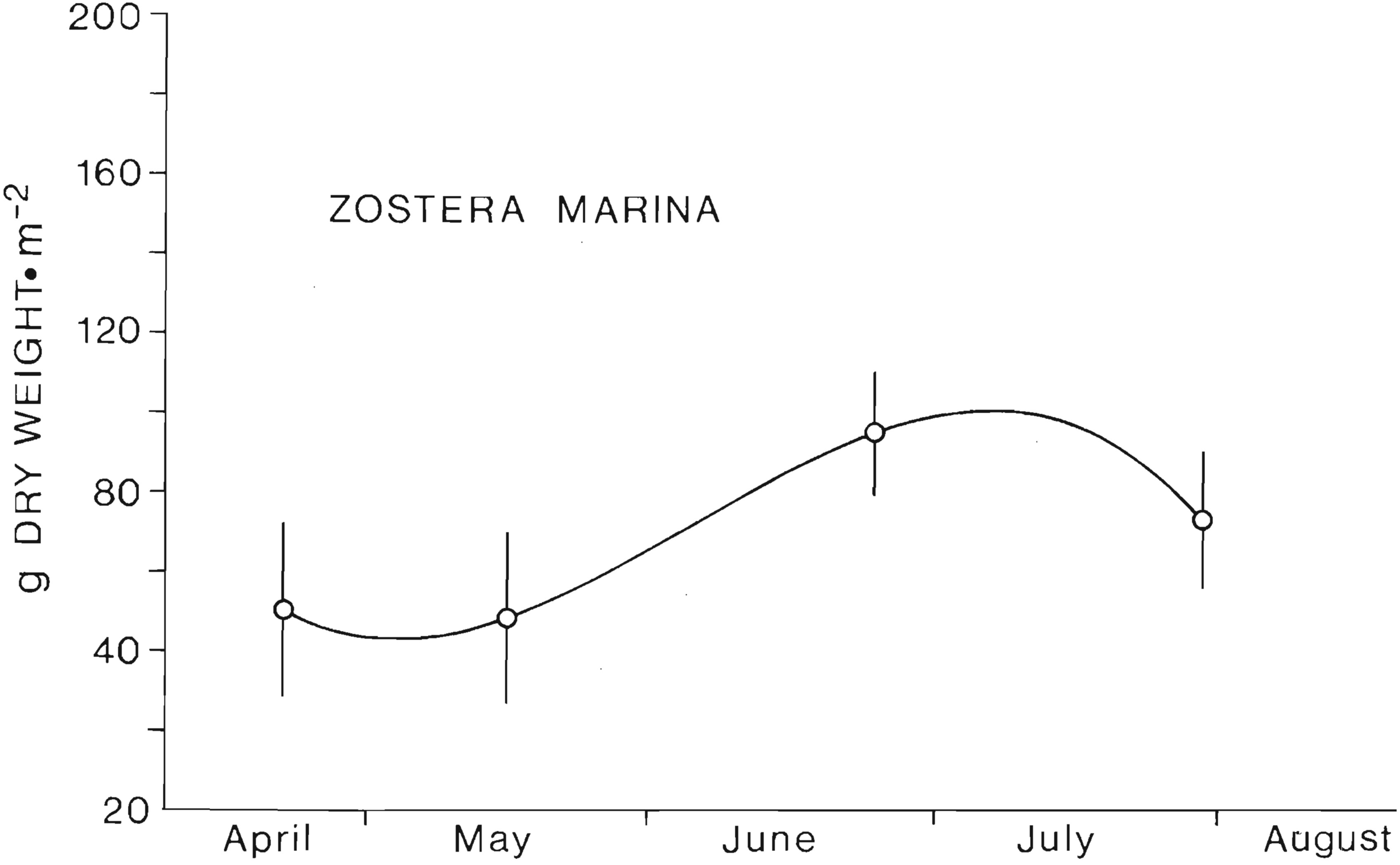


Figure 18. Seasonal changes in the mean live standing crop (g dry wt.·m^{-2}) of *Zostera marina* on the east and west sides of Yakoun River estuary, April to August, 1980. Plants were harvested in five 0.0625 m^2 randomly selected quadrats on each side of the estuary at monthly intervals. All samples were dried at 105°C for 24 hours. Vertical lines indicate the standard deviations of each mean.

