THE UNIVERSITY OF MANITOBA

DISTRIBUTION AND PRIMARY PRODUCTION OF BENTHIC ALGAE ON THE SQUAMISH RIVER DELTA, BRITISH COLUMBIA

by

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ABSTRACT

Investigations of spatial and temporal variations in the distribution, biomass and primary production of benthic algae on the Squamish River Delta were undertaken from May, 1972 to April, 1973. Variations in these factors for a particular algal species or assemblage were found to be limited by substrate availability and one or more of the physico-chemical parameters : salinity, temperature and incident light. Nutrients were assumed not to be limiting in this esturine - brackish water habitat.

Annual net production estimates, using dissolved oxygen techniques, ranged from 0.91 to 2.78 Kg C m^{-2}. In terms of daily net production, values from 0.01 to 5.42 g C m^{-2} day^{-1} were recorded, with Chlorophytes being the most productive.

Dawn to dusk production curves indicated maximum net production to occur in the two hour period prior to the time of strongest illumination. On a seasonal basis, a shift of the time of production maxima towards mid-day, and thus towards stronger light was evident suggesting an adaptive mechanism.

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INTRODUCTION

Investigations of primary production and patterns of algal seasonal succession in the aquatic environment have primarily been directed at the plankton (Strickland 1960, Talling 1965, Dickman 1969). Comparatively little data of this type are available for phyto-benthos of marine environments (Vladimirova 1969). However, available data do indicate that shallow marine habitats such as coral reefs, mangrove swamps, marshes and estuaries with their adjacent alluvial plains are among the most naturally productive ecosystems known to man (Odum 1961, 1971, Westlake 1963, Keefe 1972).

The high productivity of esturine-deltaic ecosystems has not been generally understood. As a result, they have frequently been considered worthless areas suitable only for dumping of wastes or useful only if drained, filled and converted to terrestrial use (Odum 1971). The Squamish River Delta on the southwest coast of British Columbia reflects just such a situation. Development has resulted in either the alteration of many of the existing deltaic habitats (eg. altered water flow patterns, salinities, etc.) or the formation of entirely new habitats through the presentation of fresh substrates potentially available for colonization of macro-vegetation and/or benthic algae.

The present research was designed to illustrate seasonal patterns of benthic algal distribution, species succession, biomass and primary production occurring in a recently altered deltaic ecosystem. Daily patterns of primary production were also studied. Physico-chemical parameters such as substrate type, salinity, temperature and incident light were monitored concurrently to determine significant limitations or controls to algal growth. To this end, major forms of benthic algae occurring in a wide range of habitats on the delta were monitored over a one year period.

Studies of benthic algal primary production pose many technical problems as evidenced by the numerous techniques suggested in the last few years (Pamatmat 1968). In this thesis, the usefulness of a modified dissolved oxygen method for measuring primary production was investigated.

LITERATURE REVIEW

A. Background

Essentially all of the literature on benthic algae in esturine-deltaic situations prior to 1950 was descriptive in nature. The first detailed ecological taxonomic study of algae in esturine salt marshes was carried out in the Bay of Fundy by Gangong (1903). Seasonal spatial patterns were noted but no explanations were put forth to account for them.

Johnson and York (1915) apparently set the format for subsequent work with their studies of benthic algae at Cold Spring Harbour. These authors attempted to correlate algal distribution in esturine areas to physico-chemical environmental factors. Fassett (1928) documented the algal vegetation in estuaries along the northeastern coast of North America with some consideration given to physico-chemical factors. Similar studies were conducted by MacGinitie (1935) on a California estuary and by Sykes (1937) on the delta of the Colorado River. In England, Carter (1932, 1933) produced a significant work on the algal flora of salt marsh estuaries, stressing taxonomy as well as spatial and temporal distribution. She attempted to explain algal distribution on the basis of physico-chemical factors such as tide as did Johnson and York (1915). Carter also indicated the possible migration of benthic diatoms towards strong illumination.

Blinks (1951) suggested that the instability of freshwater in esturine-deltaic areas inhibited the growth of marine algae, the effect decreasing with decreasing temperatures and depth. The work of Luther (1951) on the distribution of algae along salinity gradients ranging from 0 - 8 $^{o}/00$ salinity as well as the studies of Doty and Newhouse (1954) on the distribution of marine algae into estuaries substantiated Blinks' findings.

The studies of Day (1950), Day et al (1951, 1952, 1954), Millard et al (1954) and Scott et al (1952) on South African estuaries dealt only superficially with benthic algae. No studies relating to the latter have appeared to date in these estuaries.

A change of emphasis in the literature was noted in the mid 1950's with comparatively few papers dealing strictly with survey work being published. Rather, considerable interest has been shown in the production and physiological adaptation of esturine benthic algae.

The remainder of this literature review will be divided into sections each presenting relevant papers in a chronological sequence. Literature pertaining to production in general, as well as the primary production and adaptation of macrobenthic and microbenthic algae in particular will be reviewed.

B. Primary Production

The unusually high productivity of benthic algae in certain shallow water esturine habitats was suggested by Nelson (1947) in his observations of oxygen bubbles trapped in mats of Schizonema sp. on tidal flats. Since then a great deal of interest has been shown in primary production.

Moul and Mason (1957) indicated high production in terms of cell counts and chlorophyll content of microbenthic algal communities in comparison to the phytoplankton in a similar unit area of coastal water. Odum (1957) working in Florida estuaries and Odum and Hoskins (1958) in those of Texas also found very high primary productivity. With respect to the relative magnitude of production, Pomeroy (1959) estimated that ¼ to 1/3 of total primary production occurring in a salt marsh-delta area in Georgia resulted from the activity of benthic algae. Subsequently, Schelske and Odum (1962) studying the same marsh area estimated that of the total esturine net primary production (marsh plus open water) 90% was accounted for by non-planktonic production.

A summary of gross primary production estimated for selected world ecosystems was provided by Odum (1959). Estuaries ranked among the most naturally productive ecosystems along with coral reefs, alluvial plains and intensive agricultural areas with production ranging from 5 to 20 g C m^{-2} day^{-1}.

Odum (1961) and Schelske and Odum (1961) presented the first significant attempt at explaining factors maintaining high esturine production. Specifically, they point to tidal action, rapid regeneration and conservation of nutrients, optimum light, and year round production with successive crops. More recently, Pomeroy et al (1965, 1969) have indicated the importance of benthos in the retention and rapid recycling of nutrients in supporting high production. Riley (1968) indicated the importance of nutrients in estuaries, and postulated as to their marshland origin. In a paper reviewing marsh production, Keefe (1972) presents a good discussion of physico-chemical factors controlling production. Although these refer to angiosperms, the control mechanisms noted are valid in many respects for benthic algae.

C. Macrobenthic Algae.

Judging from the literature of the past 15 years, macrobenthic algae components of esturine ecosystems occupied a position of minor importance compared to microbenthic algae.

Steemann Nielsen (1951) outlined algae present in the Isefjord of Denmark, concentrating primarily on its distribution. Subsequently, Grontved (1957, 1958) reported distributional patterns and estimated yeilds of macrobenthic algar for some of the major Danish fjords.

Egler (1966) reporting on the Amazon River estuary and Kelly (1966) studying the Sacramento - San Joaquin River estuary concentrated primarily on ecological - taxonomic aspects similar to the studies of Carter (1932).

A good correlation between the distribution of benthic marine algae and temperature - salinity changes along the estuary of Indian Arm was noted by Druehl (1967). A vertical displacement (submergence effect) for marine algae in going from the mouth of the estuary to the point of river entry at its head was noted.

Botnariuc (1969) followed ecological succession in the estuary of the Danube River, noting trends towards increased gross production to biomass ratio. The river influence was suggested as a means of partially reversing this pattern.

An extensive ecological study of the littoral and sublittoral macroalgae in the estuary of the Vigo River was carried out by Niell (1971). Similarly, Nienhuis (1971 a) recorded the littoral benthic algae of Grevelinger Arm in the Netherlands as well as the seasonal periodicity of selected algae in the area (Nienhuis 1971 b).

Primary production measurements of macrobenthic algae have generally been neglected in esturine habitats.

Odum and Hoskins (1958), Parks et al (1958), Odum et al (1959) and Odum (1963) reported plant productivity of tidal marshes, providing some indication as to the production of macroalgae.

The first major work on the production of esturine macrobenthic algae was that of Lyford and Phinney (1968). Studies of primary production, community respiration and community structure as they related to seasonal succession, salinity and water temperature were carried out using oxygen methods. A characteristic algal flora and productivity were noted for saline, brackish and freshwater areas in an esturine impoundment. Johnson and Cook (1968) compared the relative merits of the dissolved oxygen and radioactive carbon (^{14}C) methods for determining the production of macroalgae. Both methods were found to be favourable with activity photosynthesising tissue, with the oxygen methods being technically easier.

Ganning and Wulff (1971) worked on daily production patterns of macroalgae in brackish water pools. Peak production was recorded in early afternoon on bright days. Maxima on dull days were noted in the morning.

D. Microbenthic Algae

Literature on microbenthic algae is much more extensive and diverse compared to that for macrobenthic algae. Numerous papers exist dealing with physiological adaptation and primary production of microbenthic algae on intertidal mud and sand flats.

The fact that microbenthic algae, especially diatoms, exist in such great numbers in certain intertidal areas where desiccation, high light intensity, and considerable variation in salinity and temperature prevail has been well documented in several ecological surveys such as those of Carter (1932, 1933). Consequently, considerable interest in the adaptive mechanisms of microbenthic algae has been shown over the past 20 years.

Aleem (1950) working on diatoms inhabiting the mud flats at Whitstable recorded a strong light response. Diatom communities became visible as brown layers when low tide occurred during the day. This suggested a positive response to light. On an incoming tide, Aleem noted a downward migration in response to increased turbidity and thus decreased light. The author suggested that vertical migrations were a means of protection against tidal washoff as well as a means of optimizing the productive period of the day. Fauré-Fremiet (1951) on the northeast coast of the United States and Callame and Debysen (1954) on the coast of Britany recorded similar vertical migrations. Littoral diatom communities in the Oden River estuary followed a diurnal rhythm with respect to vertical migration (Perkins 1960).

Hopkins (1963) investigated the effect of physical and chemical changes upon the vertical migrations of diatom communities in an intertidal mud area. Fine muds afforded greater protection and thus supported larger diatom communities in comparison to coarse mud. In both habitats, bright sunlight caused the diatoms to migrate towards the surface with increased velocities recorded from 5° - 15°C. Fluctuations of pH, dissolved oxygen and soluble organic compounds did not appear to influence the appearance of diatom communities on the surface of the sediment.

Subsequently, Hopkins (1965, 1966) published papers on the role of light and water in controlling the migration of microbenthic algae in esturine mud flats, with the former being a dominant factor. Evidence of rhythms in phototaxy, geotaxy and mobility were also presented.

Hartog (1967) indicated that in addition to light, the degree of instability of salt content greatly influences the composition of the microbenthic flora, as was found with macrobenthic algae. The alternate exposure to salt and freshwater (shock habitat) and the alternate submersion and immersion are cited as major restraints to the algae able to survive in the area. In her review of esturine littoral diatoms, Patrick (1967) indicated desiccation, high temperatures and light intensity as limiting factors to distribution and growth. Pamatmat (1968) working on tidal flats of False Bay in Puget Sound, indicated light to be more significant than temperature in controlling the distribution of intertidal microalgae.

Gargas (1971) agreed that light was the prime limiting factor indicating the littoral diatoms to be so successful as a result of sun-shade adaptations. By altering the proportion of photosynthetic pigments at the time of cell division, certain algae are able to rapidly adapt to a variety of light conditions. A similar response was noted for temperatures in which the concentrations of photosynthetic pigments could be changed.

Riznyk (1969) and Riznyk and Phinney (1972) recorded the spatial and temporal distribution of littoral microbenthic algae in an Oregon estuary. Low population densities were recorded in the upper intertidal zone compared to lower zones. Temperature, salinity, oxygen content and water content which vary as a function of tidal height and exposure show greater variations in the upper intertidal zone thus keeping the population at a minimum. An absence of seasonal fluctuations in the diatom population was attributed to a continuously regenerating supply of nutrients originating from the sediment.

Measurements of the primary production of microbenthic algae in estuaries did not begin to appear in the literature until 1959. However, their possible importance as primary producers was suggested in 1957 by Moul and Mason. Amounts of chlorophyll extract and cell numbers were comparable to those for phytoplankton found beneath a similar unit area of coastal water.

The first significant work on microbenthic algal production in estuaries was that of Pomeroy (1959). Using dissolved oxygen techniques, light was shown to be the controlling factor in primary production. During low tide, light was concluded to be limiting, particularly in spring and summer. Photosyntheses at low tide reached its annual maximum during winter when light was at its minimum. Pomeroy also noted that production of microbenthic algae reached its maximum at high tide in August when water temperature was at its highest. He suggested that the interaction of light, temperature and tidal regime results in continuous production of microbenthic algae in esturine-marsh areas.

Grontved (1960) studying the littoral diatoms of Danish fjords with ^{14}C techniques observed that production was higher in esturine than in coastal situations. Salinity and light as controlling factors were given only minor consideration. Rather, the increased shelter and detritus content of the sediment, providing for higher concentration of nutrient salts and organic compounts, were suggested by this author as factors limiting production.

Taylor and Palmer (1963) reaffirmed the prime role of light in microbenthic primary production. These workers noted only a 10% inhibition of production at a time corresponding to the highest light period of the day. Expanding on this work, Taylor (1964) investigated the production of littoral diatoms undergoing vertical migrations in the sediments towards full sunlight. He concluded that the algae actually required only a small fraction of total incident radiation to reach their maximum photosynthetic capacity. Rapid light attenuation was evident in mud with 10% of surface intensity recorded at a depth of 1.5 mm. Algae in the mud photosynthesised at 90% maximum rates from 2 mm to the surface of the sediment, with the majority of algae concentrated below 1 mm. Thus, the sediment itself acts as a strong protective mechanism for the microalgae against light, permitting near maximum production. It was suggested that the extent of vertical migration of micrbenthic algae was directly related to the intensity of radiation.

Microbenthic algal production studies on the mud flats of Ythan estuary were carried out by Leach (1970) using a ^{14}C method. Seasonal production patterns correlated with incident radiation, temperature and standing crop of functional chlorophyll but not with the amount of organic carbon. Leach also points out the possible existence of a distinct seasonal pattern for benthic production with increasing latitude. Pomeroy (1959) at 31° N latitude recorded uniform annual production whereas Grontved (1960) and Leach (1970) at 57° N latitude recorded distinct seasonal maxima.

Riznyk (1969) and Riznyk and Phinney (1972) conducted investigations on the ecology and production of microbenthic algae in a variety of esturine sediments in Yaquina Bay. Using manometric techniques, it was found that production on mud or silty sediments was highest in the upper intertidal area while production on sandy sediments was greatest in the lower intertidal zone. Primary production in the latter habitat was found to be 2 to 3 times higher than in silty sediments. It was concluded that the finer, detritus rich sediment was associated with a denser population of mieofauna and bacteria which can reduce the gross production of the microalgae by competing with the diatoms for nutrients, utilizing oxygen for respiration and over grazing the diatoms themselves.

A comparison of ^{14}C and dissolved oxygen methods for the measurement of microbenthic algal primary production conducted by Hunding and Hargrave (1972) indicated both methods to give similar measures of the magnitude of production. Measures of ^{14}C uptake offered sensitivity when production was low but when undisturbed sediment cores could be obtained, production was most easily measured using the dissolved oxygen technique.

METHODS

A. Description of the Squamish River Delta.

(a) Physiography

The Squamish River Delta (49° 42'N, 123° 10'W) is located approximately 48 km north of Vancouver at the head of Howe Sound, a glacial fjord on the south coast of British Columbia (Fig.1).

The climate in the study area can be classed as moderate maritime with a mean annual precipitation of 229 cm. Average monthly temperatures range from a low of 2.2°C in January to a high of 24.0°C in July. Steep mountains (elevation 760 m) plus a frequent haze layer of industrial origin effectly reduce both the duration and intensity of sunlight reaching the Squamish area. Generally, hours of sunlight tend to be short compared to typical lower mainland values.

Wind patterns in the Squamish area are typical of those prevailing in many British Columbia fjords. Northerly outflow and southerly inflow winds approaching 30 knots are common during the winter. The summer wind regime (May to August) is dominated by moist southerly winds, averaging 26 knots, which blow off the sound in the afternoon and early evening. These valley winds aid in maintaining summer conditions of high relative

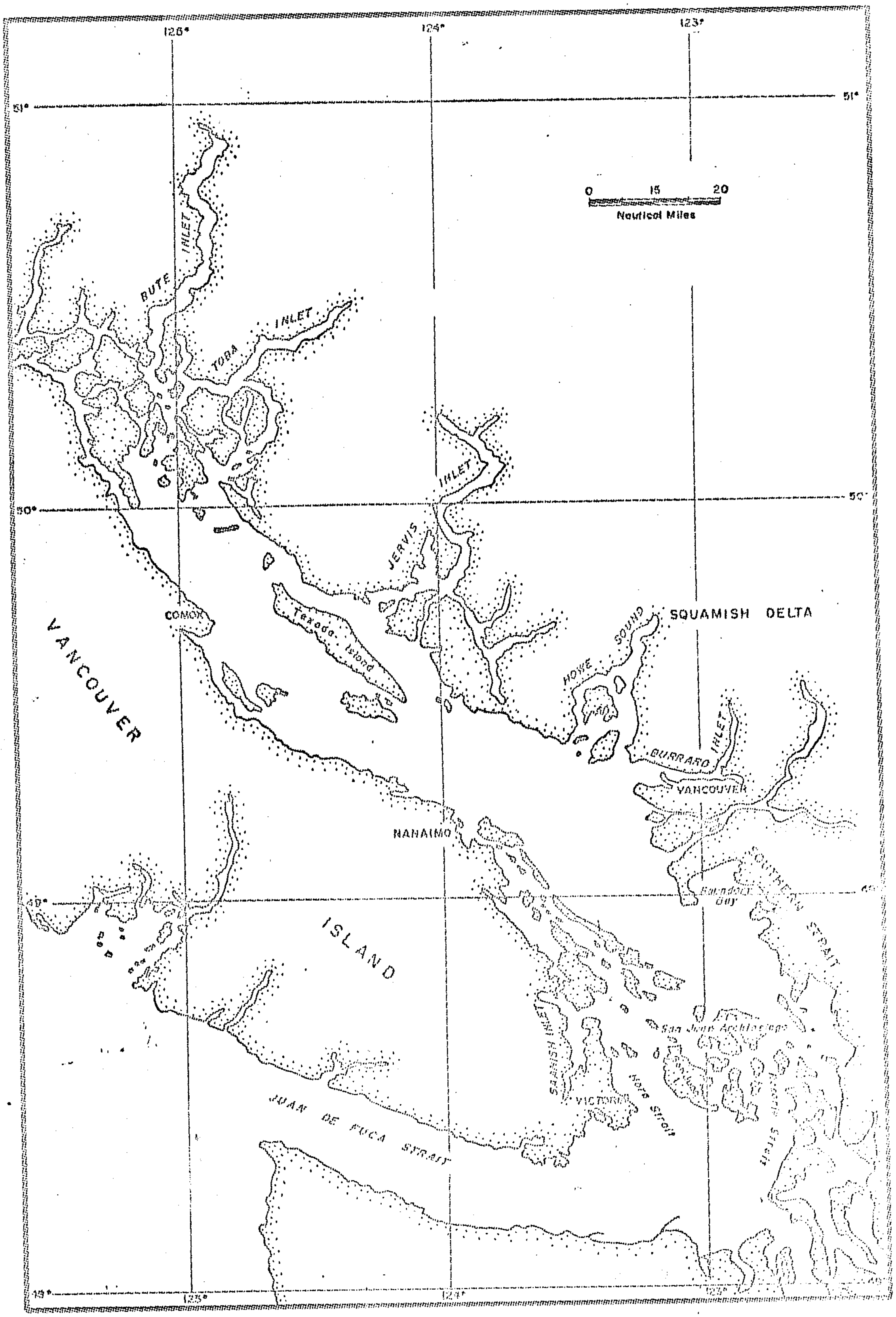


Figure 1. A map of the southeast coast of British Columbia showing the location of the Squamish River Delta.

humidities, averaging 80%, and fairly constant temperatures (Stathers MS, 1958).

Tides at the Squamish River Delta are of the mixed type typical of the Pacific Coast with 2 high and 2 low periods in a tidal day. Diurnal inequality in both time and height of succeeding tides exists. Pamatmat (1968) provides a description of annual tidal patterns applicable to the Squamish area. Tidal amplitude varies from - 0.34m to + 4.66m, with the average tidal range being 3.20 meters. These limits can be greatly exceeded during periods of strong winds or river freshet. Thus, the extent and duration of exposure of benthic algae can be quite variable. In addition, movement of tidal and river water (especially at freshet) over the intertidal lands can be of substantial velocity causing substrate instability.

The Squamish River system drains approximately 2,500 km^2 of the westerly slopes of the Coast Mountains in southern British Columbia. Annual discharge patterns are typical of glacier-fed streams, with an average maximum of 492 m^3/second during spring freshet and an average minimum flow of 72 m^3/second in March.

At freshet, the Squamish River is heavily laden with glacial "flour", appearing a distinct grey-brown color with very low light transparencies. Sedimentation at the delta front is heavy with a yearly average estimated advance of 6.4 meters. Visual estimates of silt deposition range from 2 - 4 cm year^{-1}.

Patterns of salt and freshwater distribution at the Squamish River Delta are typical of positive salt wedge estuaries (Bowden 1967). Saltwater extends as a wedge into the river with an overlying layer of freshwater separated by a sharp halocline.

The most recent information on sediment types found at the Squamish Delta indicate them to be Fluvial (alluvial) - Glacial Marine, with a slope of less than 5% (Anon MS, 1972).

The Squamish River Delta is characterized by extensive low elevation marshlands (upper intertidal area) and mud and sand flats (mid and lower intertidal areas). The marshlands support extensive pure and mixed plant communities dominated by sedges (Carex spp), grasses (Gramineae) and rushes (Juncaceae), typical flora of areas inundated by fresh or brackish waters (Lim and Levings MS, 1973). Growth of these plants begins in early March and reaches a peak some time in late summer.

Die off of marsh vegetation occurs over the fall months so that by January, a "mat" of dead vegetation is present on the delta surface. Rooted vegetation on the sand and mud flats is extremely sparce.

Vegetation in the higher infrequently flooded delta lands consists of mixed coniferous trees (Douglas fir and Western hemlock) as well as deciduous shrubs such as cottonwood and salmonberry. Orloci (MS, 1961) studying vegetation patterns in the area of the delta classified the zone as a flood plain forest.

The seaward boundary of the Squamish Delta study area extends to the lowest low water mark. The northerly or landward boundary is marked by the transition zone from marsh to forest-shrub vegetation. For descriptive purposes, the study area can be divided into three distinct zones on the basis of major topographic features, namely, the Squamish River, the Central Basin and Cattermole Creek (Fig.2).

(1) West Delta

The West Delta (0.103 km^2) is bounded on the west by steep rock cliffs and on the east by the Squamish River (Fig.2). Sediments range from coarse sand in the lower intertidal to unconsolidated or consolidated mud in the mid and upper intertidal areas. In addition to the sediments, numerous logs, tree roots and scattered pilings are available throughout the intertidal zone as growth substrates for algae. Severe slumping of the Squamish River bank presents an unstable growth substrate.

Vegetation (*Carex* spp.) is advancing at the delta front producing a gradual, indistinct border between marsh and mud flats.

Water relations on the West Delta are strongly influenced by the Squamish River. During a tidal cycle, algae can be exposed to wide variations in salinity due to the existence of a salt wedge overlain by lower salinity water. Water intrusion to the higher regions on the West Delta is primarily a result of tide acting through Castle Creek and its distributaries (Fig.2). Some direct river flow can occur at river freshet.

(2) Central Delta

The Central Delta includes the area east of the Squamish River dyke and west of a line bisecting the Central Basin, an area of 0.130 km^2 (Fig.2). Sediment variation is as outlined for the West Delta. The Central Delta has a moderate density of drift logs and pilings, especially in the lower and mid intertidal areas at the delta front. These are of value as algal growth sub-

Figure 2. Aerial photograph of the Squamish River Delta with overlay indicating major physiographic features. Study areas on each delta are those within the heavy black lines.

● incubation area for algae
------ extent of sand flats at low tide
—— boundary between sand flats and marsh land

strates along with the natural sediments. In addition, rocks used for dyke construction and spoil resulting from land fill are available as new substrates. Several shallow pools relatively free of sedge (*Carex* spp.) and open to algal growth are present throughout the marshlands.

The salt wedge effect noted for the West Delta also applies to the Central. Freshwater influence, (i.e. depth of surface layer) is somewhat reduced, being dependent upon indirect flow around the dyke and on a small amount of direct flow through culverts in the dyke at the upper end of the Central Delta (Fig.2). Water intrusion to the higher regions of the delta occur primarily through Pile and Fill Creeks and their distributaries (Fig.2). The training dyke, a 35 acre fill area dredged from the Squamish River and a large area of silt run off significantly reduce water intrusion to the uppermost parts of the delta.

The transition from mud flats to marsh vegetation is well defined along almost the entire perimeter of the delta by a bank ranging from 0.1 to 2.0 meters in height. A dense overhanging mat of sedge roots (*Carex* spp.) is prevalent along the bank.

(3) East Delta

The East Delta, encompassing some 0.233 km^2, is that area east of a line bisecting the Central Basin, extending over to the west shore of Cattermole Creek (Fig.2). Sediment varies from coarse sand in the lower and mid intertidal areas, as well as adjacent to fill areas, to unconsolidated mud contiguous to and along the banks of Cattermole Creek. More consolidated muds exist over the largest portion of the intertidal marshlands. Numerous logs scattered along the west shore (Central Basin) as well as rocks and sand from fill operations on various parts of the delta plus natural deltaic sediments are available as substrates for algal growth.

A 42 acre fill area at the delta front limits tidal intrusion to the inner portions of the East Delta to creeks leading from the Central Basin on the west side and to Cattermole Creek on the east (Fig.2). Road and rail levees have restricted flow along the creeks, resulting in certain areas remaining dry or becoming flooded only at highest tidal periods. Several large shallow pools are scattered over the delta, generally in association with tree roots or pilings.

(b) Industrial Influence

The Squamish River Delta is being affected either directly or indirectly by industrial activity. There is a large chlor-alkali plant located adjacent to the East Delta (Fig.2). Spills have occurred releasing high concentrations of mercury to the surrounding waters and sediments. Values of 2.20 ppm have been found, with the level decreasing from east to west across the delta (Thompson MS, 1973). Leakages of chlorine gas have also occurred causing considerable damage to vegetation on the higher delta areas (Harger 1971). A second chemical plant located in the same area releases heated water (19°C) directly into Cattermole Creek (Fig.2).

Log booming and storage grounds are located in the Central Basin and in Cattermole Creek (Fig.2). The addition of bark and woodchips to the surrounding waters causes lowered light transparencies and reducing conditions in certain areas.

Stack emissions from a pulp mill situated at Woodfibre, 5 miles south of the delta, exert considerable influence on the Squamish area. Consentration of low elevation smoke occurs frequently causing serious reductions in incident light reaching the delta.

The most serious industrial influence affecting the delta has been Superport development begun by the British Columbia Railway in 1970. Development activities proceeded until October, 1972 at which time results of a study carried out by the Department of Environment (Anon MS, 1972) on effects of port development on the aquatic ecosystem of the Squamish Delta halted further construction. However, by this point all areas of the delta had experienced some form of alteration. The West Delta lost approximately 61,000 m^2 of marshland to river channelization. A training dyke running the length of the Central Delta has focused almost the entire flow of the Squamish River towards the remaining West Delta, producing a very unstable habitat. Continual river bank slumping and heavy sedimentation during freshet were noted.

The training dyke has also blocked the Central Basin, previously the east arm of the Squamish River. Small 1 meter diameter culverts installed in the dyke have been relatively ineffective in maintaining significant river flow to the Central Basin (Fig.2). Thus, the area has come under stronger marine influences. Land fill on the Central Delta has claimed 35 acres of marsh habitat (Fig.2), restricted water flow and caused considerable sedimentation to occur in major tidal creeks.

The East Delta has undergone the greatest development alteration. Approximately 42 acres of mud flats and marshland have been covered by fill. Warehouses built on this area are serviced by road and rail levees resulting in several major creeks being blocked (Fig.2). The normal flow of water to certain areas has thus been restricted. Also, spill from fill operations has created expanses of new sand-flat habitat (Fig.2).

B. Sampling Schedule

Field sampling was conducted from May 25, 1972 to April 25, 1973. Throughout this period, the West Delta was sampled at monthly intervals. The Central and East Deltas were sampled at either weekly or biweekly intervals from May to August,1972 with sampling frequency varying as a function of low tides and boat availability. Sampling from September, 1972 to January, 1973 was carried out at monthly intervals using the 185 foot research vessel CFAV Laymore as a base of operations for extended field trips. Biweekly sampling was resumed in February, 1973.

During fall and winter when low tides and sampling occurred at night, algal samples were collected and exposed to prevailing light and temperature conditions. Water from the collection areas was added and changed every few hours until the following day when the algae were used for production studies. In this manner, the algae were maintained under as natural conditions as possible. When low tides occurred during the day, the algae were used immediately after removal from the substrate.

Experimental material from day trips to Squamish were returned to the Pacific Environment Institute (F.R.B.), West Vancouver for complete processing. Alternatively, material taken while on board the CFAV Laymore were processed as far as possible, appropriately stored and returned to the laboratory for completion of analysis.

C. Physical and Chemical Parameters

Daily incident solar radiation was recorded on a Belfort Pyrheliograph with daily photosynthetic energy calculated by determining the area under the curve and converting this to gram calories $cm^{-2} day^{-1}$. Multiplication of this value by 0.47 gave estimates of photosynthetically available energy (Vollenweider 1969).

A Montedoro-Whitney underwater photometer (Model LMT-8a) was used to measure percent extinction of light with depth in the water column overlying the delta at high tide. In this manner, an estimate of available light energy at 1 and 2 meters was obtained.

The percent light extinction as a function of marsh vegetation (e.g. Carex spp.) height was measured using a hand held light meter.

Salinity was determined in the laboratory with a Bissett-Berman Salinometer (Model 6230). Field determinations were made with either a portable Salinity-Conductivity-Temperature (S.C.T.) meter (Y.S.I. Model 33) or a Beckman S.C.T. meter. All meters were standardized prior to use.

Water temperature data were collected using S.C.T. meters noted above. In addition, continuous records from Ryan Recording Thermographs (Model 30-D) were obtained directly on the delta surface. Water temperatures in delta pools were taken with standard centigrade thermometers.

Analyses for pH and alkalinity were carried out according to methods described by Strickland and Parsons (1972), with pH and titrimetric end points determined on an Orion Expanded Scale pH meter.

One liter surface water samples were taken for nutrient analyses. The Water Quality Laboratory of the Department of Environment carried out nitrogen and phosphorus analyses on a Technicon "Autoanalyzer". Analyses for calcium and turbidity were carried out according to APHA Standard Methods (1971).

D. Biological Parameters

(a) Seasonal Succession

Patterns of occurrence, species composition and estimated distributional (coverage) area (m^2) for each major algal species and assemblage type were recorded at each sampling. Maps were drawn from these data showing seasonal growth patterns.

(b) Algal Biomass

At each sampling, 4 non-selective 0.06 m^2 quadrat samples of algae were taken for biomass determination. Samples were dried at $100^{o}C$ for a minimum of 48 hours. Following this, the algae were ground using a mortar and pestle, re-dried for 2 hours and weighed to obtain dry weight values. Four equally weighted sub-samples were then taken, and ashed in a muffle furnace at $550^{o}C$ for 4 hours to determine ash free dry weight. The averaged organic content or loss on ignition (L.O.I.) values obtained were inserted in the following formula to express biomass as $g\ C\ m^{-2}$:

$$g\ C\ m^{-2} = \frac{\bar{x}\ \text{L.O.I.} \cdot 0.50}{\text{g dry weight of sub sample}} \cdot \text{g dry weight of } 0.06\ m^2 \cdot 16.65$$

where : 0.50 = conversion factor for g organic to g C (Hargrave 1969).

16.65 = number of $0.06\ m^2$ quadrates per m^2

(c) Primary Production Measurements

(i) Dissolved Oxygen Method.

Primary production was measured using a modified light and dark bottle dissolved oxygen method.

Water used for incubation of algal samples was taken from their immediate growth area and passed through a $10\mu^2$ Nitex screen to remove larger planktonic organisms. To reduce the risk of oxygen supersaturation, this water was then placed in PVC carboys and left to warm to a few degrees above natural water temperature for 10 minutes with intermittent shaking (Strickland and Parsons 1972).

