Handbook of Physical, Chemical, Phytoplankton, and Zooplankton Data from Hecate Strait, Dixon Entrance, Goose Island Bank and Queen Charlotte Sound

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HANDBOOK OF PHYSICAL, CHEMICAL, PHYTOPLANKTON, AND ZOOPLANKTON DATA FROM HECATE STRAIT, DIXON ENTRANCE, GOOSE ISLAND BANK AND QUEEN CHARLOTTE SOUND

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McQueen, D., and Ware, D. 2006. Handbook of physical, chemical, phytoplankton, and zooplankton data from Hecate Strait, Dixon Entrance, Goose Island Bank and Queen Charlotte Sound. Can. Data Rep. Fish. Aquat. Sci. 1162: xi + 133 p.

This report summarizes physical and lower trophic level data collected in Hecate Strait and Queen Charlotte Sound. The purpose is to: 1) organize those portions of the physical, water chemistry, phytoplankton, and zooplankton data base which will be required for the development of lower trophic level simulation models for Hecate Strait, 2) summarize appropriate lower trophic level data (physical, water chemistry, phytoplankton, and zooplankton) to produce best estimates of interannual and decadal seasonal patterns, and 3) quantify the extent of spatial variability that may exist within the Hecate Strait Region. The report is laid out in four sections: 1) physical climatic and oceanographic factors, 2) nutrients, 3) chlorophyll and primary production, and 4) zooplankton. There was considerable between-site variability in precipitation (wetter along the mainland coast); sunlight (more hours of bright sunlight in southern Queen Charlotte Sound and northwestern Hecate Strait); sea surface temperatures (cooler near Queen Charlotte Strait); and sea surface salinity (fresher near the mainland coast). There were also some striking long-term trends and low frequency oscillations in physical conditions. In general, the data suggest that global warming has significantly increased winter and spring temperatures, but not summer or fall temperatures in the region. There were no between-site (Dixon Entrance, Hecate Strait, and Queen Charlotte Sound) differences in nutrient concentrations. During the summer, the depth of the upper wind-mixed layer varied between 10 to 30 m, and summer concentrations of NO_3, PO_4 and SiO_2 were low between 0-5 m, about doubled between 5-15 m and then gradually increased with water depth. Winter concentrations were higher than in the summer. Chlorophyll *a* concentrations measured from surface waters (<10 m deep) at three locations (Dixon Entrance, Hecate Strait, and Queen Charlotte Sound) were similar between years and between sites. During the summer, surface (0-20 m) chlorophyll *a* concentrations averaged about 2 $\mu g \cdot L^{-1}$, increased significantly between 20-30 m and decreased below 30-40 m. During the winter, chlorophyll *a* concentrations were consistently much lower. Zooplankton biomasses from Hecate Strait and Queen Charlotte Sound were statistically similar and higher than from Dixon Entrance. Long-term time trends for the years 1957-2001 suggested that some of the variability in zooplankton biomass may have been related to the periodicity of ENSO events. Short-term time trends for the 11-year period 1991-2001, suggested that zooplankton biomasses were low during the early 1990s, then increased substantially during the mid-1990s and declined during the late 1990s. These patterns were only weakly related to the ENSO events of 1992 and 1998. Biomass trends developed slowly and lasted longer than would be expected if it was driven by ENSO events alone. The implication is that trends in zooplankton biomass are driven by complex biologically and physically mediated events which may or may not be related to ENSO.

RÉSUMÉ

McQueen, D., and Ware, D. 2006. Handbook of physical, chemical, phytoplankton and zooplankton data from Hecate Strait, Dixon Entrance, Goose Island Bank and Queen Charlotte Sound. Can. Data Rep. Fish. Aquat. Sci. 1162: xi + 133 p.

Ce rapport résume les données physiques et les données relatives aux niveaux trophiques inférieurs obtenues dans le détroit d'Hécate et le détroit de la Reine-Charlotte. Il a pour buts : 1) de compiler des données physiques et chimiques ainsi que des données sur le phytoplancton et le zooplancton nécessaires pour construire des modèles des niveaux trophiques inférieurs du détroit d'Hécate, 2) de résumer les données appropriées des niveaux trophiques inférieurs (physiques, chimiques, phytoplanctoniques et zooplanctoniques) afin d'effectuer les meilleures estimations des schémas saisonniers interannuels et décennaux, et 3) de quantifier l'étendue de la variabilité spatiale dans la région du détroit d'Hécate. Le rapport comporte quatre sections : 1) les facteurs climatiques physiques et océanographiques, 2) les nutriants, 3) la chlorophylle et la production primaire et 4) le zooplancton. La variabilité entre les sites était importante en ce qui concerne les précipitations (plus abondantes le long de la côte continentale), l'ensoleillement (plus d'heures d'ensoleillement au sud du détroit de la Reine-Charlotte et au nord-ouest du détroit d'Hécate), les températures de la surface de la mer (plus froides près du détroit de la Reine-Charlotte) et la salinité de la surface de la mer (plus douce près de la côte continentale). Nous avons dénoté pour les conditions physiques quelques tendances saisissantes à long terme et d'évidentes oscillations à basse fréquence. En général, les données suggèrent que le réchauffement du globe a sensiblement augmenté les températures d'hiver et de printemps dans la région, mais non celles de l'été et de l'automne. Il n'existait aucune différence de concentration des nutriants entre les sites (entrée Dixon, détroit d'Hécate et détroit de la Reine-Charlotte). Pendant l'été, l'épaisseur de la couche de mélange variait entre 10 et 30 m et, en été, les concentrations de NO_3, PO_4 et SiO_2 étaient basses entre 0 et 5 m, doublaient entre 5 et 15 m et puis augmentaient graduellement avec la profondeur. Les concentrations étaient plus élevées en hiver qu'en été. Les concentrations en chlorophylle a mesurées dans les eaux de surface (<10 m de profondeur) à trois endroits (entrée Dixon, détroit Hécate et détroit de la Reine-Charlotte) étaient similaires pour toutes les années et pour tous les sites. Pendant l'été, les concentrations de surface (0-20 m) de la chlorophylle a étaient en moyenne d'environ 2 $\mu g \cdot L^{-1}$, augmentaient d'une façon importante entre 20-30 m, puis diminuaient au-dessous de 30-40 m. Pendant l'hiver, les concentrations en chlorophylle a étaient systématiquement plus basses. Les biomasses du zooplancton du détroit d'Hécate et du détroit de la Reine-Charlotte étaient statistiquement similaires et plus élevées que celles de l'entrée Dixon. Les tendances à long terme des années 1957-2001 permettaient de penser qu'une partie de la variabilité de la biomasse du zooplancton pourrait être expliquée par la périodicité des évènements ENSO. Les tendances à court terme au cours de la période de onze ans, de 1991 à 2001, suggéraient que durant le début des années 1990 les biomasses du zooplancton étaient basses et puis qu'elles ont augmenté fortement au milieu des années 1990 pour ensuite décroître vers la fin des années 1990. Ces

tendances avaient peu de points communs avec les évènements ENSO de 1992 et 1998. Les biomasses se développent lentement et durent plus longtemps qu'elles le feraient si elles n'étaient provoquées que par les seuls évènements ENSO. Ces tendances impliquent que la biomasse de zooplancton répond à des évènements causés par des phénomènes biologiques et physiques qui peuvent être reliés à ENSO, ou non.

INTRODUCTION

This report summarizes physical and lower trophic level data (summary table page 2) collected in Hecate Strait and Queen Charlotte Sound. Some information for Dixon Entrance is also included. The primary objective of this report is to: 1) organize those portions of the physical, water chemistry, phytoplankton and zooplankton data base which will be required for the development of lower trophic level simulation models for Hecate Strait. Currently these data are scattered in a variety of unpublished reports, technical documents and primary publications. The intent is to provide participants in the Department of Fisheries and Oceans Project: "An Ecosystem Approach to Fisheries Management in Hecate Strait" with a data handbook that will assist with lower trophic level modeling. Also, as the project develops we anticipate that participants will use these data to conduct exploratory analyses investigating linkages between the physical environment and variation in phytoplankton and zooplankton productivity; and to conduct exploratory analyses investigating linkages between interannual variability in the physical environment and the plankton, and recruitment variability in selected fish populations in Hecate Strait. The other objectives of this report are to: 2) summarize appropriate lower trophic level data (physical, water chemistry, phytoplankton and zooplankton) to produce best estimates of interannual and decadal seasonal patterns; and 3) quantify the extent of spatial variability that may exist within the Hecate Strait region.

We should also mention what is not included in this report. We do not discuss water circulation in the region. This has been elegantly summarized in Rick Thomson's 1981 book titled "Oceanography of the British Columbia Coast", and in a series of subsequent publications by Bill Crawford and his colleagues at the Institute of Ocean Sciences (IOS). So we refer readers to these publications. We also do not include other portions of the very large IOS physical-oceanographic data base which has been collected for this area. Rather we have restricted our summary of the physical data to those portions needed for lower trophic level modeling. Finally we have not included very much exploratory data analysis. We anticipate that these analyses will be conducted by many of the Project participants over the next few years, and we note in passing that there appear to be some interesting relationships between some of the variables summarized in this report.

The report is laid out in four parts: 1) physical climatic and oceanographic factors, 2) nutrients, 3) chlorophyll and primary production, and 4) zooplankton. The Table of Contents (page iii) will guide the reader to specific sections of interest. References are included and a general Hecate Strait reading list is provided in Appendix A. Reference is made within applicable sections of the report to Excel spreadsheets and Appendices C-E that are only available in electronic format. Appendix B lists these files and provides an internet link for readers to download this report and related data.

This document was prepared for the Fisheries & Oceans Canada (DFO) project "An Ecosystem Approach to Fisheries Management in Hecate Strait" managed by Jeff Fargo (DFO, Pacific Biological Station, Nanaimo, B.C.).

Table: Years covered by the data sets included in this report (shaded areas). Blanks represent years for which data are unavailable.

Year	Precip-itation	Sunlight	Sea Surface Temp	Wind	Ekman Up-welling	Mixed Layer Depth	Sea Surface Salinity	NO_3 SiO_2	Chl *a*	1^O prod	Cope-pods	Euphau-siids	Other Zoo-plankton
2001													
2000													
1999													
1998													
1997													
1996													
1995													
1994													
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1. PHYSICAL ENVIRONMENTAL FACTORS

1.1. OBJECTIVE AND SUMMARY OF RESULTS

The objective of Section 1 is to: 1) summarize the available physical environmental data for the Queen Charlotte Sound/Hecate Strait region, 2) summarize the seasonal trends, 3) investigate the extent of between-site variability within the region, and 4) identify low frequency oscillations and long-term trends. The data suggest considerable between-site variability in precipitation (wetter along the mainland coast), sunlight (more hours of bright sunlight in southern Queen Charlotte Sound and northwestern Hecate Strait), sea surface temperatures (cooler near Queen Charlotte Strait), and sea surface salinity (fresher near the mainland coast). There were also several striking long-term trends and low frequency oscillations in some of the variables we examined. In general, the winters and springs in the region have gotten warmer and wetter since the 1960s. However, the summer and fall temperatures have not risen significantly. This implies that the linear trend, which is believed to be caused by global warming, has significantly increased winter and spring temperatures, but not summer or fall temperatures in the region. There was a low frequency oscillation in the amount of bright sunlight in the summer during the 1990s. The intensity of downwelling during the winter has increased more or less steadily since the mid-1940s. In the spring, upwelling was moderate during the mid-1950s to early 1970s, but became weaker and more intermittent during the 1970s, 1980s, and most of the 1990s. However, upwelling was anomalously strong again during the spring of 1998, particularly in June. During summer, there has been an increasing trend in the upwelling index. With respect to the cumulative amount of upwelling occurring during the spring and summer, there was a large increase between the mid-1940s and mid-1960s. This was followed by a general decline between the late-1960s and mid-1980s, and then a general increase in the 1990s. Because many of the variables we examined (e.g. sunlight, temperature, wind speed, and upwelling) affect primary production either directly, or indirectly by supplying new nutrients to the euphotic zone, the potential impacts of the observed interannual and low frequency variability in these factors should be evaluated by those engaged in lower trophic level production modeling. If the impacts of physical forcing are found to have a significant effect on primary production by the microbial food web and by the diatoms, then perhaps the results should be incorporated into the Ecosim modeling activities.

1.2. PRECIPITATION

1.2.1. Precipitation Climatology

Precipitation has been measured at a number of coastal locations in the region. Rain, drizzle, freezing rain and hail are usually measured with a standard Canadian rain gauge. Snowfall is the measured depth of newly fallen snow using a snow ruler. The water equivalent of snowfall is computed by dividing the measured amount by ten. “Precipitation” in Table 1.2.1 and Fig. 1.2.1 is therefore the water equivalent of all types of precipitation.

Table 1.2.2 summarizes the monthly mean precipitation (mm·month^{-1}) and the associated variability at Port Hardy, which has the longest time series in the region.

1.2.2. Precipitation Patterns and Trends

Inspection of Table 1.2.1 indicates that it is considerably wetter along the mainland coast (average 2.6 m·year^{-1}) than it is along either the east coast of the Queen Charlotte Islands (average 1.4 m·year^{-1}) or the southern boundary of the region at Port Hardy (1.8 m·year^{-1} in Table 1.2.2).

Figure 1.2.2 illustrates that there is a large amount of interannual variability in precipitation, which is superimposed on a low frequency multidecadal trend. The data show that it was much drier in the region during the late-1940s. In the early 1950s to mid-1960s, the mean annual precipitation increased about 25%. Since then, the annual precipitation at Port Hardy appears to have oscillated around a relatively stationary mean of 1.86 m·year^{-1}.

Seasonal precipitation trends are shown in Fig. 1.2.3. These time series indicate that the winters and springs have gotten progressively wetter since the mid-1940s, while the summers have become a little drier since 1980. The fall precipitation has been relatively trendless.

1.3. SUNLIGHT

1.3.1. Sunlight Climatology

Figure 1.3.1 indicates the duration of daylight at 52°N which is roughly the latitude of Cape St. James. The actual hours of bright sunshine per day have been measured at three locations in the region: Sandspit (terminated in 1994), Prince Rupert, and Port Hardy. Bright sunshine observations are made using the Campbell-Stokes sunshine recorder. It consists of a 10-cm glass sphere that focuses sunlight on a card calibrated in hours. Sunlight burns a trace on the card, allowing the observer to determine to the nearest tenth of an hour the amount of sunshine that occurs on a given day. It should be noted that the recorder only measures “bright” sunshine, which is less frequent than “visible” sunshine. For example, sunshine immediately after sunrise and just before sunset would not be bright enough to register.

The monthly mean hours of bright sunshine per day at Sandspit and Prince Rupert for the period 1961-1990 are summarized in Figs. 1.3.2-1.3.3 and Table 1.3.1.

The average proportion of the day registering bright sunshine can be estimated by dividing columns 4 and 5 in Table 1.3.1, by column 2. On an annual basis, bright sunshine occurs only 33% of the time during the day at Sandspit and 27% at Prince Rupert. Daily observations of the hours of bright sunshine at Prince Rupert and Port Hardy for the period January 1991 to August 1999 were obtained from Environment Canada. We computed the monthly mean hours of bright sunshine during this period (Tables 1.3.2 and 1.3.3). Figures 1.3.4 and 1.3.5 indicate the interannual variability in monthly means. Presumably most of this variation is caused by year-to-year differences in the frequency of low pressure weather systems passing through the region.

The amount of solar energy reaching the sea surface is affected by many factors, such as the elevation of the sun, the cloudiness of the sky, molecular scattering by water vapor, air and dust particles, and absorptions by water vapor and ozone. Ma (1992) compiled a time series of monthly mean solar irradiation measurements ($Cal \cdot cm^{-2} \cdot day^{-1}$) at ground level at Cape St. James during clear weather (Table 1.3.1 and Fig. 1.3.6). His data show that peak solar irradiance occurs in June, and reaches a minimum value in December.

1.3.2. Sunlight Patterns and Trends

Tables 1.3.1-1.3.3 suggest a complex spatial distribution of bright sunshine in the region. There tends to be more hours of bright sunshine per month in southern Queen Charlotte Sound (Port Hardy) and in northwestern Hecate Strait (Sandspit) than there are in northeastern Hecate Strait (Prince Rupert). The sunshine time series for Prince Rupert and Port Hardy reveal a low frequency trend during the 1990s, particularly at Prince Rupert (Figs. 1.3.7 and 1.3.8). In both records, the average number of hours of bright sunshine in the summer tended to rise in the early 1990s, peaked in 1996, and then declined. These spatial and temporal variations in sunlight in the region probably affect primary production because sunlight is an important growth-regulating factor.

1.4. SEA SURFACE TEMPERATURE (SST)

1.4.1. Sea Surface Temperature Climatology

Daily and monthly mean measurements of sea surface temperature (SST) are available from the Department of Fisheries and Oceans, Institute of Ocean Sciences, for a number of shore stations in the region. The locations and lengths of these time series are listed below:

Location	Position	Area	Time Series
Egg Island	51.1°N 127.5°W	Lower Queen Charlotte Sound	1970-2001
McInnes Island	51.6°N 131.0°W	Lower Hecate Strait	1955-2001
Bonilla Island	53.3°N 130.4°W	Middle Hecate Strait	1960-2001
Cape St. James	51.6°N 131.0°W	Western Hecate Strait	1935-1991
Langara Island	54.1°N 133.0°W	Dixon Entrance	1941-2001

Figures 1.4.1-1.4.3 summarize the monthly mean sea surface temperatures at Pine Island, McInnes Island, and Bonilla Island for the period 1960-2000. These data show that Hecate Strait/Queen Charlotte Sound sea surface temperatures normally reach minimum values in January-February and peak in August. Surface temperatures in February are the most variable, while summer temperatures tend to be the least variable (Tables 1.4.1-1.4.3).

If we define the seasons in terms of the annual surface heating and cooling cycle, Figures 1.4.1-1.4.3 indicate that “winter” occurs in January, February and March, “spring” occurs in April, May, June, “summer” occurs in July, August, September, and “fall” occurs in October, November and December. We use this seasonal designation scheme later in this chapter to summarize the trends in a number of variables.

1.4.2. Sea Surface Temperature Patterns and Trends

Table 1.4.1 indicates that Pine Island is much cooler throughout the year than McInnes Island and Bonilla Island. This is largely due to strong tidal mixing in Johnstone Strait. The water in this region is in almost constant agitation from top to bottom and therefore is much cooler than the highly stratified waters in Queen Charlotte Sound (Thomson 1981).

The annual mean SST time series at each location are shown in Figures 1.4.4-1.4.6. The horizontal lines in each case indicate the mean SST for the period 1960-2000, while the curves show the low frequency decadal trends in the records. All of these time series reveal a roughly bi-decadal oscillation in SST from 1940 to the mid-1970s, followed by a sharp rise in temperature in the late 1970s. Fairly high temperatures prevailed in the 1980s and most of the 1990s. However, a sharp decline in temperature occurred in 1999. The mid-1970s rise is the much studied “regime change”. It is possible that a new regime change — toward a somewhat cooler climate — occurred in 1999. Although a cooling trend for the next decade or two has been anticipated (Ware 1995), it is too soon to tell if this is happening. Several more years of data are required to establish if a regime change really occurred in 1999, or if this anomaly was simply caused by the 1999/2000 La Niña event in the tropical Pacific.

SST trends in the region are determined by natural variability at interannual, decadal, and multidecadal time scales. Interannual and decadal variability are strongly influenced by the El Niño-southern oscillation (ENSO) phenomenon which originates in the tropical Pacific and has an average period of about 5-6 years. Table 1.4.4 summarizes the timing of warm ENSO events in the tropical Pacific since 1957 (according to Rasmusson *et al*’s (1995) SST time series, these were years when the temperature anomaly was greater than 1°C) and the strength of these events at McInnes Island.

In addition to the interannual and multi-decadal variability, there is also a linear trend in the SST time series in the region which is believed to be the greenhouse gas global warming signal. Average winter and spring SSTs have increased significantly ($p<0.05$) at a rate of about 0.2-0.15°C per decade since the 1960s. Consequently, recent winter and spring temperatures are about 0.6-0.8°C warmer than they were in the early 1960s (Fig. 1.4.7). Interestingly, however, summer and fall temperatures in the region have not risen significantly ($p>0.18$). This implies that over the last four decades, global warming has significantly increased the winter and spring temperatures in Hecate Strait and Queen Charlotte Sound, but not the summer or fall temperatures.

1.5. WIND SPEED

1.5.1. Wind Speed Climatology

Prevailing wind patterns along the west coast of Canada are controlled by the locations and intensities of two large-scale, semi-permanent atmospheric pressure cells: the Aleutian Low and the North Pacific High (Thomson 1981). The Aleutian Low gradually increases in intensity from August to December as its center shifts southeastward from the northern Bering Sea to the Gulf of Alaska. The maximum intensity of this low-pressure cell occurs in January. This is followed by a progressive weakening of the Aleutian Low and a gradual increase in the intensity of the North Pacific High. The combined pressure pattern produced by these two major pressure cells causes the winds in the late fall to early spring to be predominantly from the southeast to southwest along the BC coast. However, from May through September, the combined effects of a greatly weakened Aleutian Low and intensified North Pacific High causes the coastal winds to shift 180° to a predominantly northwesterly direction (Thomson 1981). The general pattern of this transition in the direction of the prevailing winds is apparent in Table 1.5.1. However, there are some minor differences in wind direction at several locations which are presumably caused by local topographic effects. More exposed sites like Egg Island indicate that the spring transition in wind direction in the region normally occurs in May and the fall transition happens in late September or early October.

Wind measurements summarized in Table 1.5.1 have been made with anemometers installed at ten metres above the ground. The direction is defined as that from which the wind blows. Table 1.5.1 shows that the average wind speed is lower near the mainland shore. For example, the monthly mean wind speeds at Cape St. James tend to be considerably higher than the corresponding wind speeds at Cape Scott and Egg Island.

Hourly wind speed ($m \cdot s^{-1}$) measurements have been recorded at three moored buoys in Queen Charlotte Sound and Hecate Strait since 1990. Dr. Mike Foreman at the Institute of Ocean Sciences kindly provided these records for us. We compressed these extensive data files by calculating daily wind speed time series for two of the buoys: Buoy 46204 is located approximately in the center of Queen Charlotte Sound, and Buoy 46185 is located in southern Hecate Strait. Note that the alongshore wind speed is aligned to the coastline, and the cross-shore wind speed is normal to the coastline. The wind speed records are important to the Hecate Strait Project lower trophic level modeling activities because the stress that the wind exerts on the sea surface is proportional to the square of the northwesterly alongshore wind speed, which in turn affects the amount of upwelling and primary production in the region.

Figures 1.5.2-1.5.5 show the alongshore and cross-shore wind speed time series at Buoys 46185 and 46204. *In this case, note that positive alongshore wind speeds indicate that the wind is blowing from the south (southeasterly winds), and negative wind speeds indicate that the wind is blowing from the north (northwesterly winds).* The sign of the wind speed is simply a convention, and can be changed if one is performing a statistical correlation analysis where it is important that upwelling-favorable northerly wind velocities have a positive sign, and downwelling-favorable southerly wind velocities have a negative sign. Similarly, a positive sign for the cross-shore wind speeds indicates that the wind is blowing from the west to the east (*westerly winds*), and a negative sign that the wind is blowing from the east to the west (*easterly winds*).

Figures 1.5.6 and 1.5.7 highlight the large interannual variability in the direction and strength of the winds in the region in the 1990s. During this period, the spring transition in wind direction occurred around day 120 (29 April) and the fall transition about day 270 (26 September, Fig. 1.5.6). These data also show that upwelling-favorable (northerly) and downwelling-favorable (southerly) winds occur throughout the year. However, downwelling-favorable winds tend to prevail in the region in the fall and winter. A comparison of two contrasting years (1994 and 1998, Fig. 1.5.7), shows that upwelling-favorable winds occurred more frequently in the summer of 1998.

1.6. EKMAN UPWELLING INDEX

1.6.1. Upwelling Climatology

As noted in the previous section, the weather pattern in the region is dominated by the Aleutian Low Pressure system in winter. This causes the prevailing winds to blow up Queen Charlotte Sound and Hecate Strait from the southeast. Southeasterly winds generate a downwind surface drift which is then deflected to the right by the earth's rotation. This, in turn, leads to a net onshore Ekman transport within the top 100 m or so of the water column. When this transport is blocked by the coast there is an onshore accumulation of surface waters and a depression of the nearshore isopycnals (downwelling), with only a partially compensating offshore transport at depth. Resulting pressure gradients are then balanced by the establishment of northward coastal currents in the upper layer (Thomson 1981). If the winds die, the piled-up surface waters collapse seaward and the current disappears. If the winds reverse to the northwest, then the surface Ekman transport is offshore, the isopycnals are raised (upwelling), and the resulting coastal current is southward (Thomson 1981). Prevailing winds usually shift to a northwesterly direction in May as the Aleutian Low pressure system weakens and the North Pacific high pressure system intensifies and moves poleward (Table 1.6.1). The stress exerted on the water surface by these northwesterly winds produce slow drift currents. The earth's rotation causes these drift currents to deflect to the right of the wind. As the surface water is pushed offshore, cold nutrient-rich deep water wells up to the surface to replace it. This wind-induced upwelling is extremely slow, with upward speeds of about 1-10 $m \cdot day^{-1}$. In the Hecate Strait/Queen Charlotte Sound region upwelling tends to be intermittent and weak in the summer (Figs. 1.6.2 and 1.6.3). However, at times upwelling can be large enough to add new nutrients to the upper mixed layer.

An Ekman upwelling index can be calculated from the geostrophic wind, which is derived from monthly mean atmospheric pressure fields (see Bakun 1973). The units of the index are metric tons per second per 100 m of coastline. These units may be thought of as the average amount (metric tons or cubic metres) of water upwelled along the bottom of the Ekman layer each second along 100 m of coastline. In this case, a positive upwelling index signifies upwelling and a negative index indicates downwelling (Fig. 1.6.1).

1.6.2. Upwelling Trends

Although the spring transition in the direction of the prevailing winds normally occurs in May, it can occur as early as April or as late as June. Upwelling can occur in every month of the year, but is most frequent in July and August, and least frequent from October to February (Table 1.6.1 and Fig. 1.6.2). Figure 1.6.3 shows how the frequency of months in which the upwelling index was positive during February-October changed over the time series. The number of positive months peaked in the mid-1960s (averaging 5.5 months) and then declined steadily until the mid-1980s. Since then, the number of positive months has fluctuated around a mean value of about 4. This record shows that the frequency of upwelling was lowest in 1984 and 1997 (both only 1 month); and was highest in 1955, 1964, 1965, 1972, and 1991 (7-8 months). Figure 1.6.3 further illustrates the significant interannual variability about the trend line.

To obtain a cumulative index of the total amount of upwelling that occurred each year, we summed the upwelling index values for all the positive months from February to October, inclusive (Fig. 1.6.4). The results revealed several strong trends: increasing upwelling from the mid-1940s to mid-1960s, a declining trend from the mid-1960s to mid-1980s, followed by a rising trend to 2000.

Figure 1.6.5 illustrates the trends in the seasonal mean upwelling index. Note that the alongshore wind speed is aligned to the coastline, and the cross-shore wind speed is normal to the coastline. In general, the intensity of downwelling during the winter has increased over the length of the time series. In the spring, upwelling was moderate during the mid-1950s to early 1970s, but became weaker and more intermittent during the 1970s, 1980s, and most of the 1990s. However, upwelling was anomalously strong during the spring of 1998, particularly in June. During summer, there has been an increasing trend in the upwelling index.

1.7. MIXED LAYER DEPTH

1.7.1. Mixed Layer Depth Climatology

In winter (January-March), cooling, intense wind mixing, and advective processes in the region deepen the mixed layer to its maximum annual depth of about 100-150 m. In April-May, surface heating, precipitation, and a relaxation of the wind speed result in the development of a thermocline. In June-September, there is a thin (10-20 m) mixed or near-mixed surface layer. In the absence of surface mixing, the thermocline can extend to the surface. During October-December, surface cooling plus wind-induced and convective mixing cause a thickening of the surface mixed layer and a downward displacement of the thermocline.

Perry and Dilke (1986) estimated the monthly mean depth of the mixed layer in eastern Hecate Strait for the period 1954-1971 (Fig. 1.7.1). Their results agree favorably with other estimates of mixed layer depth in the region (Fig. 1.7.2).

1.8. SEA SURFACE SALINITY

1.8.1. Sea Surface Salinity Climatology

Long-term daily measurements of sea surface salinity (SSS in parts per thousand) have been made at a number of shore stations in the region. The locations and lengths of the available time series are identical to sea surface temperature records discussed in Section 1.4. Over most of the region, the annual range of surface salinity is from 28 to 32 parts per thousand. Due to drainage from the coastal mountains (Thomson 1981), water on the mainland side of the region tends to be less salty than on the western side. Figure 1.8.1 and Tables 1.8.1-1.8.2 summarize the monthly mean salinity at Bonilla Island and McInnes Island from 1960-2000. There is an obvious contrast in the seasonal pattern at these two locations. Surface waters tend to be saltier throughout the year at Bonilla Island, in part due to the lower rainfall at this location (Fig. 1.2.1). In addition, the peak salinities in August and September probably also reflect the influence of upwelling which raises deep, higher salinity water to the surface. In contrast, the decreasing trend in salinity from June to September at McInnes Island probably reflects the drainage from mainland mountains during this period. Table 1.8.2 also indicates that the interannual variability in the monthly mean SSS at McInnes Island is larger (coefficients of variation ranging from 0.022-0.031), with July being the most variable month. In contrast, the interannual variability in the monthly mean SSS at Bonilla Island is fairly similar throughout the year (coefficient of variation ranging from 0.011-0.013).

1.8.2. Sea surface Salinity Trends

The seasonal trends in mean salinity at Bonilla Island are illustrated in Fig. 1.8.2. This time series contains a multidecadal low frequency trend, with appreciable interannual variability. In general, the seasonal mean salinities declined in the 1960s and remained low for most of the 1970s, then increased during the 1980s and most of the 1990s. The only exception to this pattern was the summer salinity from July-August, which appears to have peaked about 1990 and then declined for the rest of the decade.

1.9. SEA LEVEL

1.9.1. Sea Level Climatology

There is a direct correlation between the alongshore component of the coastal wind and nontidal variations in coastal sea level of a few centimetres in the Hecate Strait region. A northwest wind tends to move water offshore resulting in a small lowering of sea level. In contrast, a southeast wind moves water onshore causing sea level to rise. When the coast blocks this transport, there is an onshore accumulation of surface waters.

The establishment of a northward coastal current in the upper layer then balances the resulting pressure gradients. When the winds reverse to the northwest, the surface Ekman transport is offshore and the resulting coastal current will flow southward (Thomson 1981). Since the prevailing winter winds in the Hecate Strait region tend to blow from the south, the coastal current tends to flow northward during this period. Conversely in summer, when the winds blow predominantly from the north, the coastal current tends to flow southward. Tyler and Crawford (1991) found that in winter the north wind, which drives the coastal current, piles up water at the northern constricted end of Hecate Strait near Prince Rupert. Geostrophic adjustment of the sea surface due to these northward currents through the Strait raises sea level along the eastern shore.

Sea level is also affected by atmospheric pressure. When the atmospheric pressure is high, the water surface will tend to be depressed. Conversely, when the atmospheric pressure is low, sea level tends to be elevated. Consequently, any difference in atmospheric pressure between two regions will produce a tilt in sea level toward the region with the lowest pressure. For this to occur however there must be a redistribution of water via a current from the region of high pressure toward the region of low pressure. The speed of this current is usually small and is distributed over the entire depth of the water column (Thomson 1981).

1.9.2. Sea Level trends

Fig. 1.9.1 shows the pressure-adjusted winter (January-March) Prince Rupert sea level time series from 1962-2001. These data illustrate a general rise in sea level during this period with large interannual variations. This change in the flow regime has some significant biological effects in the region. For example, Tyler and Crawford (1991) found that recruitment to the Hecate Strait Pacific cod stock decreased with increasing transport during the larval period (winter).

2. NUTRIENT (NO_3, PO_4 and SiO_2) DATA

2.1. OBJECTIVE AND SUMMARY OF RESULTS

Section 2 summarizes all of the available nutrient data available for "Hecate Strait" which will be defined here to include Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound. The objective is to provide best estimates of depth-stratified monthly mean nutrient concentrations which will be used to parameterize a lower trophic level model focused on the microbial food web, diatoms, and zooplankton. These data may also be used to parameterize a more broadly-based Ecosim model that includes phytoplankton, zooplankton, and the major fish species found in Hecate Strait.

This section summarizes four data sets including Dilke *et al* (1979), Perry *et al* (1981), Forbes and Waters (1993), and Denman *et al* (1985).

In general, after correcting for sample depth and time of year, there were almost no between-site (Dixon Entrance, Hecate Strait, and Queen Charlotte Sound) differences in nutrient concentrations.

The depth-stratified data suggest that water temperature and all of the nutrients varied with respect to depth during the summer. Water between 0-10 m was isothermal, was cooler between 10–15 m and was again isothermal between 15-30 m. This implies that during the summer, the depth of the upper wind-mixed layer varies between 10-30 m depending on the average wind speeds and stability of the surface layer. This is consistent with other estimates of "typical" summer mixed layer depths in the region. In the cases of NO_3, PO_4 and SiO_2, summer concentrations were low between 0-5 m, about doubled between 5-15 m and then gradually increased with water depth.

Seasonal trends based on combined surface water data (defined here to be 1-10 m), suggested that winter NO_3 and PO_4 concentrations in the surface water were higher than in the summer. Surface-water SiO_2 concentrations showed similar trends, but less pronounced. These data are summarized in Figs 2.6.1-2.6.3 and Table 2.6.1.

2.2. SUMMARY OF Dilke *et al* (1979)

Reference characteristics: Summer and winter samples collected from 13 March 1978 through 8 April 1979. All samples were collected from a depth of 3 m.

This report includes data collected during the MV *Imperial Tofino* Ships-of-Opportunity Program summarized by the Oceanography Department, University of British Columbia. The summer and winter samples were collected during seven cruises from 13 March 1978 through 8 April 1979. Samples of seawater, which were used for the analysis of nutrients and chlorophyll *a*, where taken from a depth of 3 m using the ship's water intake. The water was pumped from the sea-chest through a Jabsco impeller pump and the sample was integrated over the length of the sampling transect (usually over 1.3 km). Nutrient samples were obtained from 125 mL of seawater, filtered through Gelman type A/E filters, and the filtrate was stored in 125 mL plastic bottles which were frozen. Nitrate, nitrite and phosphate were determined either manually or with an auto analyzer using the methods described in Strickland and Parsons (1972).

The Dilke *et al* (1979) data set comprised a total of 16 samples (4 from Dixon Entrance and 12 from Hecate Strait) (Table 2.2.1). Only a small number of samples were analyzed for nitrogen and phosphorus (Table 2.2.2), so between-month and between-site comparisons were not possible. See Appendix B to obtain the electronic spreadsheet data (*Chem Dilke et al 1979.xls*).

2.3. SUMMARY OF Perry *et al* (1981)

Reference characteristics: Summer and winter samples collected from 8 May 1979 through 7 June 1980. All samples were collected from a depth of 3 m.

The report includes data collected during the MV *Imperial Tofino* Ships-of-Opportunity Program summarized by the Oceanography Department, University of British Columbia. The summer and winter samples were collected during eight cruises from 8 May 1979 through 7 June 1980. Samples of seawater, which were used for the analysis of nutrients and chlorophyll *a*, where taken from a depth of 3 m using the ship's water intake. The water was pumped from the sea-chest through a Jabsco impeller pump and the sample was integrated over the length of the sampling transect (usually over 1.3 km). Nutrient samples were obtained from 125 mL of seawater, filtered through Gelman type A/E filters, and the filtrate was stored in 125 mL plastic bottles which were frozen. Nitrate, nitrite, phosphate and silicate were determined using a Technicon Auto Analyzer following the methods described in Strickland and Parsons (1972). See Appendix B to obtain the electronic spreadsheet data (*Chem Perry et al 1981.xls*).

The data set comprised 35 samples (5 from Dixon Entrance and 30 from Hecate Strait) (Table 2.3.1). The Dixon Entrance samples were collected on only two dates, while the Hecate Strait samples were collected both summer and winter (Table 2.3.1). With the exception of silicate which is substantially higher in Dixon Entrance (perhaps due to the Skeena River influence), the other nutrient concentrations were similar (Table 2.3.2). A seasonal analysis of these data (Fig. 2.3.1) revealed that while there were substantial differences in the concentrations of the various nutrients, the seasonal concentrations were relatively stable except during mid-summer when they declined.

2.4. SUMMARY OF Denman *et al* (1985)

Reference characteristics: 1983 (July 02-10) summer samples only, night and day samples, several depth profiles, primary production data available.

The portion of Denman *et al* (1985) included in this section is restricted to Hecate Strait and Queen Charlotte Sound. Depth-stratified samples were collected on a single cruise aboard the CFAV *Endeavour* between July 02 and 10, 1983. The onboard sensors used during 1983 included an *in situ* fluorometer for chlorophyll fluorescence, a Licor spherical quantum PAR meter, and a CTD sensor that was periodically calibrated using reversing thermometers. Inorganic nitrate, nitrite, phosphate and silicate were determined using a Technicon Auto Analyzer following the methods described in Strickland and Parsons (1972).

Because all of the data provided in Denman *et al* (1985) were collected within a one week time period, temporal comparisons are not possible. However, the data set was very large (several hundred samples - Table 2.4.1) and many of the nutrient measurements were stratified by depth, allowing a reasonably detailed examination of differences that may occur between sites and between depths. See Appendix B to obtain the electronic spreadsheet data (*Chem Denman et al 1985.xls*).

Plots of nutrient concentration patterns with respect to depth show no significant differences between Hecate Strait and Queen Charlotte Sound (Figs. 2.4.1-2.4.4). However, as expected, water temperature and all of the nutrients varied with respect to depth. Water between 0-10 m was isothermal, cooled between 10-15 m, and was again isothermal between 15-30 m. This implies that the upper wind-mixed layer depth varies between 10-30 m, depending on the average wind speeds and stability of the surface layer. This is consistent with other estimates of “typical” summer mixed layer depths in the region. In the cases of NO_3 and SiO_2, the patterns were slightly different. In both cases, nutrient concentrations were low between 0-5 m, about doubled between 5-15 m and then gradually increased with increasing water depth (Table 2.4.2).

2.5. SUMMARY OF Forbes and Waters (1993)

Reference characteristics: Samples collected between 29 June and 7 July 1985 and the data include several depth profiles.

The portion of Forbes and Waters (1993) data set included in this report is restricted to Dixon Entrance, Hecate Strait, and Queen Charlotte Sound. Depth-stratified samples were collected between June 29 and July 7, 1985. The onboard sensors used during 1985 included an *in situ* fluorometer for chlorophyll fluorescence, a Licor spherical quantum PAR meter, and a CTD sensor that was periodically calibrated using reversing thermometers. Inorganic nitrate, nitrite, phosphate and silicate were determined using a Technicon Auto Analyzer following the methods described in Strickland and Parsons (1972). See Appendix B to obtain the electronic spreadsheet data (*Chem Forbes and Waters 1993.xls*).

It should be noted that all of the data from water depths >10 m were collected only at Dixon Entrance (Table 2.5.1). When these data were combined with all of the shallow water data from Hecate Strait, Queen Charlotte Sound, and Dixon Entrance (Fig. 2.5.1), there was the expected general trend towards higher concentrations with depth. When only shallow water (0-10 m) samples were considered (Table 2.5.2), the between-site means for NO_3 and PO_4 were similar, but contrary to the patterns found in other data (Perry *et al* 1981), silicon concentrations were lowest in Dixon Entrance and highest in Queen Charlotte Sound.

2.6. TRENDS IN THE AGGREGATED SHALLOW WATER DATA

As noted in the preceding sections, nutrient data for Hecate Strait, Dixon Entrance, and Queen Charlotte Sound are available from only four published sources. Two sources (Dilke *et al* 1979, Perry *et al* 1981) have winter data but no depth stratification (all samples were taken at 3 m depth). Two (Denman *et al* 1985, Forbes and Waters 1993) have depth data, but include data only from late June and early July. Consequently, between-sample comparisons and between-year comparisons are impossible. However, it is possible to combine all surface water data (defined here to be 1-10 m) to generate average monthly nutrient concentrations (Figs. 2.6.1–2.6.3). For all three nutrients (NO_3, PO_4 and SiO_2) the patterns are the same: high concentrations during the winter months and lower concentrations during the summer and fall. A potential area for concern involves the fact that the two early studies were based on slightly different techniques than the two later studies. However, Perry *et al* (1981) include data from several times of the year including the summer months. When these data are compared to the summer data collected by Denman *et al* (1985) and Forbes and Waters (1993) (Figs. 2.6.1–2.6.3), the concordance is exceptionally good suggesting that the monthly comparisons described above are valid.

In summary, it seems reasonable to combine all available data to produce mean monthly surface concentrations for the three major nutrients considered in this review. These data are summarized in Table 2.6.1.

3. CHLOROPHYLL AND PHYTOPLANKTON PRODUCTION DATA

3.1. OBJECTIVE AND SUMMARY OF RESULTS

Section 3 summarizes all of the available chlorophyll and primary production data available for "Hecate Strait" which will be defined here to include Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound. The objective is to provide best estimates of depth-stratified monthly mean chlorophyll concentrations and to assemble data pertaining to rates of primary productivity. These data will be used to parameterize a lower trophic level model focused on the microbial food web, diatoms, and zooplankton. These data may also be used to parameterize a more broadly-based Ecosim model that includes phytoplankton, zooplankton, and all of the major fish species found in Hecate Strait.

This summary is based on five data sets (Dilke *et al* (1979), Perry *et al* (1981), Forbes and Waters (1993), Denman *et al* (1985), unpublished data from Ware and Thomson).

After reviewing and summarizing individual data sets, our approach was to: 1) combine all available data to generate a long-term data set for shallow water (<10 m water depth) chlorophyll concentrations, 2) combine all shallow water samples to generate an aggregated data set for average monthly chlorophyll *a* concentrations, and 3) use the Denman *et al* (1985) data set to generate estimates of total chlorophyll *a* concentrations for the entire mixed layer.

Comparisons of chlorophyll *a* concentrations measured from surface waters (<10 m deep) at three locations (Dixon Entrance, Hecate Strait, and Queen Charlotte Sound) suggested that the differences between years and between sites were small.

Shallow water (<10 m deep) chlorophyll *a* concentrations based on all available samples were used to generate an aggregated data set for average monthly chlorophyll *a* concentrations. Data from different sources and locations did not to deviate from each other in any significant way. There was of course, a very definite mean annual pattern with low concentrations in the winter and higher chlorophyll concentrations in the summer months. In addition, there was a strong spring algal bloom and a weaker but detectable fall bloom.

Combined chlorophyll *a* concentration data from Queen Charlotte Sound and Hecate Strait (Denman *et al* 1985) clearly reflected the existence of a mixed-depth zone. Above a depth of 20 m, chlorophyll *a* concentrations averaged about 2 $\mu g \cdot L^{-1}$, between 20-30 m concentrations increased significantly, and below 30-40 m concentrations declined. The Denman *et al* (1985) data set also illustrated a clear inverse relationship between chlorophyll *a* concentration and Pmax (a measure of primary productivity). Higher chlorophyll concentrations were associated with lower Pmax values and this was found to be, in part, a function of water depth. A linear multiple regression was used to predict Pmax with respect to Chlorophyll *a* and water depth. The relationship was not very satisfactory, but it may prove to be the best that is available for Hecate Strait.

3.2. SUMMARY OF Dilke *et al* (1979)

Reference characteristics: Summer and winter samples collected from 13 March 1878 through 8 April 1979. All samples collected from a depth of 3 m.

The report includes data collected during the MV *Imperial Tofino* Ships-of-Opportunity Program summarized by the Oceanography Department, University of British Columbia. The samples were collected during seven cruises from 13 March 1978 through 8 April 1979. All seawater samples used for the analysis of nutrients and chlorophyll *a* where taken from a depth of 3 m using the ship's water intake. The water was pumped from the sea-chest through a Jabsco impeller pump and the sample was integrated over the length of the sampling transect (usually over 1.3 km). Chlorophyll *a* samples were obtained from 200 mL of seawater filtered through Watman GF/C filters which were frozen. Chlorophyll and phaeopigments were determined by fluorometric techniques following the methods of Yentsch and Menzel (1963).

The Dilke *et al* (1979) data set comprised a total of 16 samples (4 from Dixon Entrance (DE) and 12 from Hecate Strait (HS)) (Table 2.2.1). In general, the chlorophyll concentrations measured at the two sites were similar (Table 3.2.1). See Appendix B to obtain the electronic spreadsheet data (*Chem Dilke et al 1979.xls*).

3.3. SUMMARY OF Perry *et al* (1981)

Reference characteristics: Summer and winter samples collected from 8 May 1979 through 7 June 1980. All samples were collected from a depth of 3 m.

The report includes data collected during the MV *Imperial Tofino* Ships-of-Opportunity Program summarized by the Oceanography Department, University of British Columbia. The samples were collected during eight cruises from 8 May 1979 through 7 June 1980. All seawater samples used for the analysis of nutrients and chlorophyll *a* where taken from a depth of 3 m using the ship's water intake. The water was pumped from the sea-chest through a Jabsco impeller pump and the sample was integrated over the length of the sampling transect (usually over 1.3 km). Chlorophyll *a* samples were obtained from 200 mL of seawater filtered through Watman GF/C filters which were frozen. Chlorophyll *a* and phaeopigments were determined by fluorometric techniques following the methods of Yentsch and Menzel (1963) as described in Strickland and Parsons (1972).

The data set comprised 35 samples (5 from Dixon Entrance and 30 from Hecate Strait) (Table 2.3.1). The Dixon Entrance samples were collected on only two dates, while the Hecate Strait samples were collected both summer and winter (Table 2.3.1). In general the chlorophyll concentrations measured at the two sites were similar (Table 3.3.1) and they were also similar to the values recorded by Dilke *et al* (1979), and that when the two data sets were combined, there were no obvious differences through time between 1978 and 1980 (Fig. 3.3.1). See Appendix B to obtain the electronic spreadsheet data (*Chem Perry et al 1981.xls*).

3.4. SUMMARY OF Denman *et al* (1985)

Reference characteristics: 1983 (July 02-10) summer samples only, night and day samples, several depth profiles, primary production data available.

The portion of Denman *et al* (1985) included in this analysis is restricted to Hecate Strait and Queen Charlotte Sound. Depth-stratified samples were collected on a single cruise aboard the CFAV *Endeavour* between July 02 and 10, 1983. The onboard sensors used during 1983, included an *in situ* fluorometer for chlorophyll fluorescence, a Licor spherical quantum PAR meter, and a CTD sensor that was periodically calibrated using reversing thermometers. Chlorophyll was measured using the fluorometric techniques described by Strickland and Parsons (1972). Primary productivity was estimated onboard using ^{14}C and a linear incubator (Forbes and Waters 1993).

Because all of the data provided in Denman *et al* (1985) were collected within a one week time period, temporal comparisons are not possible. However, the data set is very large (Table 2.4.1) and many of the nutrient measurements were depth-stratified, allowing comparisons between sites and between depths. See Appendix B to obtain the electronic spreadsheet data (*Chem Denman et al 1985.xls*).

A plot of combined data from Queen Charlotte Sound and Hecate Strait (Fig. 3.4.1) clearly reflects the mixed-depth zone data provided in Sections 1 and 2. Above 20 m depths, chlorophyll *a* concentrations averaged about 2 $\mu g \cdot L^{-1}$, between 20-40 m concentrations increased significantly and below 40 m concentrations declined. This pattern has been well described in other oceanographic data and reflects patterns of light and nutrient availability. We will return to these data later in this section. When the data set is restricted to depths <11 m, between-site comparisons (Table 3.4.1) suggest that there were no significant differences in chlorophyll concentrations between Hecate Strait and Queen Charlotte Sound.

3.5. SUMMARY OF Forbes and Waters (1993)

Reference characteristics: Samples collected between 29 June and 7 July 1985. Data include several depth profiles.

