PRIMARY PRODUCTIVITY OF THE FRASER RIVER DELTA FORESHORE: YIELD ESTIMATES OF EMERGENT VEGETATION.

by

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ABSTRACT

The emergent vegetation of tidal marshes of the Fraser River foreshore is probably of great importance to the rich life of the foreshore, especially to waterfowl and fish. The vegetation "fixes" solar radiation which is "released" as organic matter in the brackish marsh and salt water marsh ecosystems. Much of the foreshore vegetation, however, has been destroyed by diking and industrial development and more destruction from many sources is threatened.

My study was initiated to assay present standing crops of emergent vegetation in the major areas from Point Grey to the International Boundary and also to establish semi-permanent transects for the study of future vegetation change.

Fourteen semi-permanent transects, the combined length of which is 7,550 meters (4.7 miles), were established from shore seawards at points in the area from Point Grey to Crescent Beach, roughly a distance of 30 kilometers (19 miles). Both plant and soil samples were collected along the transects, at intervals, in 1973 and 1974; dry matter yield, ash, nitrogen and lignin were determined for plant samples; pH, organic matter and electric conductivity were determined on soil samples.

The standing crop of the tidal marshes, estimated to occupy 1,901 hectares (4,697 acres) was approximately 9,408 metric tons of dry matter with an average d.m. yield of 4.9 tons per hectare (4,400 lb./acre). Eight marsh plants contributed overwhelmingly to the d.m. yield: *Carex lyngbyei, Scirpus americanus* and *Scirpus paludosus* alone accounted for 81% of the standing crop in 1974.

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1. INTRODUCTION

The emergent vegetation of the tidal flats and marshes of Boundary Bay and the foreshore of the delta of the Fraser River in southwestern B.C. is the product of complicated interrelationships between the salt waters of the Gulf of Georgia, the fresh waters of the Fraser River and lesser streams, the many substrates, the maritime climate, the fauna and other variables. It is clear that the emergent vegetation, as a primary production element in the biological system of the estuary, is important to the more several million waterfowl, resident and transient, to the local agriculture, and, to the rich fishery of the gulf and rivers. It is also clear that the emergent vegetation, of all the components of the system, has been most modified and is, currently, most threatened by man's dikes, booming grounds, flotsam and jetsam, airports, marinas, port facilities, urban effluents, dredging and filling.

In the work reported here I have (a) established and studied transects, hopefully "permanent", running from dikes seawards on which changes in substrate and vegetation can be recorded over a period of years and (b) initiated measurement of trophodynamic processes, which may be important in the conservation of the natural resources, and, a knowledge of which, may be important in environmental repair or enhancement.

2. DESCRIPTION OF THE STUDY AREA

2.1 Location

The study area is located on the Pacific Coast of southwestern British Columbia where the 1,400 km. long Fraser River meets the sea, and where Vancouver Ciry, a major Canadian metropolis, is located. The study area includes the larger part of the estuarine marsh of the Fraser River; the river and estuary are the largest in the Pacific Coast of Canada. These tidal marshes may be sub-divided into three sections from north to south, viz. those of Sturgeon Bank, of Roberts Bank and of Boundary Bay (Fig. 1). The Sturgeon Bank marshes are northernmost and closest to Vancouver City and lie off two deltaic islands, i.e. Sea Island and Lulu Island. The Roberts Bank marshes, lying off Westham Island and the Tsawwassen area, are less accessible than those off Sturgeon Bank and are more removed from residential areas; they are, however, strong candidates for industrial sites such as a multi-million dollar oil refinery and a (4 million metric ton) steel mill. The Boundary Bay marshes are most removed from the Fraser River influences and are located on a broad low gradient tidal flat which is used for recreation.

Jurisdiction of the tide lands is not well defined. In general it would seem that the federal authority is dominant in areas seaward from the dykes and the provincial authority is dominant on land and much of the water within the dykes. Several cooperative, federal and provincial projects, such as those relating to dyking and waterfowl, relate closely to the foreshore habitat.

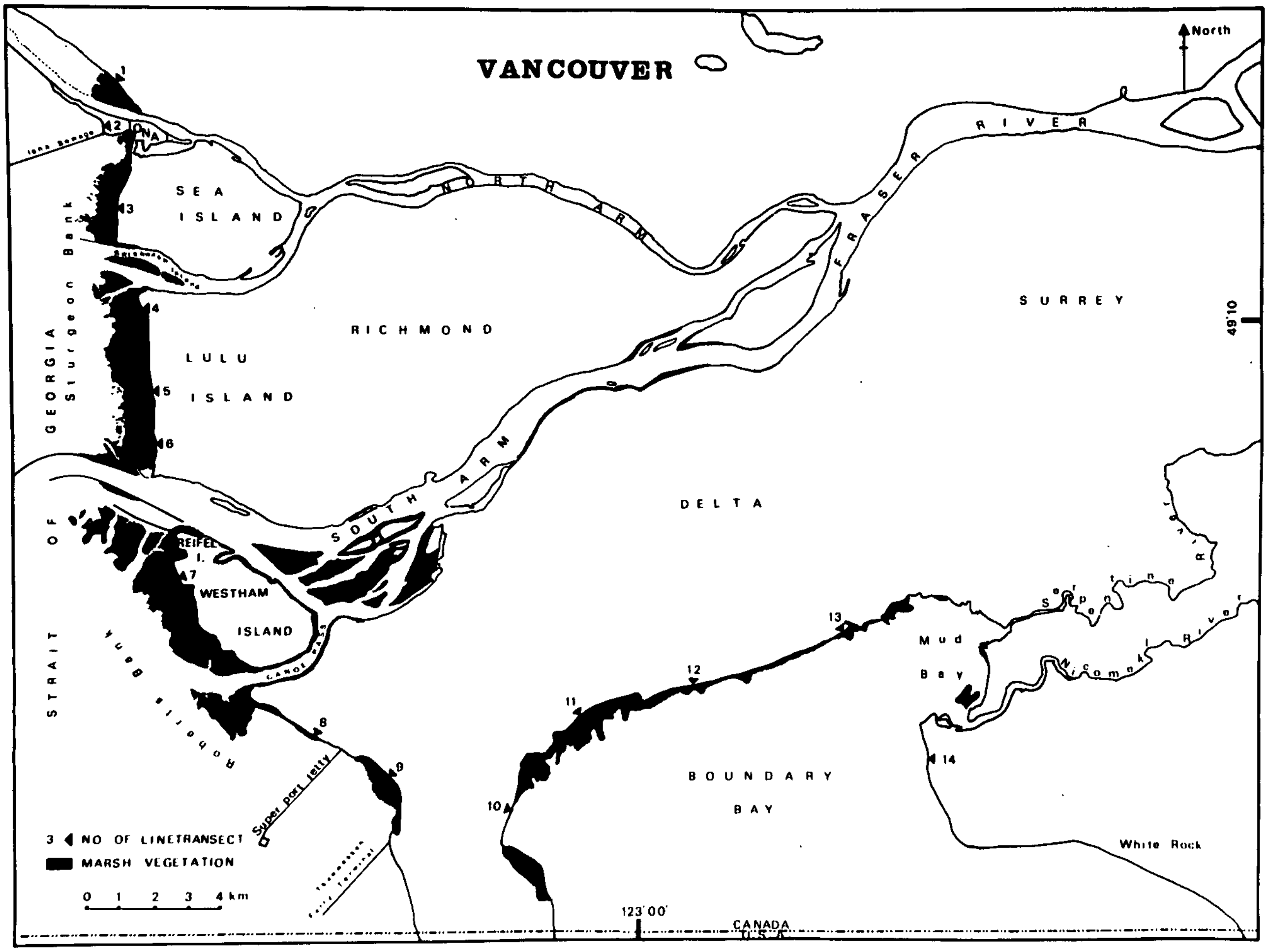


Figure 1. General location of the tidal marshes of the Fraser River Delta Foreshore and Boundary Bay.

2.2 Climate

The climate of Lower Fraser Valley, apart from the usual latitudinal influences, is mainly influenced by three factors, the prevailing westerly winds, the moist Pacific air from the warm Japan Current, and the mountain barrier. The climate of the study area falls into the general category of the West Coast Marine type, although variability is marked. Fig. 2 shows that much of the total precipitation occurs during the six months, i.e. May to October; the highest and lowest mean daily temperatures vary from 2.4^{o}C for January and 17.4^{o}C for July. The large local differences in sunshine, temperature and precipitation over short geographical distances, e.g. between Vancouver and White Rock, are shown in Table I; Vancouver receives much more rainfall; in the four months from November through February, Vancouver receives fewer sunshine hours (219) than in the single month of July (280) (Canada Department of the Environment, 1970). This is in part because the nearby Coast Mountains force cloudy, warm, moist Pacific air to rise and to release moisture. Storm tracks in winter bring maximum precipitation and much cloud. The general variability of Lower Fraser Valley climates is more clearly shown in Fig. 3 (a) and (b). The July to August mean temperatures increase from south to north. It can be seen that between Ladner and North Vancouver, there is a large difference in mean annual precipitation with the highest figure for the latter centre.

Table I: Mean daily temperature and mean total precipitation in Lower Fraser Valley, B.C. (30 year record).

Location	J	F	M	A	M	J	J	A	S	O	N	D	Year
Vancouver, U.B.C., (Lat. 49 15 N, Long. 123 15 N, Elev. 9.5 m. A.S.L.)													
M.D. Temp. (°C)	2.8	4.7	5.9	8.6	12.0	14.7	17.1	16.8	14.5	10.4	6.3	4.1	9.3
M.T. Precip. (mm)	71	132	101	68	53	48	32	48	67	150	167	195	1230
Vancouver Int. Airport, (Lat. 49 18 N, Long. 123 07 N, Elev. 5 m. A.S.L.)													
M.D. Temp. (°C)	2.4	4.4	5.8	8.9	12.4	15.3	17.4	17.1	14.2	10.1	6.1	3.8	9.8
M.T. Precip. (mm)	147	117	95	61	48	45	30	37	61	122	141	165	1069
Ladner Monitor Station, (Lat. 49 04 N, Long. 123 07 W, Elev. 0 m. A.S.L.)													
M.D. Temp. (°C)	2.3	4.2	5.7	8.6	11.8	14.6	16.4	16.1	13.5	9.6	5.9	4.3	9.4
M.T. Precip. (mm)	115	99	83	52	38	45	24	31	50	99	125	143	903
Steveston, (Lat. 49 07 N, Long. 123 11 W, Elev. 1.3 m. A.S.L.)													
M.D. Temp. (°C)	2.2	4.1	5.6	8.6	11.9	14.7	16.7	16.3	13.7	9.6	5.7	3.5	9.4
M.T. Precip (mm)	138	106	82	56	45	42	26	37	57	117	137	152	994
White Rock, (Lat. 49 02 N, Long. 122 50 W, Elev. 17 A.S.L.)													
M.D. Temp (°C)	2.6	4.7	5.9	8.7	11.9	14.3	16.2	16.1	13.9	10.2	6.2	4.2	9.6
M.T. Precip. (mm)	138	111	91	66	52	50	27	43	60	117	139	154	1047

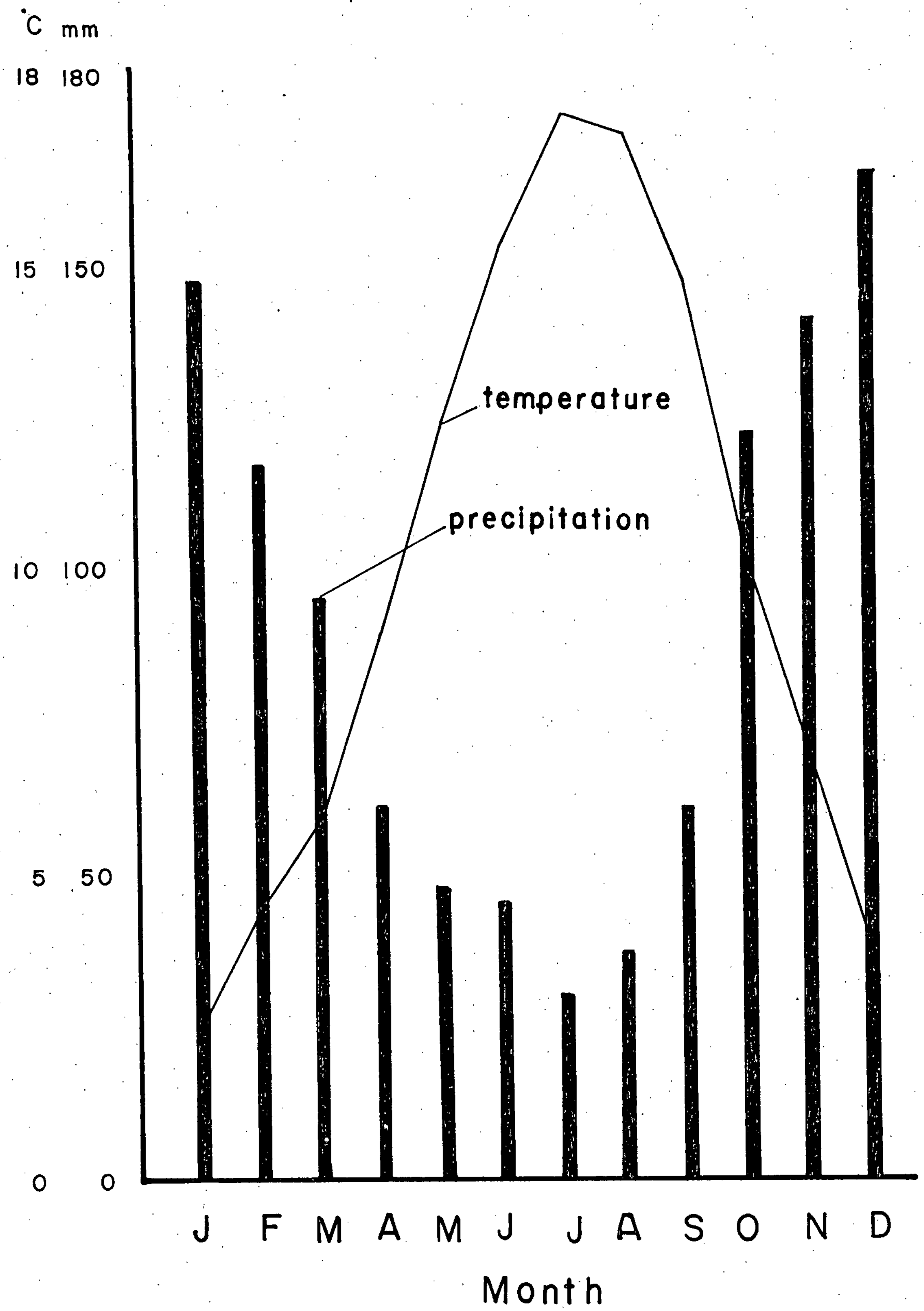
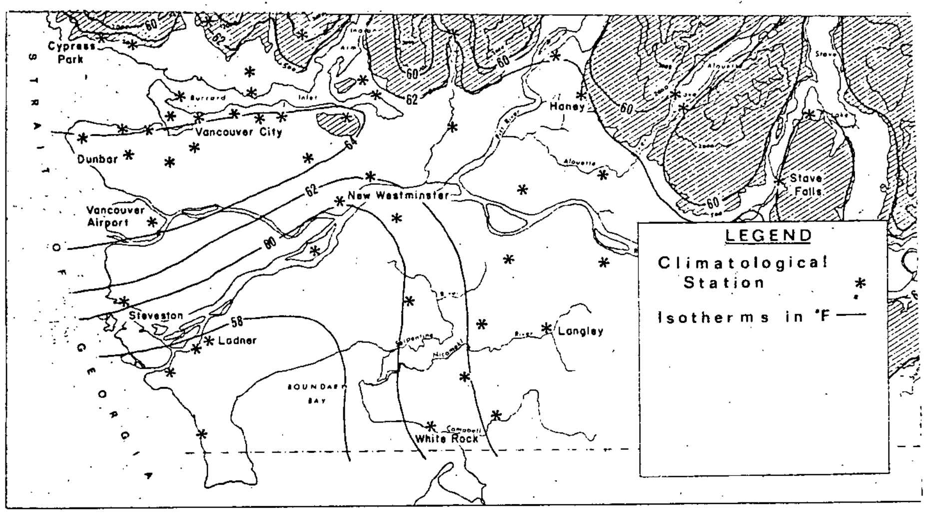
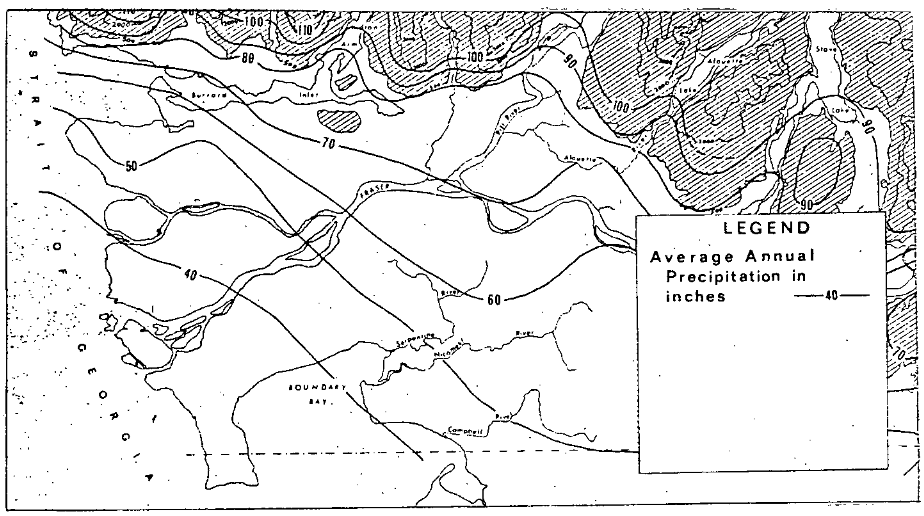


Figure 2. Mean monthly temperature and mean monthly precipitation for Vancouver International Airport, Sea Island, B. C. (30 year record).



(A)



(B)

Figure 3. July to August mean temperature in Lower Fraser Valley (A), and average annual precipitation in Lower Fraser Valley (B).

(Stager and Wallis, 1968).

2.3 Geology and Soil

Available evidence suggests that the present 1,400 km. long Fraser River delta began to fan out from the gap in the Pleistocene uplands at New Westminster about 8000 years ago. The delta has since advanced into the Strait of Georgia at an estimated rate of 13×10^6 cubic meters per year and has built up deposits 100 to 200 meters thick or 0.42 mm. per year on the average for the last 4350 years over Pleistocene sediments (Kellerhals *et al.*, 1969; Mathews *et al.*, 1962). The 23×10^4 square kilometer drainage basin of the Fraser River is underlain by plutonic, volcanic, metamorphic and sedimentary rock and glacial deposits. Mackintosh *et.al.* (1966) have noted that "sediments contributed to the lower Fraser valley by the Fraser River are composed largely of quartz, feldspar, chlorite, mica and amphibole. The finer colloidal clay particles, mostly dispersed through the delta's distributary system during the freshet months of May, June and July, flocculate as the river water mixes with sea water and settle out gravitationally at the outer edge of the delta and seaward. The finer suspended sediment has been observed to contain almost equal proportions of montmorillonite, illite, and chlorite (Griffin *et al.*, 1968).

The foreshore of this alluvium roughly consists of Sturgeon Bank, Roberts Bank, Mud Bay and Boundary Bay. The two banks together form about 15,000 hectares of silty or clayey intertidal area. The tidal flats of the two bays extend 4 km. seaward and cover an area of ca. 65 square kilometers. Mud Bay and Boundary Bay were part of the Fraser delta system in the Recent geological past. They are still influenced by currents generated by the Fraser River, and presently have a fresh water input from the Serpentine and Nicomekl Rivers (Kellerhals *et al.*, 1969; Tiffin, 1969). Mud Bay is silty or clayey and Boundary Bay sandy.

2.4 Vegetation

In the vegetation of the tidal marshes there is, as elsewhere in the world's tidal marshes, little diversity in floristic composition. In the sutdy area the most common five tidal marsh communities are *Carex lyngbyei*, *Scirpus americanus*, *Scirpus paludosus*, *Typha latifolia* and *Salicornia validus* in order of decreased standing crop yield. The *Scirpus a.* community may be the most aggressive and successfully established and certainly it occupies the largest area and at the lowest tidal flats. The *Carex l.* community, not far from dikes, is also important because of its highest standing crop yield per unit of area.

The vegetation of the Boundary Bay area is influenced the least by the Fraser River and therefore develops on a more saline substrate than the substrates of the marshes of the north and south arms of the Fraser River. It mainly consists of *Salicornia v.*, *Distichlis stricta* and *Triglochin maritimum*. These species are less importnat in terms of the trophic system due to their low dry matter yield per unit area and their limited distribution. The low stature is a characteristic feature.

The dike vegetation, the object of frequent man-induced and natural changes, shows most diversity in plant species. Some major vegetation areas of the outer Fraser valley are shown in Fig. 4.

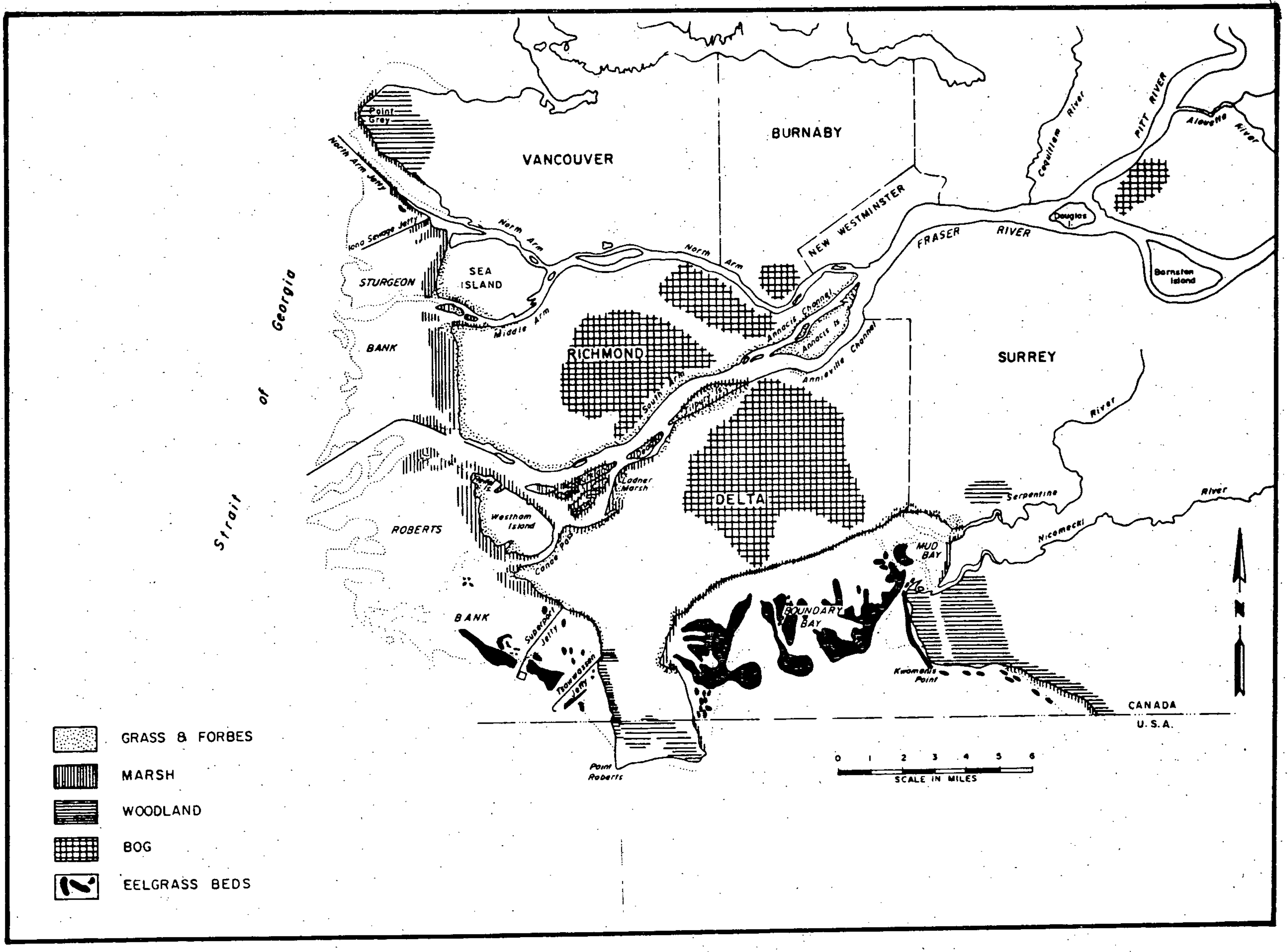


Figure 4. Some major vegetation areas.
(after Hoos et al., 1974; Forbes, 1972).

2.5 Other features

The oceanographic characteristics of the Fraser River estuary are strongly affected by quantity, quality and timing of the flow of freshwater, and by the tides and the winds of the Stratis of Georgia. The surface current patterns, particularly in the northern part of the estuary where the North Arm of the fraser River is "trained" by the North Arm Jetty, are stongly dominated by the Fraser River flow (Fig. 5). The waters are not sufficiently mixed by tidal and wind action to create vertical homogeneity. Therefore, there exists a two-layered system which extends beyond the immediate esturay into the Strait of Georgia, but not into the well mixed waters of the southern channels between the San Juan Islands (Hoos *et al.*, 1973).

Characteristic of the Pacific coast of North America, the tides of the Strait of Georgia, including the Fraser River estuary, are of the mixed type. This means that the tides are a mixture of diurnal and semidiurnal inequality which affects both the time and height of the tide. This occurs principally in the height and in the time of succeeding low tides. There is an approxiamtely two week cycle in tidal ranges, as well as a seasonal cycle. In the Fraser River estuary, as in other parts of the Strait of Georgia, the lowest tide occurs near midnight during the winter months and near midday during the summer (Hoos *et al.*, 1973).