Standard 300 ml glass stoppered light and dark bottles were filled with the "pre-treated" water and an algal sample 4.84 cm^2 in area added. Production sets consisted of similar bottles containing no algae. Water samples for the determination of initial oxygen concentration were taken at the commencement of each set. After preparation, all bottles were kept in light tight boxes until placed for incubation. At this time initial oxygen samples were fixed using standard Winkler reagents.

Sample incubation, as described below, was carried out between 1000 and 1400 hours during which time light intensity reached a maximum. After incubation, the oxygen bottles were fixed, and returned to the laboratory for oxygen analysis. Determinations were carried out within one hour of retrieval using standard Winkler titrimetric techniques (Strickland and Parsons 1972).

Incubation was carried out from May to September, 1972 either in shallow delta pools or directly on the delta surface. During this period, tides were commonly low in daylight hours, leaving algae either totally exposed or covered by only a shallow (<0.25 m) layer of water. In order to more closely approximate production during fall and winter months when high tides predominated during the day, bottles were suspended from a flotation apparatus (Fig.3) and incubated at the surface as well as 1 and 2 meters at the locations indicated in Figure 2. This was continued to the end of the study.

Prior to computing production, corrections were made to titrimetric values for production sets as indicated by corresponding initial and control bottles. Primary production and respiration were then expressed as mg O_2 l^{-1} according to methods outlined by Strickland and Parsons (1972). For comparison with other work, these values were converted to g C m^{-2} day^{-1} using the formula:

$$\text{g C m}^{-2}\ \text{day}^{-1} = \left(\frac{\text{mgO}_2\text{l}^{-1}\ \cdot 0.31 \cdot 0.278 \cdot 2066.12}{\text{Lt}}\ \cdot\right) \div 1000 \cdot \text{P}$$

where: 0.31 l = correction factor expressing O_2 concentration in 300 ml (incubation volume)

0.278 = factor for convertine mg O_2 to mg C assuming a PQ of 1.2 and an RQ of 1.0 (Westlake 1963).

2066.12 = factor for expressing mg C per 4.84 cm^2 on a m^2 basis

$$\text{Lt} = \frac{\text{incident radiation received during day}}{\text{incident radiation received during incubation period}}$$

P = estimated percentage of a m^2 actually covered by algae

1000 = conversion from mg to g

(d).Determination of Daily Production Curves.

At frequent intervals during the study, the course of daily production was followed. Consecutive 2 hour

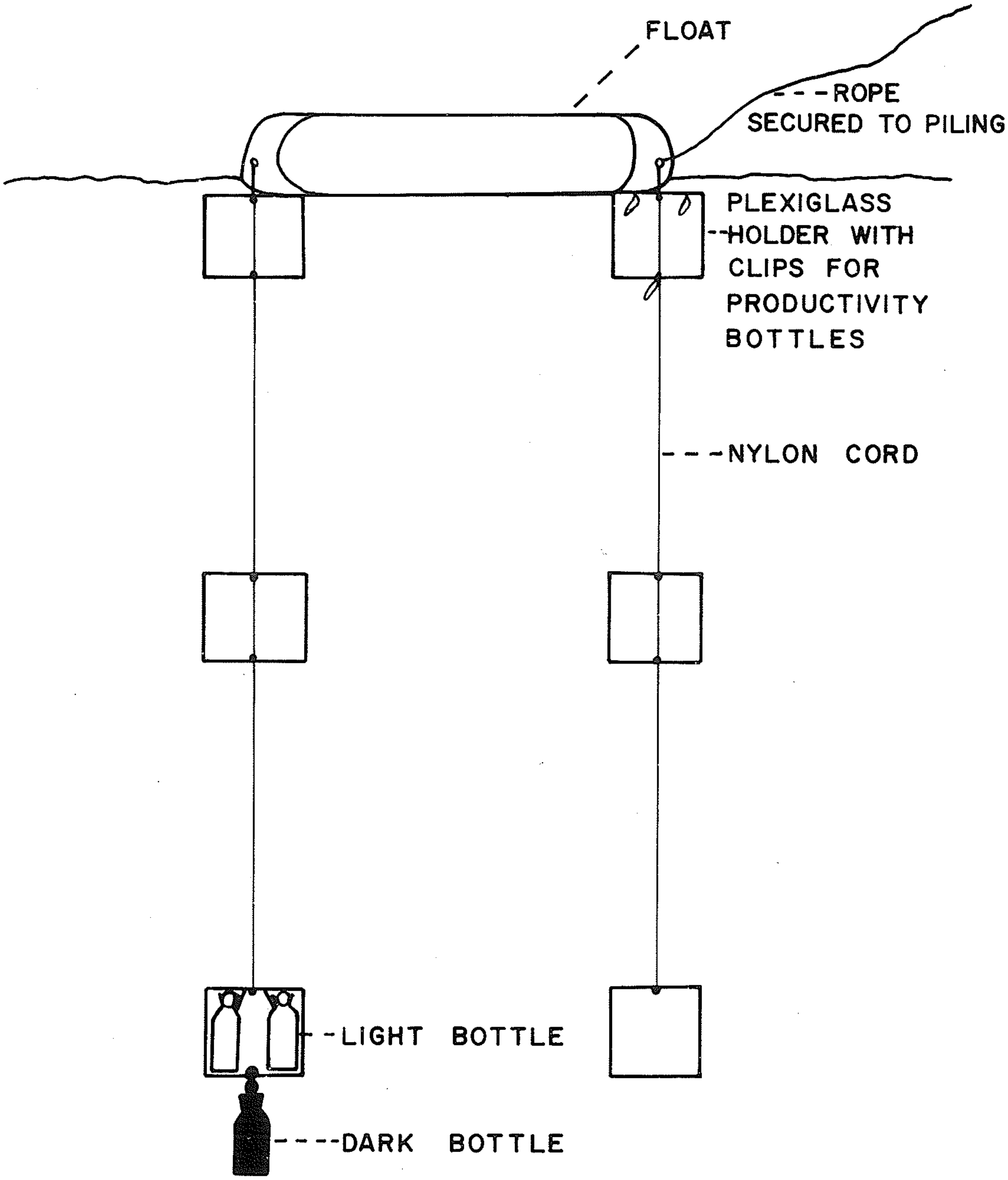


Figure 3. Flotation apparatus for incubation of primary production bottles at the surface, and 1 and 2 meters depth.

incubations at the surface and 1 meter were carried out from dawn until dusk. Results were expressed as g C m^{-2} hr^{-1}. These data were compared to the daily light curve as plotted by a pyrheliometer.

E. Statistical Treatment

All samples collected throughout the study period were treated with appropriate test statistics after the mean and variance were calculated. It was assumed that with an independent mean and variance, these data of continuous variables fit a binomial distribution and thus the simple linear regression analyses employed for analysis of these data was the appropriate test statistic without transformation. Tables of r values and their appropriate significance levels were the basis of an objective comparison of physico-chemical factors affecting production.

RESULTS

Each of the three delta areas exhibits different physico-chemical features. The West Delta is open to the full seasonal influence of the Squamish river. Isolation of the Central Delta from the direct influence of the river results in a more marine, and in some cases, more protected habitat for benthic algae. Lastly, the East Delta, being farthest from the Squamish river, experiences the strongest marine influence of all three delta areas. Accompanying this increase in marine influence from west to east is a similar increase in industrial activity and delta disturbance as was previously described.

In view of these dissimilarities, each of the three delta areas will be dealt with individually in subsequent sections of this thesis.

A. Physical and Chemical Parameters

(a) Salinity

A general pattern of increasing salinity from the West to East Delta, and with depth at both localities was a conspicuous feature of the Squamish estuary (Fig. 4). On the West Delta, a surface layer of brackish water varying in thickness from 0.1 to 1.0 m and 2.0 to $8.5^{o}/_{oo}$ salinity persisted throughout the year. Lowest

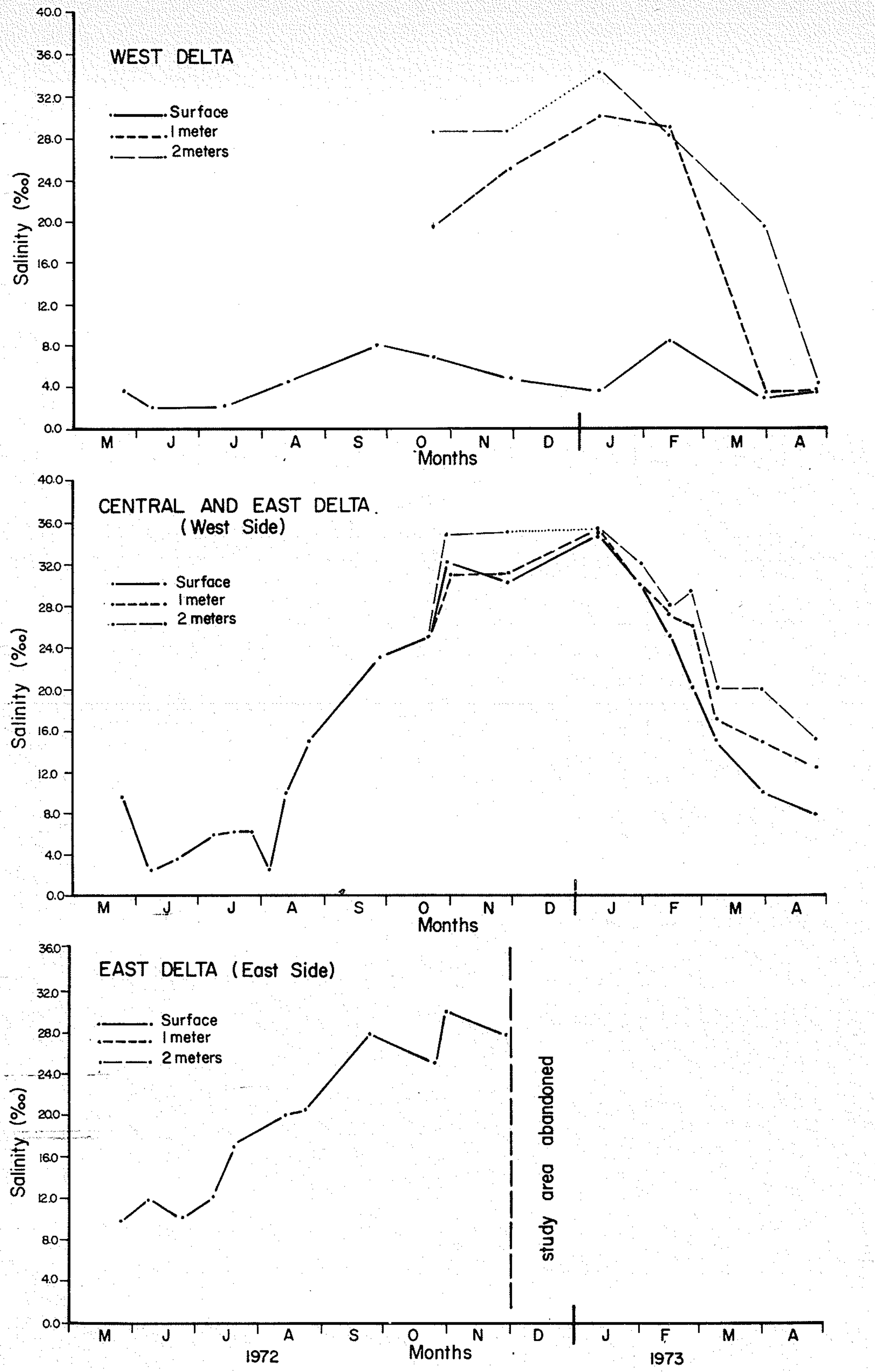


Figure 4. Salinity variations with depth and time in the area of the West, Central and East Deltas.

values were recorded at June freshet. During the winter, salinities at and below 1 m exceeded $20^{o}/_{oo}$, being approximately 4 times surface values (Fig.4).

Surface salinities adjacent to the Central Delta ranged from $2.1^{o}/_{oo}$ during summer freshet to $34.3^{o}/_{oo}$ in January. The water column remained reasonably homogenous at 30.0 to 34.0 $^{o}/_{oo}$ during the period October to January. At other times, a brackish surface layer (30.0 $^{o}/_{oo}$) was evident (Appendix I).

Seasonal salinity patterns for the East Delta approximated those outlined for the Central Delta (Fig.4). Values recorded up to September were 5 - 10 $^{o}/_{oo}$ higher on the east side than on the west side of the delta (Fig.5).

(b) Temperature

Unlike salinity, seasonal fluctuations in water temperature were quite regular for the entire Squamish Delta (Fig.5). Water temperatures generally increased slightly from west to east with the highest and lowest temperatures being noted in areas flooded at periods of very high tides (Appendix II). Maximum temperatures were recorded in July and August reaching 10.1 to 21.1°C, with minimum temperatures of 1.0°C occurring in February.

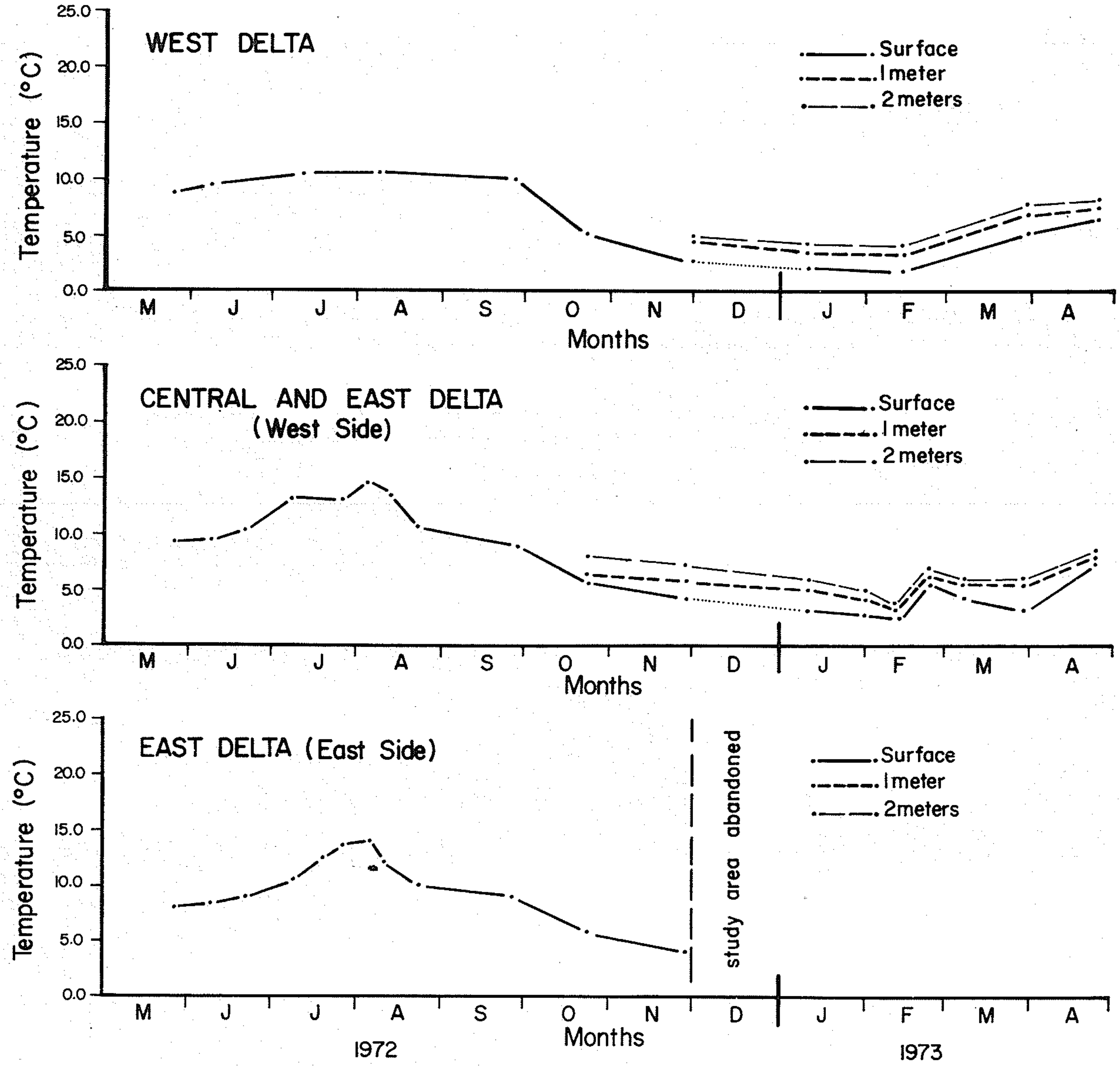


Figure 5. Temperature variations with depth and time in the area of the West, Central and East Deltas.

Temperatures at 2m depth showed an average 1.0°C increase over surface values.

(c) Light

Daily, photosynthetically available incident solar radiation (400 - 760 mμ) reaching the Squamish Delta attained a maximum monthly average in June of 248.07 g cal cm^{-2} day^{-1} (Appendix III). The December value of 20.02 g cal cm^{-2} day^{-1} was the lowest monthly average recorded (Fig.6).

Variation in light penetration as a function of water depth were noted between the areas adjacent to the West and Central Deltas where sample incubation was carried out (Fig.2). Lower transparencies and higher light attenuation characterized the West Delta (Fig.6). Light attenuation in the top meter was 40% in October compared to 66% in April. In comparison, attenuation in the water adjacent to the Central and East Deltas averaged 40% over the winter. Values 25% lower were noted in March and April (Appendix III). Turbidity values for July were lower for the central area, 19 compared to 69 J.T.U. for the west (Table 2).

Measurements of light extinction as a function of increasing height of delta macro-vegetation (*Carex* spp.)

appear in Table 1. Significant decreases in light reaching the sediment surface are evident with increased Carex spp. height. Extinction values of 75% for Carex spp. 10 cm high and 96% for Carex spp. 100 cm in height were recorded (Table 1).

(d) Nutrient Chemistry

Available nutrient data for water at the Squamish Delta appear in Table 2. Generally high values of nitrogen, phosphorus and calcium relative to those found in the outer Squamish estuary (Cliff and Stockner 1973) were noted, as were trends toward increased concentrations from West to East Delta. Dissolved NO_2 - NO_3 and PO_4 show especially significant increases, 0.04 to 0.75 mg l^{-1} and 0.004 to 0.036 mg l^{-1}, respectively (Table 2).

B. Biological Parameters

(a) Algal Species Composition

The algae recorded from the Squamish Delta during the period May 1972 to April 1973 represented dix phyla: Phaeophyla and Rhodophyta being characteristic of marine habitats; Chlorophyta, Chrysophyta, Xanthophyta and Pyrrophyta being found in freshwater, brackish and marine habitats. The dominant algae from each of these phyla are listed below. In addition to monospecific algal growths,

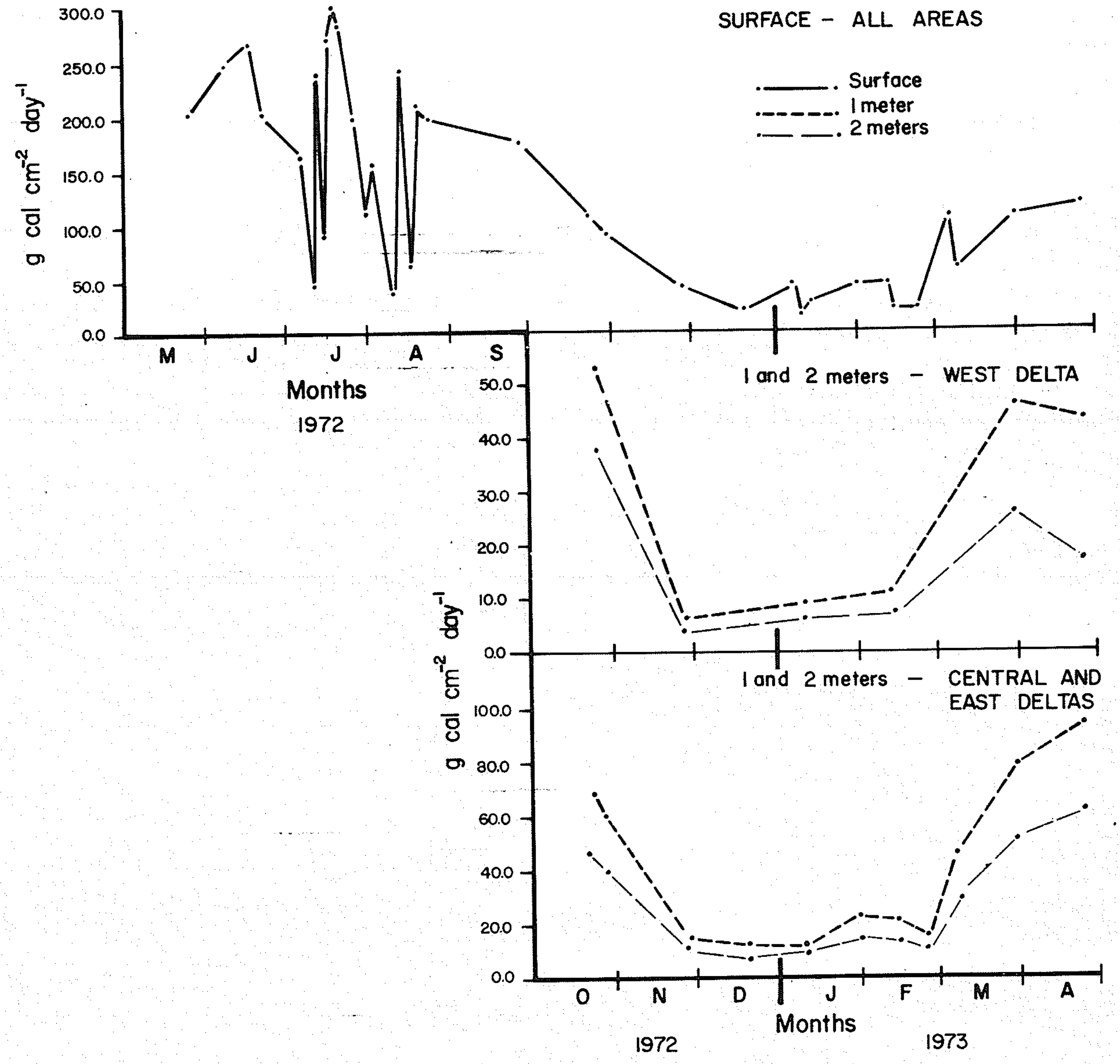


Figure 6. Variations in light intensity (photosynthetically available energy) with depth and time in the area of the West and Central Deltas where algal samples were incubated during production studies.

Table 1. Per cent light extinction at the sediment as a function of the height of *Carex* spp. cover.

Date	*Carex* spp. height cm	Extinction at base (sediment level) %
June 21, 1972	10	75
	20	80
	40	85
July 26, 1972	20	83
	40	86
	80	90
	90	95
August 23, 1972	40	84
	60	86
	100	96

Table 2. Nutrient, turbidity and pH data recorded at the Squamish River delta on July 12, 1972.

	Dissolved NO_2-NO_3 mg/1	Total P mg/1	Dissolved PO_4 mg/1	Calcium mg/1 as Ca^{++}	Turbidity J.T.U	pH
<u>WEST DELTA</u>:						
Squamish River mouth	0.04	0.300	0.005	7.55	69	6.70
Castle Creek (mid-way)	0.04	0.130	0.004	10.33	19	6.40
Castle Creek (head)	0.04	0.170	0.020	11.00	34	6.70
<u>CENTRAL DELTA</u>:						
Pile Creek (mouth)	0.01	1.170	0.004	54.90	46	6.70
Pile Creek (mid-way)	0.01	0.079	0.006	51.40	18	6.70
Pile Creek (head)	0.01	0.110	0.004	60.00	19	6.40
<u>EAST DELTA</u>:						
Cattermole Creek (mouth)	0.54	0.230	0.027	97.40	29	6.80
Cattermole Creek (bridge)	0.75	0.270	0.036	50.40	31	6.70
Cattermole Creek (sluice gate)	0.53	0.270	0.025	72.20	29	6.80

ific algal growths, the presence of either Chrysophyta - Chlorophyta; Xanthophyta - Chrysophyta; or strictly Chrysophyta multispecific algal assemblages were noted. Morphological descriptions and seasonal species changes noted are given in Appendix IV.

1. Phaeophyta (marsh vegetation substrate)

   Pylaiella littoralis (Lyngbye) Kjellman

2. Rhodophyta (wood substrate)

   Antithamnion pacificum (Harvey) Kylin

3. Chlorophyta (marsh vegetation and sediment substrate)

   Enteromorpha clathrata (Roth) Greville; E. prolifera (Muller) J. Agardh; Rhizoclonium cf. riparium; Spirogyra sp.; Ulothrix cf. flacca; Ulva lactuca Linnaeus.

4. Xanthophyta (sediment substrate)

   Vaucheria dichotoma Agardh

5. Chrysophyta (marsh vegetation and sediment substrate)

   Melosira cf. moniliformis; M. nummuloides Navicula cf. cancellata; N. grevillei (Agardh) Cleve; Pleurosigma cf. aestuarii.

6. Pyrrophyta (sediment substrate)

   Dinophyceae

In terms of the entire Squamish Delta, the chlorophytes Enteromorpha clathrata and Ulva lactuca were the most widely distributed. On an individual delta basis, Chrysophyta dominated the algal flora of the West Delta, Chrysophyta, Chlorophyta and Phaeophyta the Central Delta and Chlorophyta the East Delta.

Presence/absence data for algae on each of the three delta areas is summarized in Tables 3, 4 and 5. Many of the species and assemblages exhibited a strong seasonal distribution, occurring for only a few months. Some species were common throughout the year, showing variations in distribution and biomass as will be noted in subsequent sections.

The appearance and disappearance of 'seasonal algae' presented some interesting patterns with respect to the number of algae and total distribution of each on the three deltas.

(b) Algal Distribution

The number of algal species and/or assemblages recorded on the West Delta ranged from 6 in November to 3 at certain times during the summer (Table 3). Monthly patterns of algal distribution for the west showed a similar November maximum at 15388 m^2 km^{-2} of delta surface. A minimum value of 2689 was recorded in July (Fig.7).

Table 3. Presence/absence data for algae recorded on the West Delta.

Algal Species or Assemblage	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.
Antithamnion pacificum					x	x	x	x	x	x		
Enteromorpha clathrata	x	x	x	x	x	x	x	x	x	x	x	x
Spirogyra sp.			x	x	x	x	x					
Ulva lactuca									x	x	x	
Assemblage Type I							x	x	x	x	x	
Assemblage Type II	x				x	x	x	x	x	x	x	x
Assemblage Type XII		x	x	x	x	x	x					
Assemblage Type VII	x	x	x							x	x	x
Number of species and assemblages	3	4	4	3	5	5	6	4	5	6	5	3

Table 4. Presence/absence data for algae recorded on the Central Delta.

Algal Species or Assemblage	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.
Enteromorpha clathrata	x	x	x	x	x	x	x	x	x	x	x	x
E. prolifera	x	x	x	x						x	x	x
Pylaiella littoralis									x	x	x	x
Ulva lactuca		x	x			x	x	x	x	x	x	x
Assemblage Type I						x	x	x	x	x	x	
Assemblage Type IX									x	x	x	
Assemblage Type X									x	x	x	
Assemblage Type XI									x	x	x	x
Spill Area:												
Enteromorpha clathrata	x	x	x	x	x	x	x	x	x	x	x	x
Spirogyra sp.			x	x	x	x						
Navicula grevillei										x	x	x
Assemblage Type III	x	x	x	x	x	x	x	x	x	x	x	x
Number of species and assemblages	3	4	5	4	3	5	4	4	8	10	10	7

Table 5. Presence/absence data for algae recorded on the East Delta.

Algal Species or Assemblage	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.
<u>Enteromorpha clathrata</u>												
West side	x	x	x	x	x	x	x	x	x	x	x	x
East side	x	x	x	x[a]								
<u>E. prolifera</u>	x	x	x	x					x	x	x	x
<u>Spirogyra sp.</u>		x	x	x	x	x						
<u>Ulva lactuca</u>												
West side	x	x	x			x	x	x	x	x	x	x
Inner area						x	x	x	x	x	x	x
East side	x	x	x	x	x	x	x[a]					
<u>Pylaiella littoralis</u>									x	x	x	x
					x	x	x	x	x			
Assemblage Type III	x	x	x	x	x	x	x[a]					
Assemblage Type IV	x	x	x	x	x	x	x[a]					
Assemblage Type V	x	x										
Assemblage Type VI	x	x	x									
Number of species and assemblages	7	8	8	7	6	6	5	3	5	4	4	4

[a] Study area abandoned

The maximum number of algal species and/or assemblages recorded on the Central Delta was 10 for the months of February and March (Table 4). Primary components at this time were members of the Chrysophyta and Chlorophyta. As was noted on the West Delta, only 3 algal species and/or assemblages were recorded at certain times of the summer, with chlorophytes generally dominant. Algal coverage reached a maximum of 27062 m^2 km^{-2} in February and a minimum of 4077 in December (Fig.7).

Algal species and/or assemblages on the East Delta reached a maximum of 8 in June and July followed by a gradual decrease to 3 in December (Table 5). Chlorophytes dominated throughout. In terms of total algal distribution, 14893 m^2 km^{-2} and 2403 were recorded in May and December, respectively (Fig. 7).

Benthic algae on each of the delta were essentially restricted to two principal zones; a frontal or peripheral zone and an inner zone (i.e. areas such as pools, creek beds and fill areas located within the sedge meadows). This pattern was especially prevalent during the summer and fall when sedge (Carex spp.) was actively growing.

Figures 8, 9 and 10 present spatial and temporal

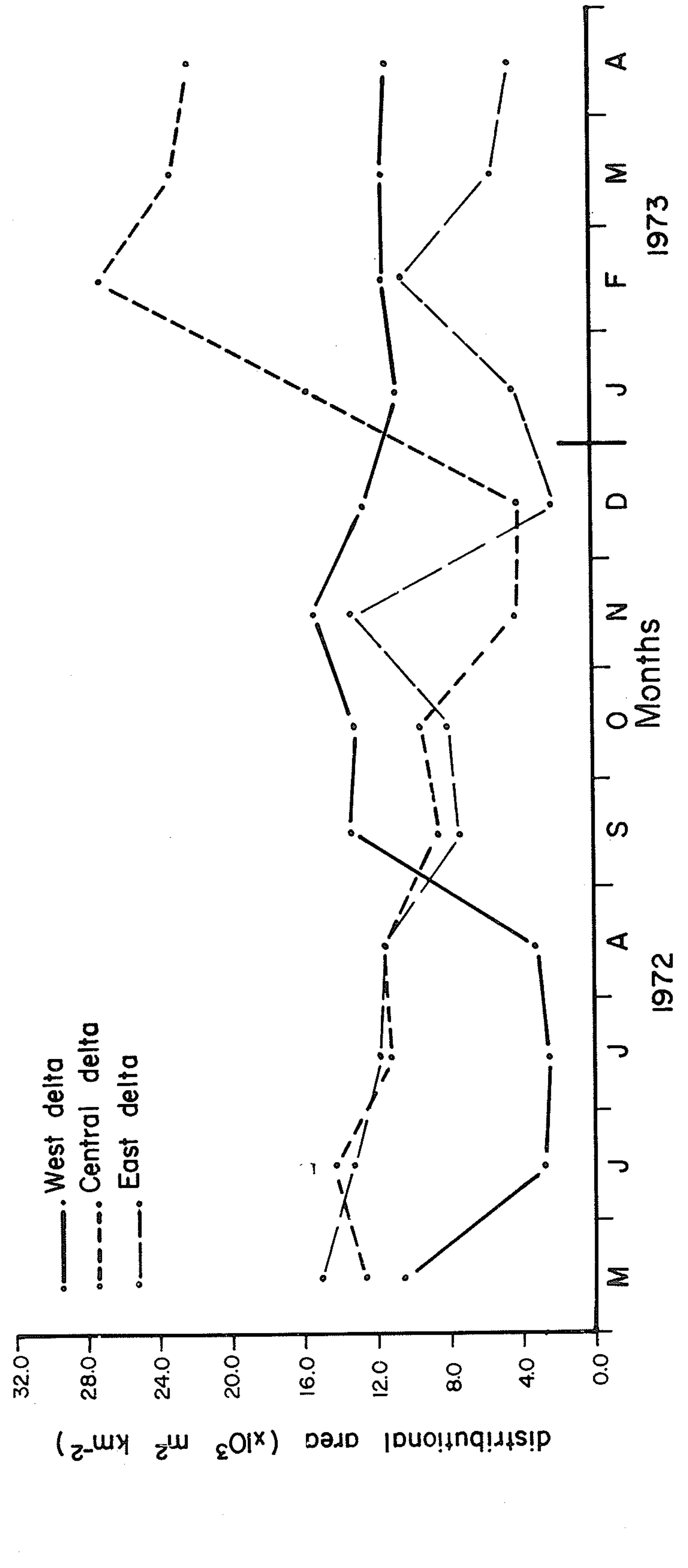


Figure 7. Average monthly distributional (coverage) area for algae on the West, Central and East Deltas.

changes in distribution for each algal species and/or assemblage recorded on the West, Central and East Deltas. The months presented were chosen as being significant since they characterized major seasonal periods. Specifically, June corresponded to river freshet, September to a late summer - early fall distribution, December to winter and March to spring pre-freshet conditions. Actual seasonable distribution changes (coverage area) in m^2 for each algal species and/or assemblage are presented in Appendix V.