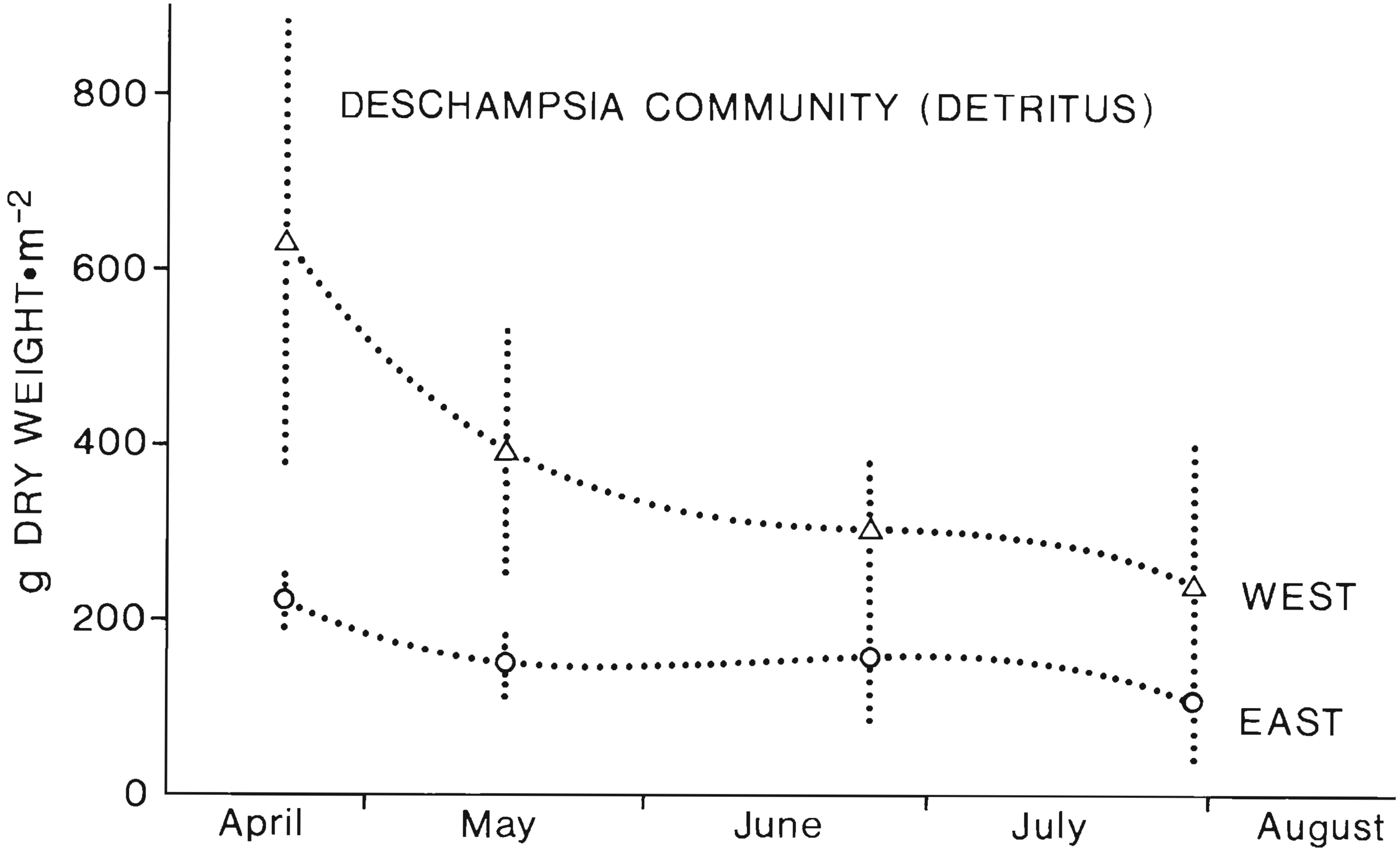


Figure 19. Seasonal changes in the mean detrital (dead) standing crop (g dry wt.$\cdot$m^{-2}) of *Deschampsia caespitosa* on the east and west sides of Yakoun River estuary, April to August, 1980. Live and dead plant material collected in each of five 0.0625 m^2 randomly selected quadrats on each side of the estuary at monthly intervals was sorted and dried at 105°C for 24 hours. Vertical lines indicate the standard deviation.