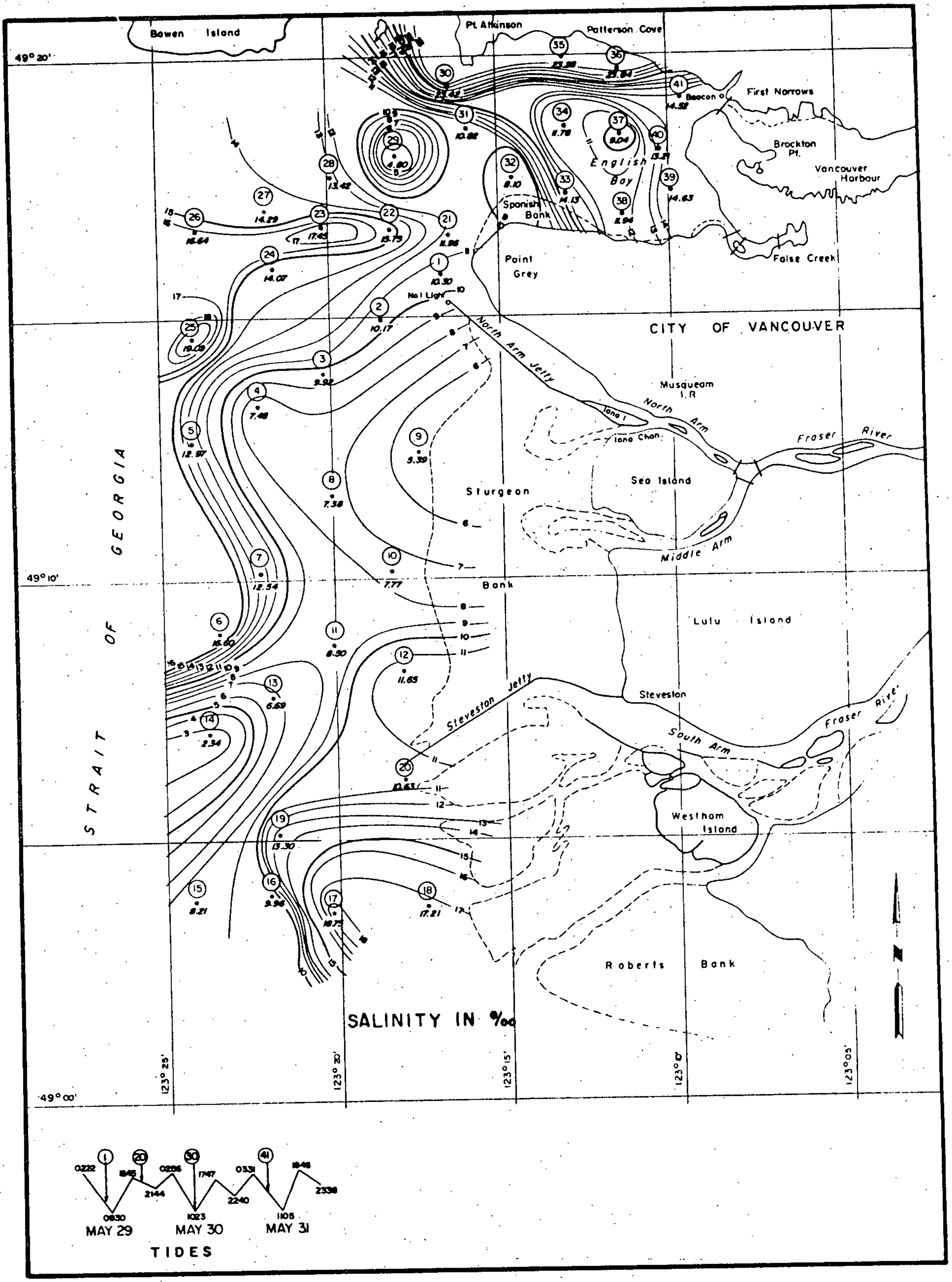


Figure 5. Surface distribution of salinity at the Fraser River estuary, May 29 - June 1, 1950.
(Waldichuk, 1957). Sample numbers and salinity in $^{0}/oo$.

3. LITERATURE REVIEW

3.1 The role of the tidal brackish marshes

Coastal tidal marshes may be grouped into: a) tidal fresh-water marsh and b) tidal brackish marsh. A tidal brackish marsh exists at the mouth of a river, on the alluvium where the river enters the sea. Smith (1966) describes the formation of the tidal brackish marshes, which are the concern of this report, as follows: the tidal brackish marshes begin in most cases as mud or sand flats, at first colonized by algae and then, if the water is not too deep, by eelgrass (*Zostera*, a submerged species not found in fresh or slightly brackish waters). As organic debris and sediments accumulate, eelgrass is replaced by the first brackish-marsh colonists or emergents. The tide flushes the brackish marsh with a diurnal regularity and, over a period of several weeks, makes the estuarine water more or less homogenous (de la Cruz, 1965).

Although to the eye salt marshes may appear as waving acres of "grass" they are, instead, a complex of distinctive and clearly demarcated plant associations (Smith, 1966). There are several functions served by tidal marshes which confer on them an importance only recently recognized.

In the first place, as Whittaker (1970) observes, salt marsh vegetation is, in comparison with many terrestrial communities, very productive of dry matter. Not only are they productive but they clearly produce an excess of organic matter which is exported seawards (Odum, 1961); much of the organic matter, probably almost half (de la Cruz, 1965) goes to the foreset beds of the delta where it provides energy for the rich life there.

Secondly the salt marsh is a region where fresh and salt water mix, and where because of their dilution, the salts of the sea may (again) become available as nutrients in generous amounts to terrestrial plants and where silts and organic debris brought down by the river may be "trapped". Daily the tides bring in nutrients and remove waste so that there is a good production of phytoplankton in the general vicinity of the estuary which with the mudbank algae are a primary food source for the various consumer levels (Wagner, 1971).

The main role of the salt marsh is probably to supply food directly for animals grazing the living plant tissues; not always apparent, this role varies from place to place in importance as do the grazers themselves; they may be waterfowl, fish or invertebrates (Fig. 6 and Fig. 7). Species as diverse as the shrimp and the bluefish may spend a critical part of their life cycle in the tidal marsh (Massachusetts Institute of Technology, 1970). According to Gareth (1974) benthic invertebrates may feed on algae which are photosynthetic in the intertidal area at times when tides are out and at times when the murky waters of the freshet or when the deep waters of the high tide screen out sunlight.

Many investigators have reported on the importance of tidal marsh vegetation as a source of energy, i.e. organic detritus, for numerous estuarine or marine consumers. Perkins (1974) estimates the contribution of particulate organic matter to the waters of the Georgia Strait, B.C. as greater than $1\text{-}2 \times 10^{6}$ tons per year. The sources of detritus are the many rivers, logging activities along the coast, the flotsam and jetsam from ships, barges, etc. and the sewage and mill wastes from industrial and suberban areas.

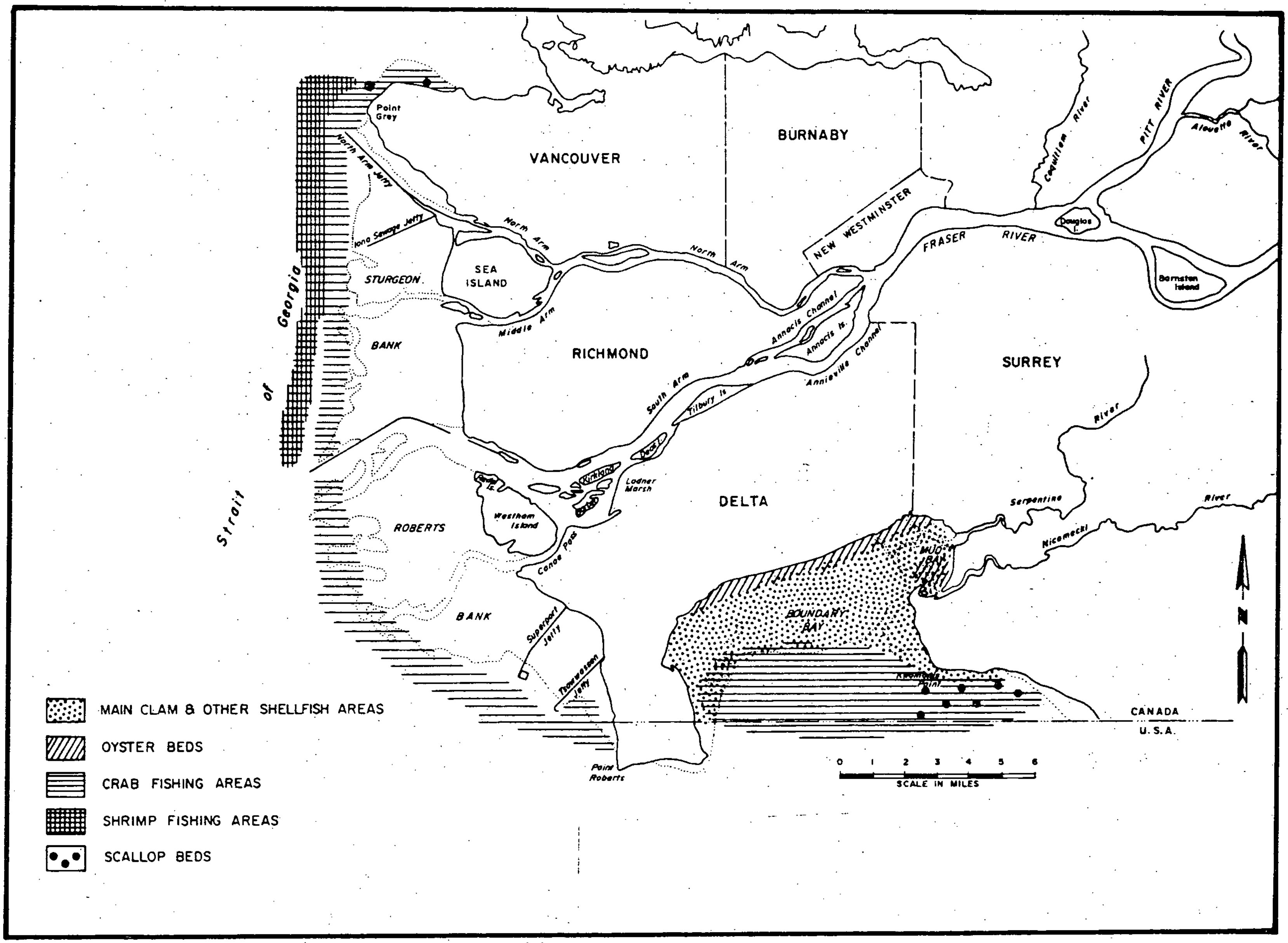


Figure 6. Major invertebrate growing and fisheries areas (U.S. Nat. Parks and Parks Canada, 1973).

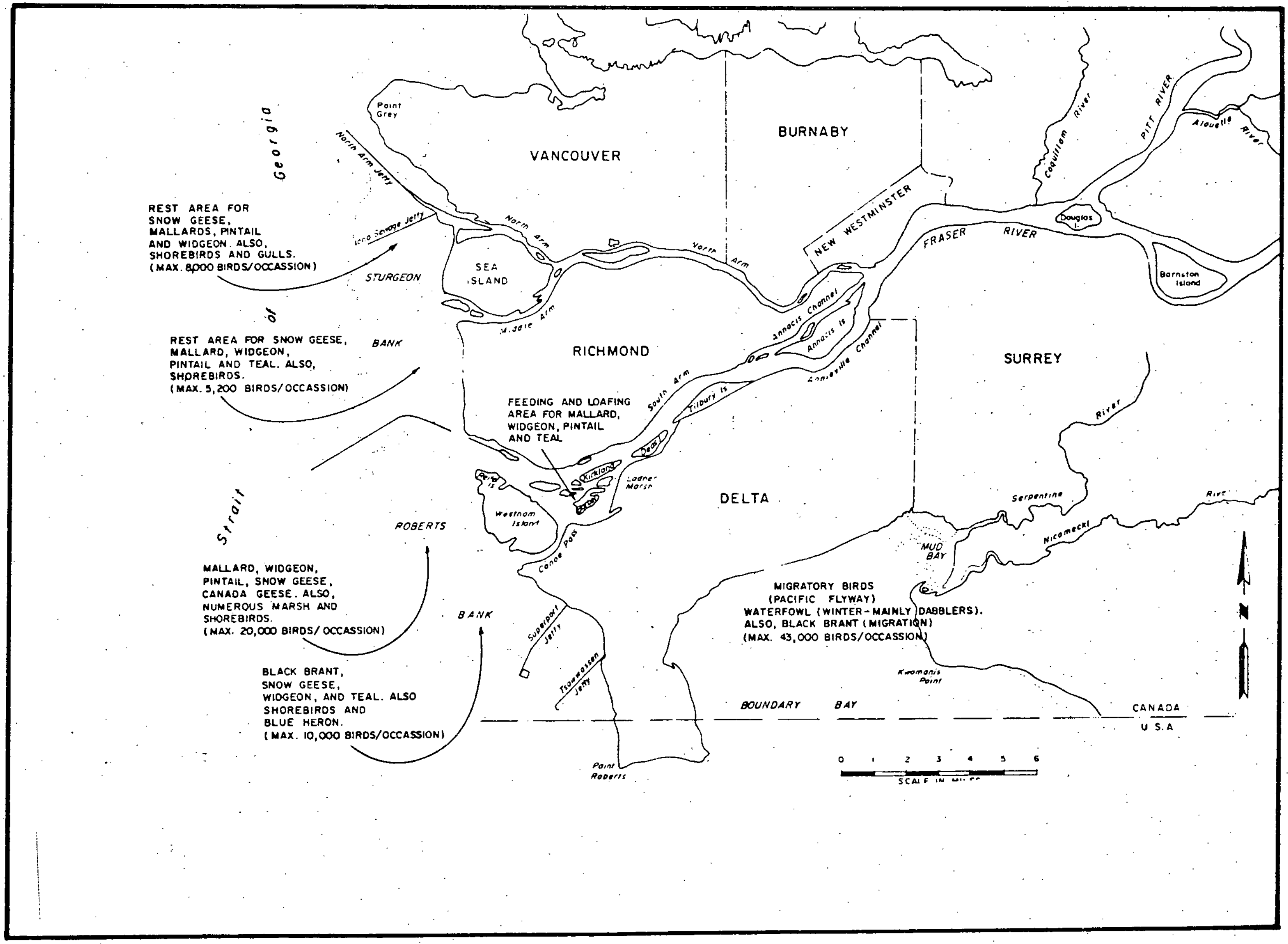


Figure 7. Foreshore areas of importance to waterfowl. (Swan Wooster, 1967 and C.W.S., unpubl.) [More precise information is now available from the Canadian Wildlife Service and the B. C. Fish and Wildlife Branch].

The contribution of organic matter from the tidal marshes of the Fraser, probably a magnitude of 10^4 tons per year (this study), as a possible contribution of litter may not seem to be great. It is, however, the contribution of only one estuary and, being herbaceous, is relatively "available" and "cycles" readily. It is doubtless a critical source of energy for many species of fish and other animals.

A small part of the energy from salt marsh vegetation is channeled through the classical "grazing" food chain. Most of the net primary production, it is believed, is directed through the "detritus" food chain (de la Cruz, 1965). Smalley (1959) found that less than 5% of the net production by *Spartina* marsh grass is consumed "on the stalk" as it were, by the insect and other eaters of or grazers on the growing grass. He also states that most of the tremendous production of salt marshes is destined to be used in the form of organic detritus.

As marsh vegetation dies, abundant micro-organisms such as fungi and bacteria convert it into particles rich in readily used proteins, carbohydrates and vitamins. This organic detritus is distributed throughout the system. Darnell (in press) pointed out that this material represents also transport and buffer mechanisms for the ecosystem. It is an energy store because organic matter produced at one time is released later; it is an energy transporter because it carries the "energy-particles" downstream from the point of production; it is an energy buffer because organic detritus is available during seasons of low primary production.

The process of decomposition of organic matter and its ultimate fate are rather complex and many living organisms are involved. Kuenzler (1961) reported that excess organic matter in the marsh is transported into estuarine waters, where it is available to a whole host of decomposers and other detritus feeders, such as the horse mussel, important in the phosphorus cycle. While filtering water to obtain its food, the mussel excretes large quantities of organic particles as pseudofeces, which sink to the bottom. Because of the importance of tidal action in nutrient cycling and production, the entire estuarine system, including marshes, flats, creeks and bays, must be considered as one ecosystem or productive unit (Odum, 1961).

Nowadays we are observing a lot of changes in estuaries which are not based on biological considerations (Odum, 1961). Especially, filling of bays and estuaries is detrimental. Once a salt marsh has been filled with waste, the options for preservation and continued renewal are forever lost, for there are limits to environmental reconstruction (Wagner, 1971). Ohba (1972), in Japan, stated recently that salt marshes are losing acreage rapidly because of endiking and also because of exploitation of the offshore sea weed *Porphyra tenera*, especially in South Japan. Slight and usually unpremeditated modifications of our environment can cause serious changes in the marsh environment. For example, Benson (1961) reported that the erection of jetties on Sea Island and near Tsawwassen in B.C. may be increasing the rate of silt deposition there. On the other hand the recent history of salt marshes in the northern part of Morecombe Bay, Norfolk, U.K. is one of progressive marsh development, a process accelerated by the building of breakwaters and embankments in the upper parts of the estuaries, and by the piecemeal reclamation of land for agriculture or as a result of railway construction. The fluctuation of the low water channels of the rivers draining into the bay has a significant effect on marsh development, producing, at many sites, intermittent phases of erosion and growth (Gray, 1972). Knowing which areas a development will destroy or alter or build, biologists can then estimate how much vital habitat will be lost, and hence what the impact on fisheries and waterfowl will be (Gareth, 1974). The Massachusetts Institute of Technology (1970) recommends that the trend of the filling of bays and estuaries should be monitored before a multitude of local encroachments has produced an irreversible global effect.

3.2 Innate factors

Unlike the usual domesticated crop plants, marsh plants are influenced by a number of factors such as tide level, salinity and others. Plant distribution within salt marshes has been correlated with a variety of factors including salinity, siltation, tidal inundation, soil type, drainage and biotic competition (Phleger, 1971). Vogal (1966) reports that in the salt marsh he studied, the emergent plant community is extremely simple in the lowest area (4 species) but grades to a more complex, yet relatively simple, community in the highest regions of the marsh (15 species). Correspondingly, the lower zones had sparse vegetational cover and the higher zones supported heavier growth, both in size and numbers of individuals.

Gray *et al.* (1972) in their studies of the salt marshes of Morecombe Bay, in Britain, report that the major variations in vegetation are provided by contrasting substrates reflecting the complex of factors associated with pedogenesis, i.e. between the vegetation of calcareous nutrient-poor sands and that of the comparatively fertile organic silty soils. A second important component of variation is the floristics related to the soil sodium content which varied with elevation, and reflected factors related in turn to tidal submergence. Chabreck (1973) studied the effect of a hurricane on the marshes of the Mississippi River Delta and their recovery. He reports that the hurricane drastically reduced the vegetation. Regrowth was rapid in the delta, rapid in the delta marshes and, after one year, plant coverage approached pre-hurricane levels; however, recovery was slower in ponds and lakes; water salinity in these increased with the hurricane but declined and by the following year the residual effect on marsh vegetation was scarcely observable.

Fundamentally, tides are harmonic waves caused by the attraction of nearby heavenly bodies. Other influences on the height of tides are related to the depth and shape of basins and conformation of coast lines. Strong steady winds may augment or reduce the height of tides. The average lunar day is 24 hours, 50 minutes and 38 seconds so each day the tide timing is about 50 minutes later than the day before. The average period between the tide extremes is 6 hours, 12 minutes (Lemon, 1962). The effects of tides on tidal marshes have been studied by a number of investigators. Smith (1966) reports that the tides, perhaps, play the most significant role in marsh plant growth and development by depriving them of the full insolation of the sun. Adams (1963) also reports that the distribution of species in regularly-flooded marshes is controlled primarily by tide-elevation influences.

The pattern of the tides over the tidal marshes is such that during the summer, lower tides occur in daylight hours, and higher tides occur during the night. In winter, this pattern is reversed, so that tides are relatively high during the shorter daylight hours. This pattern of diurnal low tides in summer aids the growth of the marsh plants (Burgess, 1970).

Gray *et al.* (1972) report that where areas of continuous vegetation may be limited by tidal factors to elevations above 4.5 m. A.O.D.[†] Point-to-point variation in the vegetation above this level reflects the interaction of such factors with local variation in soil type. Hinde (1954) found that the glasswort (*Salicornia* sp.) occurs from 10.3 ft. above MLLW[††]

[†] A.O.D. = Average of Datum. [††] MLLW = Mean Low Low Water.

to 6.4 ft. above MLLW; and the salt grass (*Distichlis* sp.) is found between 10.3 ft. and 7.15 ft. above MLLW.

Bleakney (1972) reports that extreme tides expose organisms to a variety of stresses depending upon the time of year and weather conditions; as both weather and tidal extremes are acyclic relative to the life span of short-lived species, there is no opportunity for genetic selection of suitable behavioural responses, such as those associated with seasonal changes in light and temperature. As is true of all intertidal organisms, the emergent plant species are subject to sudden and dramatic changes in temperature and insolation as tide waters ebb and flow near them.

Several studies have been done on the salinity of tidal marshes. Unhof (1941) reports that considerable controversy exists as to whether salt-marsh plants require saline conditions or merely tolerate them, i.e. are obligate or facultative halophytes (Daubenmire, 1947). Adams (1963) studied plant zonation in North Carolina salt marshes and reported that most salt-marsh species exhibit reduced growth and fertility with increasing salinity, and that salt concentrations equivalent to about 7% NaCl (twice sea strength) prohibited establishment and survival of all species.

The efficiency of net production in cattails is determined by the rate at which leaf tissue is produced, rather than by inherent differences in the assimilation efficiency of that tissue (McNaughton, 1974). McNaughton (1974) compared photosynthetic characteristics of two low-altitude and two high-altitude populations of the broad-leaved cattail (*Typha latifolia* L.). The photosynthetic differences between the ecotypes seem to have minor ecological significance, but reductions in water and nutrient uptake upon root chilling suggested strong natural selection in the high-altitude site for ability to function efficiently in cold soils. Of concern to emergent vegetation is silt, probably a factor of importance in some estuaries; it does not seem to have been given much attention except insofar as it may modify the chemical analysis of the plants.

Bacterial decomposition is an important part of the detritus breakdown, and the bacteria, algae, and associated detritus are all food for detritus feeders (Krebs, 1972). The protein is calculated to be deficient as a nitrogen source for marine animals, and it is suggested that microbial conversion of autrophs may act to step up the potential value of the pool of protein in the sea (Burkholder, 1956).

Keefe *et al.* (1973) investigated the standing crop of salt marshes surrounding Chinocoteague Bay, Maryland-Virginia, U.S.A. Chemical analysis indicated that phosphorus and potassium were rapidly leached from the dead plants while magnesium tended to be retained. Live:dead ratios changed from 0.9 to 2.3 and were lower than those found in regularly flooded marshes. Stewart (1963) states that estuarine areas are particularly rich in vitamin B_{12}, a growth factor which is essential for the growth of many of the marine micro-algae which are important primary producers in the sea and ocean around the Biritsh Isles. Burkholder *et al.* (1957) found that aerobic, heterotrophic, marine bacteria participate actively in the decomposition of *Spartina*. He also estimated that about 11% of the annual crop of marsh grass may be rapidly converted to bacteria (dry weight basis). Microbial utilization of crude fiber takes place more slowly than decomposition and use of protein and soluble carbohydrate constituents.

Animals living in the tidal marsh must be able to survive or avoid the great changes in salinity, temperature and exposure. The limited number of animals which have adapted to these extremes appears to be relatively free from competing species and enemies. Once adapted to the marsh, the lack of competition from similar animals has perhaps allowed them to occupy a broader niche and be more abundant than would otherwise be possible. In areas of dense crab populations the entire surface of the marsh is "worked over" between successive high tides. Both by "the working over" of the marsh surface and the concentration of organic matter in their feces, the crab will have considerable influence upon other organisms, especially the nematodes, annelids and bacteria (Teal, 1962).

A colony of mussels will circulate every two and a half days as much phosphorus as the water holds in suspended particles, as well as a considerable quantity of dissolved phosphorus. Therefore, a constant amount of this material remains on the surface in any given flat, and is not carried out by the tides (Louise *et al.*, 1969).

Tidal marshes are not always accessible, because the ground is soft and muddy and the tide level is always changing. For this reason, new or improved methods of studying marshes are significant. Seher (1973) studied color and color-infrared aerial photographs of waterfowl habitats to determine their usefulness for marsh vegetation evaluation and attempted to determine the optimum film type, scale, time of day, and time of year for best results. Reimold *et al.* (1973) considered remote sensing to provide quantitative data on primary production in tidal marsh ecosystems, focusing on: (1) differentiation of vegetative types (species), and (2) assessment of primary production between each vegetative type (species) and within the dominant species, *Spartina alterniflora.*

3.3 Primary productivity

The photosynthetic production of organic matter involves conversion of part of the sun's radiant energy into a form which can be used by other living organisms. Some of the organic matter initially produced is respired by the plant to provide energy for its own metabolism and the rest accumulates in the plant body. The part that is not respired is commonly termed the net production, which is contrasted with the initial gross production. The net production is available for consumption, either before or after the death of the plant, by animals, bacteria and fungi, which cannot create new organic matter themselves.

Primary production is defined as the weight of new organic matter created by photosynthesis over a period; expressed as a rate it becomes productivity. Biomass is defined as the total weight of plant present at a particular time. Crop, yield and standing crop are comparable with production, productivity and biomass respectively (Westlake, 1963).