The portion of the Forbes and Waters (1993) data set included in this report is restricted to Dixon Entrance, Hecate Strait, and Queen Charlotte Sound (Table 2.5.1). Depth-stratified samples were collected between June 29 and July 7 1985. The onboard sensors used during 1985, included an *in situ* fluorometer for chlorophyll fluorescence, a Licor spherical quantum PAR meter, and a CTD sensor which was periodically calibrated using reversing thermometers. Chlorophyll was measured using the fluorometric techniques described by Strickland and Parsons (1972). See Appendix B to obtain the electronic spreadsheet data (*Chem Forbes and Waters 1993.xls*).

As was the case with Denman *et al* (1985), some of the Forbes and Waters (1993) chlorophyll *a* data were collected at depth (Fig. 3.5.1). However, unlike Denman *et al* (1985), the data showed no particular depth profile, perhaps reflecting the small sample sizes that were obtained and/or strong vertical mixing prior to the survey. When sample depths were restricted to <10 m, between-site comparisons (Dixon Entrance, Hecate Strait, and Queen Charlotte Sound) showed no significant differences, although Queen Charlotte Sound Chl *a* was somewhat higher (Table 3.5.1).

3.6. SUMMARY OF Ware and Thomson (unpublished data)

Reference characteristics: A mix of satellite imagery and *in situ* chlorophyll concentrations estimates from 1979 and 1997.

Chlorophyll *a* concentrations from Ware and Thomson (unpublished data) are based on 1997 OCTS satellite data from Dixon Entrance (Table 3.6.1) and on a mixture of *in situ* data (Pan *et al* 1988) and satellite data for Queen Charlotte Sound (Table 3.6.2). The reported concentrations are similar to those observed at other locations (Sections 3.2-3.5) and are also similar between the two sites (Table 3.6.3). See Appendix B to obtain the electronic spreadsheet data (*Chla Ware 1979 and 1997.xls*).

3.7. TRENDS IN THE AGGREGATED SHALLOW WATER DATA

As noted in the preceding sections, chlorophyll *a* data for Hecate Strait, Dixon Entrance, and Queen Charlotte Sound are available from only four published sources. Two sources (Dilke *et al* 1979, Perry *et al* 1981) have winter data but no depth stratification (all samples were taken at 3 m depth). Two others (Denman *et al* 1985, Forbes and Waters 1993) have depth data, but include data only from late June and early July. One unpublished source (Ware and Thomson) is based on a mix of satellite and *in situ* data. These data have allowed us to: 1) combine all of the data to generate a long-term data set for shallow water (<10 m water depth) samples, 2) combine all shallow water samples to generate an aggregated data set for average monthly chlorophyll *a* concentrations, and 3) use the Denman *et al* (1985) data set to extrapolate from shallow water samples to generate total chlorophyll concentrations for the entire mixed layer. These will be the objectives of the analyses that follow.

Comparisons of summer (June-August) chlorophyll *a* concentrations measured from surface waters (<10 m deep) at three locations (DE=Dixon Entrance, HS=Hecate Strait, QCS=Queen Charlotte Sound) between 1979 and 1997 (Fig. 3.7.1) suggest that in there is no difference between sites (Kruskal Wallis $p=0.46$).

Combined shallow water (<10 m deep) samples were used to generate an aggregated data set (Table 3.7.1) for average monthly chlorophyll *a* concentrations. Samples from the five data sets (Dilke *et al* 1979, Perry *et al* 1981, Denman *et al* 1985, Forbes and Waters 1993, Ware and Thomson unpublished) appear not to deviate from each other in any significant way. There is of course a very definite mean annual pattern with low concentrations in the winter and higher chlorophyll *a* concentrations in the summer months (Table 3.7.2, Figs. 3.7.2-3.7.3).

Also, as noted in Section 3.4, combined data from Queen Charlotte Sound and Hecate Strait (Denman *et al* 1985 - Fig. 3.4.1) clearly reflects the mixed-depth zone data provided in sections 1 and 2. Above 20 m, chlorophyll *a* concentrations averaged about 2 $\mu g \cdot L^{-1}$, between 20-40 m the concentrations increased significantly, and below 40 m the concentrations declined.

Given that most of the available *in situ* chlorophyll *a* data come from shallow water samples (< 10 m water depth), and given that all of the satellite data come from very shallow water samples, it seems likely that during periods of temperature stratification (particularly June–September), "actual" integrated photic zone chlorophyll concentrations will be under-estimated from shallow water samples alone. Because both the microbial food web model and the Ecosim food web model depend on realistic estimates of the total amount of chlorophyll available in the photic zone, and because the majority of available chlorophyll *a* data has been collected from surface waters, data corrections will be required. Based on the Denman *et al* (1985) data summarized in Table 3.7.3, suggested corrections are shown in Table 3.7.4. The latter table is based on the fact that mid-summer chlorophyll concentrations integrated over a 30 m deep water column (the summer mixed layer) was 3.92 $\mu g \cdot L^{-1}$ (Denman *et al* 1985), which is substantially greater than the measurements made at surface depth intervals of 1-5 or 1-10 m.

3.8. PRIMARY PRODUCTIVITY

During July 1983, Denman *et al* (1985) collected 20 depth-stratified chlorophyll *a* and primary productivity (Pmax) samples (Table 3.8.1) from Hecate Strait and Queen Charlotte Sound. As expected, Pmax was about equal for phytoplankton taken from all depths between 0-30 m (Fig. 3.8.1). Given that wind-induced mixing events circulate cells throughout the mixed layer, we expect that all cells in the mixed layer will contribute to the total primary production capacity of the water column so that surface values should be integrated over the mixed layer.

4. ZOOPLANKTON DATA

4.1. SUMMARY

Section 4 deals with Hecate Strait zooplankton biomasses. It has two objectives: 1) to investigate potential seasonal, spatial and interannual differences in zooplankton biomasses that might exist within the Hecate Strait region, and 2) to provide best estimates of zooplankton biomasses for use in food web models.

Section 4.3 deals with the Hecate Strait stations contained in the IOS data base. Section 4.4 summarizes historical data sets collected in a variety of ways with various gears. Sections 4.5 and 4.6 deal with between-year comparisons of summary data from all of the data sets.

Analysis of the IOS data base revealed that there were some seasonal and spatial differences in Hecate Strait zooplankton biomasses. In general, most taxa were more common during the summer and some taxonomic groups showed a within-summer seasonal pattern. Also, samples taken from Hecate Strait and Queen Charlotte Sound tended to have statistically similar biomasses, while those from Dixon Entrance tended to have lower biomasses. These trends should be considered when reviewing decisions pertaining to the geographical extent and inclusion of seasonal trends in the modeling components of the Hecate Strait study.

Analysis of historical interannual time trends (1957-2001) suggested that some of the observed variability in zooplankton biomass may have been related to the periodicity of ENSO events. When the analysis was restricted to data subjectively classified as being "reliable" (Table 4.5.2), two data sets were collected when ENSO was active and two when ENSO was not active. The two associated with active ENSO events both had low zooplankton biomasses and the two collected when ENSO was not active both had higher zooplankton biomasses. It should be noted however, that these results should be viewed with extreme caution because the sample sizes were low and the 95% confidence intervals were large, often equaling the mean.

Time trends in the 11-year (1991-2001) IOS data base were less equivocal. They suggested that during the early 1990s biomasses were low, then increased substantially during the mid-1990s and then declined during the late 1990s. However, these patterns had only a vague relationship to the ENSO events of 1992 and 1998. For example, there were more copepods during the period 1993-1995 and fewer during the ENSO years (1992 and 1998), but there were also fewer after 1998 (1999-2000) and before 1992 (1989-1991). The trends seem to have developed slowly and lasted longer than would be expected if they were driven by ENSO events <u>alone</u>. The implication is that the trends are driven by complex biologically and physically mediated events which may or may not be related to ENSO. It should be noted that whatever the cause, these trends do exist in the data, and their incorporation into future Ecosim and microbial food web models should be considered.

4.2. OBJECTIVES

This chapter summarizes all of the available biomass data for zooplankton found in the Hecate Strait region which will be defined here to include Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound. Portions of six data sets are considered (Table 4.2.1).

The first objective of Section 4 is to provide best estimates of zooplankton biomasses for use in two types of food web models including: 1) a lower trophic level model focused on the microbial food web, diatoms and zooplankton, and 2) a more broadly-based Ecosim model that includes phytoplankton, zooplankton, and all of the major fish species found in Hecate Strait. Because both models require data expressed as biomasses, the standard units reported here are $mg \cdot m^{-3}$ dry weight. Where necessary, density data have been converted to dry weights using a variety of assumptions detailed in the methods sections below.

The second objective of Section 4 is to investigate the hypothesis that during the last 40-50 years, zooplankton biomasses may have significantly changed, perhaps in response to long-term changes in climate. If long-term changes are detected in the zooplankton biomass data, then it will be necessary to include these bottom-up processes in both the microbial loop and Ecosim models. If on the other hand, the long-term zooplankton data sets do not suggest that there have been significant long-term changes in Hecate Strait zooplankton biomass, then it will be possible to simplify the modeling process by using best estimates of seasonal mean biomasses, productivity, etc.

Section 4.3 deals with the Hecate Strait stations contained in the IOS data base. The objectives of this phase of the analysis are to: 1) provide best estimates of zooplankton biomasses that will be suitable for food web modeling, 2) quantify biomass changes through annual cycles, and 3) quantify biomass differences across the various geographical areas included in the entire Hecate Strait data base. Sections 4.3 provides summaries and analyses of: 1) the entire 196 station data set which includes data from Dixon Entrance, Hecate Strait, Goose Island Bank plus Queen Charlotte Sound, 2) Dixon Entrance alone, 3) Hecate Strait alone, 4) Goose Island Bank plus Queen Charlotte Sound alone, 5) a spatial comparison involving the three locations, and 6) a within-year analysis of patterns in the 196-station data set.

Section 4.4 deals with historical data sets collected in a variety of ways using assorted gear. The objective of this phase of the analysis is to use all available "Hecate Strait" zooplankton data to investigate the hypothesis that over the last 40-50 years there have been quantifiable interannual changes in zooplankton biomass. We also investigate the hypothesis that there may be some relationship between mean zooplankton biomass in Hecate Strait and long-term changes in climate patterns. The data used are summarized from the Pacific Oceanographic Group (1958), LeBrasseur (1965), Fulton *et al* (1982), Denman *et al* (1985), plus Burd and Jamieson (1991).

Sections 4.5 and 4.6 deal with between-year comparisons of summary data from all of the data sets. The objective is to search for long-term patterns in both the entire 45-year data set (recent IOS data plus historical data) and then to look for long-term patterns in the 11-year data set from IOS. In both cases, relationships with ENSO events are discussed.

4.3. THE IOS DATA BASE

4.3.1. Overview

Section 4.3 deals with 196 samples in the IOS data base, and include dates ranging from 1990 to 2001. Locations range from Dixon Entrance south through Hecate Strait and Goose Island Bank, and further south to Queen Charlotte Sound. In this analysis the data have been summarized to include 10 aggregated taxonomic groupings (see Section 4.3.2 for details) averaged across four time periods: 1) summer night, 2) summer day, 3) winter night, and 4) winter day. The data in Section 4.3 are arranged in a hierarchy, starting with all 196 stations grouped together and then broken down to give separate biomass estimates for each of three constituent areas including: 1) Dixon Entrance, 2) Hecate Strait and 3) Goose Island Bank plus Queen Charlotte Sound. Also, in order to summarize within-year patterns, the summer portion of the 196-station data set is broken into monthly intervals.

4.3.2. Methods

The version of the IOS zooplankton data base that was used here contained 53 taxonomic categories (Table 4.3.2.1). The data were recorded as biomasses (mg·m^{-3} dw) based on the taxonomic category of each individual that was counted from each sample. Size category ranges (Table 4.3.2.1) were then used to group the 53 taxa into 10 functional groups (Table 4.3.2.1) for use in model building. The field methods used for the collection of the IOS data were reasonably consistent. Three of the 196 samples were collected with a Neuston net equipped with a 500 μm mesh, but all of the remaining 193 samples were collected using metered Bongo nets equipped with 253 or 230 μm mesh.

Throughout the analysis we controlled for differences attributable to 'summer' (defined here as April–October) and 'winter' (defined here as November–March) and also for light (06:00-22:00 hours) and dark (22:01-05:59 hours). All of the resulting data are shown separately for these categories. In addition, we investigated spatial patterns by dividing the data among stations located in three areas: Dixon Entrance, Hecate Strait, and Goose Island Bank plus Queen Charlotte Sound. As noted above, these data were also combined.

Most hauls were deep, but occasionally shallow hauls were taken. When shallow hauls were taken at night, the biomasses of diel migrating species were probably overestimated. An example of this is sample WOO7 taken at 23:04 h (50 m) and 23:18 h (170 m) on July 19, 1998 (see Appendix B file: *IOS Zoo biomass Hecate Dixon QCS.xls*). The shallow sample showed a euphausiid biomass of 93 mg·m^{-3} and the deep sample had a euphausiid biomass of 44 $mg \cdot m^{-3}$. These problems are addressed in Section 4.3.8 which deals with seasonal and night-day comparisons.

4.3.3. Results from All Stations

The entire data set comprising 196 samples was sorted with respect to season and time of day, and the original 53 taxonomic groups were aggregated into 10 taxonomic groups (see Appendix B file: *IOS Zoo biomass Hecate Dixon QCS.xls*). The stations were then averaged to produce mean biomasses for: 1) summer night, 2) summer day, 3) winter night, and 4) winter day.

The results of this analysis (Table 4.3.3.1) show that small and medium copepods comprised a significant portion of the biomass, and that summer biomasses were much greater than winter biomasses. In addition, the night and day values were about equal for small and medium copepods. For the other taxonomic groupings, summer values were also higher than winter values, and night values appeared to be somewhat larger than day values due to diel migration and increased catchability.

4.3.4. Dixon Entrance Results

The data were treated as above (winter data were not available) and the results (Table 4.3.4.1 and Appendix C) suggest that the biomasses in each taxonomic group were substantially smaller than they were for the entire data set (Fig. 4.3.4.1). See Appendix B to obtain the electronic spreadsheet data (*IOS Zoo biomass Dixon.xls*; *Appendix C Dixon.xls*).

4.3.5. Hecate Strait Results

The data were treated as above and the results (Table 4.3.5.1 and Appendix D) suggest that the biomasses in each taxonomic group were substantially larger than they were for the entire data set (Fig. 4.3.4.1) and much larger than for Dixon Entrance. See Appendix B to obtain the electronic spreadsheet data (*IOS Zoo biomass Hecate.xls*; *Appendix D Hecate.xls*).

4.3.6. Queen Charlotte Sound Results

The data were treated as above and the results (Table 4.3.6.1 and Appendix E) suggest that the biomasses in each taxonomic group were about the same as they were in the overall data set (Fig. 4.3.4.1). It should be noted that the day-time euphausiid values were exceptionally high. This could have been due to the fact that a set of late fall samples were taken late in the day (between 20:00-21:00 hrs, see Appendix E) when euphausiid diel migration was in progress, or it may have been due to "swarming". Whatever the cause, these data were found to have significant effects in the day-night comparisons that will follow (Section 4.3.8). See Appendix B to obtain the electronic spreadsheet data (*IOS Zoo biomass QCS.xls*; *Appendix E QCS.xls*).

4.3.7. Spatial Comparison

The aggregated group averages (Tables 4.3.4.1–4.3.6.1 and Fig. 4.3.4.1) suggested that there were between-site differences for most taxonomic groups. Despite the large within-sample variation found in all of the data sets (exemplified by the confidence intervals for small copepods shown in Tables 4.3.4.1–4.3.6.1), ANOVA analyses based on all summer data combined (n=35 Dixon Entrance, n=42 Hecate Strait, n=102 Queen Charlotte Sound) confirmed these between-site differences ($p<0.05$) for small copepods, large copepods, chaetognaths, and several smaller taxonomic groups. Amphipod and total biomass were not different ($p>0.05$) in the three geographical areas. Additional Tukey analysis (Table 4.3.7.1) showed that the magnitude of these differences was taxon-specific. For example, biomasses for small copepods and large copepods were different for Hecate Strait (HS) and Dixon Entrance (DE) but not different for HS and Queen Charlotte Sound (QCS). It should be noted that while ANOVA showed that euphausiid biomasses were not different in the three geographical areas, sample variance was <u>very</u> large and when a non-parametric test was applied (Kruskal Wallis), the ranks were significantly ($p<0.05$) different (QCS > DE > HS). See Appendix B to obtain the electronic spreadsheet data (*IOS Zoo biomass Hecate Dixon QCS.xls*). There are no obvious explanations for any of these differences except to note that Dixon Entrance is influenced by the Skeena River which advects westward into the Pacific Ocean, and Hecate Strait includes substantial areas with relatively shallow water. Perhaps some of these issues may be resolved through future comparisons with patterns found in the physical, chemical, and algal data.

Whatever the explanation for the spatial patterns, these differences should be considered when making final decisions about the choice of the most appropriate data sets for the food web modeling exercise. It should also be noted that due to differences in sample sizes, the data zooplankton biomass data from Queen Charlotte Sound tends to overwhelm the aggregated data set (Dixon Entrance plus Hecate Strait plus Goose Island Bank plus Queen Charlotte Sound) so that the actual Hecate Strait data are under-represented. The result is that for some taxa (especially copepods), average biomasses in the aggregated data base probably under-represent the true biomasses within Hecate Strait itself.

4.3.8. Within-Year Comparisons

In order to summarize monthly trends in zooplankton biomass, the 196-station IOS data base was treated as in Section 4.3.3 above, and then further divided into night and day averages for the months of April-October (Table 4.3.8.1, Fig. 4.3.8.1, also see Appendix B to obtain the electronic spreadsheet data (*IOS Zoo biomass Hecate Dixon QCS.xls*)). During both day and night, the small and medium-sized zooplankton peaked during mid-summer, while the larger-bodied crustaceans, the smallest zooplankton and the unidentified "other taxa" all peaked in the spring. The euphausiids peaked later in the summer and fall.

Although these data suggest the presence of a summer pattern in the data (gradual increase through to mid-summer followed by a decline, see Fig. 4.3.8.1), it is important to note that there is substantial within-sample variation in all of the data (Table 4.3.8.2). The 95% confidence intervals around the means are generally large and sometimes exceed the means (i.e. mid-summer night values for small copepods). Given such large confidence intervals, it seemed prudent to test for the statistical reliability of apparent trends observed in the data.

Because "small-medium copepods" and "euphausiids" are dominant taxa that will be included in both the Ecosim and microbial food web models, they were used to test the null hypothesis that the monthly means were not different (Table 4.3.8.3).

ANOVA comparisons of monthly means for copepod biomasses based on combined day-night data revealed no differences at $\alpha=0.05$ (Table 4.3.8.3), although for night data alone, the null hypothesis was rejected ($p=0.004$) and a Tukey test suggested that the high biomass observed in August was responsible for this result. Comparisons of monthly means for euphausiid biomasses summed over night and day suggested that there were differences (Table 4.3.8.3). The peaks occurred in different months (July for night samples and September for day samples) and this resulted in a significant interaction effect. ANOVA comparisons of day vs. night biomass data summed over months (Table 4.3.8.3) revealed no differences for either copepods or euphausiids. However, sample variances were large, and when non-parametric comparisons were applied overall and within-month, day-night differences were all significant (Table 4.3.8.3). On balance it seems that while there are almost certainly day-night and seasonal patterns in the data, the inherent within-sample variability (Fig. 4.3.8.1) is so large that almost any result is obtainable through appropriate statistical “gaming”.

4.4. HISTORICAL DATA

4.4.1. Objective

The objective of this phase of the analysis was to use all available "Hecate Strait" zooplankton data to investigate the hypothesis that over the last 40-50 years there have been quantifiable interannual changes in zooplankton biomass. We also investigate the hypothesis that there may be some relationship between mean zooplankton biomass in Hecate Strait and long-term changes in climate patterns.

The eight zooplankton data sets that were available for this analysis include: Cameron (1957), Pacific Oceanographic Group (1958), LeBrasseur (1965), Dilke *et al* (1979), Perry *et al* (1981), Fulton *et al* (1982), Denman *et al* (1985), and Burd and Jamieson (1991). In the analysis that follows, only some of these data have been used. The zooplankton densities provided by Cameron (1957) were excluded because they were qualitative (densities represented as abundant, common, few, rare, etc.) rather than quantitative. The zooplankton data provided by Dilke *et al* (1979) and Perry *et al* (1981) were also excluded because they came from samples collected at 3 m water depth. Of the remaining data sets, three (Pacific Oceanographic Group 1958, LeBrasseur 1965, Fulton *et al* 1982) comprise biomass data collected using vertical hauls. All were converted to dry weights and included in the analysis that follows. The fourth and fifth data sets (Denman *et al* 1985, Burd and Jamieson 1991) include only density data, but because the collections were based on vertical hauls, the taxa were grouped, transposed into biomasses, and included.

4.4.2. Summary from the Pacific Oceanographic Group (1958)

Reference characteristics: Summer samples only, day samples only, volume wet weights.

Coastal surveys aboard the HMCS *Oshawa*, *Jonquiere* and *Ste. Terese* were conducted during April 24-May 15, July 2-12, Sept 18-Oct 2, and Nov 25-Dec 18, 1957. Zooplankton samples were obtained from selected stations using a NORPAC net (45 cm diameter, 330 μm mesh) hauled vertically at 1 $m \cdot s^{-1}$. Although samples from other areas covered by the study included night samples, those from the "Hecate Strait" area included only day samples (see Appendix B to obtain the electronic spreadsheet data (*Zoo Pacific Oceanographic Group 1958.xls*)). Organisms larger than 1.5 inches (3.8 cm) were physically removed from each haul. Hauls were sorted into seven taxonomic groups (gastropods, amphipods, copepods, decapods, euphausiids, chaetognaths, others) and wet weights were recorded as $g \cdot 1000\ m^{-3}$. In the table that follows, these data were summarized as $mg \cdot m^{-3}$ dry weight using a wet-dry conversion factor of 6.

Although the Pacific Oceanographic Group (1958) data are sparse for Dixon Entrance and slightly more abundant for Queen Charlotte Sound (Table 4.4.2.1), they suggest that the two areas have about equal summer biomasses. As was the case with the IOS data set, the majority of biomass consisted of copepods (Fig. 4.4.2.1), with substantially smaller biomasses of euphausiids and even smaller biomass of other groups.

4.4.3. Summary of LeBrasseur (1965)

Reference characteristics: Summer and winter samples, night and day samples but not identified in the data set, volume wet weights.

LeBrasseur (1965) contains 247 maps that summarize data collected between 1956 and 1964. Samples were collected with a variety of metered gear including a NORPAC net, an Isaac-Kidd mid-water trawl, and a 330-351 μm North Pacific Nylon net. Samples were recorded without regard for night and day, although the author noted that euphausiid biomasses tended to be greater in the night samples. Also, there is no recorded information about haul depths. Large taxa such as fish and squid were removed from each sample. Phytoplankton, coelenterates, ctenophores, doliolids, salps and detritus were also subtracted from the sample. Proportions of the remaining taxa were estimated "by eye" as a percentage of the remaining sample. The entire sample was blotted dry and weighed. Wet weights ($g \cdot 1000\ m^{-3}$) were then derived for: total sample, copepods, euphausiids, amphipods, decapods, chaetognaths, pteropods, and cephalopods.

These data were summarized in Table 4.4.3.1 as mg·m^{-3} dry weight using a wet-dry conversion factor of 6.

The "Hecate Strait" portion of LeBrasseur's (1965) data set extends from 1956–1962 and includes data from Dixon Entrance, Hecate Strait, and Queen Charlotte Sound (Table 4.4.3.1, see Appendix B to obtain the electronic spreadsheet data (*Zoo LeBrasseur 1965.xls*)). In general, the three areas have about equal summer biomasses, although samples sizes from Hecate Strait proper are too small to allow accurate comparisons. As was the case with the IOS data set, copepods comprised the majority of biomass (Fig. 4.4.3.1) with substantially smaller biomasses of euphausiids and even smaller biomass of other groups. It should be noted that the euphausiids were collected during both night and day, so it is likely that the resulting data underestimate the true biomass.

4.4.4. Summary of Fulton *et al* (1982)

Reference characteristics: Winter samples only, night and day samples, areal wet weights.

Fulton *et al* (1982) includes data for Dixon Entrance, Hecate Strait, and Queen Charlotte Sound. The samples were collected during four monthly cruises conducted during January 15-22, Feb 13-20, March 12-20 and April 15-23, 1980. Samples were collected using oblique Bongo tows (0.25 m^2 net opening, 351 µm mesh) to within 20 m of the bottom at shelf stations, and to 565 m depth at slope stations. The samples were preserved onboard. Fish, fish eggs, euphausiids, decapods, medusae, and ctenophores were removed from the sample later at the laboratory. The euphausiids were blotted dry and weighed. Medusae and ctenophores were counted and weighed. The remainder of the sample was drained, blotted and weighed. The wet weights were reported as areal (g·m^{-2}) wet weight biomasses for euphausiids, coelenterates, ctenophores and other zooplankton. In the analysis that follows, the wet weights for euphausiids and other zooplankton were converted to volume units (mg·m^{-3}) using the reported station depths. Wet weights were converted to dry weights using a conversion factor of 6.

The Fulton *et al* (1982) data (Fig. 4.4.4.1, see Appendix B to obtain the electronic spreadsheet data (*Zoo Fulton et al 1982.xls*)) suggest that in all three locations (Dixon Entrance, Hecate Strait and Queen Charlotte Sound), euphausiid biomasses were higher at night than during the day. However, the confidence intervals around the means are large, reflecting considerable between-site and between-station variability found in the data set (Table 4.4.4.1). This is, in part, due to the large number of stations that yielded hauls with zooplankton concentrations that were too small to weigh (shown as "TSW" in Table 4.4.4.1), were contaminated, or had too much phytoplankton (shown as "TMP" in Table 4.4.4.1). The overall result is that the total zooplankton data may have been compromised and may not represent reliable estimates of overall zooplankton biomasses.

4.4.5. Summary of Denman *et al* (1985)

Reference characteristics: summer samples only, night and day samples, species densities (conversion to dry weights was required).

The portion of Denman *et al* (1985) included in this analysis is restricted to Hecate Strait. See Appendix B to obtain the electronic spreadsheet data (*Zoo Denman et al 1985.xls*). The samples were collected during July, 1983 using metered vertical net hauls. The net opening was 0.5 m^2 and the mesh was 233 μm. Samples were preserved onboard the ship. Contents were later counted and data were recorded as individuals·m^{-2}. The counting categories used in Denman *et al* (1985) were reasonably close to the categories used in the modern IOS data base. The challenge was to convert density counts per m^2 to dry weight biomass counts per m^3. To make this extrapolation it was necessary to use the IOS data base to estimate the average weight of individuals in each taxonomic group (Table 4.4.5.1), then to convert densities per m^2 into densities per m^3, and finally to multiply densities by dry weights per individual. None of this presented significant technical problems (Table 4.4.5.1) except that the original report (Denman *et al* 1985) did not explicitly list station depths that were used to make the original density per m^2 calculations. For the moment, we have assumed that station depths are equal to the depths interpolated from station locations (latitude and longitude) referenced on a marine chart, but this should be viewed as an interim adjustment.

In general, the Denman *et al* (1985) data yield biomasses for total zooplankton, euphausiids, and copepods that are within the range of the IOS data base (Fig. 4.4.5.1). Should actual station depths become available, the results will be further analyzed for additional taxonomic detail.

4.4.6. Summary of Burd and Jamieson (1991)

Reference characteristics: summer samples only, night and day samples, species densities (conversion to dry weights was required)

The portion of the Burd and Jamieson (1991) data set included in this analysis is restricted to Hecate Strait. See Appendix B to obtain the electronic spreadsheet data (*Zoo Burd and Jamieson 1991.xls*). The samples were collected in June, 1988 using a metered Tucker Trawl (mouth opening 1 m^2) equipped with a 1000 μm mesh. The samples were preserved onboard the ship. Specimens were counted in the laboratory and data were recorded as individuals·m^{-3}. The counting categories tended to feature larger organisms (larval fish, etc.) and consequently did not conform to the categories used in the modern IOS data base (Section 4.3). This meant that it was reasonable only to cross-classify the data into four groups: amphipods, copepods, euphausiids, and chaetognaths. Because the original Burd and Jamieson (1991) data were provided as densities rather than biomasses, it was necessary to convert density counts per m^3 to dry weight biomass counts per m^3. To make this extrapolation, a sub-sample (65 stations) of the IOS data base was regrouped to produce totals for amphipods, copepods, euphausiids, and chaetognaths. This was achieved by using the 65-station portion of the IOS data base to estimate the average weight of individuals in each taxonomic group. These weights were then aggregated into the four groups noted above and all of the data were averaged to produce group mean weights for individuals in each of the four groups. These mean weights were then combined with the density data (Burd and Jamieson 1991) to yield group biomasses ($mg \cdot m^{-3}$ dw) (Table 4.4.6.1 and Fig. 4.4.6.1).

The resulting data are unusual because copepods appear to be strongly under-represented. This is probably due to: 1) the large mesh size (1000 µm) used by Burd and Jamieson (1991) and 2) to the fact that the IOS data base is focused on individual copepod species, so that small individuals and developmental stages are all represented with some precision. Of course, this would mean that the average individual weights derived from the IOS data base would tend to be smaller than they would be from a collection that was focused on larger organisms. In view of these difficulties, we recommend that only the euphausiid data from Burd and Jamieson (1991) be applied to future food web modeling activities.

4.5. COMPARISONS THROUGH TIME AND BETWEEN DATA SETS

The objective of this portion of the analysis was to investigate the hypothesis that during the last 40 years, zooplankton biomasses may have changed significantly, perhaps in response to long-term changes in climate.

To achieve this objective, it was necessary to convert the five historical data sets (Pacific Oceanographic Group 1958, LeBrasseur 1965, Fulton *et al* 1982, Denman *et al* 1985, Burd and Jamieson 1991) described in Sections 4.4.2-4.4.6 into common units ($mg \cdot m^{-3}$ dw) that would facilitate between-year comparisons with the IOS data described in Sections 4.3.2-4.3.8 (Table 4.5.1). This process led to a number of assumptions, some quite disconcerting. The data from the Pacific Oceanographic Group (1958) and LeBrasseur (1965) were based on "blotted wet weights" per m^3. These data required only one transformation into dry weights. Data from Fulton *et al* (1982) were also in wet weights but the units were areal (per m^2) and therefore required two transformations; first to volumes and then to dry weights were required. In addition, it must be noted that the Fulton *et al* (1982) samples were all collected in the winter, while most of the others were summer samples. The data provided in Denman *et al* (1985) and Burd and Jamieson (1991) were based on densities that required transformations into dry weight (see Section 4.4.5 and 4.4.6 for details) and in the case of Denman *et al* (1985) a further transformation to volume was required.

Given all of these transformations, it is probably not surprising that there was <u>no</u> discernable between-year pattern in any of these data. They were all in the same general data range (0–100 $mg \cdot m^{-3}$) but the trends were inconsistent and probably unreliable. For example, the data published in Fulton *et al* (1982) were based on winter collections, yet the calculated biomasses were much higher than the winter biomasses calculated from the other data sets (Sections 4.3.7, 4.4.2-4.4.6). Also, the data provided in Burd and Jamieson (1991) showed euphausiid biomasses that were much higher than the accompanying biomasses for copepods. Again, this is contrary to the trends observed in the other data.

So the question is "Which of the data sets provide useful (accurate) zooplankton biomass data?" (see Table 4.5.1)

- Given the number of samples involved and the methods used to collect and enumerate the data, it seems reasonable to assume that the IOS data are "accurate" and represent the standard against which the other data sets can be judged.

- The oldest data came from a 12-sample data set provided by the Pacific Oceanographic Group (1958) and a 50-sample data set from LeBrasseur (1965). The strength of these data is that they were collected as wet weights per unit volume, meaning that only one transformation was required to produce dry weights per unit volume. The weakness is that small organisms such as small copepods were probably lost when the samples were sorted and blotted to remove excess water. On balance, it is likely that the euphausiid biomasses are "accurate" and that the copepod data are underestimates.

- The strength of the data provided in Fulton *et al* (1982) is that the sample size was large (n=125) and the samples were weighed. Also, the data came from many locations in and around Hecate Strait. The difficulty with the data is that they came from winter samples and could therefore be compared only to a small number of winter samples (n=17) from the IOS data base. This type of comparison revealed that the biomasses provided by Fulton *et al* (1982) were at least twice as great as the biomasses found in the IOS winter data base. On balance there seems to be no way to resolve this problem and also there is no reason to reject the Fulton data. In this analysis they have been classified as "accurate" (Table 4.5.1).

- As noted above, the Denman *et al* (1985) data set comprised densities rather than biomasses. Several assumptions were required to transform the Denman *et al* (1985) data to dry weights. Also, there were only five samples in the data set. Taken together, these difficulties suggest that it may be wise to assume that the transformation was unsuccessful and that the Denman *et al* (1985) data should not be included in this comparison.

- The data from Burd and Jamieson (1991) also involved transformations from densities to biomasses. Because the objective of the study was to explore the resource base for fishes, the focus was on larger plankton. It seems likely therefore, that small plankton were undersampled, but that the euphausiid data represent "accurate" biomass estimates.

Whatever subjective decisions might be taken about the reliability of the historical data sets, the fact remains that they do suggest the presence of long-term trends in biomass. For example (Table 4.5.2), euphausiid biomasses were apparently low during the 1950s, higher during the 1980s and declined again during the 1990s. Recently, a number of authors have suggested that long-term trends in zooplankton productivity, biomass and species composition might be associated with long-term variability in climate and physical oceanographic conditions. To test this hypothesis we assembled long-term daily measurements of sea surface temperature which were made at a number of shore locations along the boundaries of the region. The locations and lengths of the time series are listed in the following table.

Location	Area	Time Series	Long-term average SST (°C)
Egg Island	Queen Charlotte Sound	1970-2001	
McInnes Island	Hecate Strait	1955-2001	9.6
Bonilla Island	Hecate Strait	1960-2001	9.3
Cape St. James	Hecate Strait	1935-1991	9.3
Langara Island	Dixon Entrance	1941-2001	8.8

In the Hecate Strait region, surface temperatures usually reach a minimum in January/February and a maximum in August in the region (Fig. 4.5.1). At Bonilla Island, the long-term monthly range in SST varies from 2.3-4.1^{o}C over the length of the record. The most variable month is September.

Sea surface temperature (SST) trends in the region are determined by natural variability at interannual, decadal and multidecadal time scales. Interannual and decadal variability are strongly influenced by the El Niño-southern oscillation (ENSO) which originates in the tropical Pacific and has an average period of about 5-6 years. The following table summarizes the timing of warm ENSO events in the tropical Pacific since 1957.

ENSO Event	Annual SST (°C)	Standard Deviation	Strength
1957/58	10.00 (1958)	0.82	Moderate
1965/66	9.42 (1966)	< mean	No effect
1972/73	9.00 (1973)	< mean	No effect
1982/83	10.70 (1983)	2.22	Very strong
1987	10.06 (1987)	0.94	Moderate
1991/92	9.64 (1992)	0.10	Weak
1997/98	10.47 (1998)	1.76	Strong
Average Annual SST	**9.59**	**0.50**	

When combined with the summarized between-study zooplankton data (Table 4.5.2), the El Niño data suggest that there *may have been some relationship* between biomass trends in the 45-year data set and ENSO events. From 1957 through 1988, three ENSO events moderate or strong effects near Hecate Strait (Table 4.5.2).

- During the 1957-58 event, zooplankton data were collected in 1957 by the Pacific Oceanographic Group (1958) and biomasses recorded were among the lowest in the data set. However, it is likely that the full impact of ENSO was not felt in the Hecate Strait area until April–August 1958.

- During the 1957-58 event, zooplankton data were also collected by LeBrasseur (1965) and average zooplankton biomasses during that period (1957-58) were also low (Table 4.5.2). However as noted above, the full impact of ENSO was likely not felt in the Hecate Strait area until the summer of 1958. We therefore recalculated zooplankton biomasses averaged over 1958 and found them to be a bit higher than the combined (1957-58) averages, but still low when compared to other data sets.

- During the 1982-83 ENSO event, data were collected by Denman *et al* (1985) during 1983 and the mean zooplankton biomasses were among the highest recorded. It should be noted however (Table 4.5.1) that due to the data transformations required to calculate dry weight biomasses, these estimates were rated as likely to be "incorrect".

- Finally two historical data sets (Fulton *et al* 1982, Burd and Jamieson 1991) exist when ENSO was not in evidence. In both cases zooplankton biomasses (including euphausiids) were high.

In summary, when we focus on the data subjectively classified as being "reliable" (Table 4.5.1), two data sets were collected when ENSO was active and both had low zooplankton biomasses. The other two were collected when ENSO was not active and both had higher zooplankton biomasses.

It is important to note that although some of the biomasses calculated from the various data sets seem to conform to some of the ENSO-related theories that are prominent in today's literature, the sample sizes are low and the 95% confidence intervals are large, often equaling the mean. Extreme caution is urged when interpreting trends that may be found in these data.

4.6. INTERANNUAL TRENDS WITHIN THE 11-YEAR IOS DATA SET

If interannual trends do exist, they should also be found in the IOS data base which was collected with similar gear and which required no transformation (Table 4.6.1). A plot of total zooplankton biomass through 1990-2001 (Fig. 4.6.1) suggests that zooplankton biomasses were low during 1989-1991, increased during 1992-1996 and declined again during 1998-2000. It should be noted, however, that sample sizes vary and the apparent trends could be due to small sample sizes in the earlier years (1989-1994) rather than changes in actual biomass trends. However, plots of copepod

(Fig. 4.6.2) and euphausiid (Fig. 4.6.3) biomasses suggest that there may actually be biomass trends in those taxonomic groups. In the case of copepods, biomasses were lower in the early 1990s, increased substantially during the mid-1990s, and declined slightly during the later portions of the decade. In the case of euphausiids, abundances were only high during the latter part of the 1990s.

It has been proposed that ENSO events might be linked to changes in productivity, and it is reasonable to suppose that such changes might be reflected to changes in zooplankton biomasses. This hypothesis can be investigated in a preliminary way using the data summarized above (2nd table on pg. 31). During the 1990s there were two ENSO events that were detected in Hecate Strait waters. In the first case (1992), the ENSO effect was small, the sample sizes (n=3) are very small, and zooplankton biomasses are quite low. In the second case (1998), the ENSO effect was strong, the sample sizes were much greater (n=53) and the mean zooplankton biomasses were also greater. However, in both cases, the means (1992 and 1998) were lower than mean biomasses derived from samples collected during the years (1993-1997) which are years between the ENSO years. The immediate impression is that the mean biomasses measured during the ENSO years were lower. However, mean biomasses gathered during the post-1998 period (1999-2000, n=44) when there were no ENSO events, were no higher than the 1998 biomasses. Also, the means (n=10) collected before the 1992 ENSO event were just as low as the mean biomasses collected during 1992.

The conclusion appears to be that there were long-term trends in the copepod and euphausiid data. There were more copepods during the period 1993-1995, and there were fewer during the ENSO years (1992 and 1998), but there were also fewer after 1998 and before 1992. The trend, therefore, seems to develop slowly and last longer than would be expected if it was driven by ENSO events alone. The implication is that the trends are driven by complex biologically and physically mediated events which may or may not be related to ENSO. It is interesting to note that during the periods when copepod biomasses were high (1993-1995), euphausiid biomasses were low (Fig. 4.6.3), suggesting a top-down cause for the observed copepod data. However, a simple copepod-euphausiid scatter plot (Fig. 4.6.4) appears to refute that idea. In the end, the data suggest that during the 1990s there were significant changes in both copepod and euphausiid biomass, but no simple explanation can be offered to account for these biomass patterns. Perhaps causes for the observed trends will be revealed by thorough analysis of patterns in phytoplankton biomass and production or by the food web models that will be developed from these data.

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Table 1.2.1. Monthly mean precipitation (mm·month^{-1}) at selected coastal weather stations along the margins of Queen Charlotte Sound and Hecate Strait from 1961-1990. *Source: Canadian Climate Normals, Environment Canada.*

Month	Egg Is.	McInnes Is.	Bonilla Is.	Prince Rupert	Sandspit	Cape St. James	Cape Scott
Jan	320.7	324.8	209.2	250.8	164.2	173.6	348.1
Feb	224.9	240.6	185.9	216.5	124.6	138.2	254.5
Mar	214.5	218.2	176.9	188.2	103.9	126.9	259.4
Apr	186.3	190.5	163.4	181.0	95.2	114.0	211.4
May	135.0	151.4	118.0	142.0	62.4	88.9	154.5
Jun	120.0	125.5	98.9	119.5	57.1	80.8	120.6
Jul	80.0	100.2	83.0	112.9	44.6	61.6	82.9
Aug	98.0	137.1	106.7	162.8	54.3	76.5	100.2
Sep	191.1	208.1	171.7	244.7	94.2	119.0	187.2
Oct	324.5	345.9	278.9	378.9	195.6	196.7	334.3
Nov	351.7	333.3	257.2	284.4	189.6	188.7	360.6
Dec	333.5	289.2	238.0	269.8	173.4	177.4	355.6
Total	**2,579.9**	**2,664.8**	**2,088.0**	**2,551.6**	**1,359.1**	**1,542.3**	**2,749.1**

Table 1.2.2. Variation in the monthly mean precipitation (mm·month^{-1}) at Port Hardy from 1944-2000. *Source. Environment Canada.*

Month	Minimum	Maximum	Mean	SD
Jan	63.4	456.1	227.4	103.7
Feb	14.4	366.5	166.0	70.8
Mar	32.0	277.2	142.0	55.8
Apr	23.6	211.8	112.6	43.6
May	14.2	186.5	71.5	38.1
Jun	3.8	170.2	74.2	39.5
Jul	2.5	151.2	54.1	33.5
Aug	11.6	167.1	66.8	41.3
Sep	8.7	260.4	121.0	59.9
Oct	84.6	486.7	238.4	98.6
Nov	102.3	573.5	259.5	100.8
Dec	83.6	440.9	258.5	90.5
Annual	**1,202.9**	**2,357.6**	**1,793.6**	**266.6**

Table 1.3.1. Solar irradiance data. Duration of daylight on the 15th of the month at 52°N. Average solar irradiance at Cape St. James at ground level during clear weather. *Source: Ma 1992.* Monthly mean number of hours of bright sunlight per day at Sandspit, QCI and Prince Rupert. *Source: Canadian Climate Normals 1961-1990, Environment Canada.*

Month	Duration of Daylight (hrs) mid-month	Solar Irradiance (I_0) ($Cal \cdot cm^{-2} day^{-1}$)	Sandspit Sunshine ($hr \cdot day^{-1}$)	Prince Rupert Sunshine ($hr \cdot day^{-1}$)
Jan	8.20	159	1.68	0.73
Feb	9.85	270	2.89	2.31
Mar	11.70	438	3.86	3.12
Apr	13.46	608	5.22	4.65
May	15.57	729	6.45	5.64
Jun	16.68	780	6.05	5.15
Jul	16.35	742	5.97	4.56
Aug	14.80	628	5.83	4.57
Sep	12.82	474	4.57	3.53
Oct	10.83	318	3.01	2.18
Nov	8.93	190	2.11	1.61
Dec	7.80	131	1.44	1.08
Total (yr)	**4,471**	**5,467**	**1,495.8**	**1,211.8**

Table 1.3.2. Variation in the monthly mean number of hours of bright sunshine per day at Prince Rupert from 1991-1999 (see Fig. 1.3.4). *Source: Environment Canada.*

Month	Minimum	Maximum	Mean	SD
Jan	0.14	3.48	1.54	1.000
Feb	0.00	3.61	1.70	0.971
Mar	2.49	4.18	3.43	0.598
Apr	3.49	5.74	4.54	0.793
May	3.88	7.77	5.95	1.414
Jun	2.78	6.41	4.47	1.066
Jul	3.73	6.27	4.79	0.892
Aug	3.37	6.26	5.08	1.056
Sep	2.81	6.06	3.80	1.107
Oct	1.67	2.88	2.28	0.486
Nov	0.60	2.52	1.36	0.652
Dec	0.18	1.98	0.84	0.575

Table 1.3.3. Variation in the monthly mean number of hours of bright sunshine per day at Port Hardy from 1991-1999 (see Fig. 1.3.5). *Source: Environment Canada.*

Month	Minimum	Maximum	Mean	SD
Jan	0.80	3.45	1.85	0.846
Feb	1.55	4.27	2.45	0.935
Mar	2.63	4.73	3.70	0.674
Apr	2.99	6.55	4.52	1.287
May	4.95	7.80	6.28	0.977
Jun	3.27	7.68	5.21	1.381
Jul	5.00	8.13	6.43	0.997
Aug	4.47	7.45	6.10	1.010
Sep	3.56	6.09	4.87	0.931
Oct	2.40	3.98	2.98	0.640
Nov	1.08	2.74	2.03	0.543
Dec	0.53	1.71	1.17	0.424

Table 1.4.1. Variation in the monthly mean sea surface temperature (°C) at Pine Island from 1960-2000.

Month	Minimum	Maximum	Mean	SD
Jan	6.09	8.88	7.62	0.654
Feb	5.69	9.05	7.46	0.675
Mar	6.30	9.22	7.64	0.694
Apr	6.69	9.39	8.11	0.644
May	7.80	10.00	8.89	0.652
Jun	8.60	10.92	9.61	0.600
Jul	9.19	11.38	10.14	0.567
Aug	9.19	11.30	10.24	0.540
Sep	8.89	12.03	10.03	0.661
Oct	8.30	12.10	9.81	0.788
Nov	7.80	10.39	9.07	0.639
Dec	6.69	9.47	8.14	0.612

Table 1.4.2. Variation in the monthly mean sea surface temperature (°C) at McInnes Island from 1960-2000.

Month	Minimum	Maximum	Mean	SD
Jan	5.00	7.80	6.68	0.723
Feb	4.90	8.29	6.62	0.783
Mar	5.50	8.36	6.90	0.727
Apr	6.40	9.69	7.89	0.532
May	8.19	11.39	9.60	0.713
Jun	10.39	13.00	11.49	0.669
Jul	11.19	14.60	12.93	0.618
Aug	12.10	15.00	13.56	0.648
Sep	11.10	14.53	12.85	0.807
Oct	8.80	12.10	10.81	0.617
Nov	7.09	9.95	8.71	0.733
Dec	6.00	9.22	7.45	0.669

Table 1.4.3. Variation in the monthly mean sea surface temperature (°C) at Bonilla Island from 1960-2000.

Month	Minimum	Maximum	Mean	SD
Jan	4.40	8.10	6.48	0.889
Feb	4.40	8.32	6.45	0.905
Mar	5.40	8.71	6.87	0.815
Apr	6.19	9.62	7.84	0.697
May	8.30	11.10	9.44	0.619
Jun	9.80	12.65	11.14	0.650
Jul	10.80	14.09	12.20	0.730
Aug	10.89	14.30	12.43	0.692
Sep	9.89	13.97	11.90	0.923
Oct	9.39	11.89	10.63	0.608
Nov	6.80	8.70	8.70	0.771
Dec	5.80	7.36	7.36	0.822

Table 1.4.4. Strength of warm ENSO events at McInnes Island since 1957. The warmest year during each event at McInnes Island is indicated in parentheses in Column 2.

ENSO Event	Annual SST (°C)	Standard Deviation	Strength
1957/58	10.00 (1958)	0.82	Moderate
1965/66	9.42 (1966)	< mean	No effect
1972/73	9.00 (1973)	< mean	No effect
1982/83	10.70 (1983)	2.22	Very strong
1987	10.06 (1987)	0.94	Moderate
1991/92	9.64 (1992)	0.10	Weak
1997/98	10.47 (1998)	1.76	Strong
Average Annual SST	**9.59**	**0.50**	

Table 1.5.1. Average monthly wind speed ($m \cdot s^{-1}$) and most frequent direction (blowing from) in Hecate Strait and Queen Charlotte Sound from 1961-1990. *Source: Canadian Climate Normals 1961-1990, Environment Canada.*

Month	Sandspit		Cape St. James		Egg Is.		Cape Scott	
Jan	SE	5.8	S	11.1	SE	7.2	SE	5.3
Feb	SE	5.5	S	10.6	SE	6.7	SE	5.0
Mar	SE	5.3	NW	9.2	SE	6.4	SE	4.7
Apr	SE	5.3	NW	8.9	SE	5.5	SE	4.4
May	SE	5.0	NW	8.0	NW	5.0	S	3.9
Jun	SE	4.7	NW	7.5	NW	4.7	NW	3.6
Jul	W	4.2	NW	7.2	NW	4.2	NW	3.1
Aug	W	4.2	NW	6.9	NW	3.9	N	3.3
Sep	SE	4.7	NW	7.5	NW	4.4	S	3.9
Oct	SE	5.3	S	9.4	SE	6.1	SE	5.0
Nov	SE	5.8	S	10.3	SE	7.5	SE	5.3
Dec	SE	5.8	S	10.8	SE	7.2	SE	5.3

Table 1.6.1. Variation in the monthly mean upwelling index (tonnes per 100 m of coastline), and the percent of the time in which upwelling occurred at 51°N 131°W from 1946-2000.