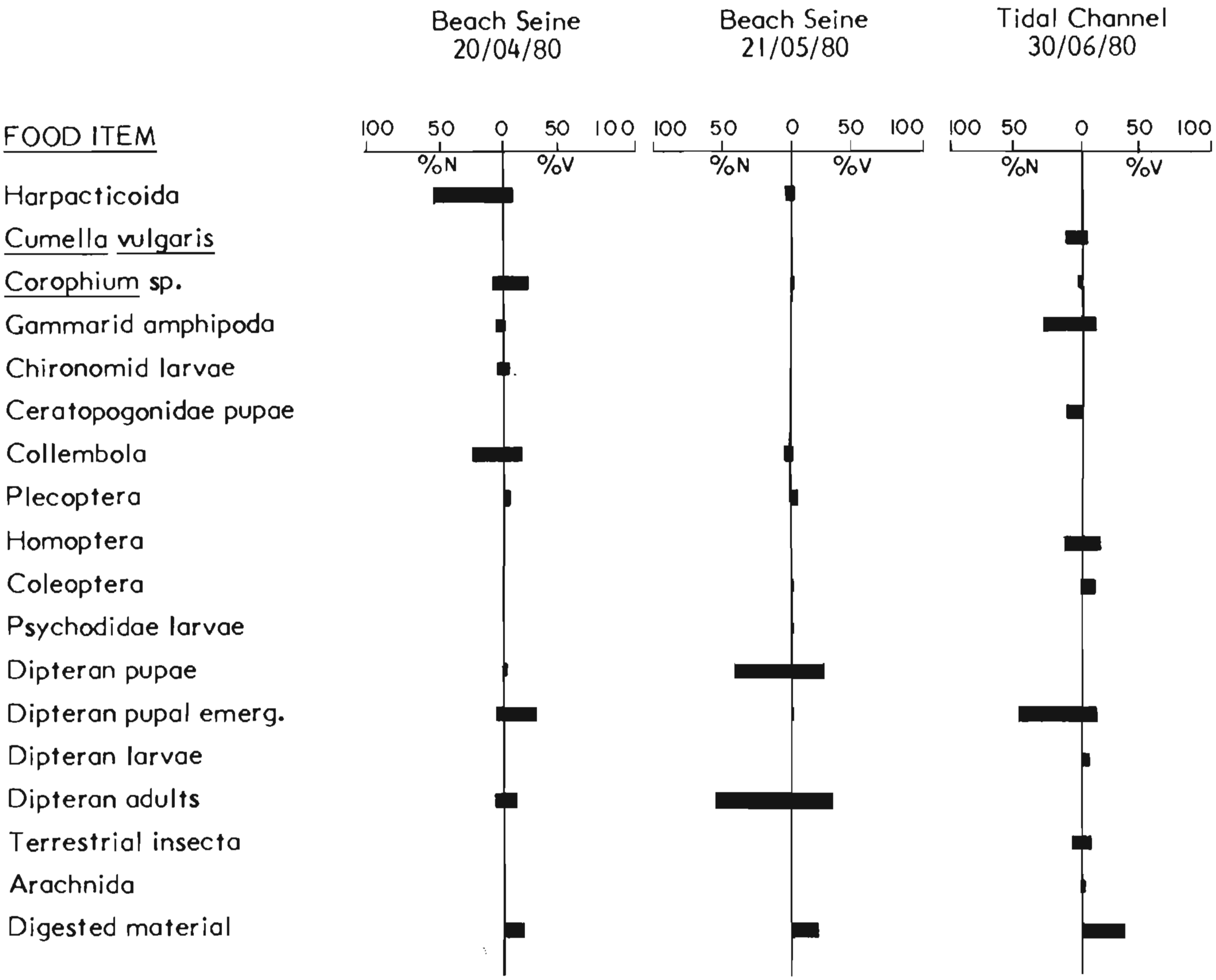


Figure 20. Composition of major food items found in the stomach contents of juvenile coho (<u>Oncorhynchus kisutch</u>) captured in beach seines(April,May; 10 fish) and marsh tidal channel traps (June; 5 fish) on the Yakoun River estuary,1980.