At Sapelo (Odum, 1961), three distinct production units may be listed as follows in order of their importance as food makers for the system as a whole: (1) The vast area of *Spartina* (cord grass) marshes; (2) The benthic or "mud algae" which grows throughout the intertidal sediments but especially on the creek banks and; (3) The phytoplankton in the water (Odum, 1961). He also states that the annual production of the marsh, or the estuary as a whole, may be double or triple that of ordinary agriculture simply becuase it grows twice or three times as long. Even in northern latitudes he suspects production by microflora may occur when land plants are inactive.

Teal (1962) investigated energy flow in the salt marsh ecosystem of Georgia State, U.S.A. and reported that gross production is 6.1% of the incident light energy; however, net production over light is a little less than 1.4%. Odum (1961) estimates that Sapelo marshes and estuaries taken together in the southern U.S.A. have an estimated gross primary production of somewhere around 2,500 grams of dry matter per square meter per year. It is thought that about 500 of these grams are used by the plants in their own respiration leaving about 2,000 grams net production average for each meter of the system. Bernard (1974) reports that in freshwater marshes in Minnesota, the *Carex rostrata* standing crop of green material varied from a minimum of 114 g/m^2 frozen in the winter ice to a high of 852 g/m^2 in late August. Westlake (1963) reports that the phytoplankton of lakes and oceans are relatively improductive even on fertile sites, with an annual dry matter production only 1-9 m.t./ha. and that benthic marine plants in shallow waters may produce more, i.e. from 25-33 m.t./ha. in the temperate zone.

There are many difficulties in determining the primary productivities. For example, Westlake (1963) also points out that the underground parts may be five times as great as the weight of harvested shoots. The roots are wholly or in part renewed annually and rhizomes may persist for many or few years. The annual production has been estimated as 0.64 of the biomass or four times the standing crop of tops. Investigating primary productivity, Teal (1962) in the Southern U.S.A. reports that, since the net production was determined by short-term harvesting, it is necessary to add the 305 Kcal/m^2 yr. consumed by the insects to arrive at the true net plant production.

Wiegert and Evans (1964) pointed out that net primary production of natural vegetation is often estimated by determining a peak standing crop and calling this value net primary production. They cite several errors inherent in this kind of approach. It does not take into account mortality of green plants prior to the time when the peak standing crop is attained. This represents growth which would not be measured by standing crop determinations. Also, growth which might occur after the peak standing crop is not measured. Another problem involved with using the peak standing crop as the estimate of net primary productions is that it does not take into account the fact that different species may reach their peak standing crop at different times.

3.4 The foreshore environment of the Fraser River Delta

One hundred years ago there were, in all probability, about 18,000 hectares (45,000 acres) of marsh (open wetland) in the Lower Fraser Valley; now only about 3,000 hectares (8,000 acres) remains and most of it lies along the Fraser delta foreshore, the focus of this study.

Wetland and waterfrontage in the Lower Mainland, although extensive, has been alienated for a multitude of purposes and with astonishing rapidity. They may now be deemed to be scarce and valuable commodities. Wharfage, booming grounds, marinas, industry and dikes have alienated hundreds of miles of shoreline and the problems associated with their development and use have been pointed up by a Lower Mainland Regional Planning Board report "Our Southwestern Shores" (1968) and by other studies.

The forward dikes of the delta, largely constructed for the reclamation of alluvium for farming late in the last century destroyed much of the marsh. Since the day of dike construction much of the land reclaimed for agriculture has been occupied by suburbia and industry and now human activities of many kinds are extending to land beyond the dikes at an increasingly rapid rate (Fig. 8). Becker (1971) recently and generally has reviewed these activities and has indicated their current patterns as they relate to the foreshore from Burrard Inlet to the International boundary from around the 49th parallel, north. They are not reviewed here because of the earlier coverage but, obviously they constitute a raison d'etre for this study.

The magnitude and nature of the contribution of the emergent vegetation to the Fraser estuarine system (or for that matter virtually all

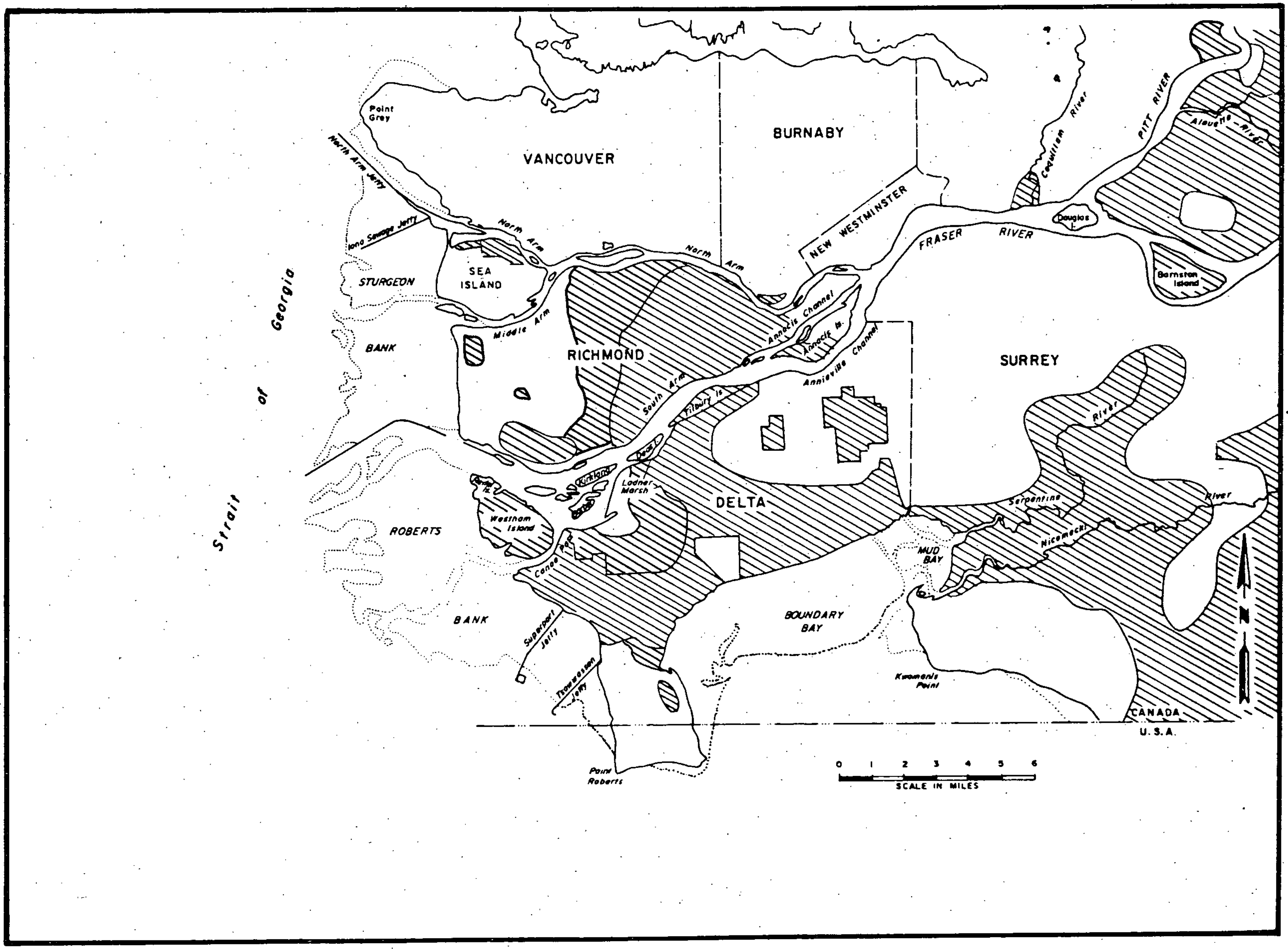


Figure 8. Land presently in agriculture. (After Hoos et al., 1974).

estuarine systems) is largely unknown. Simple observation of the digestive tracts of dead waterfowl confirms the review that the estuaring vegetation is important in the lives of the millions of birds using the Pacific flyway. A heavy dependence of brant on the submergent eelgrass (*Zostera* sp.) in the Fraser system has been indicated by Morrison (1967). Burgess (1970) has noted the use of rhizorms and seeds of emergent plants by other waterfowl. It is now believed, but not documented, that in indirect ways the emergent vegetation plays a role in the feeding of salmon (fry, parr, smolt or grilse) as they move to the sea and as they move toward fresh water to spawn; perhaps emergent vegetation functions as egg beds for other fish, e.g. herring (Fig. 9 and Fig. 10). However, as Hoos *et al.* (1974), generally investigating and summarizing the available information of Fraser River estuary, stated, literature dealing with primary producers in any environment, aquatic or terrestial, was lacking.

The study by Perkins (1963) aforementioned seems to be the only study in which detritus associated with the Fraser system is given any attention as a contributor of energy. The emergent vegetation may not loom large relative to sewage and forest industry waste but lacking broad quantitative assessments of detritus in the Fraser system there is some *a priori* evidence (Odum, 1961) for believing that this natural component is very important to the survival of the living organisms of the system.

Figure 9. Sensitive areas for fish and wildlife which should be set aside as minimal conservation habitat. (Hoos *et al*, 1974).

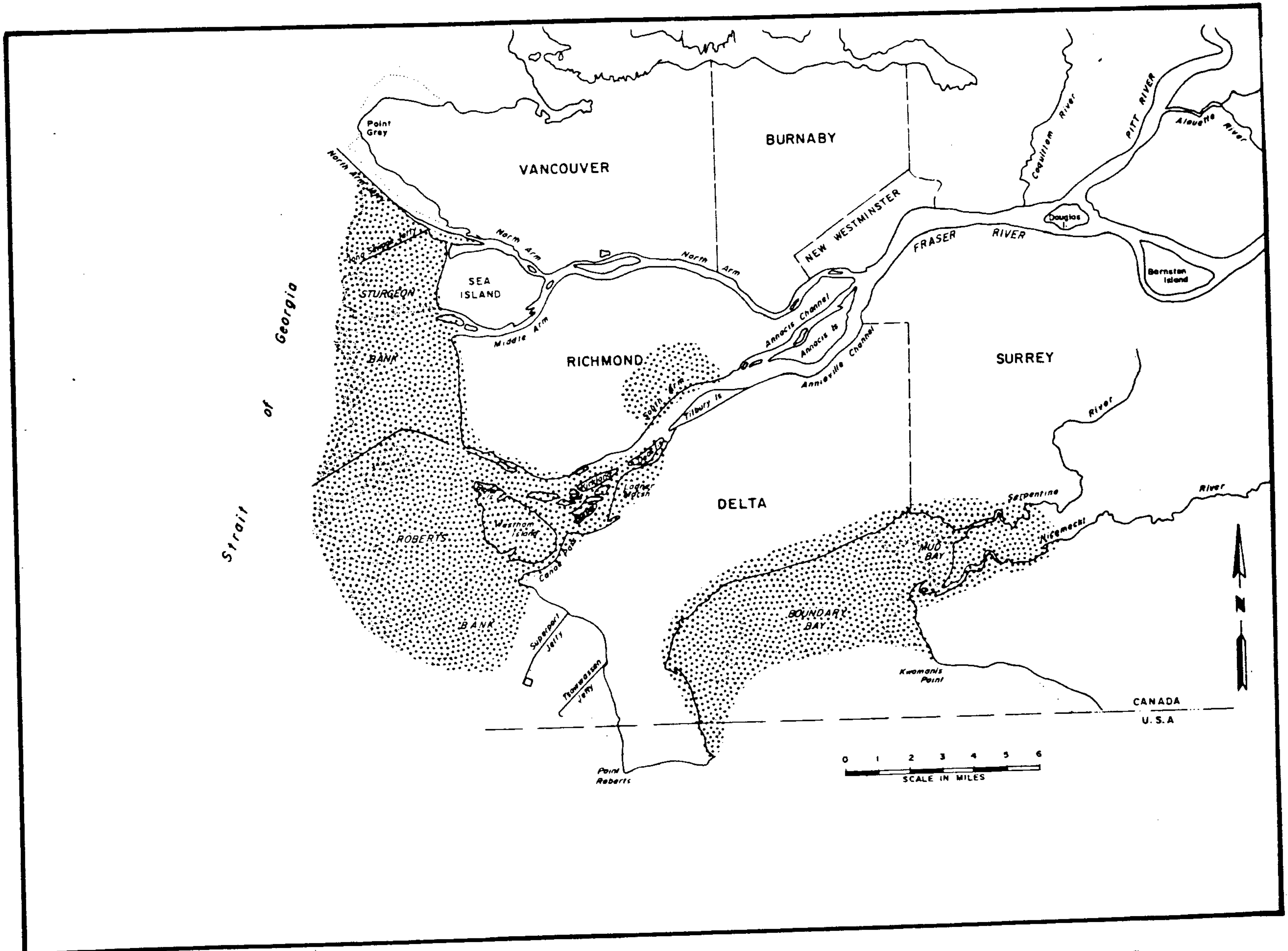
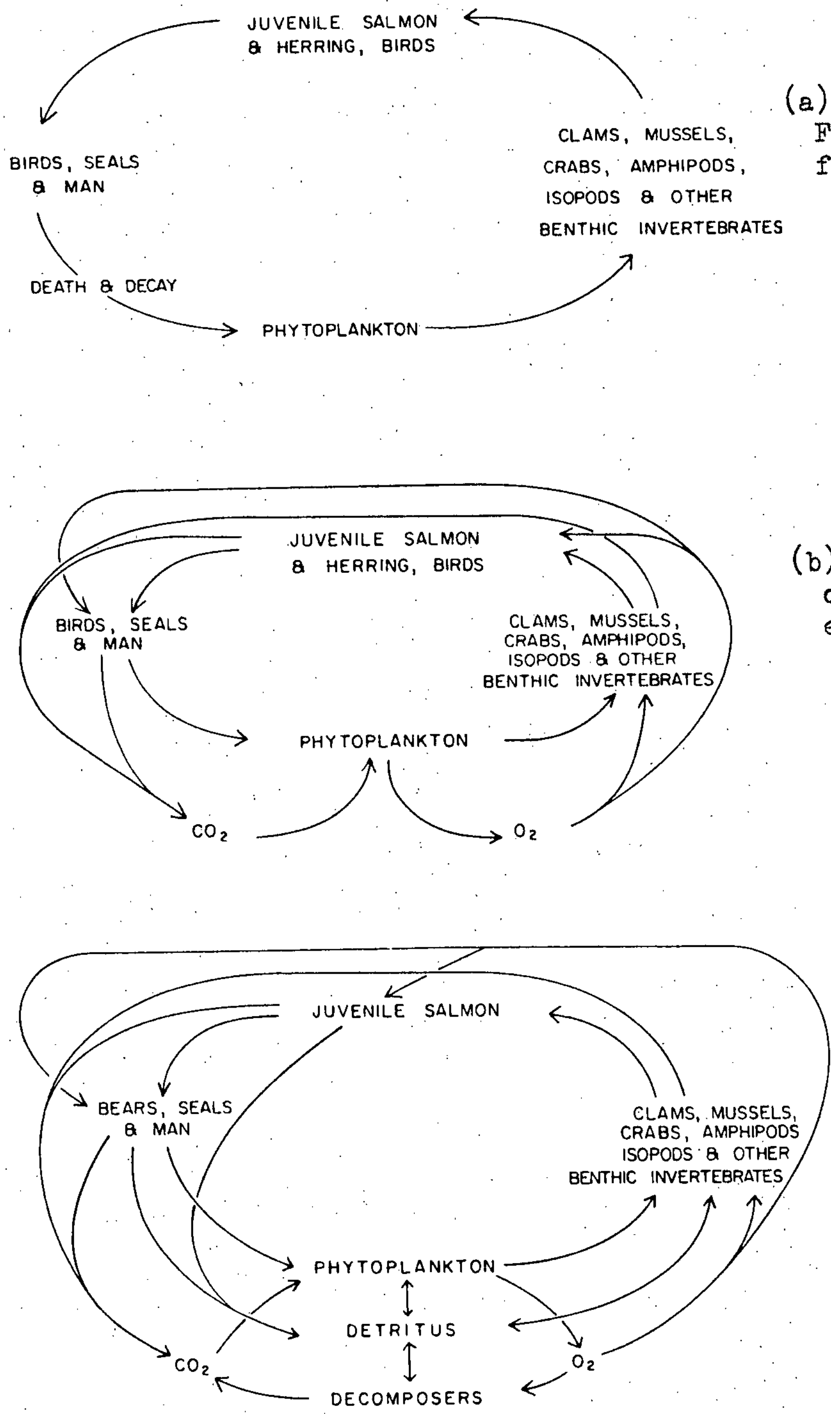


Figure 9. Sensitive areas for fish and wildlife which should be set aside as minimal

Figure 10. A food chain of Fraser estuary.



(a) A simple Fraser estuary food chain;

(b) A somewhat more complex Fraser estuary food chain;

(c) A food chain of even greater complexity.

(Hoos et al., 1974).

4. MATERIALS AND METHODS

The salt marshes were surveyed by means of a series of line transects projected at right angles, more or less, to the coastline. Field work was conducted in the summers of 1973 and 1974. Nine transects were established in the summer of 1973 and vegetation and soil along the transects were studied. In 1974, five more transects were added to the nine of 1973. In all, fourteen line transects have been established. The shortest transect was 100 m and the longest, 1100 m (Table II). Soil and plant samples were collected once at a stage judged to be at the maximum vegetative development. The emergent plant species were identified according to Hitchcock *et al.* (1973) and listed in Appendix 1.

4.1 Field sampling

Line transects: The transect sites were selected so as to cover the whole study area and a maximum range of vegetation types. The exact positions of transect lines were determined by the extent of salt marsh and the nearness of some permanent markers, such as power poles, trees, landscape features, etc. which would make the line transects easy to find. All transects began at either the upper margin of the marsh or the coastline. A measuring tape was laid out along the line of the transect, and stakes were driven at 50 m intervals. Further, a 5 x 5 cm and 1 m long cedar stake was driven 60 cm deep every 100 m and a concrete block was buried at the beginning and end of each transect (Fig. 11). Fourteen semi-permanent transects were thus established which could be

Table II: Transect designations, total length, length occupied by vegetation and quadrat intervals, 1974.

Transect No.	Location	Length (m)	Length occupied by vegetation	Sampling Interval
1	Point Grey	400†	440	50
2	Iona Island	300	0	50
3	Sea Island	900	500	100
4	Westminster Hwy.	850	815	100
5	Francis St.	1,000	1,022	100
6	Steveston Hwy.	900	885	100
7	Reifel Island	1,100	1,050	100
8	34 St., Superport	100	70	50
9	Tsawwassen Rd.	600	545	100
10	Beach Grove	250	0	50
11	72 St., Boundary Bay	450	410	50
12	88 St., Boundary Bay	250	210	50
13	112 St., Mud Bay	150	100	25
14	Crescent Beach	300	5	50
	Total Length	7,550	6,042	

† The end point was set conveniently at 400 m., although the vegetation ended at 440 m.

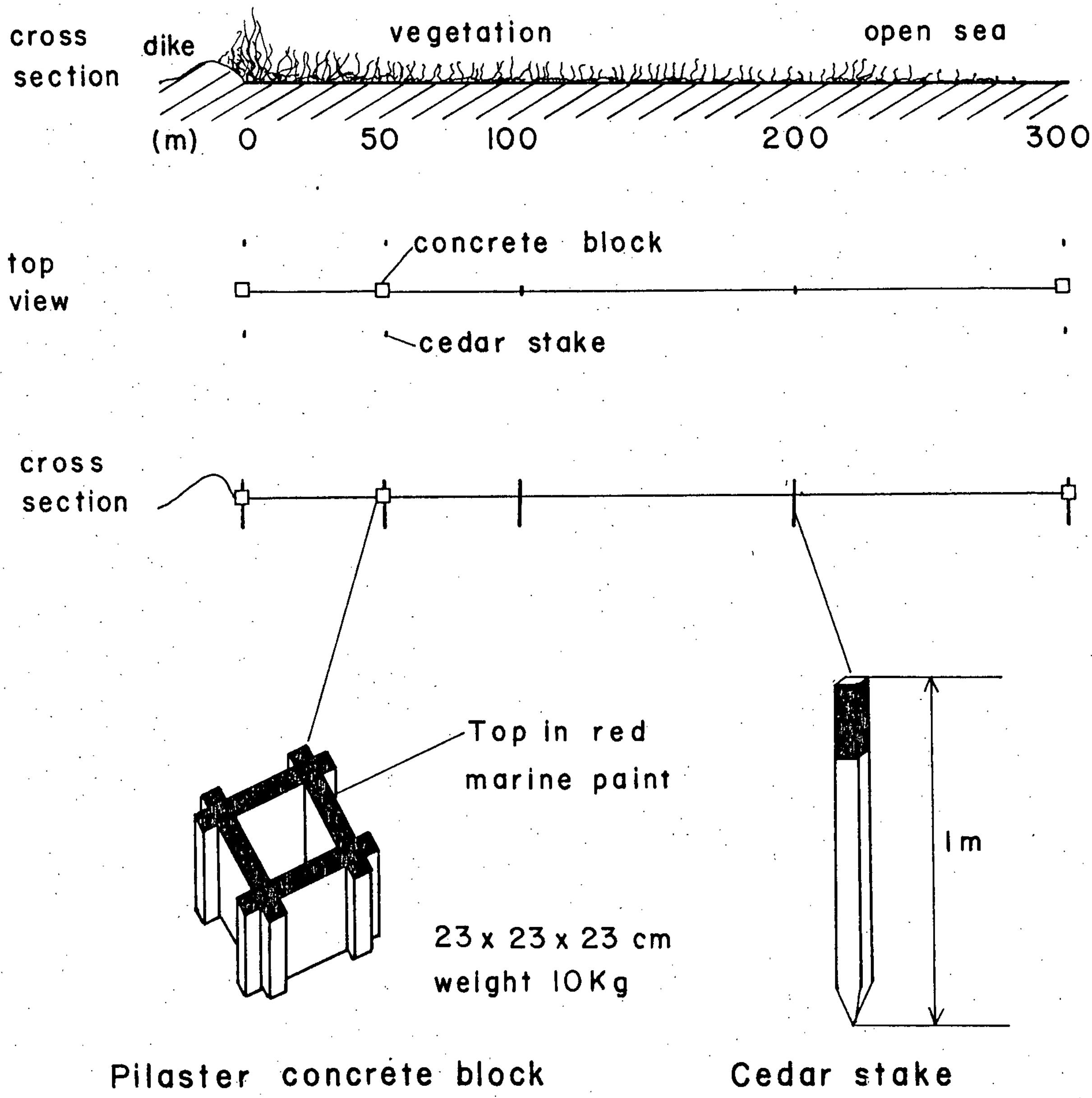


Figure 11. Sketches of (a) generalized transect profiles and (b) concrete blocks and a cedar stake.

used to study from time to time future changes in vegetation and soil.

Quadrats: 1 x 1 m^2 quadrats were used to sample plants at 25, 50 or 100 m intervals along a transect. The quadrats were laid by placing the stakes at the upper left corner of quadrats plotted in 1973. The quadrats were laid at random around the stakes in 1974 to avoid any effects of the 1973 sampling. Samples were obtained from 190 quadrats (81 on 9 transects in 1973 and 109 on 14 transects in 1974) on 14 transects.

4.2 Soil samples

Soil was sampled with a core-type sampler (5.5 cm diameter and 5.5 cm height). One core was taken from the center of each quadrat on 9 transects in the summer of 1973. Three cores were taken at random from each quadrat on all 14 transects in the summer of 1974. Soil samples were taken from every quadrat, laid to collect plant samples and, additionally, soil samples were collected along the transects on those transects and parts of transects which were not vegetated.

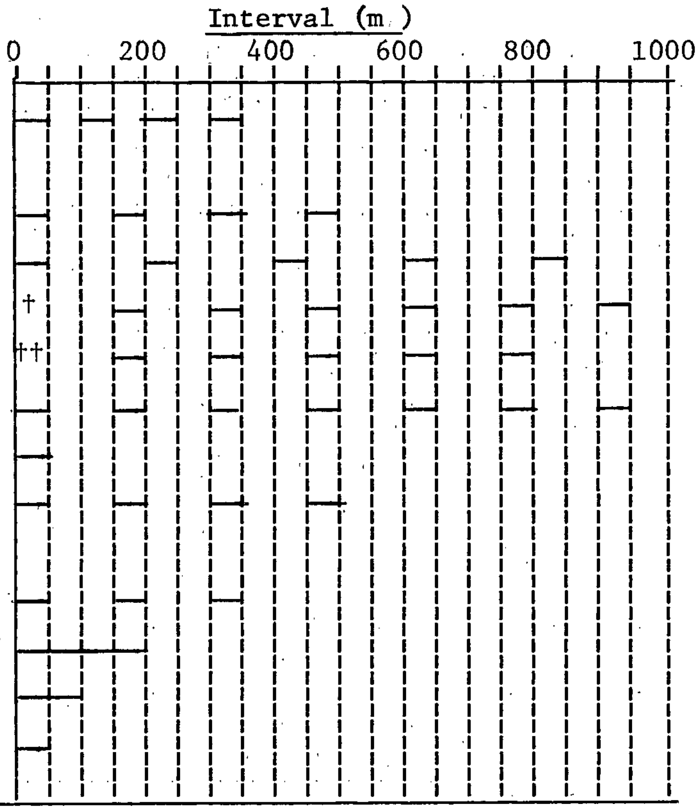
4.3 Plant samples

Height: Plant heights were measured 20 times at each 50 m interval as shown in Table III along each transect. The intervals from one reading to another reading were not always exactly 2.5 m.

Species frequency: Each vascular plant species and its frequency on every quadrat were recorded using frequency indices as shown in Table IV.

Table III: Intervals of plant height measurement, 1974. The intervals chosen depended on the length of the transects and some terrain factors. Each solid line refers to an interval of 50 meters and 20 readings of plant height.