Month	Minimum	Maximum	Mean	Percent
Jan	-309.0	12.0	-63.4	10.9
Feb	-209.0	29.0	-53.0	12.7
Mar	-124.0	35.0	-21.6	20.0
Apr	-115.0	46.0	-13.8	32.7
May	- 26.0	33.0	0.6	52.7
Jun	- 17.0	102.0	11.7	69.0
Jul	- 23.0	71.0	17.0	83.6
Aug	- 15.0	70.0	14.3	85.4
Sep	- 70.0	69.0	1.6	61.8
Oct	-151.0	16.0	-30.9	9.0
Nov	-188.0	39.0	-48.2	9.0
Dec	-225.0	25.0	-49.7	12.7

Table 1.8.1. Variation in the monthly mean sea surface salinity (parts per thousand) at Bonilla Island from 1960-2000.

Month	Minimum	Maximum	Mean	SD
Jan	30.39	31.89	31.13	0.405
Feb	30.20	32.09	31.12	0.364
Mar	30.29	31.89	31.18	0.356
Apr	30.29	32.20	31.23	0.417
May	30.29	32.00	31.24	0.393
Jun	30.29	31.79	31.23	0.355
Jul	30.39	32.00	31.21	0.350
Aug	30.50	32.29	31.30	0.418
Sep	30.70	32.20	31.40	0.414
Oct	30.20	32.00	31.27	0.423
Nov	30.00	31.89	30.96	0.392
Dec	30.39	31.79	31.08	0.396

Table 1.8.2. Variation in the monthly mean sea surface salinity (parts per thousand) at McInnes Island from 1960-2000.

Month	Minimum	Maximum	Mean	SD
Jan	29.10	32.40	30.53	0.679
Feb	29.50	32.79	30.65	0.682
Mar	29.70	32.70	30.74	0.680
Apr	27.79	32.59	30.67	0.792
May	28.50	32.20	30.72	0.738
Jun	28.60	32.00	30.53	0.845
Jul	28.10	31.89	30.32	0.937
Aug	28.10	31.89	30.43	0.840
Sep	27.79	32.40	30.27	0.875
Oct	28.70	31.79	30.18	0.720
Nov	28.39	31.60	29.82	0.780
Dec	28.39	31.89	30.35	0.710

Table 2.2.1. Dilke *et al* (1979) Hecate Strait (including samples from Hecate Strait (HS) and Dixon Entrance (DE)) data for chlorophyll *a* and nutrients. The letter 'm' indicates no data. Latitudes and longitudes are recorded either as degrees (when a decimal place is present) or as degrees and minutes (no decimal place).

Location	Sample Number	Date	Time	Latitude	Longitude	Depth (m)	Chl *a* ($\mu g \cdot L^{-1}$)	Phaeopigments ($\mu g \cdot L^{-1}$)	Nitrate + Nitrite ($\mu g \cdot L^{-1}$)	Phosphate ($\mu g \cdot L^{-1}$)
DE	UBCSOP-22	19-Aug-78	1401	55° 06'	132° 48'	3	1.58	1.75	m	m
DE	UBCSOP-23	19-Aug-78	1830	54° 10'	132° 28'	3	1.61	1.41	m	m
DE	UBCSOP-1	18-Oct-78	2100	54° 07'	131° 49'	3	0.53	0.7	m	m
DE	UBCSOP-2	18-Oct-78	2345	54° 11'	132° 25'	3	0.72	0.72	m	m
HS	UBCSOP-21	19-Aug-78	1123	54° 17'	131° 22'	3	0.19	1.37	m	m
HS	UBCSOP-26	21-Aug-78	0630	53.28°	131.88°	3	1.16	1.28	m	m
HS	UBCSOP-14	21-Aug-78	1145	53.40°	132.60°	3	1.15	0.94	m	0.29
HS	UBCSOP-16	22-Sep-78	2340	53.53°	131.37°	3	1.16	0.34	m	0.15
HS	UBCSOP-15	22-Sep-78	0900	53.55°	131.75°	3	2.32	0.83	m	0.41
HS	UBCSOP-8	20-Oct-78	2315	53.53°	131.30°	3	0.94	0.54	m	m
HS	UBCSOP-6	20-Oct-78	0630	53.90°	131.57°	3	5.68	1.78	m	m
HS	UBCSOP-7	20-Oct-78	0900	53.53°	131.75°	3	5.83	0.00	m	m
HS	UBCSOP-7	05-Jan-79	0635	53° 56'	131° 34'	3	0.40	0.42	14.10	1.41
HS	UBCSOP-8	05-Jan-79	2400	53° 16'	131° 13'	3	0.24	0.29	m	1.49
HS	UBCSOP-7	02-Apr-79	1415	52.80°	130.55°	3	0.95	0.41	12.00	1.30
HS	UBCSOP-8	02-Apr-79	1910	53.37°	131.70°	3	1.97	0.73	1.30	0.62

Table 2.2.2. Summary statistics for the nutrient data (March 1978 – April 1979) from Dilke *et al* (1979).

	Nitrate + Nitrite ($\mu g \cdot L^{-1}$)	Phosphate ($\mu g \cdot L^{-1}$)
Hecate Strait		
N	3	7
Mean	9.13	0.81
SD	6.86	0.57

Table 2.3.1. Perry *et al* (1981) Hecate Strait data (including samples from Hecate Strait (HS) and Dixon Entrance (DE)) for chlorophyll *a* and nutrients. The letter 'm' indicates no data. Latitudes and longitudes are recorded either as degrees (when a decimal place is present) or as degrees and minutes (no decimal place).

Location	Sample Number	Date	Time	Latitude	Longitude	Depth (m)	Chl *a* ($\mu g \cdot L^{-1}$)	Phaeopigments ($\mu g \cdot L^{-1}$)	Nitrate + Nitrite ($\mu g \cdot L^{-1}$)	Phosphate ($\mu g \cdot L^{-1}$)	Silicate ($\mu g \cdot L^{-1}$)
DE	UBCSOP-7	21-Jul-79	0955	54° 15'	131° 47'	3.0	2.21	0.58	1.2	0.6	16.2
DE	UBCSOP-8	21-Jul-79	1145	54° 13'	132° 26'	3.0	3.33	1.1	0.7	0.4	9.6
DE	UBCSOP-11	22-Jul-79	1530	54° 18'	131° 16'	3.0	2.74	0.58	1.8	0.8	20.4
DE	UBCSOP-19	12-Apr-80	2300	54° 14'	132° 09'	3.0	0.55	0.55	7.92	0.69	14.04
DE	UBCSOP-20	13-Apr-80	0100	54° 16'	131° 30'	3.0	0.49	0.32	15.72	1.44	26.88
HS	UBCSOP - 9	12-May-79	0035	53.40°	131.55°	3.0	0.90	0.58	m	m	7.80
HS	UBCSOP-14	27-Jun-79	1030	54° 30'	131° 05'	3.0	5.34	1.40	1.6	0.4	3.70
HS	UBCSOP-15	27-Jun-79	1210	54° 14'	131° 16'	3.0	4.29	1.99	3.7	0.7	11.60
HS	UBCSOP-16	27-Jun-79	1805	53.30°	131.93°	3.0	0.87	0.46	0.00	0.70	5.40
HS	UBCSOP-17	28-Jun-79	0845	53.70°	131.28°	3.0	0.31	0.22	0.20	0.40	1.70
HS	UBCSOP-18	28-Jun-79	1035	53.53°	130° 59'	3.0	1.19	0.34	0.20	0.40	3.70
HS	UBCSOP-14	24-Jul-79	1930	54.00°	130° 46'	3.0	2.17	0.62	0.20	0.50	3.70
HS	UBCSOP-15	24-Jul-79	2040	53° 52'	131° 00'	3.0	2.17	0.62	0.50	0.50	5.00
HS	UBCSOP-17	24-Jul-79	2400	53.42°	131.87°	3.0	0.20	0.70	m	m	5.00
HS	UBCSOP-16	24-Jul-79	2200	53.68°	131.35°	3.0	0.20	0.60	m	m	2.10
HS	UBCSOP-18	3-Feb-80	0415	53° 39'	130° 42'	3.0	0.13	0.08	14.1	1.17	m
HS	UBCSOP-19	3-Feb-80	0445	53° 37'	130° 51'	3.0	0.12	0.08	m	m	m
HS	UBCSOP-20	3-Feb-80	0515	53.60°	130.98°	3.0	0.19	0.10	m	m	m
HS	UBCSOP-21	3-Feb-80	0615	53.53°	131.23°	3.0	0.25	0.16	9.00	0.80	11.14
HS	UBCSOP-27	4-Feb-80	0500	53.62°	131.12°	3.0	0.12	0.10	13.08	1.11	23.62
HS	UBCSOP-25	4-Feb-80	0300	53.48°	131.62°	3.0	0.20	0.10	13.65	1.11	10.72
HS	UBCSOP-24	4-Feb-80	0230	53.45°	131.68°	3.0	0.24	0.14	11.97	0.96	11.74
HS	UBCSOP-26	4-Feb-80	0400	53.55°	131.35°	3.0	0.24	0.12	11.40	0.93	21.71
HS	UBCSOP-22	4-Feb-80	0100	53.28°	131.90°	3.0	0.27	0.15	24.02	1.84	22.64
HS	UBCSOP-23	4-Feb-80	0200	53.42°	131.08°	3.0	0.34	0.19	16.58	1.25	10.72
HS	UBCSOP-21	13-Apr-80	2100	53.05°	131.07°	3.0	0.37	2.66	1.14	0.42	6.91
HS	UBCSOP-23	13-Apr-80	2300	53.73°	131.30°	3.0	3.52	0.73	0.00	0.27	1.80
HS	UBCSOP-22	13-Apr-80	2200	53.60°	131.01°	3.0	7.46	2.17	0.36	0.33	4.79
HS	UBCSOP-24	14-Apr-80	0000	53° 51'	131° 02'	3.0	0.60	0.22	3.48	0.63	11.81
HS	UBCSOP-25	14-Apr-80	0100	53° 59'	130° 47'	3.0	0.50	0.43	4.56	0.62	13.61
HS	UBCSOP-18	2-Jun-80	1600	53° 59'	130° 48'	3.0	3.46	0.83	0.36	0.03	7.13
HS	UBCSOP-19	2-Jun-80	1800	53° 46'	131° 15'	3.0	4.45	1.44	0.24	0.3	2.18
HS	UBCSOP-20	2-Jun-80	2030	53.48°	131.78°	3.0	0.29	0.34	0.24	0.09	3.65
HS	UBCSOP-21	3-Jun-80	1155	53.47°	131.55°	3.0	1.09	0.50	m	m	m
HS	UBCSOP-22	3-Jun-80	1400	53° 33'	131° 02'	3.0	3.05	1.48	0.72	0.12	5.44

Table 2.3.2. Summary of between-site nutrient concentrations (May 1979 – June 1980) from Perry *et al* (1981).

	Nitrate + Nitrite ($\mu g \cdot L^{-1}$)	**Phosphate ($\mu g \cdot L^{-1}$)**	**Silicate ($\mu g \cdot L^{-1}$)**
Dixon Entrance			
N	5	5	5
Mean	5.47	0.79	17.42
SD	6.43	0.39	6.57
Hecate Strait			
N	24	24	26
Mean	5.47	0.65	8.44
SD	6.90	0.43	6.34

Table 2.4.1. Denman *et al* (1985): Hecate Strait (including samples from Hecate Strait (HS) and Queen Charlotte Sound (QCS)) data for chlorophyll *a* and nutrients. The letter ‘m’ indicates no data. Latitudes and longitudes are recorded as degrees and minutes.

Location	**Station Number**	**Date**	**Time**	**Lat**	**Lon**	**Bottle Number**	**Depth (m)**	**Temp (°C)**	**Chl *a* ($mg \cdot m^{-3}$)**	**Pmax (mg C·mg Chl $a^{-1} \cdot h^{-1}$)**	**NO_3 ($mmol \cdot m^{-3}$)**	**PO_4 ($mmol \cdot m^{-3}$)**	**SiO_2 ($mmol \cdot m^{-3}$)**
QCS	34	2-Jul-83	1559	50° 59.5'	128° 47.6'	1	66.10	8.54	m	m	9.30	2.20	15.60
QCS	34	2-Jul-83				2	50.90	8.70	m	m	16.80	2.53	27.40
QCS	34	2-Jul-83				3	31.80	9.70	m	m	12.60	2.14	22.00
QCS	34	2-Jul-83				4	18.20	10.88	m	m	5.90	1.62	9.60
QCS	34	2-Jul-83				5	11.50	11.40	m	m	1.30	1.19	6.40
QCS	34	2-Jul-83				6	3.60	14.44	m	m	m	m	m
QCS	34	2-Jul-83				7	12.80	11.47	2.47	m	m	m	m
QCS	34	2-Jul-83				8	12.80	11.40	m	m	m	m	m
QCS	34	2-Jul-83				9	4.40	14.29	m	7.30	m	m	m
QCS	34	2-Jul-83				10	4.00	14.45	0.75	m	m	m	m
QCS	36	2-Jul-83	1800	51° 04.7'	128° 59.4'	1	103.70	8.16	m	m	20.50	2.85	33.30
QCS	36	2-Jul-83				2	77.30	3.71	m	m	16.40	2.46	26.00
QCS	36	2-Jul-83				3	51.40	9.40	m	m	14.20	2,29	23.10
QCS	36	2-Jul-83				4	30.30	10.50	m	m	9.50	1.91	16.90
QCS	36	2-Jul-83				5	12.30	12.09	2.83	m	1.00	1.20	8.40
QCS	36	2-Jul-83				6	4.70	13.57	1.20	m	0.10	1.08	4.20

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg \cdot m^{-3}$)	Pmax (mg C·mg Chl $a^{-1} \cdot h^{-1}$)	NO_3 (mmol·m^{-3})	PO_4 (mmol·m^{-3})	SiO_2 (mmol·m^{-3})
QCS	38	2-Jul-83	1956	51° 10.0’	129° 11.0’	1	171.00	6.84	m	m	m	m	m
QCS	38	2-Jul-83				2	149.90	6.90	m	m	29.90	3.50	48.40
QCS	38	2-Jul-83				3	123.50	7.08	m	m	27.80	3.24	46.00
QCS	38	2-Jul-83				4	100.30	7.27	m	m	21.80	2.89	35.50
QCS	38	2-Jul-83				5	73.40	8.26	m	m	17.20	2.06	26.70
QCS	38	2-Jul-83				6	49.30	10.46	m	m	7.70	0.75	14.70
QCS	38	2-Jul-83				7	28.70	12.54	m	m	2.50	0.92	9.10
QCS	38	2-Jul-83				8	19.20	12.76	0.92	m	2.10	0.75	8.20
QCS	38	2-Jul-83				9	7.40	13.86	0.71	m	0.80	1.41	6.90
QCS	40a	2-Jul-83	2332	51° 15.6’	129° 22.3’	1	250.30	6.05	m	m	32.70	5.50	57.90
QCS	40a	2-Jul-83				2	198.30	6.63	m	m	24.70	3.39	38.40
QCS	40a	2-Jul-83				3	150.10	7.53	m	m	23.40	3.24	33.90
QCS	40a	2-Jul-83				4	125.70	7.65	m	m	25.20	2.90	36.60
QCS	40a	2-Jul-83				5	99.50	7.75	m	m	22.80	3.06	33.90
QCS	40a	2-Jul-83				6	75.00	8.34	m	m	17.30	2.58	27.30
QCS	40a	2-Jul-83				7	52.80	9.63	m	m	12.30	2.10	21.70
QCS	40a	2-Jul-83				8	30.00	10.78	m	m	8.90	2.05	17.50
QCS	40a	2-Jul-83				9	20.00	11.67	0.67	m	3.80	0.69	11.10
QCS	40a	2-Jul-83				10	7.20	13.86	0.54	m	0.30	0.92	9.10
QCS	41	3-Jul-83	0145	51° 33.4’	129° 14.6’	1	46.10	10.92	m	m	5.70	1.66	12.90
QCS	41	3-Jul-83				2	32.60	11.45	m	m	4.10	1.73	11.10
QCS	41	3-Jul-83				3	16.20	12.41	1.54	m	1.20	1.21	8.40
QCS	41	3-Jul-83				4	9.10	13.11	0.98	m	0.00	0.36	6.40
QCS	43	3-Jul-83	0325	51° 27.4’	129° 04.4’	1	60.50	10.03	m	m	9.60	1.91	16.20
QCS	43	3-Jul-83				2	31.10	11.39	m	m	2.50	1.51	8.90
QCS	43	3-Jul-83				3	20.90	12.59	0.88	m	0.00	0.67	6.70
QCS	43	3-Jul-83				4	13.10	13.15	0.64	m	0.10	0.41	6.40
QCS	45	3-Jul-83	0500	51° 21.6’	128° 54.0’	1	214.10	6.26	m	m	32.10	3.47	58.10
QCS	45	3-Jul-83				2	188.50	6.36	m	m	33.10	3.43	55.40
QCS	45	3-Jul-83				3	150.30	7.02	m	m	28.30	3.30	42.80
QCS	45	3-Jul-83				4	128.10	7.58	m	m	25.70	2.77	37.20
QCS	45	3-Jul-83				5	101.80	8.20	m	m	18.40	2.48	28.40
QCS	45	3-Jul-83				6	77.50	8.95	m	m	13.00	1.72	19.70
QCS	45	3-Jul-83				7	50.90	10.27	m	m	7.90	1.88	14.40
QCS	45	3-Jul-83				8	30.50	11.10	m	m	4.00	1.54	10.90
QCS	45	3-Jul-83				9	16.80	11.70	1.65	m	2.20	0.75	8.40
QCS	45	3-Jul-83				10	7.20	13.37	0.89	m	0.60	0.47	5.50

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg \cdot m^{-3}$)	Pmax (mg C·mg Chl $a^{-1} \cdot h^{-1}$)	NO_3 ($mmol \cdot m^{-3}$)	PO_4 ($mmol \cdot m^{-3}$)	SiO_2 ($mmol \cdot m^{-3}$)
QCS	47	3-Jul-83	0725	51° 16.0'	128° 43.2'	1	193.40	6.41	m	m	29.60	3.05	51.90
QCS	47	3-Jul-83				2	149.40	6.73	m	m	28.70	2.78	45.90
QCS	47	3-Jul-83				3	127.00	7.44	m	m	24.80	2.61	40.30
QCS	47	3-Jul-83				4	100.30	8.11	m	m	20.50	2.06	30.10
QCS	47	3-Jul-83				5	75.20	8.91	m	m	13.80	2.08	21.30
QCS	47	3-Jul-83				6	49.40	9.90	m	m	9.70	1.81	60.20
QCS	47	3-Jul-83				7	30.80	10.65	m	m	6.40	1.59	12.90
QCS	47	3-Jul-83				8	20.40	11.54	1.35	m	3.70	1.13	11.50
QCS	47	3-Jul-83				9	11.90	12.73	0.87	m	0.10	m	7.10
QCS	49	3-Jul-83	0845	51° 12.6'	128° 30.5'	1	198.80	6.50	m	m	30.90	3.47	56.50
QCS	49	3-Jul-83				2	148.00	6.57	m	m	30.30	3.19	52.30
QCS	49	3-Jul-83				3	123.70	6.90	m	m	29.90	3.12	52.10
QCS	49	3-Jul-83				4	97.90	7.72	m	m	21.70	2.65	35.70
QCS	49	3-Jul-83				5	75.00	8.63	m	m	19.50	2.74	32.10
QCS	49	3-Jul-83				6	50.00	9.35	m	m	16.60	2.26	28.60
QCS	49	3-Jul-83				7	29.10	10.61	m	m	12.30	2.08	22.80
QCS	49	3-Jul-83				8	10.20	12.26	2.48	m	0.20	0.99	2.20
QCS	49	3-Jul-83				9	3.70	12.90	1.41	m	0.30	0.19	1.30
QCS	50	3-Jul-83	0936	51° 09.9'	128° 24.9'	1	17.50	10.33	m	11.70	m	m	m
QCS	50	3-Jul-83				2	17.10	10.41	1.41	m	10.90	1.49	17.70
QCS	50	3-Jul-83				3	4.60	12.29		21.00	m	m	m
QCS	50	3-Jul-83				4	4.60	12.28	3.12	m	0.50	1.13	4.00
HS	70	5-Jul-83	0335	51° 42.4'	128° 53.5'	1	44.50	10.29	m	m	9.10	0.90	16.40
HS	70	5-Jul-83				2	32.00	11.19	m	m	9.30	2.37	16.60
HS	70	5-Jul-83				3	19.50	12.86	0.62	m	m	m	m
HS	70	5-Jul-83				4	6.90	13.40	1.02	m	0.00	1.64	7.20
HS	71	5-Jul-83	0512	51° 48.8'	129° 10.6'	1	110.30	7.97	m	m	20.90	3.14	33.10
HS	71	5-Jul-83				2	75.40	9.35	m	m	13.60	2.65	21.90
HS	71	5-Jul-83				3	50.80	9.97	m	m	10.80	2.50	18.40
HS	71	5-Jul-83				4	29.60	11.53	m	m	3.60	1.80	10.70
HS	71	5-Jul-83				5	16.30	12.47	1.68	m	0.50	0.55	8.90
HS	71	5-Jul-83				6	8.10	12.68	1.43	m	0.00	1.50	9.20

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg \cdot m^{-3}$)	Pmax (mg C·mg Chl $a^{-1} \cdot h^{-1}$)	NO_3 (mmol·m^{-3})	PO_4 (mmol·m^{-3})	SiO_2 (mmol·m^{-3})
HS	72	5-Jul-83	0645	51° 55.4'	129° 27.5'	1	208.10	5.90	m	m	33.10	3.70	62.10
HS	72	5-Jul-83				2	151.80	6.80	m		30.30	1.67	51.80
HS	72	5-Jul-83				3	124.50	7.41	m	m	25.10	3.25	4.20
HS	72	5-Jul-83				4	100.00	8.03	m	m	15.30	2.92	22.30
HS	72	5-Jul-83				5	73.00	8.79	m	m	16.30	2.78	25.50
HS	72	5-Jul-83				6	49.80	9.44	m	m	13.50	2.38	21.40
HS	72	5-Jul-83				7	35.80	11.54	0.77	m	4.30	1.84	12.90
HS	72	5-Jul-83				8	19.20	13.43	0.50	m	1.00	1.57	10.30
HS	72	5-Jul-83				9	10.60	13.49	m	m	0.00	1.62	10.00
HS	73	5-Jul-83	0835	52° 03.4'	129° 42.8'	1	147.90	7.19	m	m	26.20	3.38	44.20
HS	73	5-Jul-83				2	102.40	8.17	m	m	17.40	2.92	27.60
HS	73	5-Jul-83				3	74.40	8.84	m	m	11.60	2.43	16.15
HS	73	5-Jul-83				4	52.90	9.78	m	m	9.50	2.18	13.40
HS	73	5-Jul-83				5	31.40	11.08	m	m	2.40	1.68	9.10
HS	73	5-Jul-83				6	9.50	13.82	m	m	0.00	1.52	9.10
HS	73	5-Jul-83				7	10.40	13.82	m	m	m	m	m
HS	73	5-Jul-83				8	10.10	13.82	0.19	8.50	m	m	m
HS	73	5-Jul-83				9	31.90	10.90	m	m	m	m	m
HS	73	5-Jul-83				10	32.80	10.83	0.97	17.70	m	m	m
HS	74	5-Jul-83	1020	52° 17.8'	129° 54.0'	1	129.80	8.06	m	m	17.50	1.82	27.40
HS	74	5-Jul-83				2	100.50	8.44	m	m	14.10	2.38	20.90
HS	74	5-Jul-83				3	77.50	8.74	m	m	11.60	1.00	17.10
HS	74	5-Jul-83				4	52.40	9.57	m	m	9.00	1.77	13.60
HS	74	5-Jul-83				5	30.80	11.72	0.95	m	0.50	1.57	9.60
HS	74	5-Jul-83				6	9.80	13.58	0.35	m	0.00	m	8.90
HS	75	5-Jul-83	1223	52° 34.2'	130° 01.9'	1	252.80	5.54	m	m	34.90	4.02	70.30
HS	75	5-Jul-83				2	199.80	6.15	m	m	m	m	m
HS	75	5-Jul-83				3	149.30	7.28	m	m	23.60	3.16	36.30
HS	75	5-Jul-83				4	124.50	8.03	m	m	17.70	2.76	25.80
HS	75	5-Jul-83				5	99.60	8.63	m	m	13.50	2.67	19.60
HS	75	5-Jul-83				6	75.20	9.08	m	m	10.90	2.25	15.80
HS	75	5-Jul-83				7	49.50	9.77	m	m	8.40	2.03	13.10
HS	75	5-Jul-83				8	28.50	11.79	0.93	m	1.00	0.73	9.30
HS	75	5-Jul-83				9	14.10	13.28	m	m	0.00	1.40	9.10
HS	75	5-Jul-83				10	6.80	13.45	0.46	m	0.00	0.36	8.90

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg \cdot m^{-3}$)	Pmax (mg C·mg Chl $a^{-1} \cdot h^{-1}$)	NO_3 ($mmol \cdot m^{-3}$)	PO_4 ($mmol \cdot m^{-3}$)	SiO_2 ($mmol \cdot m^{-3}$)
HS	76	5-Jul-83	1418	52° 52.5’	130° 05.8’	1	253.00	5.33	m	m	37.10	4.21	80.30
HS	76	5-Jul-83				2	201.20	5.82	m	m	34.90	m	64.50
HS	76	5-Jul-83				3	145.10	7.20	m	m	26.80	3.16	44.50
HS	76	5-Jul-83				4	127.30	7.72	m	m	21.60	2.97	33.20
HS	76	5-Jul-83				5	101.90	8.38	m	m	15.90	2.62	24.00
HS	76	5-Jul-83				6	74.90	8.95	m	m	13.90	2.24	21.60
HS	76	5-Jul-83				7	51.90	9.65	m	m	13.10	2.15	21.60
HS	76	5-Jul-83				8	37.60	10.76	m	m	7.00	1.81	14.20
HS	76	5-Jul-83				9	23.80	12.74	1.07	m	0.00	0.90	8.50
HS	76	5-Jul-83				10	9.60	13.40	0.52	m	0.20	1.06	8.50
HS	77	5-Jul-83	1617	53° 05.5’	130° 21.1’	1	200.70	5.70	m	m	35.10	4.02	73.40
HS	77	5-Jul-83				2	150.00	6.71	m	m	29.70	3.58	51.80
HS	77	5-Jul-83				3	124.40	7.23	m	m	26.30	2.34	46.30
HS	77	5-Jul-83				4	100.80	8.20	m	m	17.40	2.76	27.60
HS	77	5-Jul-83				5	74.70	9.10	m	m	11.00	1.16	16.00
HS	77	5-Jul-83				6	49.20	10.04	m	m	8.30	1.77	14.50
HS	77	5-Jul-83				7	32.00	9.95	m	m	12.00	2.10	21.60
HS	77	5-Jul-83				8	20.40	11.08	1.63	m	5.70	1.80	14.70
HS	77	5-Jul-83				9	11.20	13.62	0.48	m	0.00	1.37	9.10
HS	79	5-Jul-83	2008	53° 19.2’	130° 18.1’	1	125.50	8.63	m	m	19.30	2.78	35.10
HS	79	5-Jul-83				2	100.70	8.77	m	m	18.50	2.73	32.00
HS	79	5-Jul-83				3	75.60	9.08	m	m	16.00	2.30	28.70
HS	79	5-Jul-83				4	50.20	10.47	m	m	9.60	1.62	17.80
HS	79	5-Jul-83				5	29.10	11.64	m	m	3.10	1.14	10.50
HS	79	5-Jul-83				6	20.00	13.50	0.88	m	0.00	0.50	7.80
HS	79	5-Jul-83				7	10.50	13.41	1.25	m	0.00	0.88	6.70
HS	79	5-Jul-83				8	20.20	13.49	m	m	m	m	m
HS	79	5-Jul-83				9	19.80	13.49	1.09	8.70	m	m	m
HS	82	5-Jul-83	2248	53° 16.7’	130° 34.0’	1	161.30	6.61	m	m	28.60	3.64	55.60
HS	82	5-Jul-83				2	125.20	7.55	m	m	25.50	1.52	46.90
HS	82	5-Jul-83				3	99.20	8.18	m	m	19.30	1.51	33.60
HS	82	5-Jul-83				4	74.50	9.10	m	m	12.20	1.44	18.90
HS	82	5-Jul-83				5	49.40	9.62	m	m	10.70	1.77	16.70
HS	82	5-Jul-83				6	28.70	10.41	0.76	m	6.60	1.69	13.60
HS	82	5-Jul-83				7	19.00	12.65	m	m	0.30	0.79	7.30
HS	82	5-Jul-83				8	9.80	13.47	0.39	m	0.00	1.13	7.30

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg \cdot m^{-3}$)	Pmax (mg C·mg Chl $a^{-1} \cdot h^{-1}$)	NO_3 ($mmol \cdot m^{-3}$)	PO_4 ($mmol \cdot m^{-3}$)	SiO_2 ($mmol \cdot m^{-3}$)
HS	83	5-Jul-83	2338	53° 15.5’	130° 41.0’	1	184.80	6.22	m	m	31.00	3.25	62.70
HS	83	5-Jul-83				2	151.30	6.75	m	m	24.00	2.96	46.90
HS	83	5-Jul-83				3	127.60	7.30	m	m	27.10	3.28	51.60
HS	83	5-Jul-83				4	99.80	8.23	m	m	18.80	1.56	31.10
HS	83	5-Jul-83				5	76.40	8.91	m	m	14.80	2.40	23.40
HS	83	5-Jul-83				6	48.60	10.05	m	m	7.40	1.24	12.00
HS	83	5-Jul-83				7	35.90	10.44	m	m	10.50	1.89	18.20
HS	83	5-Jul-83				8	23.70	10.88	0.67	m	5.70	1.76	14.20
HS	83	5-Jul-83				9	10.00	13.69	0.43	m	0.40	1.38	8.50
HS	84	6-Jul-83	0115	53° 13.6’	130° 51.0’	1	117.90	7.45	m	m	m	2.92	m
HS	84	6-Jul-83				2	100.60	7.82	m	m	22.60	m	40.50
HS	84	6-Jul-83				3	76.30	8.69	m	m	14.90	m	23.40
HS	84	6-Jul-83				4	51.80	9.35	m	m	9.80	m	15.10
HS	84	6-Jul-83				5	30.40	10.55	m	m	5.30	1.76	10.50
HS	84	6-Jul-83				6	20.00	11.42	1.54	m	1.30	1.57	6.90
HS	84	6-Jul-83				7	11.00	12.79	0.86	m	0.00	1.39	6.90
HS	86	6-Jul-83	0320	53° 12.0’	131° 02.7’	1	47.50	9.13	m	m	m	m	m
HS	86	6-Jul-83				2	30.60	11.14	m	m	3.60	1.36	8.70
HS	86	6-Jul-83				3	20.70	12.05	5.82	m	0.60	1.43	4.70
HS	86	6-Jul-83				4	10.10	12.49	4.26	m	0.30	1.13	5.60
HS	92	6-Jul-83	0932	53° 14.2’	131° 02.8’	1	25.50	12.26	4.85	m	0.20	1.52	2.90
HS	92	6-Jul-83				2	25.50	12.28	m	m	m	m	m
HS	92	6-Jul-83				3	14.80	12.32	4.29	16.00	0.00	1.29	2.20
HS	92	6-Jul-83				4	14.60	1.35	m	m	m	m	m
HS	92	6-Jul-83				5	10.00	12.59	3.98	m	0.00	1.24	2.00
HS	92	6-Jul-83				6	10.00	12.59	m	m	m	m	m
HS	92	6-Jul-83				7	4.70	12.62	4.44	m	0.00	1.43	2.20
HS	92	6-Jul-83				8	4.70	12.61	m	m	m	m	m
HS	92	6-Jul-83				9	2.40	12.63	3.92	m	0.00	0.84	2.40
HS	92	6-Jul-83				10	2.50	12.63	m	m	m	m	m
HS	94	6-Jul-83	1537	53° 11.6’	131° 00.3’	1	30.10	11.84	6.52	11.40	2.40	1.50	7.10
HS	94	6-Jul-83				2	30.20	11.86	m	m	m	m	m
HS	94	6-Jul-83				3	9.10	12.55	3.07	12.70	0.00	1.40	3.10

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg \cdot m^{-3}$)	Pmax (mg C·mg Chl $a^{-1} \cdot h^{-1}$)	NO_3 (mmol·m^{-3})	PO_4 (mmol·m^{-3})	SiO_2 (mmol·m^{-3})
HS	96a	6-Jul-83	2045	53° 13.2’	131° 02.8’	1	49.30	9.49	m	m	13.30	2.43	26.00
HS	96a	6-Jul-83				2	33.40	9.58	m	m	11.60	2.17	20.30
HS	96a	6-Jul-83				3	20.30	11.17	m	m	m	m	m
HS	96a	6-Jul-83				4	20.30	11.16	16.19	m	4.20	1.37	9.30
HS	96a	6-Jul-83				5	10.30	12.04	4.50	m	0.00	1.08	2.40
HS	96a	6-Jul-83				6	4.60	12.79	m	m	1.10	1.14	3.60
HS	96g	7-Jul-83	0245	53° 13.2’	131° 02.8’	1	30.80	11.93	5.46	m	m	m	m
HS	96g	7-Jul-83				2	306.00	12.02	5.59	3.90	m	m	m
HS	96j	7-Jul-83	0545	53° 13.2’	131° 02.8’	1	27.80	11.60	13.90	m	m	m	m
HS	96j	7-Jul-83				2	27.70	11.73	18.72	5.40	m	m	m
HS	96m	7-Jul-83	0847	53° 13.2’	131° 02.8’	1	29.50	11.42	14.43	6.70	m	m	m
HS	96m	7-Jul-83				2	29.40	11.56	m	m	m	m	m
HS	96n	7-Jul-83	0947	53° 13.2’	131° 02.8’	1	48.80	9.69	7.10	m	11.30	1.30	21.10
HS	96n	7-Jul-83				2	36.70	9.82	8.70	m	8.40	1.28	15.30
HS	96n	7-Jul-83				3	27.40	10.15	9.83	m	6.40	1.09	12.20
HS	96n	7-Jul-83				4	15.10	11.90	4.75	m	0.30	0.50	2.40
HS	96n	7-Jul-83				5	5.00	12.73	2.44	m	0.30	0.44	1.10
HS	96p	7-Jul-83	1145	53° 13.2’	131° 02.8’	1	26.90	11.08	8.46	8.60	m	m	m
HS	96p	7-Jul-83				2	26.90	11.14	m	m	m	m	m
HS	Q	7-Jul-83	1247	53° 13.2’	131° 02.8’	1	53.80	9.52	1.39	m	m	m	m
HS	Q	7-Jul-83				2	41.70	9.74	2.53	m	m	m	m
HS	Q	7-Jul-83				3	29.20	10.99	15.24	m	m	m	m
HS	Q	7-Jul-83				4	19.60	12.21	3.37	m	m	m	m
HS	Q	7-Jul-83				5	9.90	12.59	2.94	m	m	m	m
HS	S	7-Jul-83				1	26.10	11.86	15.49	5.90	m	m	m
HS	T	7-Jul-83	1547	53° 13.2’	131° 02.8’	1	47.80	9.81	m	m	m	m	m
HS	T	7-Jul-83				2	44.90	9.80	m	m	m	m	m
HS	T	7-Jul-83				3	31.20	11.17	11.13	m	m	m	m
HS	T	7-Jul-83				4	20.40	12.07	4.79	m	m	m	m
HS	T	7-Jul-83				5	10.00	12.60	2.67	m	m	m	m
HS	V	7-Jul-83	1750	53° 13.2’	131° 02.8’	1	20.20	11.51	11.37	m	m	m	m
HS	V	7-Jul-83				2	20.40	11.48	11.43	7.10	m	m	m

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg \cdot m^{-3}$)	Pmax (mg C·mg Chl $a^{-1} \cdot h^{-1}$)	NO_3 ($mmol \cdot m^{-3}$)	PO_4 ($mmol \cdot m^{-3}$)	SiO_2 ($mmol \cdot m^{-3}$)
HS	W	7-Jul-83	1851	53° 13.2’	131° 02.8’	1	69.10	9.31	0.45	m	m	m	m
HS	W	7-Jul-83				2	49.40	9.36	0.51	m	m	m	m
HS	W	7-Jul-83				3	25.30	11.30	9.51	m	m	m	m
HS	W	7-Jul-83				4	17.70	12.05	3.76	m	m	m	m
HS	W	7-Jul-83				5	8.70	12.76	2.14	m	m	m	m
HS	Y	7-Jul-83	2045	53° 13.2’	131° 02.8’	1	80.30	9.05	m	m	15.10	1.52	28.80
HS	Y	7-Jul-83				2	50.80	9.21	m	m	12.50	1.37	21.70
HS	Y	7-Jul-83				3	30.50	9.71	m	m	9.60	1.09	16.20
HS	Y	7-Jul-83				4	21.10	10.80	m	m	2.60	0.74	6.90
HS	Y	7-Jul-83				5	9.90	12.15	m	m	0.30	0.40	1.30
HS	Y	7-Jul-83				6	22.80	11.30	m	m	m	m	m
HS	Y	7-Jul-83				7	22.90	11.28	12.59	4.20	m	m	m
HS	97	7-Jul-83	2117	53° 14.7’	131° 05.3’	1	46.70	9.71	m	m	10.40	1.23	18.80
HS	97	7-Jul-83				2	29.70	9.78	m	m	9.80	1.06	15.50
HS	97	7-Jul-83				3	19.80	10.24	10.79	m	1.60	0.65	4.40
HS	97	7-Jul-83				4	10.00	12.34	m	m	0.30	0.30	1.60
HS	98	7-Jul-83	2147	53° 14.7’	131° 00.3’	1	88.00	8.73	m	m	17.40	1.66	33.70
HS	98	7-Jul-83				2	75.00	8.70	m	m	15.10	1.63	28.60
HS	98	7-Jul-83				3	50.30	8.99	m	m	14.20	1.28	25.00
HS	98	7-Jul-83				4	29.80	10.37	m	m	2.90	0.82	8.00
HS	98	7-Jul-83				5	19.30	11.70	8.47	m	0.20	0.53	2.70
HS	98	7-Jul-83				6	9.90	13.07	m	m	0.10	0.30	2.00
HS	99	7-Jul-83	2214	53° 11. 7’	131° 00.3’	1	76.50	8.90	m	m	15.70	1.41	29.70
HS	99	7-Jul-83				2	48.90	9.19	m	m	11.30	1.29	19.50
HS	99	7-Jul-83				3	25.50	10.52	13.76	m	2.70	0.81	7.50
HS	99	7-Jul-83				4	15.00	11.95	m	m	0.20	0.34	3.50
HS	99	7-Jul-83				5	4.80	12.96	m	m	0.10	0.38	2.70
HS	100	7-Jul-83	2245	53° 11.7’	131° 05.3’	1	42.50	9.73	m	m	11.20	0.86	20.80
HS	100	7-Jul-83				2	28.80	9.76	m	m	10.30	0.96	19.70
HS	100	7-Jul-83				3	17.70	10.32	7.71	m	5.60	0.86	2.20
HS	100	7-Jul-83				4	10.00	12.02	m	m	2.30	0.54	4.90
HS	101	7-Jul-83	2345	53° 11.5’	131° 13.6’	1	35.20	10.28	m	m	8.70	1.23	18.40
HS	101	7-Jul-83				2	22.70	10.33	m	m	1.00	0.62	4.40
HS	101	7-Jul-83				3	9.80	12.46	1.87	m	0.20	0.48	1.80
HS	101	7-Jul-83				4	4.80	12.76	m	m	0.20	0.48	1.80
HS	101	7-Jul-83				5	10.10	12.59	1.87	3.60	m	m	m
HS	101	7-Jul-83				6	10.00	12.57	m	m	m	m	m

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg \cdot m^{-3}$)	Pmax (mg C·mg Chl *a* $^{-1} \cdot h^{-1}$)	NO_3 ($mmol \cdot m^{-3}$)	PO_4 ($mmol \cdot m^{-3}$)	SiO_2 ($mmol \cdot m^{-3}$)
HS	111	8-Jul-83	0950	53° 11.5'	131° 13.6'	1	24.70	10.83	6.00	m	6.30	1.07	14.80
HS	111	8-Jul-83				2	19.80	10.89	5.66	m	5.60	5.01	13.50
HS	111	8-Jul-83				3	14.60	11.20	3.69	m	1.40	0.64	4.60
HS	111	8-Jul-83				4	9.90	12.33	0.99	m	0.10	0.41	2.20
HS	111	8-Jul-83				5	4.80	12.70	0.94	m	0.20	0.36	1.10
HS	125	8-Jul-83	2348	53° 11.6'	131° 13.6'	1	31.50	10.78	m	m	5.30	0.98	11.70
HS	125	8-Jul-83				2	21.50	10.79	m	m	5.30	1.00	11.90
HS	125	8-Jul-83				3	9.70	12.60	m	m	0.30	0.43	2.20
HS	125	8-Jul-83				4	5.10	12.68	m	m	0.20	0.41	2.20
HS	125	8-Jul-83				5	10.00	12.66	0.99	6.00	m	m	m
HS	125	8-Jul-83				6	9.70	12.65	m	m	m	m	m
HS	126	9-Jul-83	0028	53° 11.5'	131° 18.6'	1	37.20	11.12	m	m	4.60	0.79	11.90
HS	126	9-Jul-83				2	28.90	11.14	m	m	3.90	0.94	10.40
HS	126	9-Jul-83				3	19.80	11.33	m	m	1.80	0.69	6.60
HS	126	9-Jul-83				4	10.00	12.34	2.66	m	0.50	0.46	3.10
HS	127	9-Jul-83	0100	53° 08.5'	131° 18.6'	1	35.90	11.59	m	m	3.00	0.80	9.30
HS	127	9-Jul-83				2	30.60	11.59	m	m	3.10	0.82	9.90
HS	127	9-Jul-83				3	20.60	11.61	3.36	m	3.00	0.84	9.10
HS	127	9-Jul-83				4	10.60	12.01	m	m	0.80	0.49	3.80
HS	128	9-Jul-83	0128	53° 08.5'	131° 13.6'	1	37.50	10.69	m	m	7.20	1.14	16.60
HS	128	9-Jul-83				2	28.60	10.70	m	m	7.10	1.18	16.20
HS	128	9-Jul-83				3	19.50	11.14	5.93	m	4.60	0.95	12.00
HS	128	9-Jul-83				4	8.50	12.80	m	m	0.20	0.48	1.50
HS	129	9-Jul-83	0155	53° 11.5'	131° 13.6'	1	35.10	10.67	m	m	7.10	1.10	16.20
HS	129	9-Jul-83				2	29.40	10.68	m	m	7.10	1.20	15.90
HS	129	9-Jul-83				3	21.00	10.74	m	m	6.60	1.06	14.80
HS	129	9-Jul-83				4	20.90	10.74	6.40	6.10	m	m	m
HS	129	9-Jul-83				5	10.40	12.70	m	m	0.30	0.34	2.20
HS	129	9-Jul-83				6	10.50	12.71	1.05	3.50	m	m	m
HS	134	10-Jul-83	0730	54° 04.0'	130° 43.0'	1	111.10	9.27		m	16.20	1.64	33.80
HS	134	10-Jul-83				2	101.00	9.51		m	15.40	1.14	30.90
HS	134	10-Jul-83				3	74.80	9.85			14.00	1.55	28.50
HS	134	10-Jul-83				4	50.50	11.44			5.50	0.86	12.80
HS	134	10-Jul-83				5	30.20	13.06			1.00	0.57	6.00
HS	134	10-Jul-83				6	21.50	13.24			0.60	0.53	6.00
HS	134	10-Jul-83				7	10.90	13.12	0.63	m	0.60	0.53	5.70

Table 2.4.1. (Continued)

Location	Station Number	Date	Time	Lat	Lon	Bottle Number	Depth (m)	Temp (°C)	Chl *a* ($mg{\cdot}m^{-3}$)	Pmax (mg C·mg Chl $a^{-1}{\cdot}h^{-1}$)	NO_3 ($mmol{\cdot}m^{-3}$)	PO_4 ($mmol{\cdot}m^{-3}$)	SiO_2 ($mmol{\cdot}m^{-3}$)
HS	135	10-Jul-83	0845	54° 06.0'	130° 32.0'	1	108.60	9.00		m	16.50	1.72	34.50
HS	135	10-Jul-83				2	98.30	9.03		m	16.80	1.71	34.50
HS	135	10-Jul-83				3	73.70	9.60			13.80	1.49	27.60
HS	135	10-Jul-83				4	49.80	10.12			12.90	1.33	26.90
HS	135	10-Jul-83				5	29.80	10.72			9.00	1.09	19.40
HS	135	10-Jul-83				6	20.10	11.70			4.80	0.78	11.90
HS	135	10-Jul-83				7	9.30	12.26	0.55	m	3.80	0.75	10.40
HS	136	10-Jul-83	0934	54° 12.3'	130° 28.0'	1	82.40	8.54		m	19.70	1.80	39.70
HS	136	10-Jul-83				2	74.40	8.72		m	18.80	1.82	39.00
HS	136	10-Jul-83				3	50.90	11.09			6.40	1.00	13.20
HS	136	10-Jul-83				4	31.00	12.82			1.50	0.70	5.50
HS	136	10-Jul-83				5	15.60	12.78			1.60	0.61	6.40
HS	136	10-Jul-83				6	5.10	12.45	1.63	m	2.10	0.70	10.80

Table 2.4.2. Temperature and nutrient means with respect to water depth for combined data from Hecate Strait and Queen Charlotte Sound. Samples were collected during July 1983.

Depth range (m)	Temperature (°C)	NO_3 ($mmol{\cdot}m^{-3}$)	SiO_2 ($mmol{\cdot}m^{-3}$)
0-5	13.04	0.280	2.440
5-10	13.12	0.400	6.625
10-15	12.63	0.436	5.404
15-20	11.81	2.682	7.794
20-25	11.60	3.067	9.733
25-30	11.14	5.531	12.731
30-35	11.09	5.780	12.650
35-40	10.77	6.756	14.778
40-45	9.92	10.150	18.600
45-50	9.79	10.046	21.369
50-55	9.77	11.213	19.187

Table 2.5.1. Forbes and Waters (1993) Hecate Strait (including samples from Hecate Strait (HS), Queen Charlotte Sound (QCS), and Dixon Entrance (DE)) data for chlorophyll *a* and nutrients. The letter 'm' indicates no data. Latitudes and longitudes are recorded as degrees and minutes.