%N = percent number of food items counted

%V = percent of total volume

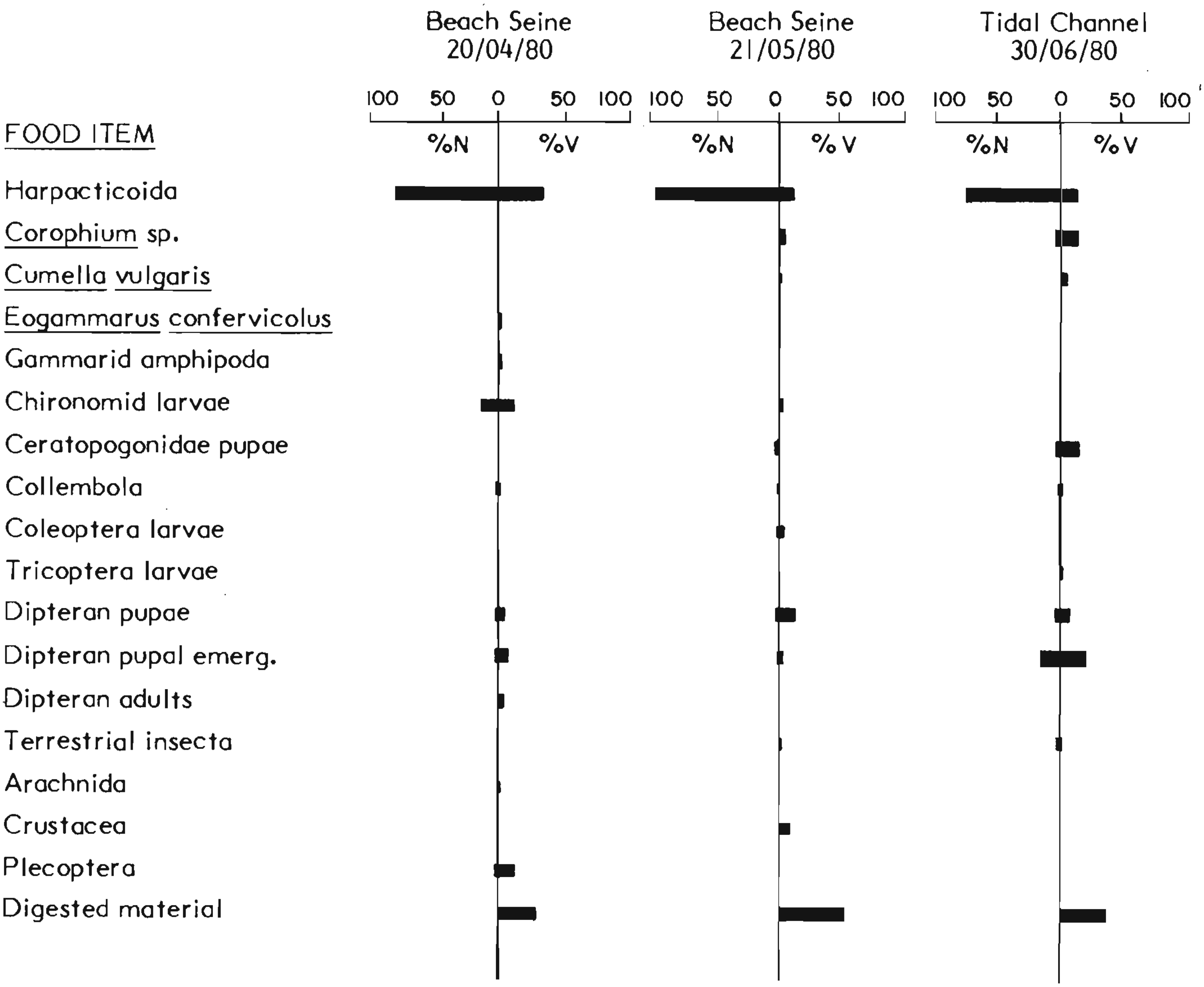
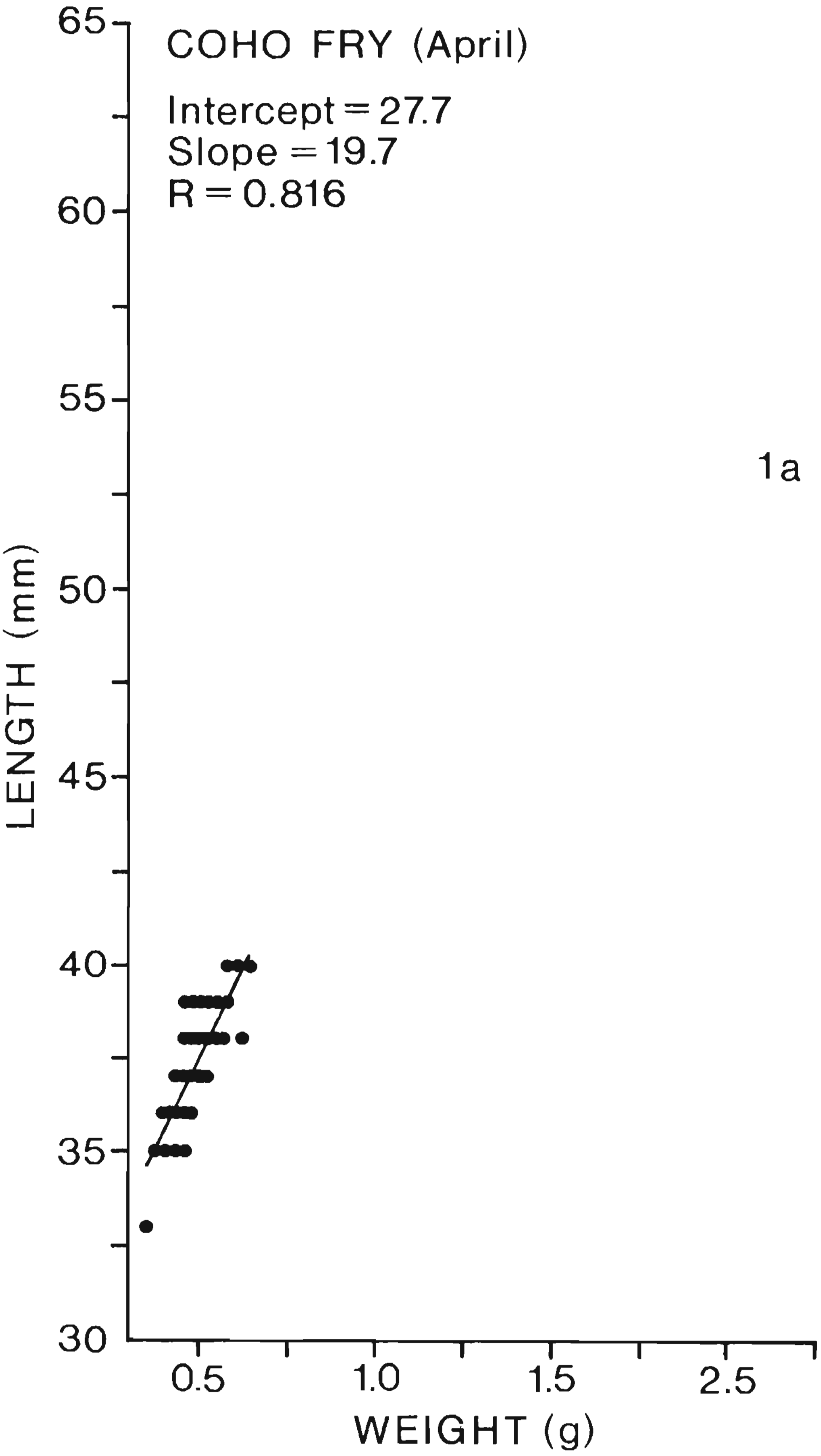