Algal growth at the inner zone of the West Delta became apparent in June and continued through September, being dominated by the chlorophytes (Rhizoclonium cf. riparium and Spirogyra sp. Algae on the delta front were restricted at June freshet, consisting primarily of Enteromorpha clathrata. This alga persisted throughout the remainder of the study, with the zone being dominated by extensive growths of mud diatom assemblages; Navicula cf. cancellata dominating on the intertidal mud flats, Melosira spp. at the edge of the sedge growth and Pleurosigma cf. aestuarii on the banks of Castle Creek. Very localized growths of the marine alga Antithamnion pacificum were recorded in September through to December in the lower intertidal zone (Fig. 8).

LEGEND:

- ⁘ _ Diatom growth
- ▲ _ Antithamnion pacificum
- ■ _ Enteromorpha clathrata
- ∴ _ Enteromorpha prolifera
- █ _ Ulva lactuca
- ▥ _ Pylaiella littoralis
- ▩ _ Spirogyra sp.
- ⊠ _ Navicula grevillei
- ⁙ _ Rhodophyta
- ◎ _ Assemblage type XI
- ✳ _ Assemblage type XII

- ▧ _ Assemblage type I
- ▩ _ Assemblage type II
- ▤ _ Assemblage type III
- ▨ _ Assemblage type IV
- ▦ _ Assemblage type V
- ☰ _ Assemblage type VI
- + + + _ Assemblage type VII
- ⩚ _ Assemblage type VIII
- ▧ _ Assemblage type IX
- ▭ _ Assemblage type X

Legend for algae shown in Figures 8, 9 and 10

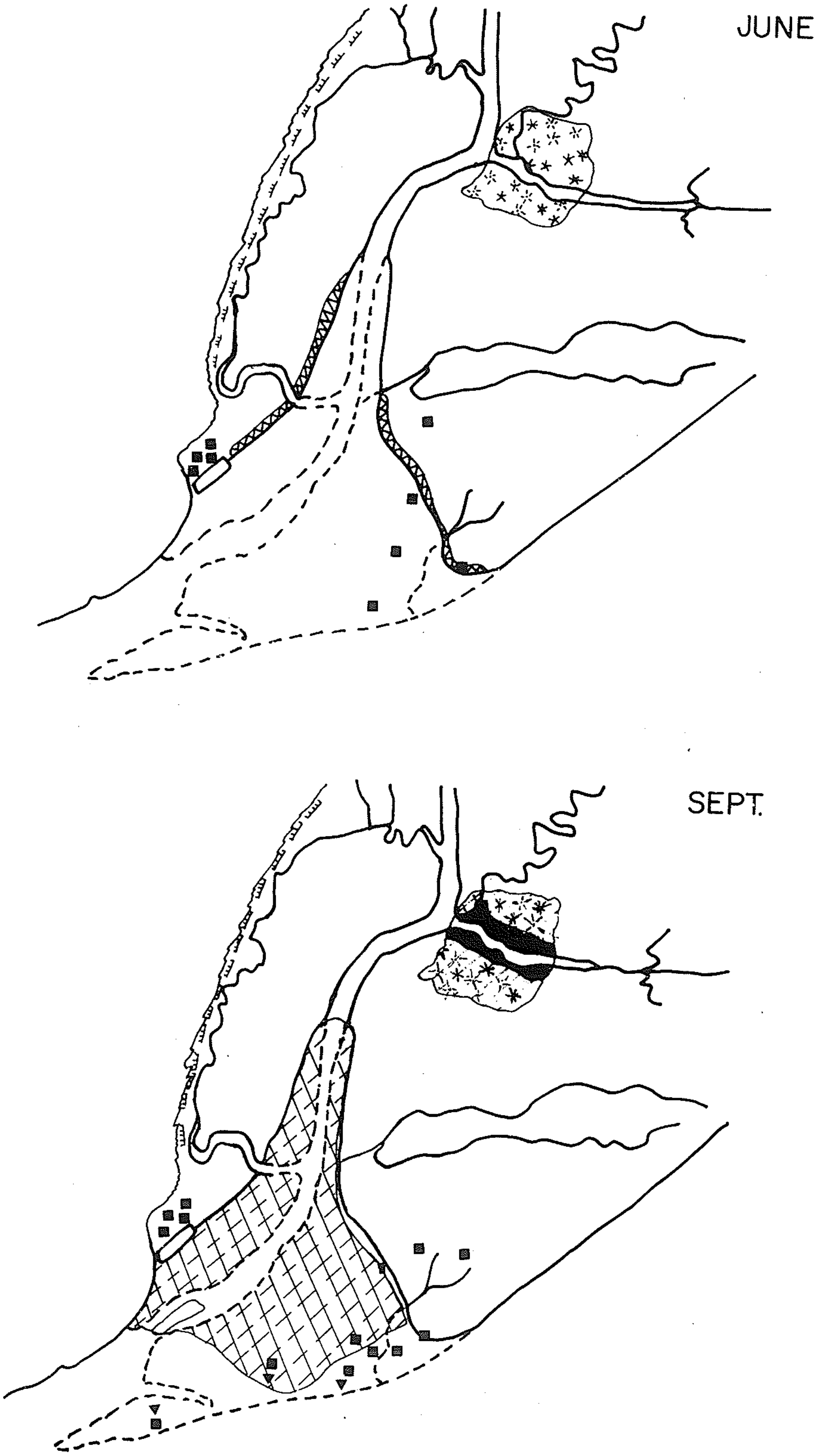


Figure 8. Map of West Delta illustrating the distribution of algae recorded in June and September.

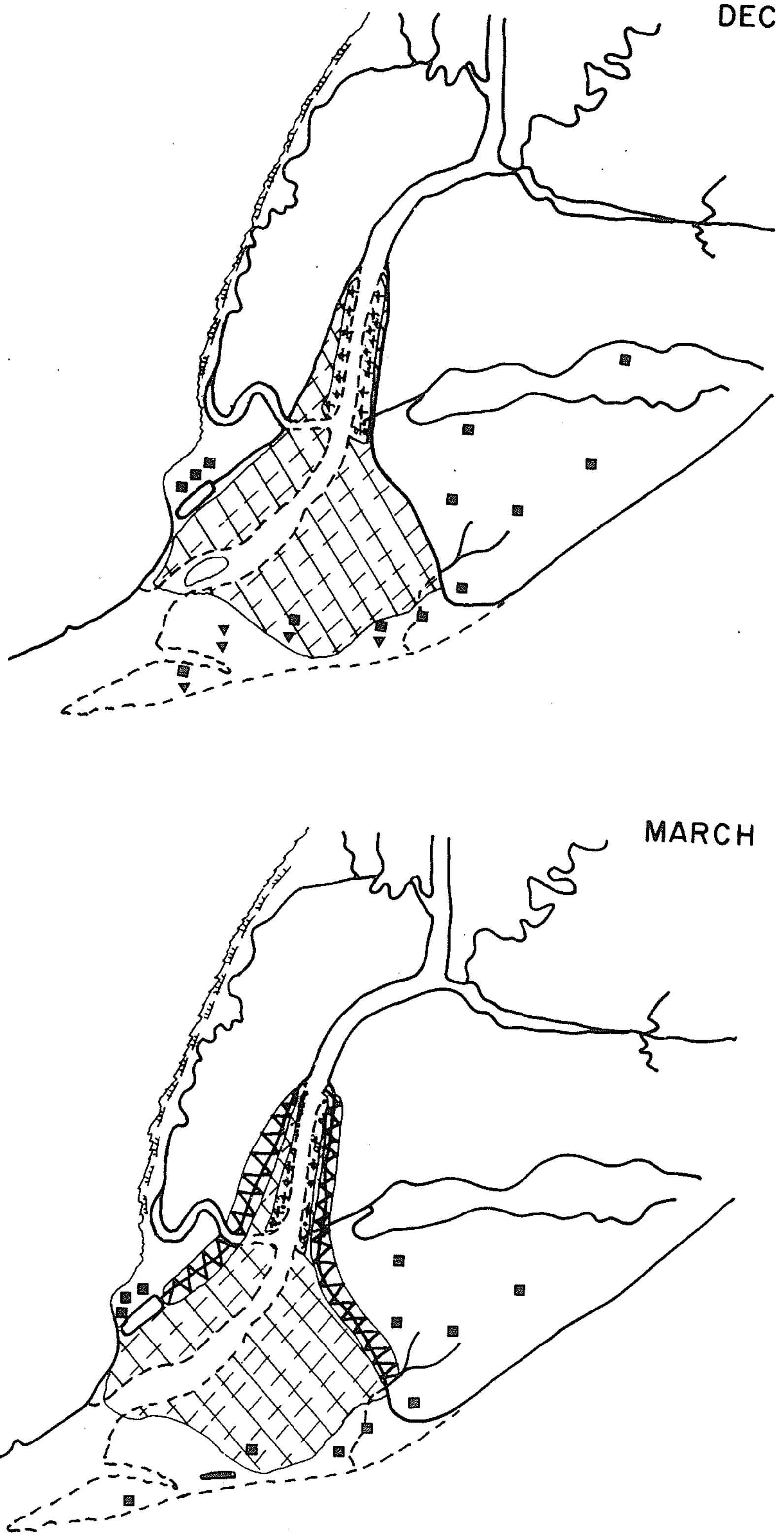


Figure 8. (cont'd) Map of the West Delta illustrating the distribution of algae recorded in December and March.

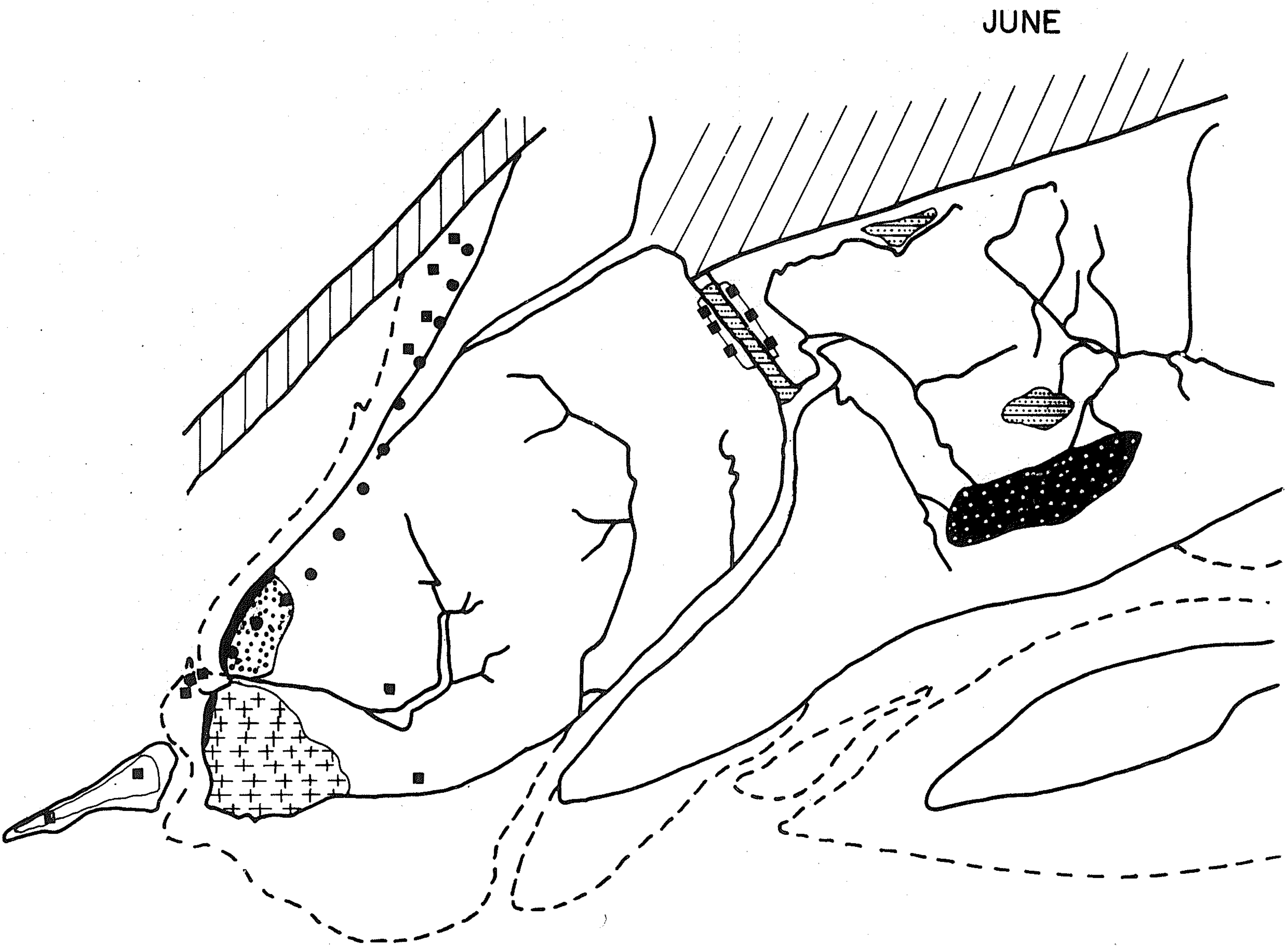


Figure 9. Map of the Central Delta illustrating the distribution of algae recorded in June.

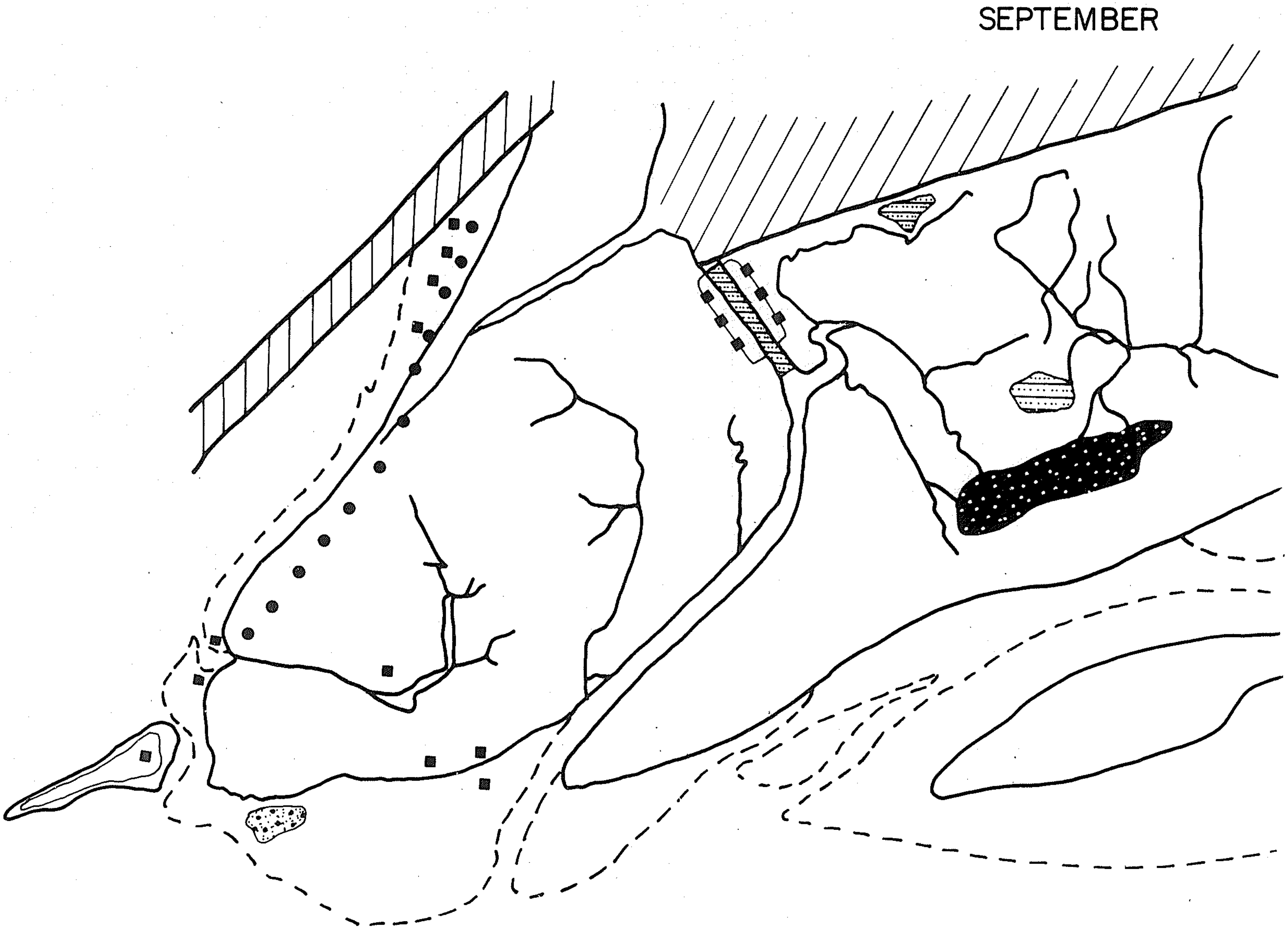
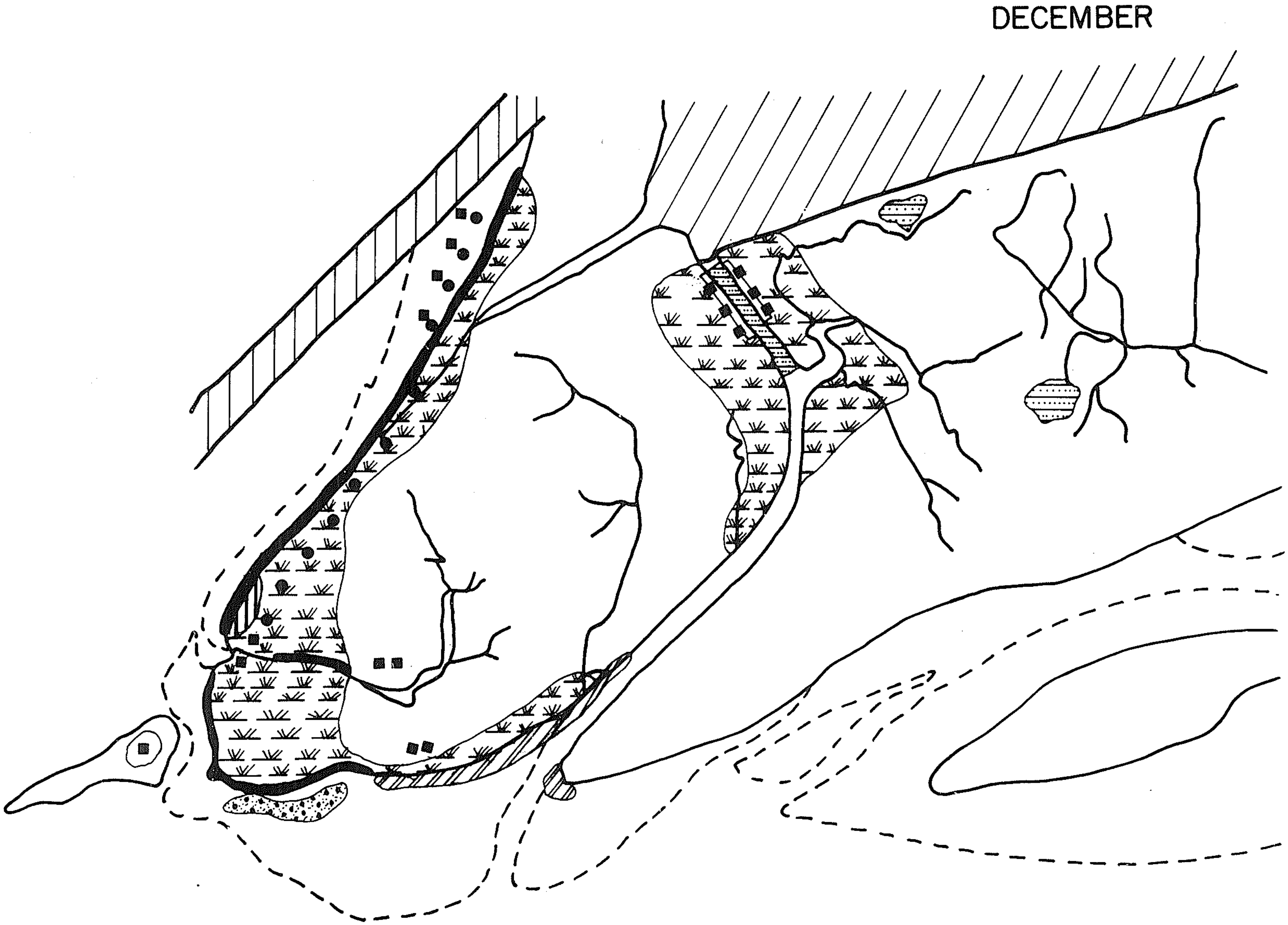


Figure 9. (cont'd) Map of the Central Delta illustrating the distribution of algae recorded in September.



DECEMBER

Figure 9. (cont'd) Map of the Central Delta illustrating the distribution of algae recorded in December.

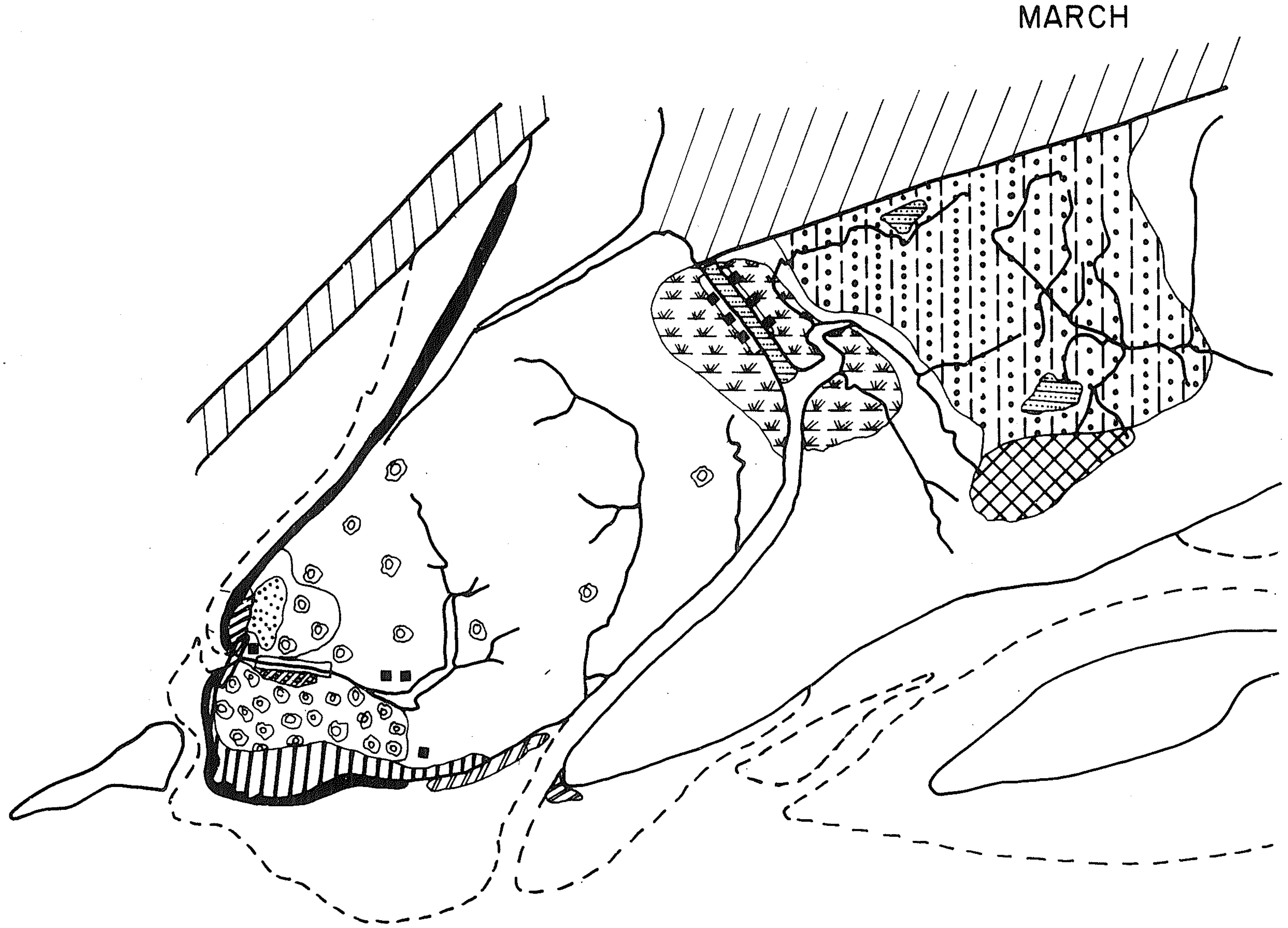


Figure 9. (cont'd) Map of the Central Delta illustrating the distribution of algae recorded in March.

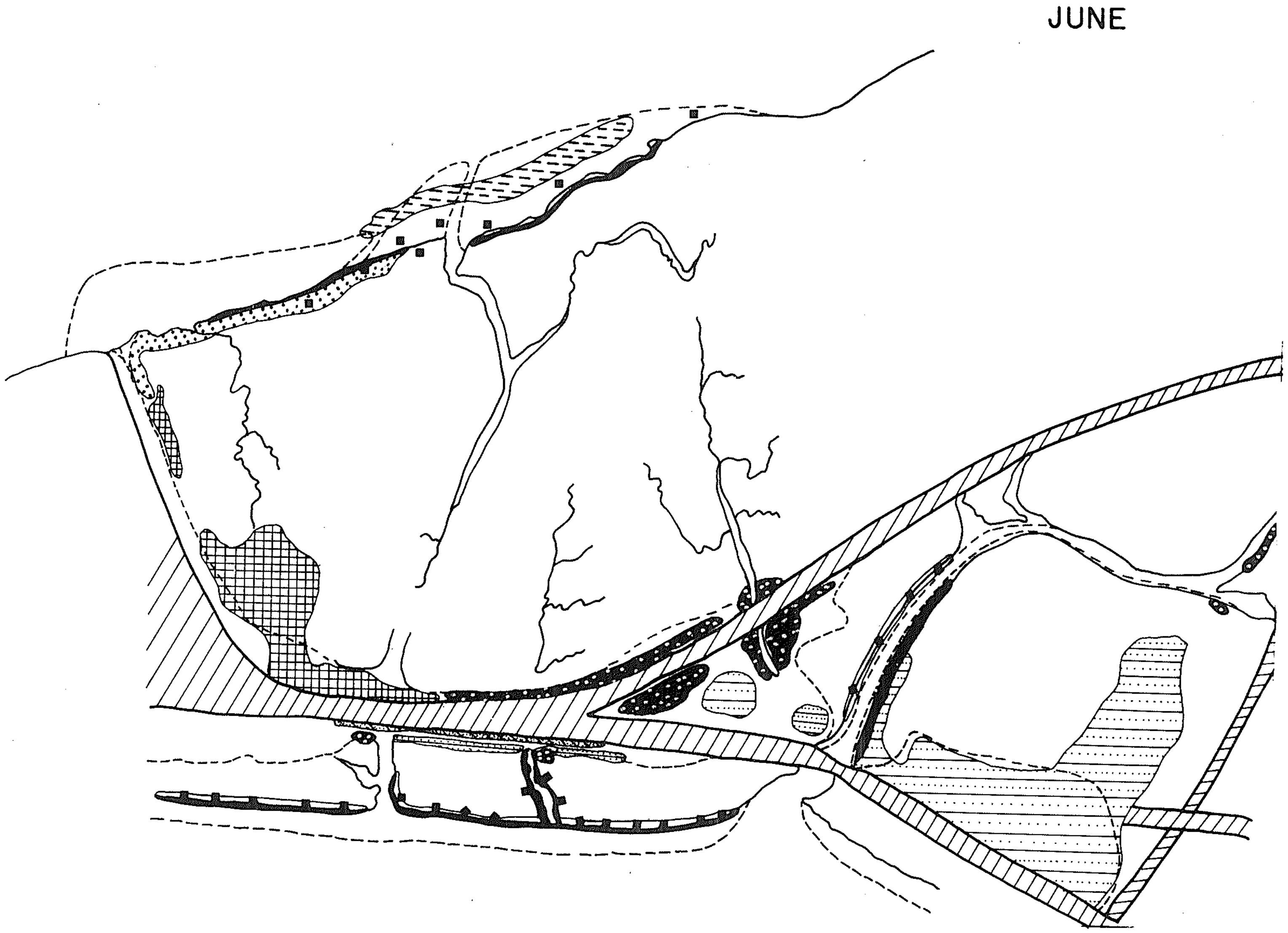


Figure 10. Map of the East Delta illustrating the distribution of algae recorded in June.

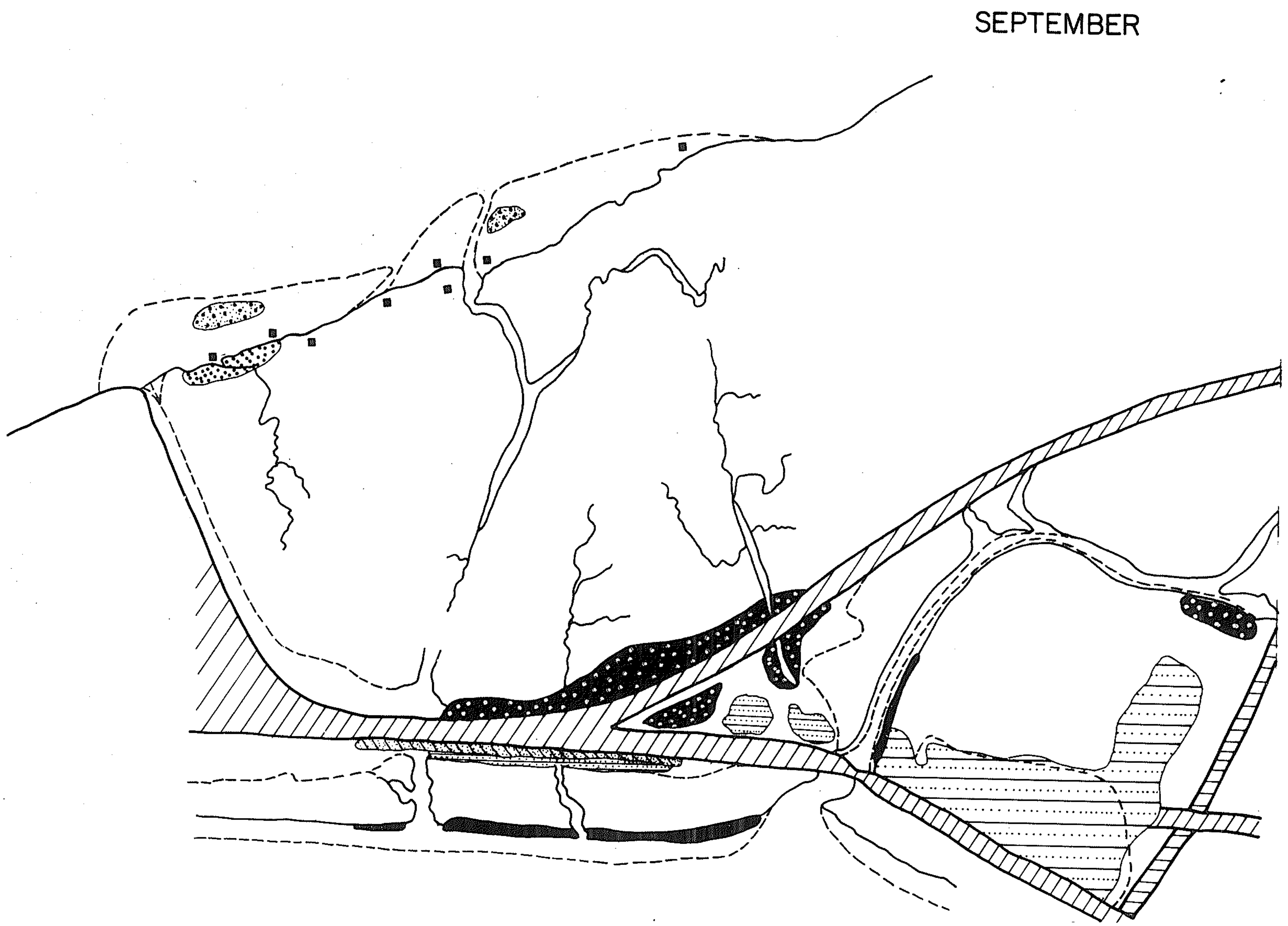


Figure 10. (cont'd) Map of the East Delta illustrating the distribution of algae recorded in September.