Site	Station number	Date	Lat	Long	Depth (m)	Chl *a* ($\mu g \cdot L^{-1}$)	NO_3 ($mmol \cdot m^{-3}$)	PO_4 ($mmol \cdot m^{-3}$)	SiO_2 ($mmol \cdot m^{-3}$)
DE	54-5	4-Jul-85	54° 38.4'	132° 08.3'	30.7	1.7	9.9	1.08	14.6
DE	54-9	4-Jul-85	54° 38.4'	132° 08.3'	2	0.9	2	0.44	4.4
DE	55-7	4-Jul-85	54° 23.3'	132° 06.5'	31.2	1.3	13	1.18	20
DE	55-10	4-Jul-85	54° 23.3'	132° 06.5'	2.4	1.1	0.2	0.41	3.9
DE	56-3	4-Jul-85	54° 10.2'	132° 06.5'	19.9	0.3	19.3	1.56	33.3
DE	56-5	4-Jul-85	54° 10.2'	132° 06.5'	1.9	1.6	6.5	0.74	10.9
DE	57-3	4-Jul-85	54° 23.2'	131° 46.0'	151.7	0.3	31.9	2.28	56.9
DE	57-6	4-Jul-85	54° 23.2'	131° 46.0'	53.9	0.6	21.6	1.8	34.8
DE	57-10	4-Jul-85	54° 23.2'	131° 46.0'	1.8	0.6	0.2	0.28	0.9
DE	57B-3/5	4-Jul-85	54° 23.2'	131° 46.0'	24.1	1.9	0.2	0.3	0.9
DE	57B-9/10	4-Jul-85	54° 23.2'	131° 46.0'	6.6	1.8	0.2	0.29	0.9
DE	57B-6/9	4-Jul-85	54° 23.2'	131° 46.0'	0	0.6	0.2	0.28	0.9
DE	58A-1	5-Jul-85	54° 23.3'	131° 45.9'	28	0.9	19	1.67	28.4
DE	58A-4	5-Jul-85	54° 23.3'	131° 45.9'	6.6	1.5	1.8	0.5	3.5
DE	58A-7	5-Jul-85	54° 23.3'	131° 45.9'	1.9	1.5	0.2	0.38	1.9
HS	6/0300	6-Jul-85	53° 46.6'	131° 22.7'	0	3.8	0.4	0.55	4.6
HS	6/0430	6-Jul-85	53° 32.5'	131° 09.0'	0	2.5	1.3	0.86	8
HS	6/0800	6-Jul-85	52° 57.1'	130° 35.6'	0	0.9	0.2	0.38	2.5
HS	6/0930	6-Jul-85	52° 42.0'	130° 21.6'	0	0.8	0.2	0.48	7.1
HS	6/1200	6-Jul-85	52° 17.7'	129° 59.1'	0	1.9	0.2	0.56	10.9
QCS	K4a	29-Jun-85	51° 38.0'	131° 00.0'	0	4.3	0	0.49	10.9
QCS	K4b	29-Jun-85	51° 38.8'	131° 00.0'	0	4.3	0	0.49	10.9
QCS	K4c	29-Jun-85	51° 38.0'	131° 00.0'	0	4.3	0	0.49	10.9
QCS	K4d	29-Jun-85	51° 38.0'	131° 00.0'	0	4.3	0	0.49	10.9
QCS	L2	29-Jun-85	51° 44.4'	131° 15.5'	0	1.9	4.8	0.78	15.5
QCS	29/0830	6-Jul-85	51° 17.5'	130° 34.0'	0	2.9	2.7	0.66	14.6
QCS	6/1530	6-Jul-85	51° 49.3'	129° 42.2'	0	0.9	0.1	0.4	8.2
QCS	6/1830	6-Jul-85	51° 40.7'	130° 33.0'	0	1.3	0.7	0.49	8.4
QCS	7/0030	7-Jul-85	51° 47.0'	130° 54.8'	0	1.9	3.1	0.7	13.9
QCS	7/0230	7-Jul-85	51° 36.7'	130° 35.2'	0	1	0.3	0.42	7.5
QCS	7/0430	7-Jul-85	51° 23.1'	130° 08.1'	0	0.9	0	0.43	10.5
QCS	7/0730	7-Jul-85	51° 05.0'	129° 31.3'	0	1.1	0	0.44	9.8
QCS	7/0930	7-Jul-85	51° 02.7'	129° 16.3'	0	2.4	0.2	0.43	8.7
QCS	7/1300	7-Jul-85	51° 02.7'	128° 28.5'	0	2.6	3.2	0.57	7.3
QCS	7/1500	7-Jul-85	51° 06.0'	127° 57.6'	0	1.8	17.5	1.47	27.6

Table 2.5.2. Summary of surface water (<10 m) nutrient data (29 June – 7 July 1985) from Forbes and Waters (1993).

	NO_3 ($mmol \cdot m^{-3}$)	**PO_4 ($mmol \cdot m^{-3}$)**	**SiO_2 ($mmol \cdot m^{-3}$)**
Dixon Entrance			
N	8	8	8
Mean	1.41	0.42	3.41
SD	2.20	0.15	3.35
Hecate Strait			
N	5	5	5
Mean	0.46	0.57	6.62
SD	0.48	0.18	3.22
Queen Charlotte Sound			
N	15	15	15
Mean	2.17	0.58	11.71
SD	4.52	0.27	5.05

Table 2.6.1. Mean nutrient concentrations grouped with respect to time of year.

		NO_3 ($mmol \cdot m^{-3}$)	**PO_4 ($mmol \cdot m^{-3}$)**	**SiO_2 ($mmol \cdot m^{-3}$)**
Jan-Feb	N	12	12	9
	Mean	14.21	1.21	16.04
April	N	9	9	7
	Mean	5.18	0.70	11.41
June	N	14	14	15
	Mean	0.86	0.42	7.40
July	N	76	74	78
	Mean	0.85	0.71	6.14
Aug.	N	0	1	0
	Mean		0.29	
Sept - Oct.	N	0	2	0
	Mean		0.28	

Table 3.2.1. Summary of the chlorophyll *a* and phaeopigment data from Dilke *et al* (1979).

	Chl *a* (μg·L^{-1})	**Phaeopigments (μg·L^{-1})**
Dixon Entrance		
N	4	4
Mean	1.11	1.15
SD	0.57	0.52
Hecate Strait		
N	12	12
Mean	1.83	0.74
SD	1.94	0.52

Table 3.3.1. Summary of the chlorophyll *a* data from Perry *et al* (1981).

	Chl *a* (μg·L^{-1})	**Phaeopigments (μg·L^{-1})**
Dixon Entrance		
N	5	5
Mean	1.86	0.63
SD	1.29	0.29
Hecate Strait		
N	30	30
Mean	1.48	0.65
SD	1.90	0.68

Table 3.4.1. Between site (Hecate Strait and Queen Charlotte Sound) comparisons of chlorophyll *a* concentrations (μg·L^{-1}) from Denman *et al* (1985).

	Chl *a* (μg·L^{-1})
Hecate Strait	
N	30
Mean	1.69
SD	1.30
Queen Charlotte Sound	
N	13
Mean	1.45
SD	0.92

Table 3.5.1. Summary of surface water (<10 m) chlorophyll *a* concentrations from Forbes and Waters (1993).

	Chl *a* (μg·L^{-1})
Dixon Entrance	
N	8
Mean	1.20
SD	0.47
Hecate Strait	
N	5
Mean	1.98
SD	1.24
Queen Charlotte Sound	
N	15
Mean	2.39
SD	1.33

Table 3.6.1. Mean chlorophyll *a* concentration (μg·L^{-1}) in Dixon Entrance estimated from OCTS 1997 satellite imagery (Ware and Thomson, unpublished data).

Date	**Chl *a* (μg·L^{-1})**
6-Apr-97	1.1
13-Apr-97	0.8
20-Apr-97	1.9
27-Apr-97	1.1
4-May-97	1
11-May-97	2.3
18-May-97	3.9
25-May-97	2.4
1-Jun-97	1.3
8-Jun-97	2.8
15-Jun-97	3

Table 3.6.2. Mean chlorophyll *a* concentration (µg·L^{-1}) in Queen Charlotte Sound estimated from CZCS Level-2 data (Ware 1979 unpublished data; Pan *et al* 1988), OCTS 1997 satellite imagery (Ware and Thomson, unpublished data), and measured in water samples collected in 1979 (indicated by *italics*, Pan *et al* 1988).

Date	Chl *a* (µg·L^{-1})
22-Apr-79	*1.8*
26-Apr-79	*1.9*
30-Apr-79	1.5
2-May-79	3.7
21-May-79	3.7
26-May-79	4.7
27-May-79	4.5
31-May-79	*1.3*
9-Jul-79	1.3
12-Jul-79	1.9
14-Jul-79	*1.4*
15-Jul-79	*1.1*
6-Aug-79	*2.5*
11-Aug-79	1.9
17-Aug-79	1.7
25-Aug-79	*1.7*
8-Sep-79	1.8
10-Sep-79	1.8
12-Sep-79	*2.1*
17-Sep-79	*2.4*
6-Apr-97	2
20-Apr-97	1.4
27-Apr-97	1.2
4-May-97	1.7
11-May-97	2.3
18-May-97	2.8
25-May-97	2.5
1-Jun-97	1.3
8-Jun-97	2.1
15-Jun-97	1.3

Table 3.6.3. Ware and Thomson (unpublished) comparison of chlorophyll concentration data (Chl *a* µg·L^{-1}) from Dixon Entrance and Queen Charlotte Sound.

	Mean	Standard Deviation	N
Dixon Entrance	1.96	1.00	11
Queen Charlotte Sound	2.11	0.93	30

Table 3.7.1. Summary of all available chlorophyll *a* data collected from surface samples (1-10 m depth). The data sources are Dilke *et al* 1979, Perry *et al* 1981, Denman *et al* 1985, Forbes and Waters 1993, and Ware and Thompson (unpublished).

Source	Location	Date	Chl *a* ($mg \cdot m^{-3}$)
Forbes	DE	04-Jul-85	0.9
Forbes	DE	04-Jul-85	1.1
Forbes	DE	04-Jul-85	1.6
Forbes	DE	04-Jul-85	0.6
Forbes	DE	04-Jul-85	1.8
Forbes	DE	04-Jul-85	0.6
Forbes	DE	05-Jul-85	1.5
Forbes	DE	05-Jul-85	1.5
Perry	DE	21-Jul-79	2.21
Perry	DE	21-Jul-79	3.33
Perry	DE	22-Jul-79	2.74
Perry	DE	12-Apr-80	0.55
Perry	DE	13-Apr-80	0.49
Dilke	DE	19-Aug-78	1.58
Dilke	DE	19-Aug-78	1.61
Dilke	DE	18-Oct-78	0.53
Dilke	DE	18-Oct-78	0.72
Ware	DE	06-Apr-97	1.1
Ware	DE	13-Apr-97	0.8
Ware	DE	20-Apr-97	1.9
Ware	DE	27-Apr-97	1.1
Ware	DE	04-May-97	1.0
Ware	DE	11-May-97	2.3
Ware	DE	18-May-97	3.9
Ware	DE	25-May-97	2.4
Ware	DE	01-Jun-97	1.3
Ware	DE	08-Jun-97	2.8
Ware	DE	15-Jun-97	3.0
Denman	HS	05-Jul-83	1.02
Denman	HS	05-Jul-83	1.43
Denman	HS	05-Jul-83	m
Denman	HS	05-Jul-83	m
Denman	HS	05-Jul-83	m
Denman	HS	05-Jul-83	0.19
Denman	HS	05-Jul-83	0.35
Denman	HS	05-Jul-83	0.46
Denman	HS	05-Jul-83	0.52

Table 3.7.1. (Continued)

Source	Location	Date	Chl *a* ($mg \cdot m^{-3}$)
Denman	HS	05-Jul-83	0.48
Denman	HS	05-Jul-83	1.25
Denman	HS	05-Jul-83	0.39
Denman	HS	05-Jul-83	0.43
Denman	HS	06-Jul-83	0.86
Denman	HS	06-Jul-83	3.98
Denman	HS	06-Jul-83	m
Denman	HS	06-Jul-83	4.44
Denman	HS	06-Jul-83	m
Denman	HS	06-Jul-83	3.92
Denman	HS	06-Jul-83	m
Denman	HS	06-Jul-83	3.07
Denman	HS	06-Jul-83	4.5
Denman	HS	06-Jul-83	m
Denman	HS	07-Jul-83	2.44
Denman	HS	07-Jul-83	2.94
Denman	HS	07-Jul-83	2.67
Denman	HS	07-Jul-83	2.14
Denman	HS	07-Jul-83	m
Denman	HS	07-Jul-83	m
Denman	HS	07-Jul-83	m
Denman	HS	07-Jul-83	m
Denman	HS	07-Jul-83	m
Denman	HS	07-Jul-83	1.87
Denman	HS	07-Jul-83	m
Denman	HS	07-Jul-83	1.87
Denman	HS	07-Jul-83	m
Denman	HS	08-Jul-83	0.99
Denman	HS	08-Jul-83	0.94
Denman	HS	08-Jul-83	m
Denman	HS	08-Jul-83	m
Denman	HS	08-Jul-83	0.99
Denman	HS	08-Jul-83	m
Denman	HS	09-Jul-83	2.66
Denman	HS	09-Jul-83	m
Denman	HS	09-Jul-83	m
Denman	HS	09-Jul-83	m
Denman	HS	09-Jul-83	1.05
Denman	HS	10-Jul-83	0.63
Denman	HS	10-Jul-83	0.55
Denman	HS	10-Jul-83	1.63

Table 3.7.1. (Continued)

Source	Location	Date	Chl *a* ($mg \cdot m^{-3}$)
Forbes	HS	06-Jul-85	3.8
Forbes	HS	06-Jul-85	2.5
Forbes	HS	06-Jul-85	0.9
Forbes	HS	06-Jul-85	0.8
Forbes	HS	06-Jul-85	1.9
Perry	HS	12-May-79	0.9
Perry	HS	27-Jun-79	5.34
Perry	HS	27-Jun-79	4.29
Perry	HS	27-Jun-79	0.87
Perry	HS	28-Jun-79	0.31
Perry	HS	28-Jun-79	1.19
Perry	HS	24-Jul-79	2.17
Perry	HS	24-Jul-79	2.17
Perry	HS	24-Jul-79	0.2
Perry	HS	24-Jul-79	0.2
Perry	HS	03-Feb-80	0.13
Perry	HS	03-Feb-80	0.12
Perry	HS	03-Feb-80	0.19
Perry	HS	03-Feb-80	0.25
Perry	HS	04-Feb-80	0.12
Perry	HS	04-Feb-80	0.2
Perry	HS	04-Feb-80	0.24
Perry	HS	04-Feb-80	0.24
Perry	HS	04-Feb-80	0.27
Perry	HS	04-Feb-80	0.34
Perry	HS	13-Apr-80	0.37
Perry	HS	13-Apr-80	3.52
Perry	HS	13-Apr-80	7.46
Perry	HS	14-Apr-80	0.6
Perry	HS	14-Apr-80	0.5
Perry	HS	02-Jun-80	3.46
Perry	HS	02-Jun-80	4.45
Perry	HS	02-Jun-80	0.29
Perry	HS	03-Jun-80	1.09
Perry	HS	03-Jun-80	3.05
Dilke	HS	19-Aug-78	0.19
Dilke	HS	21-Aug-78	1.16
Dilke	HS	21-Aug-78	1.15
Dilke	HS	22-Sep-78	1.16
Dilke	HS	22-Sep-78	2.32

Table 3.7.1. (Continued)

Source	Location	Date	Chl *a* (mg·m^{-3})
Dilke	HS	20-Oct-78	0.94
Dilke	HS	20-Oct-78	5.68
Dilke	HS	20-Oct-78	5.83
Dilke	HS	05-Jan-79	0.4
Dilke	HS	05-Jan-79	0.24
Dilke	HS	02-Apr-79	0.95
Dilke	HS	02-Apr-79	1.97
Denman	QCS	02-Jul-83	2.47
Denman	QCS	02-Jul-83	m
Denman	QCS	02-Jul-83	m
Denman	QCS	02-Jul-83	0.75
Denman	QCS	02-Jul-83	2.83
Denman	QCS	02-Jul-83	1.2
Denman	QCS	02-Jul-83	0.71
Denman	QCS	02-Jul-83	0.54
Denman	QCS	03-Jul-83	0.98
Denman	QCS	03-Jul-83	0.64
Denman	QCS	03-Jul-83	0.89
Denman	QCS	03-Jul-83	0.87
Denman	QCS	03-Jul-83	2.48
Denman	QCS	03-Jul-83	1.41
Denman	QCS	03-Jul-83	
Denman	QCS	03-Jul-83	3.12
Forbes	QCS	29-Jun-85	4.3
Forbes	QCS	29-Jun-85	4.3
Forbes	QCS	29-Jun-85	4.3
Forbes	QCS	29-Jun-85	4.3
Forbes	QCS	29-Jun-85	1.9
Forbes	QCS	06-Jul-85	2.9
Forbes	QCS	06-Jul-85	0.9
Forbes	QCS	06-Jul-85	1.3
Forbes	QCS	07-Jul-85	1.9
Forbes	QCS	07-Jul-85	1.0
Forbes	QCS	07-Jul-85	0.9
Forbes	QCS	07-Jul-85	1.1
Forbes	QCS	07-Jul-85	2.4
Forbes	QCS	07-Jul-85	2.6
Forbes	QCS	07-Jul-85	1.8

Table 3.7.1. (Continued)

Source	**Location**	**Date**	**Chl *a* ($mg \cdot m^{-3}$)**
Ware	QCS	22-Apr-79	1.8
Ware	QCS	26-Apr-79	1.9
Ware	QCS	30-Apr-79	1.5
Ware	QCS	02-May-79	3.7
Ware	QCS	21-May-79	3.7
Ware	QCS	26-May-79	4.7
Ware	QCS	27-May-79	4.5
Ware	QCS	31-May-79	1.3
Ware	QCS	09-Jul-79	1.3
Ware	QCS	12-Jul-79	1.9
Ware	QCS	14-Jul-79	1.4
Ware	QCS	15-Jul-79	1.1
Ware	QCS	06-Aug-79	2.5
Ware	QCS	11-Aug-79	1.9
Ware	QCS	17-Aug-79	1.7
Ware	QCS	25-Aug-79	1.7
Ware	QCS	08-Sep-79	1.8
Ware	QCS	10-Sep-79	1.8
Ware	QCS	12-Sep-79	2.1
Ware	QCS	17-Sep-79	2.4
Ware	QCS	06-Apr-97	2.0
Ware	QCS	20-Apr-97	1.4
Ware	QCS	27-Apr-97	1.2
Ware	QCS	04-May-97	1.7
Ware	QCS	11-May-97	2.3
Ware	QCS	18-May-97	2.8
Ware	QCS	25-May-97	2.5
Ware	QCS	01-Jun-97	1.3
Ware	QCS	08-Jun-97	2.1
Ware	QCS	15-Jun-97	1.3

Table 3.7.2. Monthly means and standard deviations for chlorophyll *a* concentrations (μg·L^{-1}) based on shallow water (<10 m) data from five data sets (Dilke *et al* 1979, Perry *et al* 1981, Denman *et al* 1985, Forbes and Waters 1993, Ware and Thomson unpublished).

Month	Mean Chl *a* (μg·L^{-1})	Standard deviation	Sample size
Jan	0	0	0
Feb	0.23	0.09	12
April	1.64	1.60	19
May	2.99	1.28	19
June	2.26	1.55	16
July	1.62	1.05	77
August	1.50	0.63	9
Sept	1.93	0.45	6
Oct	2.74	2.76	5

Table 3.7.3. Depth-stratified chlorophyll *a* concentrations (μg·L^{-1}) from Denman *et al* (1985) grouped into 5-m depth intervals.

Depth interval (m)	Mean Chl *a* (μg·L^{-1})	Standard deviation	Sample size
<5	2.21	1.35	9
5-10	1.18	0.88	16
10-15	2.05	1.45	21
15-20	3.74	3.18	16
20-25	5.10	4.97	17
25-30	9.25	5.89	15
>30	3.73	4.11	9

Table 3.7.4. Suggested correction required to estimate the actual chlorophyll concentration available in an integrated water column 30 m deep where mean chl *a* concentration is 3.92 μg·L^{-1}.

Depth strata from which the chlorophyll samples are taken	Mean chlorophyll *a* concentrations μg·L^{-1} based on data from Denman *et al* (1985)	Suggested correction required to estimate the actual chlorophyll concentration available in an integrated water column 30 m deep
0-5 m	2.21	multiply by 1.77
0-10 m	1.69	multiply by 2.31

Table 3.8.1. Summary of productivity data taken from Denman *et al* (1985). Sampling sites are Queen Charlotte Sound and Hecate Strait.

Area	**Date**	**Depth (m)**	**Chl *a* ($mg \cdot m^{-3}$)**	**Pmax ($mg\ C \cdot mg\ Chl\ a^{-1} \cdot h^{-1}$)**
QCS	2-Jul-83	4.40	m	7.30
QCS	2-Jul-83	4.00	0.75	m
QCS	3-Jul-83	17.50	m	11.70
QCS	3-Jul-83	17.10	1.41	m
QCS	3-Jul-83	4.60		21.00
QCS	3-Jul-83	4.60	3.12	m
HS	5-Jul-83	10.10	0.19	8.50
HS	5-Jul-83	32.80	0.97	17.70
HS	5-Jul-83	19.80	1.09	8.70
HS	6-Jul-83	14.80	4.29	16.00
HS	6-Jul-83	30.10	6.52	11.40
HS	6-Jul-83	9.10	3.07	12.70
HS	7-Jul-83	27.70	18.72	5.40
HS	7-Jul-83	29.50	14.43	6.70
HS	7-Jul-83	26.90	8.46	8.60
HS	7-Jul-83	26.10	15.49	5.90
HS	7-Jul-83	20.40	11.43	7.10
HS	7-Jul-83	22.90	12.59	4.20
HS	7-Jul-83	10.10	1.87	3.60
HS	8-Jul-83	10.00	0.99	6.00
HS	9-Jul-83	20.90	6.40	6.10
HS	9-Jul-83	10.50	1.05	3.50

Table 4.2.1. Summary of data sources analyzed in this report. Areas sampled are appended to each study. Samples were taken from Dixon Entrance, Hecate Strait, Queen Charlotte Sound (QCS), and Goose Island Bank (GIB).

Data set	Collection Years	Day and/or night	Collection Season	Samples Collected
Pacific Oceanographic Group (1958)	1957			
Dixon Entrance		day	summer	2
QCS		day	summer	10
LeBrasseur (1965)	1956 - 1962			
Dixon Entrance		day & night	summer & winter	20
Hecate Strait		day	summer	3
GIB & QCS		day & night	summer & winter	33
Fulton *et al* (1982)	1980			
Dixon Entrance		day & night	winter	29
Hecate Strait		day & night	winter	76
GIB & QCS		day & night	winter	20
Denman *et al* (1985)	1983			
Hecate Strait		day & night	summer	5
Burd and Jamieson (1991)	1988			
Hecate Strait		day	summer	20
IOS 1990 - 2001	1990 - 2001			
Dixon Entrance		day & night	summer	34
Hecate Strait		day & night	summer & winter	48
GIB & QCS		day & night	summer & winter	109

Table 4.3.2.1. Original (n=53) IOS taxonomic categories with respect to individual weight ranges (after Mackas and Galbraith 1991) and subjective size classifications used for assignment to the 10 taxonomic groups (group names) used to summarize the data in this report.

Group name	Taxonomic group	Weight (mg dw)
Small and medium copepods	*Acartia clausi*	0.002 - 0.007
	Acartia danae	0.0015 - 0.005
	Acartia longiremis	0.002 - 0.007
	Aetideus	0.023 - 0.05
	Calanus marshallae	0.008 - 0.23
	Calocalanus	0.0005 - 0.003
	Calanus pacificus	0.003 - 0.22
	Centropages	0.005 - 0.03
	Clausocalanus	0.0025 - 0.008
	Corycaeus	0.001 - 0.005
	Ctenocalanus	0.004 - 0.012
	Mesocalanus tenuicornis	0.007 - 0.04
	Metridia pacifica	0.012 - 0.14
	Microcalanus	0.0015 - 0.0035
	Oithona spinirostris, atlantica	0.002 - 0.0035
	Oithona similis	0.0005 - 0.001
	Oncaea	0.002 - 0.004
	Paracalanus	0.0015 - 0.0065
	Pseudocalanus	0.0018 - 0.012
	Racovitzanus	0.016 - 0.1
	Scolecithricella	0.0035 - 0.011
Large copepods	*Neocalanus plumchrus*	0.013 - 0.55
	Neocalanus cristatus	0.04 - 2.6
	Eucalanus bungii	0.008 - 0.68
	Eucalanus californicus	0.025 - 1.3
Chaetognatha general	Chaetognatha general	0.014 - 0.063
	Eukrohnia	0.18 - 1.4
	Sagitta decipiens, elegans	0.1 - 1.0
	Sagitta scrippsae	0.18 - 6.5
Euphausiids	Euphausiids (juvenile)	0.001 - 0.04
	Euphausia pacifica	0.65 - 8.5
	Thysanoessa inspinata	0.9 - 10.0
	Thysanoessa spinifera	1.25 - 31.0
Amphipod	Amphipod *Themisto*, *Parathemisto*	0.75 - 3.7
	Amphipod *Primno*	0.32 - 40
Urochordates, Salps etc	Urochordate Doliolids	0.2 - 1.2
	Urochordate larvae	0.01 - 0.2
	Urochordate Salps	7 - 130
Coelenterates	Coelenterates Hydrozoan medusae	0.5 - 60
	Coelenterates *Aurelia*, *Cyanea*, *Chrysaora*	200
	Coelenterates	0.2 - 15
	Ctenophores	0.9 - 6.9
Large items, molluscs (*Clione*) and polychaetes	Mollusc Pteropod *Clione*	0.5 - 3.5
	Polychaete	0.04 - 3.5
Small items including eggs	Barnacle larvae Cirripedia	0.04
	Cladocera, *Evadne*, *Podon*	0.005
	Ostracod *Conchoecia*	0.1
	Cyphocaris	
	General Eggs	0.0016
	Mollusc Pteropod *Limacina*	0.1 - 1
	Mollusc Gastropoda	0.002
Remainder	Other	

Table 4.3.3.1. Average biomass ($mg \cdot m^{-3}$ dw) for all of the stations found in Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound, aggregated into 10 taxonomic groups.

		Number of samples	Small and medium copepods	Large copepods	Chaetognatha general	Euphausiids	Amphipod	Urochordate Salps etc.	Coelenterates	Molluscs (*Clione*) and Polychaetes	Small items including eggs	Other Remainder
summer	night	50	19.96	4.06	2.45	14.57	0.15	1.93	2.57	0.27	23.49	12.04
summer	day	129	19.08	1.39	1.46	7.90	0.08	0.52	5.66	0.08	18.66	6.52
winter	night	5	2.33	0.08	0.71	6.23	0.20	0.03	0.03	0.00	0.46	2.89
winter	day	12	1.31	0.12	0.66	0.23	0.01	0.06	0.00	0.01	0.40	0.52

Table 4.3.4.1. Average biomass ($mg \cdot m^{-3}$ dw) for all of the stations found in Dixon Entrance, aggregated into 10 taxonomic groups. For small and medium copepods, the 95% confidence interval around the mean is shown in parentheses.

		Number of samples	Small and medium copepods	Large copepods	Chaetognatha general	Euphausiids	Amphipod	Urochordate Salps etc	Coelenterates	Molluscs (Clione) and Polychaetes	Small items including eggs	Other Remainder
summer	night	11	6.92 (2.8)	6.16	4.49	18.68	0.15	1.95	3.34	0.47	18.91	2.79
summer	day	23	3.73 (1.1)	3.17	2.62	3.72	0.22	0.38	5.30	0.11	10.11	2.16
winter	night	0	-	-	-	-	-	-	-	-	-	-
winter	day	0	-	-	-	-	-	-	-	-	-	-

Table 4.3.5.1. Average biomass (mg·m^{-3} dw) for all of the stations found in Hecate Strait, aggregated into 10 taxonomic groups. For small and medium copepods, the 95% confidence interval around the mean is shown in parentheses.

		Number of samples	Small and medium copepods	Large copepods	Chaetognatha general	Euphausiids	Amphipod	Urochordate Salps etc.	Coelenterates	Molluscs (*Clione*) and Polychaetes	Small items including eggs	Other Remainder
summer	night	9	52.73 (55.7)	1.11	1.23	17.51	0.21	1.75	3.08	0.03	14.10	13.07
summer	day	34	31.65 (20.5)	0.29	0.74	2.81	0.02	0.41	2.61	0.02	3.52	12.06
winter	night	1	0.07 (1.5)	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.90
winter	day	4	0.99 (6.4)	0.27	1.77	0.69	0.00	0.00	0.00	0.03	0.04	0.22

Table 4.3.6.1. Average biomass (mg·m^{-3} dw) for all of the stations found in Goose Island Bank and Queen Charlotte Sound aggregated 10 taxonomic groups. For small and medium copepods, the 95% confidence interval around the mean is shown in parentheses.

		Number of samples	Small and medium copepods	Large copepods	Chaetognatha general	Euphausiids	Amphipod	Urochordate Salps etc.	Coelenterates	Molluscs (*Clione*) and Polychaetes	Small items including eggs	Other Remainder
summer	night	31	16.13 (9.7)	4.08	2.04	12.35	0.13	1.97	2.16	0.26	27.54	15.06
summer	day	71	18.25 (10.9)	1.31	1.42	11.75	0.07	0.62	7.25	0.11	28.80	5.34
winter	night	3	3.87 (7.5)	0.02	1.00	9.45	0.32	0.03	0.05	0.00	0.56	4.79
winter	day	4	2.40 (4.5)	0.07	0.18	0.00	0.01	0.00	0.00	0.00	0.44	0.71

Table 4.3.7.1. Between-site ANOVA, Tukey and Kruskal Wallis analyses of all available summer biomass data (night and day combined) for Dixon Entrance (DE), Hecate Strait (HS), and Queen Charlotte Sound (QCS). A line joining adjacent cells indicates no significant difference at α=0.05. See text for details.

Taxonomic group	Test of H_o: mean biomasses are the same	Tukey comparison
Small copepods	reject (p=0.006)	DE QCS HS
Large copepods	reject (p=0.005)	DE QCS HS
Chaetognaths	reject (p=0.001)	DE QCS HS
Euphausiids	ANOVA - do not reject (p=0.507) Kruskal Wallis - reject (p<0.05)	DE QCS HS
Amphipods	do not reject (p=0.062)	DE QCS HS
Total biomass	do not reject (p=0.128)	DE QCS HS

Table 4.3.8.1. Average biomass (mg·m^{-3} dw) for all of the stations found in Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound, aggregated into 10 taxonomic groups, and summarized on a monthly basis.

Month	Period	Number of samples	Small and medium copepods	Large copepods	Chaetognatha	Euphausiids	Amphipods	Urochordate Salps etc.	Coelenterates	Molluscs (*Clione*) and Polychaetes	Small items including eggs	Other Remainder
April	night	0										
May	night	18	9.78	7.27	2.19	9.77	0.07	2.25	4.96	0.20	41.46	23.12
June	night	10	18.61	6.24	2.98	7.49	0.33	2.30	2.56	0.95	30.55	11.58
July	night	2	23.83	1.72	2.42	68.78	0.84	0.00	6.52	0.10	0.99	5.93
Aug	night	6	73.04	0.34	2.55	0.08	0.00	0.30	0.02	0.00	2.23	1.86
Sept	night	2	14.30	0.00	2.32	24.34	0.11	0.00	0.00	0.00	0.01	2.15
Oct	night	12	10.11	0.38	2.37	24.24	0.06	2.59	0.02	0.01	8.94	3.56
April	day	3	4.49	1.25	1.34	0.08	0.00	0.00	0.02	0.00	38.06	1.97
May	day	23	14.41	3.17	0.58	2.40	0.06	1.74	3.95	0.11	48.45	17.13
June	day	35	30.22	2.38	0.72	1.29	0.09	0.30	14.53	0.19	26.05	9.21
July	day	23	13.92	0.42	2.05	3.85	0.08	0.20	4.44	0.01	8.40	1.49
Aug	day	20	24.14	0.19	2.19	4.67	0.05	0.06	0.71	0.02	0.66	1.61
Sept	day	10	16.91	0.39	4.29	63.49	0.26	0.22	1.43	0.11	2.11	3.69
Oct	day	15	5.77	0.10	0.83	6.75	0.06	0.57	0.06	0.00	2.61	1.02
winter	night	5	2.33	0.08	0.71	6.23	0.20	0.03	0.03	0.00	0.46	2.89
winter	day	12	1.31	0.12	0.66	0.23	0.01	0.06	0.00	0.01	0.40	0.52

Table 4.3.8.2. Average biomass (mg·m^{-3} dw) and 95% CIs (in parentheses) for all of the stations found in Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound, aggregated into 10 taxonomic groups, and summarized on a monthly basis.

Month	Period	Number of samples	Small and medium copepods	Large copepods	Chaetognatha	Euphausiids	Amphipods	Urochordate Salps etc.	Coelenterates	Molluscs (*Clione*) and Polychaetes	Small items including eggs	Other Remainder
April	night	0										
May	night	18	9.78	7.27	2.19	9.77	0.07	2.25	4.96	0.20	41.46	23.12
			(4.7)	(4.1)	(1.1)	(4.4)	(0.1)	(2.0)	(4.4)	(0.2)	(36.0)	(36.8)
June	night	10	18.61	6.24	2.98	7.49	0.33	2.30	2.56	0.95	30.55	11.58
			(17.7)	(5.4)	(2.6)	(8.1)	(0.5)	(3.1)	(2.5)	(1.1)	(26.4)	15.7)
July	night	2	23.83	1.72	2.42	68.78	0.84	0.00	6.52	0.10	0.99	5.93
			(102.3)	(20.4)	(2.7)	(309.1)	(0.7)		(32.6)	(1.3)	(1.1)	(20.3)
Aug	night	6	73.04	0.34	2.55	0.08	0.00	0.30	0.02	0.00	2.23	1.86
			(88.1)	(0.6)	(2.9)	(0.2)		(0.7)	(0.1)		(2.8)	(1.9)
Sept	night	2	14.30	0.00	2.32	24.34	0.11	0.00	0.00	0.00	0.01	2.15
			(26.1)	(0.0)	(25.1)	(273.0)	(0.7)				(0.1)	(3,4)
Oct	night	12	10.11	0.38	2.37	24.24	0.06	2.59	0.02	0.01	8.94	3.56
			(3.4)	(0.7)	(1.6)	(34.3)	(0.1)	(2.3)	(0.1)	(0.1)	(12.3)	(2.3)
April	day	3	4.49	1.25	1.34	0.08	0.00	0.00	0.02	0.00	38.06	1.97
			(6.6)	(5.2)	(4.2)	(0.3)			(0.1)		(158.0)	(5.9)
May	day	23	14.41	3.17	0.58	2.40	0.06	1.74	3.95	0.11	48.45	17.13
			(10.8)	(2.1)	(3.5)	(2.4)	(0.1)	(0.9)	(4.9)	(0.1)	(57.1)	(19.1)
June	day	35	30.22	2.3	0.72	1.29	0.09	0.30	14.53	0.19	26.05	9.21
			(20.1)	(1.9)	(0.3)	(1.1)	(0.1)	(0.3)	(9.6)	(3.1)	(19.1)	(5.1)
July	day	23	13.92	0.42	2.05	3.85	0.08	0.20	4.44	0.01	8.40	1.49
			(13.2)	(0.2)	(1.9)	(3.1)	(0.1)	(0.2)	(2.1)	(0.1)	(8.6)	(0.7)
Aug	day	20	24.14	0.19	2.19	4.67	0.05	0.06	0.71	0.02	0.66	1.61
			(35.9)	(0.2)	(1.4)	(4.8)	(0.1)	(0.1)	(0.5)	(0.1)	(0.4)	(0.9)
Sept	day	10	16.91	0.39	4.29	63.49	0.26	0.22	1.43	0.11	2.11	3.69
			(8.9)	(0.5)	(3.6)	(65.8)	(0.4)	(0.2)	(2.2)	(0.3)	3.1)	(2.7)
Oct	day	15	5.77	0.10	0.83	6.75	0.06	0.57	0.06	0.00	2.61	1.02
			(1.8)	(0.1)	(0.5)	(7.2)	(0.1)	(0.4)	(0.1)		(2.6)	(0.8)
winter	night	5	2.33	0.08	0.71	6.23	0.20	0.03	0.03	0.00	0.46	2.89
			(3.7)	(0.9)	(0.9)	(9.9)	(0.4)	(0.1)	(0.1)		(0.7)	(5.4)
winter	day	12	1.31	0.12	0.66	0.23	0.01	0.06	0.00	0.01	0.40	0.52
			(1.1)	(0.2)	(0.9)	(0.5)	(0.1)	(0.10		(0.1)	(.05)	(0.4)

Table 4.3.8.3. Statistical comparisons and associated probabilities for a two-way AVOVA. Non-parametric Kruskal Wallis or Mann Whitney U tests probabilities are included in parentheses.

Comparison	Probability
Small and medium copepod - monthly means	$p = 0.064$
Small and medium copepod - day vs. night	$p = 0.437$ (0.02)
Euphausiid - monthly means	$p = 0.001$
Euphausiid - day vs. night	$p = 0.143$ (0.002)

Table 4.4.2.1. Pacific Oceanographic Group (1958) zooplankton taxonomic group biomass ($mg \cdot m^{-3}$ dw) for Dixon Entrance, and Queen Charlotte Sound (QCS).

Date (1957)	Station Number	Time	Total zooplankton	Gastropods	Amphipods	Copepods	Decapods	Euphausiids	Chaetognaths
Dixon Entrance									
April 14-May 15	26	08.59	7.35	0.00	0.00	7.35	0.00	0.00	0.00
July 2-July 12	26	18:44	28.50	0.00	0.00	11.37	0.00	0.00	17.50
Queen Charlotte Sound									
April 14-May 15	48	03:14	31.00	0.02	0.02	30.00	0.02	0.00	0.95
April 14-May 15	49	07:28	41.00	0.00	0.00	39.50	0.00	0.00	0.42
April 14-May 15	50	10:45	22.33	0.00	0.00	22.33	0.00	0.00	0.00
April 14-May 15	51	12:32	2.00	0.00	0.00	1.73	0.00	0.00	0.00
April 14-May 15	52	14:23	12.00	0.00	0.00	10.67	0.00	0.00	1.33
Sept 18-Oct 02	48	11:15	6.57	0.00	0.00	5.25	0.00	1.40	0.00
Sept 18-Oct 02	49	14:50	13.85	0.00	0.00	3.07	0.00	6.15	4.62
Sept 18-Oct 02	50	17:29	17.23	0.00	0.00	5.65	0.00	0.23	11.08
Sept 18-Oct 02	51	19:26	14.58	0.00	0.00	13.53	0.00	0.00	1.03
Sept 18-Oct 02	52	21:02	13.08	0.00	0.00	1.53	0.00	12.32	0.77

Table 4.4.3.1. LeBrasseur (1965) zooplankton taxonomic group biomass (mg·m^{-3} dw) for Dixon Entrance (DE), Hecate Strait (HS) and Queen Charlotte Sound (QCS); summarized from the original wet weigh data mapped by LeBrasseur (1965).

Area	Season	Date	Ship	N	Total Zooplankton	Copepods	Euphausiids	Amphipods	Chaetognaths	Pteropods
DE	**winter**									
	1957	23 Jan - 4 March	*Oshawa*	1	0.67	0.33	0.00	0.00	0.17	0.00
	1957	24 Jan - 4 March	*Oshawa*	1	0.33	.	0.00	.	0.17	0.00
	1957	25 Jan - 4 March	*Oshawa*	1	7.00	1.00	0.17	.	.	.
DE	**summer**									
	1956	22 May - 10 June	*Key West*	1	30.17	27.17	0.83	0.00	1.50	0.00
	1956	30 July - 13 Sept	*Oshawa*	1	9.33	0.50	0.50	0.17	0.17	0.00
	1956	31 July - 13 Sept	*Oshawa*	1	29.50	4.33	0.00	5.67	17.17	0.00
	1956	32 July - 13 Sept	*Oshawa*	1	11.50	2.33	5.83	0.00	3.50	0.00
	1957	25 April - 30 May	*Fort Ross*	1	31.33	30.67	0.00	0.00	0.33	0.00
	1957	26 April - 30 May	*Oshawa*	1	7.33	7.33	0.00	0.00	0.00	0.00
	1957	6 June - 6 July	*Oshawa*	1	28.50	11.33	0.00	0.00	1.67	3.00
	1957	26 Nov - 3 Dec	*Oshawa*	1	3.50	0.17	3.00	0.33	1.83	0.00
	1957	27 Nov - 3 Dec	*Oshawa*	1	3.83	0.83	0.00	2.50	0.17	0.00
	1958	11 March - 1 April	*Oshawa*	1	3.50	2.67	0.50	0.00	0.17	0.00
	1958	12 March - 1 April	*Oshawa*	1	3.50	0.17	0.17	0.00	0.00	0.00
	1958	22 July - 22 August	*Oshawa*	1	63.83	19.50	39.00	0.67	3.83	0.00
	1960	28 June - 6 August	*Oshawa*	1	8.83	0.50	3.00	0.00	5.33	0.00
	1961	16 May - 30 June	*Western Crusader*	1	34.33	20.67	0.00	0.00	1.67	12.00
	1962	28 May - 13 June	*Oshawa*	1	14.00	11.17	1.33	0.00	0.83	0.00
	1962	28 May - 13 June	*Oshawa*	1	22.33	6.67	6.67	0.17	6.67	0.17
	1962	28 May - 13 June	*Oshawa*	1	39.17	19.67	3.50	0.00	15.67	0.00
HS	**summer**									
	1957	25 April - 30 May	*Fort Ross*	1	12.33	2.33	9.17	0.00	0.83	0.00
	1959	20 May - 24 June	*Oshawa*	1	7.50	3.50	1.00	0.00	0.00	.
	1959	21 May - 24 June	*Oshawa*	1	13.33	7.83	4.67	0.00	0.00	0.67
QCS	**winter**									
	1958	12 March - 1 April	*Oshawa*	1	0.67	0.17	0.00	0.00	0.33	0.00
	1958	12 March - 1 April	*Oshawa*	1	0.67	0.33	0.00	0.00	0.33	0.00
	1958	12 March - 1 April	*Oshawa*	1	7.67	1.17	6.00	0.00	1.83	0.00

Table 4.4.3.1. (Continued)

Area	Season	Date	Ship	N	Total Zooplankton	Copepods	Euphausiids	Amphipods	Chaetognaths	Pteropods
QCS	**summer**									
	1957	25 April - 30 May	*Oshawa*	1	31.00	30.00	0.00	0.00	1.00	0.00
	1957	26 April - 30 May	*Oshawa*	1	22.33	22.33	0.00	0.00	0.00	0.00
	1957	27 April - 30 May	*Oshawa*	1	41.17	39.83	0.00	0.00	0.50	0.00
	1957	9 Aug - 30 Aug	*Oshawa*	1	10.17	9.17	0.17	0.33	0.17	0.17
	1957	10 Aug - 30 Aug	*Key West*	1	8.33	5.83	1.67	0.00	0.50	0.00
	1957	11 Aug - 30 Aug	*Key West*	1	2.83	2.33	0.00	0.00	0.83	0.00
	1957	18 Sept - 2 Oct	*Oshawa*	1	6.67	5.33	0.00	0.00	1.33	0.00
	1957	19 Sept - 2 Oct	*Oshawa*	1	13.83	3.17	6.17	0.00	4.67	0.00
	1957	20 Sept - 2 Oct	*Oshawa*	1	17.33	5.67	0.00	0.00	11.17	0.00
	1958	10 May - 30 June	*Oshawa*	1	22.17	12.50	0.00	0.00	0.67	0.00
	1958	11 May - 30 June	*Oshawa*	1	13.83	11.17	0.17	0.17	2.00	0.00
	1958	22 July - 22 August	*Oshawa*	1	33.83	19.67	14.33	0.00	0.00	0.00
	1958	22 July - 22 August	*Oshawa*	1	19.67	18.33	0.17	0.50	0.17	0.00
	1958	22 July - 22 August	*Oshawa*	1	20.67	20.00	0.00	0.17	0.17	0.00
	1958	22 July - 22 August	*Oshawa*	1	8.33	4.17	0.00	2.17	1.67	0.50
	1958	22 July - 22 August	*Oshawa*	1	8.33	6.83	0.83	0.00	0.00	0.00
	1959	31 March - 25 May	*Key West*	1	4.50	0.83	0.00	0.00	0.00	3.67
	1959	32 March - 25 May	*Key West*	1	7.67	0.83	1.50	0.00	0.00	5.33
	1959	20 May - 24 June	*Oshawa*	1	10.00	1.00	2.67	0.00	0.00	6.00
	1959	21 May - 24 June	*Oshawa*	1	5.83	5.83	0.00	0.00	0.00	0.00
	1959	26 July - 29 August	*Fort Ross*	1	26.83	24.83	0.00	2.00	0.00	0.00
	1959	26 July - 29 August	*Fort Ross*	1	36.50	30.00	4.67	0.00	1.17	0.00
	1960	8 May - 5 Jane	*Fort Ross*	1	11.83	10.67	0.50	0.00	0.00	0.00
	1960	28 June - 6 August	*Oshawa*	1	3.50	3.17	0.00	0.00	0.17	0.00
	1960	28 June - 6 August	*Oshawa*	1	1.33	1.17	0.00	0.17	0.00	0.00
	1962	10 May - 24 May	*Whitethroat*	1	8.33	6.67	0.83	0.00	0.33	0.17
	1962	18 June - 30 June	*Oshawa*	1	19.00	8.33	3.33	0.00	0.00	2.50
	1963	20 May - 3 June	*Western Crusader*	1	31.50	25.17	0.00	0.33	3.17	1.50
	1963	20 May - 3 June	*Western Crusader*	1	16.83	6.67	5.00	0.00	1.67	0.83
	1963	20 May - 3 June	*Western Crusader*	1	4.17	1.67	0.00	0.33	1.67	0.33

Table 4.4.4.1. Fulton *et al* (1982) dry weight biomasses (mg·m^{-3}) for euphausiids and other zooplankton for stations from Dixon Entrance (DE), Hecate Strait (HS) and Queen Charlotte Sound (QCS). All samples were collected during the winter. Some samples were too small to weigh (TSW) or contained too much phytoplankton (TMP) in the sample.