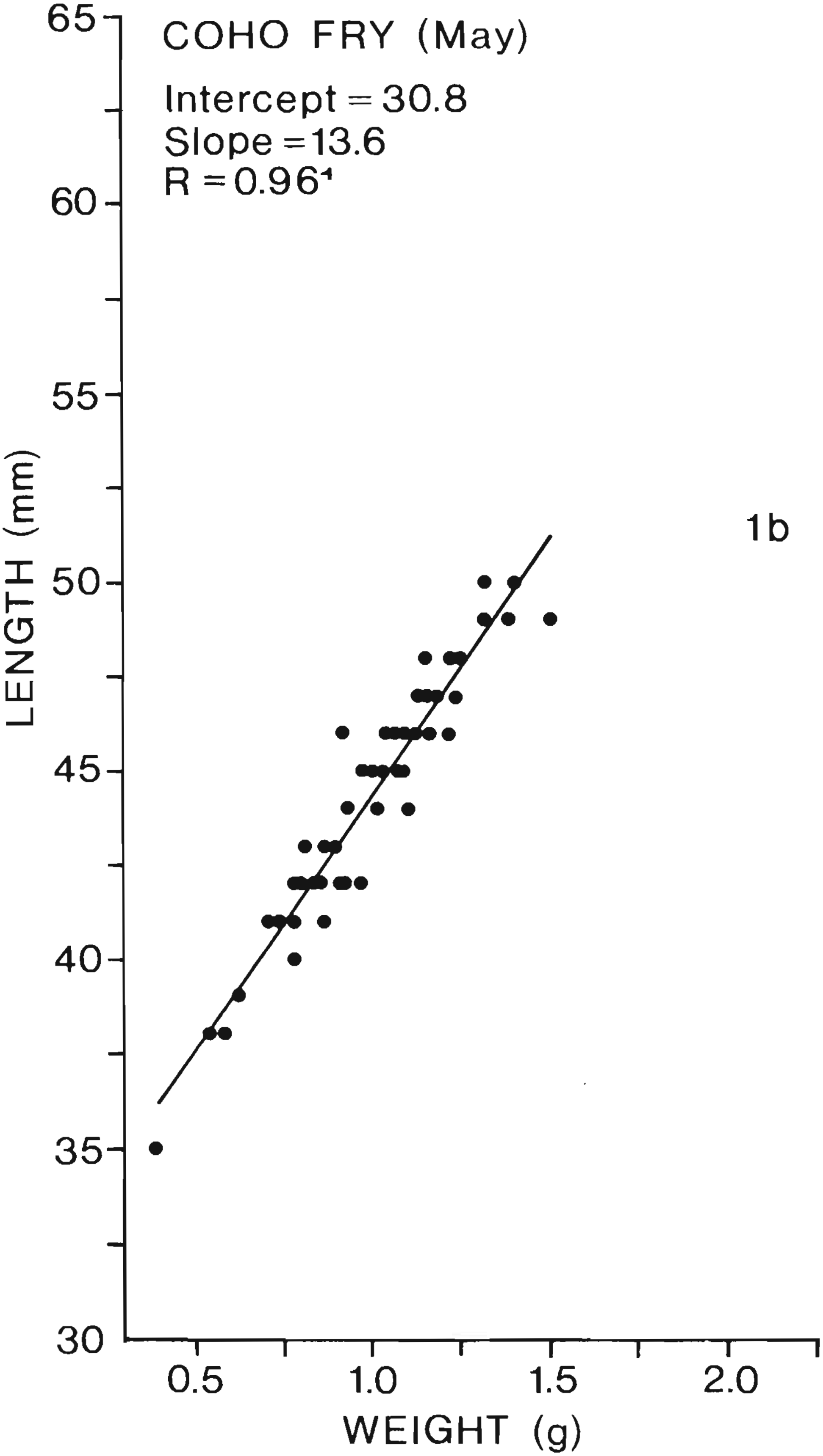
Figure 21. Composition of major food items found in the stomach contents of juvenile chum (<u>Oncorhynchus</u> <u>keta</u>) salmon captured in beach seines (April,May) and marsh tidal channel traps (June) on the Yakoun River estuary, 1980. Each sample represents the pooled contents of 10 fry.