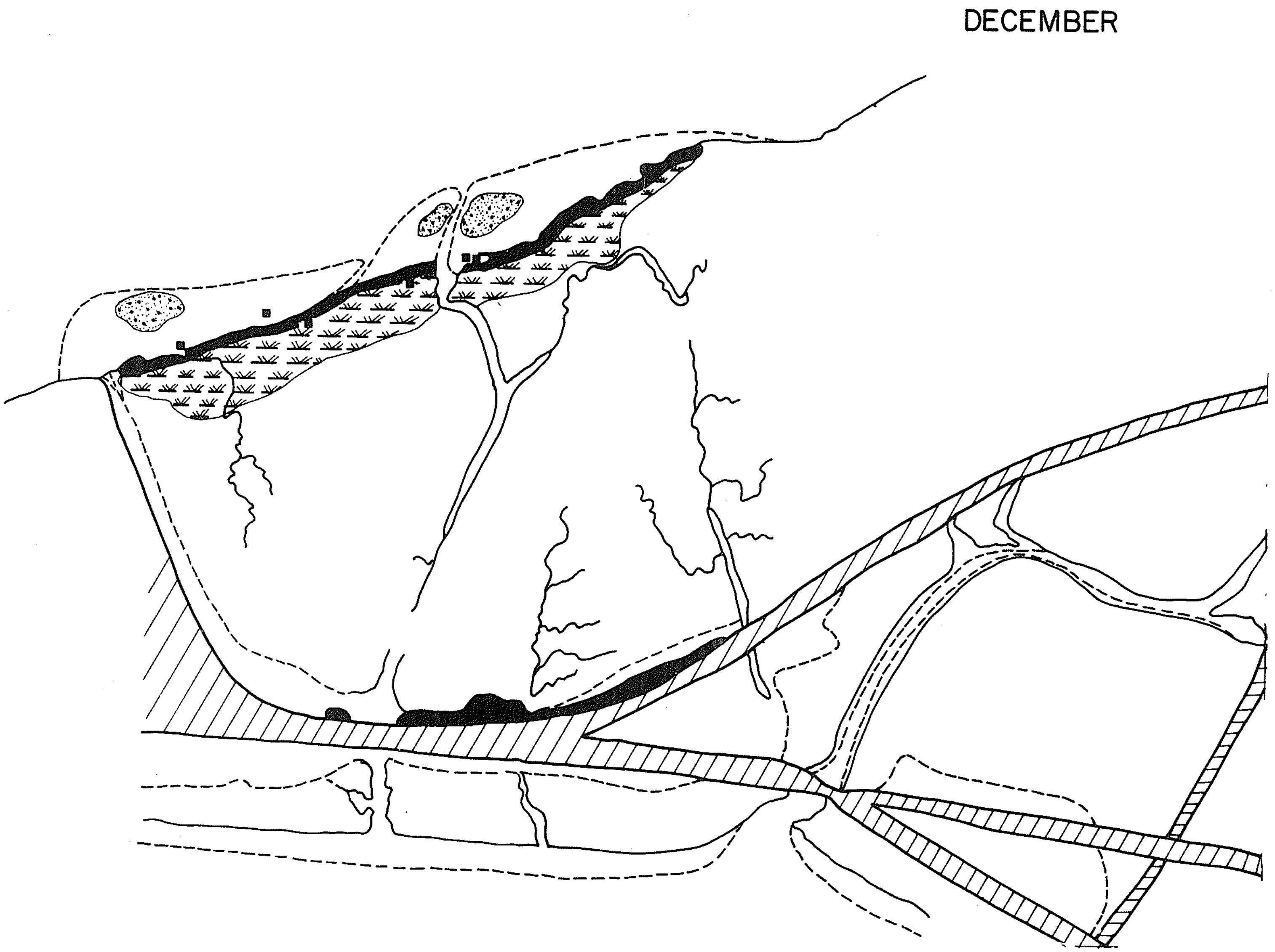


Figure 10. (cont'd) Map of the East Delta illustrating the distribution of algae recorded in December.

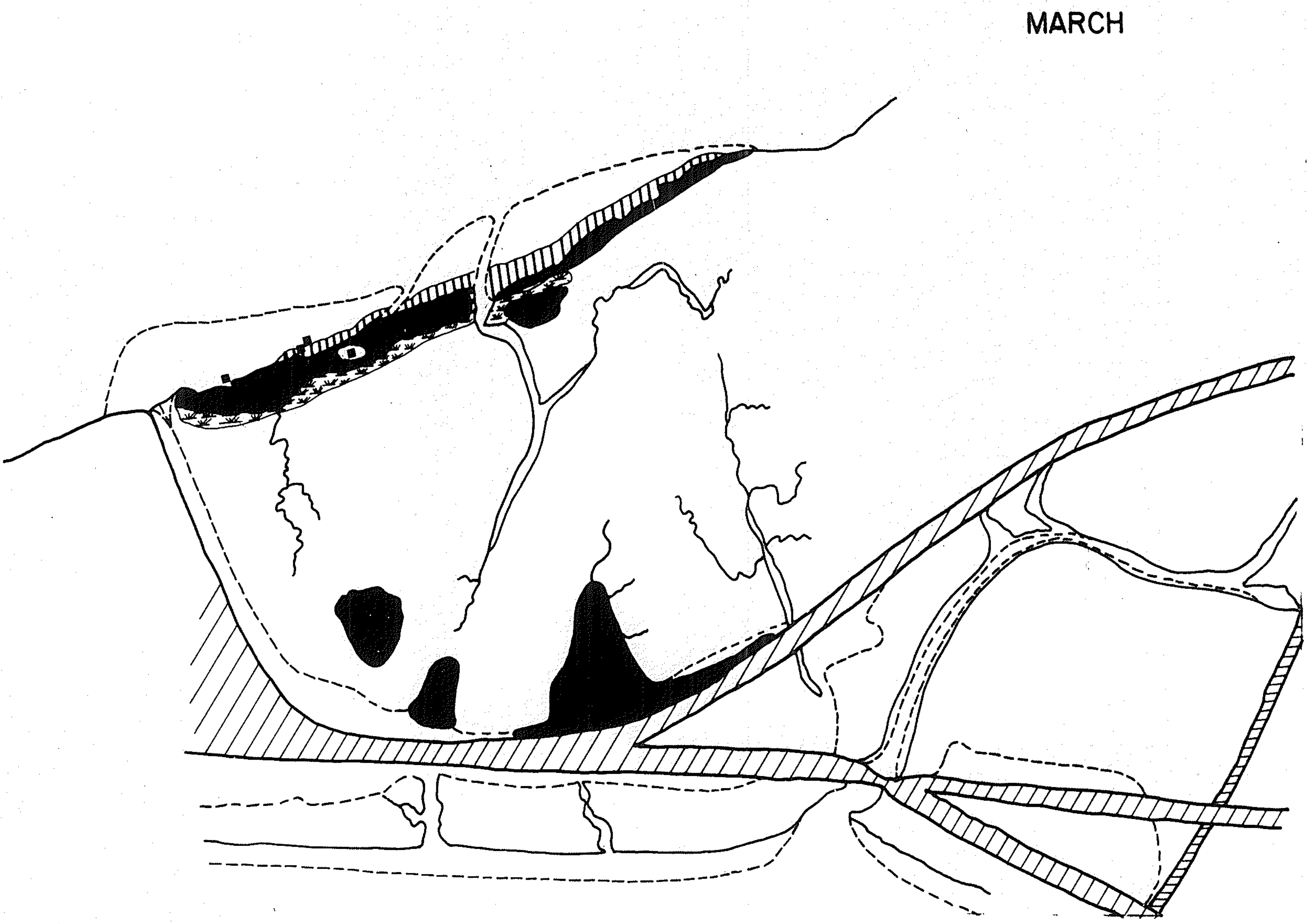


Figure 10. (cont'd) Map of the East Delta illustrating the distribution of algae recorded in March.

Growth patterns on the Central Delta were more variable compared to the west (Fig.9). The inner growth zone, resulting from land fill operations, was dominated by *Spirogyra* sp., *Enteromorpha clathrata*, and *Vaucheria dichotoma* through Spetember with the December flora being comprised primarily of the latter two species plus *Ulothrix* cf. *flacca*. The establishment of *Navicula grevellei* in the area previously occupied by *Spirogyra* sp. was noted in March along with the apparent initiation of diatom colonization on the greater portion of the mud and sand flats originating from fill operations. In June, during river freshet the delta front was dominated by heavy growths of *Enteromorpha clathrata* and *E. prolifera* as well as *Melosira* spp. Algal distribution in September was restricted to *E. clathrata* species plus a Rhodophyte on the intertidal mud flats. *Ulva lactuca*, *Ulothrix* cf. *flacca*, a rhodophyte and *Pleurosigma* cf. *aestuarii* were winter dominants. The brown alga *Pylaiella littoralis* was also first noted at this time. This alga, along with a *Navicula grevillei* assemblage and *Ulva lactuca*, was one of the most prevalent noted at the March sampling.

The inner regions of the East Delta were dominated by *Rhizoclonium* cf. *riparium* assemblages and *Spirogyra* sp. in shallow pools and *Vaucheria dichotoma* assemblages on open sand flats originating from fill (Fig.10). By late summer, only the latter two algae were recorded.

On the periphery of the East Delta, the chlorophytes *Ulva lactuca*, *Enteromorpha clathrata*, *E. prolifera* and *Rhizoclonium* cf. *riparium* assemblages predominated. The west and east sides possessed different floras by September. *Ulva lactuca* was the only algae recorded from the east side while *Enteromorpha* spp. and *Rhizoclonium* cf. *riparium* assemblages were noted on the west.

Log storage and continued construction activities east of the road and rail line resulted in the abandonment of the study area after November 1972. In the remaining inner delta areas, *Ulva lactuca* dominated to the termination of the study in May 1973. On the western periphery of the East Delta, the winter algal flora was dominated by the chlorophytes *Ulva lactuca*, *Ulothrix* cf. *flacca*. *Pylaiella littoralis* was recorded as a dominant species at the March sampling period in addition to the two former species.

(c) Algal Biomass

Trends of decreasing biomass (Kg C km^{-2} month^{-1}) from Central to East to West Deltas were evident with variations as to periods of seasonal maxima and minima (Fig.11).

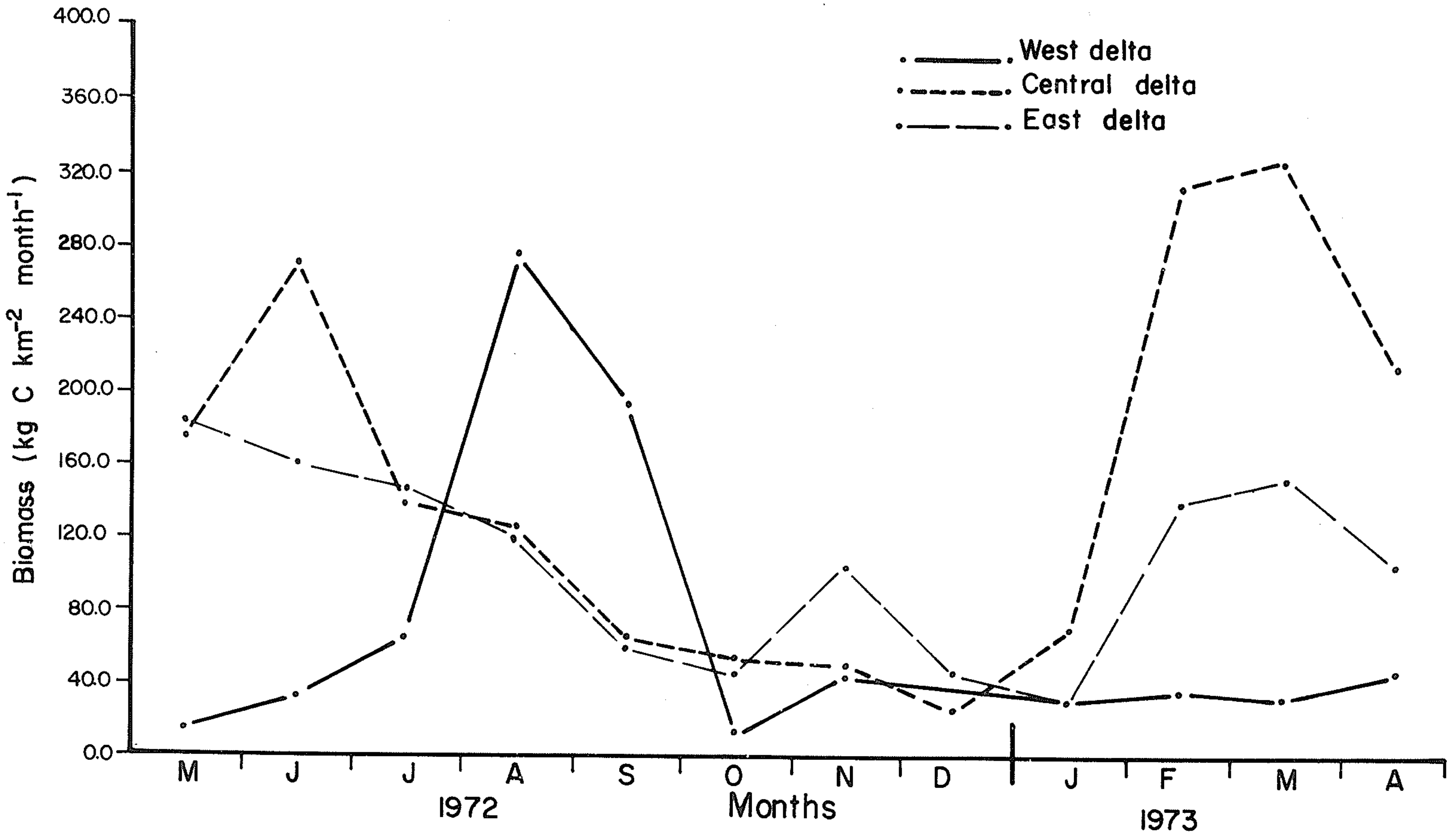


Figure 11. Average monthly biomass recorded for algae on the West, Central and East Deltas.

Biomass on the Central Delta ranged from 27.8 kg C km^{-2} in December to maximum values of 269.8 and 322.4 in June and March, respectively (Fig.11). Algal biomass on the East Delta showed similar seasonal patterns, with peak values of 183.9 recorded in May dropping to a low of 30.6 by January. On the West Delta, a minimum biomass of 12.8 kg C km^{-2} occurred in October, two months earlier than on the other two deltas. A high of 65.0 was recorded in July, two months later than the maxima on the other two delta areas. Average biomass values of 153.2, 108.8, and 34.0 for the Central, East and West Deltas respectively were noted over the study period.

Minimum, maximum and average biomass values noted for each algal species or assemblage appear in Table 6. Detailed seasonal biomass data are presented in Appendix V.

On a square meter basis (g C m^{-2}), the Rhizoclonium cf. riparium assemblage (46.5), Enteromorpha clathrata (22.9) and rhodophyte filaments (21.1) exhibited the highest biomass values (Table 6). Minimum values were recorded for Ulva lactuca (0.2), Spirogyra sp. (1.4) and many of the diatom assemblages (Table 6).

Estimates of total average biomass as kg C km^{-2} delta, based on the distribution area of each algae, indicated Rhizoclonium riparium (112.9), Pylaiella littoralis

Table 6. Minimum, maximum and average biomass values for algae on the West, Central and East Deltas.

Algal Species or Assemblage	Min. gCm^{-2}	Month	Max. gCm^{-2}	Month	Average gCm^{-2}	Average $Kg\ C\ km^{-2}$
WEST DELTA						
Enteromorpha clathrata	2.40	July	31.59	April	10.83	7.08
Ulva lactuca	0.14	Jan.	0.27	Feb	0.20	0.003
Spirogyra sp.	0.42	Nov.	2.95	Sept.	1.35	0.28
Antithamnion pacificum	0.43	Feb.	2.07	Jan.	1.49	0.05
Assemblage type I	1.10	March	4.73	Jan.	3.02	7.33
Assemblage type VII	0.90	Sept.	2.00	April	1.52	13.65
Assemblage type A	0.10	July	10.75	March	3.90	1.50
Assemblage type XII	10.18	Nov.	110.40	Aug.	46.50	112.86
CENTRAL DELTA						
E. clathrata	1.01	April	37.17	July	13.20	8.00
E. prolifera	1.50	Feb.	29.04	June	16.43	34.85
U. lactuca	3.40	Oct.	14.37	Feb.	7.75	1.47
Spirogyra sp.	0.74	Oct.	11.40	Aug.	3.88	23.88
Navicula grevillei	1.10	April	31.00	March	14.37	58.95
Pylaiella littoralis	3.71	Jan.	17.10	March	10.24	80.74
Assemblage type I	0.98	Oct.	4.98	Jan.	3.14	4.43
Assemblage type II	3.05	Jan.	12.90	July	8.12	9.37
Assemblage type IX	1.02	Jan.	3.98	Feb.	2.27	0.26
Assemblage type X	0.98	March	2.15	Feb.	1.63	0.05
Assemblage type XI	3.10	Jan.	12.30	March	6.66	51.23
	3.94	Jan.	42.90	Nov.	21.13	13.65
	4.35	July	23.52	June	12.15	75.55

Continued

Table 6 (Continued)

Algal Species or Assemblage	Min. gCm^{-2}	Month	Max. gCm^{-2}	Month	Average gCm^{-2}	Average Kg C km^{-2}
EAST DELTA						
E. clathrata-west side	0.50	Feb.	28.54	July	9.36	1.51
E. clathrata-east side	7.32	Aug.	33.82	July	22.92	13.08
E. prolifera-west side	3.14	Jan.	33.82	July	19.76	18.08
U. lactuca-west side	3.02	Oct.	24.71	March	8.94	12.20
U. lactuca-east side	3.96	May	8.41	July	5.63	2.43
U. lactuca-inner area	1.00	Feb.	2.91	Dec.	1.97	1.60
Spirogyra sp.	1.29	Oct.	12.35	Aug.	5.22	6.76
Pylaiella littoralis	0.90	Jan.	3.42	March	2.24	0.84
Rhodophyte filaments	4.10	Jan.	39.19	Nov.	19.40	8.99
Assemblage type III	6.10	Oct.	11.58	July	9.39	52.39
Assemblage type IV	9.10	Oct.	51.60	July	27.74	1.63
Assemblage type V	2.14	May	8.20	June	6.36	19.11
Assemblage type VII	2.00	July	14.91	June	10.11	16.71

Table 7. Total monthly net algal production by algae on the West, Central and East Deltas together with monthly averages and yearly estimates of net production for each delta area.

Month	West Delta[a] Kg C km^{-2}	Central Delta[b] Kg C km^{-2}	East Delta[c] Kg C km^{-2}
May 1972	127.9	207.7	240.8
June 1972	20.6	403.8	422.4
July 1972	39.9	457.8	610.7
August 1972	90.4	423.3	329.9
September 1972	177.7	170.8	206.1
October 1972	119.8	44.8	131.7
November 1972	51.0	27.5	86.9[d]
December 1972	-	23.8	84.1
January 1973	50.3	164.5	241.4
February 1973	55.1	358.2	472.0
March 1973	79.5	295.7	149.8
April 1973	94.7	204.7	92.9
Monthly average	82.5	231.9	255.7
Yearly estimate	907.0	2783.0	2653.0

[a] delta area = 0.103 km^2

[b] delta area = 0.130 km^2

[c] delta area = 0.233 km^2

[d] delta area = 0.140 km^2

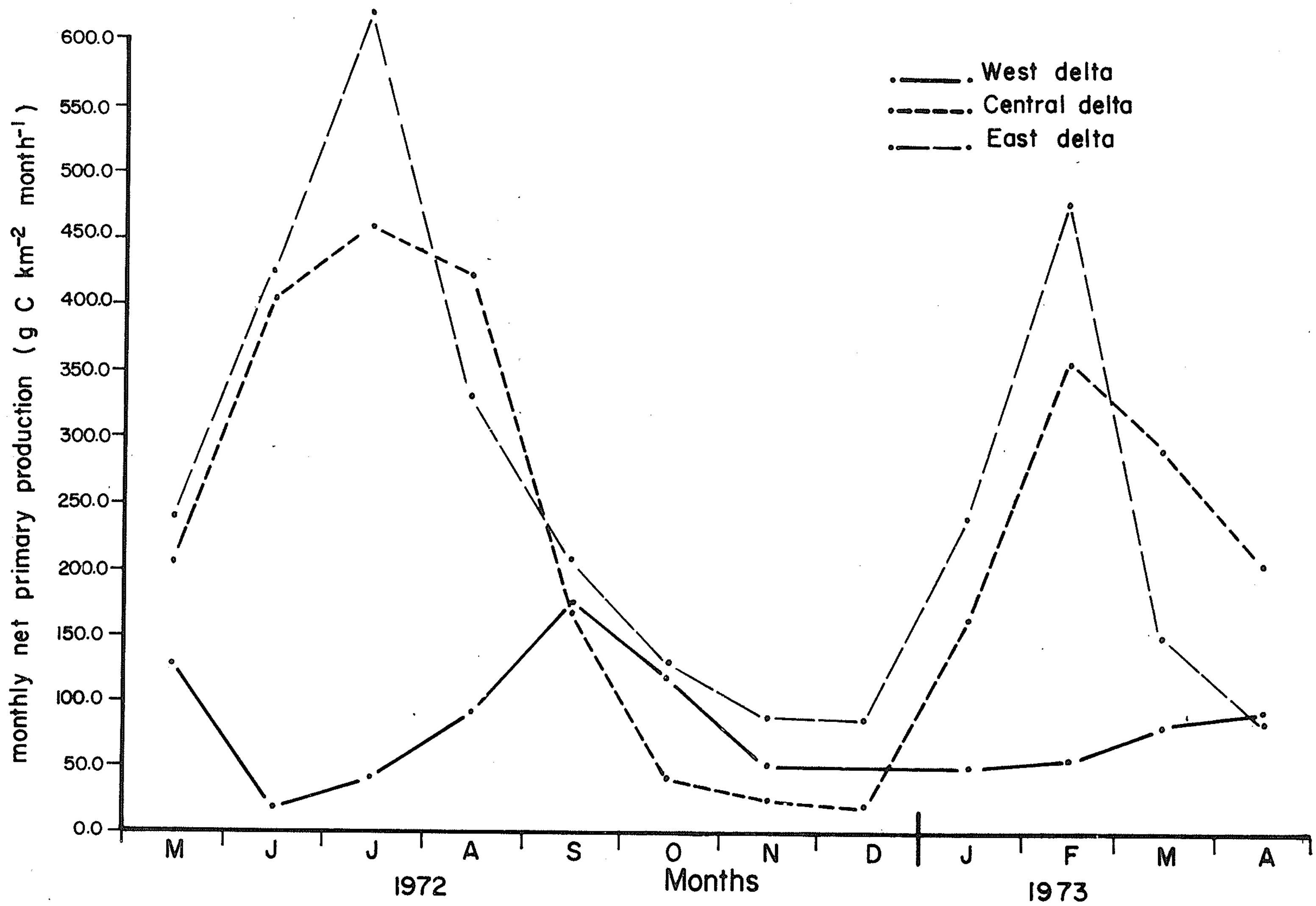


Figure 12. Average monthly net algal production recorded on West, Central and East Deltas.

(80.7) and *Vaucheria dichotoma* (52.4) as major contributors. Diatom assemblages approximated the biomass values for *Enteromorpha clathrata* which averaged 8.3 kg C km^{-2}.

(d) Primary Production

(i) Dissolved Oxygen Production

Average net primary production values of 82.5, 231.9 and 255.7 kg C km^{-2} month^{-1} were noted for the West, Central and East Deltas, respectively over the period May, 1972 to April, 1973 (Table 7). Production remained greatest on the East Delta except for August, March and April when exceeded by that on the Central (Fig. 12). Estimates of annual net production for the West, Central and East Deltas were 907, 2783, 2653 kg C km^{-2} year^{-1} respectively (Table 9).

Maximum net production on the Central and East Deltas was recorded in July, with values as high as 457.8 and 610.7 kg C km^{-2} month^{-1}, respectively (Table 7). Biomass on the Central Delta was about 40% its maximum at this time while that on the East was 80%. Low net production values of 23.8 for the Central and 84.1 kg C km^{-2} month^{-1} for the East were recorded in December, concurrent with low biomass. Peak net production for the West Delta was noted in September at 177.7 with a minimum of 20.6

during June river freshet (Table 9). Biomass values for the West showed an inverse relationship with production being highest in June and lowest in September (Fig.11).

The relative contribution of each of the major algal phyla to total net production are shown in Table 10. Chrysophyte assemblages, dominated by Navicula spp. and Pleurosigma aestuarii, showed the highest net production on the West Delta with values ranging from 0.01 at June freshet to 5.0 kg C km^{-2} day^{-1} in September (Table 8). Highest net production by the chlorophyta of 2.3 was noted in August. A minimum value of 0.2 was recorded in January along with a reading of 0.11 during the June freshet period. The average net production value for Chrysophyta was 1.9 compared to 0.9 kg C km^{-2} day^{-1} for Chlorophyta.

In comparison to the West Delta, the Central displayed relatively more seasonal variations with respect to the most productive algal group. Members of the Chlorophyta displayed the greatest net production July through December. Values ranged from 14.4 in July to 0.43 kg C km^{-2} day^{-1} in December, averaging 5.3 (Table 8). The highest net productivity to occur on the Squamish Delta over the study period was 12.5 recorded for Spirogyra sp. in July. In terms of consistent production, Enteromorpha clathrata and Ulva lactuca were the most significant. The

Table 8. Relative contribution (kg C km^{-2} day^{-1}) of each major algal phylum to net primary production recorded on the West, Central and East Deltas.

	West Delta					Central Delta					East Delta				
	Chl	Chr	P	R	X	Chl	Chr	P	R	X	Chl	Chr	P	R	X
May	0.32	4.38	-	-	-	1.97	5.25	-	-	0.81	2.22	3.43	-	-	4.52
June	0.11	0.01	-	-	-	5.08	7.65	-	-	0.82	10.02	2.53	-	-	5.02
July	1.20	0.01	-	-	-	14.38	1.38	-	-	0.28	18.13	0.12	-	-	3.24
August	2.37	-	-	-	-	13.94	-	-	-	0.40	8.11	0.07	-	-	2.50
September	2.33	5.02	-	0.01	-	1.99	-	-	0.27	0.24	2.13	0.01	-	0.34	1.96
October	1.18	0.88	-	0.01	-	0.71	0.11	-	0.47	0.23	1.57	0.01	-	0.42	1.77
November	0.28	1.93	-	0.01	-	0.50	0.15	-	0.12	0.04	1.07	0.01	-	0.18	1.10
December	-	-	-	-	-	0.43	0.20	-	0.12	2.28	-	-	-	0.20	-
January	0.02	0.69	-	0.01	-	0.21	5.32	0.82	0.08	0.03	3.67	-	0.05	0.06	-
February	0.30	1.55	-	-	-	0.88	8.63	3.69	-	0.17	17.97	-	0.24	-	-
March	0.96	2.16	-	-	-	0.67	4.66	4.00	-	0.39	3.56	-	0.30	-	-
April	1.14	2.06	-	-	-	1.44	0.49	3.74	-	0.57	4.44	-	0.27	-	-
Average Values	0.92	1.87	0.00	0.01	0.00	3.52	3.39	3.06	0.22	0.32	6.26	0.88	0.22	0.24	2.87

Chl. - Chlorophyta; Chr. - Chrysophyta; P - Phaeophyta; R - Rhodophyta; X - Xanthophyta.

chrysophyta (primarily *Navicula grevillei* and *Melosira* spp.) accounted for the highest average net production May - June (6.5) and January - April (6.2). In the latter period, *Pylaiella littoralis*, a phaeophyte, was also a significant net producer averaging 3.1 kg C km^{-2} day^{-1} (Table 8). On an annual basis, average daily net productivities for the chlorophyta, chrysophyta and phaeophyta was quite close at 3.5, 3.4 and 3.1, respectively (Table 8).

The Chlorophyta (primarily *Enteromorpha clathrata*) and *Ulva lactuca* dominated net productivity on the East Delta with values ranging from 1.1 in November to 18.1 kg C km^{-2} day^{-1} in July (Table 8). A *Vaucheria dichotoma* assemblage (Xanthophyta) showed values from 5.0 in June to 1.1 in November, being the second most productive algal group on the East Delta. Production values for the phaeophyta averaged approximately 1/15 of those recorded on the Central Delta.

The preceding section indicated the relative productive capacity of each delta area together with the relative contribution of each algal group to totals observed. The following results, expressed as g C m^{-2} day^{-1}, considers the productive capacity of each algal species and/or assemblage, unencumbered by the vagarities imposed by differences in distribution area.

Table 9 summarizes surface net production and $^{P}/_{R}$ ratios (gross production/respirational) recorded over the study period. Detailed seasonal data are presented in Appendix V.

Members of the chlorophyta were responsible for the highest algal net production recorded on the Squamish Delta over the study period (Table 9). Maximum and minimum values averaged 2.4 and 0.2 g C m^{-2} day^{-1}, respectively. Corresponding average $^{P}/_{R}$ ratios of 4.9 and 1.6 were noted. The five remaining algal groups displayed average maximum net productivition and $^{P}/_{R}$ ratios 5 - 40% lower than those noted above.

Among the chlorophyta, *Ulva lactuca* proved the most productive with an average maximum for the three delta areas of 2.66 g C m^{-2} day^{-1} with a mean $^{P}/_{R}$ of 9.30. *Enteromorpha clathrata* and *Spirogyra* sp. had average maximum net production of 2.59 and 2.45, respectively. Average $^{P}/_{R}$ ratios of 4.07 for *E. clathrata* and 2.99 for *Spirogyra* sp. were noted. Lowest minimum net production among the chlorophyta, was recorded for these two algal species.

Considerable variation was evident as to degree of

Table 9. Maximum and minimum net primary production and corresponding $^{P}/_{R}$ values for algae on the West, Central and East Deltas.

	Maximum net production $gCm^{-2}day^{-1}$	$^{P}/_{R}$	Month	Minimum net production $gCm^{-2}day^{-1}$	$^{P}/_{R}$	Month
Enteromorpha clathrata						
west	2.13	5.54	March	0.05	1.70	Nov.
central	1.24	3.64	June	0.08	2.12	Jan.
east	3.67	3.27	July	0.12	1.16	Aug.
E. prolifera						
central	1.49	3.62	June	0.31	1.77	Feb.
east	2.50	3.08	July	0.31	1.77	Feb.
Spirogyra sp.						
west	1.42	3.61	Aug.	0.01	1.04	Nov.
central	2.03	2.58	July	0.05	1.07	Oct.
east	3.91	2.78	July	0.71	1.58	Aug.
Ulva lactuca						
west	0.32	3.17	Jan	0.03	1.07	March
central	3.42	15.67	Feb.	0.27	2.60	July
east						
west	3.42	15.67	Feb.	0.27	2.60	July
inner	0.71	3.59	March	0.34	1.98	Dec.
east	5.42	8.39	July	0.41	1.66	Nov.
Rhizoclonium riparium						
west	0.81	2.10	Aug.	0.10	1.31	Nov.
Pylaiella littoralis						
central	0.69	3.56	Feb.	0.20	1.94	Jan.
east	0.69	3.56	Feb.	0.20	1.94	Jan.
Antithamnion pacificum						
west	0.17	2.24	Nov.	0.04	1.23	Feb.

Continued

Table 9. (Continued)

	Maximum net production $gCm^{-2}day^{-1}$	$^{P}/_{R}$	Month	Minimum net production $gCm^{-2}day^{-1}$	$^{P}/_{R}$	Month
Assemblage type III (*V. dichotoma*)						
central	0.81	3.75	June	0.03	1.34	Jan.
east	0.90	2.57	June	0.20	1.70	Nov.
Assemblage type I						
west	0.94	2.94	Nov.	0.03	1.18	March
central	0.62	2.66	Oct.	0.12	3.37	March
Assemblage type II	0.52	3.42	Sept.	0.05	1.25	Nov.
Assemblage type IV						
east	0.99	2.32	June	0.14	1.25	Aug.
Assemblage type V						
east	0.45	2.17	June	0.04	1.15	June
Assemblage type VI						
east	0.90	3.98	June	0.13	1.19	July
Assemblage type VII						
west	0.89	2.37	June	0.00	0.95	July
Assemblage type IX						
central	0.17	1.41	Jan.	0.10	1.24	March
Assemblage type X						
central	0.47	2.06	Jan.	0.19	1.36	March
Assemblage type XI						
central	0.91	2.11	Feb.	0.06	1.20	April
Assemblage type XII						
west	0.81	2.10	July	0.10	1.31	Nov.
Navicula grevillei						
central	0.71	4.60	Feb.	0.01	1.10	April
	0.89	5.43	Sept.	0.20	1.96	Jan.
east	1.00	6.52	Sept.	0.20	1.95	Jan.

maximum net primary productivity between the West, Central and East Deltas for recurrent algal species (Table 9). Members of the Chlorophyta generally showed a significant increase in net production in going from West to East Deltas. For example, *Spirogyra* sp. increased from 1.4 to 3.9 and *Ulva lactuca* changed from 0.3 to 3.4 (Table 9). Similar patterns were evident for the Rhodophyta and Xanthrophyta, the latter increasing from 0.8 on the Central to 0.8 on the East Delta. Trends of higher minimum net production values from West to East Deltas were also recorded (Table 9).