	Date (1980)	Night/Day	Station	Depth	Euphausiids	Other zooplankton
DE	19-Jan	day	52	307	2.16	27.17
	19-Jan	day	53	350	0.93	26.86
	19-Jan	day	54	183	5.64	19.84
	20-Jan	day	55	234	13.34	118.47
	20-Jan	day	56	96	TSW	TSW
	17-Feb	day	49	430	0.95	27.52
	18-Feb	day	50	261	1.46	21.43
	19-Feb	day	51	247	7.31	10.97
	20-Feb	day	52	278	1.28	18.66
	21-Feb	night	53	304	26.56	21.66
	22-Feb	night	54	152	16.99	18.34
	23-Feb	night	55	234	46.38	TSW
	24-Feb	night	56	147	33.37	23.97
	16-Mar	night	49	1204	1.86	11.13
	16-Mar	night	50	256	24.82	9.37
	16-Mar	night	51	256	29.00	9.05
	17-Mar	night	52	384	4.44	12.33
	17-Mar	night	53	375	8.96	132.45
	17-Mar	day	54	256	5.84	76.86
	17-Mar	day	55	275	3.31	54.79
	17-Mar	day	56	143	3.08	113.94
	20-Apr	night	49	1463	0.36	31.84
	20-Apr	day	50	220	2.05	93.16
	20-Apr	day	51	274	2.78	32.88
	20-Apr	day	52	380	14.93	35.98
	20-Apr	day	53	373	3.42	58.11
	20-Apr	day	54	285	5.00	75.36
	20-Apr	day	55	284	10.37	43.17
	20-Apr	night	56	137	4.28	TMP
HS	20-Jan	day	57	21	TSW	TSW
	20-Jan	day	58	29	0.03	TSW
	20-Jan	day	59	69	TSW	TSW
	20-Jan	night	60	129	0.33	TSW
	20-Jan	night	61	34	0.26	TSW
	20-Jan	night	62	18	0.22	TSW
	21-Jan	night	63	34	0.12	TSW
	21-Jan	night	64	116	0.17	TSW
	21-Jan	day	65	169	6.40	TSW
	21-Jan	day	66	190	4.65	31.97
	21-Jan	day	67	151	1.70	TSW
	21-Jan	night	68	219	3.21	18.37
	21-Jan	night	69	78	TSW	TSW
	21-Jan	night	70	119	1.51	TSW
	21-Jan	night	71	194	13.54	TSW
	21-Jan	night	72	202	78.76	8.75
	21-Jan	day	73	78	1.05	TSW
	21-Jan	day	74	155	1.86	TSW

Table 4.4.4.1. (Continued)

	Date (1980)	Night/Day	Station	Depth	Euphausiids	Other zooplankton
HS	21-Jan	day	75	84	TSW	TSW
	18-Feb	night	57	13	0.00	TSW
	18-Feb	night	58	18	0.00	TSW
	18-Feb	day	59	51	0.00	TSW
	18-Feb	day	60	101	0.00	TSW
	18-Feb	day	61	26	0.00	TSW
	18-Feb	day	62	18	0.00	TSW
	18-Feb	night	63	16	0.00	TSW
	18-Feb	night	64	106	0.00	TSW
	18-Feb	night	65	170	336.68	TSW
	18-Feb	night	66	168	18.12	TSW
	19-Feb	night	67	176	17.96	TSW
	19-Feb	night	68	238	1.58	TSW
	19-Feb	day	69	62	0.00	TSW
	19-Feb	day	70	97	0.00	TSW
	19-Feb	day	71	97	1.65	TSW
	19-Feb	day	72	190	6.75	TSW
	19-Feb	night	73	208	0.37	TSW
	19-Feb	night	74	100	235.44	TSW
	19-Feb	night	75	119	4.14	TSW
	17-Mar	day	57	24	0.00	TMP
	17-Mar	day	58	36	0.00	34.36
	17-Mar	day	59	64	0.05	6.16
	17-Mar	night	60	110	5.83	21.28
	17-Mar	night	61	37	0.08	19.81
	18-Mar	night	62	24	0.00	TMP
	18-Mar	night	63	31	0.00	139.55
	18-Mar	day	64	92	1.28	11.01
	18-Mar	day	65	220	11.15	24.15
	18-Mar	day	66	256	0.00	22.13
	18-Mar	day	67	200	1.88	15.53
	18-Mar	day	68	310	0.32	TMP
	18-Mar	night	69	99	TSW	11.74
	18-Mar	night	70	137	0.13	11.98
	18-Mar	night	71	245	148.07	16.29
	19-Mar	night	72	284	117.24	20.21
	19-Mar	night	73	117	97.61	66.51
	19-Mar	night	74	201	10.80	36.48
	19-Mar	day	75	117	0.06	42.62
	20-Apr	night	58	18	0.00	.
	21-Apr	night	59	37	0.00	.
	21-Apr	night	60	70	TSW	47.33
	21-Apr	night	61	139	1.50	30.91
	21-Apr	day	62	37	0.00	.
	21-Apr	day	63	22	0.00	44.45
	21-Apr	day	64	24	22.29	.
	21-Apr	day	65	55	0.00	.
	21-Apr	day	66	187	2.57	21.92
	21-Apr	day	67	220	1.85	46.06
	21-Apr	night	68	183	227.90	31.55
	21-Apr	night	69	311	44.13	TSW

Table 4.4.4.1. (Continued)

	Date (1980)	Night/Day	Station	Depth	Euphausiids	Other zooplankton
HS	22-Apr	night	70	102	0.00	24.00
	22-Apr	night	71	146	0.00	47.55
	22-Apr	day	72	229	8.62	TMP
	22-Apr	day	73	283	7.01	55.60
	22-Apr	day	74	110	0.00	TMP
	22-Apr	day	75	192	6.61	22.86
	22-Apr	day	57	113	0.04	30.54
QCS	22-Jan	night	29	170	31.95	7.99
	22-Jan	night	30	38	0.08	TSW
	22-Jan	night	31	54	TSW	TSW
	22-Jan	day	32	144	2.50	TSW
	17-Jan	night	33	477	0.39	TSW
	20-Feb	night	29	192	42.96	33.00
	20-Feb	night	30	46	0.17	TSW
	20-Feb	night	31	55	0.00	TSW
	15-Feb	day	32	148	3.68	TSW
	15-Feb	day	33	445	11.35	19.24
	19-Mar	day	29	194	11.01	49.60
	19-Mar	day	30	53	0.09	63.23
	19-Mar	day	31	55	0.00	67.78
	14-Mar	day	32	183	8.11	31.18
	14-Mar	day	33	914	3.07	11.12
	23-Apr	day	29	183	12.65	153.20
	23-Apr	night	30	42	0.00	TMP
	23-Apr	night	31	55	0.04	TMP
	23-Apr	night	32	183	66.99	118.91
	22-Apr	night	33	914	1.13	31.44

Table 4.4.5.1. Denman *et al* (1985) zooplankton biomasses (mg·m^{-3} dw) transformed from original data tabulated as numbers per m^{-2}.

	Station	70	72	77	78	84
	Longitude	128° 53’5”	129° 27’5”	130° 21’1”	130° 13’7”	130° 51’0”
	Latitude	51° 42’4”	51° 55’4”	53° 05’5”	53° 19’8”	53° 13’6”
Mean weight based on 65 IOS stations (mg dw per individual)	**Depth (m)**	79	61	110	57	107
	Date (1983)	5-July	5-July	5-July	5-July	7-July
	Day/night	night	day	day	day	night
	Taxonomic group					
0.006	*Acartia clausi*	0.00	0.00	0.00	0.00	0.00
	Acartia danae	0.00	0.00	0.00	0.00	0.00
0.005	*Acartia longiremis*	1.50	0.76	1.14	5.46	0.17
0.045	*Aetideus*	0.00	0.00	0.00	0.00	0.00
0.129	*Calanus marshallae*	0.58	21.87	20.32	42.26	2.60
0.003	*Calocalanus*	0.00	0.00	0.00	0.00	0.00
0.146	*Calanus pacificus*	1.30	0.44	3.09	18.67	2.93
0.016	*Centropages*	0.14	0.00	0.00	1.53	0.00
0.049	Chaetognatha general	0.01	0.36	0.28	0.23	0.01
0.125	Barnacle larvae Cirripedia	0.00	0.00	0.00	5.94	9.36
0.005	Cladocera, *Evadne, Podon*	0.00	0.00	0.00	0.00	0.00
0.009	*Clausocalanus*	0.00	0.11	0.12	0.00	0.02
2.901	Mollusc Pteropod *Clione*	0.00	0.00	0.00	0.00	0.00
0.100	Ostracod *Conchoecia*	0.00	0.00	0.65	0.00	0.00
0.003	*Corycaeus*	0.00	0.00	0.00	0.00	0.00
0.008	*Ctenocalanus*	0.00	0.14	0.00	0.00	0.05
1.244	Ctenophores	0.79	0.00	0.00	0.13	0.07
2.400	*Cyphocaris*	0.00	0.00	0.00	0.00	0.00
0.032	Urochordate Doliolids	0.00	0.00	0.00	0.00	0.00
0.004	General Eggs	0.00	0.00	0.31	0.00	0.00
0.417	*Eucalanus bungii*	0.03	2.84	0.21	0.00	0.00
1.102	*Eucalanus californicus*	0.00	0.00	0.00	0.00	0.00
0.751	Euchaeta	0.00	0.60	0.16	0.00	0.00
0.610	*Eukrohnia*	0.00	2.88	0.45	0.41	0.00
0.003	Euphausiids (juv)	0.12	0.00	0.03	0.16	0.01
2.995	*Euphausia pacifica*	0.00	1.87	0.74	0.00	0.00
0.038	Urochordate larvae	4.77	0.00	0.00	24.61	9.52
0.626	Mollusc Pteropod *Limacina*	33.46	3.74	4.07	29.85	23.00
7.327	Coelenterates Hydrozoan medusae	0.00	0.00	0.00	0.00	0.00
0.018	*Mesocalanus tenuicornis*	0.00	0.00	0.00	0.00	0.00
0.063	*Metridia pacifica*	1.12	10.75	6.59	3.01	0.84
0.002	*Microcalanus*	0.00	0.03	0.03	0.00	0.00
0.002	Mollusc Gastropoda	0.00	0.00	0.00	0.00	0.00
1.368	*Neocalanus cristatus*	0.00	2.78	0.21	0.00	0.00
0.213	*Neocalanus plumchrus*	0.00	3.09	0.60	0.21	0.03
0.003	*Oithona spinirostris, atlantica*	0.00	0.06	0.00	0.00	0.00
0.001	*Oithona similis*	1.55	0.66	1.02	2.16	0.80
	Oncaea	0.00	0.00	0.00	0.00	0.00
0.004	*Paracalanus*	0.47	0.03	0.12	0.89	0.43
1.054	Amphipod *Themisto, Parathemisto*	0.00	0.00	0.00	0.00	0.00
1.783	Amphipod *Primno*	0.00	0.00	0.00	0.16	3.07
0.008	*Pseudocalanus*	20.50	7.85	13.79	70.39	3.49
0.064	*Racovitzanus*	0.00	0.00	0.00	0.00	0.00
0.032	Other	2.34	0.57	0.21	3.90	6.30
0.531	*Sagitta decipiens, elegans*	0.00	0.89	0.32	0.00	0.03
5.126	*Sagitta scrippsae*	0.00	0.45	0.25	0.00	0.00
9.360	Urochordate Salps	0.00	0.00	0.47	0.00	0.00
0.008	*Scolecithricella*	0.07	0.07	0.00	0.18	0.00
134.956	Coelenterates *Aurelia, Cyanea, Chrysaora*	0.00	0.00	0.00	0.00	0.00
0.467	Coelenterates	0.00	0.00	0.00	0.00	0.00
3.713	*Thysanoessa inspinata*	0.00	0.00	0.00	0.00	0.00
14.288	*Thysanoessa spinifera*	0.00	1.41	10.65	0.00	0.00
1.264	Polychaete	0.00	0.00	0.00	0.00	10.56

Table 4.4.6.1. Burd and Jamieson (1991) Tucker trawl biomasses (mg·m^{-3} dw) collected in Hecate Strait during 1988. Times are ranges over which each sample was collected. Depth ranges bracket the depths over which the first and then the second Tucker nets were hauled. Biomasses for each taxonomic group are averaged over the two haul depths.

Date (1988)	Time	Station	Depth 1	Depth 2	Amphipods	Copepods	Euphausiids	Chaetognaths
13-Jun	07:24 – 09:07	48	49-26	26-0	0.07	1.82	9.59	0.13
13-Jun	10:42 – 11:55	49	49-25	25-0	0.28	0.34	6.38	0.02
13-Jun	15:51 – 16:55	50	45-26	26-0	0.24	2.45	41.37	0.00
13-Jun	18:15 – 21-45	51	55-25	25-0	0.24	32.02	16.80	0.02
14-Jun	09:03 – 10:11	73	49-21	21-0	0.07	0.30	3.00	0.00
14-Jun	11:46 – 13:15	74	55-26	26-0	0.27	20.32	74.08	0.02
14-Jun	14:10	75	44-21	21-0	0.13	11.07	257.69	0.04
14-Jun	15:54 - 17:10	76	47-23	23-0	0.77	21.03	97.57	0.05
14-Jun	18:06	77	51-23	23-0	0.05	6.34	150.90	0.01
15-Jun	08:10 - 09:45	98	53-25	25-0	0.09	0.43	11.42	0.03
15-Jun	10:58 - 12:10	99	47-21	21-0	0.01	0.03	2.43	0.01
15-Jun	13:05	100	20-10	23-0	0.01	0.10	2.63	0.00
16-Jun	06:52 - 08:50	118	27		0.01	0.02	7.90	0.00
17-Jun	10:55 - 11:51	119	10		0.01	0.05	0.57	0.00
17-Jun	13:00 - 14:03	120	33		2.40	0.02	4.58	0.00
17-Jun	15:03 - 16:10	121	20		0.03	0.11	8.76	0.00
17-Jun	17.25 - 18:50	122	22		0.01	0.06	4.52	0.00
18-Jun	16:28 - 17:37	126	33		0.04	0.00	3.43	0.01
18-Jun	18:30 - 19:37	127	33		0.00	0.01	4.52	0.01
18-Jun	20:40 - 21:55	128	33		0.00	0.00	4.75	0.01

Table 4.5.1. Summary of reported and transformed mean zooplankton biomasses collected between 1957 and 2001. Where necessary, the original data were transposed to common units (mg·m^{-3} dw) using methods described in the text. See text for analysis. Italic data are likely to be incorrect. Underline data are probably better but may represent underestimates. Bold data are likely the most accurate.

Data set	Data	Number of samples	Years	Total zooplankton	Total copepods	Euphausiids
Pacific Oceanographic Group (1958)	mean summer day	12	1957	17.46	12.67	**1.68**
LeBrasseur (1965)	mean summer day & night	50	1956-1962	16.92	10.45	**2.42**
Fulton *et al* (1982)	winter day	125	1980	**56.41**		**16.50**
Denman *et al* (1985)	mean summer night & day	5	1983	*96.45*	*3.00*	*56.42*
Burd and Jamieson (1991)	mean summer day	20	1988		*4.82*	**35.64**
IOS 1990 - 2001	mean summer night & day	196	1990-2001	**66.98**	**21.46**	**9.76**

Table 4.5.2. Summary of reported average zooplankton biomasses ($mg \cdot m^{-3}$ dw) collected between 1956 and 2001. All of the original data have been transposed to common units ($mg \cdot m^{-3}$ dw) using methods described in earlier sections of this report. ENSO events are summarized from the in-text tables.

Data set	Data	Years	ENSO events and strength at McInnes Island	Total zooplankton	Total copepods	Euphausiids
Pacific Oceanographic Group (1958)	mean summer day	1957	1957-58 moderate	17.46	12.67	1.68
LeBrasseur (1965)	mean summer day & night	1957-58	1957-58 moderate	17.91	11.85	3.10
LeBrasseur (1965)	mean summer day & night	1958	1958 moderate	21.04	12.02	6.04
Fulton *et al* (1982)	winter day	1980	1980 no ENSO	56.41		16.50
Denman *et al* (1985)	mean summer night & day	1983	1982-83 very strong	96.45	3.00	56.42
Burd and Jamieson (1991)	mean summer day	1988	1988 no ENSO		4.82	35.64
IOS 1990 - 2001	mean summer night & day	1990 - 2001	see next section	66.98	21.46	9.76

Table 4.6.1. IOS data base summer average biomasses (mg·m^{-3} dw) for the major zooplankton taxa sampled from Dixon Entrance, Hecate Strait, Goose Island Bank and Queen Charlotte Sound.

Summer	Number of stations sampled	Small and medium copepods	Large copepods	Chaetognatha	Euphausiids	Amphipod	Urochordate Salps etc.	Coelenterates	Large items molluscs (*Clione*) and polychaetes	Small items including eggs	Other Remainder	Total
1990 - 91	10	7.33	0.26	0.83	0.49	0.06	0.10	0.16	0.00	4.80	2.25	16.28
1992	3	4.73	0.07	0.29	0.00	0.00	0.00	0.12	0.00	37.47	1.65	44.32
1993 - 97	19	81.28	0.33	0.75	0.06	0.01	0.66	0.60	0.00	4.84	25.29	113.82
1998	53	9.66	0.75	1.71	5.45	0.06	0.34	8.50	0.02	29.80	3.37	59.66
1999-01	44	7.21	2.96	1.70	16.46	0.16	0.81	6.06	0.22	13.07	3.51	52.16

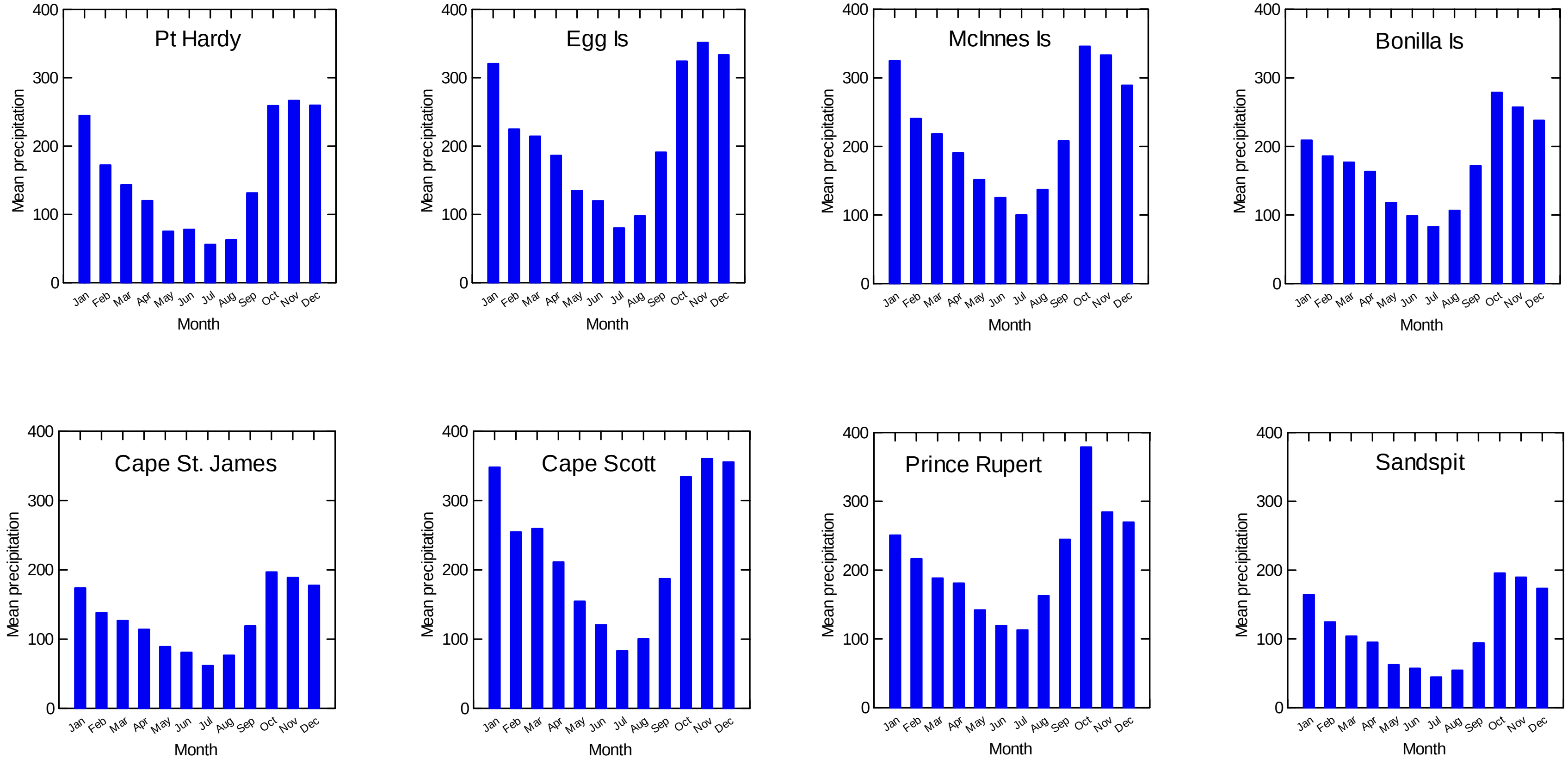


Figure 1.2.1. Monthly mean precipitation (mm·month^{-1}) from 1961-1990 at selected locations in the Queen Charlotte Sound/Hecate Strait region. *Source: Environment Canada.*

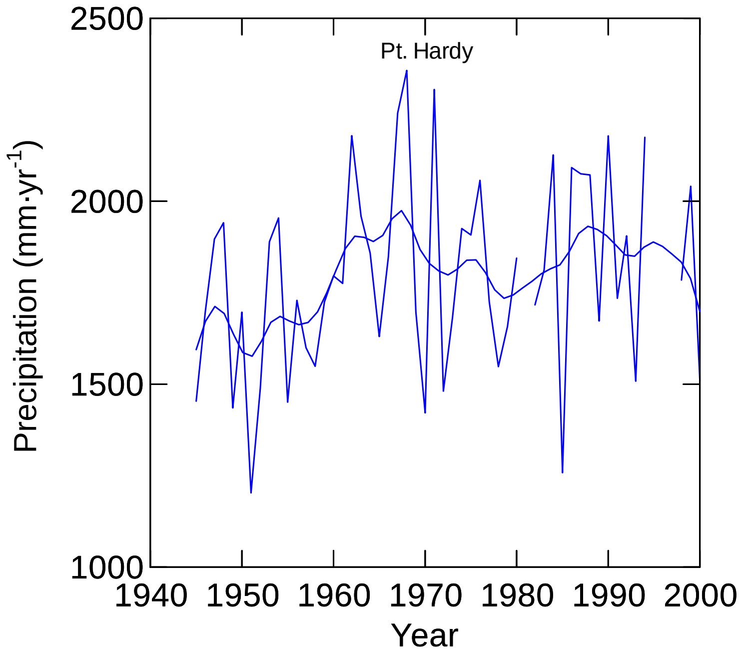


Figure 1.2.2. Annual mean precipitation (mm·yr^{-1}) at Port Hardy. The curve indicates the low frequency decadal and multidecadal variability. *Source: Environment Canada*

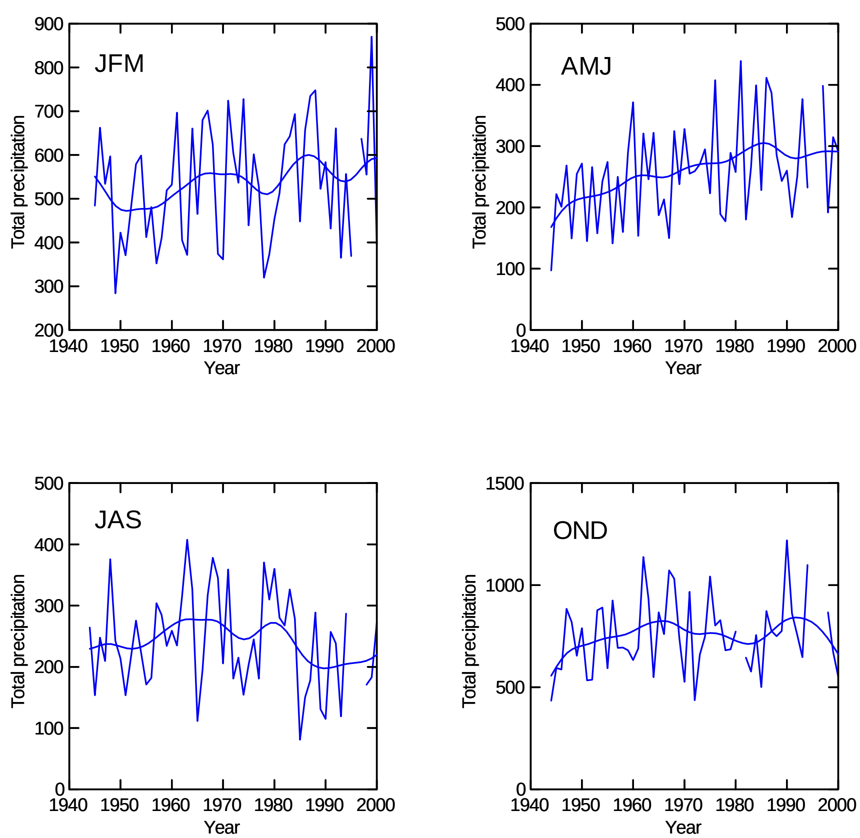


Figure 1.2.3. Seasonal total precipitation (mm) at Port Hardy. The curve indicates the low frequency trend in the time series. *Source: Environment Canada.*

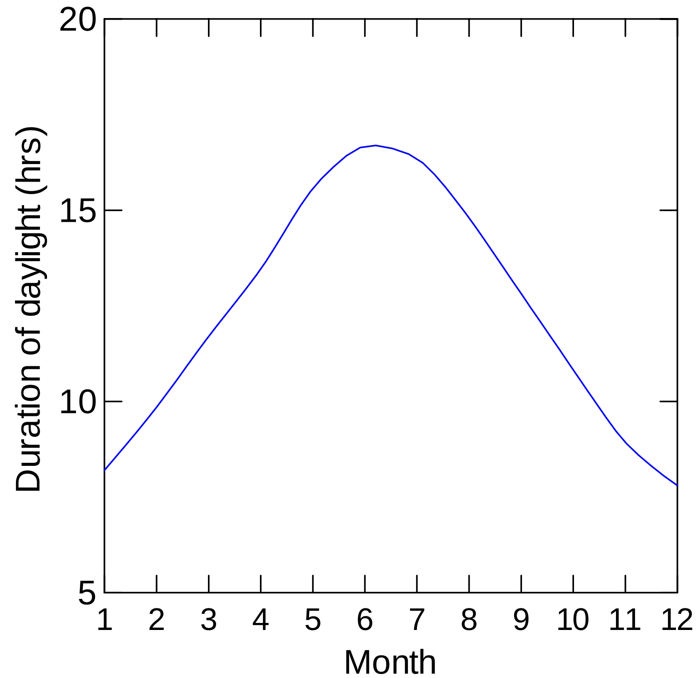


Figure 1.3.1. Duration of daylight (hrs) at 52°N. *Source: Handbook of Marine Science (1974).*

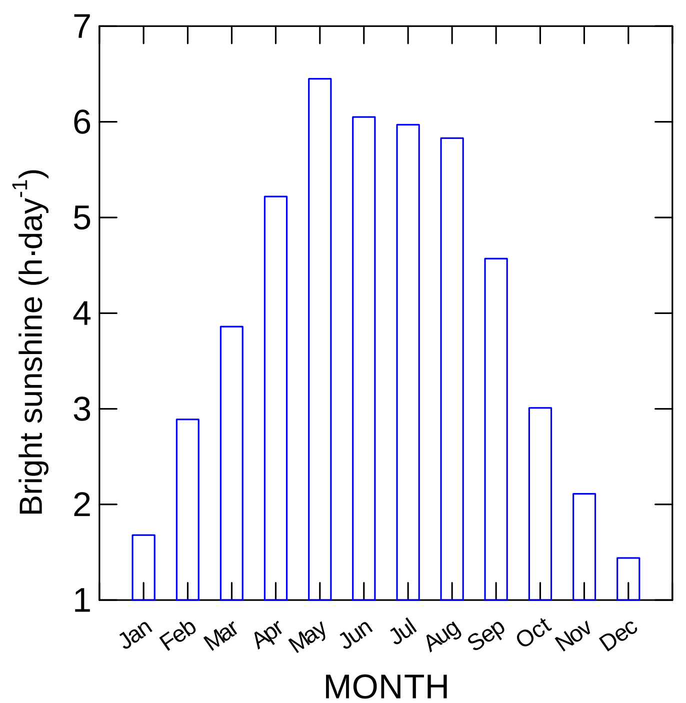


Figure 1.3.2. Average bright sunshine (hrs·day^{-1}) at Sandspit. *Source: Environment Canada*.

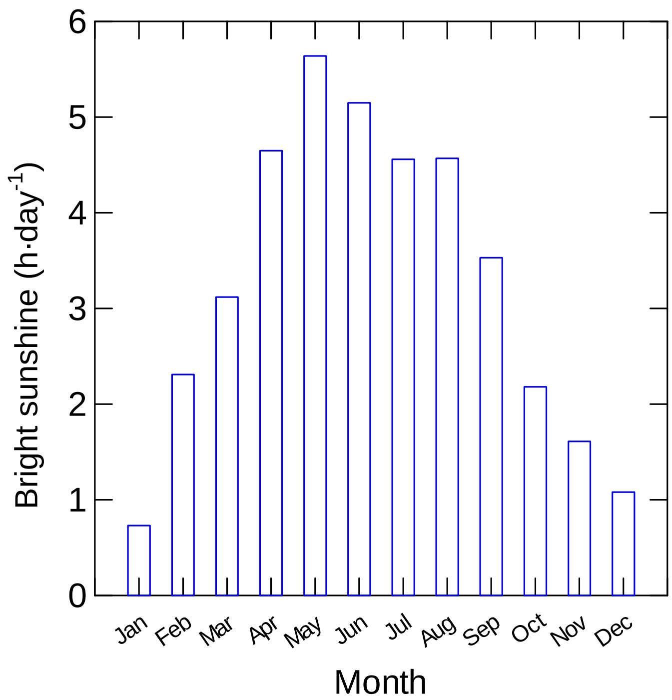


Figure 1.3.3. Average bright sunshine (hrs·day^{-1}) at Prince Rupert. *Source: Environment Canada*.

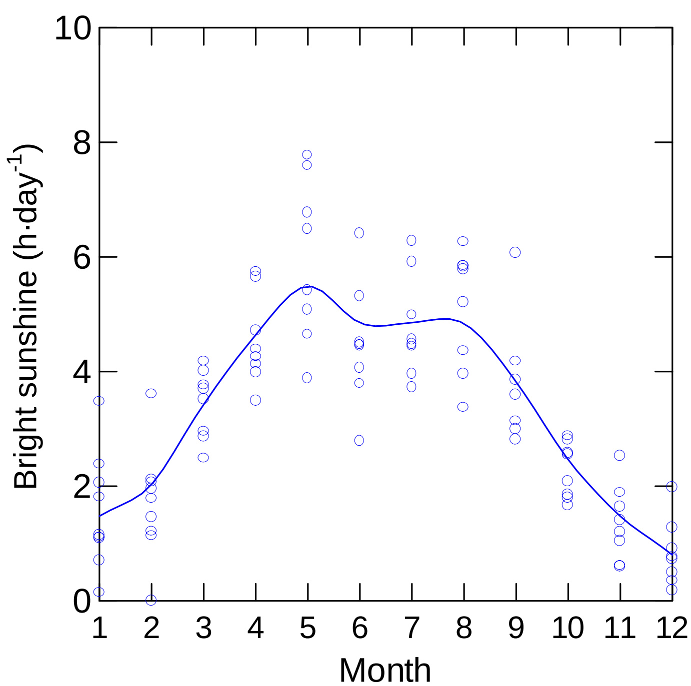


Figure 1.3.4. Average hours of bright sunshine per day at Prince Rupert (1991-1999). *Source: Environment Canada*.

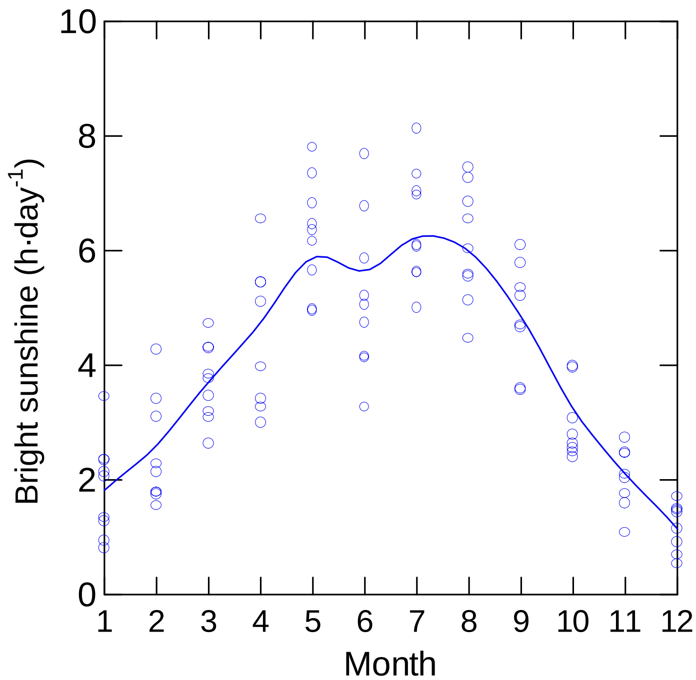


Figure 1.3.5. Average hours of bright sunshine per day at Port Hardy (1991-1999). *Source: Environment Canada*.

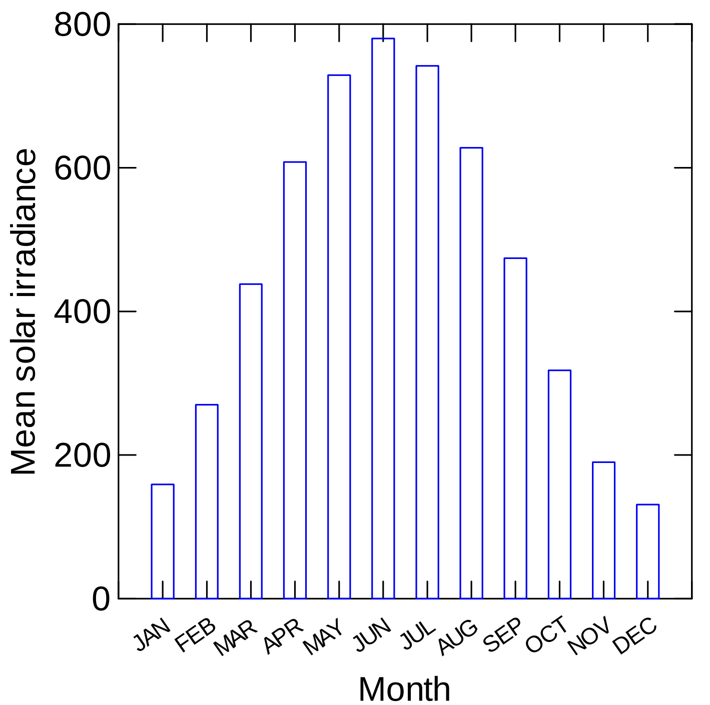


Figure 1.3.6. Monthly mean solar irradiance (Cal·cm^{-2}·day^{-1}) at ground level during clear weather at Cape St. James. *Source: Ma (1992).*

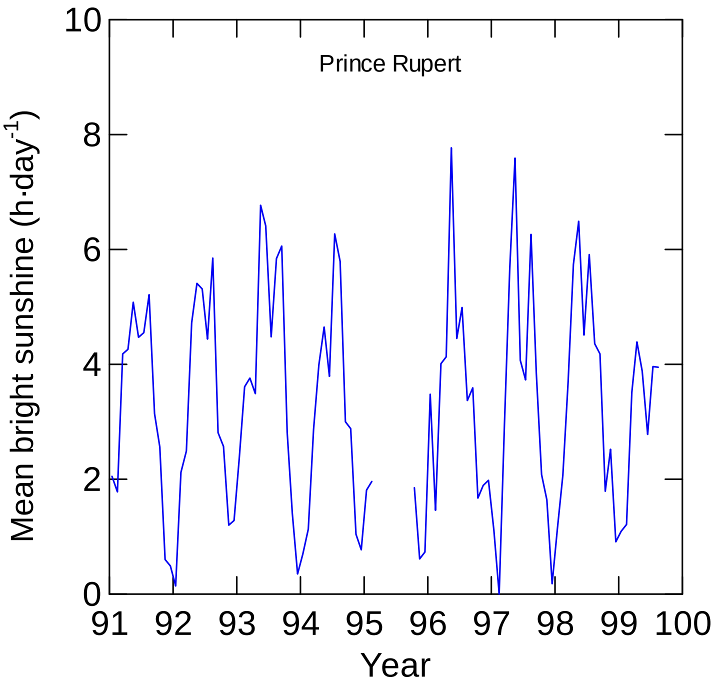


Figure 1.3.7. Monthly mean hours of bright sunshine per day at Prince Rupert (Jan. 1991 to Aug. 1999). *Source: Environment Canada.*

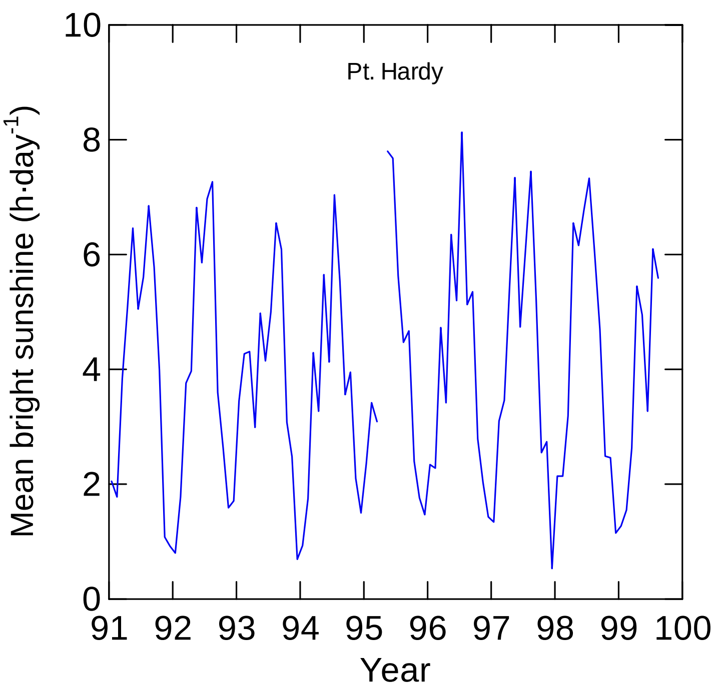


Figure 1.3.8. Monthly mean hours of bright sunshine per day at Port Hardy (Jan. 1991 to Aug. 1999). *Source: Environment Canada.*

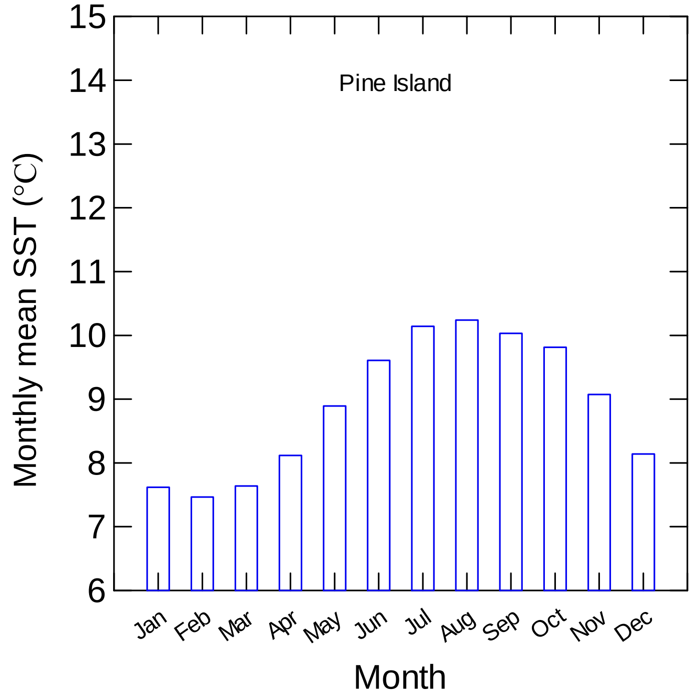


Figure 1.4.1. Monthly mean sea surface temperature (°C) at Pine Island between 1960-2000.

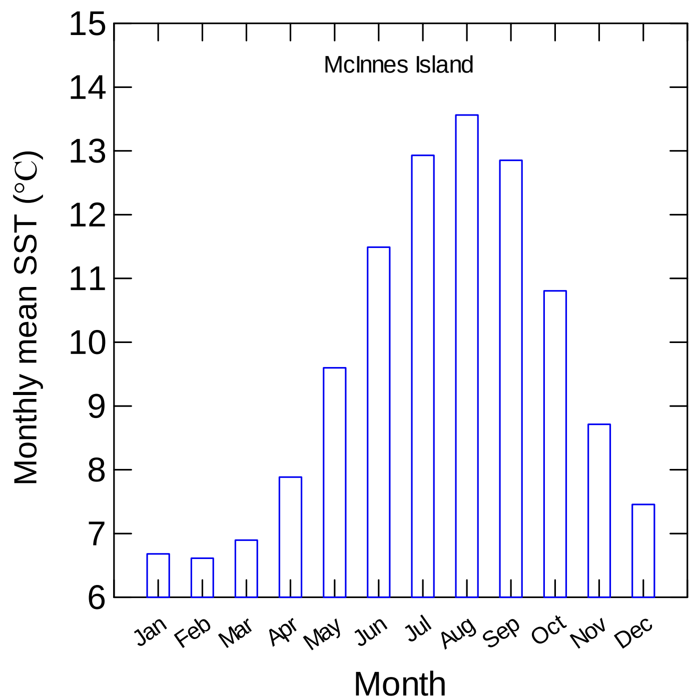


Figure 1.4.2. Monthly mean sea surface temperature (°C) at McInnes Island between 1960-2000.

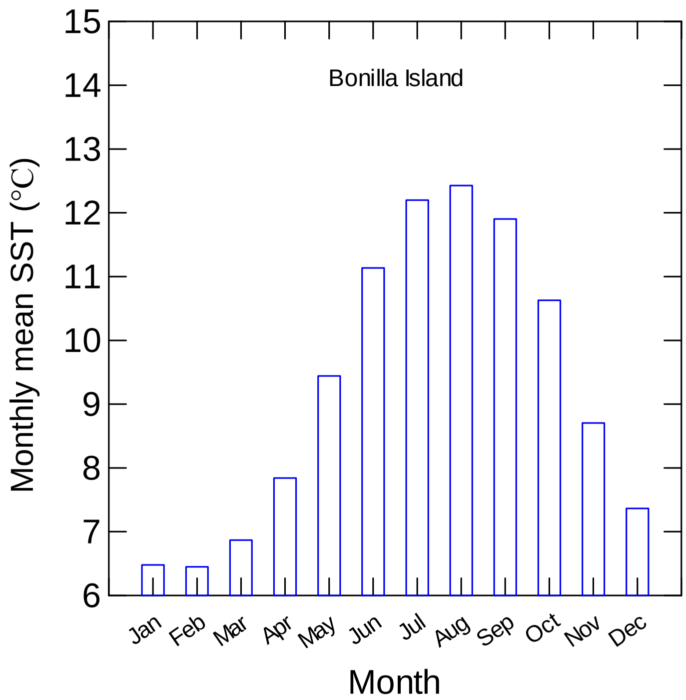


Figure 1.4.3. Monthly mean sea surface temperature (°C) at Bonilla Island between 1960-2000.

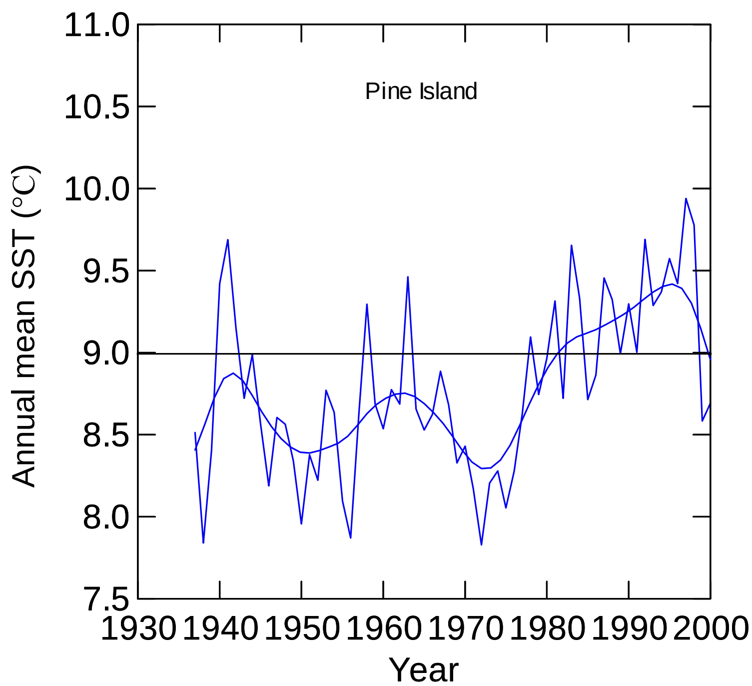


Figure 1.4.4. Annual mean sea surface temperature (°C) at Pine Island. The horizontal line indicates the 1960-2000 mean, and the curve the low frequency decadal variability. *Source: Fisheries and Oceans.*

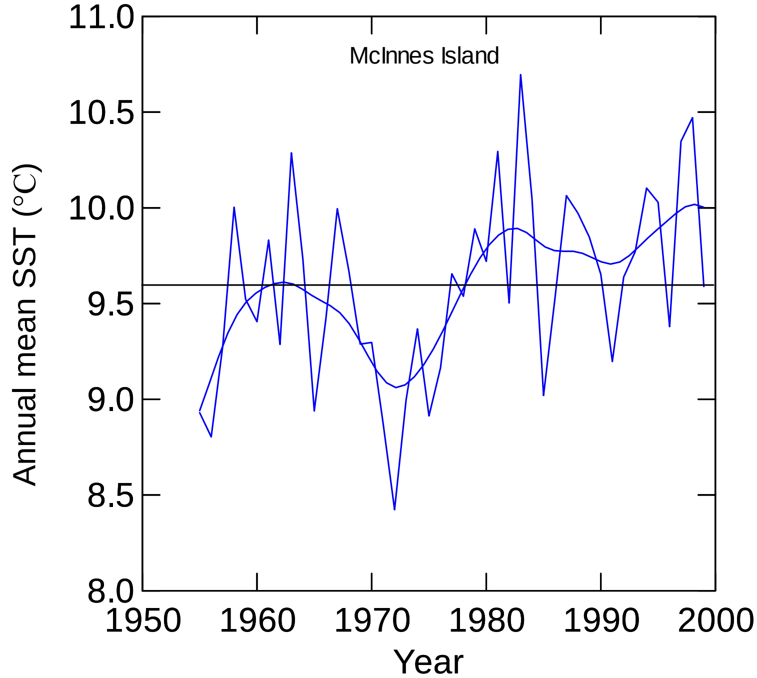


Figure 1.4.5. Annual mean sea surface temperature (°C) At McInnes Island. The horizontal line indicates the 1960-2000 mean, and the curve the low frequency decadal variability. *Source: Fisheries and Oceans.*

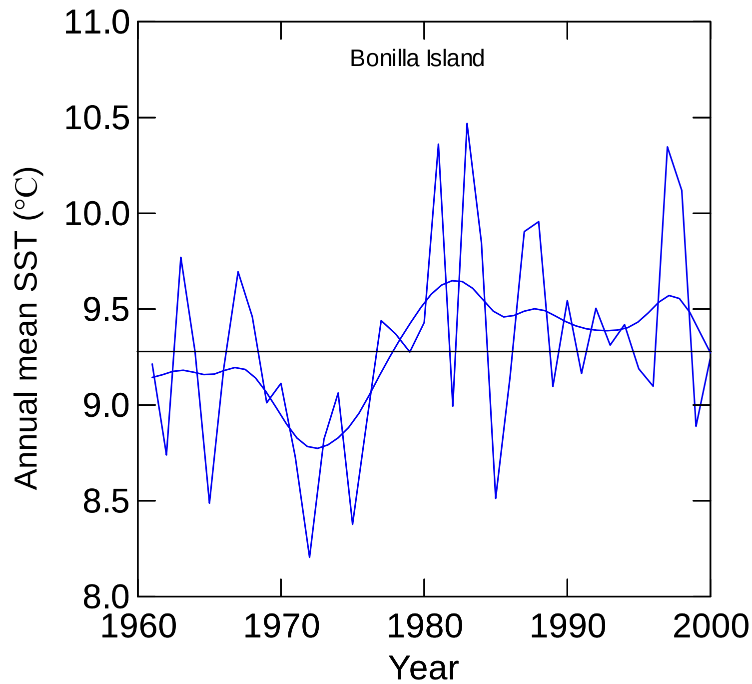


Figure 1.4.6. Annual mean sea surface temperature (°C) at Bonilla Island. The horizontal line indicates the 1960-2000 mean, and the curve the low frequency decadal variability. *Source: Fisheries and Oceans.*

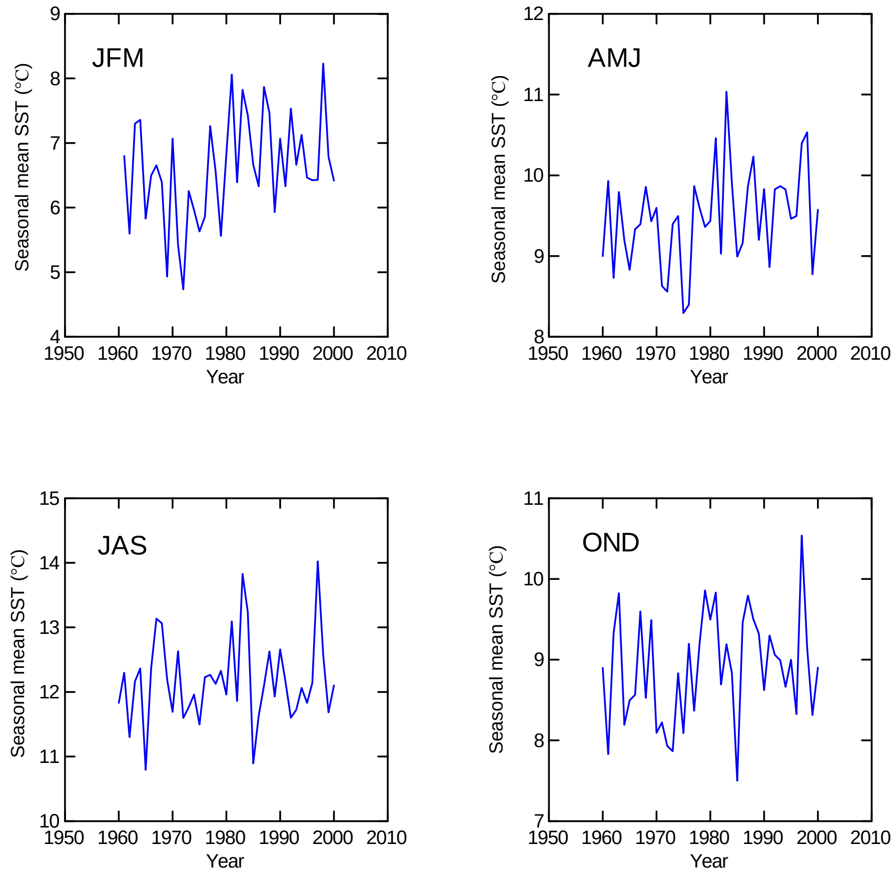


Figure 1.4.7. Mean sea surface temperature (°C) by season at Bonilla Island from 1960-2000.