Transect No.	Location
1	Point Gray
2	Iona Island
3	Sea Island
4	Westminster Hwy.
5	Francis St.
6	Steveston Hwy.
7	Reifel Island
8	34 St., Superport
9	Tsawwassen Rd.
10	Beach Grove
11	72 St., Boundary Bay
12	88 St., Boundary Bay
13	112 St., Mud Bay
14	Crescent Beach



† The area was bulldozed and destroyed before the survey of 1974.

†† A cattle corral lies on the first 0-150 m interval of the transect.

Table IV: Species frequency indices for transect quadrats

Cuscuta (Dodder) sp. frequency was not included.

Index	Stalks/m^2
5	1 - 5
10	6 - 14
25	15 - 39
70	40 - 99
100	100 -

Aerial plant material: The above-ground materials were obtained by clipping all "living" and "dead" materials at 5 cm high from the soil line in each quadrat. Plant parts lying on the ground and no longer attached to the plant were also included in the "dead" materials. Most samples were immediately sorted into living and dead portions based on whether or not the harvest contained green tissue. The ground condition in the marsh, i.e. wet and muddy, prevented accurate dead material collections in many cases. The above-ground materials were collected for dry matter weight and chemical analysis.

Since sampling was done near the peak of the growing season, the portion of the samples was expected to represent "maximum summer standing crop" or "cumulative growth" of the current year per square meter. Below-ground materials were not sampled from the one square meter quadrats.

4.4 Laboratory analysis

4.4 Laboratory Analysis

Soil: Soil samples were air dried at 40°C and sieved through a 2 mm mesh before physical and chemical analyses were made. Both soil and plant analyses were done in the Plant Science Dept. laboratory, The University of B.C.

pH: A 1:2 soil-water slurry was prepared by mixing 50 g of each soil sample with 100 ml of distilled water in a plastic jar. Some samples, however, needed a 1:4 soil-water ratio, to obtain a reasonable slurry. Each sample was stirred at 15 minutes intervals for one hour. The sample was then thoroughly stirred and, within one minute, the electrode of a Beckman pH meter was inserted.

Salinity: Electrical conductivity of the soil samples was measured with a "Soil-Tester Solubridge" and expressed in millimhos per cubic centimeter. The preparation steps were the same as for soil pH measurement preparation.

Organic Matter: Organic matter content was determined by a wet oxidation procedure according to Gilchrist (1967).

Plant Analysis: The plant samples collected from the marsh were air-dried at 40°C for about two days in a large tunnel dryer; then they were hammer-milled. The representative sub-sample taken from the hammer-mill sample was again milled in a Wiley mill to pass a 0.6 mm mesh, and oven-dried to constant weight at 100°C in a forced-draft oven. The sub-sample prepared as above was used for nitrogen and lignin analyses.

Dry Weight: The plant samples were weighed after they were completely air-dried (at 40°C for about two days, sometimes four days).

Nitrogen: Total nitrogen content was determined by a semi-micro Kjeldahl procedure (Nelson *et al.*, 1973).

Lignin: Lignin was determined by the acetyl bromide technique after Morrison (1972).

Ash: Ash content was determined by weighing approximately 2 gm of a hammer-milled sub-sample and ashing it at 550°C until the ash weight remained constant.

5. OBSERVATIONS AND RESULTS

5.1 Area, productivity and quality estimates for the total marsh area

The area and dry matter yield for each principal plant species and for each band or island were estimated by the help of air-photos, following field reconnaissance and data collection during the summers of 1973 and 1974.

The study area was divided into three sections, i.e. (a) Sturgeon Bank, (b) Roberts Bank and (c) Boundary Bay. Each, respectively, accounted for 41%, 54% and 5% of the total standing crop of emergents in 1974. Westham Island occupied 33% of the marsh land and accounted for 43% of the total standing yield (Table VI).

The total area of the marsh studied was 1901 hectares and 9408 metric tons of dry matter of various marsh plants were produced. The average yield was 4.9 tons per hectare.

The four species giving, in decreasing order, highest standing yields were *Carex lyngbyei, Scirpus americanus, Scirpus paludosus* and *Typha latifolia*. *Scirpus americanus* occupied 40% of the marsh land and accounted 32% of the total standing yield in 1974. Drift wood (Fig. 29) was important and occupied 56 hectares, an area equal to one-third of the marsh land of Sea Island (Table V and Table VI).

The dry matter yield of (maximum) standing crop per unit differs from area to area. However, there is a roughly linear decrease in dry matter weight with increasing distance from the dikes. The data for

Table V: Estimates of the area and dry matter yields of principal species for the whole area, 1974.

Species	Area ha.	Area (%)	Standing Crop Yield Totals tons	Standing Crop Yield Totals (%)	Standing Crop Average Yields tons/ha.
Carex l.	366	(19)	3,393	(36)	9.3
Scirpus a.	752	(40)	3,039	(32)	4.0
Scirpus p.	247	(13)	1,225	(13)	5.0
Typha l.	144	(8)	684	(7)	4.8
Salicornia v.	140	(7)	452	(5)	3.2
Scirpus v.	63	(3)	305	(3)	4.8
Triglochin m.	91	(5)	165	(2)	1.8
Distichlis s.	42	(2)	145	(2)	3.5
Drift wood	56	(3)	0	(0)	0
Total	1,901	(100)	9,408	(100)	4.9

Table VI: Estimates of the area and dry matter yields of emergent vegetation for the whole area and its major parts, 1974

Location	Area of Marsh ha.	Area of Marsh (%)	Standing Crop Yield Totals tons	Standing Crop Yield Totals (%)	Standing Crop Average Yields tons/ha.
Point Grey - Sturgeon Bank					
Point Grey	75	(3)	410	(5)	5.5
Sea Island	169	(9)	931	(10)	5.5
Lulu Island	543	(29)	2,475	(26)	4.6
Total	787	(41)	3,816	(41)	4.8
Roberts Bank Area					
Westham Island	629	(33)	4,040	(43)	6.4
Brunswick	164	(9)	807	(8)	4.9
Tsawwassen	84	(4)	277	(3)	3.3
Total	877	(46)	5,124	(54)	5.8
Boundary Bay Area					
Boundary Bay	237	(13)	468	(5)	2.0
Total	237	(13)	468	(5)	2.0
Ground Total	1,901	(100)	9,408	(100)	4.9

dry matter weight, collected from eight transects in 1973, were plotted against distance from the dikes (Fig. 12).

The plant height of the same eight transects was also plotted against the distance from the dikes (Fig. 13). There were significant differences in height with distance within each of the eight line-transects. There were no significant differences in plant height between line-transects. Plant height of all the transects except Tsawwassen Rd. Transect (No. 9) decreased significantly from the dikes and that the pattern of change in plant height remains much the same from transect to transect (Fig. 13).

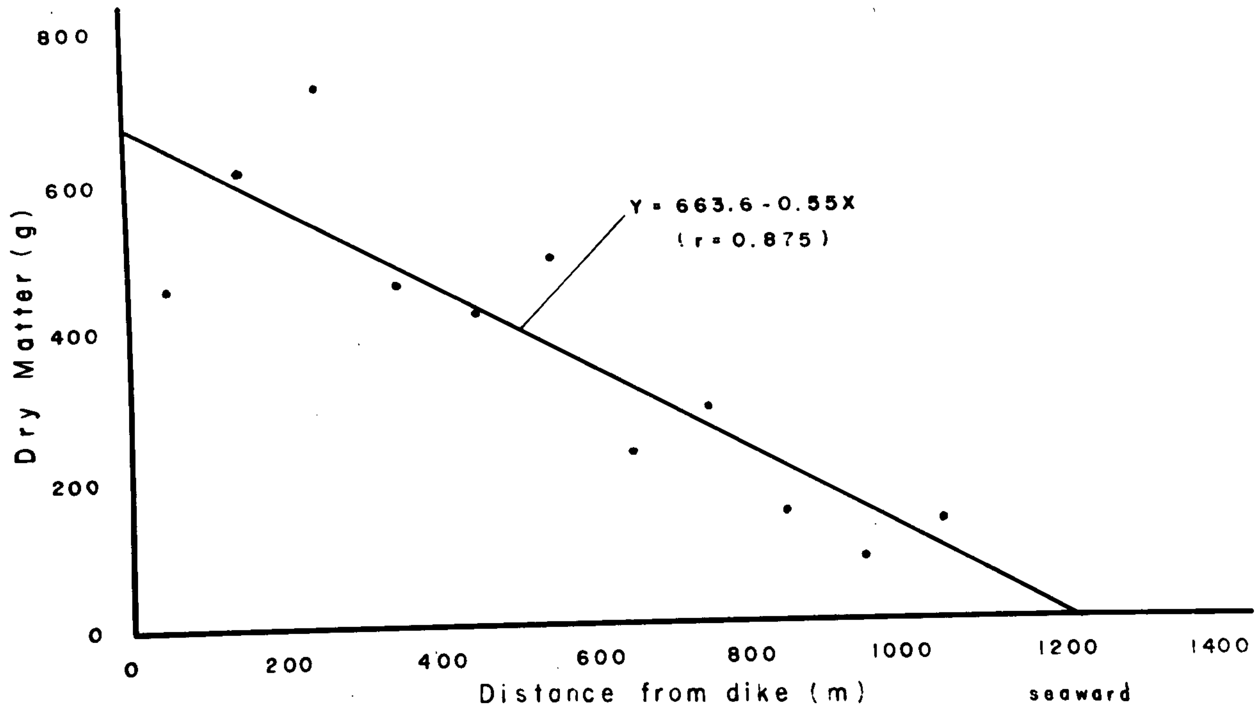


Figure 12. Averages of dry matter weights in grams per m^2 (based on unequal numbers of variable per sample) against distance in meters from dikes, 1973.

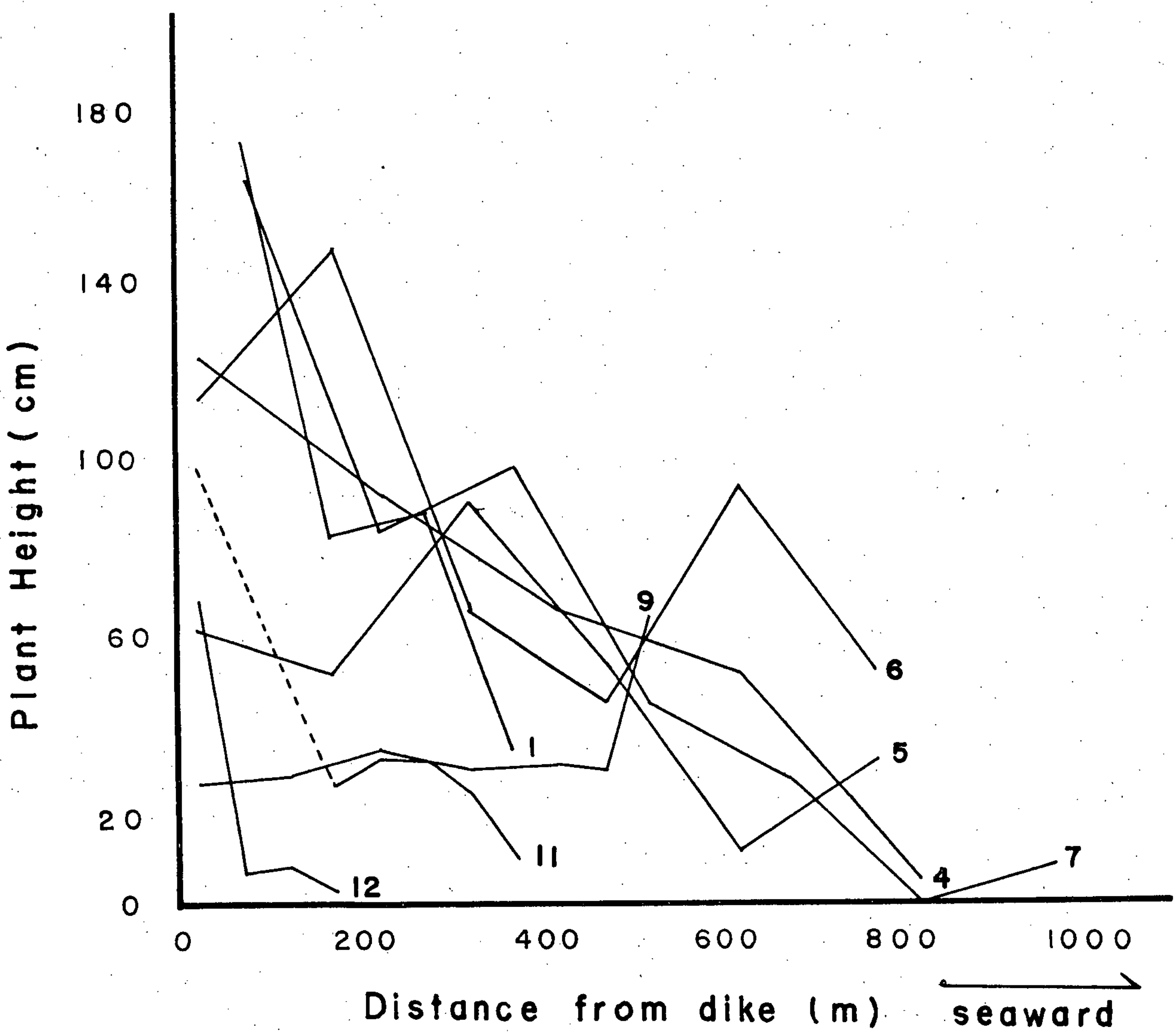


Figure 13. Changes in plant height in cm. against distance in m. from dikes, 1973. (Each point is an average of 20 observations.)

1 - Point Grey Transect
4 - Westminster Hwy. Transect
5 - Frances St. Transect
6 - Steveston Hwy. Transect
7 - Reifel Island Transect
9 - Tsawwassen Rd. Transect
11 - 72 St. Boundary Bay Transect
12 - 99 St. Boundary Bay Transect
(- - -) Area covered by debris, mainly logs

5.2 Principal species

Five principal species from representative stands were collected from Reifel marsh and 88th St. transects in the middle of September, 1973. They were *Typha latifolia, Carex lyngbyei, Scirpus americanus, Scirpus validus* and *Salicornia virginica* (Table VII). Each was observed in the field. Later, samples were analyzed for nitrogen, lignin and ash. An important species not included in the 1973 study was *Scirpus paludosus* (Fig. 14).

Carex lyngbyei showed markedly different growth from the others as expressed in number of stalks per unit area, top/root ratio and lignin percentage. *Carex l.*[†] averaged 739 shoots/m^2 and had the largest weights of living material per m^2, but *Typha l.* had the largest combined weight of living and dead material. Inflorescence bearing shoots of *Carex l.* were shorter than those not bearing inflorescences.

The top/root ratios of *Scirpus a.* (Fig. 15) and *Salicornia v.* were approximately 0.6 and 0.2 respectively and showed the greatest variability among the five. The height of shoots with and without inflorescences was measured; it was found that, in the cases of *Carex l.* and *Scirpus v.*, the inflorescence-bearing shoots were shorter than those not bearing inflorescences.

The lignin percentages of *Typha l.* and *Carex l.* were higher than those of the other species, but the differences were small.

The very high percentages of ash were unquestionably due to mud adhering to the stalks which were not washed for chemical analysis (Table VII).

[†]Abbreviations are not standard; it was deemed useful for the purposes of this study to give the generic name in full and to abbreviate the specific name.

Table VII: Estimates from meter square quadrats of several phytomass and chemical fractions for four (4) principal species, Reifel Island transect (No. 7), and one (1) 88 St., Boundary Bay transect (No. 12), 1973.

	Typha latifolia		Carex lyngbyei		Scirpus americanus		Scirpus validus		Salicornia virginica	
Sampling date	Sept. 11, 1973		Sept. 13, 1973		Sept. 12, 1973		Sept. 12, 1973		Sept. 15, 1973	
Location	Reifel (No. 7)		Reifel (No. 7)		Reifel (No. 7)		Reifel (No. 7)		88 St.,B.B. (No.12)	
Distance from dike (m)	50		150		300		300		150	
GROSS PLANT FRACTIONS										
No. and height (cm) of:	No.	(cm)	No.	(cm)	No.	(cm)	No.	(cm)	No.	(cm)
Shoots with inflorescence	1	(-)	151	(57)	245	(74)	46	(169)	-	-
Shoots without inflorescence	26	(160)	588	(109)	296	(75)	80	(144)	-	-
Total and average	27	(160)	739	(98)	541	(75)	126	(153)	-	(8)
GROSS PHYTOMASS FRACTIONS										
Dry matter weight, g. (%)	g.	(%)	g.	(%)	g.	(%)	g.	(%)	g.	(%)
Inflorescence (Husk and seed)	16	(0.4)	62	(1.7)	7	(0.5)	12	(0.4)	0	(0)
Living and senescent top	517	(12.6)	1,070	(29.8	844	(57.9)	385	(14.0)	304	(18.4)
Dead	755	(18.4)	0	(0)	0	(0)	0	(0)	0	(0)
Detritus	1,324	(32.3)	0	(0)	0	(0)	282	(10.2)	0	(0)
Crowns and underground shoot root†	1,221	(29.8)	772	(21.5)	152	(10.4)	1,714	(62.1)	230	(13.9)
Root (10 cm. deep)	270	(6.5)	1,691	(47.0)	454	(31.2)	366	(13.3)	1,120	(67.7)
Total g /m^2	4,103	(100.0)	3,595	(100.0)	1,457	(100.0)	2,759	(100.0)	1,654	(100.0)
CHEMICAL FRACTIONS										
Plant Analyses:										
Living Top (L) and Dead (D)	L	D	L	D	L	D	L	D	L	D
Dry matter, ash free	479	286	944	-	640	-	346	-	216	-
Nitrogen (%)	0.48	0.28	0.61	-	0.67	-	0.53	-	0.60	-
Nitrogen (g/m^2)	5.0	4.2	6.5	-	5.7	-	2.0	-	1.8	-
Nitrogen, ash free (%)	0.51	0.74	0.69	-	0.88	-	0.59	-	0.84	-
Lignin (%)	11.1	12.5	11.5	-	9.0	-	8.6	-	6.5	-
Lignin, ash free (%)	12.0	33.0	13.0	-	11.9	-	9.6	-	9.1	-
Ash (%)	7.3	62.1	11.7	-	24.2	-	10.1	-	28.8	-

† Crowns and underground shoot root include material below 5 cm from ground level. Three samples were collected with a core-type sampler (12.5 cm diameter and 10 cm height) and converted to one meter square.

(A)

Figure 14. Scirpus paludosus; Photo taken from the dike looking seawards along the transect, Sea Island, August, 1974.

(B)

Figure 15. Scirpus americanus; photo taken at 450 m. looking seawards along the transect, Sea Island, August, 1974.

5.3 Area, productivity and quality estimates for Sturgeon Bank-Point Grey (Transect No. 1-6)

Sturgeon Bank was divided into three sub-areas; (a) Point Grey, (b) Sea Island and (c) Lulu Island (Table VIII and Fig. 16). A total of six transects were set out and soil and plant samples, collected from each transect, were subjected to physical and/or chemical analysis.

The five principal species of Sturgeon Bank were *Scirpus a.*, *Scirpus p.*, *Scirpus v.*, *Carex l.* and *Typha l.* In Sea Island, sub-area (b), *Scirpus p.* occupied 44% (75 hectares) of the marsh area and accounted for 41% (382 tons) of the standing crop dry matter. In the Lulu Island, sub-area (c), *Carex l.*, *Scirpus a.* and *Scirpus p.* accounted for 33%, 33% and 30% of the standing crop dry matter respectively. The average unit area yields (ton/ha) of three sub-areas were much the same (Table VIII).

Figure 16. Map to show the vegetational areas and the location and vegetation of the line-transects (No. 1-6) in the Point Grey-Sturgeon Bank area, 1974.

Legend

1 - Point Grey Transect

2 - Iona Island Transect

3 - Sea Island Transect

4 - Westminster Hwy. Transect

5 - Francis St. Transect

6 - Steveston Hwy. Transect

(Swishwash Island is included with Lulu Island)

Carex lyngbyei

Distichlis stricta

Salicornia virginica

Scirpus americanus

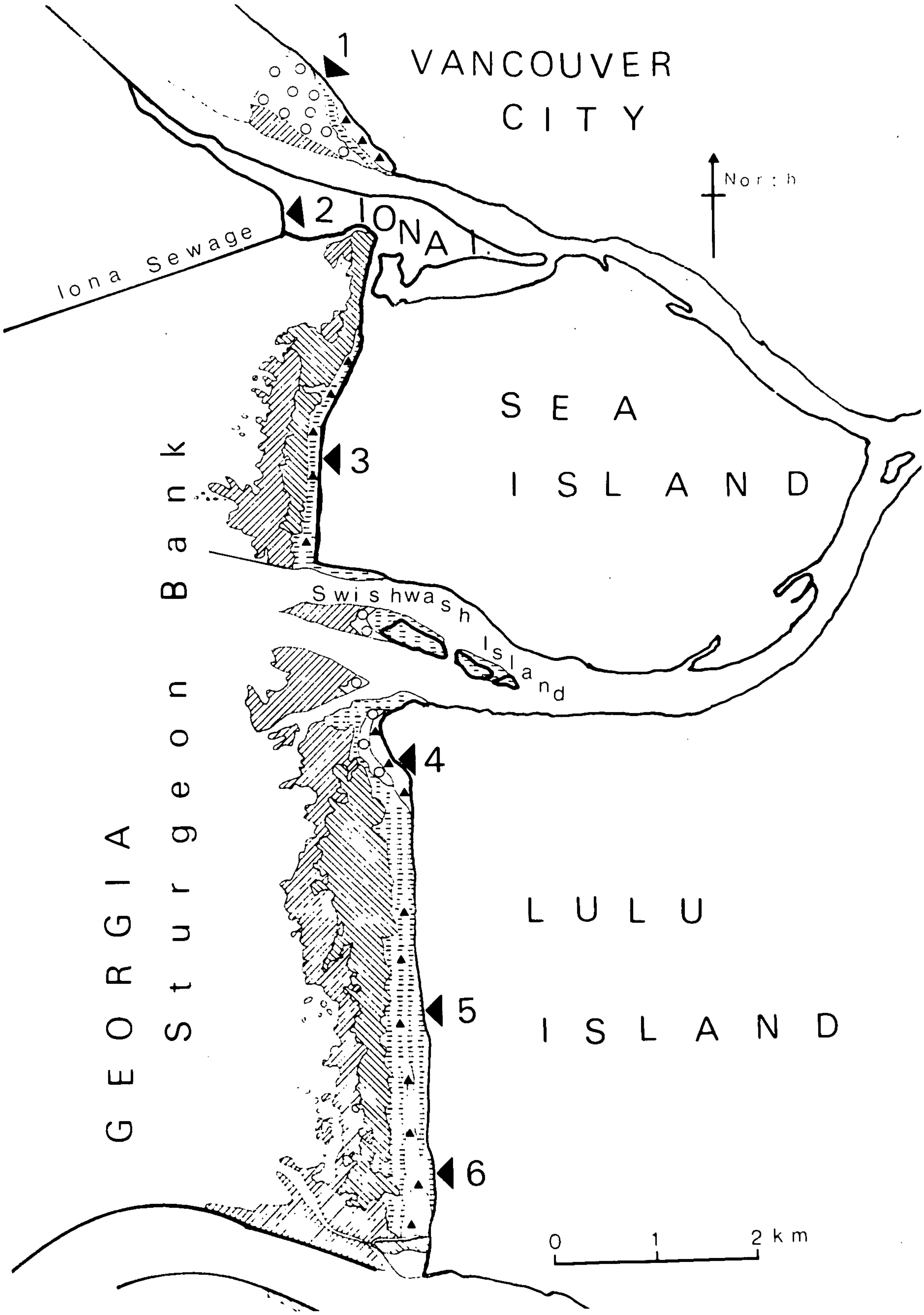
Scirpus paludosus

Scirpus validus

Triglochin maritimum

Typha latifolia

Drift wood



1
VANCOUVER
CITY
North
2
IONA I.
Iona Sewage
SEA
ISLAND
3
Sturgeon Bank
Swishwash
Island
4
GEORGIA
LULU
5
ISLAND
6
0
1
2 km

Table VIII: Estimates of the area and dry matter yields of emergent vegetation of the several sections for the Point Grey - Sturgeon Bank Area, 1974.

Location and Species	Area ha.	Area (%)	Standing Crop dry matter ton	Standing Crop (%)	Average Yield dry matter ton/ha.
<u>Point Grey</u>:					
Scirpus a.	18	(24)	148	(36)	8.2
Scirpus v.	40	(53)	124	(30)	3.1
Carex l.	7	(10)	91	(22)	13.2
Typha l.	10	(13)	47	(12)	4.7
Total	75	(100)	410	(100)	5.5
<u>Sea Island</u>:					
Scirpus p.	75	(44)	382	(41)	5.1
Scirpus a.	68	(40)	271	(29)	4.0
Carex l.	17	(10)	185	(20)	10.6
Typha l.	9	(6)	93	(10)	10.6
Total	169	(100)	931	(100)	5.5
<u>Lulu Island</u>:					
Carex l.	147	(27)	825	(33)	5.6
1*Scirpus a.*	201	(37)	807	(33)	4.0
Scirpus p.	153	(28)	749	(30)	4.9
Scirpus v.	14	(3)	77	(3)	5.6
Typha l.	28	(5)	17	(1)	3.3
Total	543	(100)	2,475	(100)	4.6

5.3.1 Point Grey Transect (No. 1)

The highest dry matter yields in the entire study area were obtained from the Point Grey transect in 1973 and 1974, i.e. 1,819 g/m^2 and 1,668 g/m^2, respectively.