In addition to above noted spatial variations in in maximum and minimum net productivities, temporal variations were also evident. A comparison of chlorophytes common to the three delta areas indicates reasonably good agreement between the time of production maxima on the Central and East Deltas (Table 9). The two *Enteromorpha* species show a lag of one month for the East Delta whereas the timing of *Spirogyra* sp. and *Ulva lactuca* maxima on the two deltas coincide. Production maxima for chlorophytes on the West Delta either preceded or followed those on the other deltas by one month, with the exception of *Enteromorpha clathrata*. This alga reached peak production in March prior to June river freshet, a time when maximum production values were being recorded on the Central and East Deltas.

Differentiation of two algal groups was possible based on time of year at which maximum production was reached (Table 10). One group composed of the Chlorophyta, Xanthophyta, and one diatom assemblage (*Melosira* spp.) favored the high light intensities of spring and summer. A second group, made up of the Phaeophyta, Rhodophyta and the Chrysophyta, reached peak productivities during the autumn and winter when light intensities were low (Table 10). Patterns of minimum production values for these groups were reversed.

Representative seasonal biomass, net production and respiration curves for each of the two categories noted above appear in Figures 13 and 14.

Enteromorpha clathrata, being persistent throughout the study and generally reflecting the periods of maxima and minima shown by most other high light algae, was chosen as representative of this group. High light intensities and water temperatures, along with low salinities prevailed at the time of production maxima. Peak surface net production values of 2.00 g C m^{-2} day^{-1} were reached on the West Delta in June and March. High June values

Table 10. Classification of benthic algae based on the time of net primary production.

Low light algal species and assemblages
winter and autumn production maxima

- *Ulva lactuca*
- *Pylaiella littoralis*
- *Antithamnion pacificum*
- *Navicula grevillei*
- Assemblage type I
- Assemblage type IX
- Assemblage type X
- Assemblage type XI
- Rhodophyte filaments

High light algal species and assemblages
spring and summer production maxima

- *Enteromorpha clathrata*
- *E. prolifera*
- *Spirogyra* sp.
- *Rhizoclonium* cf *riparium*
- *Vaucheria dichotoma*
- Assemblage type II
- Assemblage type IV
- Assemblage type VI
- Assemblage type VII

occurred at a time of low biomass (2.5 g C m^{-2}) while that for March coincided with a biomass of 14.0 g C m^{-2} (Fig. 13). Light intensities were high and salinities low at both times. On the Central Delta, high net surface production (1.30 g C m^{-2} day^{-1}) occurred in June when biomass was increasing. A secondary production peak of 0.82 g C m^{-2} day^{-1} was reached in April with biomass approaching its lowest point (Fig. 13). The East Delta showed good correlation between the time of maximum net surface production and biomass, with the former reaching 3.29 g C m^{-2} day^{-1}. Net production with depth on all three deltas was lowest over the winter months, rising to a maximum by April (Fig. 13).

Pylaiella littoralis from the Central Delta was chosen as representative of algae favoring low light intensities. Maximum net production at the surface was 0.69 g C m^{-2} day^{-1} for February at a time of rapidly increasing biomass (Fig.14). High salinity (25°/oo) accompanied by low water temperatures and light intensities were prevalent at this time. Lower daily production values were noted for successive months when biomass reached its peak (Fig.14). Temperatures and light intensities rose steadily during this time while salinities dropped by about 50%. Similar patterns were noted at

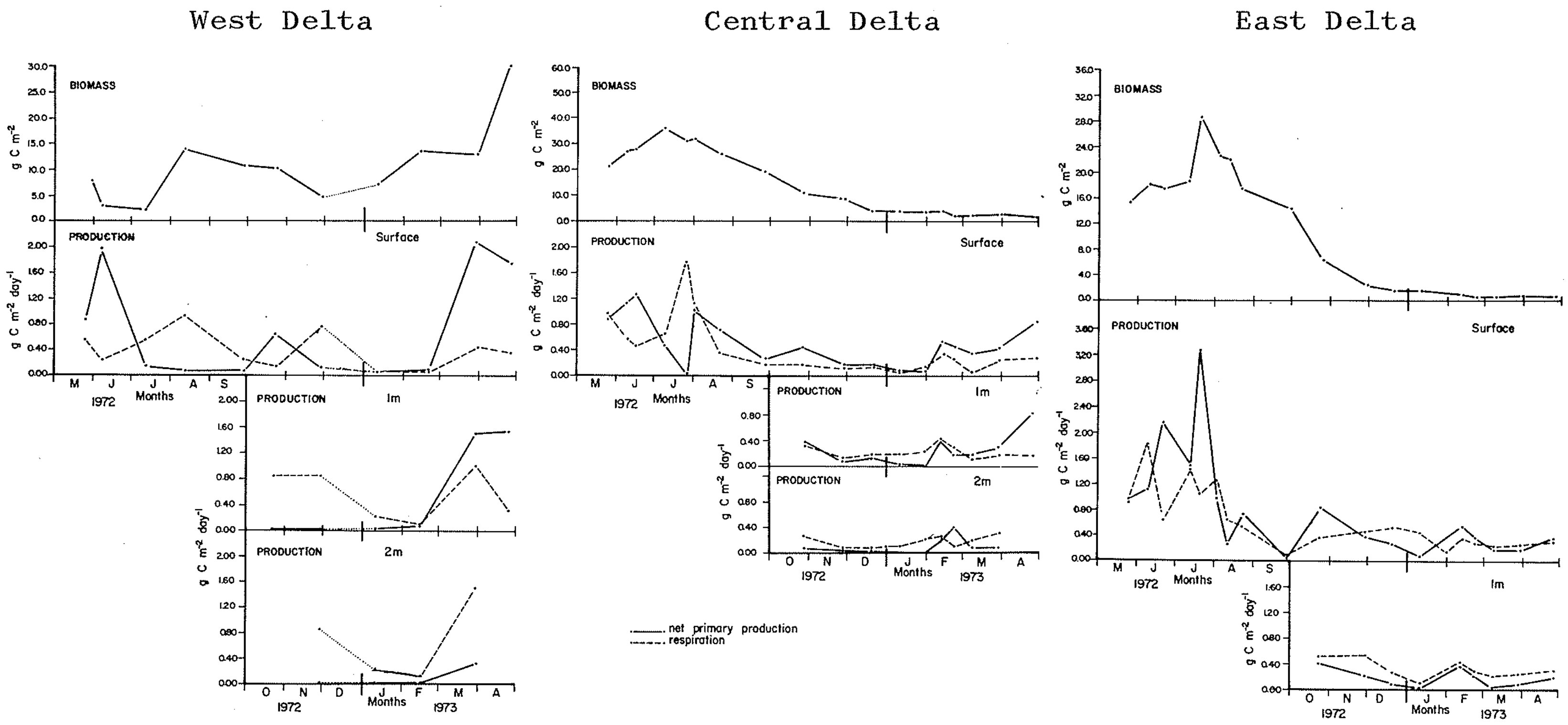


Figure 13. Seasonal patterns of biomass, net production and respiration recorded for Enteromorpha clathrata on the West, Central and East Deltas.

one and two meters depth.

Recurrent patterns of decreased net production at 1 and 2 meters depth in comparison to surface values was most evident in the area of the West Delta (Table 11). Enteromorpha clathrata showed no net production at and below 1 meter water depth from October to February. However, at the March sampling with increased light intensities and water transparencies, net production at 1 and 2 meters depth had risen to 70% and 13%, respectively, of the recorded surface value (Table 11). The opposite pattern was shown by Antithamnion pacificum. This algae reached a peak of 65% surface production at 1 meter in November when light intensity was at a low of 12.87 g cal cm^{-2} day^{-1}. Net production was not recorded below the surface after January when light began to increase. Chrysophyte assemblages presented varying production patterns with depth. A Pleurosigma dominated assemblage produced a high value of 233% surface net production at 1 meter depth in March (Table 11). Average net production values were 113% and 50% surface values for 1 and 2 meters depth, respectively. In comparison, a Navicula spp. dominated assemblage inhabiting the same mud flat averaged 50% and 10% surface production at 1 and 2 meters, respectively.

Algal production with depth seemed less affected

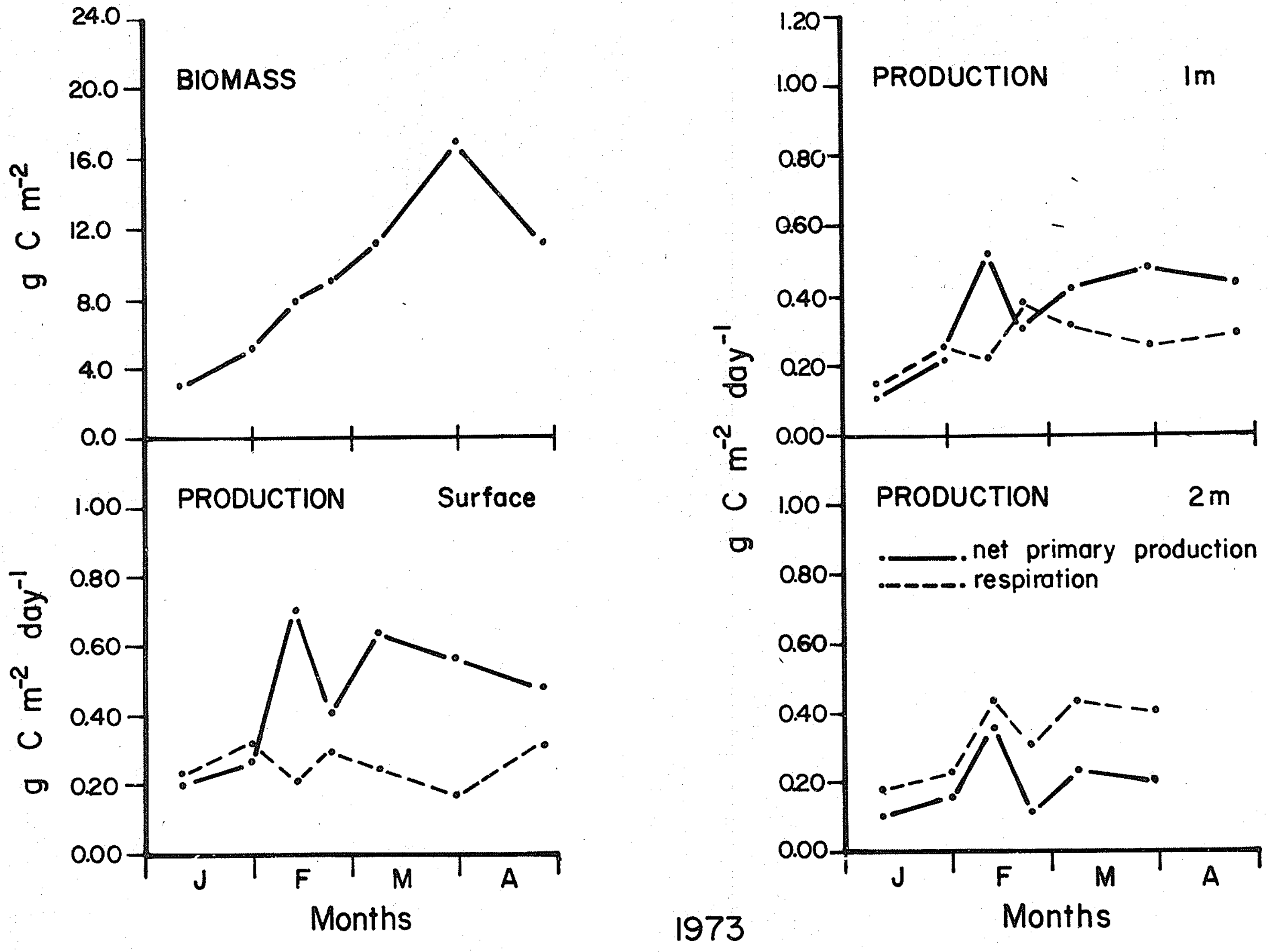


Figure 14. Seasonal patterns of biomass, net production and respiration recorded for *Pylaiella littoralis* on the Central Delta.

Table 11. Per cent surface net algal production recorded at 1 and 2 meters depth on West, Central and East Deltas.

WEST DELTA

Month	*Enteromorpha clathrata*		*Ulva lactuca*		*Pleurosigma* Assemblage		*Navicula* spp. Assemblage		*Antithamnion pacificum*	
	1 m	2m	1m	2m	1m	2m	1m	2m	1m	2m
Oct. 1972	0	-	-	-	-	-	42	0	20	0
Nov. 1972	0	0	-	-	86	50	0	0	65	35
Dec. 1972	-	-	-	-	-	-	-	-	-	-
Jan. 1973	0	0	48	28	86	43	56	0	57	24
Feb. 1973	50	0	60	25	51	40	60	15	0	0
March 1973	80	13	133	0	233	67	55	8	-	-
April 1973	100	-	-	-	-	-	47	6	-	-

CENTRAL AND EAST DELTAS

Month	*Enteromorpha clathrata*		*Enteromorpha prolifera*		*Ulva lactuca*		*Pylaiella littoralis*		*Pleurosigma* Assemblage		*Rhizoclonium*	
	1m	2m	1m	2m	1m	2m	1m	2m	1m	2m	1m	2m
Oct. 1972	95	20	-	-	30	18	-	-	32	3	66	34
Nov. 1972	50	31	-	-	62	78	-	-	73	13	63	-
Dec. 1972	59	30	-	-	69	49	-	-	37	26	95	81
Jan. 1973	0	0	-	-	90	50	65	50	75	0	90	65
Feb. 1973	70	40	68	39	85	48	74	53	59	18	-	-
March 1973	54	22	75	28	92	52	58	35	50	0	-	-
April 1973	97	-	62	-	75	-	77	-	-	-	-	-

compared to the West Delta (Table 11). *Enteromorpha clathrata* showed production in excess of 50% surface values at 1 meter and 20% surface values at 2 meters except for January when no net production was recorded below the surface. Values exceeding 90% surface production were noted at 1 meter in October and April. *Ulva lactuca* also showed high production with depth (Table 11). Averages of 72% and 50% surface values were noted for 1 and 2 meters depth, respectively. Net production of a *Pleurosigma* assemblage averaged 54% at 1 meter, approximately 50% lower than that recorded on the West Delta.

(e) Dawn to Dusk Primary Production Curves

(i) Dissolved Oxygen Production

Production and incident radiation curves recorded for *Ulva lactuca* on a very overcast day in February appear in Fig. 15. The highest net production rate (0.09 g C m^{-2} $hour^{-1}$) was recorded in the first two hour period after dawn: 0800-1000 hours. Net production decreased during the day to a low of 0.01 g C m^{-2} $hour^{-1}$ by 1600 - 1800 hours (Table 12), showing no apparent response to light which reached its maximum at 1000 hours (Fig.15).

Table 12. Production, respiration and $^{P}/_{R}$ values recorded at the surface and 1 meter depth from dawn to dusk on February 14, 1973. using the dissolved oxygen technique.

Incubation depth	Gross Production $gCm^{-2}hour^{-1}$		Net Production $gCm^{-2}hour^{-1}$		Respiration $gCm^{-2}hour^{-1}$		$^{P}/_{R}$	
	S[b]	1m	S	1m	S	1m	S	1m
Ulva lactuca								
0800-1000[a]	0.16	0.07	0.09	0.02	0.07	0.05	2.26	1.37
1000-1200	0.09	0.04	0.05	0.01	0.05	0.03	2.00	1.35
1200-1400	0.08	0.03	0.03	0.01	0.05	0.02	1.49	1.56
1400-1600	0.05	0.02	0.02	0.01	0.03	0.02	1.81	1.33
1600-1800	0.03	0.01	0.001	Nil	0.03	0.01	1.16	1.08

[a] Incubation times

[b] Surface incubation

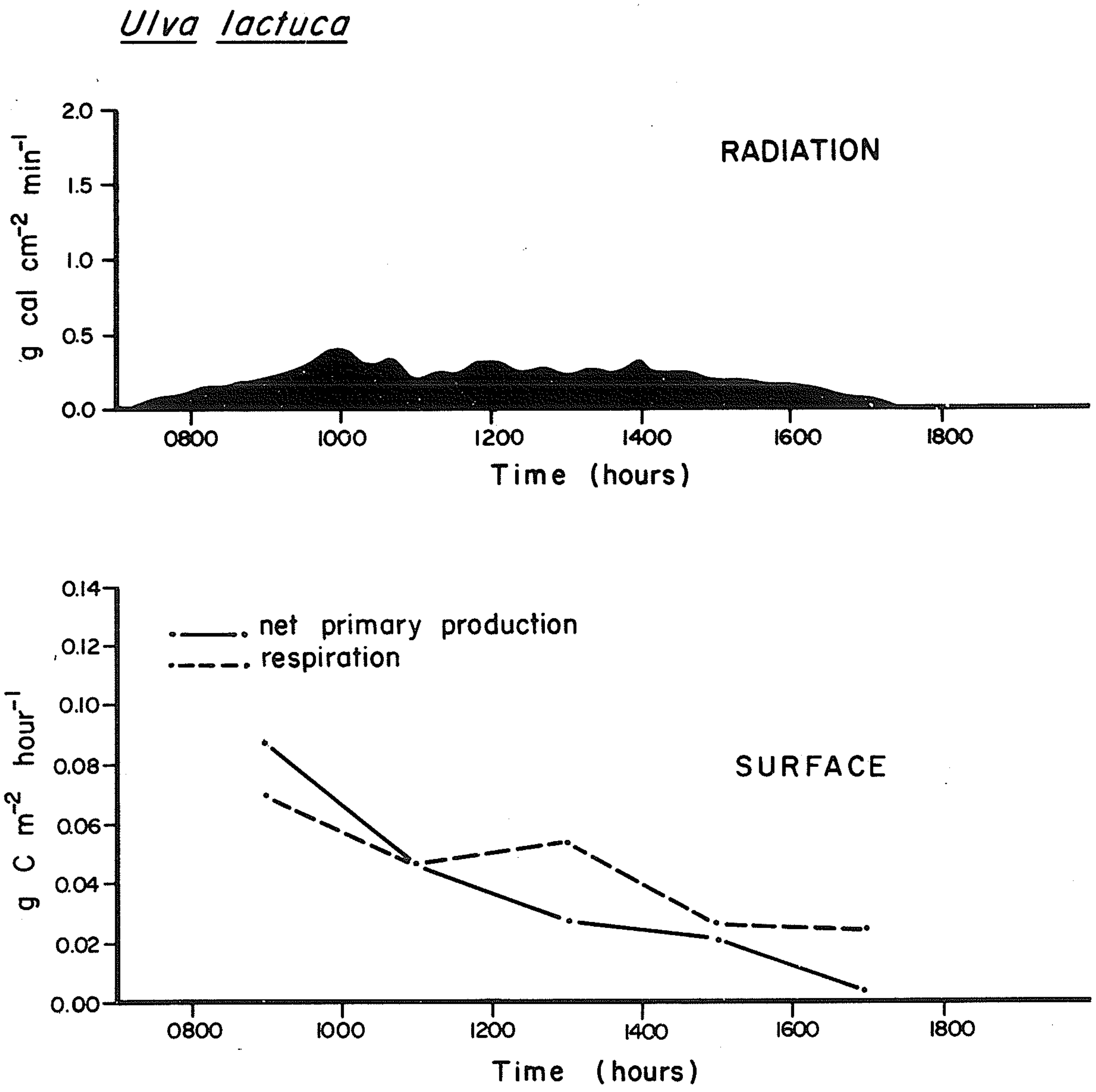


Figure 15. Dawn to dusk incident radiation and primary production curves for Ulva lactuca recorded on February 14, 1973.

Production data collected during a lightly overcast March day displayed different patterns in response to changes in light intensity than noted above for heavy overcast. Maximum net production values for *Enteromorpha clathrata*, *Ulva lactuca* and *Pylaiella littoralis* at the surface and 1 meter generally occurred between 0800 - 1000 hours; the second two hour period after dawn (Table 13). Mean light intensity paralleled that recorded at the time of maximum production in the February sampling, namely 0.25 g cal cm^{-2} min^{-1}. Mean net production values of 0.10 and 0.07 g Cm^{-2} $hour^{-1}$ were noted for the surface and 1 meter, respectively, decreasing to lows of 0.03 and 0.01 g C m^{-2} $hour^{-1}$ by 1600 - 1800 hours (Fig.16). The highest light intensity of the day (0.40 g cal cm^{-2} min^{-1}) was recorded between 1000 - 1400 hours when net production was rapidly decreasing.

The only exception to this pattern was *Ulva lactuca* incubated at the surface. Peak net production was not recorded until 1100 - 1200 hours with a secondary peak being noted at last light (dusk) when light averaged 0.1 g cal cm^{-2} min^{-1}. (Fig.16).

Surface $^{P}/_{R}$ ratios for the chlorophyta peaked at highest light during the day while those for the phaeophyta (*Pylaiella*) peaked at low light periods. The highest values

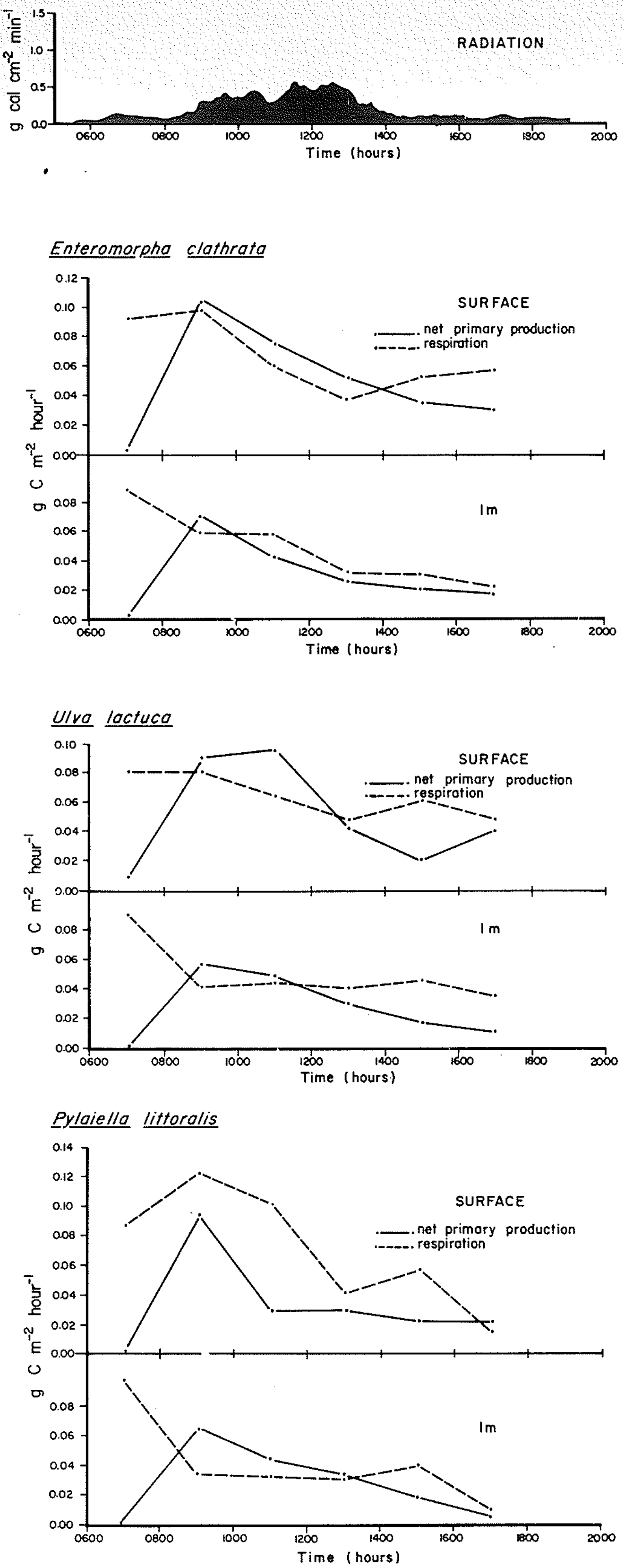


Figure 16. Dawn to dusk incident radiation and primary production curves recorded on March 29, 1973.

March 29, 1973

Table 13. Production, respiration and P/R values recorded at the surface and 1 meter depth from dawn to dusk on March 29, 1973. using the dissolved oxygen technique.

	Gross Production gCm^{-2}hour^{-1}		Net Production gCm^{-2}hour^{-1}		Respiration gCm^{-2}hour^{-1}		$^{P}/_{R}$	
Incubation depth	S[b]	1m	S	1m	S	1m	S	1m
Enteromorpha clathrata								
0600-0800[a]	0.09	0.07	Nil	Nil	0.09	0.09	1.00	0.78
0800-1000	0.20	0.13	0.11	0.07	0.10	0.06	2.00	2.17
1000-1200	0.16	0.10	0.10	0.04	0.06	0.06	2.67	1.67
1200-1400	0.09	0.06	0.05	0.03	0.04	0.03	2.25	2.00
1400-1600	0.09	0.05	0.04	0.02	0.05	0.03	1.80	1.67
1600-1800	0.09	0.04	0.03	0.02	0.06	0.02	1.50	2.00
Ulva lactuca								
0600-0800	0.09	0.07	0.01	Nil	0.08	0.09	1.13	0.77
0800-1000	0.17	0.10	0.09	0.06	0.08	0.04	2.13	2.50
1000-1200	0.16	0.09	0.10	0.05	0.06	0.05	2.67	1.80
1200-1400	0.09	0.07	0.04	0.03	0.05	0.04	1.80	1.75
1400-1600	0.08	0.06	0.02	0.02	0.06	0.05	1.33	1.20
1600-1800	0.09	0.05	0.04	0.01	0.05	0.04	1.80	1.25
Pylaiella littoralis								
0600-0800	0.09	0.07	Nil	Nil	0.09	0.10	1.00	0.70
0800-1000	0.22	0.10	0.10	0.07	0.12	0.04	1.83	2.50
1000-1200	0.13	0.08	0.03	0.05	0.10	0.03	1.30	2.66
1200-1400	0.07	0.07	0.03	0.04	0.04	0.03	1.75	2.33
1400-1600	0.09	0.06	0.02	0.02	0.06	0.04	1.50	1.50
1600-1800	0.04	0.02	0.03	0.01	0.02	0.01	2.00	1.00

[a] Incubation times

[b] Surface incubation

at one meter were recorded at moderate light intensities (Table 13).

Considerably different results were obtained from dawn to dusk experiments conducted on a bright April day compated to those noted for overcast days. Surface net production for the chlorophytes Enteromorpha clathrata and Ulva lactuca reached an average of 0.10 g C m^{-2} $hour^{-1}$ between 1100 and 1300 hours, corresponding to a period of maximum light energy, 1.0 g cal cm^{-2} $min.^{-1}$ (Fig.17). The phaeophyte Pylaiella littoralis displayed a generally suppressed production peak of 0.6 g C m^{-2} $hour^{-1}$ from 0900 to 1700 hours.

Net production maxima for all three species of algae averaged 0.05 g C m^{-2} $hour^{-1}$ at 1 meter depth (Table 14). With the exception of Ulva lactuca, production peaks at the surface and one meter corresponded with respect to time (Fig.17). Average minimum net production values of 0.015 g C m^{-2} $hour^{-1}$ were recorded in the two hours following dawn and preceding dusk for all algae tested (Fig.17).

$^P/_R$ ratios recorded at the surface were highest in the two hours after dawn when light was at its lowest, with the chlorophyte species averaging 5.32 compared to 9.83

April 25, 1973

Table 14. Production, respiration and P/R values recorded at the surface and 1 meter depth from dawn to dusk on April 25, 1973 using the dissolved oxygen technique.

	Gross Production $gCm^{-2}hour^{-1}$		Net Production $gCm^{-2}hour^{-1}$		Respiration $gCm^{-2}hour^{-1}$		$^{P}/_{R}$	
Incubation depth	S[b]	1m	S	1m	S	1m	S	1m
Enteromorpha clathrata								
0500-0700[a]	0.03	0.02	0.02	0.01	0.01	0.01	3.00	2.00
0700-0900	0.06	0.05	0.02	0.02	0.04	0.03	1.50	1.67
0900-1100	0.06	0.07	0.04	0.04	0.02	0.03	3.00	2.33
1100-1300	0.16	0.12	0.11	0.05	0.04	0.07	4.00	1.71
1300-1500	0.08	0.08	0.07	0.05	0.01	0.03	8.00	2.67
1500-1700	0.08	0.08	0.05	0.04	0.03	0.03	2.67	2.67
1700-1900	0.03	0.02	0.02	0.01	0.01	0.01	3.00	2.00
Ulva lactuca								
0500-0700	0.06	0.05	0.05	0.02	0.01	0.03	6.00	1.67
0700-0900	0.08	0.05	0.03	0.02	0.05	0.03	1.60	1.67
0900-1100	0.07	0.05	0.05	0.03	0.02	0.02	3.50	2.50
1100-1300	0.15	0.11	0.10	0.05	0.05	0.06	3.00	1.83
1300-1500	0.07	0.08	0.06	0.06	0.01	0.02	7.00	4.00
1500-1700	0.08	0.06	0.05	0.03	0.02	0.04	4.00	1.50
1700-1900	0.08	0.06	0.06	0.02	0.02	0.03	4.00	2.00
Pylaiella littoralis								
0500-0700	0.04	0.06	0.03	0.02	0.01	0.04	4.00	1.50
0700-0900	0.04	0.06	0.02	0.02	0.02	0.06	2.00	1.00
0900-1100	0.07	0.06	0.06	0.02	0.01	0.04	7.00	1.50
1100-1300	0.10	0.10	0.07	0.05	0.03	0.05	3.33	2.00
1300-1500	0.08	0.08	0.06	0.04	0.02	0.03	4.00	2.67
1500-1700	0.09	0.05	0.06	0.03	0.02	0.02	4.50	2.50
1700-1900	0.04	0.05	0.03	0.01	0.01	0.04	4.00	1.25

[a] Incubation times

[b] Surface incubation

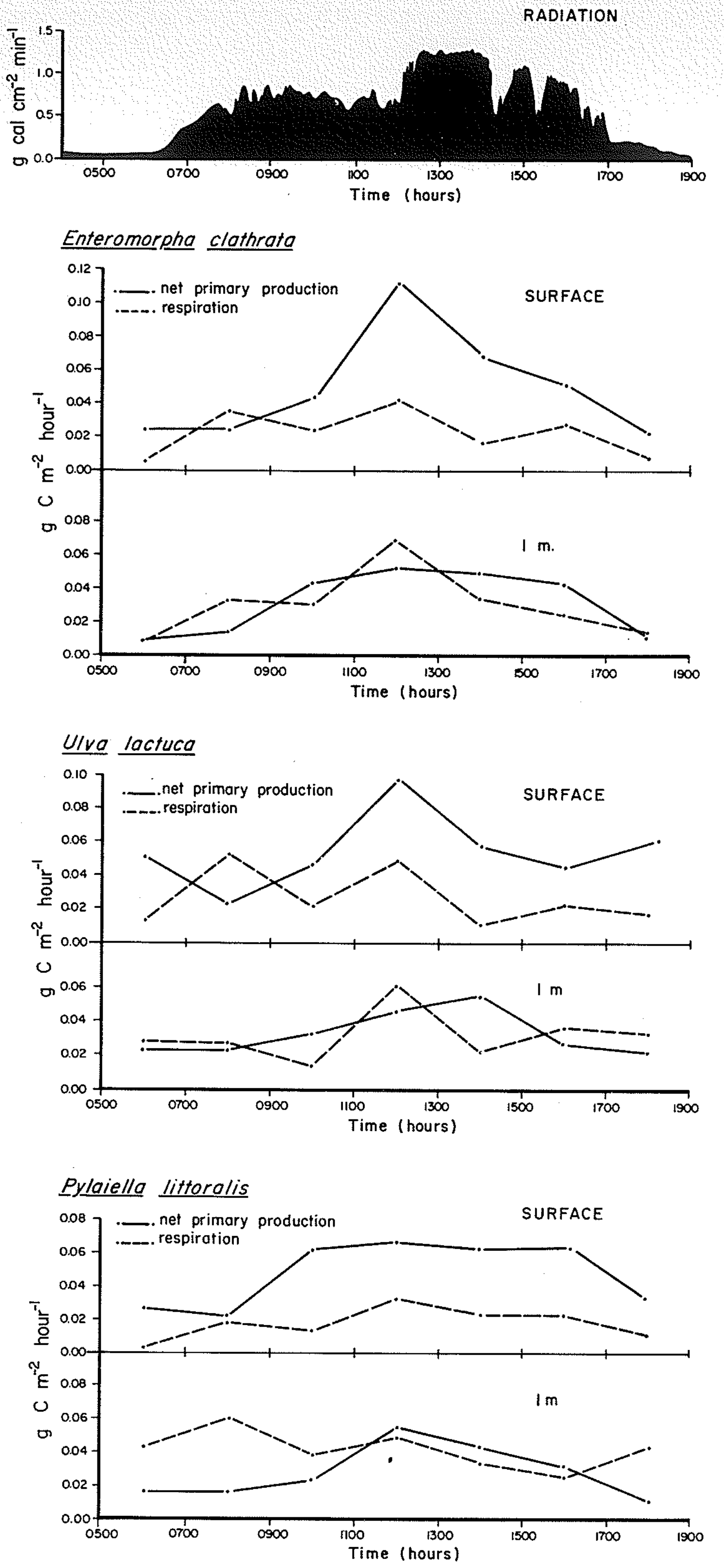


Figure 17. Dawn to dusk incident radiation and primary production curves recorded on April 25, 1973.

for the phaeophyte species. High values were also noted just prior to dusk (Table 14). At the time of peak net production and light intensity, 1100 - 1300 hours, $^{P}/_{R}$ ratios of 3.32 and 2.94 were noted for the Chlorophyta and Phaeophyta respectively. $^{P}/_{R}$ ratios at 1 meter depth reached their maxima near mid-day (Table 14).