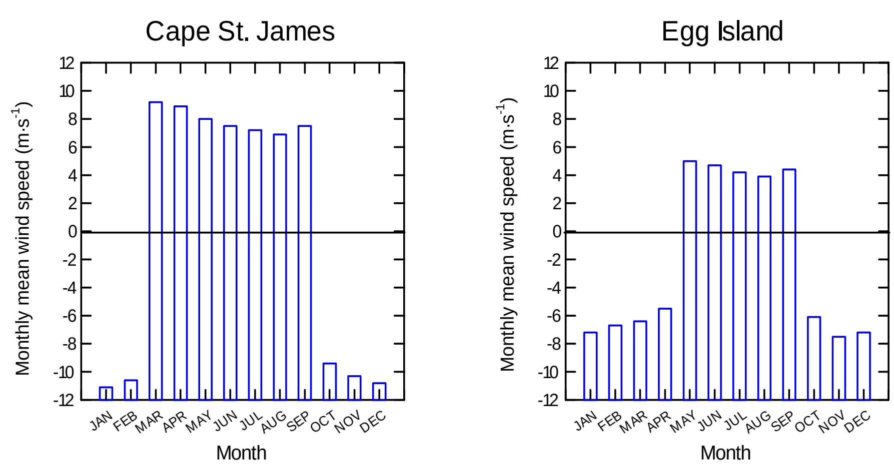


Figure 1.5.1. Monthly mean wind speed (m·s^{-1}) at Cape St. James and Egg Island (1961-1990). Negative speeds indicate winds blowing from the south, Positive speeds indicate winds blowing from the north. *Source: Canadian Climate Normals 1961-1990, Environment Canada.*

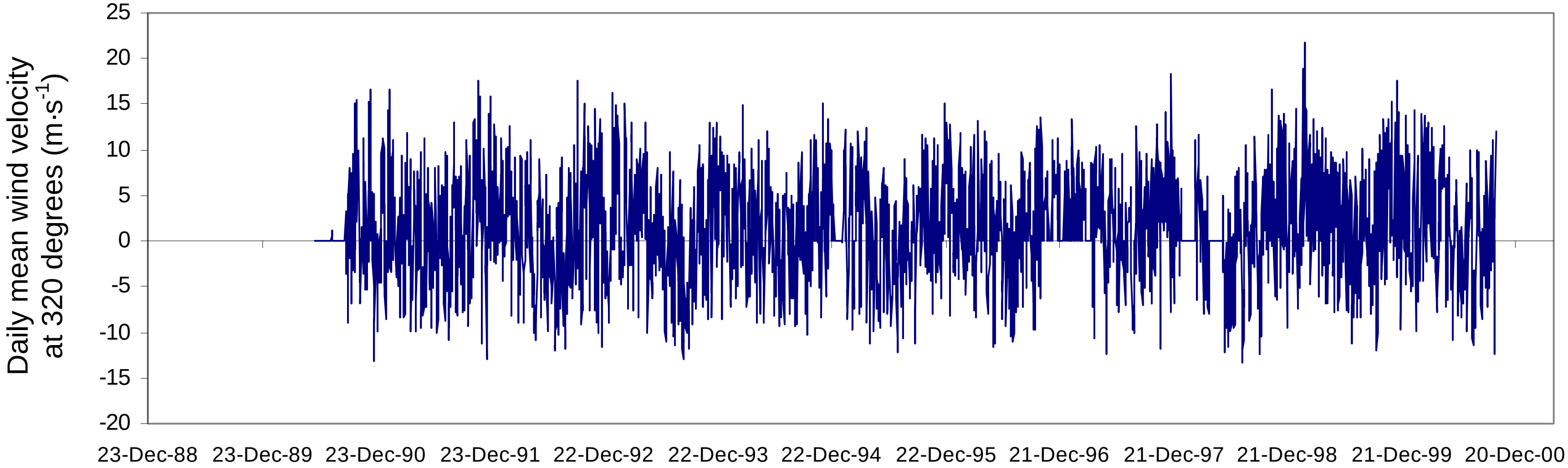


Figure 1.5.2. Alongshore wind speed (m·s^{-1}) measured at Buoy 46185 located in southern Hecate Strait. Velocities are recorded as daily means based on the average of 24 hourly samples.

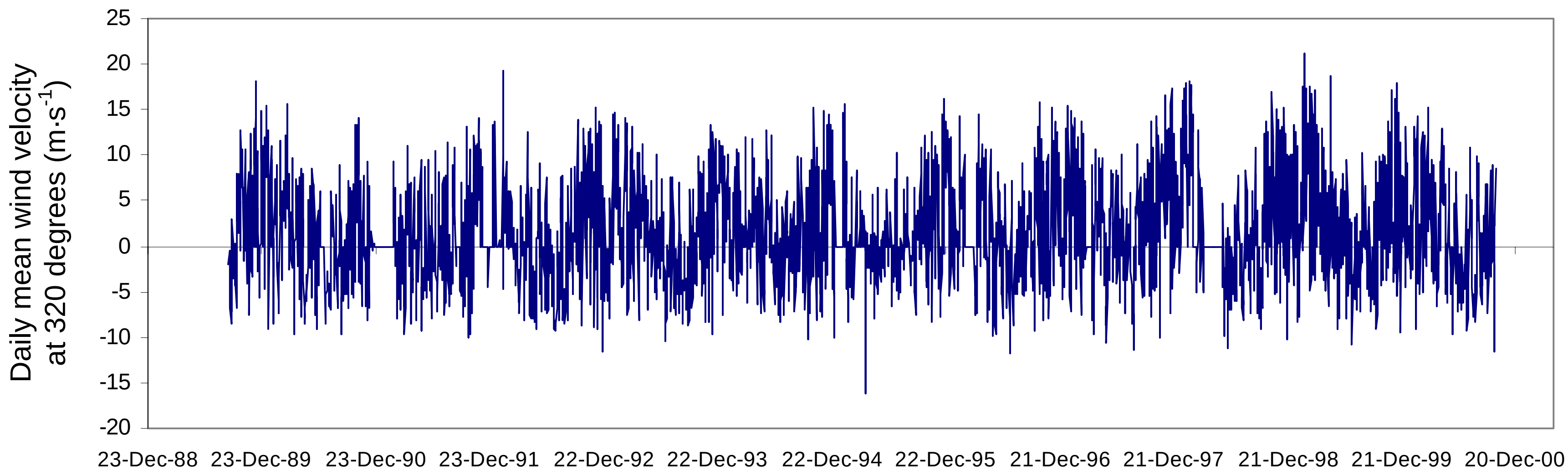


Figure 1.5.3. Alongshore wind speed (m·s^{-1}) measured at Buoy 46204 located in Queen Charlotte Sound. Velocities are recorded as daily means based on the average of 24 hourly samples.

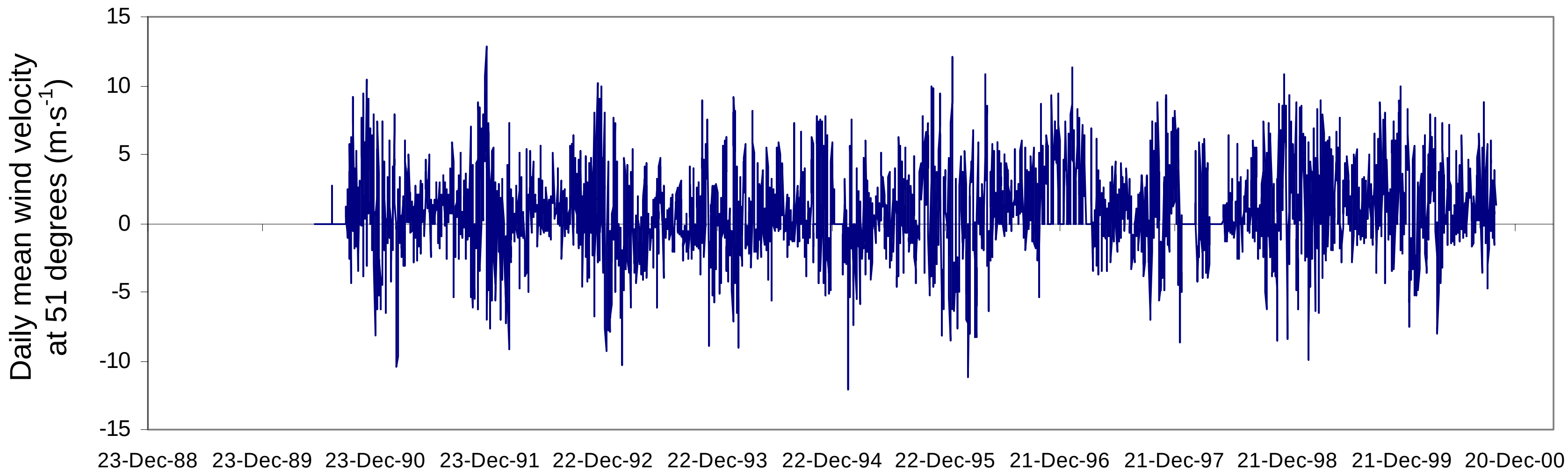


Figure 1.5.4. Cross-shore wind speed measured at Buoy 46185 located in southern Hecate Strait. Velocities are recorded as daily means based on the average of 24 hourly samples.

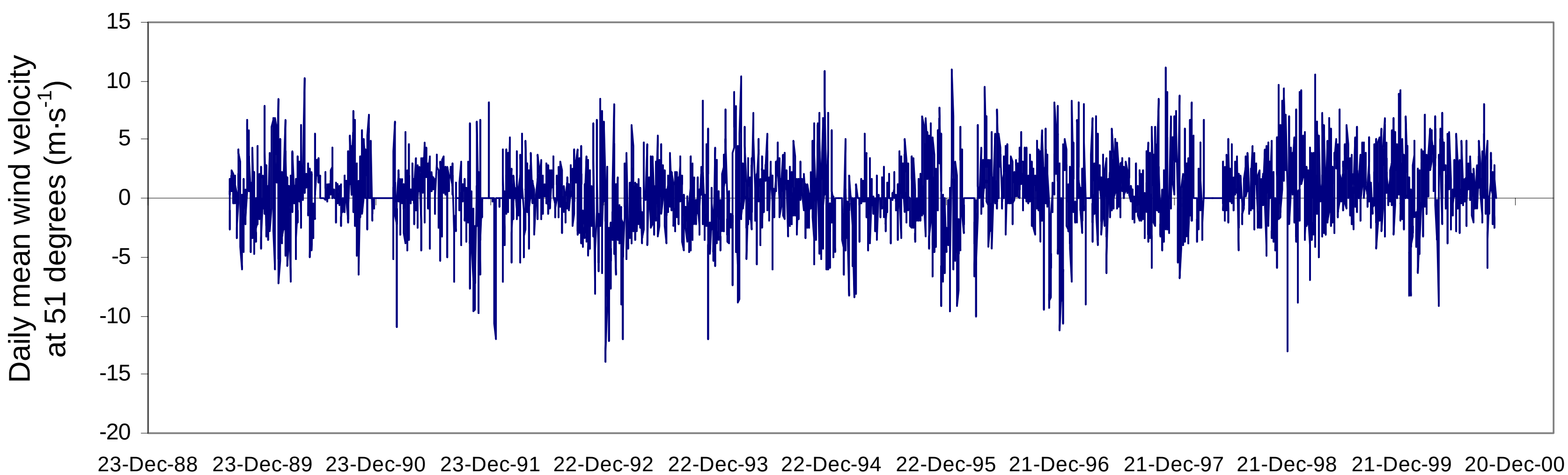


Figure 1.5.5. Cross-shore wind speed measured at Buoy 46204 located in Queen Charlotte Sound. Velocities are recorded as daily means based on the average of 24 hourly samples.

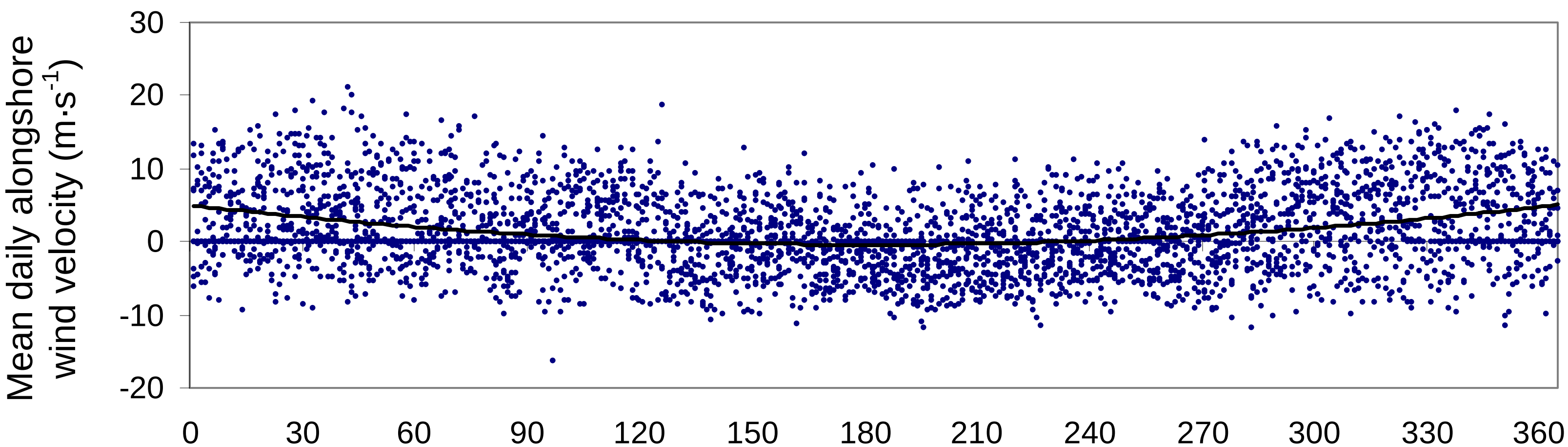


Figure 1.5.6. Interannual variability in Station 46204 alongshore wind speed. Daily mean data for an 11-year period (1989-99) are plotted and a polynomial trend line fitted.

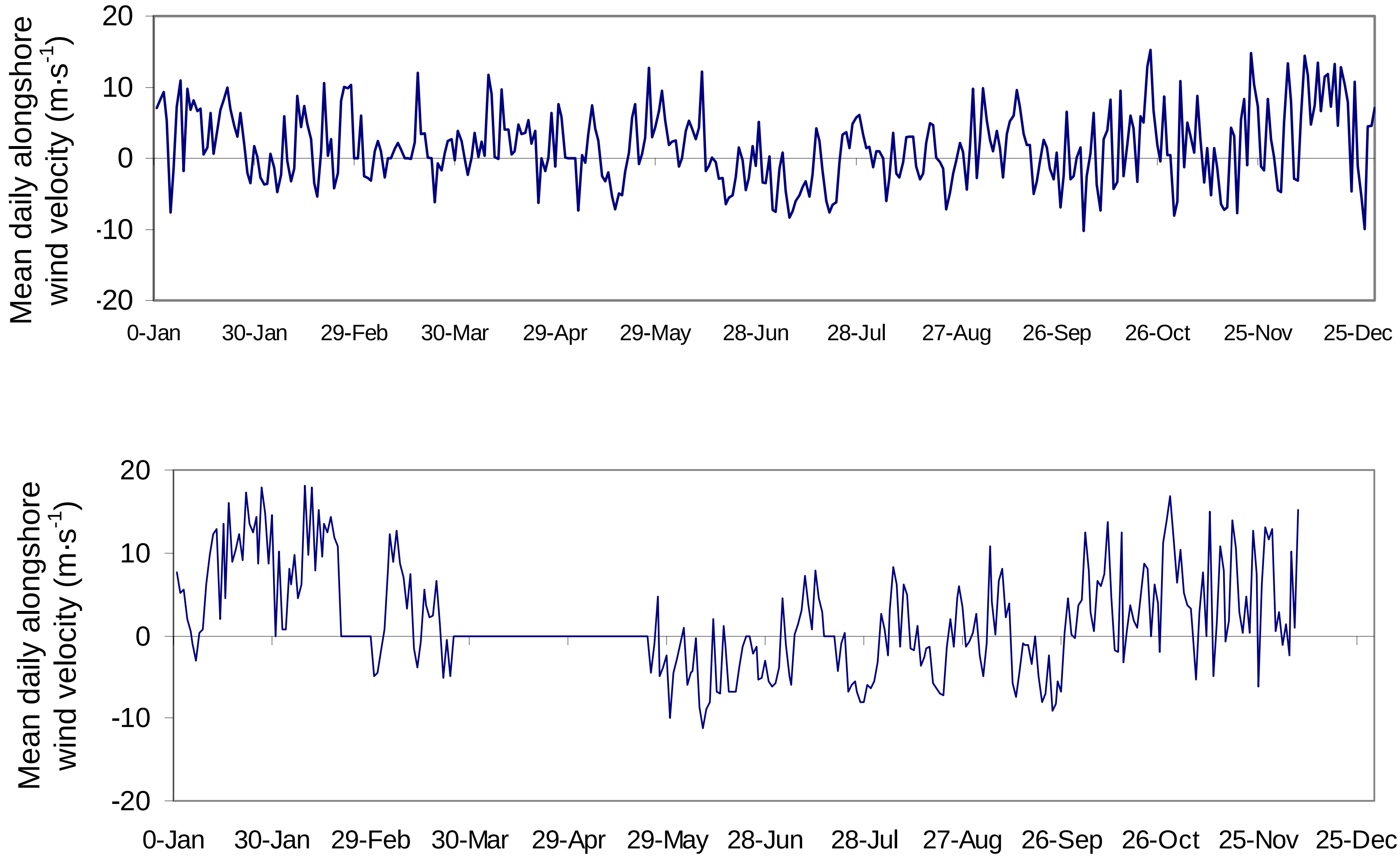


Figure 1.5.7. Contrasting wind speed patterns. Station 46204 (Queen Charlotte Sound) average daily alongshore wind speed (based on 24 hourly samples) for 1994 (top figure) and 1998 (bottom figure). Note that upwelling-favourable winds (negative sign) prevailed more frequently in the summer of 1998.

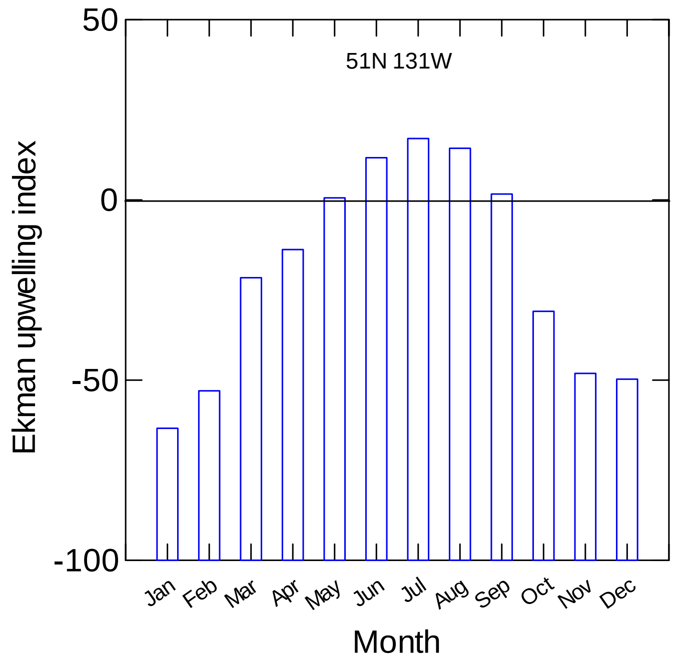


Figure 1.6.1. Monthly mean Ekman upwelling index (metric tons·s^{-1}·100m of $coastline^{-1}$) at 51°N 131°W between 1946 and 2000, inclusive. A positive index signifies "upwelling" and a negative index means "downwelling". *Source: NOAA, Pacific Fisheries Environmental Laboratory.*

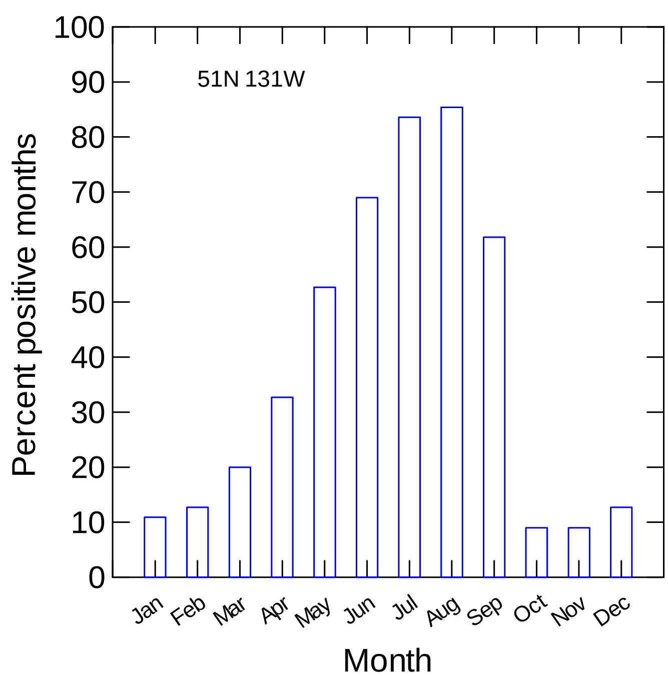


Figure 1.6.2. Percent of months between 1946 to 2000 where the monthly mean upwelling index was positive. *Source: NOAA, Pacific Fisheries Environmental Laboratory.*

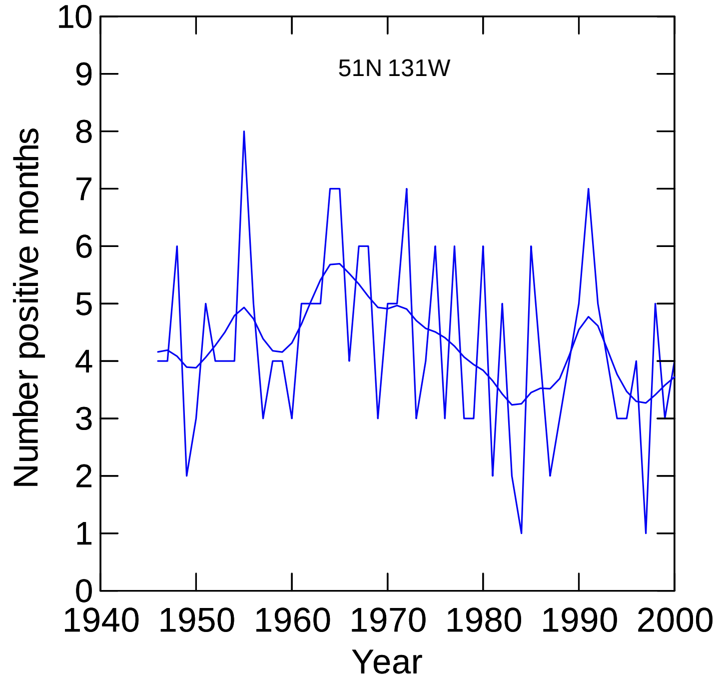


Figure 1.6.3. Number of months between February to October (1946 to 2000) where the mean upwelling index was positive. *Source: NOAA, Pacific Fisheries Environmental Laboratory.*

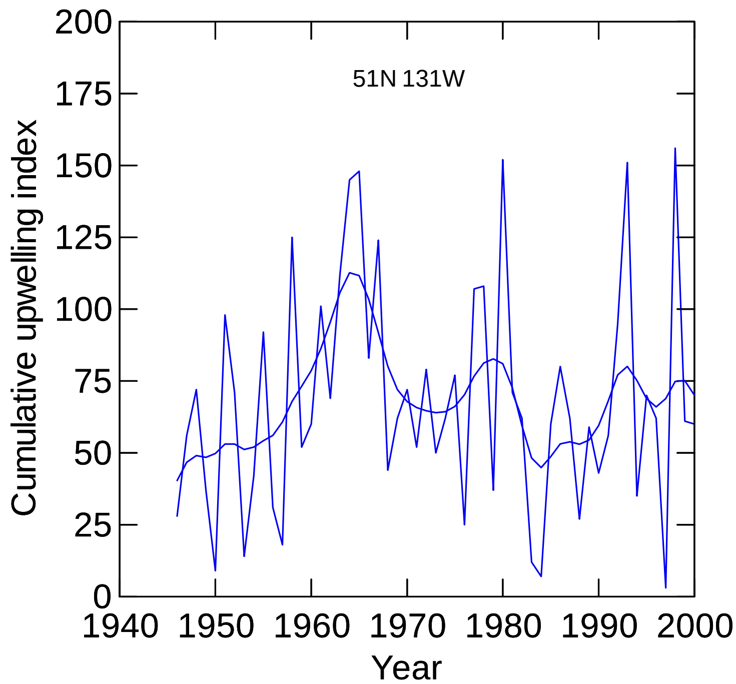


Figure 1.6.4. Cumulative amount of upwelling from February to October. *Source: NOAA, Pacific Fisheries Environmental Laboratory.*

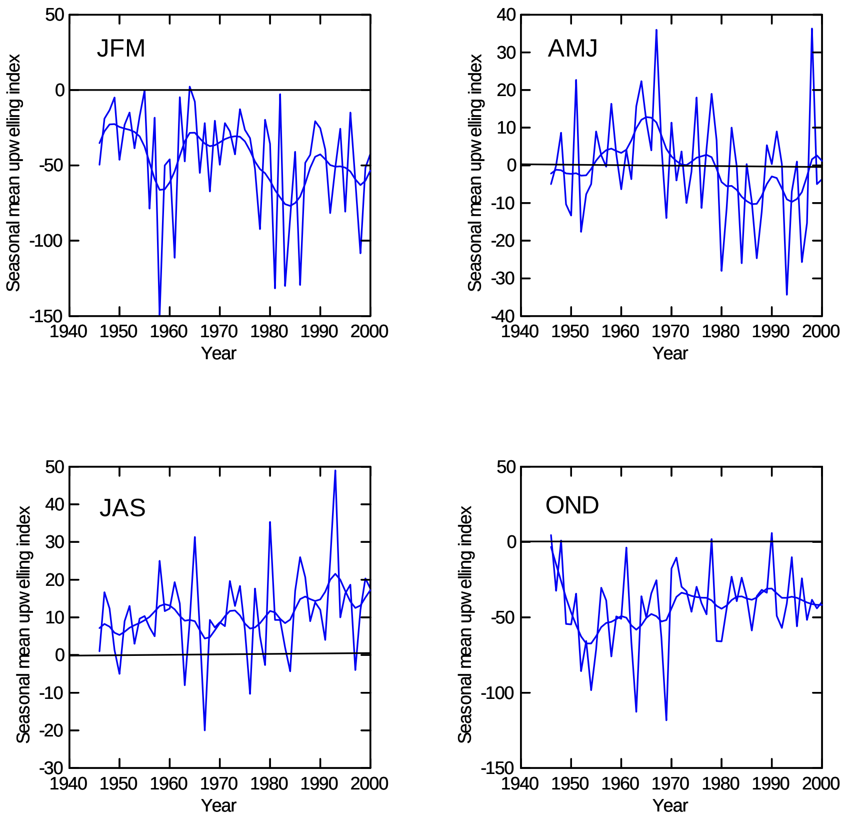


Figure 1.6.5. Seasonal mean upwelling index (1946-2000) at 51°N 131°W. *Source: NOAA, Pacific Fisheries Environmental Laboratory.*

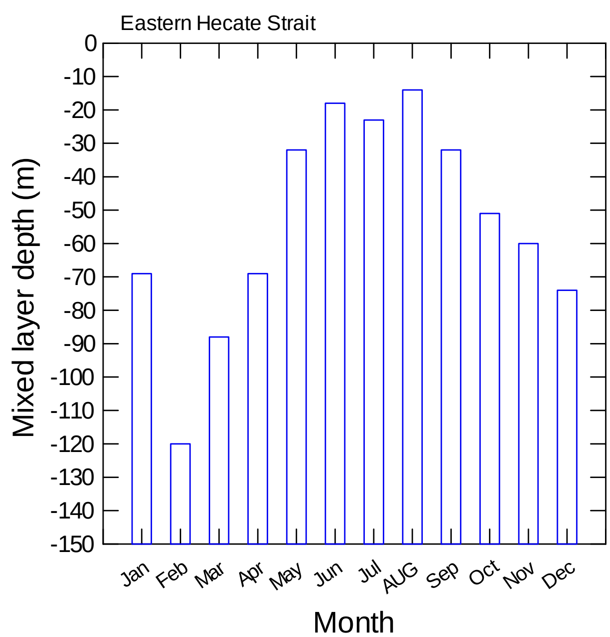


Figure 1.7.1. Monthly mean depth (m) of the mixed layer (1954-1971) in eastern Hecate Strait. *Source: Perry and Dilke (1986).*

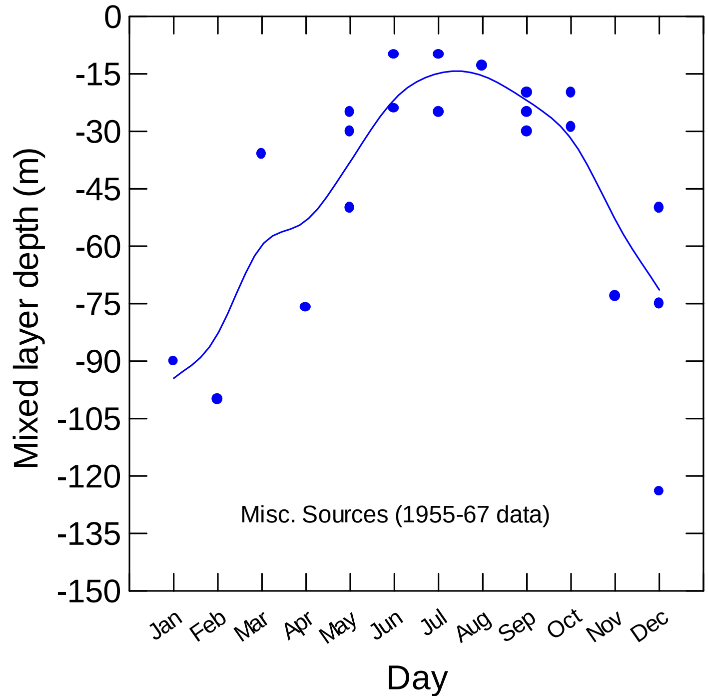


Figure 1.7.2. Mixed layer depth (m) measurements in Queen Charlotte Sound and southern Hecate Strait for the period 1954-1967. *Source: Anon. (1958).*

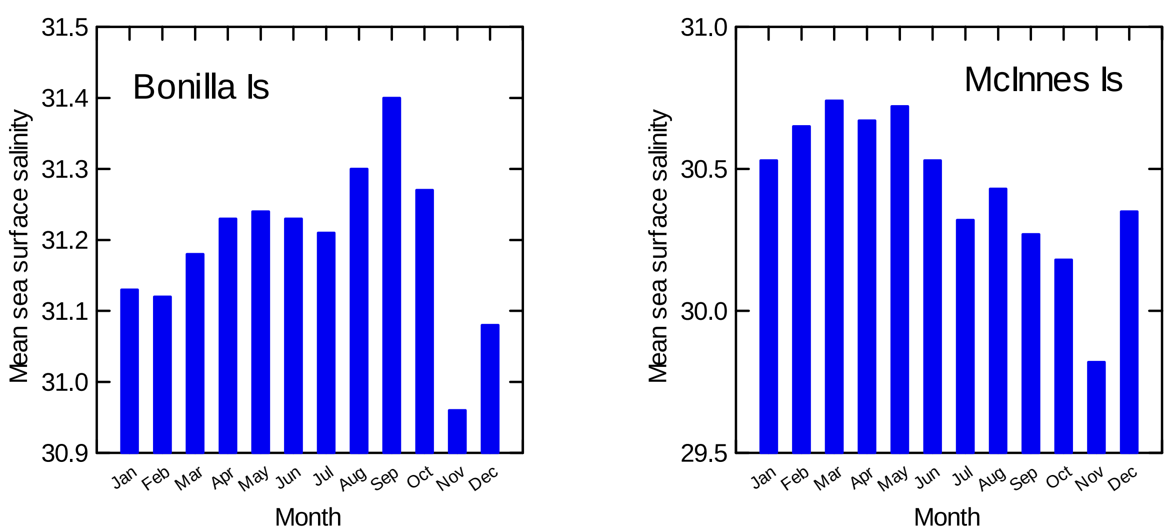


Figure 1.8.1. Monthly mean sea surface salinity (parts per thousand) at Bonilla Island and McInnes Island from 1960-2000. *Source: Department of Fisheries and Oceans.*

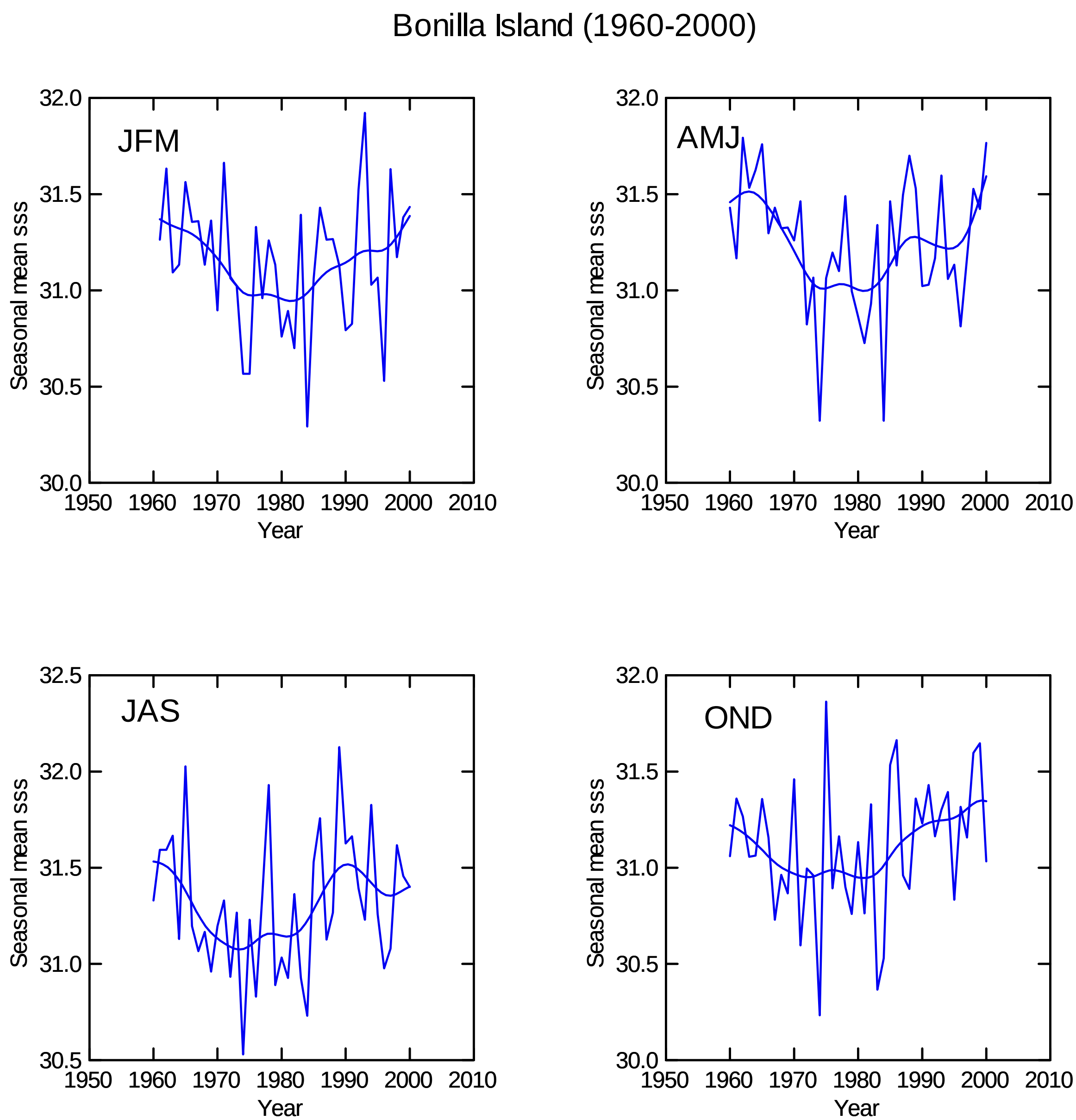


Figure 1.8.2. Seasonal mean sea surface salinity (parts per thousand) at Bonilla Island (1960-2000). The curve indicates the low frequency trend in the time series. *Source: Department of Fisheries and Oceans.*

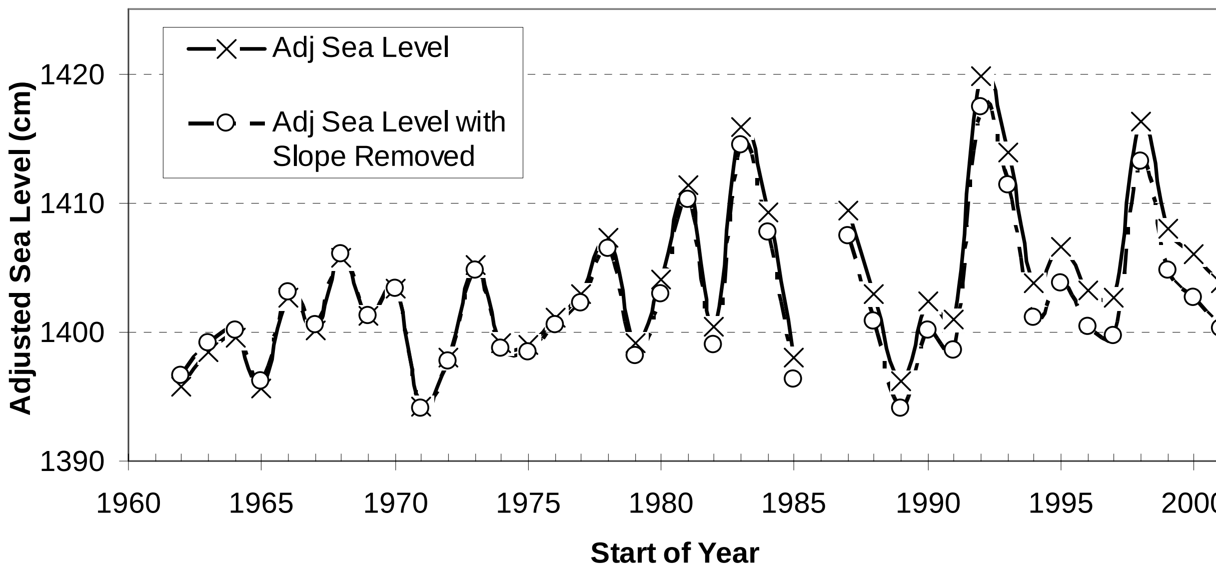


Figure 1.9.1. Winter adjusted sea level at Prince Rupert relative to chart datum.

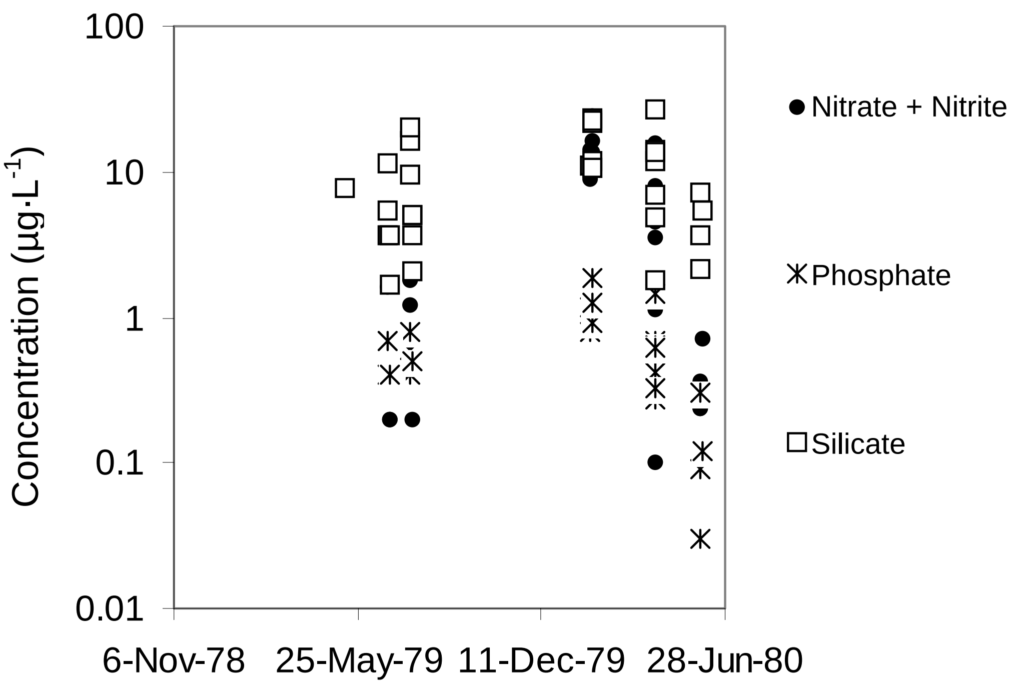


Figure 2.2.1. Seasonal comparison of nutrient concentrations in Hecate Strait from data provided in Perry *et al* (1981).

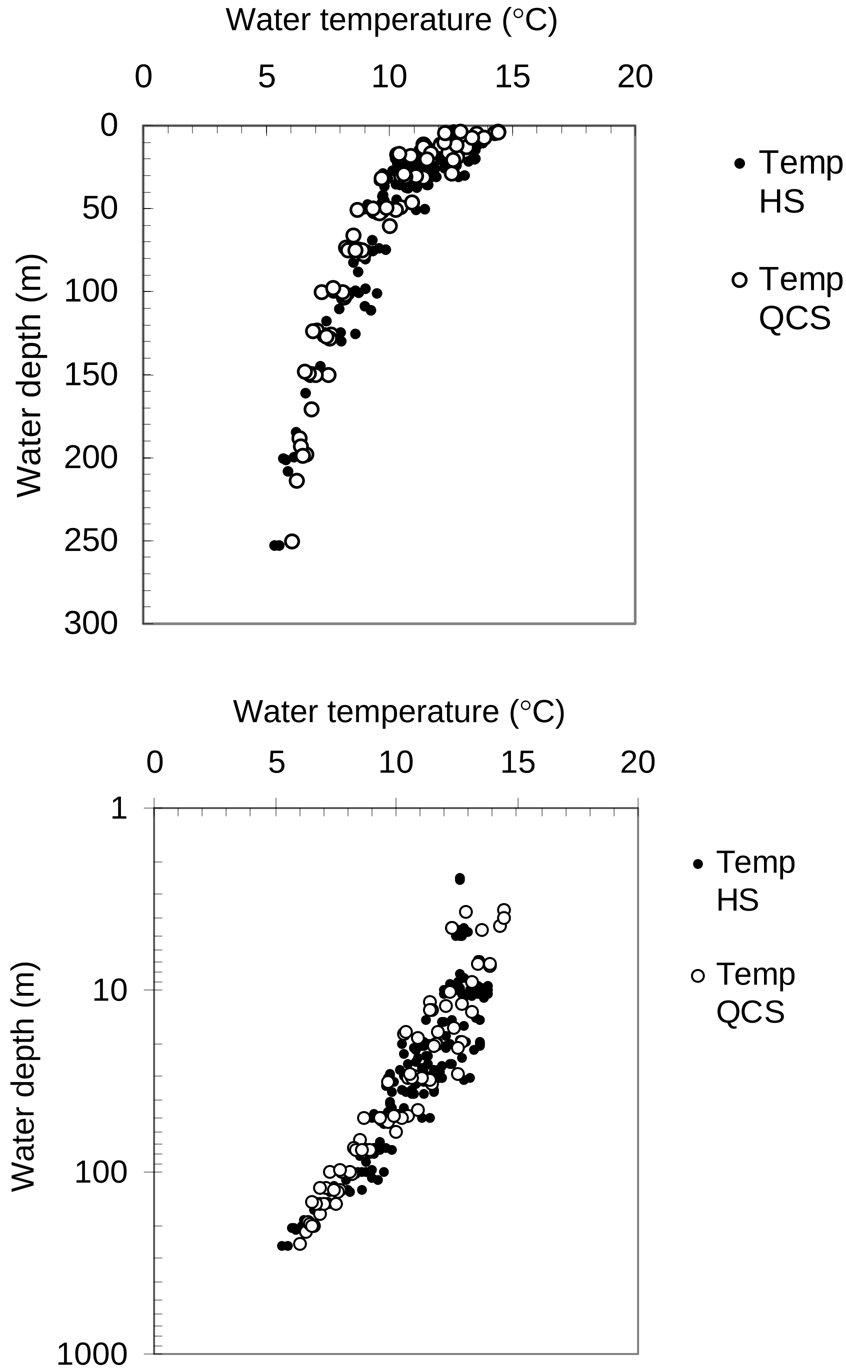


Figure 2.3.1. Water temperature (°C) with respect to depth in Hecate Strait (HS) and Queen Charlotte Sound (QCS). Data collected during late June and early July, 1983 (Denman *et al* 1985).

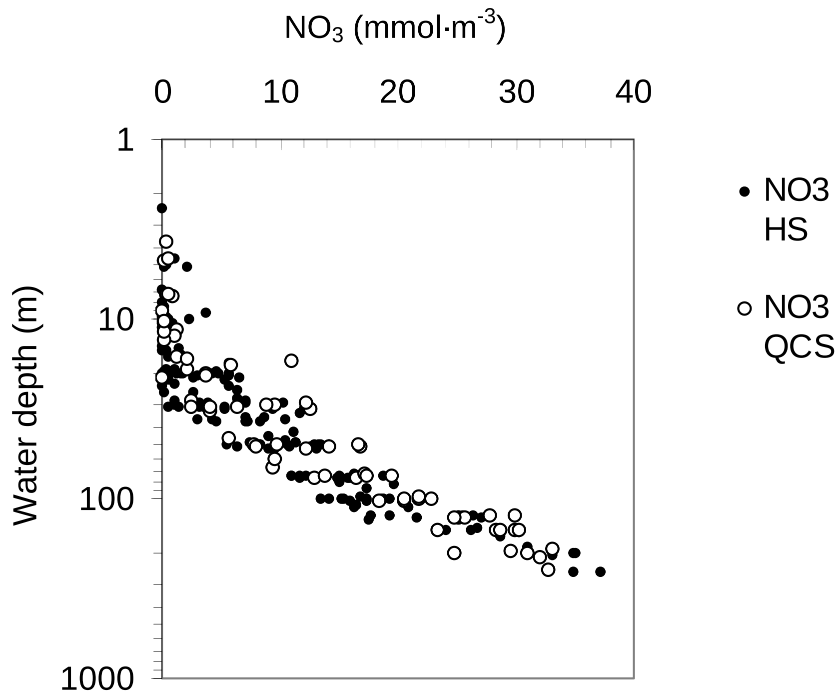
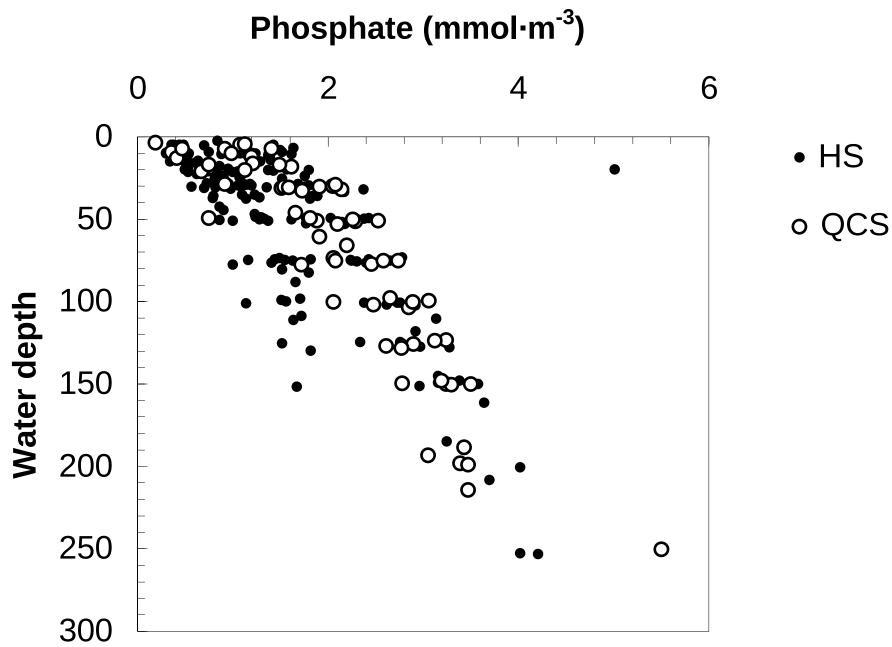


Figure 2.3.2. NO_3 concentrations with respect to depth in Hecate Strait (HS) and Queen Charlotte Sound (QCS). Data from June and July 1983.