Vegetation:

The sub-area is located along the North Arm of Fraser River. Although the area is small and apparently "wasteland", the order of plant communities is typical and representative of delta foreshore area (Table IV). Much of dead material, mostly *Typha latifolia*, remained *in situ* from 0 m up to 150 m from the road. The plant height varied greatly. This must be attributed, in part, to the surficial disturbance of soil and vegetation by escaped logs. The dry matter yields were high at between 100 m and 250 m from the road verge. The nigrogen percentage increased further from the road. There were no special relationships between nitrogen percentage, nitrogen yield, lignin and ash percentage (Table IV).

Soil:

The organic content of soils from 50 m to 200 m was high and varied from 8% to 31%. The pH values at 50 m to 250 m were below 6, but were above 7 at 350 m and 400 m. The electric conductivity was approximately 1 mmhos at all places along the transect except at 0 m. The soils were silty or clayey except those at 0 m which were sandy (Table IV).

Table IX: Point Grey Transect (No. 1): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	0	50	50	100	100	150	150	200	250	300	350	400
Principal species	E.f. R.l.	-	T.l. A.g.	-	T.l. A.g.	-	T.l. A.g.	-	C.l.	C.l. T.l.	S.v. T.m.	S.v. T.m.	S.a. S.v.
Living (L) material; Dead (D) material	L	D	L	D	L	D	L	D	L	L	L	L	L
Height (cm) Plants			111				193			66		114	
Interval (m) between samples			(0-50)				(100-150)			(200-250)		(300-350)	
Dry matter (g)	317	240	360	173	686	962	377	409	968	1668	380	245	818
D. matter - ash (g)	284	214	330	162	642	929	356	350	861	1512	394	216	665
Nitrogen (%)	0.41	0.36	0.66	0.49	0.44	0.35	0.64	0.35	0.54	0.55	0.81	0.88	0.75
Nitrogen (g/m^2)	1.3	0.87	2.4	0.85	3.0	3.4	2.4	1.4	5.2	9.2	3.1	2.2	6.1
Nitrogen in ash-free d.m. (%)	0.46	0.40	0.72	0.52	0.47	0.36	0.68	0.41	0.61	0.61	0.90	0.99	0.92
Lignin (%)	7.7	11.5	10.0	14.2	5.6	7.5	5.0	10.6	11.8	11.3	8.0	7.2	7.3
Lignin in ash-free d.m. (%)	8.6	12.9	10.9	15.2	6.0	7.8	5.3	12.4	13.3	12.5	8.9	8.1	9.0
Ash (%)	10.5	10.8	8.4	6.3	6.4	3.4	5.5	14.4	11.1	9.4	9.6	11.7	18.8
Soil organic matter (%)	6.2	-	31.2	-	21.8	-	8.2	-	9.9	6.8	2.8	2.6	2.3
Soil pH (1:2)	6.1	-	5.8	-	5.8	-	5.9	-	5.9	5.7	6.8	7.1	7.3
Electric conductivity (mmhos. 1:2)	0.22	-	0.74	-	0.74	-	0.75	-	0.82	0.92	1.00	1.02	0.83

5.3.2 Iona Island Transect (No. 2)

This small island is located on the south side of the North Arm of the Fraser River. The existence of a large sewage disposal unit on this island, given over to secondary treatment, is a notable feature. It is also worthy of note that the unit also serves as a storm sewer outlet and, on occasion, it is reported, raw sewage may reach the tidal areas when storm water flow is heavy.

Vegetation:

Little plant life exists on the Iona transect (No. 2). The level of the tidal flat was well below mean sea level, a factor to consider in plant establishment.

Soil:

Soil samples were taken at seven locations along the transect. The percentage of soil organic matter was low near the shoreline, but was higher further from the shoreline. The electric conductivity followed the organic matter content; it was 4 mmhos at 300 m. The pH values were from ca. 7 from 0 m - 150 m, but became higher from 200 m - 300 m (Table X). Sedimentation seemed to be occurring with a resultant mosaic of silt and sand.

Table X: Iona Island Transect (No. 2): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	50	100	150	200	250	300
Principal species	sea weed	-	-	-	-	-	-
Living (L) material; Dead (D) material	D	-	-	-	-	-	-
Height (cm.) Plants	-	-	-	-	-	-	-
Interval (m) between samples							
Dry matter (g.)	340	-	-	-	-	-	-
D. matter - ash (g.)	142	-	-	-	-	-	-
Nitrogen (%)	0.76	-	-	-	-	-	-
Nitrogen (g/m^2)	3.0	-	-	-	-	-	-
Nitrogen in ash-free d.m. (%)	2.1	-	-	-	-	-	-
Lignin (%)	2.8	-	-	-	-	-	-
Lignin in ash-free d.m. (%)	7.9	-	-	-	-	-	-
Ash (%)	64.5	-	-	-	-	-	-
Soil organic matter (%)	0.4	0.2	0.9	0.4	0.8	1.9	2.2
Soil pH (1:2)	6.9	7.0	7.1	6.7	8.0	7.2	7.5
Electric conductivity (mmhos. 1:2)	0.48	0.90	1.14	1.06	1.10	2.30	2.20

5.3.3 Sea Island Transect (No. 3)

The emergent vegetation extends approximately 500 m from the dike; by contrast, emergent vegetation off Lulu Island extended 800 m to 1,000 m from the dike (Table II). More tidal flat off Sea Island seemed to have been included in the past by dikes than off Lulu Island. As a result the *Typha l.* - *Carex l.* zone just outside the Sea Island dike is very narrow (Fig. 18 and Fig. 22).

Vegetation:

The first 0 m to 100 m of this transect was well vegetated by six species, that is, by *Scirpus paludosus, Typha latifolia, Carex l, Potentilla pacifica, Scirpus validus* and *Scirpus a.* (Table VIII, Table XV and Fig. 16). This might imply that the area from the dike to 100 m had substantial environmental diversity to "fit" these species. The areas from 100 m to 200 m and 200 m to 500 m were well established to *Scirpus p.* and *Scirpus a.*, respectively. There was no dead material in the quadrats on this transect. Plant height ($\bar{x}$), starting from 122 cm at 0 m, gradually declined to 33 cm at 500 m, the transect end. The highest yield obtained was 1,061 g/m^2 from the 0 m quadrat; then yield gradually decreased to 140 g from the m^2 quadrat at 400 m. The nitrogen percentage of ash free d.m. increased from 0.66% at 0 m to 1.13% at 400 m, but the nitrogen yield decreased from 6.4 g/m^2 to 1.4 g/m^2 at 0 m and 400 m respectively. The lignin percentage also tended to decrease with distance from the dike. Ash percentage changed irregularly (Table XI).

Soil:

The pH values dropped from 7.0 at 0 m to 5.4 at 200 m, then gradually increased to 7.6 at 900 m. The organic matter percentage dropped from 6.1% at 0 m to 1.2% at 400 m, and thereafter remained at the latter figure. The electric conductivity followed the trend of soil organic matter (Fig. 17 and Table XI).

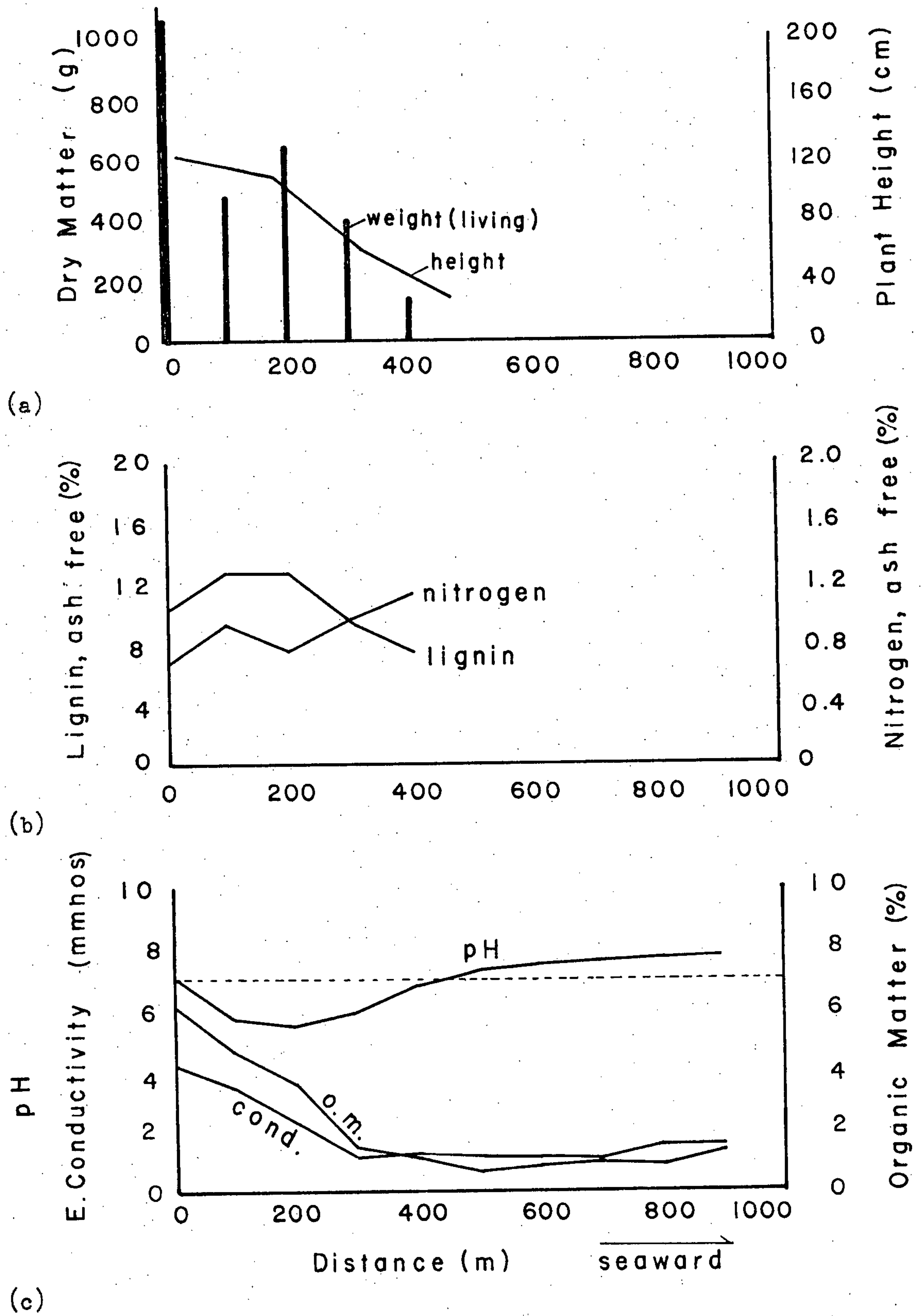
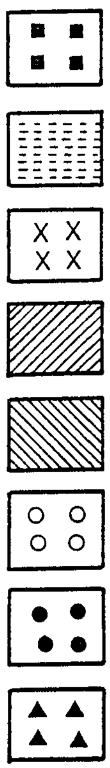


Figure 17. Sea Island Transect (No. 3); (a) dry matter weight and plant height, (b) nitrogen % and lignin % and (c) soil organic matter, pH and conductivity, 1974.

Legend



Agrostis exarata

Carex lyngbyei

Potentilla pacifica

Scirpus americanus

Scirpus paludosus

Scirpus validus

Triglochin maritimum

Typha latifolia

Figure 18. Vegetation micro-map for the Sea Island Transect (No. 3), 1974.

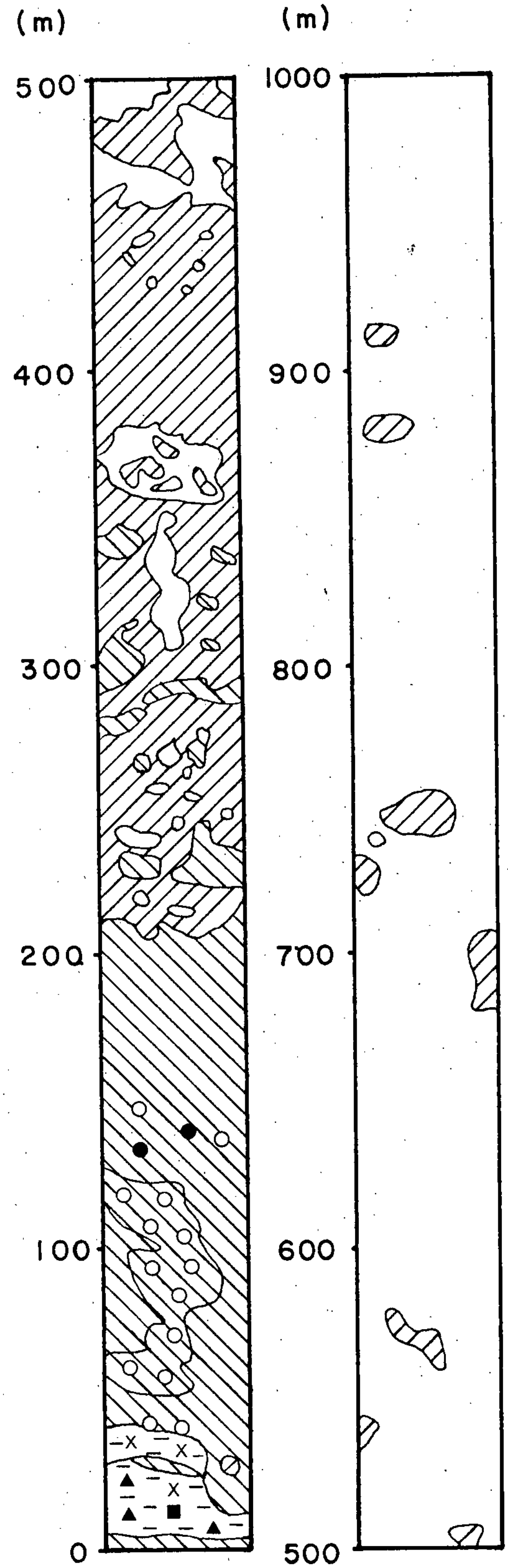

(m)
(m)
500
400
300
200
100
0
1000
900
800
700
600
500

Table XI: Sea Island Transect (No. 3): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	100	200	300	400	500	600	700	800	900
Principal species	C.l. T.l. P.l	S.p.	S.a. S.p.	S.a. S.p.	S.a.	-	-	-	-	-
Living (L) material; Dead (D) material	L	L	L	L	L	-	-	-	-	-
Height (cm.) Plants	122		113	61		33	-	-	-	-
Interval (m) between samples	(0-50)		(150-200)	(300-350)		(450-500)	-	-	-	-
Dry matter (g.)	1061	481	644	405	140	-	-	-	-	-
D. matter - ash (g)	958	436	556	357	121	-	-	-	-	-
Nitrogen (%)	0.60	0.84	0.66	0.85	0.98	-	-	-	-	-
Nitrogen (g/m^2)	6.4	4.0	4.2	3.4	1.4	-	-	-	-	-
Nitrogen in ash-free d.m.(%)	0.66	0.93	0.76	0.96	1.13	-	-	-	-	-
Lignin (%)	9.1	11.6	11.0	8.5	6.6	-	-	-	-	-
Lignin in ash-free d.m. (%)	10.1	12.8	12.7	9.6	7.6	-	-	-	-	-
Ash (%)	9.7	9.3	13.6	11.8	13.1	-	-	-	-	-
Soil organic matter (%)	6.1	4.6	3.6	1.5	1.2	0.7	0.8	1.0	0.9	1.3
Soil pH (1:2)	7.0	5.7	5.4	5.8	6.7	7.2	7.4	7.5	7.6	7.6
Electric conductivity (mmhos. 1:2)	4.1	3.4	2.3	1.1	1.2	1.1	1.1	1.0	1.5	1.6

5.3.4 Westminster Highway Transect (No. 4), Lulu Island

The distinctive feature of this transect was the very marked roughness of the microtopography from 250 m to 350 m. Again the microtopography of the transect surface from 600 m to 800 m was quite rough and many pools were to be seen at low tide (Fig. 19 and Fig. 21). There was a network of channels approximately 50 cm to 60 cm deep and 30 cm to 50 cm wide; the raised parts or "islands" were densely covered by *Carex l.* Often the *Carex* foliage drooped into the channels. This transect showed the most diversity in plant species among the three transects off Lulu Island.

Vegetation:

Although this area showed more diversity in plant species, the order of the communities is much the same as that of most other transects. *Carex l.* and *Typha l.* dominated the first 100 m followed by *Scirpus v.*, *Scirpus p.*, *Tiglochin m* and *Scirpus a.* (Table XV). The 0 m quadrat only yielded dead materials, while the others had no dead material. The plant stature gradually declined, from 126 cm at 0 m and to 17 cm at 800 m. The dry matter yield followed the trend of plant stature except for the extremely high yield of 1,036 g/m^2 at 300 m. The ash percentage varied from 8.2% to 15.2% and appeared to be without special patterns. All of the nitrogen percentages of ash free d.m. fell in the range of 0.49% and 1.05% except for that of the material harvested at 800 m, viz. 1.66%. The lignin percentages of ash free d.m. tended to decrease away from the dike (Table XII).

Soil:

The pH at 0 m was the lowest; then the pH gradually rose to 7.4 at 800 m. The organic matter was high at 0 m point, then gradually fell to 1.2% at 800 m. The electric conductivity did not change very much and all values fell in the range of 0.7 and 1.8 mmhos (Table XII).

(A)

(B)

Figure 19. Photographs of a small channel (A) and a large channel (B), Lulu Island marsh, 1974. Water flows quite rapidly at times washing plants and carrying detritus which may be an energy source for the fauna of marsh and sea.

Table XII: Westminster Highway Transect (No. 4): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	0	100	200	300	400	500	600	700	800
Principal species	C.l. P.p. T.l.	-	T.l.	S.v. S.p.	C.l. S.v.	S.a.	S.a. T.m.	S.a. T.m.	S.a.	S.a.
Living (L) material; Dead (D) material	L	D	L	L	L	L	L	L	L	L
Height (cm.) Plants	126			107		90		69		17
Interval (m)	(0-50)			(200-250)		(400-450)		(600-650)		(800-850)
Dry matter (g.)	794	558	563	608	1036	3317	501	328	287	35
D. matter - ash (g.)	691	418	517	555	879	274	448	281	250	31
Nitrogen (%)	0.64	0.37	0.80	0.61	0.67	0.79	0.69	0.90	0.72	1.47
Nitrogen (g/m^2)	5.1	2.1	4.5	3.7	6.9	2.5	3.5	3.0	2.1	0.5
Nitrogen in ash-free d.m. (%)	0.73	0.49	0.87	0.67	0.79	0.91	0.77	1.05	0.83	1.66
Lignin (%)	10.6	13.8	8.5	10.5	8.8	7.2	7.8	7.4	6.4	6.0
Lignin in ash-free d.m. (%)	12.2	18.4	9.3	11.5	10.4	8.3	8.7	8.7	7.4	6.8
Ash (%)	12.9	25.2	8.2	8.7	15.2	13.5	10.7	14.5	13.0	11.7
Soil organic matter (%)	11.9	-	5.2	6.1	4.1	2.9	3.1	2.4	2.5	1.2
Soil pH (1:2)	5.7	-	5.7	5.9	6.3	6.3	6.7	6.4	6.8	7.4
Electric conductivity (mmhos. 1:2)	0.8	-	0.7	1.8	1.4	1.1	1.3	1.7	1.0	0.9

5.3.5 Francis St. Transect (No. 5)

This transect is located almost in the middle off the Lulu Island foreshore. The dike was cleaned and reconstructed during the summer of 1974 (Photograph 9, Appendix 2). The surface of the tidal flat was relatively uniform but was traversed by a few well developed channels (Fig. 21).

Vegetation:

Carex l. mainly dominated the 0 m to 200 m area, then *Scirpus p.*, 200 m to 400 m and *Scirpus a.* from 400 m to 1,000 m. Many small pools and bare places were observed over the area from 600 m to 900 m (Fig. 22 and Table IV). Dead material was obtained from quadrats at 100 m, 200 m and 700 m. The dry matter yields were high at 700 m, 1,000 m and 200 m viz. 855, 661 and 541 g/m^2 respectively. The plant height varied from a low of 59 cm at 175 m and to a high of 108 cm at 325 m and at 725 m. Ash percentage showed little pattern, but lignin percentage of ash free d.m. tended to decrease with distance from the dike. Nitrogen % of ash free material varied from 0.64% to 1.14% (but was 0.39% for dead material at 700 m) (Fig. 20 and Table XIII).

Soil:

Organic matter % was high near the dike, but decreased substantially near the outward margin of the vegetated zone. The pH was 5.6 at 0 m, then gradually increased to 7.1 at 1,000 m (exception, 6.9 at 400 m and 7.2 at 700 m). Electric conductivity was relatively high, from 0 m to 600 m, but decreased to 0.8 mmhos at 1,000 m (Fig. 20 and Table XIII).

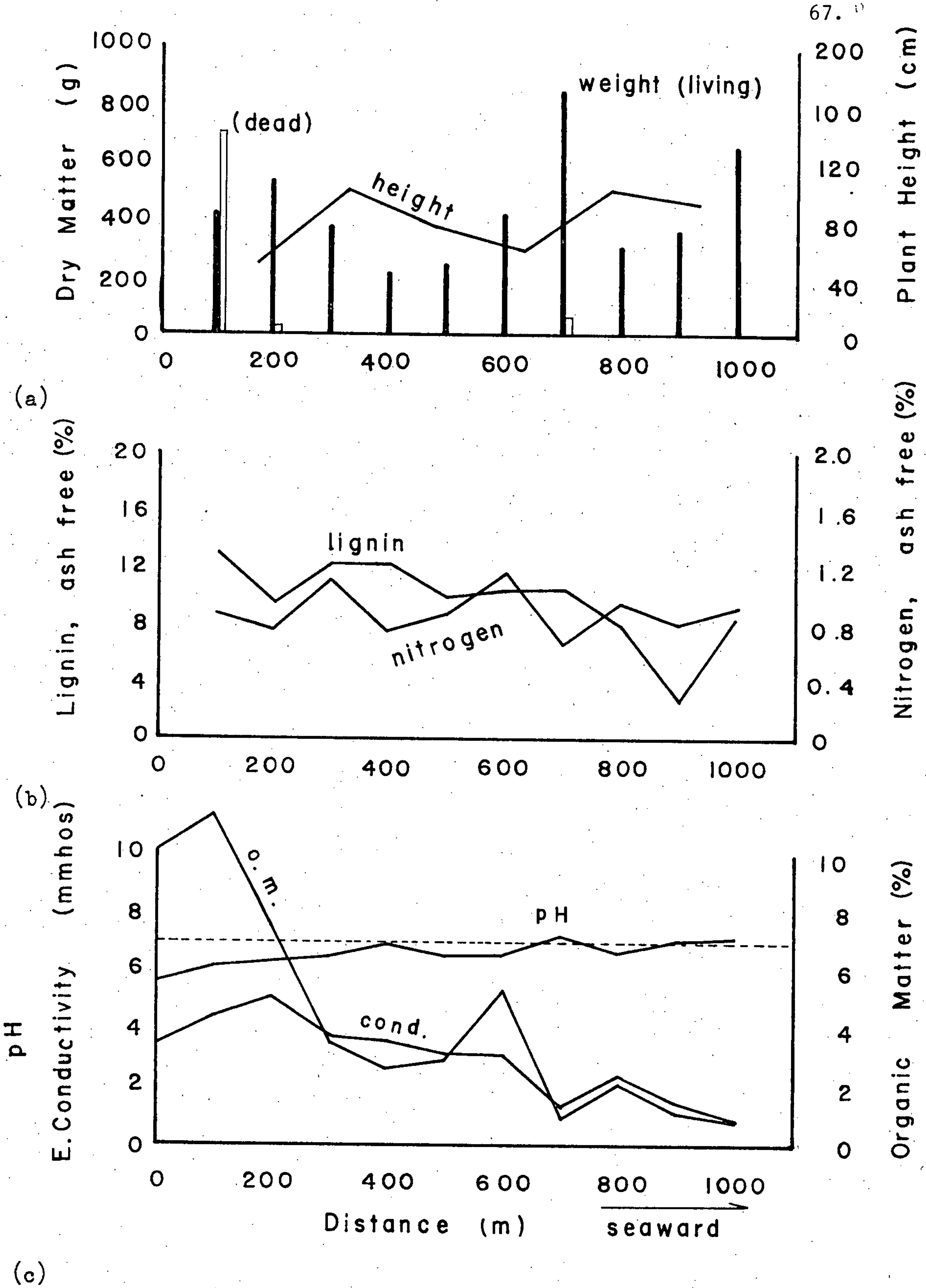


Figure 20. Francis St. Transect (No. 5); (a) dry matter weight and height, (b) nitrogen % and lignin % and (c) soil organic matter, pH and conductivity, 1974.

Figure 21. Photographs of a small pool (A) on the Westminster Highway Transect (No. 4), Lulu Is., and a large channel (B) near the Francis St. Transect (No. 5), Lulu Is., 1974. The small pool may support anadromous fish even at low tide. The large channel, at high tide, is shown as a rest area for waterfowl.

(A)

(B)

Legend

Agrostis exarata

Carex lyngbyei

Potentilla pacifica

Distchlis stricta

Scirpus americanus

Scirpus paludosus

Triglochin maritimum

Figure 22. Vegetation micro-map for the Francis St. Transect (No. 5), Sturgeon Bank, 1974.