Respiration patterns for both overcast and bright days showed no correlation with either light or production curves (Fig. 15, 16, 17). The only significant points to be noted were the considerably higher respiration values noted for overcast days.

A seasonal effect with respect to the timing of daily maximum net production was suggested by patterns exhibited in Figures 15, 16 and 17. This was reflected in increased light energy, net productivity and a shift of production maxima towards mid-day.

C. Statistical Analysis of Production Data

Data presented in Table 15 indicates the effect of a single physico-chemical factor on net production.

Salinity appeared to be an important factor controlling primary production. Of the seven benthic algal species and/or assemblages tested, salinity was significant (p = 0.01), explaining between 35 and 88% of the variation in net production for five of the algae (Table 15).

Light intensity also appeared significant (p = 0.01), explaining between 55 and 73% of the noted variation in net production. Temperature showed little correlation with net production (Table 15).

Table 15. Statistical analysis of net production as affected by salinity, temperature and light intensity using simple linear regression.

	Salinity	Temperature	Light Intensity
WEST DELTA			
Enteromorpha clathrata	[a]0.30^{*}	0.64^{**}	0.16^{*}
Assemblage type II	0.35^{**}	0.14	0.55^{**}
CENTRAL DELTA			
E. clathrata	0.73^{**}	0.07	0.64^{**}
E. prolifera	0.55^{**}	0.14	0.39^{*}
Ulva lactuca	< 0.01	0.03^{**}	< 0.01
Pylaiella littoralis	0.52^{**}	< 0.01	0.48^{**}
Assemblage type III	0.73^{**}	0.03	0.73^{**}
EAST DELTA			
Assemblage type III	0.88^{**}	0.02	0.76^{*}
Rhodophyte filaments	0.34	0.61	0.76

[a] values are given as a per centage in the discussion (i.e. 0.35 = 35%).

*p = 0.05 level

**p = 0.01 level

DISCUSSION

A. Character of benthic algae on the Squamish Delta.

The salinity gradient from seawater to freshwater is not continuous but can be divided into definite stages on the basis of biological components. The scheme of Redeke (1935) which has been widely accepted was used in this discussion

Category	Salinity range
Oligohaline	0.21 - 1.84 $^o/oo$
Mesohaline	1.84 - 18.00 $^o/oo$
Polyhaline	18.00 - 30.00 $^o/oo$

Aquatic habitats on the Squamish Delta fell mainly into the meso- and polyhaline categories. Marine conditions ($>$ 30.00 $^o/oo$ S) became prevalent at 2 meters depth on the West Delta in January and at all depths in the area of the Central and East Deltas from October to January (Fig.4). Thus, it is clear that at most times of the year, benthic algae must pass through a wide salinity range during a tidal cycle. This was especially evident on the West Delta where a change of nearly 30.0 $^o/oo$ existed between 0 and 2 meters depth.

On the basis of this, benthic algae colonizing the Squamish Delta are classed as euryhaline. Before proceeding, it must be pointed out that degrees of euryhalinity exist (Stammer 1935). Some algae are able to survive from saltwater down to 3 °/oo salinity (strongly euryhaline) while others can only exist in the range 30 to 15 °/oo salinity (weakly euryhaline).

The Chlorophyta possess members which have been shown to be strongly euryhaline. *Enteromorpha clathrata*, *Ulva lactuca* and *Rhizoclonium* cf *riparium* were commonly found on the Squamish Delta. These were also components of the algal flora at the Ynyslas and Canvey marshes in England (Carter 1933), at Cold Spring Harbour in the eastern United States (Johnson and York 1915) and several embayments in the Netherlands (Jorde and Klavestad 1963). Remane and Schlieper (1971) recorded *Enteromorpha clathrata* from waters of 0 °/oo up to 200°/oo salinity. This algae was present at Squamish over the full salinity range, 2.0 to 35.0°/oo. *E. prolifera*, on the other hand, was only weakly euryhaline, being restricted to higher salinity areas east of the dyke (Fig.9).

Members of the Rhodophyta present at Squamish tended to be weakly euryhaline. *Antithamnion pacificum* and rhodophyte filaments were present during the winter in the lower intertidal zones where salinity was relatively high. Jorde and Klavestad (1963) recorded these algae in higher salinity areas of Hardangerfjord and Sorfjord in Denmark.

The phaeophyte Pylaiella littoralis can also be placed in this weakly euryhaline category. Records of this algal in higher salinity brackish water habitats appear from England (Carter 1933) and the Netherlands (Jorde and Klavestad 1963).

One of the most characteristic esturine-deltaic algae is the xanthophyte Vaucheria dichotoma. This strongly euryhaline algae forms thick, extensive carpets on the surface of mud and sand flats. Growth similar to those recorded on the Squamish Delta have been noted on the deltas of the Ynyslas (Carter 1933), New England salt-marshes (Blum and Conover 1953), and those of the Rhine and Eider (Remane and Schlieper 1971). Johnson and York (1915) have also recorded vast mats of this alga on inter-tidal sediments of Cold Spring Harbour.

A large number of Chrysophytes appear specific to brackish water. Melosira nummuloides, Synedra spp., Nitzschia spp., Achnanthes sp., Navicula cancellata and Pleurosigma aestuarii are characterized as euryhaline brackish water forms (Carter 1933, Remane and Schlieper (1971). However, the present investigation suggests a split into two major groups. A N. cancellata and N. ammophlia assemblage represents a strongly euryhaline grouping while other diatom assemblages on the delta dominated by species such as P. aestuarii, M. nummuloides, etc. (Appendix IV) represent weakly euryhaline assemblages. The latter were present only during winter and spring when salinity values were higher.

Euryhaline algae can be further classified according to their response to incident radiation. Certain algae survive better under high light intensity while others prefer low light situations. This aspect will be discussed in a subsequent section.

Several species of Enteromorpha have been classed as eurythermal (Remane and Schlieper 1971). Present data from Squamish indicates E. Clathrata to fall within this category, being recorded from 2.0 up to 14.0°C.

B. Distribution of benthic algae.

Distribution patterns of benthic algae on the Squamish Delta were initially determined by substrate availability since the majority of the algal species and/or assemblages were substrate specific (Appendix IV). In the presence of a suitable substrate, physico-chemical factors required for algal colonization and growth became significant in determining benthic algal distribution. Spatial patterns can best be explained on the basis of salinity and substrate, while temporal variations represent interactions of substrate, salinity and light intensity.

(a) Spatial variations.

Enteromorpha clathrata was found attached to wood surfaces on all three delta areas from low to high tide level. Rock, mud and sand surfaces were available but not readily colonized indicating the preference for a firm, stable and irregular surfaced substrate. *E. prolifera*, on the other hand, appeared entangled with marsh vegetation at the periphery of the Central and East Deltas. Its absence on vegetation of the West Delta is attributed to lower salinities as this alga is classed as weakly euryhaline. The same holds true for *Pylaiella littoralis* and *Ulothrix* cf. *flacca*.

Ulva lactuca was mainly found in association with sedge roots overhanging the banks of the Central and East Deltas (Fig. 9 and 10). This illustrates a mechanism for minimizing desiccation whereby the algae are kept damp during outgoing tides by water runoff from the marsh lands. Johnson and York (1915) noted a similar situation at Cold Spring Harbour, indicating the susceptibility of *U. lactuca* to desiccation.

Members of the Chrysophyta were also strongly substrate specific. An assemblage of diatoms (*Navicula* spp.) recorded on the intertidal mud flats of the West Delta was not apparent on adjacent sand flats. Its absence on the other deltas suggests either a preference for low mesohaline conditions or a lower light condition that occurs on the West Delta. Overlap was evident between this diatom assemblage and a second dominated by *Pleurosigma aestaurii* appearing on the sloping mud banks of Castle Creek where stronger water currents were prevalent (Fig. 8). This assemblage was found in a similar situation on the Central Delta (Fig.9). The great majority of *Rhizoclonium riparium*/diatom assemblages appeared in association with marsh vegetation on the Central and East Deltas during winter and spring when light intensities were increasing and salinities were moderating, thus permitting the survival of these weakly euryhaline species.

Rhodophytes recorded on the delta preferred wood and soft mud substrates in the lower intertidal zones, indicating a preference for minimum exposure times and high salinity, indicative of their marine nature. Blinks (1951), Luther (1951), Doty and Newhouse (1954) and Druehl (1967) suggested similar factors as limiting marine algae in esturine habitats.

Extensive mats of *Vaucheria dichotoma* were restricted to relatively open areas of sandy substrate, primarily in disturbed upper intertidal zones on the Central and East Deltas. Other areas of sand in mid-and lower intertidal zones were not colonized suggesting a preference for shallow waters and higher light intensities. Blum and Conover (1953) and Remane and Schlieper (1971) indicated similar habitat preference for this alga.

It is evident from the aforementioned remarks on spatial distribution that "favored" habitats for benthic algae occur predominately in areas east of the Squamish River training dyke (Fig.2). Reduced sedimentation rates and lower current velocities maintain a greater proportion of stable substrate available for colonization. The existence of large areas of new substrate (ie. sand from fill operations) also increased substrate availability. Maintenance of higher salinities east of the dyke permitted weakly euryhaline algae to colonize the area.

Vertical distribution patterns displayed by each benthic algal species were not thoroughly studied due to the absence of a single substrate type extending from high to low water. However, the common vertical succession pattern for benthic algae of Chlorophytes at high water levels grading into Xanthophytes, Chrysophytes, Phaeophytes and Rhodophytes with depth was evident at the Squamish Delta.

(b) Temporal variations

Seasonal changes in distribution of benthic algae illustrate the changing nature of the esturine-deltaic habitat at Squamish. The algal flora was composed of a variety of species and assemblages which waxed and waned in response to seasonal physico-chemical factors and, in a few instances, as a response to substrate availability.

The greatest diversity of benthic algae was noted during the winter months on the West and Central Deltas when light was just beginning to show significant vernal increases in the presence of high salinities. Such is logical when one considers the preference of Chrysophytes, Phaeophytes and Rhodophytes, the prime components of the algal flora at this time, for relatively low light situations. The East Delta, on the other hand, showed maximum diversity in June.

C. Algal Biomass

Algal biomass or standing crop is the result of the interation of primary production, respiration, export, grazing and loss of algae via mechanical damage. The latter three represent loss factors which were given only minimal consideration in this thesis due to time and equipment limitations. However, the following general comments can be made. Export of benthic algae and march vegetation was noted in the surface waters on outgoing tides, being especially heavy during fall and early winter months. The magnitude of this export was not determined. With respect to grazing by delta invertebrates, Levings (MS, 1973) showed that the amphipod *Anisogammerus confervicolus*, commonly found on the delta, was able to directly consume a variety of benthic algae. The good correlation between amphipods and benthic algae in terms of spatial and temporal distribution as well as the timing of their biomass maxima suggests a relationship based either on food requirements or perhaps protection as large numbers of amphipods were noted under clumps of algae during low tides.

The extent of export, grazing and mechanical damage of benthic algae plus the spatial and temporal variations of these factors on the Squamish Delta are completely unknown. It is quite likely that they are superimposing "secondary" patterns of biomass distribution over those initiated solely by primary production.

Biomass data collected from the Squamish Delta appears to reflect the natural suitability of an area for algal growth. For example, the generally higher biomass (kg C km^{-2}) reported for the Central Delta is apparently a result of protection afforded by the trainine dyke. Higher salinities resulted in greater species diversity. Reduced current action and large areas of new substrate amidst stands of sedge produced considerably more habitat available for algal colonization. In comparison, the West Delta with biomass values approximately 1/5 those of the Central Delta reflects the strong influence of the river (reduced species diversity) as well as unstable substrates resulting from strong currents and high sedimentation rates.

To some extent, biomass reported as g C m^{-2} gives an indication as to the suitability of a particular area for a specific algal species. To illustrate, Enteromorpha clathrata reached 2.40 g C m^{-2} on the West Delta compared to 37.2 g C m^{-2} on the Central in June indicating the latter as the favored habitat for this algae at the time of June river freshet. However, a reverse pattern was evident from September to May, 1973 (Fig.13). Since surface salinity was the only physico-chemical parameter differing significantly in the two areas at this time, being approximately 6 times higher in the Central (Fig. 4), it is suggested that E. clathrata has a requirement for an exposure to mesohaline (1.84 - 18.00 $^{o}/oo$) brackish waters for optimum growth. On return of lower surface salinities in the Central area during 1973 freshet, higher biomass was again noted.

The effect of salinity can also be seen for algae appearing for only a few months of the year. *Antithamnion pacificum* reached peak biomass at the time and place of highest salinity and lowest light, specifically, January on the West Delta. Its marine nature is well illustrated. *Spirogyra* sp., on the other hand, displayed its highest biomass in the late summer concurrent with strong light. This alga was generally restricted to areas of lower salinity such as the upper intertidal lands of the West Delta as well as areas around Cattermole Creek which experienced some oligohaline conditions.

The foregoing should suffice to illustrate that biomass, expressed as $g\ C\ m^{-2}$, gives some indication as to the existence of favorable physico-chemical growth factors.

Interspecies comparison of biomass, for the purpose of determining habitat suitability, must be made with caution, taking the gross morphology of the algae into consideration. Biomass of *Enteromorpha clathrata* on the West Delta was considerably greater than that for mud diatom assemblages even though they all appeared to be equally well suited to the area. Large variations in biomass were also evident on the Central Delta among *Pylaiella littoralis*, *Ulva lactuca* and *Rhizoclonium riparium*/diatom assemblages which all appeared to be well adapted.

A much clearer evaluation of habitat suitability, both on inter and intra-specific levels, would appear to be comparisons of primary production. Distribution patterns indicate the presence of satisfactory growth conditions - i.e. suitable substrate and a tolerable "range" of physico-chemical parameters. Biomass patterns permit further delineation as to favored habitats within the larger algal growth zones and/or indicate significant physico-chemical factors controlling growth. However, it appears that primary production patterns are far more valuable in establishing the suitability of a particular area for algal growth. In this, the vagaries and variations due to differential export, grazing and mechanical damage are removed, revealing the potential productive capacity of an area. At this level, significant physico-chemical parameters can be delineated with relative ease.

D. Primary Production

(a) Dissolved Oxygen Production

Estimated annual net production values of 907 kg C km^{-2} $year^{-1}$ for the West Delta and an average of 2718 for the area east of the training dyke point to its greater habitat stability. Converting average annual estimates for the Squamish Delta to a m^2 basis produced a value of 215 g C m^{-2} $year^{-1}$ net production. This approximates the "net" production estimate of 180 g C m^{-2} $year^{-1}$ arrived at by Pomeroy (1959) for algae in the Duplin River marshes, Georgia. Differences in methodology and lack of complete floristic descriptions for the Duplin marsh render comparison impractical.

Some comparative data is available in the literature for diatom communities inhabiting mud flats. At Squamish, net production estimates of 150 and 80 g C m^{-2} $year^{-1}$ for a _Pleurosigma aestuarii_ assemblage and a _Navicula_ spp. assemblage were recorded respectively. Leach (1970) noted production of 31 g C m^{-2} $year^{-1}$, using ^{14}C techniques, on the mud flats of the Ythan estuary, Scotland. Grontved (1960), also using ^{14}C methods, arrived at an estimate of 116 g C m^{-2} $year^{-1}$ for Norwegian fjords. Considering the ^{14}C method overestimates net production (Riley 1952), the latter two values may require scaling down to be comparable with oxygen values. This being the case, the foregoing suggests that as one proceeds to higher latitudes a general decrease in annual primary production occurs in esturine-deltaic habitats.

The Central and East Deltas displayed good correlation with respect to the magnitude of net production as well as the timing of maxima and minima (Fig.12). Summer and spring net production peaks as noted at Squamish were also recorded by Grontved (1960) for Norwegian fjords.

Seasonal net production curves for algae on the Central and East Deltas show a positive correlation with light (Fig.6) and an inverse relationship with salinity (Fig.4). Objective statistical tests indicated both these factors to be significant ($p = 0.01$), explaining an average of 56% of the variation in seasonal net production patterns (Table 15).

Net production patterns on the West Delta clearly indicated the adverse effects of river freshet on production with minimum values being noted in June (Fig.12). Continued suppression of production as a result of the river was evident throughout the year. It is suggested that low salinities prevent the establishment of weakly euryhaline algae and shading from steep cliffs adjacent to the West Delta may have some retardant effect on strongly euryhaline algal species able to colonize the area. The extent of light reduction through shading could not be determined due to the lack of light data, but it is estimated that as high as 20 - 40% reductions in daily incident radiation may occur.

A discussion of net production on a square meter basis is valuable in that is illustrates the productive capacity, both spatially and temporally, of individual algal species and/or assemblages. Also at this level of production, significant physico-chemical factors which may be controlling primary production can be seen more clearly.

The most productive algal phyla on the Squamish Delta was the Chlorophyta, specifically _Ulva lactuca_. This alga displayed a maximum net production of 2.7 g C m^{-2} day^{-1}. Primary production of _E. clathrata_ and _Spirogyra_ sp. approximated values noted for _U. lactuca_. The next most productive algal groups were the _Rhizoclonium riparium_ diatom assemblages common to the Central Delta.

Primary production increased in going from West to East Deltas, as previously stated. It has been suggested that increased habitat-substrate stability is a key factor accounting for this pattern. However, salinity, which increases west to east (Fig.4), also appears to be significant in enhancing production. Linear regression showed salinity to be responsible for between 35 and 88% of the variation in net production (p = 0.01). Thus when assessing esturine-deltaic production it appears necessary to consider the interplay between habitat-substrate stability and salinity.

Light intensity is also a significant factor (p = 0.01) controlling temporal variations in net production. Results of this study suggest the existence of two major algal groups, one favoring high and the other low light intensities (Table 10). *Enteromorpha clathrata*, Assemblage type II (*Navicula* spp.) and *Vaucheria dichotoma* were recorded as high light algae. Objective statistical analysis indicated significant correlation (p = 0.01) between light intensity and net production for this algal grouping, with light explaining 16 - 76% of the variation in production (Table 15). *Pylaiella littoralis* displayed inverse relation between light and production, indicative of the low light intensity algal grouping.

Odum et al (1959), Pomeroy (1959), Taylor and Palmer (1963) and Ganning and Wulff (1971) all indicated the positive effect of light in increasing primary production in certain macro and micro benthic algae. These data add credence to the existence of two light response algal groups.

Water temperature had little effect on production at the Squamish Delta with the exception of *Ulva lactuca* on the Central Delta and *Enteromorpha clathrata* on the West Delta. The suggestion is put forward that in the presence of lower salinities, temperature may be a critical factor in the production of *E. clathrata*, a strongly euryhaline algae.

Patterns of decreased net production as a function of water depth reflected light reduction (Table 13). This has been noted in phytoplankton studies and past phytobenthic work. Wide variations in production with depth illustrate a major problem in determining primary production of habitats with fluctuating water levels. To arrive at reasonable estimates, time of exposure and net production at all water depths should be determined. However, such a task was beyond the scope of this study. By averaging production values from surface to 2 meters depth, an estimate of production over a tidal cycle can be obtained.

Light extinction with depth in the area of the West Delta was nearly twice that noted for the Central area (Fig.6). This resulted in lower production with depth on the West Delta for members of the Chlorophyta but higher production values for the Chrysophytes compared to the Central Delta where light intensities were higher with depth. This illustrates again, the separation of algae on the basis of light intensities (Table 10).

Nutrients did not appear to be of significance in controlling production of benthic algae on the Squamish Delta. The very limited analyses carried out indicated nitrogen and phosphorus values to be much higher on the delta than those noted concurrently for the outer estuary - Howe Sound area by Cliff and Stockner (MS, 1973). Pomeroy (1959) and Odum (1971) indicated the abundant non-limiting nutrient supply of estuarine-deltaic areas referring to them as nutrient sinks. It is therefore assumed that production on the Squamish Delta is not nutrient limited.

E. Dawn to dusk primary production curves

Dawn to dusk primary production studies using the dissolved oxygen technique on macro-benthic algae indicated a daily production periodicity similar to that recorded in the literature for phytoplankton (Ryther 1956, Doty and Oguri 1957, Schindler personal communication) and micro-benthic algae (Pomeroy 1959). Light intensity appears to be a prime factor limiting net primary productivity in three algal groups tested. Statistical tests showed light to be significant ($p = 0.01$), explaining up to 64% of the variation in production (Table 15).

Net primary production at the surface and one meter depth recorded for benthic macroalgae reached their maxima in the two hour interval prior to the time of maximum light intensity for the day. Pomeroy (1959) has indicated the optimum light intensity for algae to range between 350 - 3000 fc depending upon the taxonomic group, with higher or lower illumination retarding photosynthesis. Such a pattern is evident in curves presented in Figures 15, 16 and 17.

A shift in production maxima recorded for an algal species towards mid-day and stronger illumination was evident from February to April, 1973. An accompanying increase in net production was also recorded. These factors suggest the operation of an adaptive mechanism such as that recorded by Gargas (1971) for micro algae resulting in a raised level of optimum light intensity for an algal species. Alteration of the relative proportion of photosynthetic enzymes and pigments at the time of cell division permit algae to adapt to prevailing conditions of illumination as the seasons progress (Steemann Nielsen and Jorgensen 1968 a & b). Physico-chemical factors such as salinity and temperature which increased with time may also be interacting with light to advance the time of production maxima. Since the present thesis is not physiologically oriented, further discussion along these lines will be omitted, except to suggest that certain algae on the delta exhibited chromatic adaptation, appearing as shade "adapted" during the winter and fall and sun "adapted" during the spring and summer.

SUMMARY AND CONCLUSIONS

a.) The Squamish River Delta is a meso-to polyhaline brackish water habitat (1.84 to 3.00 ^{o}/oo salinity), becoming marine ($>$ 30.00 ^{o}/oo at all depths during the winter in areas east of the training dyke.

b.) Benthic algae recorded on the Squamish Delta were either strongly (3.0 to 30.0 ^{o}/oo) or weakly (15.0 to 30.0 ^{o}/oo) euryhaline. Chlorophytes, Xanthophytes and a few Chrysophytes fell into the former category. Phaeophytes, Rhodophytes and the majority of the Chrysophytes were only weakly euryhaline, appearing primarily during the fall and winter.

c.) Strong substrate specificity shown by the majority of algal species or assemblages studied on the Squamish Delta suggests recorded spatial distribution patterns to be primarily a result of substrate availability. The most significant physico-chemical factors controlling algal distribution were found to be salinity. Spatial patterns can best be explained on the basis of salinity and substrate, while temporal variations represent interactions of substrate, salinity and light intensity.

d.) The algal flora of the Squamish Delta is fairly typical of those recorded in esturine areas of England, Georgia and Norway. The range of habitats and physico-chemical factors recorded at Squamish were also comparable to those noted in other esturine studies. Spatially, however, the Squamish River Delta exhibits habitat variations (ie. substrates, salinity, water transparency) which are extremely compressed in comparison to other esturine-delta areas reported in the literature.

e.) Observed patterns of algal biomass on the Squamish River Delta were a composite of primary production, respiration, export, grazing and mechanical damage to the algae. The latter three factors were not studied but it is suggested that they superimpose "secondary" patterns on biomass which may mask those initiated by primary production.

The Central Delta, east of the training dyke, appeared to be the optimum area for algal growth in that it had approximately five times the total algal biomass (kg C km^{-2}) of the West Delta. It is suggested that the protective function of the training dyke reduces river currents and sedimentation while maintaining higher salinities favorable to weakly euryhaline algae.

Biomass as g C m^{-2} reflected the suitability of an area for a single algal species while indicating the important physico-chemical growth factors. As an illustration of this, Enteromorpha clathrata evidently requires exposure to mesohaline conditions for optimum growth as is indicated by the shifting of biomass maxima from the Central Delta to the West Delta during winter when salinity was high in the area of the Central Delta.

The gross morphology of algae must be taken into consideration when making interspecific comparisons of biomass for the purpose of determining habitat suitability. Clearly, Enteromorpha clathrata, Ulva lactuca and Chrysophyte assemblages vary as to biomass but may be equally well suited to a particular area.

f.) Estimated annual net primary production of 215 g C m^{-2} $year^{-1}$ approximated the value of 180 g C m^{-2} $year^{-1}$ arrived at by Pomeroy (1959) for benthic algae colonizing the Duplin River Delta. The generally disturbed nature of the Squamish Delta plus varying algal floras and physico-chemical factors may account for the variation.

Net primary production estimates from Georgia, Squamish, Scotland and Norway indicated a general trend of decreased production as one proceeds to higher latitudes. Such is to be expected in view of reduced temperatures and light intensities.

Seasonal net primary production curves for the algal flora of the Central and East Deltas showed a positive correlation with light intensity and an inverse relation with salinity. Statistical tests showed these two factors to be significant ($p = 0.01$) with salinity explaining up to 88% and light explaining up to 73% of the observed variation in net production (Table 15).

The importance of weakly euryhaline algae, which prefer moderate to high light intensities and salinities, in upgrading the primary production of areas east of the training dyke, and thus protected from the instability of the river, is evident at Squamish. The West Delta, open to the full influence of the river, seems to be primarily suitable for the growth of strongly euryhaline algae. The paucity of weakly euryhaline algae plus a suppression of primary production resulting from mountain shading may explain the lower primary production noted for the West Delta.

From the foregoing it appears that prior to the establishment of the training dyke in 1972, algal growth on the Squamish Delta may have resembled that now present on the West Delta. In this case, total primary production for the area would have been considerably lower.

g.) The most productive algal phylum of the Squamish River Delta was the Chlorophyta, specifically _Ulva_ _lactuca_ with the majority of production being incorporated into biomass. Enteromorpha clathrata and Spirogyra sp. approximated the production of U. lactuca but lower percentages were incorporated into biomass.

Net primary production for a species of algae increased from West to East Delta along with salinity. It appears that an esturine algae, whether weakly or strongly euryhaline, is better able to carry on production under polyhaline conditions (18.0 to 30.0 °/oo). This bears out findings in the literature that fresh to mesohaline conditions impart instability to esturine-deltaic ecosystems which retard algal growth. Linear regression analysis indicated salinity to be significant ($p = 0.01$) in primary production.

Light intensity also appeared to be a significant factor ($p = 0.01$) for primary production on the Squamish Delta. This study indicated the existence of two major groups of benthic algae, one favoring high light (Chlorophyta and Xanthophyta) and the other favoring low light intensities (Phaeophyta, Rhodophyta and Chrysophyta) for maximum net production. As previously noted, these algae are placed in similar groupings on the basis of salinity tolerance, thus the following groups can be defined.

a) strongly euryhaline high light algae

b) weakly euryhaline low light algae.

h.) Dawn to dusk primary production studies indicated maximum net production in the two hour period prior to time of maximum daily light intensity. A seasonal, adaptive mechanism is suggested on the part of certain algal species which exhibited a shift of production maxima towards the high light intensities of mid-day with the onset of spring. Present data indicate benthic algae on the Squamish Delta to be "shade" adapted during the winter and "sun" adapted at other times of the year.

LITERATURE CITED

Aleem, A.A. 1950. The diatom community inhabiting the mud-flats at Whitstable. New Phytol. 49: 174-187.

American Public Health Association et.al., 1971, Standard Methods for the Examination of Water and Wastewater. 13th. Ed. American Public Health Association, New York.

Anon, MS, 1972. Preliminary impact assessments of proposed port development in the Mamquam Channel and rail yard expansion in the Squamish estuary. Dept. of The Environment, Vancouver. (Published Dec. 1972.)

Blinks, L.R. 1951. Physiology and Biochemistry of Algae. In: Manual of Phycology. G.M. Smith (Ed.). Waltham, Mass. Chronica Botanica. pp. 263-291.

Blum, J.L. and J.T. Conover. 1953. New or noteworthy Vaucheria from New England salt marshes. Biol. Bull. 105:395-401.

Botnariuc, N. 1969. Some characteristic features of the floodplain ecosystems of the Danube. Hydrobiologia. (Bucharest). 8:39-50.

Bowden, K.F. 1967. Circulation and Diffusion. In: Estuaries. II Physical Factors. G.H. Lauff (Ed.) American Association for the advancement of Science. Publication No. 83. Horn-Shafer Co. Baltimore. 757 pp.

Burkholder, P.R., A. Repark and J. Sibert. 1965. Studies on some Long Island Sound littoral communities of microorganisms and their primary productivity. Bull. Torrey bot. Club. 92: 378-402.

Callome, B. and J. Debysen. 1954. Observations sur les movements des diatomees a la surface des sediments marins de la zone intercotidale. Vie et Milieu. 5: 242-249.

Carter, N. 1932. A comparative study of the algal flora of two salt marshes. Part I. J. Ecol. 20: 341-370.

Carter, N. 1933. A comparative study of the algal flora of two salt marshes. Part II. J. Ecol. 20: 128-208.

Cliff, D.D. and J.G. Stockner. MS, 1973. Primary and secondary components of the food-web of the outer Squamish River Estuary. Fish. Res. Bd. Canada Manuscript Series No. 1214.

Day, J.H., 1950. The ecology of South African estuaries. Part I. A review of esturine conditions in general. Trans. Roy. Soc. S. Afr. 33: 53-91.

Day, J.H., Millard, N.A.H. and A.D. Harrison, 1952. The ecology of South African estuaries. Part III. Knysna: A clear open estuary. Trans. Roya. Soc. S. Afr. 33(3): 367-413.

Day, J.H., Millard, N.A.H., and G.J. Brockhvysen. 1943. The ecology of South African estuaries. Part IV: The St. Lucia system. Trans. Roy. Soc. S. Afr. 34(1): 129-156.

Dickman, M. 1969. Some effects of lake renewal on phytoplankton productivity and species composition. Limnol. and Oceanogr. 14(5): 660-666.

Doty, M.S., and J. Newhouse. 1954. The distribution of marine algae into esturine waters. Amer. Jour. Bot. 41: 508-515.

Druehl, L.D. 1967. Vertical distributions of some benthic marine algae in a British Columbia Inlet as related to some environmental factors. J. Fish. Res. Bd. Canada. 24(1): 33-46.

Egler, W.A. and H.D. Schwassmann. 1966. Limnological studies in the Amazon Estuary. In: 15th. Congress of the Societas Internationalis Limnologiae. Madison, Wisconsin. 20-255 August, 1962. Int. Ver. Theor. Agnew. Limnol. Verh. 15 (Part 2): 1059-1066.

Fassett, N.C. 1928. The vegetation of the estuaries of northeastern North America. Proc. Boston. Soc. Nat. Hist. 39(3): 73-130.

Faure - Fremiet, E., 1951. The tidal rhythm of the diatom, *Hantzschia amphioxys*. *Biol. Bull.*, Woods Hole. 100: 173-177.

Gangong, W.F. 1903. The vegetation of the Bay of Fundy salt and dyked marshes: an ecological study. *Botan. Gaz*. 36: 161-186, 280-302, 349-367, 429-455.

Ganning, B. and F. Wulff. 1971. Measurements of community metabolism in some Baltic brackish water rockpools by means of diel oxygen curves.

Gargas, E. 1970. Measurements of primary production, dark fixation and vertical distribution of the micro-benthic algae in the Oresund, *Ophelia*. 8: 231-253.

Gargas, E. 1971. Sun-shade adaptation in micro-benthic algae from the Oresund. *Ophelia*. 9(1): 107-112.

Gargas, E. 1972. Measurements of microalgal primary production (phytoplankton and microbenthos) in the Smalandshavet (Denmark).*Ophelia*. 10:75-89.

Grontved, J. 1957. A sampler for underwater macrovegetation in shallow waters. *J. Cons. Int. Explor. Mer*. 22: 293-297.

Grontved, J. 1960. On the productivity of microbenthos and phytoplankton in some Danish fjords. *Medd. Danm. Fisk. Havund.*, NY Serie. 3: 55-92.