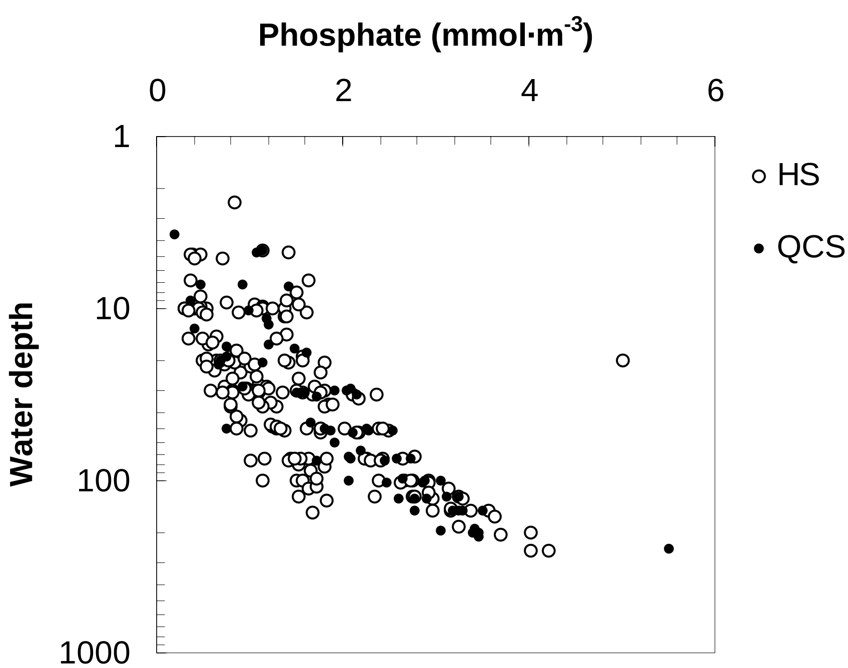
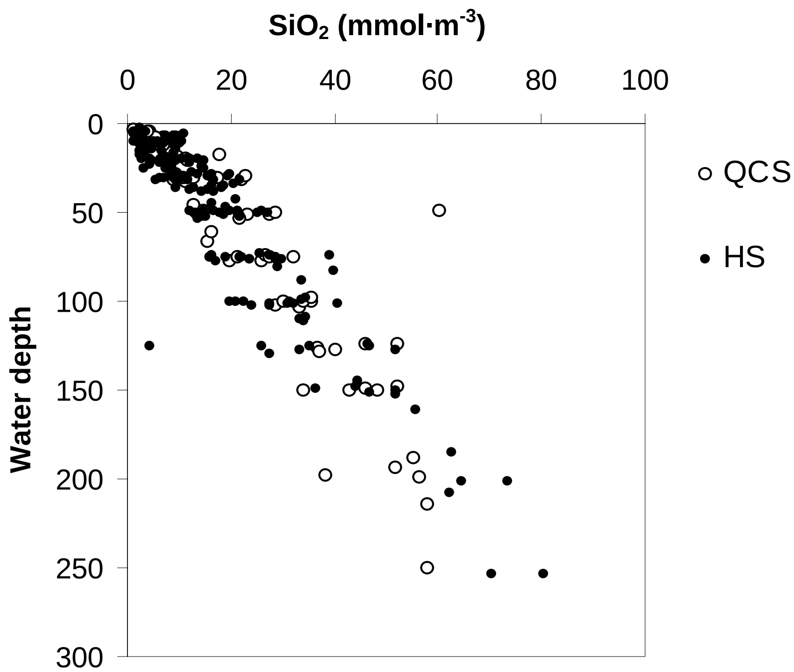


Figure 2.3.3. PO_4 concentrations with respect to depth in Hecate Strait (HS) and Queen Charlotte Sound (QCS). Data from June and July 1983.



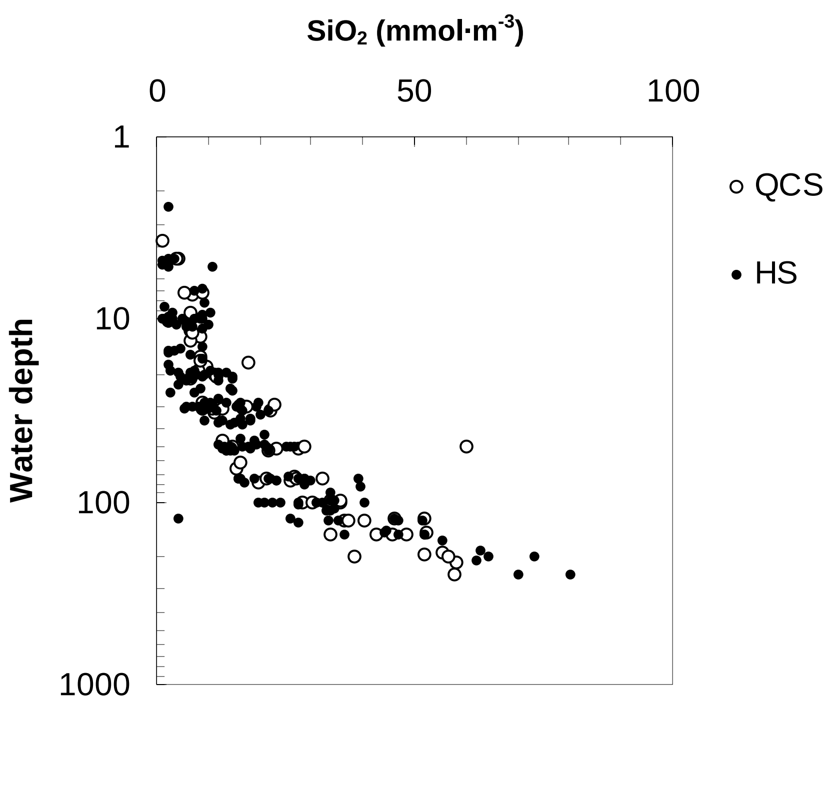
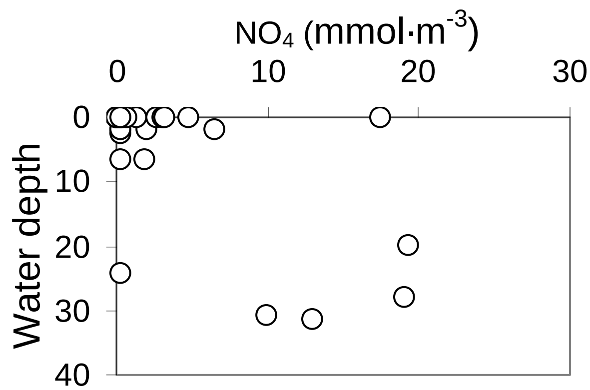
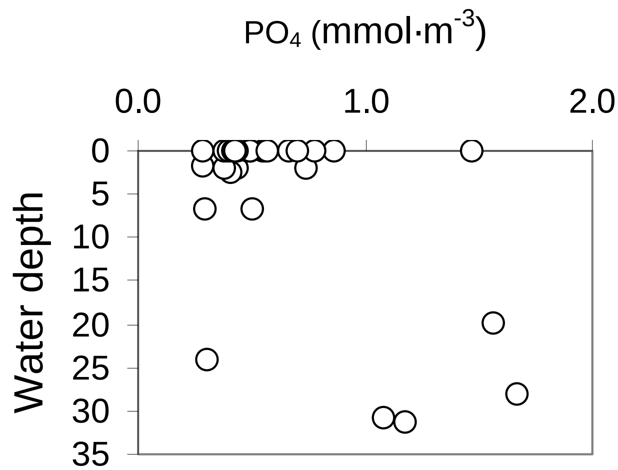


Figure 2.3.4. SiO_2 concentrations (mmol·m^{-3}) with respect to depth (m) in Hecate Strait (HS) and Queen Charlotte Sound (QCS). Data from June and July 1983.





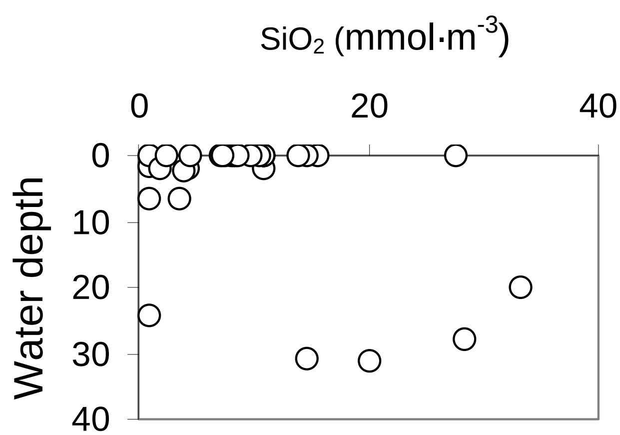


Figure 2.4.1. Nutrients (mmol·m^{-3}) with respect to water depth (m) for the combined Hecate Strait, Queen Charlotte Sound and Dixon Entrance data from Forbes and Waters (1993).

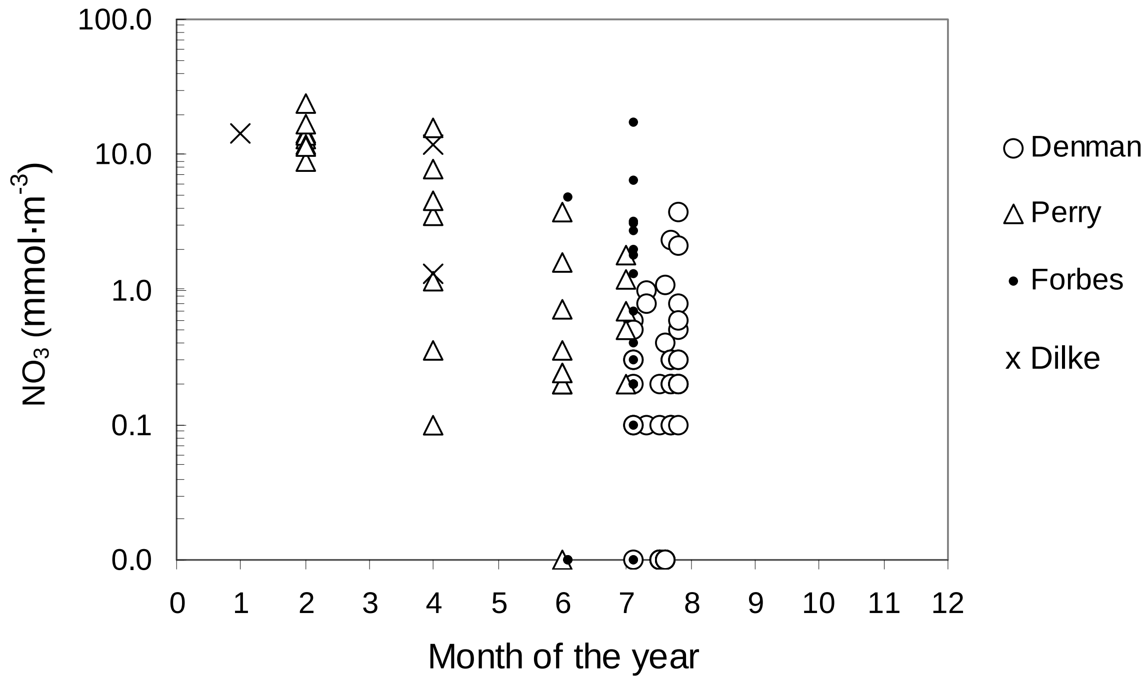


Figure 2.5.1. Monthly trends in NO_3 concentrations (mmol·m^{-3}). Data are taken from four studies (Dilke *et al* 1979, Perry *et al* 1981, Denman *et al* 1985, Forbes and Waters 1993).

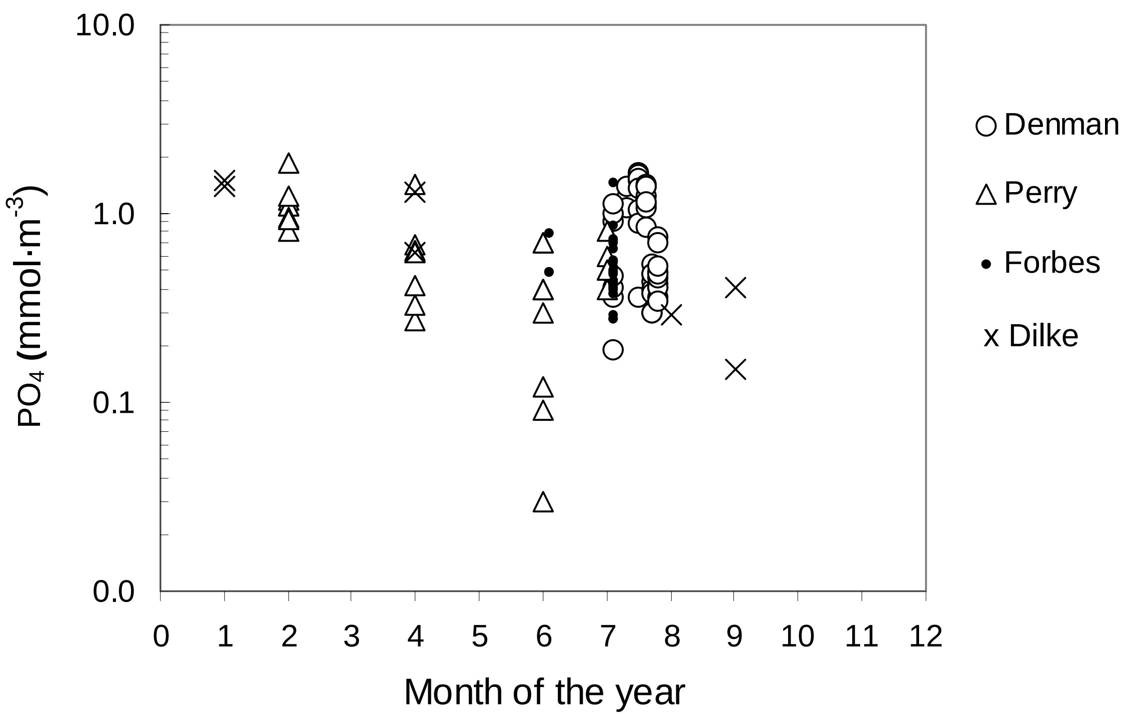


Figure 2.5.2. Monthly trends in PO_4 concentrations (mmol·m^{-3}). Data are taken from four studies (Dilke *et al* 1979, Perry *et al* 1981, Denman *et al* 1985, Forbes and Waters 1993).

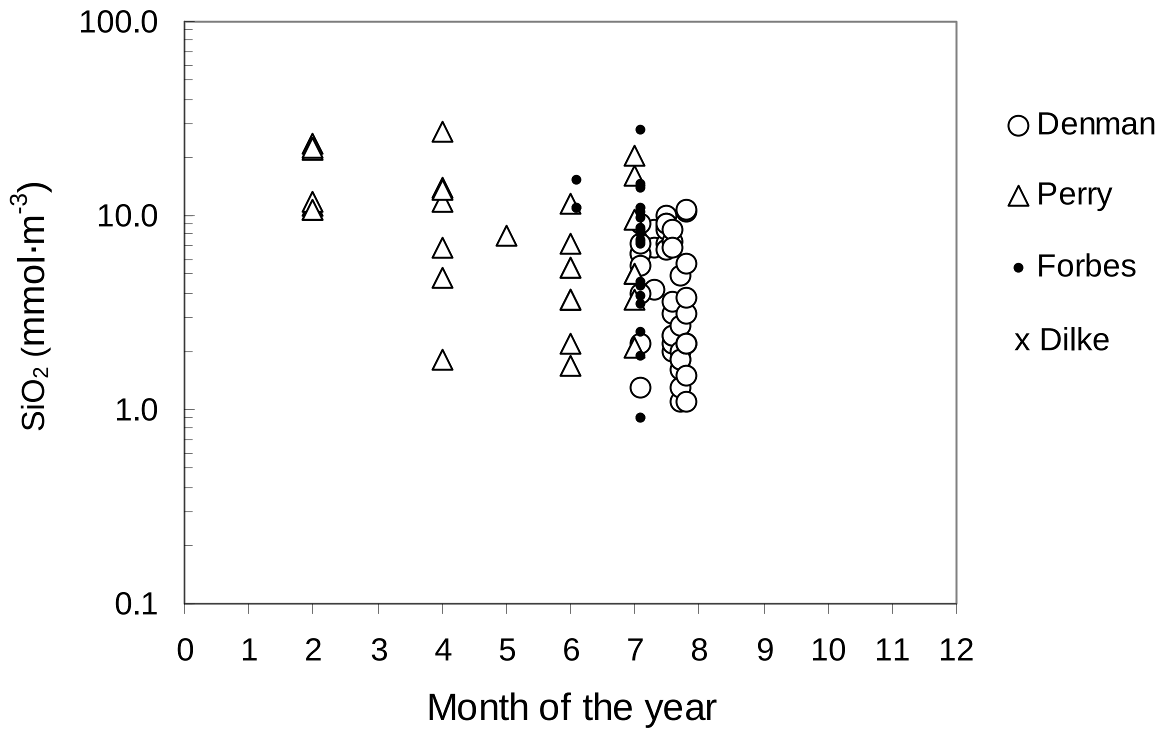


Figure 2.5.3. Monthly trends in SiO_2 concentrations (mmol·m^{-3}). Data are taken from four studies (Dilke *et al* 1979, Perry *et al* 1981, Denman *et al* 1985, Forbes and Waters 1993).

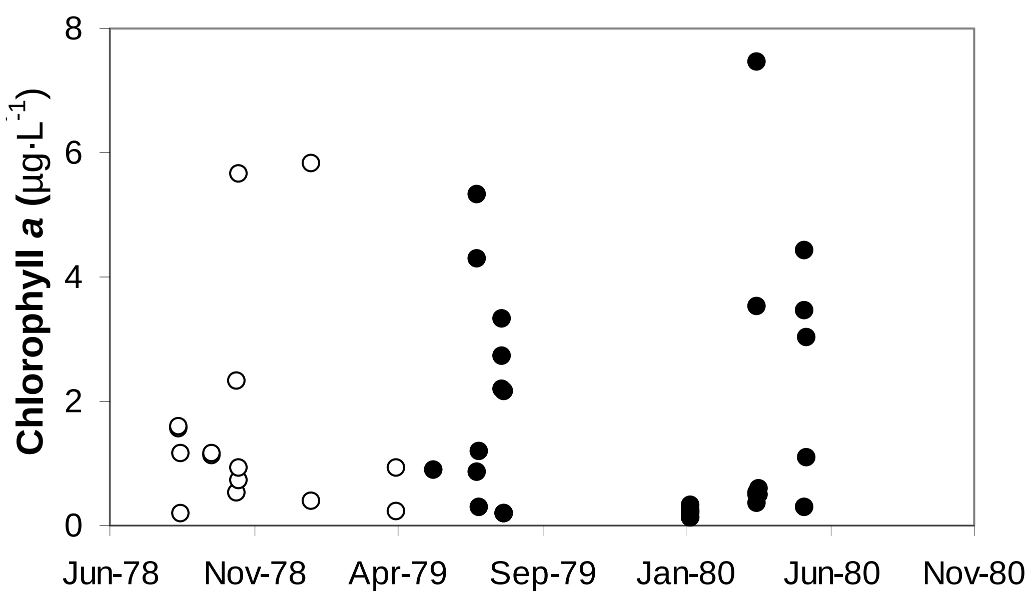


Figure 3.3.1. Comparison of chlorophyll *a* concentration data (µg·L^{-1}) collected by Dilke *et al* (1979) – open symbols (○) and Perry *et al* (1981) closed symbols (●). All samples came from 3-m water depth.

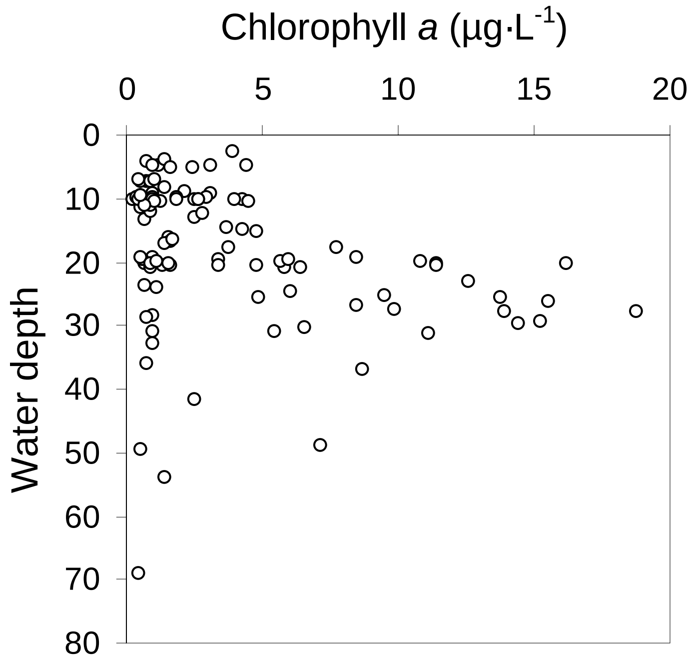


Figure 3.4.1. Denman *et al* (1985) chlorophyll *a* concentrations (µg·L^{-1}) plotted with respect to water depth (m).

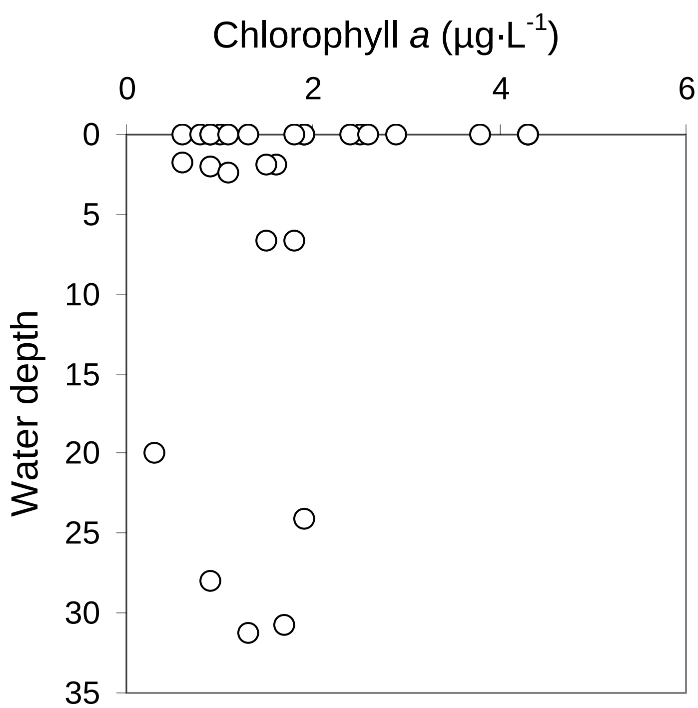


Figure 3.5.1. Forbes and Waters (1993) chlorophyll *a* concentrations (µg·L^{-1}) plotted with respect to water depth.

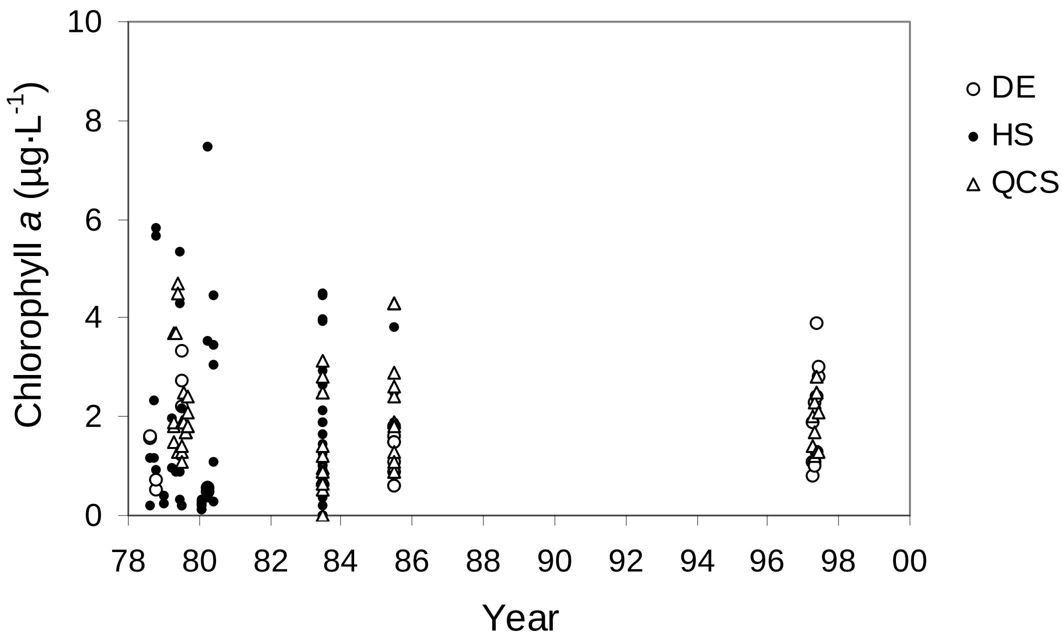


Figure 3.7.1. Comparison of chlorophyll *a* concentrations (µg·L^{-1}) measured from surface waters (<10 m deep) at three locations (DE = Dixon Entrance, HS = Hecate Strait, and QCS = Queen Charlotte Sound) between 1979 and 1997.

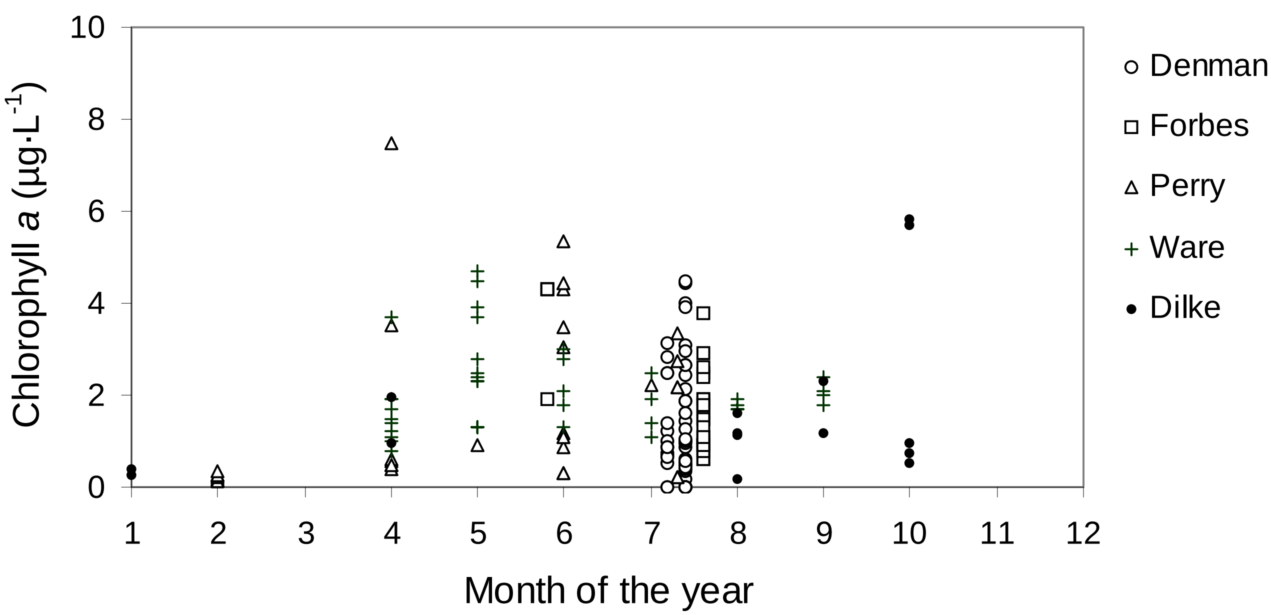


Figure 3.7.2. All shallow water (<10 m deep) samples combined to generate an aggregated data set for average monthly chlorophyll *a* concentrations (µg·L^{-1}). Samples from the five data sets are shown separately (Dilke *et al* 1979, Perry *et al* 1981, Denman *et al* 1985, Forbes and Waters 1993, Ware and Thompson unpublished).

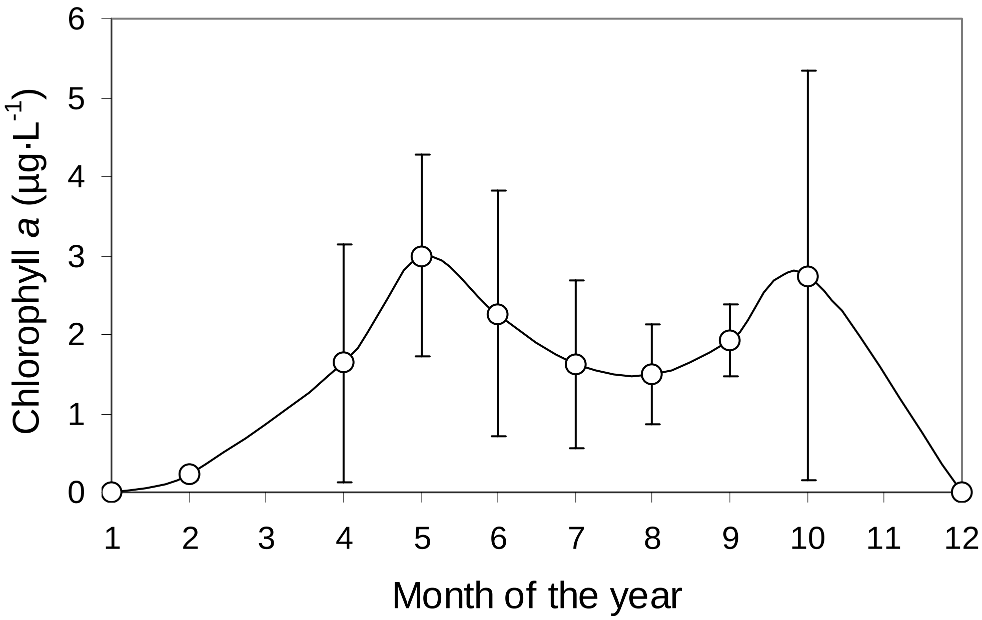


Figure 3.7.3. Monthly means and standard deviations for chlorophyll *a* concentrations (µg·L^{-1}) based on shallow water (<10 m) data from five data sets (Dilke *et al* 1979, Perry *et al* 1981, Denman *et al* 1985, Forbes and Waters 1993, Ware and Thompson unpublished).

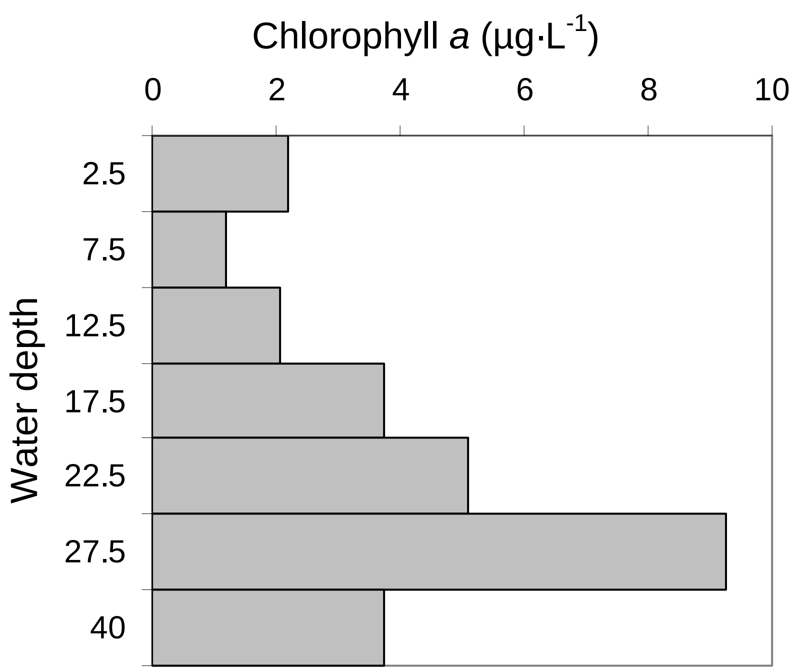


Figure 3.7.4. Depth-stratified chlorophyll *a* concentrations (µg·L^{-1}) from Denman *et al* (1985) grouped into 5-m depth intervals. Means, sample sizes and deviations are summarized in Table 3.7.3.

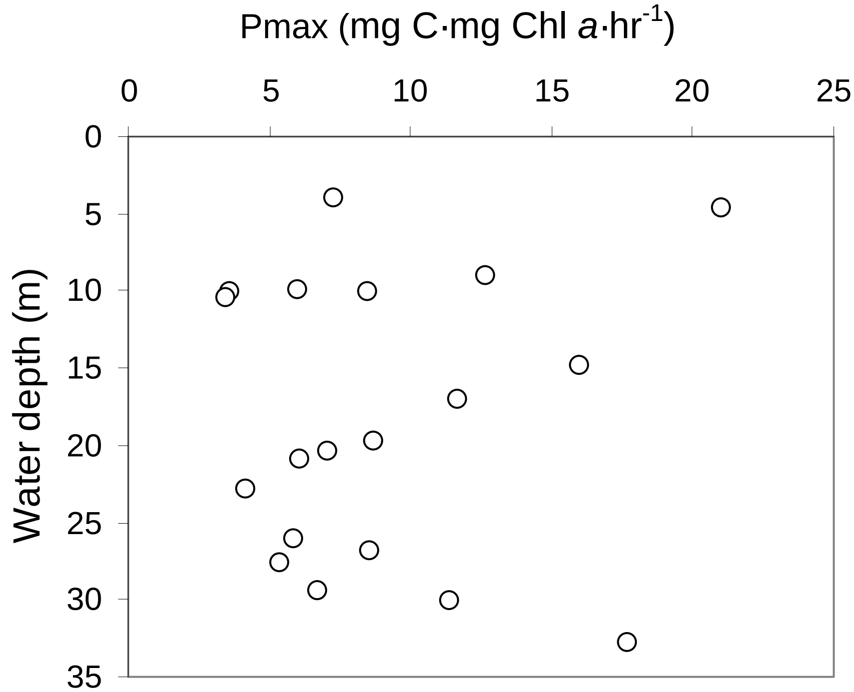


Figure 3.8.1. Relationship between water depth and algal primary production (Pmax as mg C·mg Chl a·hr^{-1}).

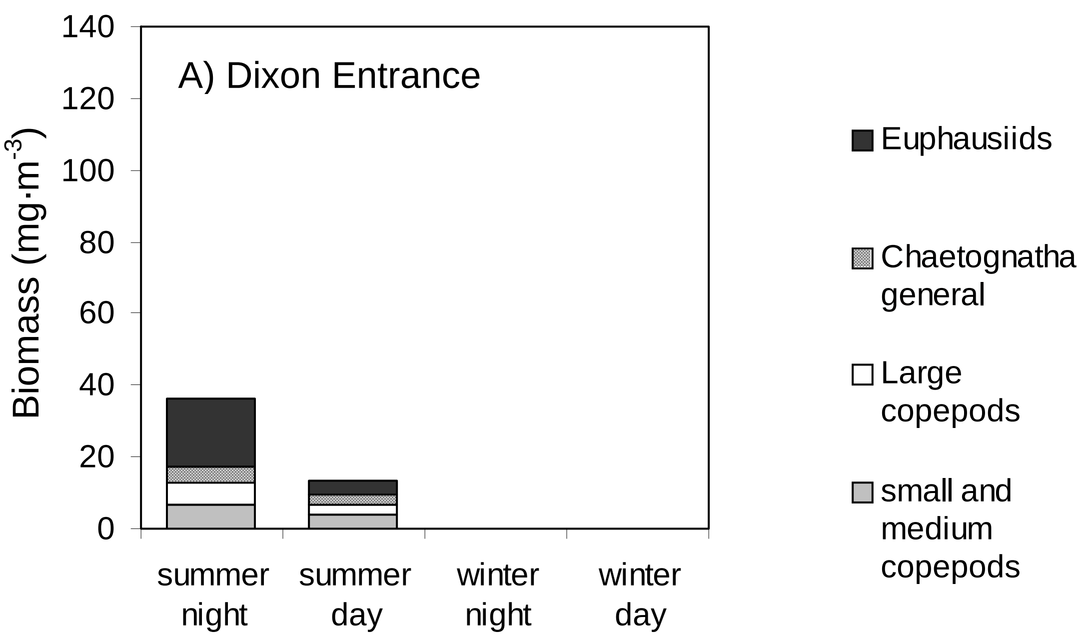
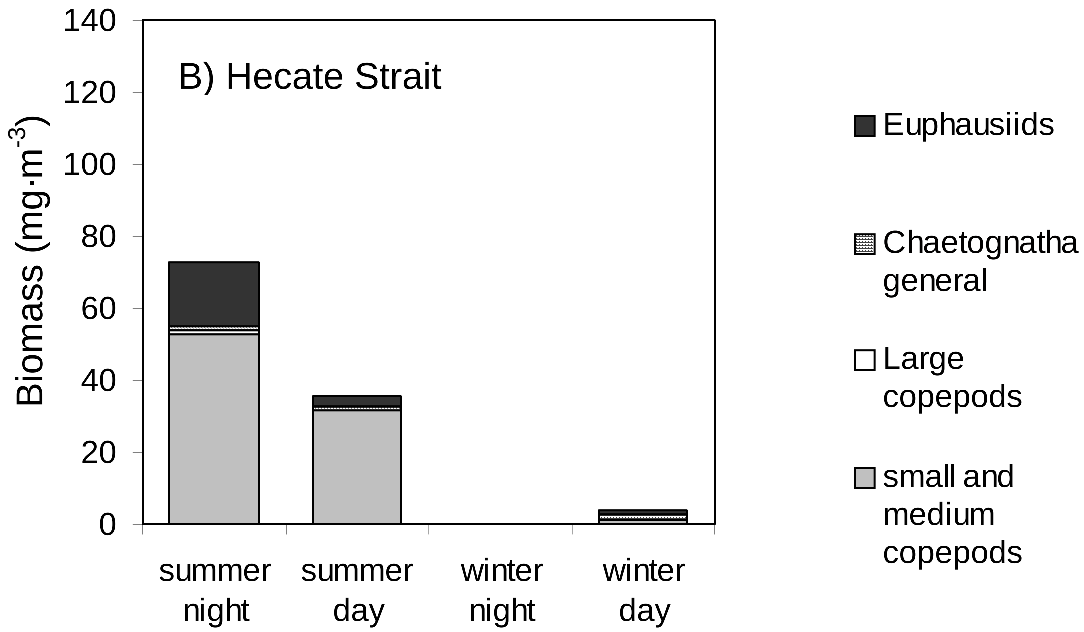


Figure 4.3.4.1. Biomass comparison for the major zooplankton groups sampled from: A) Dixon Entrance, B) Hecate Strait, and C) Goose Island Bank plus Queen Charlotte Sound.



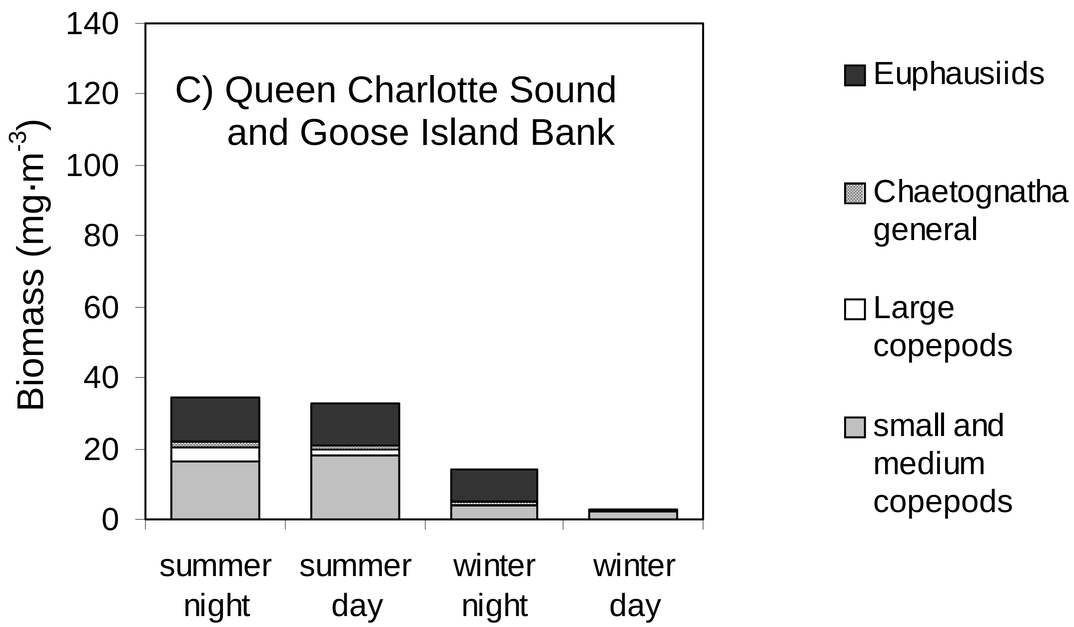


Figure 4.3.4.1. (continued)

A) **NIGHT** samples

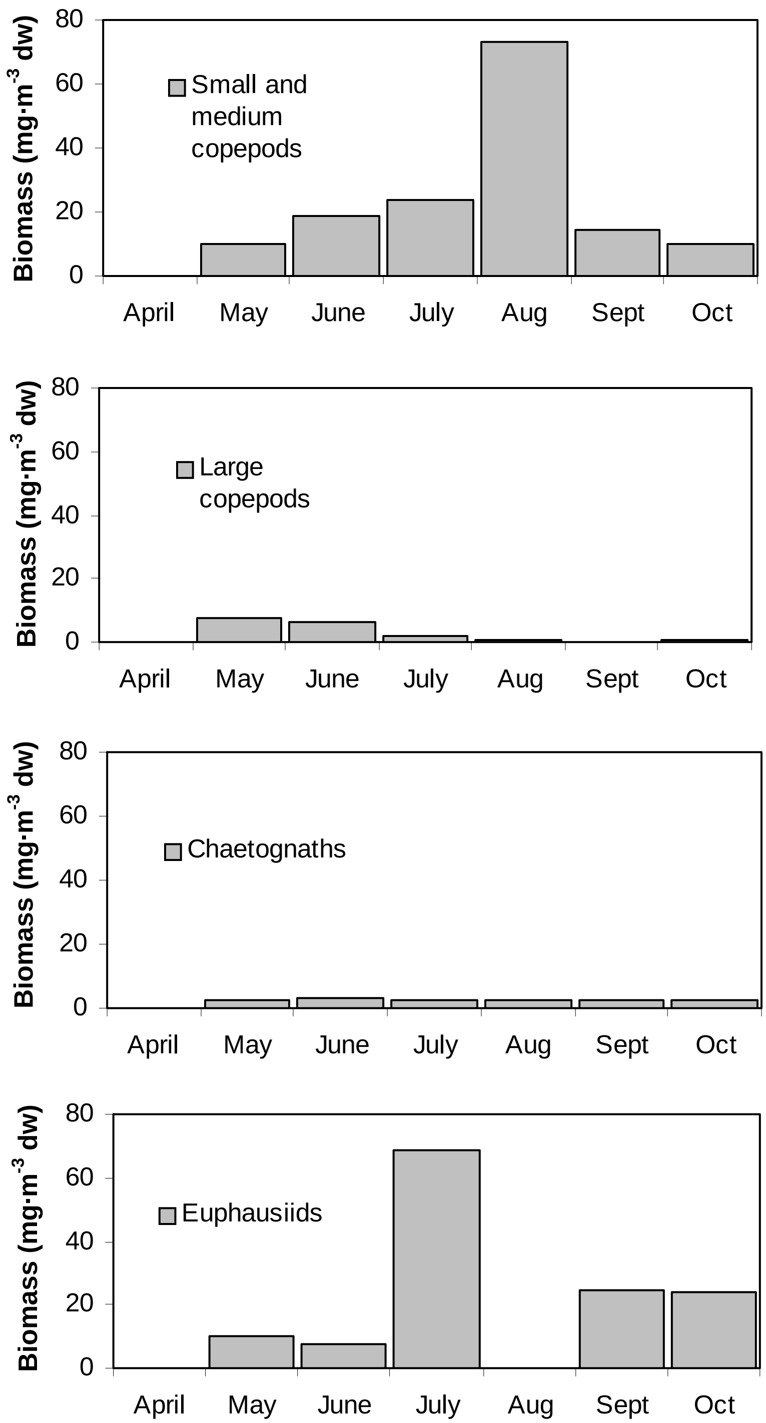


Figure 4.3.8.1. Average monthly biomasses (mg·m^{-3} dw) of selected zooplankton taxa, summarized from the IOS data base aggregated from samples taken in Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound. Plots are grouped by A) night samples and B) day samples (next page).