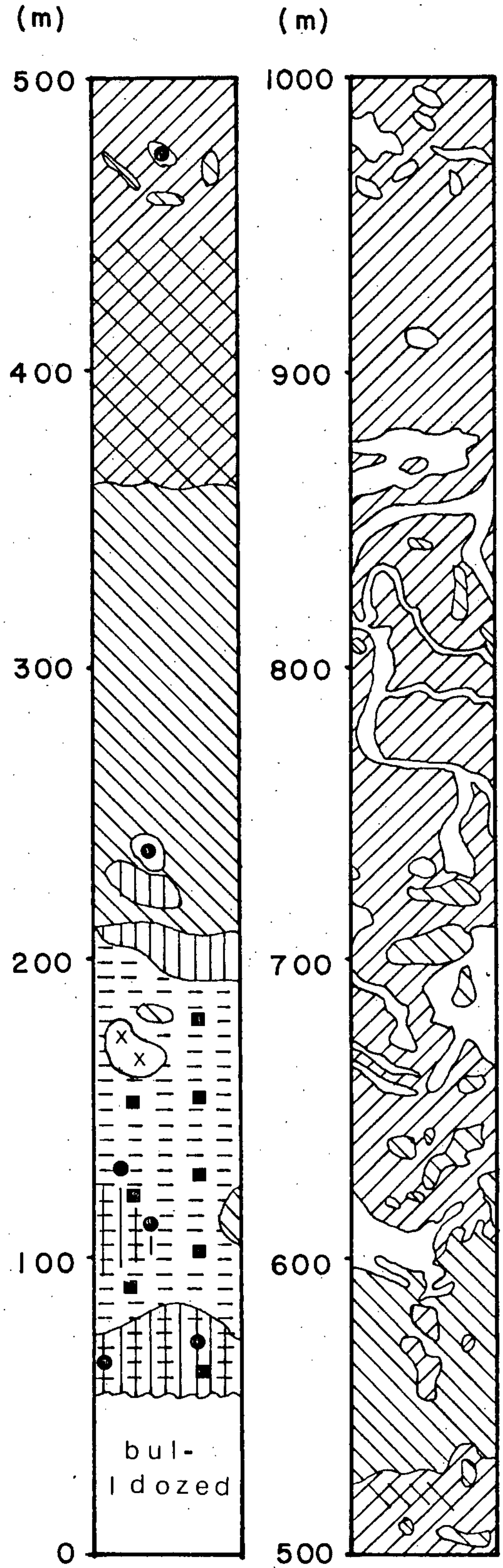

(m)
500
400
300
200
100
0
bul-
ldozed
(m)
1000
900
800
700
600
500

Table XIII: Francis St. Transect (No. 5): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	100	100	200	200	300	400	500	600	700	700	800	900	1000
Principal species	bull-dozed	C.l. A.s. T.m.	-	D.s. S.p.	-	S.p.	S.p. S.a.	S.a. S.p.	S.a. S.p.	S.a. S.p	-	S.a.	S.a.	S.a.
Living (L) material; Dead (D) material	-	L	D	L	D	L	L	L	L	L	D	L	L	L
Height (cm) Plants	-			59		108		78	61			108	86	
Interval (m) between samples				(150-200)		(300-350)		(450-500)	(600-650)			(750-800)	(900-950)	
Dry matter (g)	-	428	704	541	32	381	222	254	425	855	61	315	370	661
D. matter - ash (g)	-	402	471	471	25	327	200	224	361	762	53	265	316	568
Nitrogen (%)	-	0.81	0.53	0.68	0.59	0.94	0.67	0.76	0.97	0.57	0.34	0.79	0.68	0.77
Nitrogen (g/m^2)	-	3.5	3.7	3.7	0.2	3.6	1.5	1.9	4.1	4.9	0.2	2.5	2.5	5.1
Nitrogen in ash-free d.m. (%)	-	0.86	0.79	0.78	0.79	1.09	0.74	0.86	1.14	0.64	0.39	0.94	0.79	0.90
Lignin (%)	-	12.1	13.6	8.3	29.3	10.3	10.9	8.6	8.9	9.4	19.3	6.8	2.2	2.1
Lignin in ash-free d.m. (%)	-	12.9	20.3	9.5	38.1	12.1	12.1	9.8	10.5	10.6	22.3	7.9	2.6	8.3
Ash (%)	-	6.1	33.1	12.9	23.0	14.0	10.0	11.8	15.0	10.9	13.3	15.7	14.4	14.1
Soil organic matter (%)	10.1	11.4	-	7.5	-	3.5	2.6	2.9	5.3	0.9	-	2.1	1.1	0.8
Soil pH (1:2)	5.6	6.1	-	6.2	-	6.4	6.9	6.5	6.5	7.2	-	6.6	7.0	7.1
Electric conductivity (mmhos. 1:2)	3.4	4.4	-	5.0	-	3.7	3.5	3.1	3.1	1.3	-	2.4	1.5	0.8

5.3.6 Steveston Highway Transect (No. 6)

The transect off the end of the Steveston Highway is near the Steveston jetty. There was not much surface disturbance and the topography was fairly uniform. A cattle holding yard made by a farmer occupied a large area, outside the dike; from 0 m to 200 m along the transect, where otherwise *Distichlis s.*, *Carex l.* or *Typha l.* would grow (Photographs 11 and 12, Appendix 2), the vegetation had been grazed or trampled down.

<u>Vegetation:</u>

The first 200 m outside the cattle holding yard, and parallel to the transect, was dominated by *Typha l.* followed by *Triglochin m.* and *Scirpus a.* with occasional *Scirpus p.* (Table XV). No dead material was obtained from this transect. The plants were relatively tall and varied in height from 136 cm at 200 m to 81 cm at 800 m. The highest dry matter yield was 618 g/m^2 at 700 m, and the lowest 144 g/m^2 at 200 m. The other yields varied from 347 to 588 g/m^2. The ash % was high especially at 300 m and at 400 m. The nitrogen % of ash free materials was fairly constant and lay in the range of 0.78% to 1.05%. Lignin % decreased irregularly (Table XIV).

<u>Soil:</u>

Organic matter % was relatively high and decreased gradually seawards from the dike, except at 200 m where an anomalous value was obtained. The pH value increased gradually from 5.6 to 7.2. The electric conductivity was relatively high and ranged from 1.3 mmhos to 3.0 mmhos (Table XIV).

Table XIV: Steveston Highway Transect (No. 6): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	100	200	300	400	500	600	700	800
Principal species	cattle padlock bulldozed		T.l.	T.m. S.a. S.p.	T.m. S.a.	S.a.	S.a.	S.a.	S.a.
Living (L) material; Dead (D) material	-	-	L	L	L	L	L	L	L
Height (cm) Plants	-	-	136	81		48	91		81
Interval (m) between samples			(150-200)	(300-350)		(450-500)	(600-650)		(750-800)
Dry matter (g.)	-	-	144	588	404	450	367	618	347
D. matter - ash (g.)	-	-	132	482	328	394	312	516	297
Nitrogen (%)	-	-	0.86	0.77	0.72	0.64	0.76	0.65	0.90
Nitrogen (g/m^2)	-	-	1.2	4.5	2.9	2.9	2.8	4.0	3.1
Nitrogen in ash-free d.m. (%)	-	-	0.93	0.94	0.89	0.73	0.90	0.78	1.05
Lignin (%)	-	-	5.6	8.0	5.1	3.7	7.1	2.9	3.4
Lignin in ash-free d.m. (%)	-	-	6.1	9.8	6.3	4.2	8.4	3.5	4.0
Ash (%)	-	-	7.9	18.1	18.7	12.4	15.1	16.5	14.5
Soil organic matter (%)	-	-	10.7	3.6	3.4	2.4	1.6	1.7	1.3
Soil pH (1:2)	-	-	5.6	6.2	6.3	6.5	6.8	6.9	7.2
Electric conductivity (mmhos. 1:2)	-	-	2.0	2.3	3.0	1.8	1.5	1.3	1.3

Table XV: Principal species log for transect (No. 1 - 6) of Point Grey, Sea Island and Lulu Island, 1974.

Point Grey Transect (No. 1):

Distance (m)	Species	Index
0	*Equisetum f.*	100
0	*Rubus l.*	25
50	*Typha l.*	10
50	*Angelica g.*	70
100	*Typha l.*	25
100	*Angelica g.*	25
150	*Typha l.*	25
150	*Angelica g.*	2
200	*Carex l.*	100
250	*Carex l.*	100
250	*Typha l.*	100
300	*Scirpus v.*	100
300	*Triglochin m.*	100
350	*Scirpus v.*	100
400	*Scirpus a.*	100
400	*Scirpus v.*	70

Sea Island Transect (No. 3):

Distance (m)	Species	Index
0	*Carex l.*	100
0	*Typha l.*	10
0	*Potentilla p.*	25
100	*Scirpus p.*	100
200	*Scirpus a.*	100
200	*Scirpus p.*	100
300	*Scirpus a.*	100
300	*Scirpus p.*	70
400	*Scirpus a.*	100

Westminster Hwy. Transect (No. 4):

Distance (m)	Species	Index
0	*Carex l.*	100
0	*Potentilla p.*	25
0	*Lathyrus p.*	10
0	*Typha l.*	10
100	*Typha l.*	25
200	*Scirpus v.*	100
200	*Scirpus p.*	25
300	*Carex l.*	100
300	*Scirpus v.*	70
400	*Scirpus a.*	100
500	*Scirpus a.*	100
500	*Triglochin m.*	5
500	*Scirpus p.*	5
500	*Scirpus v.*	5
600	*Scirpus a.*	100
600	*Triglochin m.*	100
700	*Scirpus a.*	100

Francis St. Transect (No.5):

Distance (m)	Species	Index
0	bulldozed	-
100	*Carex l.*	100
100	*Triglochin m.*	25
100	*Potentilla p.*	15
100	*Agrostis s.*	100
200	*Distichlis s.*	100
200	*Scirpus p.*	70
200	*Scirpus a.*	10
300	*Scirpus p.*	100
400	*Scirpus p.*	100
400	*Scirpus a.*	100

... continued

Table XV: continued

Francis St. Transect (continued):

Distance (m)	Species	Index
500	*Scirpus a.*	100
500	*Scirpus p.*	70
600	*Scirpus a.*	100
600	*Scirpus p.*	25
700	*Scirpus a.*	100
700	*Scirpus p.*	100
800	*Scirpus a.*	100
900	*Scirpus a.*	100
1000	*Scirpus a.*	100

Steveston Hwy. Transect (No. 6):

Distance (m)	Species	Index
0	bulldozed	-
100	cattle paddock	-
200	*Typha l.*	25
300	*Triglochin m.*	100
300	*Scirpus p.*	5
300	*Scirpus a.*	100
400	*Triglochin m.*	100
400	*Scirpus a.*	100
500	*Scirpus a.*	100
600	*Scirpus a.*	100
600	*Scirpus p.*	5
700	*Scirpus a.*	100
800	*Scirpus a.*	100

5.4 Area, productivity and quality estimates for Roberts Bank Area (Transect No. 7-9)

The Roberts Bank Area was sub-divided into three areas; (a) Westham Island, (b) Brunswick-Canoe Pass and (c) Tsawwassen. One transect was laid off Reifel Island in the Westham Island area; no transects were laid in the Brunswick area; two were laid in the Tsawwassen area (one near the Roberts Bank terminal and one near the Tsawwassen ferry terminal (Table XVI and Fig. 23). *Triglochin m., Salicornia v.* and *Distichlis s.*, not found to be very important species in the area from Point Grey to Steveston, were common in this area in addition to the five dominants of Sturgeon Bank. The average yield (ton/ha) of emergent vegetation (standing crop) was the lowest on the Tsawwassen ferry transect of the three transects charted; the drift wood off the Tsawwassen Rd. alone accounted for 7 hectares.

Figure 23. Map to show the vegetational areas and the location and vegetation of the line-transects (No. 7-9) in the Roberts Bank Area, 1974.

Legend

7 - Reifel Island Transect

8 - 34th St. (Superport) Transect

9 - Tsawwassen Rd. Transect

Carex lyngbyei

Distichlis stricta

Salicornia virginica

Scirpus americanus

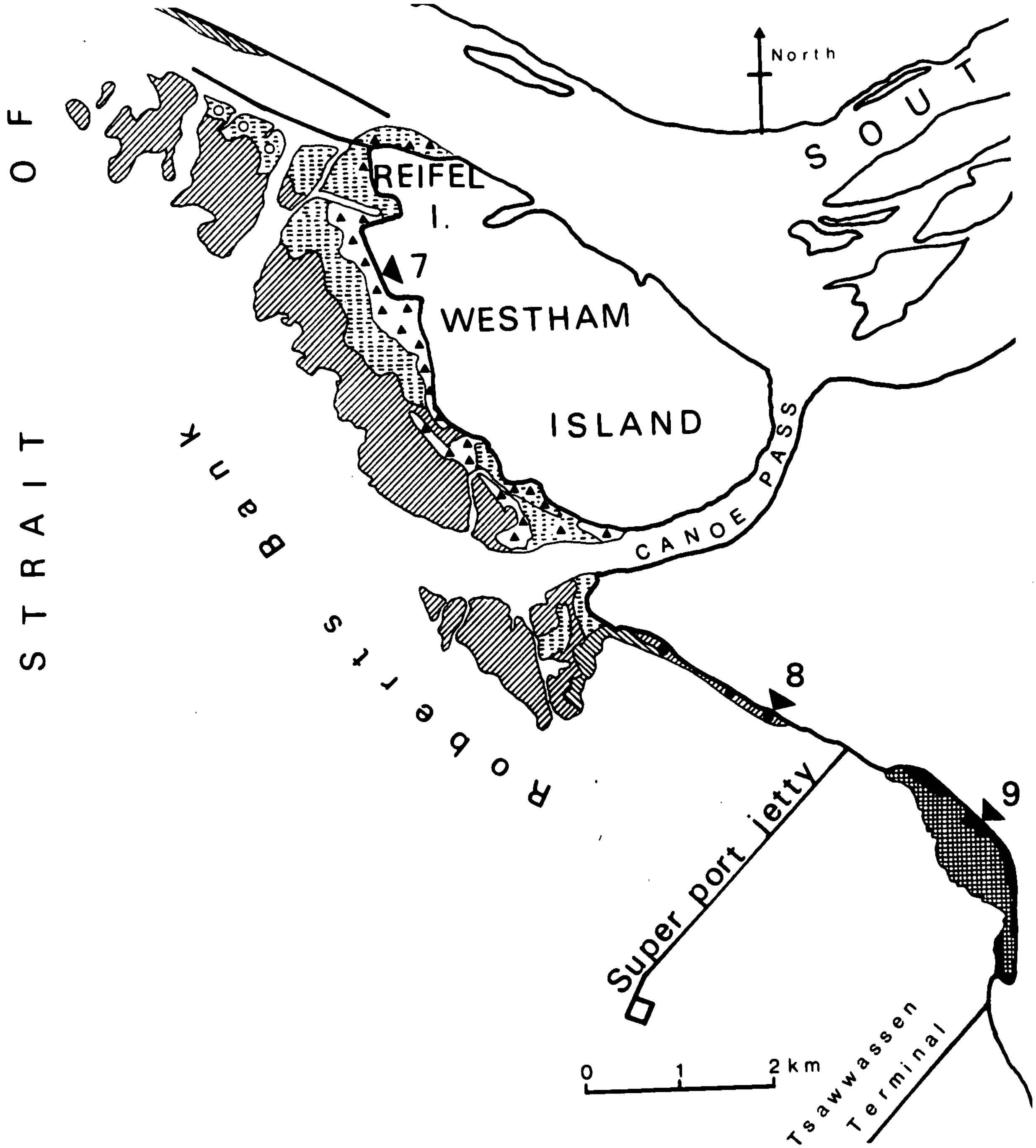
Scirpus paludosus

Scirpus validus

Triglochin maritimum

Typha latifolia

Drift wood



North
SOUT
REIFEL
I.
7
WESTHAM
ISLAND
CANOE PASS
STRAIT OF
Roberts Bank
8
9
Super port jetty
0 1 2 km
Tsawwassen
Terminal

Table XVI: Estimates of the area and dry matter yields of emergent vegetation of several sections of the Roberts Bank area, 1974.

Location and Species	Area ha.	Area (%)	Standing Crop ton	Standing Crop (%)	Average Yield dry matter ton/ha.
Westham Island:					
Carex l.	173	(28)	2,043	(51)	11.8
Scirpus a.	350	(56)	1,366	(34)	3.9
Typha l.	97	(15)	527	(13)	5.4
T *Scirpus v.*	9	(1)	104	(2)	11.8
Total	629	(100)	4,040	(100)	6.4
Brunswick‡:					
Scirpus a.	115	(70)	447	(55)	3.9
Carex l.	21	(13)	249	(31)	11.8
Scirpus p.	19	(12)	94	(12)	4.9
Triglochin m.	9	(5)	17	(2)	1.9
Total	164	(100)	807	(100)	4.9
Tsawwassen:					
Salicornia v.	40	(48)	142	(51)	3.6
Distichlis s.	37	(44)	135	(49)	3.6
Driftwood	7	(8)	0	(0)	0
Total	84	(100)	277	(100)	3.3

‡ The data for this area may not be correct; because of deep channels, the area was difficult to reach and the estimates are ocular based on estimates from other areas.

5.4.1 Reifel Island Transect (No. 7)

This transect had the widest vegetation belt to cross, i.e. 1050 m, of the 14 transects (Table II). The surface was much the same as that off Francis St., Lulu Island. There were a number of well developed channels (Fig. 24) which, at high tide, became excellent resting areas for waterfowl (Fig. 21 (B)). The vegetation was quite uniformly distributed but the pools observed on the Francis St. transect (Fig. 22) were not encountered here.

Vegetation:

The changes of the principal plant species from the dike to the open sea are broadly recorded as *Typha l.* to *Carex l.* to *Scirpus a.* (Table XX). Minor communities were *Scirpus v.*, *Triglochin m.* and *Scirpus p.* The 0 m *Typha l.* quadrat had theonly dead material on this transect. The gradual decline of the plant height curve without sudden change may be compared to the irregularity of the dry matter weight. The plant height heavily depended on the species rather than on the "density" of the species. The nitrogen % of the ash free material tended to increase to a high in the middle and to the end of the transect; the nitrogen yield per square meter declined from 3.8 g/m^2 at 0 m to 1.2 g/m^2 at 1000 m but with exceptionally high values at 100 m and at 400 m. The lignin % of ash free materials fell in the range of 9.1% to 6.1% (except 13.2% at 100 m). The ash % varied from 6.9% to 28.9% (Fig. 25 and Table XVII).

Soil:

The soil organic matter % decreased from 4.1% at 0 m to 1.5% at 100 m. The pH values were on a slightly different pattern to those of similar transects, but pH increased in general as going from the dike seawards. The electric conductivities along the transect were slightly above or below 1 mmhos at all places (Fig. 25 and Table XVII).

Figure 24. Photographs of a typical mud flat (A) 900 m from the dike on the Reifel Island, Westham Island area and of a large channel with its adjacent of emergent vegetation (*Scirpus americanus*) also Reifel Island Transect (No. 7), 1974.

(A)

(B)

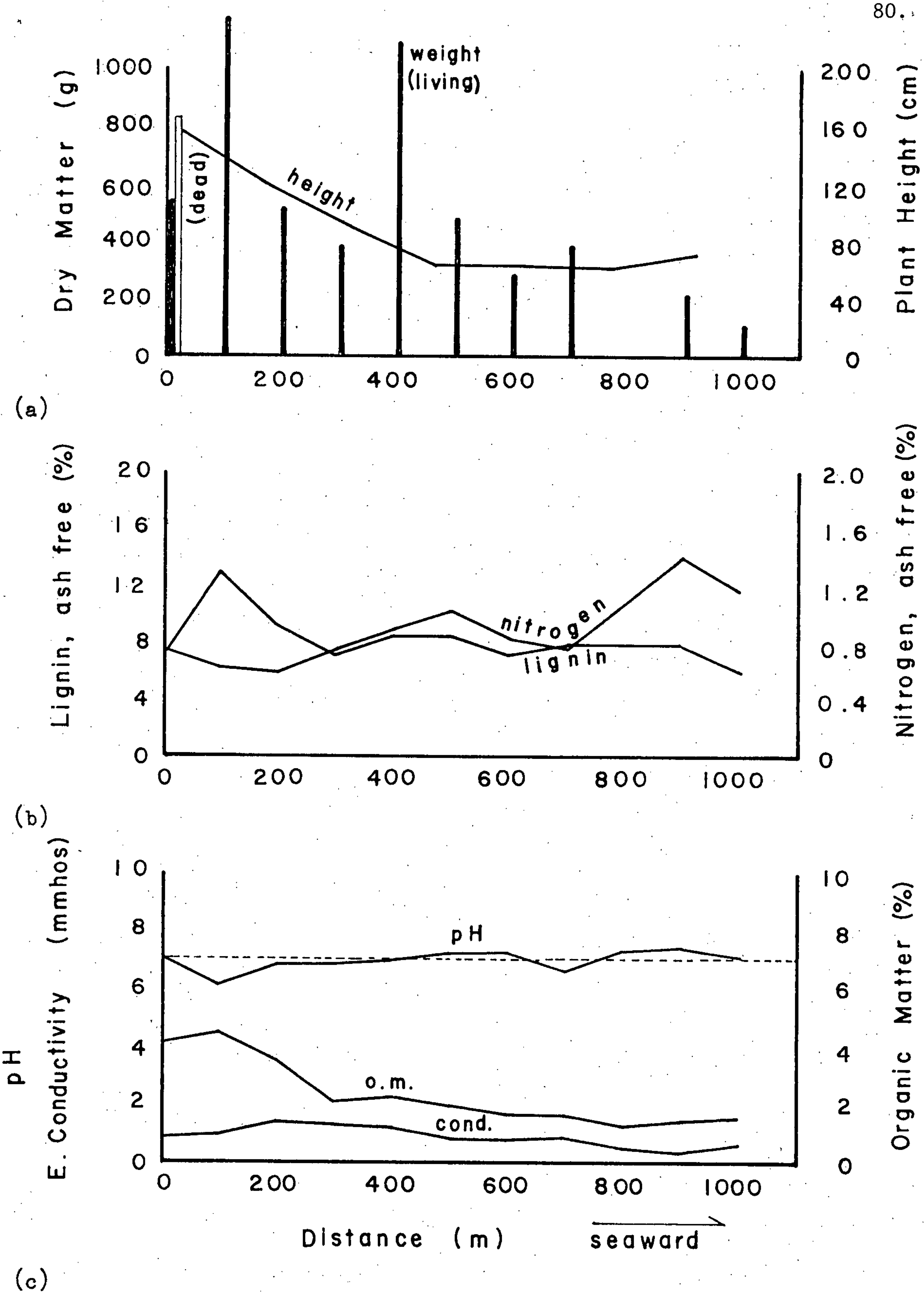


Figure 25. Reifel Island Transect (No. 7); (a) dry matter weight and height, (b) nitrogen % and lignin % and (c) soil organic matter, pH and conductivity, 1974.

Table XVII: Reifel Island Transect (No. 7): Soil and Plant Analyses, 1974.

Distance from dike (m)	0		100	200	300	400	500	600	700	800	900	1000
Principal species	T.l.	-	S.v. C.l. T.l.	S.a. S.v. S.p.	S.a.	S.a. T.m.	S.v. S.a.	S.a.	S.a.	-	S.a.	S.a.
Living (L) material; Dead (D) material	L	D	L	L	L	L	L	L	L	-	L	L
Height (cm) Plants	158	-	-	119	93	-	64	64	-	62	71	-
Interval (m) between samples	(0-50)			(150-200)		(300-350)	(450-500)		(600-650)	(750-800)		(900-950)
Dry matter (g)	542	831	1179	520	388	1090	482	292	396	-	222	114
D. matter - ash (g)	504	429	994	488	340	775	407	249	336	-	186	99
Nitrogen (%)	0.71	0.22	0.52	0.53	0.65	0.70	0.87	0.71	0.65	-	1.18	1.02
Nitrogen (g/m^2)	3.8	1.8	6.1	2.8	2.5	7.6	4.2	2.1	2.6	-	2.6	1.2
Nitrogen in ash-free d.m. (%)	0.76	0.43	0.62	0.58	0.74	0.98	1.03	0.83	0.77	-	1.40	1.17
Lignin (%)	6.5	6.5	11.1	8.3	6.4	6.0	7.2	6.2	6.7	-	6.6	5.3
Lignin in ash-free d.m. (%)	7.0	12.6	13.2	9.1	7.3	8.4	8.5	7.3	7.9	-	7.9	6.1
Ash (%)	6.9	48.3	15.7	9.1	12.3	28.9	15.7	14.8	15.3	-	16.0	13.0
Soil organic matter (%)	4.1	-	4.5	3.5	2.0	2.2	1.9	1.6	1.6	1.2	1.4	1.5
Soil pH (1:2)	7.0	-	6.1	6.7	6.7	6.9	7.2	7.2	6.6	7.3	7.3	7.1
Electric conductivity (mmhos. 1:2)	0.68	-	0.95	1.31	1.25	1.14	0.70	0.67	0.88	0.49	0.36	0.58

5.4.2 34th Street Transect (No. 8), (Superport)

This transect is located south of Canoe Pass and north of the Superport jetty (Fig. 23). The vegetation extended only 70 m from the dike. The tidal flat, however, extended a long distance beyond the vegetation. Some of the tidal flat was covered by algae. Small vegetation islands were also observed on this tidal flat, but they were not far from the dike.

Vegetation:

Triglochin m. and *Scirpus a.* were the main species. No dead material was found. The plants were only about 30 cm high. Nitrogen % of ash free materials was relatively high, but that of lignin was low. The ash % was exceptionally high (Table XVIII and Table XX).

Soil:

The soil organic matter percentages were about 2%. The pH changed from 6.9, 6.1 to 7.2 at 0m, 50 m and 100 m respectively. The electric conducitvities were high and varied from 5.4 to 8.0 mmhos (Table XVIII).