%N = percent number of food items counted

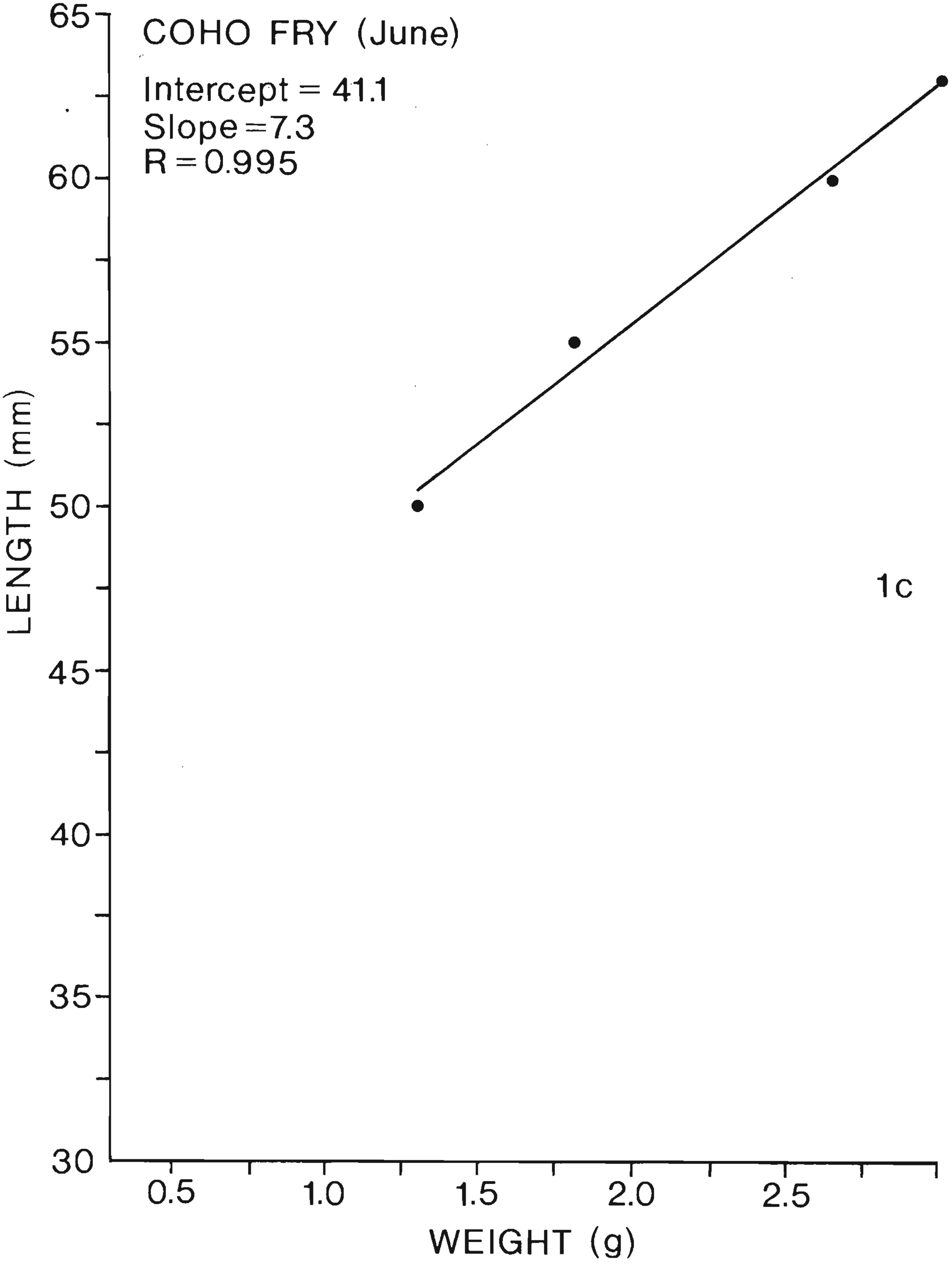
%V = percent of total volume

Appendix figures 1a-c. Linear regressions of length (cm) - weight (g) measurements of juvenile coho (Oncorhynchus kisutch) salmon captured in beach seines and marsh tidal traps on the Yakoun River estuary, in April, May and June, 1980. (Sample sizes: April n=31; May n=46; June n=4)