B) DAY samples

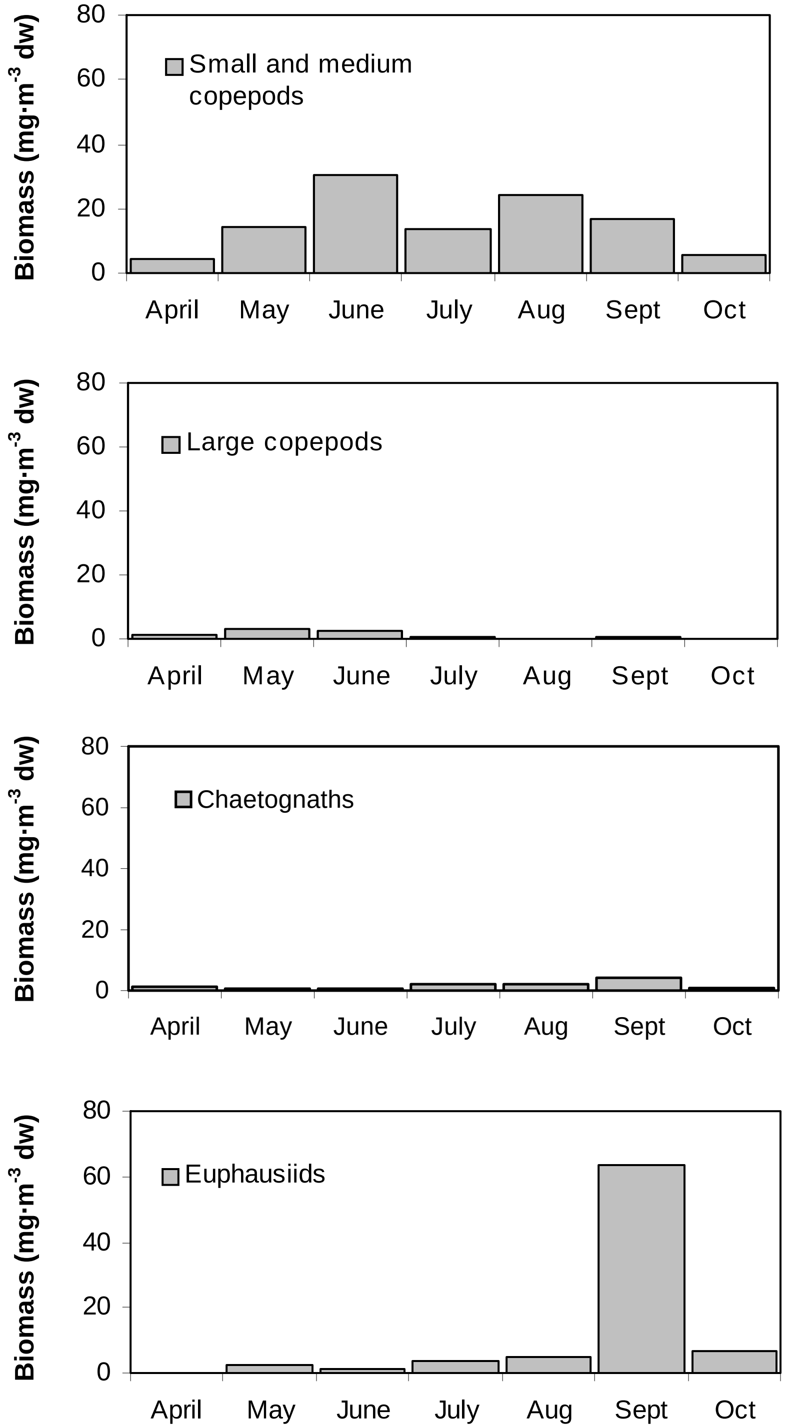
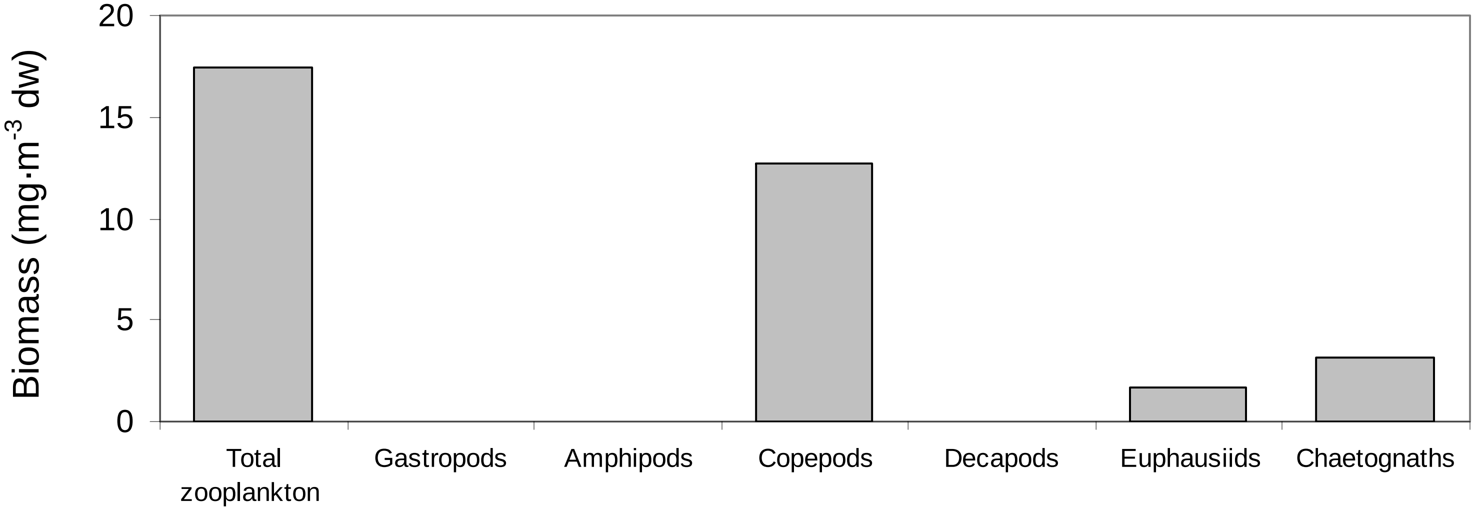
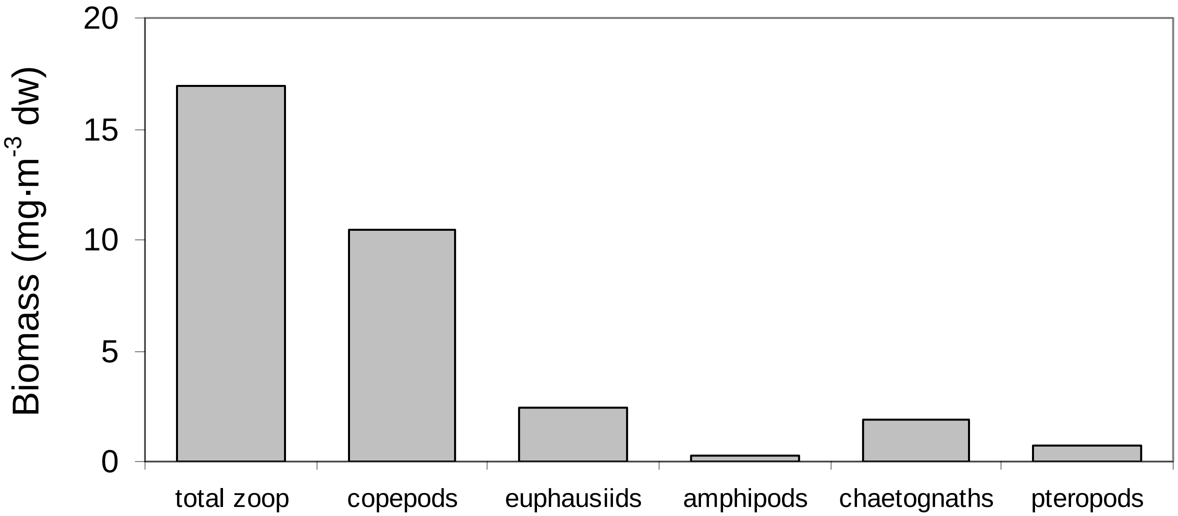


Figure 4.3.8.1. (continued)



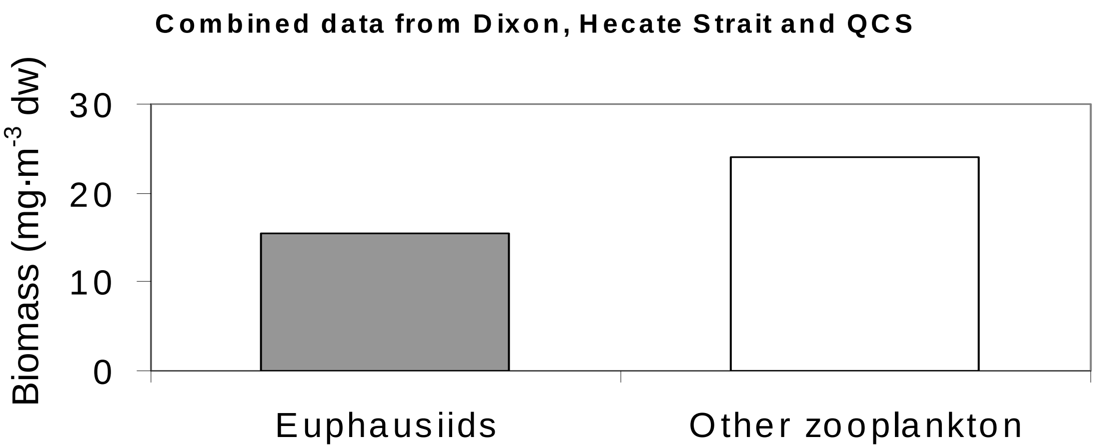
	Total zooplankton	Gastropods	Amphipods	Copepods	Decapods	Euphausiids	Chaetognaths
N	12	12	12	12	12	12	12
Mean	17.46	0.00	0.00	12.67	0.00	1.68	3.14
SE	3.27	0.00	0.00	3.46	0.00	1.09	1.59
95% CI	7.2	0.00	0.00	7.63	0.00	2.4	3.51

Figure 4.4.2.1. Pacific Oceanographic Group (1958) average summer zooplankton taxonomic group biomass (mg·m^{-3} dw) for Dixon Entrance and Queen Charlotte Sound (QCS) combined.



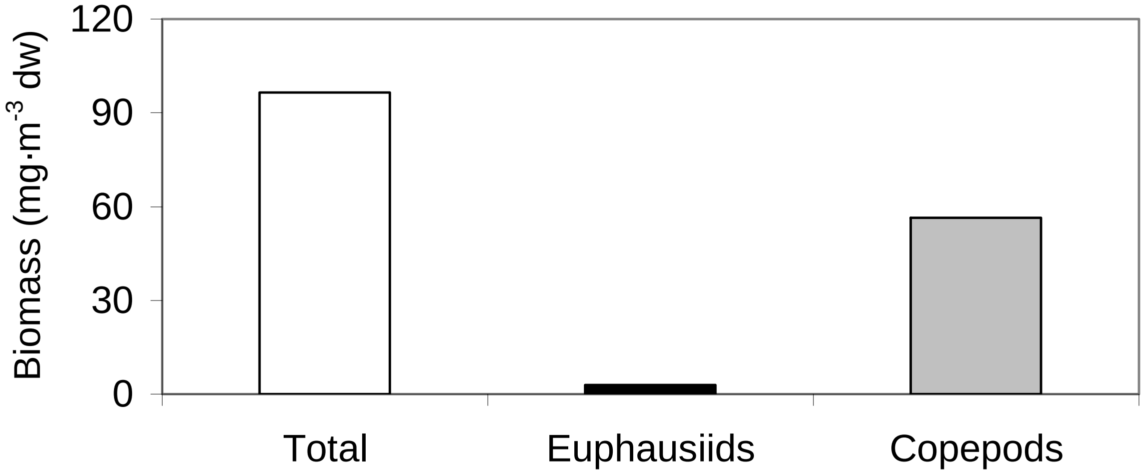
	Total zooplankton	Copepods	Euphausiids	Amphipods	Chaetognaths	Pteropods	N
Mean	16.92	10.45	2.42	0.31	1.89	0.75	50
SE	1.84	1.42	0.84	0.13	0.51	0.29	
95% CI	3.74	2.86	1.7	0.26	1.03	0.59	

Figure 4.4.3.1. LeBrasseur (1965) average summer zooplankton taxonomic group biomass (mg·m^{-3} dw) for Hecate Strait including all stations from Dixon Entrance, Hecate Strait (HS), and Queen Charlotte Sound (QCS). These data are summarized from the original wet weigh data mapped by LeBrasseur (1965).



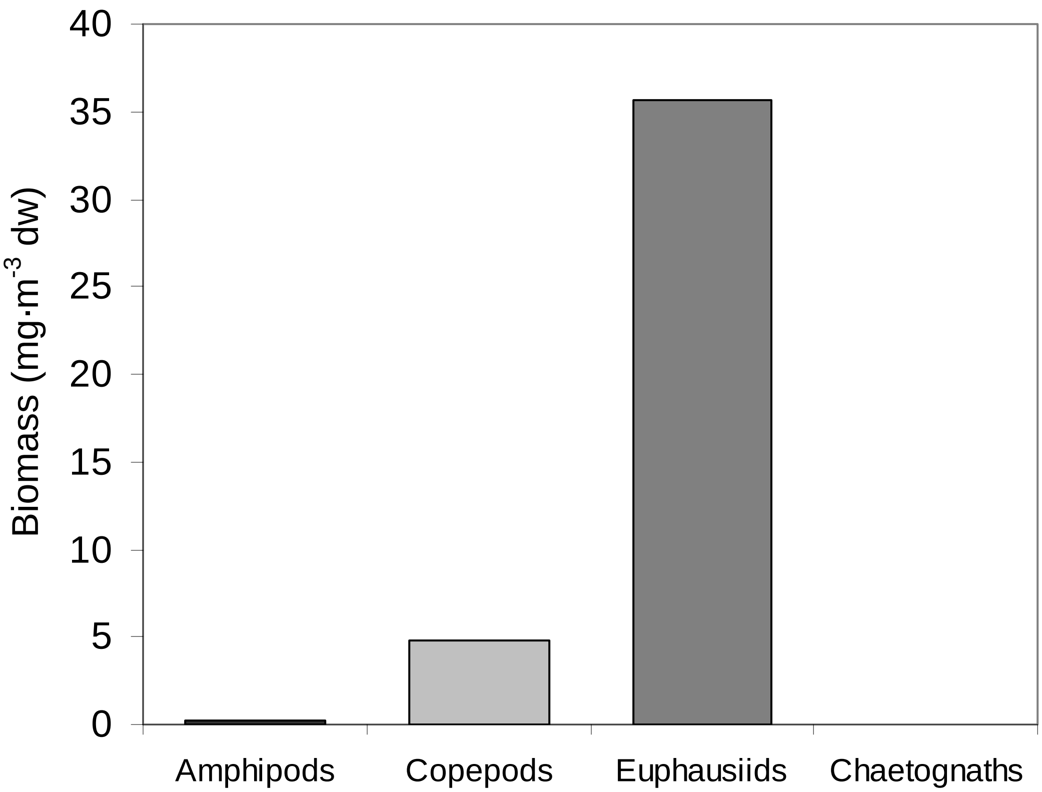
Location			Euphausiids	Other zooplankton	Location			Euphausiids	Other zooplankton	Location			Euphausiids	Other zooplankton
Dixon	Day	Mean	**4.66**	**47.52**	**Hecate**	Day	Mean	**2.39**	**13.75**	**QCS**	Mean	Day	**5.83**	**43.94**
		SE	1.01	8.24			SE	0.73	3.20		SE		1.66	16.07
		95% CI	2.04	17.29			95% CI	1.48	6.55		95% CI		3.83	37.07
	Night	Mean	**17.91**	**27.02**		Night	Mean	**35.03**	**15.46**		Mean	Night	**13.07**	**21.36**
		SE	4.58	12.05			SE	12.38	4.50		SE		7.05	13.00
		95% CI	10.20	27.27			95% CI	25.06	9.19		95% CI		15.72	29.98
	Overall	Mean	**9.69**	**40.20**		Overall	Mean	**19.14**	**14.68**		Mean	Overall	**9.81**	**32.65**

Figure 4.4.4.1. Fulton *et al* (1982) dry weight biomasses (mg·m^{-3}) for euphausiids and other zooplankton for stations from Dixon Entrance, Hecate Strait, and Queen Charlotte Sound. All samples were collected during the winter (see Table 4.4.4.1). The attached table provided means and confidence intervals for both night and day samples. The attached figure provides an average for all stations together.



Station	70	72	77	78	84	
Longitude	128° 53’5”	129° 27’5”	130° 21’1”	130° 13’7”	130° 51’0”	
Latitude	51° 42’4”	51° 55’4”	53° 05’5”	53° 19’8”	53° 13’6”	
Depth (m)	79	61	110	57	107	
Day/night	night	day	day	day	night	
						Average
Total	68.75	64.25	65.83	210.13	73.28	**96.45**
Euphausiids	0.12	3.27	11.41	0.16	0.01	**3.00**
Copepods	27.27	51.49	47.24	144.75	11.37	**56.42**

Figure 4.4.5.1. Denman *et al* (1985) zooplankton biomasses (mg·m^{-3} dw) transformed from original data tabulated as numbers per m^{-2}.



	Amphipods	Copepods	Euphausiids	Chaetognaths
Mean	0.23	4.82	35.64	0.02
SE	0.12	2.04	14.62	0.01
95% CI	0.25	4.27	30.61	0.01
N	20	20	20	20

Figure 4.4.6.1. Burd and Jamieson (1991) Tucker trawl biomasses (mg·m^{-3} dw) collected in Hecate Strait during 1988. Biomasses for each taxonomic group are averaged over 20 stations.

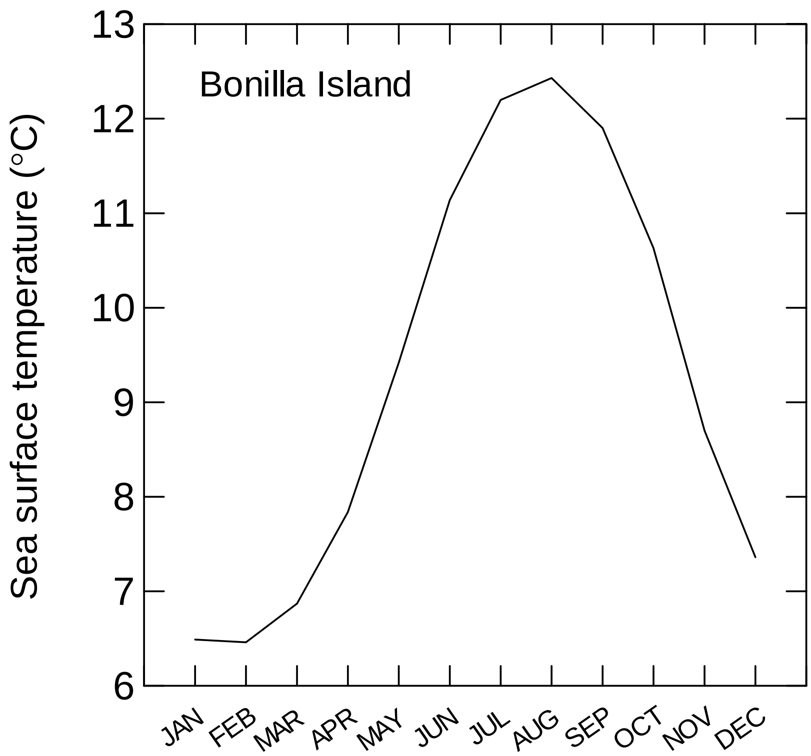
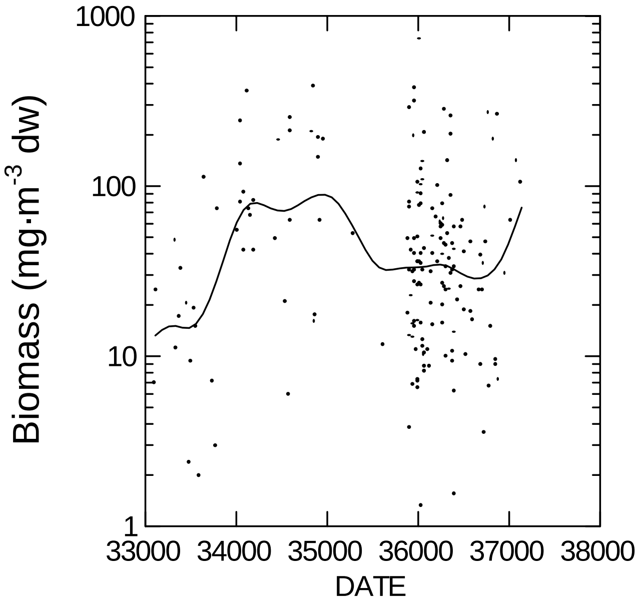


Figure 4.5.1. Sea surface temperatures (°C) at Bonilla Island based on monthly means collected between 1960 and 2001.



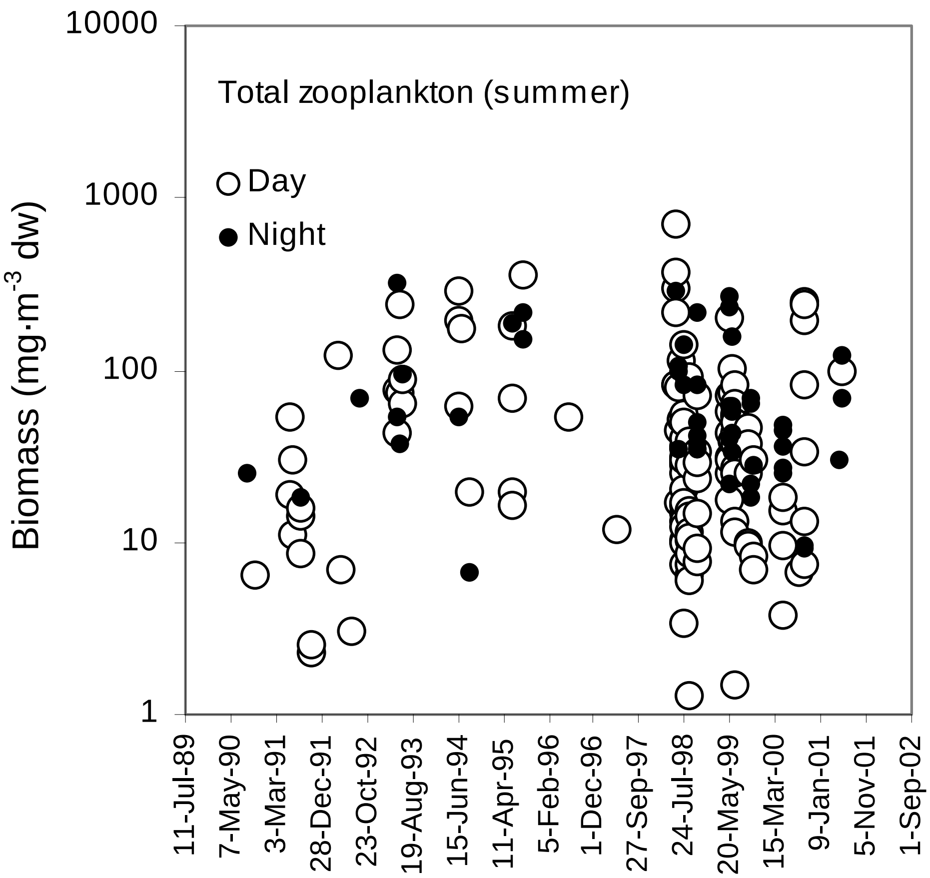
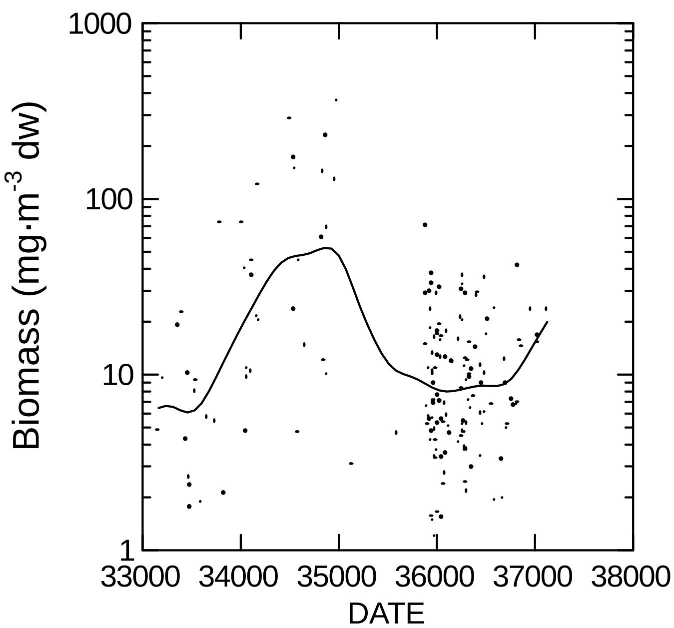


Figure 4.6.1. IOS data set (summer only) total zooplankton biomass (mg·m^{-3} dw). [Bottom figure] - day and night data with respect to date during the 1990s. [Top figure] - distance weighted least square fit to the data. The data set comprises all available stations from Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound.



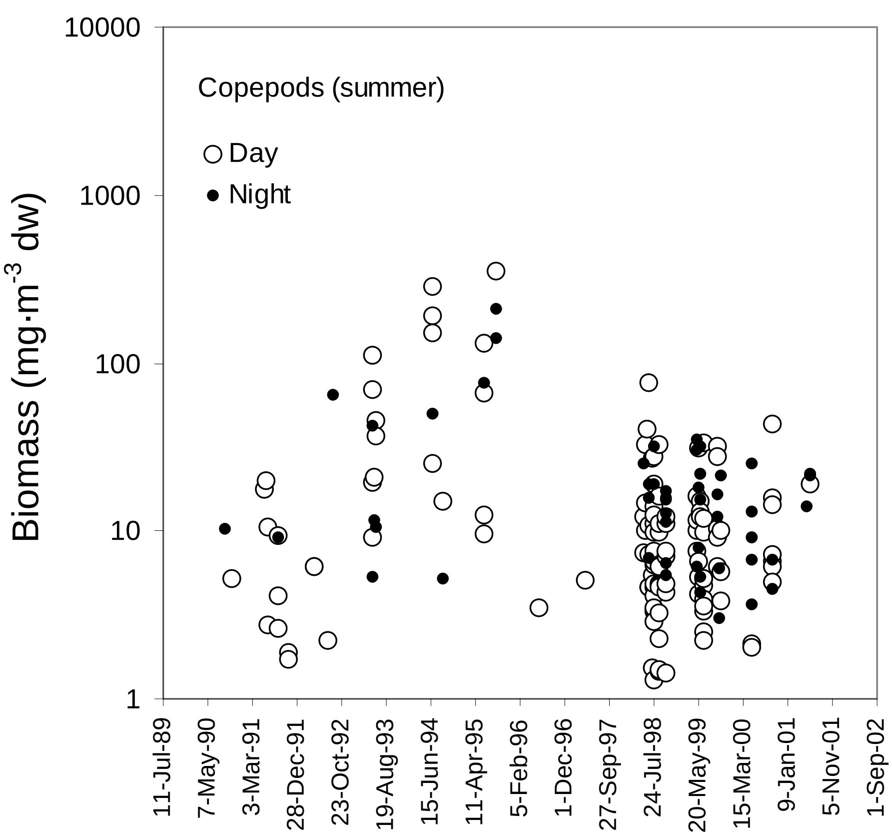


Figure 4.6.2. IOS data set (summer only) total copepod biomass (mg·m^{-3} dw). [Bottom figure] - day and night data with respect to date during the 1990s. [Top figure] – distance weighted least square fit. The data set comprises all available stations from Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound.

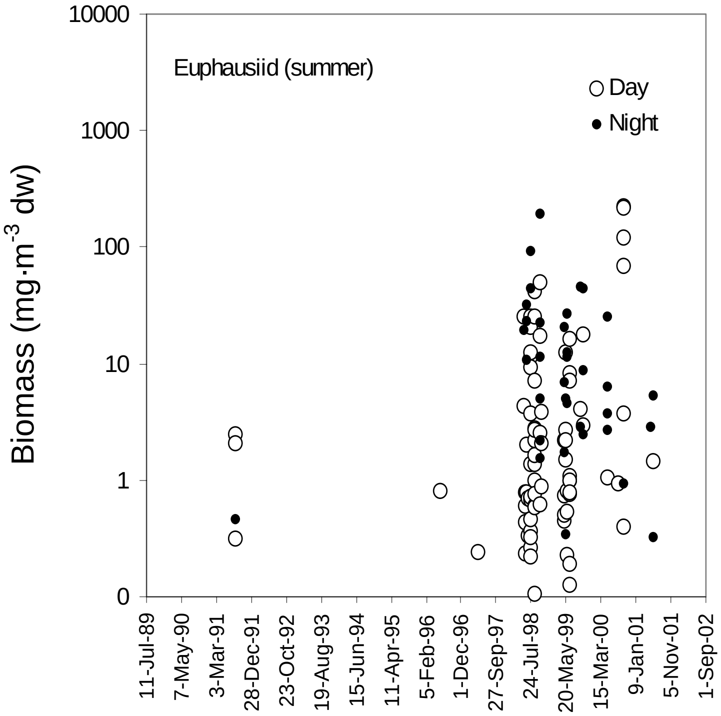


Figure 4.6.3. IOS data set (summer only) total euphausiid biomass (mg·m^{-3} dw) plotted with respect to date during the 1990s. Most data from the mid-1990s are very low (values between 0.0-0.1 mg·m^{-3}) and therefore do not plot on the figure shown below. The data set comprises all available stations from Dixon Entrance, Hecate Strait, Goose Island Bank, and Queen Charlotte Sound.

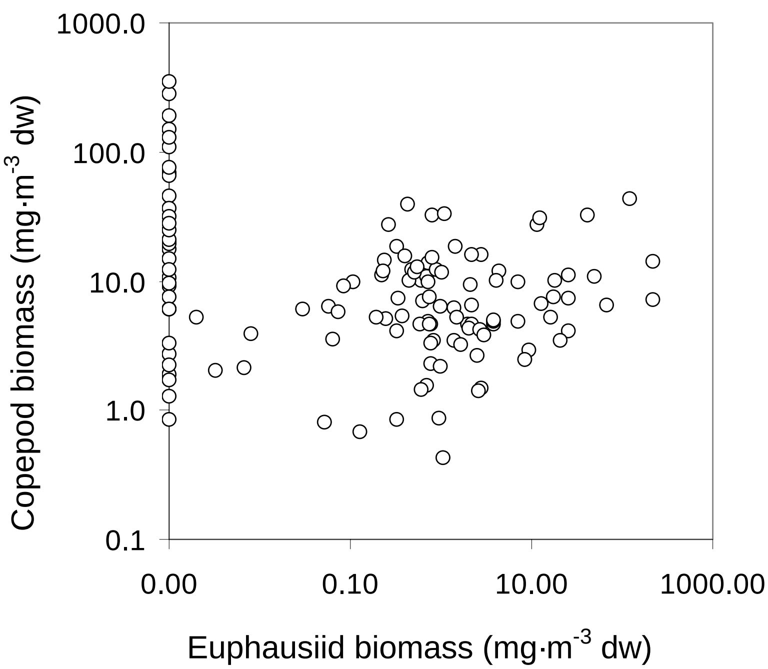


Figure 4.6.4. IOS data base (summer) copepod biomass with respect to euphausiid biomass (mg·m^{-3} dw).

APPENDICES

Appendix A: Reading List

APPRISE – International Variability and Fisheries Management. contains 16 papers which I have not entered in this data base yet. *In* Ziemann, D.A., and K.W. Fulton-Bennett. [eds.].

Beattie, A. 1999. The Hecate Strait: A preliminary present day model. *In* Haggan and A. Beattie. [eds.]. Back to the Future: Reconstructing the Hecate Strait Ecosystem. Fisheries Centre Research Reports. 7(3): 13-25.
Key words: zooplankton
Comment: Ecosim model of Hecate Strait.

Burd, B.J., and **Jamieson**, G.S. 1991. Survey of larval stages of commercial species in the area and time of the 1988 seismic survey in Queen Charlotte Sound and Hecate Strait. pp. 513-544. *In* Evolution and hydrocarbon potential of the Queen Charlotte Basin, British Columbia. Geological Survey of Canada, 90-10.
Key words: zooplankton
Comment:

Calbert, A., and Landry, M.R. 1999. Mesozooplankton influences on the microbial food web: Direct and indirect trophic interactions in the oligotrophic open ocean. Limnol. Oceanogr. 44: 1370-1380.
Key words: microbial loop
Comment: good to look at this for model construction....contains rates and pathways.

Cameron, F.E. 1957. Some factors influencing the distribution of pelagic copepods in the Queen Charlotte Islands area. J. Fish. Res. Board Canada. 14: 165-202.
Key words: zooplankton
Comment:

Carr, M.E. 1998. A numerical study of the effect of periodic nutrient supply on pathways of carbon in a coastal upwelling regime. J. Plankton Res. 20: 491-516
Key words: modeling
Comment: should read carefully, may be basis for model construction.

Crawford, W.R. 1997. Physical oceanography of the waters around the Queen Charlotte Islands. pp. 8-17. *In* K. Vermeer and Morgan, K.H. [eds.] The ecology, status, and conservation of marine and shoreline birds of the Queen Charlotte Islands. Occasional Paper (Canadian Wildlife Service) 93.
Key words: oceanography, chemistry, physics
Comment: deals with Hecate Strait. See summary for quite a good overview of summer and winter conditions.

Denman, K., Forbes, R., Mackas, D., Hill S., and Sefton, H. 1985. Ocean ecology data report British Columbia Coastal Waters 29 June – 10 July, 1983. Canadian Data Report of Hydrography and Ocean Sciences 36. Institute of Ocean Sciences, Dept of Fisheries and Oceans, Sidney, BC V8L 4B2.
Key words:
Comment:

Denman, K.L., Freeland, H.J., and Mackas, D.L. 1989. pp. 255-264. *In* Beamish, R.J., and McFarlane, G.A. [eds]. Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108.
Key words: zooplankton, fish, modeling
Comment: modeling of biomass propagation.

Dilke, B.R., McKinnell, S., and Perry, R.I. 1979. Data Report 46. Ship-of-Opportunity Program March 1978 – March 1979. Oceanography, University of British Columbia.
Key words: zooplankton, phytoplankton, chemistry, data
Comment: these data do deal with Hecate Strait. First few pages copied. Document at PBS library.

Dunbrack, R., and Ware, D.M. 1986. Particle size spectrum estimation of the standing stock of pelagic fish. *In* A.V. **Tyler** [ed.]. Hecate Strait Project: results of the first two years of multispecies fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. 1470.
Key words: zooplankton
Comment:

Fargo, J. 1994. Examining recruitment relationships for Hecate Strait English sole (*Pleuronectes vetulus*). Netherlands J. Sea Res. 32: 385-397.
Key words: fish
Comment: general for Hecate Strait.

Fulton, J., Arai, M.N., and Mason, J.C. 1982. Euphausiids, coelenterates, ctenophores, and other zooplankton from the Canadian Pacific Coast Ichthyoplankton Survey, 1980. Can. Tech. Rep. Fish. Aquat. Sci. 1125. 75 p.
Key words: zooplankton, Euphausiid
Comment: deals with Hecate Strait.

Hershey, A.E., Gettel, G.M., McDonald, M.E., Miller, M.C., Moores, H., O'Brien, J.W., Pastor, J., Richards, C., and Schuldt, J.A. 1999. A geomorphic-trophic model for landscape control of Arctic lake food webs. Bioscience 49: 887-897.
Key words: food web, modeling
Comment: general interest.

Haney, J.D., and Jackson, G.A. 1996. Modelling phytoplankton growth rates. J. Plankton. Res. 18: 63-85.
Key words: modeling, phytoplankton
Comment: some parameters, very detailed re the exact function to use to model phytoplankton growth rates.

Hay, D., Keiser, R., and McCarter, P.B. 1986. Distribution of herring in winter. pp 11-16. *In* **Tyler,** A.V. [ed.]. Hecate Strait Project: results of the first two years of multispecies fisheries research. Can. Tec. Rep. Fish. Aquat. Sci. 1470.
Key words: zooplankton
Comment:

Healey, M.C., Incze, L.S., Tabata, S., Reed, R., and Pearcy, W. 1985. Inventory of time series of physical, chemical, biological and fisheries data from the eastern North Pacific. Can. Tech. Rep. Fish. Aquat. Sci. 1416.
Key words: fish
Comment:

Johnson, K.S., Chavez, F.P, and Friederich, G.E. 1999. Continental-shelf sediment as a primary source of iron for coastal phytoplankton. Nature 398: 697-699.
Key words: phytoplankton
Comment: general interest

LeBrasseur, R.J. 1965. Biomass atlas of net zooplankton in the northeastern Pacific Ocean, 1956-1964. Fish. Res. Board Manuscr. Rep. (Oceanographic and Limnological) 201.
Key words: zooplankton
Comment: many figures, will be very useful

Mackas, D.L., and Galbraith, M. 1991. Zooplankton on the west coast of Vancouver Island: distribution and availability to marine birds. pp. 15-21. *In* The ecology, status, and conservation of marine shoreline birds on the west coast of Vancouver Island. Occasional Paper 75, Canadian Wildlife Service. Proceedings of a symposium sponsored by the Institute of Ocean Sciences, the Canadian Parks Service, and the Canadian Wildlife Service, held at IOS in Sydney, B.C., 8 April 1991.
Key words: zooplankton
Comment: many figures, will be very useful

Mackas, D.L., Goldblatt, R., and Lewis, A.G. 1998. Interdecadal variation in development timing of *Neocalanus plumchrus* populations at Ocean Station P in the subarctic North Pacific. Can. J. Fish. Aquat. Sci. 55: 1878-1893.
Key words: zooplankton
Comment: might be ok for area west of Queen Charlottes

Mackas, D.L., Thompson, R.E., and Galbraith, M. 2001. Changes in the zooplankton community of the British Columbia continental margin, 1985-1999, and their covariation with oceanographic conditions. Can. J. Fish. Aquat. Sci. 58: 685-702.
Key words: zooplankton
Comment: deals with south coast off of Vancouver Island.

McFarlane, G.A., **Ware**, D.M., Thompson, R.E., Mackas, D.L., and Robinson, C.L.K. 1997. Physical, biological and fisheries oceanography of a large ecosystem (west coast of Vancouver Island) and implications for management. pp. 191-200. *In* G. Bachelet and Castel, J. [eds.]. Long-Term Changes in Marine Ecosystems. Oceanologica ACTA 20.
Key words: fish, zooplankton
Comment: west Vancouver Island

McPhaden, M.J. 1999. El Niño: The child prodigy for 1997-98. Nature 398: 559-562.
Key words: climate, oceanography
Comment: general interest

Moloney, C.L., and Field, J.G. 1991. The size-based dynamics of plankton food webs. I. A simulation model of carbon and nitrogen flows. J. Plankton Res. 13: 1003-1038.
Key words: modeling, food web
Comment: many parameters

Moloney, C.L., Field, J.G., and Lucas, M.I. 1991. The size-based dynamics of plankton food webs. II. Simulations of three contrasting southern Benguela food webs. J. Plankton. Res. 13: 1039-1092.
Key words: modeling, food web
Comment: many parameters

Mostajir, B., Demers, S., de Mora, S., Belzile, C., Chanut, J.P., Gosselin, M., Roy, S., Villegas, P.Z., Fauchot, J., Bouchard, J., Bird, D., Monfort, P., and Levasseur, M. 1999. Experimental test of the effect of ultraviolet-B radiation in a planktonic community. Limnol. Oceanogr. 44: 586-596.
Key words: phytoplankton
Comment: of general interest, not dealing with Hecate Strait

Pacific Oceanographic Group. 1958. Physical, chemical and plankton data record. Coastal Surveys April 25 to December 17, 1957. Fish. Res. Board Can. Manuscr. Rep. Series (Oceanographic and Limnological) 17. 274 p.
Key words: zooplankton, phytoplankton, water chemistry
Comment: some Hecate data

Painting, S.J., **Moloney**, C.L., and Lucas, M.I. 1993. Simulation and field measurements of plankton-bacteria-zooplankton interactions in the southern Benguela upwelling region. Mar. Ecol. Prog. Ser. 100: 55-69.
Key words: modeling, food web
Comment:

Peperzak, L., Colijn, F., Gieskes, W.W.C., and Peeters, J.C.H. 1998. Development of the diatom – *Phaeocystis* spring bloom in the Dutch coastal zone of the North Sea: the silicone depletion versus the daily irradiance threshold hypothesis. J. Plankton Res. 20: 517-537 .
Key words: diatom, phytoplankton
Comment:

Perry, R.I., Thompson, P.A., Mackas, D.L., Harrison, P.L., and Yelland, D.R. 1999. Stable carbon isotopes as pelagic food web tracers in adjacent shelf and slope regions off British Columbia, Canada. Can. J. Fish. Aquat. Sci. 56: 2477-2486.
Key words: carbon, isotope, food web
Comment:

Perry, R.I., Dilke, B.R., Louttit, G.C., and McKinnell, S. 1981. Data Report 49. Ship-of-Opportunity Program May 1979 - June 1980. Oceanography, University of British Columbia.
Key words: zooplankton, phytoplankton, chemistry, data
Comment: these data deal with Hecate Strait

Perry, R.I., Dilke, B.R., and Parsons, T.R. 1983. Tidal mixing and summer phytoplankton distributions in Hecate Strait, British Columbia. Can. J. Fish. Aquat. Sci. 40: 871-887.
Key words: zooplankton, phytoplankton, chemistry, data
Comment: phytoplankton model for Hecate Strait

Perry, R.I., and Dilke, B.R. 1986. The importance of bathymetry to seasonal plankton blooms in Hecate Strait, B.C. Lecture Notes of Coastal and Estuarine Studies 17. *In* Bowman, J., Yentsch, M., and Peterson, W.T. [eds.]. Tidal Mixing and Plankton Dynamics. Springer-Verlag Berlin Heidelberg. 1986.
Key words: zooplankton, phytoplankton, chemistry, data
Comment: phytoplankton model for Hecate Strait

Perry, R.I, and Waddell, B.J. 1996. Zooplankton in the Queen Charlotte Islands waters: distribution and availability to marine birds. pp. 8-17. *In* K. Vermeer and K.H. Morgan [eds.]. The ecology, status, and conservation of marine and shoreline birds of the Queen Charlotte Islands. Occasional Paper (Canadian Wildlife Service) 93.
Key words: zooplankton
Comment: deals with Hecate Strait

Robards, M.D., Piatt, J.F., and Rose, G.A. 1999. Maturation, fecundity, and intertidal spawning of Pacific sand lance in the northern Gulf of Alaska. J. Fish Biol. 54: 1050-1068.
Key words: fish
Comment: general interest

Robinson, C.L.K., and Ware, D.M. 1994. Modelling pelagic fish and plankton trophodynamics off southwestern Vancouver Island, British Columbia. Can. J. Fish. Aquat. Sci. 51: 1734-1751.
Key words: modeling, food web
Comment:

Robinson, C.L.K. 1994. The influence of ocean climate on coastal plankton and fish production. Fisheries Oceanography. 3: 159-171.
Key words: modeling, food web
Comment:

Robinson, C.L.K., and Ware, D.M. 1999. Simulated and observed response of the southwest Vancouver Island pelagic ecosystem to oceanic conditions in the 1990s. Can. J. Fish. Aquat. Sci. 56: 3433-2443.
Key words: modeling, food web
Comment:

Salomon, A., Waller, N., McIlhagga, C., and Yung, R. 2000. Modeling the trophic effects of marine protected areas zoning policies in Gwaii Haanas National Marine Conservation Area. Class Report from UBC.
Key words: modeling, food web
Comment: deals with Hecate Strait

Serchuk, F., Rivard, D., Casey, J., and Mayo, R. 1997. Precautionary approach to fish management. North Atlantic Fisheries Organization. Serial No. N2911, NAFO SCS Doc 97/12. 18 p.
Key words:
Comment: general interest

Shaw, W., and **Robinson**, C.K.L. 1998. Night vs. day abundance estimates of zooplankton at two British Columbia, Canada, coastal stations. Marine Ecology Progress Series 175: 143-153.
Key words:
Comment: only have the abstract

Steele, J.H. 1998. Incorporating the microbial loop in a simple plankton model. Proc. R. Soc. Lond. Series B 265: 1771-1777.
Key words: microbial loop, modeling
Comment: we should probably use this as our starting point.

Straile, D. 1997. Gross growth efficiencies of protozoan and metazoan zooplankton and their dependence on food concentration, predator-prey weight ratio, and taxonomic group. Limnol. Oceanogr. 42: 1375-1385.
Key words: modeling, food web, microbial loop, zooplankton
Comment: contains growth data

Tanasichuk, R.W., **Ware**, D.M., Shaw, W., and McFarlane, G.A. 1991. Variation in diet, daily ration, and feeding periodicity of Pacific Hake (*Merluccius productus*) and spiny dogfish (*Squalus acanthias*) off the lower west coast of Vancouver Island. Can. J. Fish. Aquat. Sci. 48: 2118-2128.
Key words: fish
Comment: general interest

Tanasichuk, R.W. 1998. Interannual variations in the population biology and productivity of the euphausiid *Thysanoessa spinifera* in Barkley Sound, Canada, with special reference to the 1992 and 1993 warm ocean years. Marine Ecology Progress Series 173: 181-195.
Key words:
Comment: only have the abstract

Tyler, A. 1986. Hecate Strait Project: Results of the first two years of multispecies research. Can. Tech. Rep. Fish. Aquat. Sci. 1470. 50 p.
Key words: fish
Comment: general for Hecate Strait...must read summary.

Tyler, A.V., Richards, L.J., and Walters, C.J. 1986. Hecate Strait Project: Report of the Hecate Strait ecosystem modelling workshop. Can. Manuscr. Rep. Fish. Aquat. Sci. 1829. 23 p.
Key words: modeling
Comment: they show the basic parameters but do not produce any model output. Will have to look for some kind of paper that presents the finished model (if there is one). See two papers presented by Tyler *et al* 1986 and Walters *et al* 1986 (references found on page 60 of the 1989 report).

Tyler, A,V. 1989. Hecate Strait project: Results from four years of multispecies fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. 1667. 60 p.
Key words: fish
Comment: general for Hecate Strait...must read summary.

Tyler, A.V., and Crawford, W.R. 1991. Modelling of recruitment patterns in Pacific cod (*Gadus macrocephalus*) in Hecate Strait, British Columbia. Can. J. Fish. Aquat. Sci. 48: 2240-2249.
Key words: fish
Comment: general for Hecate Strait...must read summary.

Walters, C.J., Stocker, M., **Tyler**, A.V., and Westrheim, J.S. 1986. Interaction between Pacific cod (*Gadus macrocephalus*) and herring (*Clupea herengus pallasi*) in the Hecate Strait, British Columbia. Can. J. Fish Aquat. Sci. 43: 830-837.
Key words: fish
Comment: general for Hecate Strait...must read summary.

Waddell, B.J., and McKinnell, S. 1995. Ocean Station 'Papa" detailed zooplankton data: 1956-1980. Can. Tech. Rep. Fish. Aquat. Sci. 2056. 21 p.
Key words: zooplankton
Comment: data are pretty far south being collected along the 50th parallel north

Walters, C.J., Hilborn, R., Peterman, R.M., and Staley, M. 1978. Model for examining early ocean limitation of Pacific salmon production. J. Fish. Res. Board Canada. 35: 1303-1315.
Key words: modeling
Comment:

Ware, D.M., and McFarlane, G.A. 1989. Fisheries production domains in the north east Pacific Ocean. pp. 359-379. *In* R.J. Beamish and G.A. McFarland [eds.]. Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108.
Key words: zooplankton, fish
Comment: deals with large scale data sets, includes P/B ratios for zooplankton

Ware, D.M., and McFarlane, G.A. 1995. Climate change and northern fish populations. Can. Spec. Publ. Fish. Aquat. Sci. 121: 509-521.
Key words: climate change
Comment:

Wada, T., **Ware**, D.M., Kashiwai, M., Yamamura, O., and Robinson, C.L.K. 1998. Responses of plankton and fish production dynamics to sardine abundance regime shifts in the Oyashio Current region. pp. 123-130. *In* Ohtani *et al* [eds.] Comparison Oyashio region and Bering Sea ecosystems. Memoirs of the Faculty of Fisheries, Hokkaido University 45(1).
Key words: modeling, food web
Comment:

Ware, D.M. 2000. Aquatic Ecosystems: Properties and models. pp. 161-206. *In* Harrison, P.J. and Parsons, T.R. [eds.]. Fisheries Oceanography: An interpretative approach to fisheries ecology and management. Blackwell Science Ltd.
Key words: modeling, food web
Comment:

Willette, T.M., Cooney, R.T., and Hyer, K. 1999. Predator mode foraging shifts affecting mortality of juvenile fishes during the subarctic spring bloom. Can. J. Fish. Aquat. Sci. 56: 364-376.
Key words: fish
Comment: general interest

Appendix B: Reference Data Files

The following Excel spreadsheets are listed in order of appearance in the main text, and are included on the CD attached to the back cover of this printed report. Alternately, electronic editions of the report ("DR1162 McQueen Ware – Hecate Handbook.pdf") and data files will be available online (http://inter01.dfo-mpo.gc.ca/waves2/search.html) by searching the Fisheries and Oceans Canada "Waves" Library catalogue for this report. Once your search locates the report, choose "View Online" from the DFO internet copy near the bottom left of the web page to download selected files, or download "Handbook data.zip" (734 KB) which contains all files.

File Name (file size)	Report Section(s)
Chem Dilke et al 1979.xls (24 KB)	2.2, 3.2
Chem Perry et al 1981.xls (44 KB)	2.3, 3.3
Chem Denman et al 1985.xls (726 KB)	2.4, 3.4
Chem Forbes and Waters 1993.xls (45 KB)	2.5, 3.5
Chla Ware 1979 and 1997.xls (16 KB)	3.6
IOS Zoo biomass Hecate Dixon QCS.xls (941 KB)	4.3.2, 4.3.3, 4.3.7, 4.3.8
IOS Zoo biomass Dixon.xls (81 KB)	4.3.4
Appendix C Dixon.xls (53 KB)	4.3.4
IOS Zoo biomass Hecate.xls (90 KB)	4.3.5
Appendix D Hecate.xls (28 KB)	4.3.5
IOS Zoo biomass QCS.xls (183 KB)	4.3.6
Appendix E QCS.xls (51 KB)	4.3.6
Zoo Pacific Oceanographic Group 1958.xls (28 KB)	4.4.2
Zoo LeBrasseur 1965.xls (59 KB)	4.4.3
Zoo Fulton et al 1982.xls (75 KB)	4.4.4
Zoo Denman et al 1985.xls (42 KB)	4.4.5
Zoo Burd and Jamieson 1991.xls (72 KB)	4.4.6
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