Table XVIII: 34th St. (Superport) Transect (No. 8): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	50	100
Principal species	T.m.	S.a. T.m.	-
Living (L) material; Dead (D) material	L	L	-
Height (cm.) Plants		31	-
Interval (m.)		(0-50)	-
Dry matter (g.)	190	190	-
D. matter - ash (g.)	137	156	-
Nitrogen (%)	0.79	1.07	-
Nitrogen (g/m^2)	1.5	2.0	-
Nitrogen in ash-free d.m. (%)	1.10	1.30	-
Lignin (%)	4.7	2.8	-
Lignin in ash-free d.m. (%)	6.5	3.4	-
Ash(%)	28.2	18.0	-
Soil organic matter (%)	1.7	1.6	2.1
Soil pH (1:2)	6.9	6.1	7.2
Electric conductivity (mmhos. 1:2)	5.4	5.5	7.0

5.4.3 Tsawwassen Road, (Roberts Bank jetty) Transect (No. 9).

This transect differed from the others in many respects. The surface was flat seawards to the end of emergent vegetation and then a sharp break (gradient) was encountered beyond which, on the flat, there was no emergent vegetation. Some small weakly developed channels were observed (Fig. 26). This area was not inundated even at high tides while the study took place during the summers of 1973 and 1974. The area is located in front of the Tsawwassen Indian reserve; the residential area is well isolated from other residential areas. Large quantities of drift logs and flotsam occupied the area on the seaward side of Tsawwassen Rd. (Fig. 23).

Vegetation:

This transect crossed vegetation predominantly given to *Distichlis s.* and *Salicornia v.* admixed with minor species such as *Atriplex patula, Grindelia integrifolia* and *Hordeum jubatum* (Table XX). The quadrats, except one at 100 m, had more dead material (litter) than living material in terms of dry matter weight per square meter. The plant height was lowest at 300 m, but it varied only from 26 cm to 40 cm along the transect. The vegetation was uniformly distributed and the dry matter weights per square meter were relatively constant, varying from 209 to 341 g/m^2. Nitrogen percentages of ash free materials were high and constant with the exception of those at 0 m (0.75%) and at 500 m (0.93%). The nitrogen percentages of dead material were lower than those of living material; however, the nitrogen yields (g/m^2) were higher than those of the living material. The lignin % of ash free living material varied from 8.4% to 10.1% with exception of 13.1% and 18.6% at 0 m and 500 m respectively.

The lignin percentages of ash free dead material were higher than those of the living material, the lowest, 13.2%, at 300 m, and the highest, 16.5%, at 400 m. The ash percentages of both living and dead materials varied substantially with the lowest, 5.0%, at 0 m and the highest, 18.6%, at 200 m (Fig. 26, Fig. 27 and Table XIX).

Soil:

The organic matter percentages in the soil decreased steadily from 22.5% at 100 m to 0.5% at 500 m except at 0 m where it was 3.6%. pH values were generally below 6 except at 0 m (6.7) and 600 m (6.7). The electric conductivities were extremely high, but decreased at 500 m and 600 m (Table XIX).

(A)

(B)

Figure 26. Photographs of a weakly developed channel (A) and mud flat (B) looking seawards from 600 m both on the Tsawwassen Road Transect (No. 9), 1974.

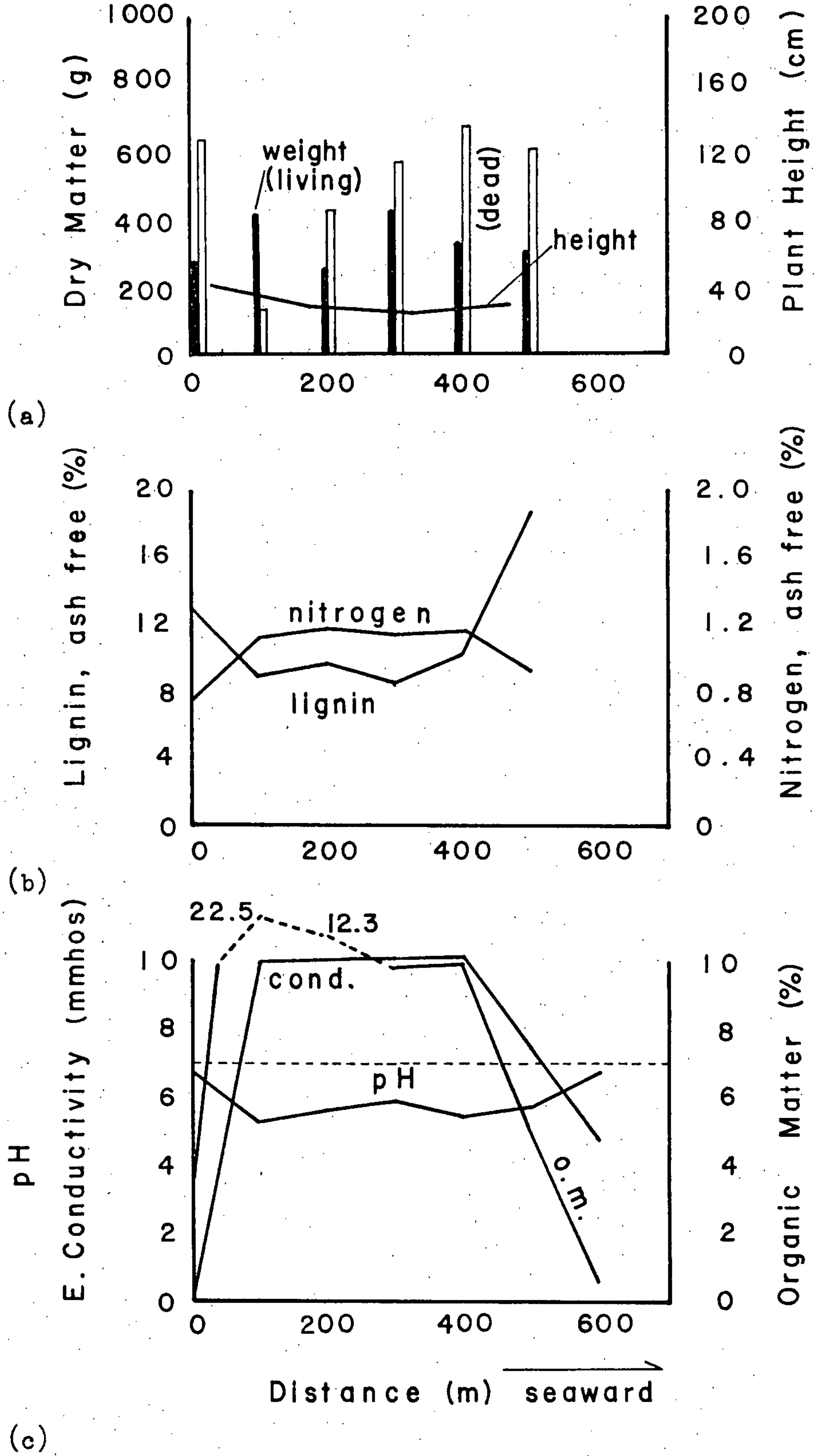


Figure 27. Tsawwassen Rd. Transect (No. 9); (a) dry matter weight and height, (b) nitrogen % and lignin % and (c) soil organic matter, pH and conductivity, 1974.

Table XIX: Tsawwassen Rd. Transect (No. 9): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	0	100	100	200	200	300	300	400	400	500	500	600
Principal species	P.pl. E.m.	-	D.s. Sa.v. A.p.	-	D.s. Sa.v. A.p.	-	D.s. Sa.v. A.p.	-	D.s. Sa.v. A.p.	-	Sa.v. D.s. A.p.	-	-
Living (L) material; Dead (D) material	L	D	L	D	L	D	L	D	L	D	L	D	-
Height (cm) Plants			40		28		26				31		
Interval (m)			(0-50)		(150-200)		(300-350)				(450-500)		
Dry matter (g)	275	628	415	137	257	423	428	568	336	779	305	611	-
D. matter - ash (g)	261	568	341	115	209	357	284	498	306	643	259	450	-
Nitrogen (%)	0.64	0.61	0.92	0.81	0.97	0.79	0.90	0.64	0.97	0.59	0.79	0.73	-
Nitrogen (g/m^2)	1.8	3.8	3.8	1.1	2.5	3.3	3.0	3.6	3.3	4.6	2.4	4.5	-
Nitrogen in ash-free d.m. (%)	0.75	0.67	1.12	0.96	1.19	0.94	1.04	0.73	1.06	0.72	0.93	0.89	-
Lignin (%)	11.1	14.1	7.2	13.0	7.8	11.3	7.3	11.6	9.2	13.6	15.8	11.0	-
Lignin in ash-free d.m. (%)	13.1	15.9	8.8	15.4	9.6	13.4	8.4	13.2	10.1	16.5	18.6	13.4	-
Ash (%)	5.0	9.5	17.8	15.5	18.6	15.6	13.5	12.2	8.9	17.5	15.0	18.2	-
Soil organic matter (%)	3.6	-	22.5	-	12.3	-	9.8	-	9.9	-	5.1	-	0.5
Soil pH (1:2)	6.7	-	5.2	-	5.6	-	5.8	-	5.4	-	5.7	-	6.7
Electric conductivity (mmhos. 1:2)	<0.1	-	>10	-	>10	-	>10	-	>10	-	7.3	-	4.7

Table XX: Principal species log for transects (No. 7 - 9) in the Roberts Bank area, 1974.

Reifel Island Transect (No. 7):

Distance (m)	Species	Index
0	*Typhas l.*	25
100	*Typha l.*	5
100	*Scirpus v.*	100
100	*Carex l.*	100
200	*Scirpus a.*	100
200	*Scirpus v.*	100
200	*Scirpus p.*	25
200	*Sagittaria c.*	5
300	*Scirpus a.*	100
300	*Sagittaria c.*	5
400	*Triglochin m.*	100
400	*Scirpus v.*	5
400	*Scirpus a.*	100
400	*Scirpus p.*	5
500	*Scirpus v.*	100
500	*Scirpus a.*	100
600	*Scirpus a.*	100
600	*Triglochin m.*	5
700	*Scirpus a.*	100
800	no vegetation	-
900	*Scirpus a.*	100
1000	*Scirpus a.*	100

34th St. (Superport) Transect (No. 8):

Distance (m)	Species	Index
0	*Triglochin m.*	100
0	*Spergularia m.*	5
50	*Scirpus a.*	100
50	*Triglochin m.*	100

Tsawwassen Rd. Transect (No. 9):

Distance (m)	Species	Index
0	*Poa p.*	100
0	*Elymus m.*	70
100	*Distichlis s.*	100
100	*Salicornia v.*	100
100	*Atriplex p.*	100
200	*Distichlis s.*	100
200	*Salicornia v.*	100
200	*Atriplex p.*	25
300	*Distichlis s.*	100
300	*Salicornia v.*	100
300	*Atriplex p.*	70
400	*Distichlis s.*	100
400	*Salicornia v.*	70
400	*Atriplex p.*	70
500	*Salicornia v.*	100
500	*Distichlis s.*	100
500	*Atriplex p.*	100
500	*Grindelia i.*	25
500	*Hordeum j.*	5

5.5 Area, productivity and quality estimates for the Boundary Bay area (Transect No. 10-14).

Boundary Bay, largely under the influence of the salt waters of the Gulf and lightly under the influence of the fresh waters of the Nicomekl and Serpentine rivers has a magnificent tidal flat. Nonetheless the dry matter yield of emergent vegetation produced from Boundary Bay accounted for only 5% of that of the whole study area. Three species, *Salicornia v.*, *Triglochin m.* and *Distichlis s.* were the principal species. *Salicornia v.* accounted for 68% of the dry matter yield of the periphyton of Boundary Bay. The average yield of the area was only 2.0 ton/ha. Drift wood occupied a large area (49 hectares) near the dike which could be potentially supportive of vegetation (Table XXI and Fig. 28). *Zostera marina* which grew plentifully on Boundary Bay as a submergent far from the dike was not included in this study.

Figure 28. Map to show the vegetational areas and the location and vegetation of the line-transects (No. 10-14) in the Boundary Bay area, 1974.

Legend

10 - Beach Grove Transect

11 - 72 St. Boundary Bay Transect

12 - 88 St. Boundary Bay Transect

13 - 112 St. Mud Bay Transect

14 - Crescent Beach Transect

Salicornia virginica

Triglochin maritimum

Drift wood

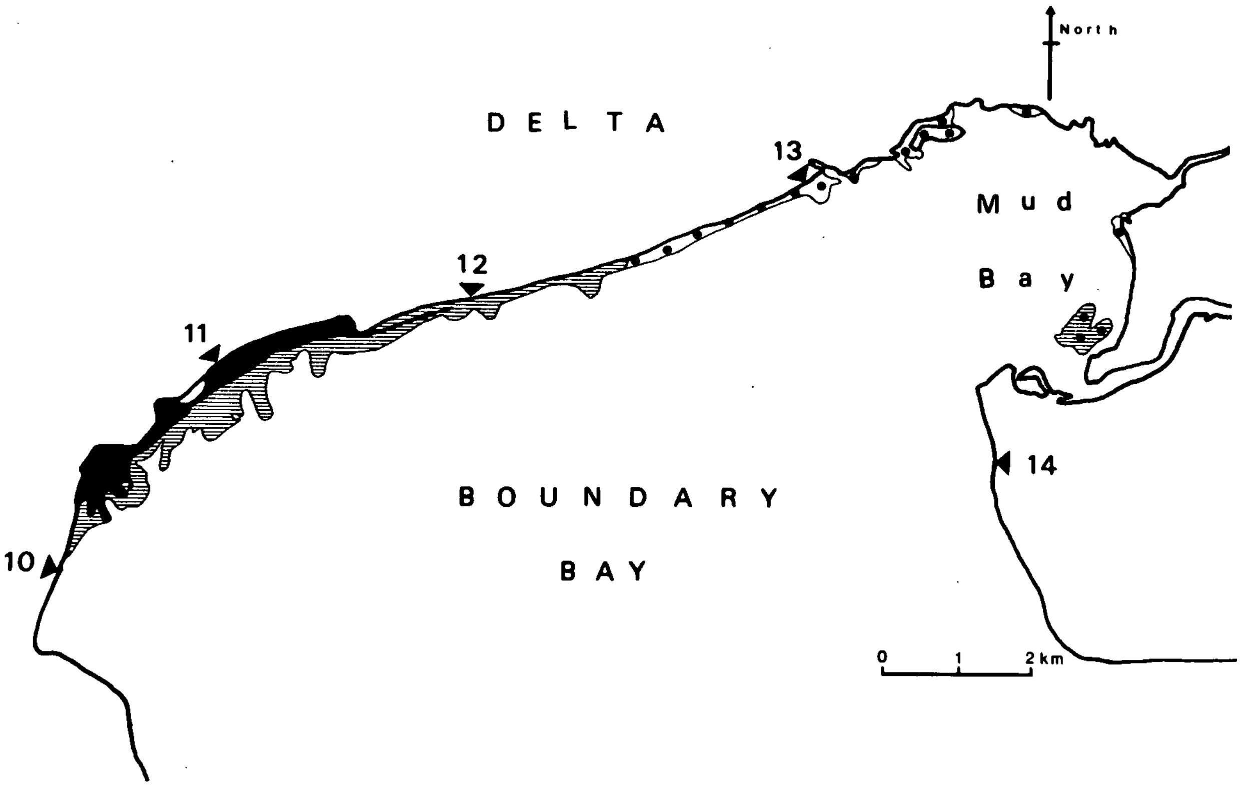

North
DELTA
13
Mud
Bay
12
11
BOUNDARY
BAY
14
10
0
1
2 km

Table XXI: Estimates of the area and dry matter yields of emergent vegetation of the several sections for the Boundary Bay area, 1974.

Location and Species	Area ha.	Area (%)	Standing Crop ton	Standing Crop (%)	Average Yield ton/ha.
Boundary Bay:					
Salicornia v.	102	(43)	317	(68)	3.1
Trijlochin m.	83	(35)	148	(31)	1.8
Distichlis s.	3	(1)	3	(1)	1.1
Drift wood	49	(21)	0	(0)	0
Total	237	(100)		(100)	2.0

5.5.1 Beach Grove Transect (No. 10)

This transect was located some distance from fresh water sources and much of its soil was sandy (Fig. 28). The transect was close to private residences. Both permanent stakes and blocks were destroyed by vandalism within a month after their establishment. The transect length was only 250 m (Table II).

Vegetation:

There were no higher plants growing on this transect except *Zostera marina* and it grew far from the shore (Table XXII).

Soil:

The organic matter percentages were extremely low and the pH values were below 7 but increased with distance from the shore. The electric conductivities were between 3.8 and 5.0 mmhos except at 0 m where it was less than 0.1 mmhos (Table XXII).

Table XXII: Beach Grove Transect (No. 10): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	50	100	150	200	250
Principal species	-	-	-	-	-	-
Living (L) material; Dead (D) material	-	-	-	-	-	-
Height (cm.) Plants	-	-	-	-	-	-
Interval (m)	-	-	-	-	-	-
Dry matter (g.)	-	-	-	-	-	-
D. matter - ash (g.)	-	-	-	-	-	-
Nitrogen (%)	-	-	-	-	-	-
Nitrogen (g/m^2)	-	-	-	-	-	-
Nitrogen in ash-free d.m. (%)	-	-	-	-	-	-
Lignin (%)	-	-	-	-	-	-
Lignin in ash-free d.m. (%)	-	-	-	-	-	-
Ash (%)	-	-	-	-	-	-
Soil organic matter (%)	1.2	0.4	0.3	0.4	0.3	0.3
Soil pH (1:2)	6.2	6.1	6.6	6.3	6.5	6.8
Electric conductivity (mmhos. 1:2)	0.1	5.0	4.2	4.1	3.8	4.3

5.5.2 72 St. Transect (No. 11)

Drift wood from Fraser River accounted for approximately 170 m of the 450 m transect (Fig. 29). The dike was well vegetated and was seldom disturbed except by recreational horsemen (Photograph 27, Appendix 2).

Vegetation:

Salicornia v., Grindelia i., Atriplex p. and *Distichlis s.* were the dominant species of this area. *Atriplex p.* particularly was widely distributed in this area. It appeared in most of the quadrats (Table XXVII). Dead material was found at 0 m only. All species were of short stature but the dry matter yields were not so low relative to height as compared to other transects. The nitrogen percentages of ash free materials varied from 0.56% to 1.18% while those for lignin in ash free materials varied from 4.5% to 10.8%. The ash percentages were over 20% with exception of 6.2% and 9.2% at 0 m and 250 m respectively (Table XXIII).

Soil:

Organic matter percentages were extremely high except at 300 m, 350 m and 400 m. This due to the decay of the drift wood. The pH values were below 7 and varied only from 5.5 to 6.5. The electric conductivity was above or about 10 mmhos except at 0 m (0.9 mmhos) and 100 m (0.1 mmhos) (Table XXIII).

Table XXIII: 72 St., Boundary Bay Transect (No. 11): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	0	50	100	150	200	250	300	350	400
Principal species*	E.m. S.c.	-	-	S.a.v. G.i. A.p.	-	G.i. D.s. A.p.	A.p. H.j. G.i.	S.a.v. A.p. D.s.	S.a.v. T.m. D.c.	-
Living (L) material; Dead (D) material	L	D	-	L	-	L	L	L	L	-
Height (cm.) Plants			41			16			29	
Interval (m)			(0-50)			(150-200)			(300-350)	
Dry matter (g.)	515	523	-	309	-	107	784	455	178	-
D. matter- ash (g.)	483	481	-	239	-	84	712	357	133	
Nitrogen (%)	0.64	0.69	-	0.78	-	0.93	0.51	0.76	0.55	
Nitrogen (g/m^2)	3.3	3.6	-	2.4	-	1.0	4.0	3.5	1.0	-
Nitrogen in ash-free d.m. (%)	0.68	0.75	-	1.01	-	1.18	0.56	0.97	0.74	-
Lignin (%)	4.2	13.6	-	4.1	-	4.1	9.1	8.5	4.6	-
Lignin in ash-free d.m. (%)	4.5	14.8	-	5.3	-	5.2	10.0	10.8	6.1	-
Ash (%)	6.2	8.0	-	22.7	-	21.4	9.2	21.6	25.2	-
Soil organic matter (%)	52.8	-	41.4	29.5	27.1	24.3	21.1	4.2	9.9	0.4
Soil pH (1:2)	6.2	-	5.6	5.5	5.7	6.0	5.9	5.8	5.9	6.5
Electric conductivity (mmhos. 1:2)	0.9	-	>10	<0.1	>10	>10	>10	>10	8.3	10.0

Figure 29. Photograph of drift wood and flotsam on the seaward side of the dike, foot of 72 St. (Transect No. 11), Boundary Bay (Delta Municipality), 1974.

5.5.3 88 St. Transect (No. 12).

This transect was much the same as the one at 72 St. (No. 11), Boundary Bay in many respects. The emergent vegetation, however, extended only ca. 200 m from the dike and its growth and composition were limited (Fig. 30). Some half-decayed drift wood lies along the dike.

Vegetation:

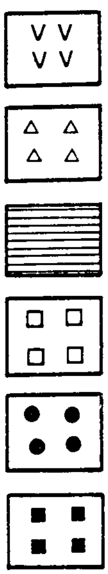
The commonest higher plant was *Salicornia v.* followed by *Triglochin m.* (Table XXVII). The dead material except that of 0 m listed in Table XXIV was largely *Zostera m.* brought to shore by wind and tide from the bay. The plants of this transect except those at 0 m were short and the dry matter per square meter was also low (Photographs 23 and 24, Appendix 2). Nitrogen percentages of ash free living material were quite constant, but the nitrogen yield (g/m^2) dropped sharply as the dry matter yield dropped. The lignin percentages of ash free material tended to decrease seawards. Ash percentages were above 30% except at 0 m where it was 8.7% (Table XXIV).

Soil:

The organic matter percentages were very low, except at 0 m where they were extremely high at 43.0%, and except for this single value, ranged from 0.4% to 3.1%. The soil pH values were below 7 but tended to increase from the dike to the sea. The electric conductivities, except at 0 m (2.0 mmhos) were above 8.9 mmhos (Table XXIV).

Figure 30. Vegetation micro-map of the 88 St. Transect, Boundary Bay, 1974. The surface from 25 m to 50 m was apparently lower than that at 100 m. *Spergularia marina* and *Triglochin maritimum* of the higher plants grew over the longest distances from the dike.

Legend



over 10 species

Puccinellia nuttalliana

Salicornia virginica

Spergularia marina

Triglochin maritimum

Agrostis exarata

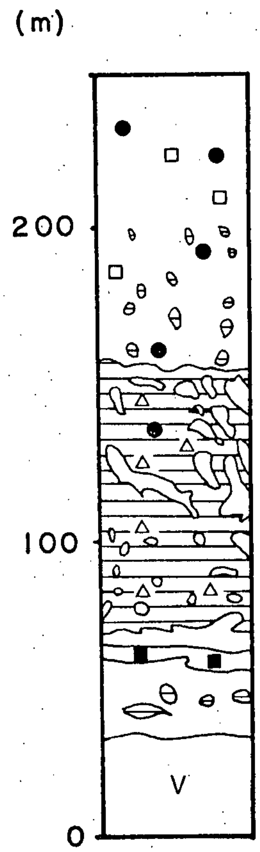

(m)
200
100
0
V

Table XXIV: 88 St. Boundary Bay Transect (No. 12): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	0	50	100	100	150	150	200	200	250
Principal species*	A.r. D.c.	-	-	Sa.v. T.m. P.n.	-	Sa.v. T.m. P.n.	-	Sa.v. S.m.	-	-
Living (L) material; Dead (D) material	L	D	-	L	D	L	D	L	D	-
Height (cm) Plants			27	8		16		6		
Interval (m)			(0-50)	(50-100)		(100-150)		(150-200)		
Dry matter (g)	645	362	-	243	96	127	78	8	34	-
D. matter - ash (g)	589	328	-	167	64	89	56	5	11	-
Nitrogen (%)	0.74	0.49	-	0.64	0.80	0.67	0.48	0.66	0.35	-
Nitrogen (g/m^2)	4.8	1.8	-	1.6	0.77	0.85	0.38	0.05	0.12	-
Nitrogen in ash-free d.m. (%)	0.81	0.54	-	0.93	1.2	0.96	0.67	0.97	1.10	-
Lignin (%)	8.8	12.0	-	6.0	9.9	4.0	10.8	4.9	2.9	-
Lignin in ash-free d.m. (%)	9.6	13.2	-	8.7	14.9	5.7	15.1	7.2	9.1	-
Ash (%)	8.7	9.3	-	31.3	33.7	30.4	28.5	32.3	68.3	-
Soil organic matter (%)	43.0	-	1.6	3.1	-	0.6	-	0.3	-	0.4
Soil pH (1:2)	5.4	-	6.6	5.5	-	5.8	-	6.5	-	6.4
Electric conductivity (mmhos. 1:2)	2.0	-	>10	>10	-	>10	-	>10	-	8.9

5.5.4 112 St. Transect (No. 13)

The transect was located just inside Mud Bay proper where access roads were not available. The emergent vegetation extended only 100 m from the dike. Occasional *Zostera m.* plants were observed in tiny pools along the transect. The soils were blackish and some gave off sulphurous gas indicative of poor aeration.

Vegetation:

The principal species was *Triglochin m.*, though *Spergularia marina* occurred in small areas (Table XXVII). The dead material collected was mainly *Zostera m.* carried in by the tide. The vegetation did not grow uniformly and formed vegetation islands; the values for average plant height and dry matter yield (g/m^2) were thus much reduced. The nitrogen percentages of ash free material were very high, i.e. above 1.38%, and lignin percentages of ash free material were below 5.4%. Ash percentages of both living and dead materials were above 22.1% and 37.3% respectively (Table XXV).

Soil:

Organic matter percentages except at 50 m (2.0%) decreased from 1.3% to 0.4% from the dike to the sea. Soil pH changed irregularly over short distances; electric conductivity was high (Table XXV).