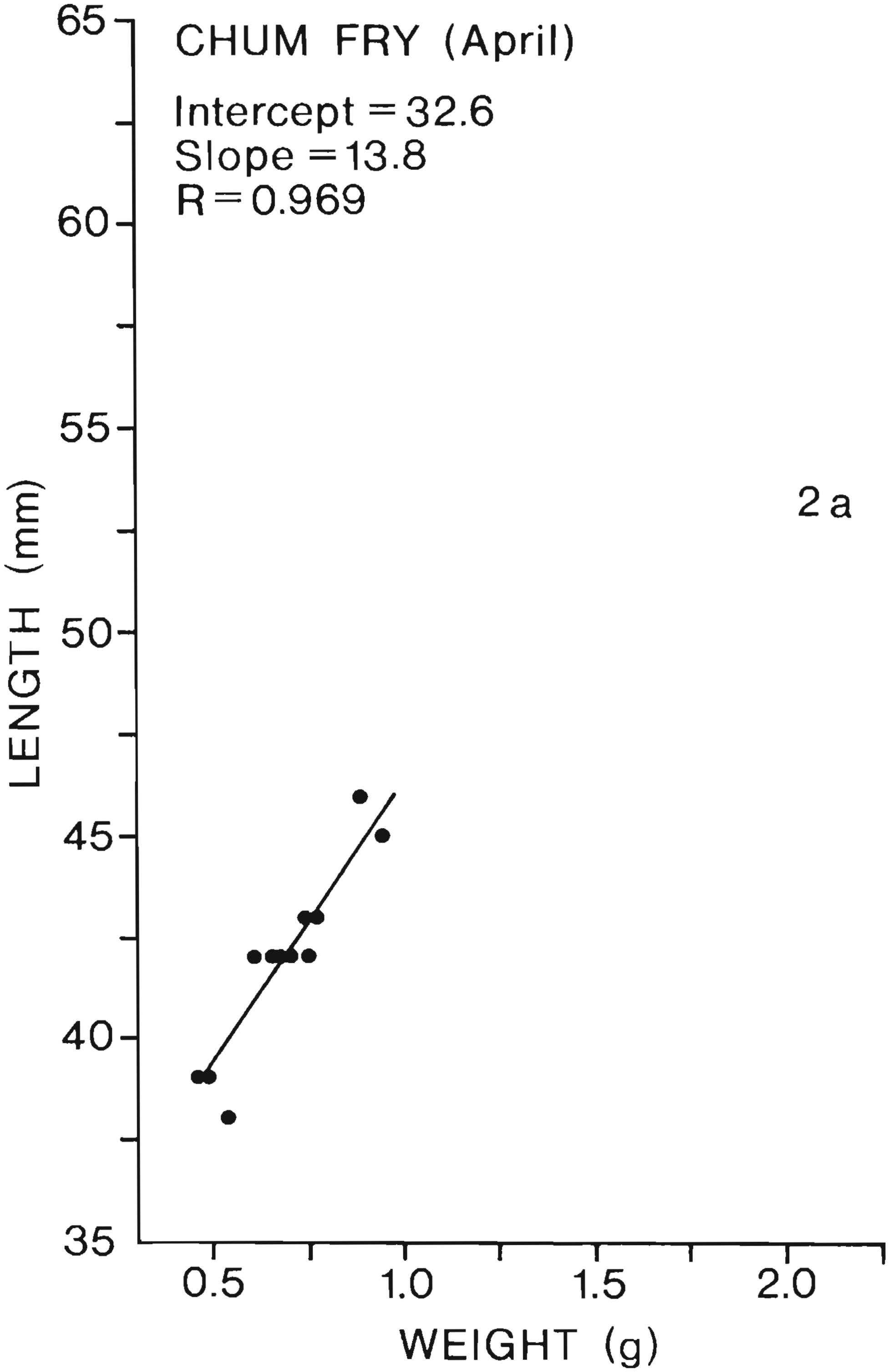

COHO FRY (April)
Intercept = 27.7
Slope = 19.7
R = 0.816
1a
LENGTH (mm)
65
60
55
50
45
40
35
30
0.5
1.0
1.5
2.5
WEIGHT (g)