Harger, J.R.E. MS. 1971. Damage to vegetation by chlorine gas. (Unpublished manuscript).

Hargrave, B.T. 1969. Epibenthic algal production and community respiration in the sediments of Marion Lake. *Jour. Fish. Res. Bd. Can*. 26(8): 2003-2026.

Hopkins, J.T. 1963. A study of the diatoms of the Ouse Estuary, Sussex. I. The movement of the mudflat diatoms in response to some chemical and physical changes. *J. Mar. Biol. Ass*. 43: 653-663.

Hopkins, J.T. 1965. Some light induced changes in behaviour and cytology of an esturine mud-flat diatom. In: Light as an Ecological Factor. R. Bainbridge (Ed). Blackwell Publ. Oxford.

Hopkins, J.T. 1966. The role of water in the behaviour of an esturine mud-flat diatom. J. Mar. Biol. Ass. U.K. 46: 617-626.

Hunding, G. and B.T. Hargrave. 1972. A comparison of benthic microalgal production measurement by C^{14} and oxygen methods. J. Res. Res. Bd. Canada. 30(2): 309-312.

Johnson, C.S. and J.P. Cook. 1968. A preliminary assessment of the techniques for measuring production in macrophytic marine algae. Experimentia. 24(11): 1176-1177.

Johnson, D.S., and H.H. York. 1915. The relation of plants to tide levels. Carnegie Institute, Washington, D.C. The Lord Baltimore Press, Baltimore.

Jorde, I., and N. Klavestad. 1963. The natural history of the Hardangerfjord 4. The benthonic algal vegetation. Sarsia. 9: 1-99.

Kelbey, D.W. 1966. Ecological studies of the Sacramento-San Joaquin Estuary: Description of the Sacramento-San Joaquin Estuary. Calif. Dep. Fish. Game Fish. Bull. 133: 8-17.

Leach, J.H. 1970. Epibenthic algal production in an intertidal mudflat. Limnol. Oceanogr. 15(4): 514-521.

Levings, C.D. MS 1973. Intertidal benthos of the Squamish Estuary. Fish. Res. Bd. Canada, Manuscript Report Series No. 1218.

Lim, P.G., and C.D. Levings. MS, 1973. Distribution and biomass of intertidal vascular plants on the Squamish Delta. Fisheries Research Board of Canada, Manuscript Report Series No. 1219.

Luther, H. 1951. Verbreitung und Oekologie der hoeberen Wasserpflanzen in Brackwasser der Eskenaes - Gegend in Suedfinnland. Part I. Allgemeiner Teil. Part II. Specieller Teil. Acta . Bot. Fennicae. 49: 1-232; 50: 1-370.

Lyford, J.H., and H.K. Phinney. 1968. Primary productivity and community structure of an esturine impoundment. Ecology. 49(5): 854-866.

MacGinitie, G.E. 1935. Ecological aspects of a California Marine Estuary. Amer. Midl. Nat. 16(5): 629-765.

Millard, N.A.H., and A.D. Harrison, 1954. The ecology of South African estuaries. Part V: Richard's Bay. Trans Roy. Soc. S. Afr. 34(1): 154-174.

Moul, E.T., and D. Mason. 1957. Study of diatom populations on sand and mud flats in the Woods Hole area. Biol. Bull. 113: 351.

Nelson, T. 1947. Some contributions from the land in determining conditions of life in the sea. Ecol. Monogr. 17: 337-346.

Niell, F.X. 1971. Adiciones a la flora de algas bentonicas de la ria de Vigo. (Contribution to the knowledge of the benthic algae of the Estuary of Vigo) Invest. Pesq. 34(2): 299-308.

Nienhuis, P.H. 1971a. The benthic algal communities of flats and salt marshes in the Grevelingen, a sea arm in the southwestern Netherlands. Neth. J. Sea. Res. 5(1): 20-49.

Nienhuis, P.H. 1971b. Vaucheria species and some other algae on a Dutch salt marsh with ecological notes on their periodicity. ACTA BOT. Neerl. 20(1): 107-118.

Odum, H.T. 1957. Trophic structure and productivity of Silver Springs, Florida. Ecol. Monogr. 27: 55-112.

Odum, E.P. 1961. The role of tidal marshes in esturine production. New York State Conservationist.

Odum, E.P. 1971. *Esturine Ecology* In: *Fundamentals of Ecology*. W.B. Saunders and Co., Toronto. 572 pp.

Odum, H.T. and C.M. Hoskin. 1959. Comparative studies on the metabolism of marine waters. *Publs. Inst. Mar. Sci. Univ. Texas.* 5: 15-46.

Olson, J.S. 1964. Gross and net production of terrestrial vegetation. *J. Ecol.* 62: 99-118.

Orloci, L. MS. 1961. Forest types of the Coastal Western Hemlock Zone. M. Sc. Thesis. University of British Columbia. 206 pp.

Pamatmat, M.M. 1968. Ecology and metabolism of a benthic community on an intertidal sandflat. *Int. Revue ges. Hydrobiol.* 53: 211-298.

Park, Kilho, D.W. Wood and H.T. Odum. 1958. Diurnal pH variation in Texas bays and its application to primary production estimation. *Pub. Inst. Mar. Sci., Texas.* 5: 57-64

Perkins, E.J. 1960. The dirunal rhythm of the littoral diatoms of the River Eden estuary, Fife. *J. Ecol.* 48: 725-728.

Pomeroy, L.R. 1959. Algal productivity in Georgia salt marshes. *Limnol. Oceanogr.* 4: 386-397.

Pomeroy, L.R., Smith, E.E., and C.M. Grant. 1965. The exchange of phosphate between estuarine water and sediment. *Limnol. Oceanogr.* 10: 167-172.

Pomeroy, L.R., Johannes, R.E., Odum, E.P., and B. Roffman. 1969. The phosphorus and zinc cycles and productivity of a salt marsh. In: *Proc. 2nd. Sym. on Radioecology* (Nelson and Evans, eds). Clearinghouse Fed. Sci. Tech. Info., Springfield, Va. pp. 412-419.

Redeke, H.C. 1935. De Zuiderzee als brackwatergebied. - Handelingen 25. Nederlandel, Natur - Geneeskundig. Congr. Delft.

Remane, A. and C. Schlieper. 1971. *Biology of Brackish Waters.* John Wiley and Sons. Toronto. 372 p.

Riley, G.A. 1952. Letter to the editor. J. Conseil Mer. 19: 85-89.

Riznyk, R.Z. 1969. Ecology of benthic microalgae of esturine intertidal sediments. Ph.D. Thesis. Oregon State University.

Riznyk, R.Z., and H.K. Phinney. 1972. The distribution of intertidal phytopsammon in an Oregon estuary. Marine Biol. 13: 318-324.

Riznyk, P.Z., and H.K. Phinney. 1972. Manometric assessment of intertidal microalgae production in two esturine sediments. Oecologia (Berl.) 10: 193-203.

Ryther, J.H. 1956. Photosynthesis in the ocean as a function of light intensity. Limnol. and Oceanogr. 1: 61-70.

Scheleske, C.L., and E.P. Odum. 1962. Mechanisms maintaining high productivity in Georgia estuaries. Proc. Gulf and Carib. Fish. Inst. 14: 75-80.

Scott, K.M.F., A.D. Harrison and W. Macnae. 1952. The ecology of South African estuaries. The Klein river estuary, Hermanus, Cape. Trans. Roy. Soc. South Africa. 33: 283-334.

Stammer, J.H. 1935. Ein neuer Hohlenpharomide, Troglomysis Vjetrenicensis n.g.n. sp., zugleich eine Ubersicht der bisker aus dem Brack-und SuBwasser bekannten Schizopoden - Zool. Jb. Syst. 68: 53-104.

Stather, J.K. MS, 1958. A geographical investigation of development potential in the Squamish Valley region, British Columbia. M.Sc. Thesis. The University of British Columbia, Vancouver, B.C. 194 p.

Steemann Nielsen, E. 1951. The marine vegetation of the Isefjord. Meddelelsen Fra Kommissionen For Denmarks Fiskerie - OG Havundersogelsen. 5(6): 1 - 114.

Steemann Nielsen, E. and E. Jorgensen. 1968a. The adaption of planktonic algae. E. General part. Physiologia Pl. 21. 401-413.

Steemann Nielsen, E. and E. Jorgensen. 1968b. The adaption of planktonic algae. III. with special consideration of the importance in nature. Physiologia Pl. 21: 647-654.

Strickland, J.D.H. 1960. Measuring the production of marine phytoplankton. Fish. Res. Bd. Canada., Bulletin No. 122. 173 p.

Strickland, J.D.H. and T.R. Parsons. 1972. A Practical Handbook of Seawater Analysis. Fish. Res. Bd. Can. Bulletin 167. 311 p.

Sykes, G. 1937. The Colorado delta. Carnegie Inst. of Wash. Publ. 460, 193 pp.

Talling, J.F. 1965. The photosynthetic activity of phytoplankton in East African lakes. Int. Rev. ges. Hydrobiol. 50: 1-32.

Taylor, R.W. 1964. Light and photosynthesis in intertidal benthic diatoms. Helgolander Wiss. Meer. 10: 29-37.

Taylor, W.R., and J.D. Palmer. 1963. The relationship between light and photosynthesis in intertidal benthic diatoms. Biol. Bull. 125: 395.

Thompson, J.A.J. and F.T. McComas. MS, 1973. Distribution of mercury in the sediments and waters of Howe Sound, British Columbia. Fish. Res. Bd. Canada. Technical Report No. 396.

Vladimirova, K.S. 1969. Metodika izucheniya pervichnoi produktsii donnykh vodoroslei (Methods for studying the primary production of benthic algae) Gidrobiol. Z.H. 5(4): 128-130.

Vollenweider, R.A. 1969. A manual on methods for measuring primary production in aquatic invironments. I B P Handbook No. 12. Blackwell Scientific Publications, Oxford. 213 pp.

Westlake, D.F. 1963. Comparisons of plant productivity. Biol. Rev. 38: 385-425.

Wetzel, R.G. 1964. A comparative study of the primary productivity of higher aquatic plants, periphyton, and phytoplankton in a large shallow lake. Int. Revue ges. Hydrobiol. 49(1): 1-61.

APPENDIX I

Salinity values recorded over the Squamish River delta

APPENDIX I

	WEST DELTA		
		General Intertidal	
AREA DATE	S[a]	1m	2m
May 25, 1972	3.7[b]	-	-
June 7, 1972	2.0	-	-
July 11, 1972	2.0	-	-
August 11, 1972	4.6	-	-
September 27, 1972	8.1	-	-
October 23, 1972	7.0	18.6	28.2
November 30, 1972	5.2	23.9	28.5
January 10, 1973	3.7	30.6	34.5
February 14, 1973	8.5	28.2	28.4
March 29, 1973	3.3	3.6	19.8
April 25, 1973	3.9	3.9	4.1

[a] Surface salinity

[b] Salinity as parts per thousand

APPENDIX I

DATE / AREA	CENTRAL DELTA			
	General Intertidal			Spill Region
	S[a]	1m	2m	S
May 25, 1972	8.8[b]	-	-	-
June 8, 1972	2.1	-	-	-
16	2.2	-	-	-
July 8, 1972	6.1	-	-	7.0
26	7.0	-	-	7.5
August 1, 1972	3.8	-	-	8.0
23	15.0	-	-	8.9
September 27, 1972	22.1	-	-	19.4
October 27, 1972	31.8	32.0	34.3	22.9
November 29, 1972	30.0	31.4	34.6	-
December 20, 1972	-	-	-	-
January 10, 1973	34.3	34.1	34.3	-
31	30.1	30.7	31.9	-
February 13, 1973	25.0	27.9	29.0	28.7
22	20.1	26.4	27.9	23.1
March 8, 1973	14.5	18.1	20.0	16.9
30	10.2	16.4	20.0	12.0
April 25, 1973	6.7	6.8	15.8	10.0

[a] Surface salinity

[b] Salinity as parts per thousand

APPENDIX I

EAST DELTA

DATE / AREA	West Side (Central Basin) S[a]	West Side (Central Basin) 1m	West Side (Central Basin) 2m	West of BCR rail line S	Inner Areas West of BCR rail line S	Sluicegate (Upper Cattermole Creek) S	East Side (Cattermole Creek) S	East Side (Cattermole Creek) 1m	East Side (Cattermole Creek) 2m
May 25, 1972	8.8[c]	–	–	8.4	9.0	–	9.5	–	–
June 8, 1972	2.1	–	–	2.0	–	–	12.3	–	–
9	2.2	–	–	2.0	12.6	–	12.4	–	–
16	2.2	–	–	2.0	–	–	10.9	–	–
21	4.0	–	–	3.5	10.5	–	10.0	–	–
July 8, 1972	6.1	–	–	4.1	–	–	12.0	–	–
9	6.7	–	–	5.9	–	–	12.0	–	–
10	6.6	–	–	6.0	–	14.3	11.9	–	–
12	6.8	–	–	6.0	14.0	–	13.7	–	–
19	7.1	–	–	6.0	–	–	18.9	–	–
20	7.8	–	–	7.2	17.0	17.1	17.0	–	–
26	7.0	–	–						
Aug. 3, 1972	3.0	–	–	5.7	18.0	18.4	–		
11	9.3	–	–	10.0	18.5	–	19.0	–	–
23	15.0	–	–	15.1	19.0	20.1	21.0	–	–
Sept.27, 1972	22.1	–	–	20.1	–		22.4	–	–
28	22.4	–	–	20.3	21.0	23.4[b]	22.9	–	–
Oct. 24, 1972	24.9	25.0	26.1	25.9	24.0	–	25.0	26.1	27.0
27	31.8	32.0	34.3	29.7	28.0	–	30.9	32.1	32.3
Nov.28, 1972	30.2	31.0	34.2	30.7	34.0	–	28.2	31.0	34.7
29	30.0	31.4	34.6	31.0	34.1[b]	–	28.2[b]	31.5[b]	34.3[b]
Dec. 20,1972	–	–	–	–	–	–	–	–	–

APPENDIX I

EAST DELTA (Continued)

DATE \ AREA	West Side (Central Basin)			West of BCR rail line	Inner Areas West of BCR rail line	Sluicegate (Upper Cattermole Creek)	East Side (Cattermole Creek)		
	S^a	1m	2m	S	S	S	S	1m	2m
Jan 10, 1973	34.3	34.1	34.3	34.7	-	-	-	-	-
31	30.1	30.7	31.9	32.1	-	-	-	-	-
Feb.13, 1973	25.0	27.9	29.0	27.1	-	-	-	-	-
14	25.5	27.4	29.1	27.3	-	-	-	-	-
22	20.1	26.4	27.9	24.0	-	-	-	-	-
Mar. 8,1973	14.5	18.1	20.0	17.5	-	-	-	-	-
30	10.2	16.4	20.0	12.0	-	-	-	-	-
Apr.25,1973	6.7	6.8	15.8	18.9	-	-	-	-	-

[a] Surface salinity

[b] Study area abandoned

[c] Salinity as parts per thousand

APPENDIX II

Temperature values recorded over the Squamish River delta

APPENDIX II

DATE \ AREA	WEST DELTA		
		General Intertidal	
	S[a]	1m	2m
May 25, 1972	7.5[b]	-	-
June 7, 1972	8.2	-	-
July 11, 1972	10.1	-	-
August 11, 1972	10.5	-	-
September 27, 1972	9.1	-	-
October 23, 1972	5.0	-	-
November 30, 1972	2.5	4.2	4.8
January 10, 1973	2.0	3.5	3.9
February 14, 1973	1.5	2.9	3.2
March 29, 1973	5.3	6.4	6.9
April 25, 1973	6.8	7.1	7.6

[a] Surface temperature

[b] Temperature as °C

APPENDIX II

DATE / AREA	CENTRAL DELTA			
	General Intertidal			Spill Region
	S[a]	1m	2m	S
May 25, 1972	7.8[b]	-	-	-
June 8, 1972	8.4	-	-	-
16	8.8	-	-	-
July 8, 1972	13.5	-	-	17.3
26	13.6	-	-	18.9
August 1, 1972	13.9	-	-	14.8
23	11.4	-	-	21.1
September 27, 1972	8.5	-	-	18.2
October 27, 1972	6.0	6.3	6.9	14.4
November 29, 1972	4.5	5.4	5.7	-
December 20, 1972	-	-	-	-
January 10, 1973	3.5	5.0	5.3	-
31	3.0	4.3	4.9	-
February 13, 1973	2.0	2.4	2.5	1.3
22	5.5	5.6	6.1	1.0
March 8, 1973	4.5	5.2	5.4	9.4
30	3.5	5.1	5.5	12.0
April 25, 1973	7.0	7.1	7.4	14.1

[a] Surface temperature

[b] Temperature as °C

APPENDIX II

EAST DELTA

DATE / AREA	West Side (Central Basin)			West of BCR rail line	Inner Areas West of BCR rail line	Sluicegate (Upper Cattermole Creek)	East Side (Cattermole Creek)		
	S[a]	1m	2m	S	S	S	S	1m	2m
May 25, 1972	7.8[c]	-	-	9.0	9.4	-	8.0	-	-
June 8, 1972	8.4	-	-	9.2	-	-	8.9	-	-
9	8.4	-	-	9.2	13.4	-	8.9	-	-
16	8.8	-	-	9.4	-	-	8.7	-	-
21	10.3	-	-	11.8	17.1	-	9.1	-	-
July 8, 1972	13.5	-	-	14.4	-	-	10.7	-	-
9	13.4	-	-	14.3	-	-	10.8	-	-
10	13.1	-	-	14.7	-	10.9	10.8	-	-
12	13.5	-	-	15.0	17.5	-	11.3	-	-
19	13.7	-	-	14.2	-	-	12.7	-	-
20	13.4	-	-	15.9	19.1	13.2	13.1	-	-
26	13.6	-	-	16.0	-	-	13.2	-	-
Aug. 6, 1972	13.9	-	-	17.4	20.1	12.9	13.4	-	-
11,	13.2	-	-	17.3	20.02	-	12.0	-	-
23	11.4	-	-	14.9	16.3	10.9	10.1	-	-
Sept.27, 1972	8.5	-	-	10.0	-	-	9.0	-	-
28	8.5	-	-	10.5	12.1	10.2[b]	9.5	-	-
Oct. 24, 1972	6.0	6.3	6.9	8.1	6.4	-	5.8	5.9	6.4
27	6.0	6.5	6.9	7.4	6.7	-	5.8	6.0	6.7
Nov. 28, 1972	4.5	5.2	5.8	5.2	5.3	-	4.8	5.3	5.6
29	4.5	5.4	5.7	5.4	5.0[b]	-	4.8[b]	5.5[b]	5.9[b]
Dec. 20, 1972	-	-	-	-	-	-	-	-	-

APPENDIX II

EAST DELTA (Continued)

DATE \ AREA	West Side (Central Basin)			West of BCR rail line	Inner Areas West of BCR rail line	Sluicegate (Upper Cattermole Creek)	East Side (Cattermole Creek)		
	S[a]	1m	2m	S	S	S	S	1m	2m
Jan. 10, 1973	3.5	5.0	5.3	4.1	–	–	–	–	–
31	3.0	4.3	4.9	4.0	–	–	–	–	–
Feb. 13, 1973	2.0	2.4	2.5	1.0	–	–	–	–	–
14	2.5	2.7	2.9	1.5	–	–	–	–	–
22	5.5	5.6	6.1	6.3	–	–	–	–	–
March 8, 1973	4.5	5.2	5.4	5.9	–	–	–	–	–
30	3.5	5.1	5.5	5.2	–	–	–	–	–
April 25, 1973	7.0	7.1	7.4	12.3	–	–	–	–	–

[a] Surface temperature

[b] Study area abandoned

[c] Temperature as °C

APPENDIX III

Light intensity recorded in the area of the West Delta and Central Basin where algae were incubated for primary production studies.

APPENDIX III

DATE	WEST INCUBATION AREA		
	S[a]	1m	2m
May 25, 1972	208.95[b]	-	-
June 7, 1972	234.70	-	-
July 11, 1972	49.63	-	-
August 11, 1972	37.13	-	-
September 27, 1972	63.63	-	-
October 23, 1972	90.12	54.07	38.75
November 30, 1972	12.87	6.18	4.12
January 10, 1973	18.32	9.53	6.60
February 14, 1973	18.80	10.53	7.14
March 29, 1973	102.20	46.00	26.57
April 25, 1973	125.27	42.59	17.54

[a] Surface light

[b] Light as g cal $cm^{-2} day^{-1}$

APPENDIX III

DATE	CENTRAL INCUBATION AREA		
	S[a]	1m	2m
May 25, 1972	208.95[b]	-	-
June 8, 1972	265.40	-	-
9	247.10	-	-
16	271.34	-	-
21	208.45	-	-
July 8, 1972	165.38	-	-
9	150.74	-	-
10	136.69	-	-
11	48.63	-	-
12	247.08	-	-
19	297.58	-	-
20	284.21	-	-
26	199.54	-	-
August 1, 1972	120.00	-	-
3	153.10	-	-
11	37.13	-	-
23	224.80	-	-
September 27, 1972	-	-	-
28	174.30	-	-
October 24, 1972	104.78	68.11	47.15
27	91.30	59.35	41.09
November 28, 1972	27.37	13.69	10.41
29	33.67	16.84	12.79
December 20, 1972	20.02	12.51	9.01

APPENDIX III

	CENTRAL INCUBATION AREA (Continued)		
DATE	S[a]	1m	2m
January 10, 1973	18.32	13.74	9.16
31	29.12	21.84	14.56
February 13, 1973	37.41	28.06	18.71
14	18.80	14.10	9.40
22	22.28	16.71	11.14
March 8, 1973	61.40	46.05	30.70
29	102.20	76.65	51.10
30	107.42	80.56	53.70
April 25, 1973	125.27	93.95	62.64

[a] Surface light

[b] Light as g cal cm^{-2} day^{-1}

APPENDIX IV

Morphological descriptions and seasonal species changes for multi-specific algal assemblages.

APPENDIX IV

Assemblage Type	Form	Major Constituents	Substrata Type	Areas Where Found
I	reddish-brown gelatinous layer ($\leq$ 2.00 mm thick)	diatoms	unconsolidated soft mud	banks at Castle and Fill Creeks (Fig. 2.)
II	brown layer ($\leq$ 1.00mm thick)	diatoms	intertidal mud flats	front of west delta
III	green felt-like carpet ($\leq$ 5.0 mm thick)	*Vaucheria dichotoma*	fresh sand (resulting from fill operations)	areas associated with or adjacent to fill operations
IV	green to copper colored mucilaginous mass of prostrate filaments ($\leq$ 5.0 mm thick)	diatoms	fresh sand (resulting from road construction)	sand flats adjacent to road on east delta
V	dark brown filamentous clumps ($\leq$ 8.0 cm long)	diatoms	fresh sand and mud	open delta pools and marsh surface until sedge growth restricts occurrence to pools
VI	small light brown filamentous clumps ($\leq$ 5.0 cm long)	diatoms	small rocks and log surfaces	mid-intertidal region on west side of east delta
VII	dense brown filamentous clumps ($\leq$ 5.0 cm long)	diatoms (*Melosira* spp.)	sand and mud substrata in association with sedge	upper intertidal regions of west and central deltas

APPENDIX IV

Assemblage Type	Form	Major Constituents	Substrata Type	Areas Where Found
VIII	green filamentous layer (≤ 1.0 mm thick)	*Ulothrix* cf *flacca*	marsh vegetation (e.g. Carex sp.)	up to mean high water on central and east deltas
IX	unconsolidated green layer (≤ 1.0 mm thick)	diatoms (*Navicula* spp.)	consolidated mud	open area adjacent to Pile Creek
X	short red-brown filamentous clumps (≤ 5.0 cm long)	diatoms (*Navicula grevillei*)	small rocks or coarse sand	bottom of Pile Creek and its primary tributaries
XI	light brown filamentous clumps (≤ 10.0 cm long)	diatoms	consolidated mud	Upper intertidal marsh region on central delta, generally shallow pools to mean high water
XII	coarse green felt-like mat with definite peaks and ridges (≤ 1.0 cm thick)	*Rhizoclonium* sp.	unconsolidated mud	bottom and sides of Pile Creek plus adjacent marsh lands.

APPENDIX IV

Assemblage type I

Algal Species	West Delta				Central Delta					
	November 1972	January 1973	February 1973	March 1973	October 1972	November 1972	December 1972	January 1973	February 1973	March 1973
Pleurosigma cf *aestuarii*	90	85	70	80	90	85	75	80	75	70
Navicula spp. *Pinnularia* sp. *Thallasionema* sp. *Licmorphora* sp. *Synedra tabulata* *Diploneis* sp. *Nitzschia* cf *sigma*; *N*. cf *apiculata* *Hantzschia* sp. *Melosira* spp. Dinoflagellates	10	15	30	20	10	15	25	20	25	30

APPENDIX IV

Assemblage type II

	West Delta							
Algal Species	May 1972[a]	September 1972	October 1972	November 1972	January 1973	February 1973	March 1973	April 1973
Navicula cancellata	70	50	60	70	70	70	70	70
N. ammophila								
N. sp.								
Pinnularia cf *trevelyana*	30	20	10	10	10	10	5	5
Pleurosigma cf *aestuarii*		25						
Melosira spp.								
Synedra tabulata			35	15	15	15	20	20
Thallasionema sp.								
Nitzschia cf *sigma*								
N. closterium								
Dinoflagellates	1	5	5	5	5	5	5	

[a] absent June 1972 - August 1972

APPENDIX IV

Assemblage type III

Algal Species	Central Delta											
	May 1972	June 1972	July 1972	August 1972	September 1972	October 1972	November 1972	December 1972	January 1973	February 1973	March 1973	April 1973
Vaucheria dichotoma	80	80	80	80	80	80	80	80	80	80	80	80
Synedra tabulata	20	20	20	20	20	20	20	20	20	20	20	20
Thallasionema sp.												
Navicula spp.												
Pinnularia sp.												
Nitzschia sp.												
Diploneis sp.												
Licmorphora sp.												

Assemblage type III

Algal Species	East Delta						
	May 1972	June 1972	July 1972	August 1972	September 1972	October 1972	November 1972[a]
Vaucheria dichotoma	90	90	90	90	90	90	90
Synedra tabulata	10	10	10	10	10	10	10
Thallasionema sp.							
Licmorphora sp.							
Navicula spp.							
Nitzschia sp.							

[a] study area abandoned

APPENDIX IV

Assemblage type IV

	East Delta						
Algal Species	May 1972	June 1972	July 1972	August 1972	September 1972	October 1972	November 1972 [a]
	70	70	70	60	50	50	50
Thallasionema sp.	5	5	10	10	10	10	10
Synedra tabulata	5	5	5	5	10	10	10
Diatoma cf *hiemale* *Achnanthes* sp. *Navicula* spp. *Melosira* cf. *moniliformis* *Licmorphora* sp.	20	20	15	25	30	30	30

[a] study area abandoned

APPENDIX IV

Assemblage type V

	East Delta	
Algal Species	May 1972	June 1972
Rhizoclonium sp.	70	80
Thallasionema sp *Synedra tabulata* *Tetraspora* sp.	30	20

Assemblage type VI

	East Delta		
Algal Species	May 1972	June 1972	July 1972
Rhizoclonium sp.	70	75	60
Navicula grevillei	20	15	5
Melosira cf. *moniliformis*	5	5	10
Melosira sp. *Synedra tabulata* *Thallasionema* sp.	5	5	25

Assemblage type VII

	Central Delta		
Algal Species	May 1972	June 1972	July 1972
Melosira cf. *moniliformis* *M. nummuloides* *M.* sp.	80	60	
Thallasionema sp.			15
Synedra tabulata	10	10	15
Synedra sp.			
Navicula grevillei	5		
Rhizoclonium sp.	5	30	70

Assemblage type VII

	West Delta				
Algal Species	May 1972	June[a] 1972	Feb. 1973	March 1973	April 1973
Melosira cf. *moniliformis* *M. nummuloides* *M.* sp.	90	90	50	60	75
Thallasionema sp. *Synedra tabulata* *Synedra* sp. *Navicula grevillei*	10	10	50	40	25

[a] absent July 1972 - January 1973

APPENDIX IV

Assemblage type VIII

Algal Species	Central and East Delta				
	November 1972	December 1972	January 1973	February 1973	March 1973
Ulothrix cf. *flacca*	80	80	80	80	80
Synedra tabulata *Navicula grevillei* *N.* spp. *Melosira* spp. *Pleurosigma* sp. *Licmorphora* sp. *Achnanthes* sp.	20	20	20	20	20

Assemblage type IX

Algal Species	Central Delta		
	January 1973	February 1973	March 1973
Navicula cancellata *N.* spp.	70	80	80
Pinnularia sp. *Pleurosigma* sp. *Nitzschia closterium* *Caloneis* sp. *Hantzschia* sp.	30	20	20

Assemblage type X

Algal Species	Central Delta		
	January 1973	February 1973	March 1973
Navicula grevillei	98	80	50
Melosira nummuloides		10	30
M. moniliformis *M.* sp. *Thallasionema* sp. *Synedra* sp.	2	10	20

APPENDIX IV

Assemblage type XI

Algal Species	Central Delta January 1973	February 1973	March 1973	April 1973
Navicula grevillei	60	70	50	50
Navicula sp.				
Melosira cf *nummuloides* *M. moniliformis*	40	30	10	30
Thallasionema sp.			40	20
Licmorphora sp.				

Assemblage type XII

Algal Species	West Delta July 1972	August 1972	September 1972	October 1972	November 1972
Rhizoclonium sp.	90	80	80	20	50
Navicula spp.					
Achnanthes sp.	10	20	20	30	30
Licmorphora sp.					
Synedra tabulata					
Thallasionema sp.					20

APPENDIX V

Primary production, respiration, P/R ratio, biomass and distributional (coverage) area for algae recorded on the Squamish River Delta.

WEST DELTA

APPENDIX V

Enteromorpha clathrata

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 26, 1972	37.50	S[a]	1.41	0.89	0.59	2.39	7.70
June 7, 1972	37.50	S	1.22	0.31	0.91	1.34	3.11
July 11, 1972	50.00	S	0.71	0.15	0.56	1.27	2.40
August 11, 1972	80.00	S	1.02	0.08	0.94	1.09	13.91
September 27, 1972	80.00	S	0.43	0.06	0.27	1.60	10.74
October 23, 1972	80.00	S	0.84	0.64	0.20	4.20	10.48
		1	0.73	Nil	0.82	0.89	
		2	-	-	-	-	
November 30, 1972	70.00	S	0.90	0.11	0.79	1.14	4.92
		1	0.60	Nil	0.81	0.73	
		2	0.60	Nil	0.89	0.67	
January 10, 1973	75.00	S	0.13	0.05	0.08	1.70	7.10
		1	0.07	Nil	0.24	0.31	
		2	0.08	Nil	0.28	0.27	
February 14, 1973	75.00	S	0.13	0.08	0.05	2.56	14.46
		1	0.13	0.04	0.09	1.44	
		2	0.09	Nil	0.10	0.94	
March 29, 1973	75.00	S	2.60	2.13	0.47	5.54	12.76
		1	2.58	1.50	1.08	2.38	
		2	1.87	0.33	1.54	1.22	
April 25, 1973	80.00	S	1.86	1.54	0.32	5.81	31.59
		1	1.72	1.40	0.32	5.38	
		2	-	-	-	-	

[a] Surface incubation

APPENDIX V

Ulva lactuca

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
January 17, 1972	2.0	S[a]	0.47	0.32	0.15	3.13	0.14
		1	0.37	0.12	0.25	1.48	
		2	0.37	0.09	0.28	1.33	
February 14, 1972	2.0	S	0.37	0.20	0.17	2.21	0.27
		1	0.35	0.12	0.23	1.53	
		2	0.21	0.05	0.16	1.31	
March 29, 1973	2.0	S	0.46	0.03	0.42	1.10	0.19
		1	0.41	0.04	0.37	1.11	
		2	0.31	Nil	0.39	0.80	
			algae absent				

Assemblage type VII

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
May 26, 1972	5.0	S[a]	1.41	0.89	0.37	3.81	1.57
June 7, 1972	5.0	S	0.55	0.18	0.38	1.45	0.75
July 11, 1972	2.0	S	0.29	Nil	0.43	0.67	0.10
			algae absent				
February 14, 1973	75.0	S	1.37	0.71	0.66	2.08	3.84
March 29, 1973	80.0	S	1.02	0.52	0.50	2.04	10.75
April 25, 1973	70.0	S	0.51	0.22	0.29	1.76	6.39

[a] Surface incubation

APPENDIX V

<u>Antithamnion pacificum</u>

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respitation $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
September 27, 1972	1.0	S[a]	0.38	0.12	0.17	2.24	1.42
October 23, 1972	2.0	S	0.26	0.16	0.13	2.00	1.68
		1	0.11	0.02	0.09	1.22	
		2	0.07	Nil	0.10	0.70	
November 30, 1972	5.0	S	0.31	0.17	0.14	2.20	1.84
		1	0.24	0.11	0.13	1.85	
		2	0.13	0.06	0.07	1.86	
January 17, 1973	4.0	S	0.31	0.14	0.17	1.82	2.07
		1	0.22	0.08	0.14	1.57	
		2	0.17	0.02	0.15	1.13	
February 14, 1973	4.0	S	0.22	0.04	0.18	1.22	0.43
		1	0.04	Nil	0.07	0.57	
		2	0.04	Nil	0.08	0.50	
				algae absent			

[a] Surface incubation

APPENDIX V

Assemblage type I

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
November 30, 1972	250.0	S[a]	1.41	0.94	0.48	2.94	2.14
		1	1.40	0.81	0.59	2.37	
		2	1.00	0.47	0.53	1.89	
January 17, 1973	250.0	S	0.32	0.14	0.18	1.78	4.73
		1	0.30	0.12	0.17	1.77	
		2	0.14	0.06	0.08	1.75	
February 14, 1973	250.0	S	0.22	0.10	0.12	1.83	4.10
		1	0.17	0.05	0.12	1.42	
		2	0.13	0.04	0.09	1.44	
March 29, 1973	250.0	S	0.20	0.03	0.17	1.18	1.10
		1	0.18	0.07	0.11	1.64	
		2	0.14	0.02	0.11	1.27	
			algae absent				

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[a] Surface incubation

APPENDIX V

Assemblage type II

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 26, 1972	1000.0	S[a]	0.72	0.45	0.27	2.67	1.39
			algae absent				
September 27, 1972	1000.0	S	0.73	0.52	0.21	3.48	0.90
October 23, 1972	1000.0	S	0.47	0.19	0.27	1.74	1.52
		1	0.36	0.08	0.29	1.24	
		2	0.14	Nil	0.28	0.50	
November 30, 1972	1000.0	S	0.24	0.05	0.19	1.25	1.21
		1	0.14	Nil	0.14	1.00	
		2	0.12	Nil	0.27	0.44	
January 17, 1973	800.0	S	0.27	0.11	0.17	1.59	1.74
		1	0.24	0.06	0.18	1.33	
		2	0.18	Nil	0.20	0.90	
February 14, 1973	800.0	S	0.37	0.20	0.17	2.18	1.67
		1	0.32	0.12	0.20	1.60	
		2	0.24	0.03	0.21	1.14	
March 29, 1973	800.0	S	0.65	0.40	0.25	2.60	1.76
		1	0.53	0.22	0.31	1.71	
		2	0.21	0.03	0.19	1.11	
April 25, 1973	1000.0	S	0.57	0.36	0.24	2.38	2.00
		1	0.41	0.17	0.25	1.64	
		2	0.12	0.02	0.10	1.20	

[a] Surface incubation

APPENDIX V

Assemblage type XII

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
June 7, 1972	250.0	S[a]	-	-	-	-	15.14
July 11, 1972	250.0	S	0.69	0.38	0.31	2.30	26.00
August 11, 1972	250.0	S	1.55	0.81	0.74	2.10	110.40
September 27,1972	250.0	S	1.69	0.80	0.89	1.90	74.20
October 23, 1972	250.0	S	1.47	0.49	0.98	1.50	43.09
November 30, 1972	250.0	S	0.43	0.10	0.33	1.30	10.18
			algae absent				

Spirogyra sp.

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
July 11, 1972	25.0	S[a]	1.17	0.85	0.32	3.66	1.10
August 11, 1972	25.0	S	1.76	1.42	0.49	3.61	1.39
September 27, 1972	25.0	S	1.64	1.34	0.30	5.47	2.95
October 23, 1972	20.0	S	0.51	0.25	0.26	1.96	0.90
November 30, 1972	10.0	S	0.17	0.01	0.17	1.00	0.42
			algae absent				

[a] Surface incubation

CENTRAL DELTA

APPENDIX V

Enteromorpha clathrata - Frontal zone

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1972	100.0	S[a]	1.84	0.89	0.96	1.92	21.07
June 8, 1972	100.0	S	1.69	1.16	0.58	2.91	26.56
June 16, 1972	110.0	S	1.71	1.24	0.47	3.64	27.57
July 8, 1972	150.0	S	1.10	0.46	0.64	1.72	37.17
July 26, 1972	150.0	S	1.53	Nil	1.78	0.86	31.40
August 1, 1972	150.0	S	2.19	1.08	1.11	1.97	31.50
August 23, 1972	150.0	S	1.08	0.70	0.38	2.84	26.57
September 27, 1972	150.0	S	0.45	0.26	0.20	2.25	19.94
October 27, 1972	100.0	S	0.59	0.41	0.19	3.11	11.34
		1	0.69	0.39	0.31	2.23	
		2	0.35	0.08	0.27	1.30	
November 29, 1972	80.0	S	0.27	0.16	0.12	2.25	8.42
		1	0.20	0.08	0.11	1.82	
		2	0.12	0.05	0.07	1.71	
December 20, 1972	30.0	S	0.32	0.17	0.16	2.00	3.28
		1	0.27	0.10	0.17	1.59	
		2	0.12	0.05	0.07	1.71	
January 10, 1973	20.0	S	0.13	0.08	0.05	2.60	3.00
		1	0.19	0.03	0.16	1.18	
		2	0.18	Nil	0.22	0.82	
January 31, 1973	20.0	S	0.18	0.08	0.10	1.80	2.14
		1	0.17	Nil	0.21	0.81	
		2	0.16	Nil	0.21	0.76	
February 13, 1973	20.0	S	0.88	0.53	0.35	2.50	2.17
		1	0.76	0.37	0.39	1.95	
		2	0.54	0.20	0.33	1.64	

APPENDIX V

Enteromorpha clathrata (Continued)

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
February 22, 1973	20.0	S[a]	0.60	0.44	0.26	2.31	1.93
		1	0.51	0.20	0.30	1.70	
		2	0.50	0.40	0.10	5.00	
March 8, 1973	20.0	S	0.44	0.37	0.07	6.29	2.05
		1	0.30	0.20	0.10	3.00	
		2	0.25	0.08	0.17	1.47	
March 30, 1973	20.0	S	0.65	0.43	0.22	2.96	2.10
		1	0.49	0.30	0.19	2.58	
		2	0.41	0.11	0.30	1.37	
April 25, 1973	20.0	S	0.98	0.82	0.16	6.13	1.01
		1	0.98	0.80	0.18	5.44	
		2	-	-	-	-	

[a] Surface incubation

APPENDIX V

Enteromorpha clathrata - Fill Creek

Date	Coverage Area m^2	Incubation Depth m[a]	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1972	20.0	S	1.17	0.59	0.58	2.02	3.10
June 8, 1972	20.0	S	1.71	0.84	0.97	1.77	4.20
June 16, 1972	20.0	S	1.94	0.91	1.03	1.89	4.17
July 8, 1972	20.0	S	1.47	0.51	0.96	1.54	6.59
July 26, 1972	25.0	S	1.19	0.71	0.48	2.49	6.50
August 1, 1972	25.0	S	2.19	1.08	1.11	1.97	6.20
August 23, 1972	30.0	S	1.22	0.63	0.59	2.07	4.40
September 27, 1972	20.0	S	0.74	0.51	0.23	3.25	2.14
October 27, 1972	20.0	S	0.72	0.50	0.22	3.27	2.00
November 29, 1972	10.0	S	0.51	0.20	0.31	1.65	1.40
December 20, 1972	10.0	S	0.41	0.25	0.16	2.54	1.10
January 10, 1973	10.0	S	0.19	0.09	1.10	1.90	1.08
January 31, 1973	10.0	S	0.14	0.04	0.11	1.27	1.00
February 13, 1973	5.0	S	0.16	0.09	0.07	2.29	0.92
February 22, 1973	2.0	S	0.20	0.09	0.11	1.82	0.75
March 8, 1973	2.0	S	0.19	0.07	0.12	1.65	1.74
March 30, 1973	15.0	S	0.74	0.47	0.27	2.75	1.39
April 25, 1973	15.0	S	0.61	0.37	0.24	2.54	2.79

[a] Surface incubation

APPENDIX V

Enteromorpha prolifera

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
May 2 , 1972	400.0	S[a]	1.06	0.38	0.68	1.56	23.07
June 8, 1972	450.0	S	1.49	0.76	0.73	2.05	29.04
June 16, 1972	440.0	S	2.06	1.49	0.57	3.62	17.47
July 8, 1972	450.0	S	2.10	0.92	1.27	1.68	23.33
July 26, 1972	300.0	S	1.25	0.55	0.69	1.82	24.00
August 1, 1972	300.0	S	2.19	1.08	1.11	1.97	21.80
August 23, 1972	300.0	S	1.08	0.70	0.38	2.84	6.00
			algae absent				
February 13, 1973	50.0	S	0.71	0.31	0.40	1.77	0.90
		1	0.53	0.21	0.32	1.65	
		2	0.27	0.12	0.15	1.78	
February 22, 1973	70.0	S	0.57	0.25	0.32	1.78	2.04
		1	0.41	0.21	0.20	2.03	
		2	0.30	0.12	0.18	1.67	
March 3, 1973	120.0	S	0.79	0.69	0.10	7.76	6.10
		1	0.64	0.47	0.17	3.73	
		2	0.39	0.11	0.28	1.38	
March 30, 1973	200.0	S	0.68	0.60	0.08	8.34	16.87
		1	0.57	0.44	0.13	4.39	
		2	0.49	0.17	0.32	1.54	
April 25, 1973	200.0	S	1.00	0.90	0.11	9.06	18.30
		1	0.72	0.56	0.15	4.80	
		2	-	-	-	-	

[a] Surface incubation

APPENDIX V

<u>Ulva lactuca</u>

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
June 16,1972	10.0	S[a]	1.04	0.67	0.37	2.82	4.93
July 9, 1972	10.0	S	1.39	0.90	0.49	2.84	12.13
July 26, 1972	8.0	S	0.44	0.27	0.17	2.60	5.07
			algae absent				
October 27, 1972	25.0	S	1.32	1.13	0.19	6.95	3.40
		1	0.52	0.34	0.24	2.18	
		2	0.57	0.13	0.45	1.27	
November 29, 1972	40.0	S	1.75	1.72	0.03	56.40[b]	3.98
		1	1.11	1.07	0.04	25.30[b]	
		2	1.46	1.34	0.11	13.27	
December 20, 1972	40.0	S	1.86	1.70	0.16	11.63	7.04
		1	1.43	1.17	0.26	5.47	
		2	1.25	0.84	0.41	3.02	
January 10, 1973	40.0	S	0.96	0.86	0.10	9.60	8.94
		1	0.95	0.77	0.18	5.28	
		2	0.84	0.43	0.41	2.05	
January 31, 1973	40.0	S	0.92	0.79	0.13	7.08	12.19
		1	1.08	0.76	0.32	3.38	
		2	0.83	0.37	0.46	1.80	
February 13, 1973	40.0	S	3.53	3.12	0.41	8.60	14.37
		1	2.88	2.66	0.43	6.78	
		2	1.99	1.50	0.49	4.06	
February 22, 1973	40.0	S	3.92	3.42	0.25	15.68	14.00
		1	3.10	2.75	0.35	8.86	
		2	0.70	0.44	0.26	2.69	

APPENDIX V

<u>Ulva</u> <u>lactuca</u> (Continued)

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
March 8, 1973	40.0	S[a]	0.61	0.50	0.21	2.91	10.98
		1	0.77	0.46	0.31	2.49	
		2	0.54	0.26	0.28	1.93	
March 30, 1973	40.0	S	0.53	0.28	0.25	2.12	10.21
		1	0.53	0.23	0.30	1.78	
		2	0.47	0.21	0.26	1.81	
April 26, 1973	40.0	S	0.70	0.59	0.11	6.36	7.19
		1	0.59	0.44	0.15	3.93	
		2	-	-	-	-	

[a] Surface incubation

[b] Light leak suspected

APPENDIX V

<u>Spirogyra</u> sp.

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
July 8, 1972	800.0	S[a]	3.31	2.03	1.28	2.59	1.43
July 22, 1972	800.0	S	3.22	1.66	1.56	2.07	3.00
August 1, 1972	800.0	S	4.31	1.74	2.57	1.68	3.89
August 23, 1972	800.0	S	2.54	1.49	1.03	2.47	11.40
September 27, 1972	800.0	S	0.93	0.15	0.78	1.19	4.89
October 27, 1972	800.0	S	0.74	0.05	0.69	1.07	0.74
			algae absent				

<u>Navicula</u> <u>grevillei</u>

Date	Coverage Area m^2	Incubation Depth m	Production $gCm^{-2}day^{-1}$	Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
February 13, 1973	800.0	S[a]	0.91	0.71	0.20	4.55	14.05
February 22, 1973	800.0	S	0.71	0.51	0.20	3.55	30.00
March 8, 1973	800.0	S	0.81	0.61	0.21	3.86	31.00
March 30, 1973	400.0	S	0.12	0.04	0.08	1.50	8.40
April 25, 1973	200.0	S	0.11	0.01	0.10	1.10	1.10

[a] Surface incubation

APPENDIX V

Pylaiella littoralis

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2} day^{-1}$	Net Production $gCm^{-2} day^{-1}$	Respiration $gCm^{-2} day^{-1}$	P/R	Biomass gCm^{-2}
January 10, 1973	200.0	S[a]	0.41	0.20	0.21	1.94	3.71
		1	0.31	0.13	0.18	1.72	
		2	0.29	0.10	0.19	1.53	
January 31, 1973	800.0	S	0.59	0.29	0.30	1.97	5.00
		1	0.51	0.23	0.28	1.82	
		2	0.40	0.17	0.23	1.74	
February 12, 1973	1200.0	S	0.94	0.70	0.23	4.09	7.90
		1	0.80	0.52	0.27	2.96	
		2	0.80	0.37	0.43	1.86	
February 22, 1973	1200.0	S	0.71	0.40	0.31	2.29	9.00
		1	0.69	0.30	0.39	1.77	
		2	0.42	0.10	0.32	1.31	
March 8, 1973	1200.0	S	0.96	0.69	0.27	3.56	11.00
		1	0.72	0.40	0.32	2.25	
		2	0.68	0.24	0.45	1.51	
March 30, 1973	1200.0	S	0.78	0.59	0.19	4.11	17.10
		1	0.72	0.48	0.25	2.88	
		2	0.61	0.20	0.41	1.49	
April 25, 1973	1200.0	S	0.88	0.57	0.31	2.84	14.10
		1	0.73	0.44	0.29	2.52	
		2	-	-	-	-	

[a] Surface incubation

APPENDIX V

Assemblage type I

Date	Coverage Area m^2	Incubation Depth m	Gross Production gCm^{-2}day^{-1}	Net Production gCm^{-2}day^{-1}	Respiration gCm^{-2}day^{-1}	P/R	Biomass gCm^{-2}
October 27, 1972	50.0	S[a]	0.99	0.62	0.37	2.68	0.98
		1	0.52	0.20	0.32	1.63	
		2	0.22	0.02	0.20	1.10	
November 29, 1972	200.0	S	0.37	0.15	0.22	1.68	2.95
		1	0.31	0.11	0.20	1.55	
		2	0.29	0.02	0.27	1.07	
December 20, 1972	200.0	S	0.41	0.19	0.22	1.86	3.89
		1	0.30	0.07	0.22	1.36	
		2	–	–	–	–	
January 10, 1973	250.0	S	0.37	0.20	0.18	2.06	4.98
		1	0.36	0.15	0.21	1.72	
		2	0.18	Nil	0.18	1.00	
February 13, 1973	300.0	S	0.31	0.17	0.14	2.21	4.90
		1	–	–	–	–	
		2	0.19	0.03	0.16	1.19	
March 8, 1973	100.0	S	0.17	0.12	0.05	3.34	2.10
		1	0.19	0.06	0.13	1.46	
		2	0.12	Nil	0.17	0.71	
			algae absent				

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[a] Surface incubation

APPENDIX V

Assemblage type III

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2} day^{-1}$	Net Production $gCm^{-2} day^{-1}$	Respiration $gCm^{-2} day^{-1}$	P/R	Biomass gCm^{-2}
May 25, 1972	150.0	S[a]	1.13	0.70	0.43	2.63	11.13
June 8, 1972	150.0	S	1.18	0.61	0.57	2.07	11.00
June 16, 1972	150.0	S	1.11	0.81	0.30	3.70	11.58
July 8, 1972	150.0	S	0.51	0.30	0.21	2.43	11.74
July 26, 1972	150.0	S	0.29	0.19	0.10	2.90	12.90
August 1, 1972	150.0	S	0.81	0.30	0.52	1.56	12.02
August 23, 1972	150.0	S	1.19	0.38	0.81	1.47	12.00
September 27, 1972	150.0	S	0.89	0.21	0.68	1.31	9.12
October 27, 1972	150.0	S	0.81	0.20	0.62	1.31	7.38
November 29, 1972	150.0	S	0.17	0.04	0.13	1.31	5.10
December 20, 1972	150.0	S	0.39	0.10	0.29	1.35	3.10
January 10, 1973	150.0	S	0.11	0.03	0.08	1.39	3.05
January 31, 1973	150.0	S	0.11	0.03	0.09	1.22	3.98
February 13, 1973	150.0	S	0.29	0.09	0.20	1.45	3.90
February 22, 1973	150.0	S	0.37	0.19	0.18	2.06	4.50
March 8, 1973	150.0	S	0.60	0.29	0.31	1.94	7.75
March 30, 1973	150.0	S	0.74	0.37	0.37	2.00	10.00
April 25, 1973	150.0	S	0.92	0.49	0.46	2.00	10.50

APPENDIX V

Assemblage type VII

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1973	1000.0	S[a]	1.43	0.68	0.75	1.91	9.87
June 8, 1972	1100.0	S	1.63	1.20	0.44	3.71	11.71
June 16, 1972	1120.0	S	1.02	0.60	0.44	2.32	23.52
July 8, 1972	350.0	S	2.22	0.51	1.71	1.30	13.60
July 26, 1972	200.0	S	1.48	Nil	2.10	0.71	4.35
	algae absent						

Assemblage type IX

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
January 31, 1973	15.0	S[a]	0.60	0.17	0.43	1.40	1.02
February 13, 1973	15.0	S	0.41	0.10	0.31	1.32	2.73
February 22, 1973	15.0	S	0.37	0.10	0.27	1.37	3.98
March 8, 1973	15.0	S	0.69	0.12	0.57	1.21	3.70
March 30, 1973	15.0	S	0.51	0.10	0.42	1.21	1.14
	algae absent						

[a] Surface incubation

APPENDIX V

Assemblage type X

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
January 31, 1973	4.0	S[a]	0.91	0.47	0.44	2.07	1.39
February 13, 1973	4.0	S	0.74	0.30	0.43	1.72	2.10
February 22, 1973	4.0	S	0.71	0.37	0.34	2.09	2.15
March 8, 1973	4.0	S	0.60	0.30	0.30	2.00	1.75
March 30, 1973	4.0	S	0.72	0.19	0.53	1.36	0.98
				algae absent			

Assemblage type XI

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
January 10, 1973	1000.0	S[a]	1.02	0.42	0.60	1.70	3.10
January 31, 1973	1000.0	S	1.59	0.90	0.69	2.30	5.72
February 13, 1973	1000.0	S	1.73	0.91	0.82	2.11	5.98
February 22, 1973	1000.0	S	-	-	-	-	9.19
March 8, 1973	1000.0	S	1.14	0.31	0.83	1.37	12.30
March 30, 1973	1000.0	S	1.01	0.37	0.64	1.58	6.12
April 25, 1973	1000.0	S	0.37	0.06	0.31	1.20	5.50

[a] Surface incubation

APPENDIX V

Rhodophyte filaments

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
September 27, 1972	40.0	S[a]	1.09	0.89	0.20	5.45	7.84
October 27, 1972	120.0	S	1.14	0.76	0.38	3.00	31.21
		1	1.02	0.50	0.52	1.96	
		2	1.00	0.27	0.73	1.37	
November 29, 1972	100.0	S	0.41	0.21	0.20	2.05	42.90
		1	0.40	0.17[b]	0.23	1.74	
		2	-	0.07	-	-	
December 20, 1972	100.0	S	0.47	0.21	0.26	1.81	19.76
		1	0.41	0.20	0.21	1.95	
		2	0.38	0.17	0.21	1.81	
January 10, 1973	60.0	S	0.41	0.20	0.21	1.95	3.94
		1	0.39	0.18	0.21	1.86	
		2	0.36	0.13	0.23	1.57	
				algae absent			

[a] Surface incubation

[b] Dark bottle lost

EAST DELTA

APPENDIX V

Enteromorpha clathrata - West side

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
May 25, 1972	60.0	S[a]	1.94	0.99	0.96	2.03	15.20
June 9, 1972	60.0	S	2.94	1.11	1.82	1.62	18.00
June 21, 1972	60.0	S	2.79	2.15	0.64	4.32	17.42
July 12, 1972	60.0	S	2.96	1.49	1.47	2.02	18.86
July 20, 1972	60.0	S	4.31	3.29	1.03	4.18	28.54
August 3, 1972	60.0	S	2.25	0.98	1.26	1.79	22.74
August 11, 1972	60.0	S	0.94	0.29	0.65	1.45	22.00
August 23, 1972	60.0	S	1.27	0.71	0.56	2.27	17.30
September 28, 1972	40.0	S	0.06	0.02	0.05	1.20	14.20
October 24, 1972	40.0	S	1.21	0.82	0.39	3.10	6.41
		1	0.87	0.40	0.46	1.89	
November 28, 1972	40.0	S	0.92	0.40	0.52	1.78	2.50
		1	0.71	0.23	0.48	1.48	
December 20, 1972	20.0	S	0.69	0.28	0.41	1.68	1.80
		1	0.37	0.10	0.27	1.37	
January 10, 1973	20.0	S	0.19	0.07	0.12	1.58	1.74
		1	0.07	0.02	0.05	1.40	
February 13, 1973	20.0	S	0.90	0.52	0.38	2.39	1.00
		1	0.81	0.40	0.41	1.98	
February 22, 1973	20.0	S	0.68	0.39	0.29	2.35	0.50
		1	0.49	0.21	0.28	1.75	
March 8, 1973	20.0	S	0.41	0.19	0.22	1.86	0.52
		1	0.23	0.04	0.19	1.21	
March 30, 1973	20.0	S	0.42	0.17	0.25	1.70	0.84
		1	0.37	0.11	0.26	1.46	
April 25, 1973	10.0	S	0.67	0.34	0.33	2.03	0.90
		1	0.50	0.22	0.28	1.79	

[a] Surface incubation

APPENDIX V

<u>Enteromorpha prolifera</u>

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1972	200.0	S[a]	1.64	0.77	0.87	1.89	25.00
June 9, 1972	200.0	S	3.71	2.10	1.61	2.30	26.40
June 21, 1972	200.0	S	2.99	2.44	0.55	5.42	22.00
July 12, 1972	200.0	S	2.51	0.70	1.81	1.39	28.00
July 20, 1972	150.0	S	3.71	2.50	1.21	3.03	33.82
August 3, 1972	100.0	S	1.67	0.57	1.09	1.53	26.50
August 11, 1972	100.0	S	1.50	1.19	0.31	4.84	16.00
August 23, 1972	100.0	S	1.37	0.50	0.87	1.58	6.10
			algae absent				
January 10, 1973	20.0						3.14
February 13, 1973	100.0						10.90
February 22, 1973	250.0		production values for <u>E. prolifera</u> on central delta applicable				12.92
March 8, 1973	300.0						15.71
March 30, 1973	300.0						19.75
April 25, 1973	300.0						30.00

[a] Surface incubation

APPENDIX V

<u>Enteromorpha</u> <u>clathrata</u> - East side

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1972	100.0	S[a]	1.92	1.12	0.80	2.40	24.90
June 9, 1972	150.0	S	4.37	2.97	1.40	3.12	25.13
June 21, 1972	200.0	S	3.62	2.71	0.91	3.98	22.00
July 12, 1972	200.0	S	5.10	3.01	2.09	2.44	23.70
July 20, 1972	200.0	S	5.45	3.67	1.66	3.28	33.82
August 3, 1972	200.0	S	0.89	0.12	0.77	1.16	18.88
August 11, 1972	150.0	S	0.59	0.24	0.35	1.69	10.00
August 23, 1972	50.0	S	1.38	0.59	0.80	1.73	7.32
	algae absent and study area abandoned						

<u>Spirogyra</u> sp. - Central area

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
June 21, 1972	300.0	S[a]	3.94	2.84	1.11	3.56	7.20
July 10, 1972	335.0	S	2.18	1.63	0.55	3.96	7.80
July 20, 1972	660.0	S	5.31	3.32	1.99	2.67	8.40
August 3, 1972	950.0	S	3.55	2.48	0.84	4.23	11.91
August 11, 1972	900.0	S	1.94	0.71	1.23	1.58	12.35
August 23, 1972	600.0	S	1.92	0.99	0.92	2.09	8.19
September 28, 1972	300.0	S	1.73	0.89	0.84	2.06	5.92
October 24, 1972	100.0	S	1.90	1.25	0.66	2.88	1.29
	algae absent						

[a] Surface incubation

APPENDIX V

Spirogyra sp. - Cattermole Creek

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2} day^{-1}$	Net Production $gCm^{-2} day^{-1}$	Respiration $gCm^{-2} day^{-1}$	P/R	Biomass gCm^{-2}
		[a]					
July 10, 1972	175.0	S	2.46	1.75	0.71	3.47	1.72
July 20, 1972	285.0	S	6.11	3.91	2.19	2.79	3.14
August 3, 1972	200.0	S	6.56	3.38	3.18	2.06	4.92
August 23, 1972	200.0	S	3.71	1.81	1.90	1.95	4.70
September 28, 1972	50.0	S	2.49	0.51	1.98	1.26	1.89
			algae absent				

[a] Surface incubation

APPENDIX V

Ulva lactuca - West side

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1972	100.0	S[a]	1.89	0.91	0.98	1.93	5.10
June 9, 1972	140.0	S	1.94	0.90	1.04	1.87	4.75
June 21, 1972	80.0	S	1.31	0.71	0.60	2.18	4.70
July 10, 1972	20.0	S	1.47	0.81	0.66	2.23	3.02
			algae absent				
October 24, 1972	50.0	S	1.59	1.42	0.16	9.94	4.10
		1	1.03	0.77	0.26	3.96	
November 28, 1972	100.0		production values for *U. lactuca* on central delta applicable.				5.00
December 20, 1972	200.0						7.00
January 10, 1973	200.0						7.10
January 31, 1973	600.0						10.30
February 13, 1973	1000.0						17.19
February 22, 1973	1000.0						20.73
March 8, 1973	800.0						24.71
March 30, 1973	600.0						20.30
April 25, 1973	500.0						10.13

[a] Surface incubation

APPENDIX V

Ulva lactuca - East side

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
May 25, 1972	100.0	S[a]	1.74	1.02	0.72	2.42	3.96
June 9, 1972	150.0	S	3.06	1.76	1.30	2.35	4.80
June 21, 1972	200.0	S	2.37	1.62	0.75	3.16	5.60
July 10, 1972	200.0	S	3.83	3.12	0.70	5.47	8.41
July 19, 1972	200.0	S	6.15	5.42	0.73	8.42	8.41
August 3, 1972	100.0	S	3.67	1.57	1.09	3.37	7.36
August 11, 1972	100.0	S	1.11	0.51	0.60	1.85	7.10
August 23, 1972	50.0	S	3.11	1.20	1.91	1.63	6.92
September 28, 1972	50.0	S	3.51	0.94	2.57	1.37	6.49
October 24, 1972	50.0	S	1.85	1.00	0.85	2.18	4.10
November 28, 1972	50.0	S	1.03	0.41	0.62	1.66	3.99
			- study area abandoned -				

[a] Surface incubation

APPENDIX V

Ulva lactuca - Central area

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2} day^{-1}$	Net Production $gCm^{-2} day^{-1}$	Respiration $gCm^{-2} day^{-1}$	P/R	Biomass gCm^{-2}
October 24, 1972	200.0	S[a]	1.19	0.70	0.49	2.43	1.71
November 28, 1972	200.0	S	0.61	0.39	0.22	2.79	2.20
December 20, 1972	200.0	S	0.69	0.34	0.35	1.98	2.91
January 10, 1973	200.0	S	0.65	0.39	0.26	2.50	2.10
February 13, 1973	200.0	S	1.00	0.53	0.47	2.13	1.00
February 22, 1973	200.0	S	0.92	0.57	0.35	2.63	1.65
March 8, 1973	200.0	S	1.01	0.71	0.30	3.37	2.80
March 30, 1973	200.0	S	0.99	0.71	0.28	3.54	2.00
April 26, 1973	200.0	S	0.88	0.71	0.17	5.18	1.20

[a] Surface incubation

APPENDIX V

Rhodophyte filaments

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
September 28, 1972	80.0	S[a]	1.17	0.99	0.18	6.50	6.14
October 24, 1972	120.0	S	1.31	1.00	0.32	4.09	15.42
		1	1.01	0.62	0.39	2.59	
November 28, 1972	140.0	S	0.79	0.31	0.48	1.65	39.19
		1	0.62	0.29	0.33	1.88	
December 20, 1972	140.0	S	0.71	0.39	0.32	2.22	32.14
		1	0.48	0.13	0.26	1.85	
January 10, 1973	60.0	S	0.41	0.20	0.21	1.95	4.10
		1	0.21	0.08	0.12	1.75	
				algae absent			

Pylaiella littoralis

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
January 10, 1973	50.0						0.90
February 13, 1973	100.0						2.14
February 22, 1973	100.0		production values for *P. littoralis* on central delta applicable.				2.90
March 8, 1973	100.0						3.42
March 30, 1973	100.0						3.10
April 26, 1973	100.0						2.24

[a] Surface incubation

APPENDIX V

Assemblage type III

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1972	1300.0	S[a]	1.39	0.81	0.58	2.40	12.70
June 9, 1972	1300.0	S	1.47	0.90	0.57	2.58	11.63
June 21, 1972	1300.0	S	1.09	0.62	0.47	2.32	10.71
July 10, 1972	1300.0	S	0.92	0.57	0.35	2.63	10.98
July 20, 1972	1300.0	S	0.81	0.41	0.40	2.03	11.58
August 3, 1972	1300.0	S	0.91	0.47	0.44	2.07	10.93
August 11, 1972	1300.0	S	0.74	0.39	0.35	2.11	9.11
August 23, 1972	1300.0	S	1.12	0.48	0.64	1.75	8.37
September 28, 1972	1300.0	S	0.82	0.35	0.47	1.75	8.14
October 29, 1972	1300.0	S	0.72	0.32	0.40	1.80	6.10
November 28, 1972	1300.0	S	0.48	0.20	0.28	1.71	6.90
			- study area abandoned -				

[a] Surface incubation

APPENDIX V

Assemblage type IV

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	P/R	Biomass gCm^{-2}
May 25, 1972	10.0	S[a]	1.71	0.97	0.74	2.31	38.14
June 9, 1972	10.0	S	1.74	0.99	0.75	2.32	40.10
June 21, 1972	10.0	S	1.40	0.92	0.48	2.92	40.25
July 10, 1972	15.0	S	1.51	0.74	0.77	1.96	47.08
July 20, 1972	20.0	S	1.40	0.93	0.47	2.98	51.60
August 3, 1972	20.0	S	1.15	0.75	0.40	2.88	48.13
August 11, 1972	25.0	S	0.71	0.14	0.57	1.25	30.19
August 23, 1972	25.0	S	1.10	0.47	0.63	1.75	21.30
September 28, 1972	15.0	S	1.00	0.21	0.79	1.27	14.10
October 24, 1972	10.0	S	0.87	0.22	0.65	1.34	9.10
November 28, 1972	10.0	S	0.89	0.17	0.72	1.24	10.14
			- study area abandoned -				

[a] Surface incubation

APPENDIX V

Assemblage type V

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1972	1000.0	S[a]	0.91	0.42	0.49	1.85	8.20
June 9, 1972	600.0	S	0.83	0.45	0.38	2.17	4.88
June 21, 1972	200.0	S	0.31	0.04	0.27	1.15	2.14
			algae absent				

Assemblage type VI

Date	Coverage Area m^2	Incubation Depth m	Gross Production $gCm^{-2}day^{-1}$	Net Production $gCm^{-2}day^{-1}$	Respiration $gCm^{-2}day^{-1}$	$^P/_R$	Biomass gCm^{-2}
May 25, 1972	600.0	S[a]	0.99	0.62	0.37	2.68	14.09
June 9, 1972	600.0	S	1.95	0.80	1.15	1.70	14.91
June 21, 1972	450.0	S	1.20	0.90	0.30	4.00	12.80
July 12, 1972	50.0	S	1.20	0.47	0.78	1.54	2.76
July 20, 1972	10.0	S	0.81	0.13	0.68	1.19	2.00
			algae absent				

[a] Surface incubation