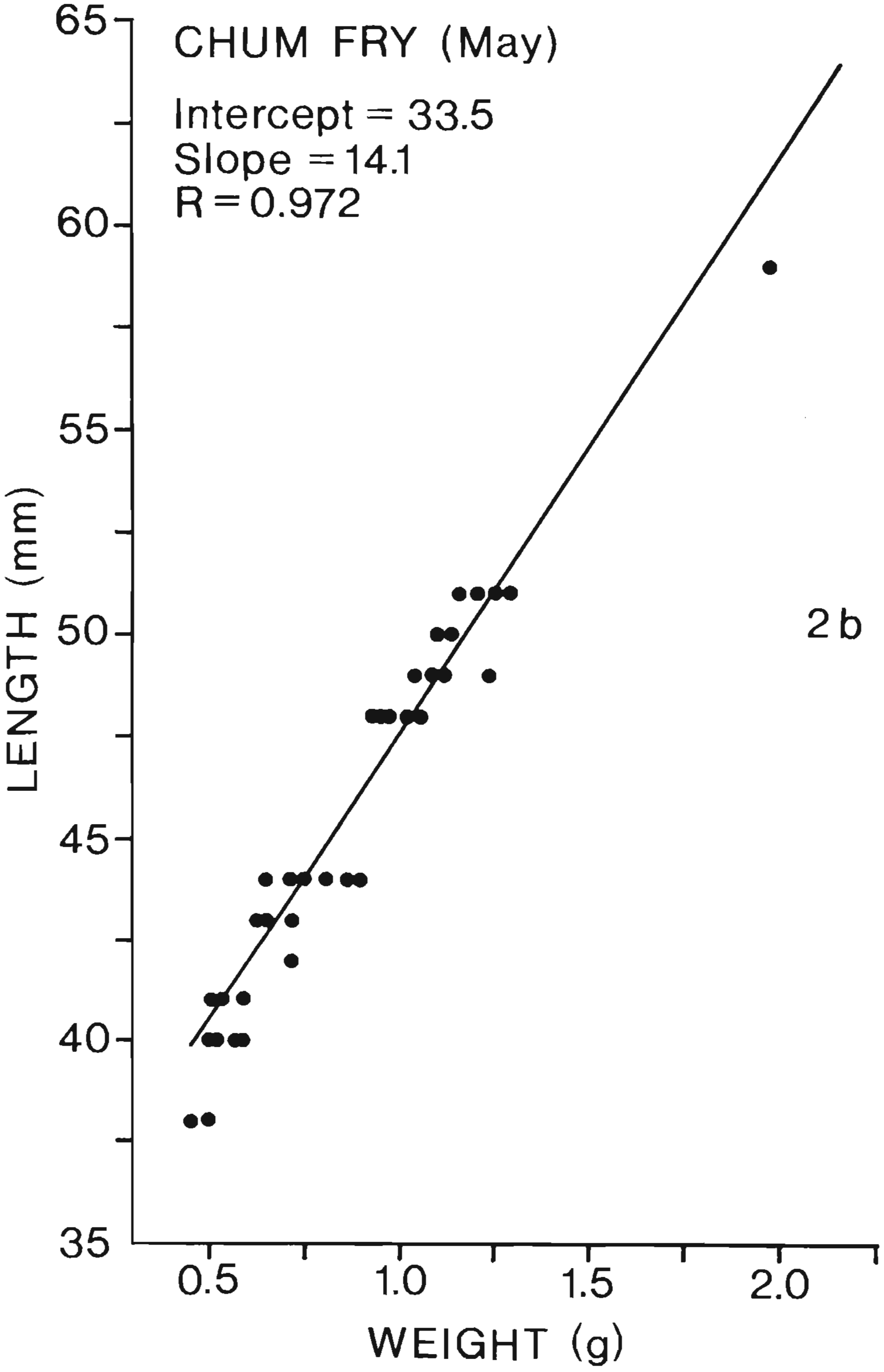

COHO FRY (May)
Intercept = 30.8
Slope = 13.6
R = 0.96¹
LENGTH (mm)
65
60
55
50
45
40
35
30
WEIGHT (g)
0.5
1.0
1.5
2.0

1b


COHO FRY (June)
Intercept = 41.1
Slope = 7.3
R = 0.995
LENGTH (mm)
65
60
55
50
45
40
35
30
0.5
1.0
1.5
2.0
2.5
WEIGHT (g)
1c

Appendix figures 2a-b. Linear regressions of length (cm) - weight (g) measurements of juvenile chum (Oncorhynchus keta) salmon captured in beach seines and marsh tidal channel traps on the Yakoun River estuary in April and May, 1980. (Sample sizes: April n=12; May n=35)


CHUM FRY (April)
Intercept = 32.6
Slope = 13.8
R = 0.969
2 a
LENGTH (mm)
65
60
55
50
45
40
35
0.5
1.0
1.5
2.0
WEIGHT (g)


CHUM FRY (May)
Intercept = 33.5
Slope = 14.1
R = 0.972
2 b
LENGTH (mm)
WEIGHT (g)
65
60
55
50
45
40
35
0.5
1.0
1.5
2.0