Table XXV: 112 St. Mud Bay Transect (No. 13): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	25	25	50	50	75	100	125	150
Principal species*	Sea Weed	T.m. E.m.	-	T.m. S.m.	-	T.m.	-	-	-
Living (L) material; Dead (D) material	D	L	D	L	D	L	-	-	-
Height (cm.) Plants				4			5		
Interval (m)				(0-50)			(50-100)		
Dry matter (g.)	478	89	131	84	163	165	-	-	-
D. matter - ash (g.)	300	70	65	60	95	127	-	-	-
Nitrogen (%)	0.58	1.16	0.78	0.98	0.76	1.13	-	-	-
Nitrogen (g/m^2)	2.8	1.0	1.0	0.8	1.2	1.9	-	-	-
Nitrogen in ash-free d.m. (%)	0.93	1.49	1.58	1.38	1.31	1.47	-	-	-
Lignin (%)	13.6	4.2	5.2	3.8	6.9	3.5	-	-	-
Lignin in ash-free d.m. (%)	21.7	5.4	10.5	5.3	11.9	4.5	-	-	-
Ash (%)	37.3	22.1	50.7	29.0	41.8	22.9	-	-	-
Soil organic matter (%)	1.3	1.3	-	2.0	-	0.9	0.5	0.5	0.4
Soil pH (1:2)	6.5	6.0	-	5.4	-	6.4	6.2	6.1	6.7
Electric conductivity (mmhos. 1:2)	8.3	9.8	-	>10	-	5.9	6.0	8.8	7.4

5.5.5 Crescent Beach Transect (No. 14)

This transect was in a part of the large tidal flat of Boundary Bay. The soil was sandy and virtually no emergent vegetation was growing. The area was much used for recreation during the summer of 1974.

Vegetation:

Very limited vegetation existed on the seaward side of the Burlington Northern railroad track which skirted the outwash bluffs. The vegetation consisted of four species (Table XXVII) which grew on relatively good soil free of salt. The ground level dropped sharply from this point to the next sampling point (50 m) where no vegetation existed (Table XXVI).

Soil:

The organic matter percentages were below 0.3%. The pH values decreased from 8.0 at 50 m to 6.3 at 300 m. The electric conductivity changed within the range of 3.3 and 5.5 mmhos. The soil values, however, at 0 m did not fall within the above ranges (Table XXVI).

Table XXVI: Crescent Beach Transect (No. 14): Soil and Plant Analyses, 1974.

Distance from dike (m)	0	50	100	150	200	250	300
Principal species*	P.a. E.m. H.l	-	-	-	-	-	-
Living (L) material; Dead (D) material	L	-	-	-	-	-	-
Height (cm.) Plants	10						
Interval (m)	(0-50)						
Dry matter (g.)	908	-	-	-	-	-	-
D. matter - ash (g)	829	-	-	-	-	-	-
Nitrogen (%)	0.86	-	-	-	-	-	-
Nitrogen (g/m^2)	7.8	-	-	-	-	-	-
Nitrogen in ash-free d.m. (%)	0.94	-	-	-	-	-	-
Lignin (%)	7.8	-	-	-	-	-	-
Lignin in ash-free d.m. (%)	8.5	-	-	-	-	-	-
Ash (%)	8.7	-	-	-	-	-	-
Soil organic matter (%)	3.4	0.2	0.3	0.3	0.2	0.3	0.2
Soil pH (1:2)	6.7	8.0	7.5	7.0	6.5	6.1	6.3
Electric conductivity (mmhos. 1:2)	0.3	4.4	3.9	5.5	3.3	3.5	4.8

Table XXVII: Principal species log for the transects (No. 11 - 14) of the Boundary Bay area, 1974.

72 St. Boundary Bay Transect (No. 11):

Distance (m)	Species	Index
0	*Solidago c.*	10
0	*Elymus m.*	25
50	Drift wood	0
100	*Atriplex p.*	70
100	*Grindelia i.*	100
100	*Hordeum j.*	10
100	*Salicornia v.*	100
150	Drift wood	0
200	*Atriplex p.*	10
200	*Grindelia i.*	100
200	*Distichlis s.*	70
250	*Atriplex p.*	100
250	*Hordeum j.*	100
250	*Grindelia i.*	100
250	*Salicornia v.*	70
300	*Salicornia v.*	100
300	*Atriplex p.*	100
300	*Distichlis s.*	100
350	*Salicornia v.*	100
350	*Triglochin m.*	25
350	*Atriplex p.*	5
350	*Deschampsia c.*	25

88 St. Boundary Bay Transect (No. 12):

Distance (m)	Series	Index
0	*Agropyron r.*	100
0	*Deschampsia c.*	25
0	*Grindelia i.*	5

88 St. Boundary Bay Transect (continued)

Distance (m)	Species	Index
0	*Aster e.*	5
0	*Juncus* spp.	5
50	no vegetation	0
100	*Salicornia v.*	100
100	*Triglochin m.*	25
100	*Puccinellia n.*	10
150	*Salicornia v.*	100
150	*Triglochin m.*	25
150	*Spergularia m.*	10
150	*Puccinellia n.*	70
200	*Salicornia v.*	70
200	*Spergularia m.*	5

112 St. Mud Bay Transect (No. 13):

Distance	Species	Index
0	no vegetation	0
25	*Triglochin m.*	70
25	*Zostera m.*	25
50	*Triglochin m.*	100
50	*Spergularia m.*	10
75	*Triglochin m.*	70

Crescent Beach Transect (No. 14):

Distance (m)	Species	Index
0	*Phalaris a.*	100
0	*Elymus m.*	25
0	*Holcus l.*	10
0	*Cirsium a.*	5

6. DISCUSSION

6.1 Vegetation types and habitat factors

The emergent vegetation of the tidal marsh develops in an environment substantially different from that in which most terrestrial vegetation develops. Admittedly, as for most terrestrial vegetation, there is a soil substrate but in this instance it is highly modified by flooding and by saline waters, to varying degrees and at varying times. The aerial environment is, when the tide is out, much like that of the aerial environment in which most terrestrial vegetation develops. As the tide comes in the ambient medium changes dramatically but changes in degree from tide to tide. In varying degree then, the all important reception of radiant energy by the plant is modified by tides. The seasons and storms, the substrate, river flood, coastline conformation and other factors interact to make the environment, in which the emergent vegetation of the tidal marsh develops and grows, singular.

The functions of the tide in the marsh ecosystem are cardinal and vary from physical to chemical. Important aspects of tide are tidal elevation, salinity and pH. In the case of the Fraser River foreshore the fresh water of the Fraser River obviously dilutes the sea water to create complex mixtures and substantially alters chemical properties. The salinity[†] of standard sea water is about 35 $^{o}/oo$ or 48 millimhos/cm at 20^{o}C (Cox, 1971) and its pH 7.5 to 8.4 (Horne, 1969). The electric conductivity measurements of the study area soils clearly showed the

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[†] Salinity is defined as the total amount of solid material, in grams, contained in one kilogram of seawater after certain precautionary steps have been taken. Salinity is, roughly speaking, a measure of the total salt content of the sea water (Horne, 1969).

complexity of the influence of the seawater and freshwater on the soils of Fraser River foreshore.

The soils close to the North Arm of the Fraser River, such as those on the transects off Point Grey, Sea Island and Westminster Hwy. (Lulu Island), showed lower salinity than those of the areas further from Fraser River such as those off Francis St. (Lulu Island), Tsawwassen Rd., and Boundary Bay. The soils of the Mud Bay transects also showed slightly lower salinity due to Nicomekl River and Serpentine River influences. Among the 14 transects, Reifel Island transect (Westham I.), close to the fresh water of the South Arm of the Fraser River showed the lowest salinity. The salinity of the tidal marshes seems to be influenced by many factors such as water volume of Fraser River, the difference of water densities between the seawater and the freshwater by seasons, tide level, the current movements in Strait of Georgia, dikes and structures such as jetties and groynes constructed on the tidal flats. Extensive studies would be required to show precisely the manner in which these factors influence the salinity of the tides and hence that of substrates (soils) and waters in which emergent marsh vegetation grows and develops.

Considering the whole study area one ascertains that the marshes from Point Grey to Brunswick are really "fresh water marshes" in which *Scirpus americanus, Scirpus paludosus, Carex lyngbyei* and *Typha latifolia* are principal species. These species are common in fresh water marshes which are not tidal. On the other hand, marshes of Tsawwassen and Boundary Bay areas are truly "salt marshes", in which *Distichlis stricta, Salicornia virginica* and *Triglochin maritimum* are common species - species found in saline habitats inland and along other coasts.

The distribution of the species in "fresh water marsh" and "salt water marsh" are by no means uniform. *Scirpus americanus* appears to grow at the lowest level in relation to mean water level in the fresh water areas; on Sturgeon Bank, *Scirpus paludosus* is common but not at levels as low as those for *S. americanus*. *Carex lyngbyei* develops at slightly lower levels especially near Roberts Bank and *Typha latifolia* is invariably found at the highest levels close to the dikes. There is then an apparent vertical zonation relative to mean tide level which, however, may be modified horizontally, it would appear, by salinity and other factors.

The above simple delineation of the tidal marshes seems to indicate that salinity and solid substrate level are the two most critical factors, among many others, associated with the tidal marshes; salinity largely divides the marshes into two types, i.e. "brackish" and "salt" marshes, and the soil surface further divides them into clearly demarcated plant associations. The salinity factor has been discussed in the literature review but the soil surface level or marsh profile was not included in this study. Burgess (1970), however, studied two tidal marsh profiles, one off Lulu Island North and one off Reifel Island, in relation to the marsh soil surface level and suggested a strong relationship between the marsh soil surface level and the distribution of six principal plant species.

The marsh soil level is, of course, directly related to the tidal inundation which may also be considered to be a determinant in the distribution of the principal species. The level itself is changing, the sedimentation from transect to transect by differential sedimentation. Dyer (1972) investigated the mechanism of sedimentation, summarized as follows: the small particles carried in suspension by the river are mainly clay minerals; they normally have a negative surface charge and each particle is surrounded by absorbed anions; flocculation occurs as the ion concentration of the surrounding water rises, i.e. above a salinity of 4%; during the second stage the sediment will gradually consolidate, as the current increases at the next stage of the tide, erosion may not be intense enough to remove all of the material deposited.

Sedimentation rates for the estuarine muds of Fraser River average 1 millimeter each year (Eisbacher, 1973). Dyer (1972) also pointed that flocculation was reversible, and that the presence of sewage and industrial wastes would obviously affect the processes of both flocculation and deflocculation. The other interesting aspect of sedimentation is the substantial amount of silt consolidated on the emergent vegetation, but the significance of the vegetation on the sedimentation has not received much attention.

The pH's in the study area showed patterns. The pH tends to be below 7.0 where marsh plants flourish, but as one goes further seaward, pH rises, generally, to 7.0 - 7.5. The higher pH is probably the influence of the seawater (pH = 7.0 - 8.5), while the low pH may be a result of microbial activity. The pH of the tidal marshes changes over short distance; less than 100 m, may be of significance, since pH can influence many other factors, directly or indirectly, such as microbial activity, nutrient availability, etc.

Soil organic matter of the tidal marshes is usually high near the dikes where tidal water covers for shorter periods (because of, in relative terms, higher surfaces). A prime factor concerning organic matter levels is drift wood and flotsam decaying on and near the dikes. The soil associated with drift wood normally had very high organic matter content; the contribution of this wood as a source of organic deteritus or energy for marine animals is not known (Personal communication with Dr. Brink). The clear fact, however, is that the drift wood occupies a large area (56 ha or 3% of total vegetation area) where otherwise marsh plants would grow. Much of it no doubt reflects man's logging activities along the coast over the last century. Generally speaking, the change of soil organic matter content means change in soil properties and hence change in vegetation composition. The change of soil and vegetation, observed in most of the study area, may have meaning in the future of the foreshore ecosystem.

The tidal marsh plants are the excellent indicators of any environmental changes of the tidal marsh ecosystem, since their zonation, species composition, or even disappearance are strongly subject to the habitat factors, especially tidal factors and sedimentation. The three vegetation maps of Sea Island, Lulu Island and Boundary Bay representing the study area may be used as a comparison for the future vegetative changes.

The series of semi-permanent transects (Fig. 11) established for this purpose in 1973 and 1974 will be used to study any future changes in the vegetation and its habitats. The establishment of the semi-permanent transects was difficult and time-consuming. Some parts and markers of the established transects, nonetheless, were quickly destroyed by vandalism and other factors, such as large rolling logs on the marshes. The writer hopes that the present semi-permanent transect would last ten years. The stakes used, however, are short, 30 cm (1 foot) above ground level, and often already covered by the mud. Therefore the transects would be best traced back in spring when the marsh land is not covered by any vegetation.

The improvement of permanent transects is definitely important, because vandalism and tidal action are significantly destructive. Forbes (1972) designed and discussed concrete markers for permanent transects. These concrete markers are heavy and strong, and hopefully will stand against vandalism, sedimentation, erosion and storm. However, none of them have been used and their effectiveness cannot therefore be known.

6.2 Primary productivity

The highest estimates of dry matter yield in the entire study area were obtained from the Point Grey transect in 1973 and again in 1974, i.e. 1,819 g/m^2 and 1,668 g/m^2 at 250 m from the road, respectively. The second highest in 1973 and 1974 were 1,369 g/m^2 at 150 m from the dike at the end of Francis St. and 1,179 g/m^2 at 100 m from the Reifel Island dike. The average yield for the whole area was 490 g/m^2 in 1974. The sewage effluence of the adjacent Iona Island may account for these high yields. However the average yields of the Point Grey area was 4.9 tons/ha, lower than 5.8 tons/ha of the Roberts Bank area in 1974. The vegetation of this particular location was composed of *Typha l.* and *Carex l.* The reason for these extremely high yields from the Point Grey transect is partly due to high yield *Carex l.* These two species were well mixed with plant height more than 200 cm and showed upright leaf orientation which might maximize light interception. The soil pH, electric conductivity and organic matter were 5.6, 5.7; 1.8, 0.92 mmhos; 6.4, 6.8%; in 1973 and 1974 respectively, indicating low pH, low salinity and high organic matter. Further intensive study would be required to know the exact reasons for these extremely high yields. It must be recognized that all yield estimates are conservative and do not take into account losses from senescence, decay abrasion, or gains and losses in the underground environment; moreover, yields may not have been taken at the precise time of maximum dry matter production.

The estimate of the average yields of the principal species for the whole area (Table V) were *Carex l.*, 9.3 tons/ha; *Scirpus p.*, 5.0 tons/ha;

Typha l., 4.8 tons/ha; *Scirpus v.*, 4.8 tons/ha; *Scirpus a.*, 4.0 tons/ha in 1974. This result indicates that *Carex l.* is almost twice as "productive" as other species. The higher total and average yields off Westham Island was mainly due to this species. The combined dry matter weight of crowns, underground shoot and root of the above four species (data of *Scirpus p.* not available) were respectively for *Carex l.*, 2,463 g/m^2; *Typha l.*, 1,491 g/m^2; *Scirpus v.*, 1,350 g/m^2; *Scirpus a.*, 606 g/m^2. By these comparisons, *Carex l.*, it is suggested, is the most efficient fixer of solar energy. The low salinity of Westham Island (Table VII), in comparison with all other areas, is believed to be the reason why *Carex l.* grows so well in this location. Burgess (1970) also pointed out the possibility of low salinity off this area and discussed, "Reifel and Westham Islands, with possibly the lowest salinity, support more species, produce the most extensive growth of *Typha l.* and *Scirpus v.* and grow very little *Scirpus p.* compared to the other marsh". However, as pointed out above by him, very little *Scirpus p.* (a non-halophytic species) is found (Table XX). The reason may be salinity or other factors which may inhibit the vegetative propagation of *Scirpus p.* in spring (personal communication with D.R. Halladay).

It appears that *Carex l.* is the main reason for the high yields off both Point Grey and Westham Island. Since different faunal organisms require and depend on different floral species, of different form or "quality", and since the marsh ecosystem is very complex, further study would be necessary to define the significance of the *Carex l.* contribution to the Fraser ecosystem.

6.3 Man's impact

The tidal marsh ecosystem of Fraser River foreshore has been threatened by a series of man's activities such as diking, filling, etc. since the turn of the last century. Moreover the quality of the marsh ecosystem may be poorer because of pollution by heavy metals, sewage and countless others. No doubt there are "beneficial" effects or additions, too. Since there seems to be more alienation and intrusion projected for this area, i.e. Airport expansion, marina construction, etc., their possible impact on the tidal marsh ecosystem may be worth brief discussion.

There is no argument that any type of filling of the tidal marshes will totally destroy their prime role as energy fixers and suppliers of detritus and energy to the rich life associated with the marsh ecosystem. This type of impact to the consumers would be acute and probably proportional to area destroyed, since much less energy, i.e. organic detritus, living plants, etc. has been produced and released naturally than decades ago. The confounding of natural and artificial influences is likely to be very important but assessment of the relative roles will require much more study.

A good example of massive filling and destruction of the tidal marshes would be the International Airport exapnsion off Sea Island. The extensive expansion of this Airport would bring various ecological ralignments on the tidal marsh ecosystem. One of them will be the possible change of vegetation composition off Lulu Island, because pattern of tides, sedimentation and Fraser River water flow into the sea may well change greatly. The salinity of the water off Lulu Island will change and may become lower or higher because of the extended flow of fresh water seawards. This lower or higher salinity, for example, will have impact on *Scirpus p.* which is critically growing at slightly higher soil salinity than the other non-halophic species (Table XI, Fig. 22 and Table XVII).

The height of the tides and sedimentation near the Airport will also change depending on the size and shape of the expansion. The pattern of sedimentation at Lulu Island will also change with the tidal and water flow changes. Sedimentation may then occur largely in the deep water seaward from the foreset beds of the delta.

7. SUMMARY AND CONCLUSIONS

In spite of its great probable importance to the rich life of the Fraser river delta foreshore, especially to waterfowl and fishery, the emergent vegetation of the foreshore ecosystem is being lost by diking and industrial development. Loss of the foreshore has led also to the alienation of the "back up" lands which are highly productive agricultural areas.

As one of many studies by many agencies which seek to delineate in the delta ecosystem and to ascertain relative values to the large human community, this study was undertaken to (a) obtain an estimate of the standing crop of emergent vegetation of the tidal zone; (b) to discern some of the important environmental factors determining plant species distribution and (c) to record present vegetation on semi-permanent transects for comparisons which might be made in the future; comparative study of the plant communities, really a product of inter-acting environmental variables, might well be a most useful indication of the significance of changes which portend.

The study area, extending from Point Grey to the International Boundary, roughly a distance, north to south, of 30 km (19 miles), was divided into three sections, i.e. tidelands off Point Grey and Sturgeon Bank, tidelands off Roberts Bank and tideland associated with Boundary Bay. Fourteen semi-permanent transects, with combined length of 7,550 m (4.7 miles), were established at points along the foreshore. Both plant and soil samples were collected in 1973 and 1974 along the tran-sects at intervals; plant samples were analyzed for ash, nitrogen and lignin and soil samples for pH, organic matter and electric conductivity.

The standing crop of the tidal marshes, harvested at roughly peak yield was estimated to occupy 1,901 hectares (4,697 acres) and to yield approximately 9,408 metric tons of dry matter with average d.m. yield of 4.9 tons per hectare (4,400 lb/acre). Eight marsh plants contributed overwhelmingly to the d.m. yield; three marsh plants, *Carex lyngbyei*, *Scirpus americanus* and *Scirpus paludosus* alone accounted for 81% of the standing crop in 1974. In 1974 Point Grey, Sturgeon Bank, Roberts Bank area and Boundary Bay area accounted for 41%, 46% and 13% of the total area of the marsh, and for 4%, 51% and 5% of the total standing crop of emergents respectively. Some observations, cast largely as probable trends, may be summarized as follows:

1. Vegetation:

   (a) There is a linear decrease in dry matter weight of emergent vegetation with distance from the dikes seaward (Y = 663-0.54 X, where X = distance from dikes seawards in meters and Y = d.m. weight in grams).

   (b) The higher plant diversity was greatest near the dikes on most transects; however, the flora of the foreshore is a small one.

   (c) The tidal marsh from Point Grey to Brunswick Point may be characterized as brackish marsh, and that from Tsawwassen to Crescent Beach as salt marsh.

   (d) Substantial amounts of silt, which adhere tightly to the lower parts of brackish marsh plants, constitutes a factor of importance in chemical analysis of plant materials; the emergent plants appear to be a factor of importance in sedimentation.

2. Edaphic factors:

    (a) Soil organic matter tends to decrease from dike seawards.

    (b) The soil pH of the brackish marshes tends to increase gradually from dike seawards and to become higher than pH value 7. The soil pH of the saline marsh was variable and was often below pH 7.0; however, the salt marsh was confined, on the whole, to narrower zones.

    (c) The soils of brackish marshes are clayey or silty, but the soils of salt marshes are more or less sandy.

3. Other factors:

    (a) More tidal flat off Sea Island seems to have been included in the past by dikes than off Lulu Island or Westham Island.

    (b) Drift wood tends to stay and accumulate near the dikes and is an important contributor to the organic matter of the soils near the dikes. Drift wood was important and occupied 56 hectares; this area is equal to one-third of the marsh land of Sea Island.

Chemical analyses of plant materials yielded highly variable results. Variable silt adherence was unquestionably a major source of error and washing and various correction factors seemed only to introduce the possibility of new or larger error.

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APPENDIX 1: Species List

Scientific Name	Abbreviation	Common Name
Agropyron repens (L.) Beav.	A.r.	Quackgrass
Agrostis semiverticillata (Fiorsk.) C.	-	Christ Water Bent
Angelica genuflexa Nutt.	A.g.	Angelica
Aster eatonii (Gray) Howell	-	Aster
Atriplex patula L.	A.p.	Saltbush
Carex lyngbyei Hornem	C.l.	Sedge
Cirsium arvense (L.) Scop.	-	Thistle
Cuscuta salina Engelm.	-	Dodder, Lone-tangle
Deschampsida cespitosa (L.) Beauv.	-	Hair Grass
Distichlis stricta (Torr.) Rydb.	D.s.	Saltgrass
Elymus mollis Trin.	E.m.	American Dunegrass
Equisetum fluviatile L.	E.f.	Horsetail
Festuca rubra L.	-	Red Fescue
Grindelia integrifolia DC.	G.i.	Gumweed
Holcus lanatus L.	H.l.	Velvet-grass
Hordeum jubatum L.	H.j.	Foxtail Barley
Juncus spp.	-	Rush
Lathyrus palustris L.	P.-	Vetchling
Phalaris arundinacea L.	P.a.	Canary grass
Poa palustris L.	P.pl.	Fowl Bluegrass
Potentilla pacifica Howell	P.p.	Five-finger
Puccinellia nuttalliana (Shult.) Hitchc.	P.n.	Alkaligrass
Rubus leucodermis Dougl.	R.l.	Raspberry
Sagittaria cuneata Sheld.	S.cu.	Arrowhead
Salicornia virginica L.	Sa.v.	Saltwort
Scirpus americanus Pers.	S.a.	Three-square bulrush
Scirpus paludosus	S.p.	Seacoast bulrush
Scirpus validus Vahl.	S.v.	Softstem bulrush
Soldago canadensis L.	S.c.	Goldenrod
Spergularia marina (L.) Griseb.	S.m.	Sandspurry
Triglochin maritimum L.	T.m.	Arrow-grass
Typha latifolia L.	T.l.	Cat-tail
Zostera marina L.	Z.m.	Eel-grass
Sium sauve	-	Water-parsnip

APPENDIX 2:

Photographs to give assistance in locating
semi-permanent transects.

1. Pt. Grey T. (No.1)
   0 m point, taken
   from Pt. Grey Rd.

   Length of transect:
   400 m

2. Pt. Grey T. (No.1)
   400 m point,
   looking toward
   0 m point.

3. Sea Island T. (No.3)
   0 m point, looking toward 900 m
   point.

   Length of transect:
   900 m

4. Sea Island T. (No.3)
   900 m point, looking toward 0 m
   point.

5. Westminster Hwy. Transect (No.4) 0 m point, taken from road.

Length of transect: 850 m

6. Westminster Hwy. Transect (No.4) 0 m point, looking toward 850 m point.

7. Westminster Hwy. Transect (No.4) 800 m point, looking toward 850 m point.

8. Westminster Hwy. Transect (No.4) 200 m point, looking toward 0 m point.

9. Francis St. Transect (No. 5)
0 m point, taken from road.

Length of transect: 1,000 m

10. Francis St. Transect (No. 5)
1,000 m point, looking toward 0 m point.

11. Steveston Hwy. Transect (No.6)
150 m point, looking toward 0 m point.

Length of transect: 900 m

12. Steveston Hwy. Transect (No.6)
450 m point, looking toward 900 m point.

13. Reifel Island
Transect (No.7)
0 m point, taken
from dike.

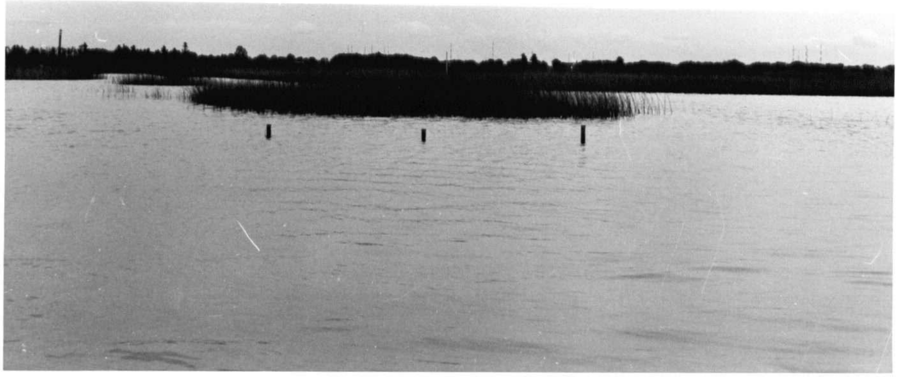
Length of transect:
1100 m

14. Reifel Island
Transect (No.7)
1,100 m point,
looking toward
0 m point.

15. 34 St., Superport
Transect (No.8)
0 m point, taken
from road.

Length of transect:
100 m

16. 34 St., Superport
Transect (No.8)
100 m point, look-
ing toward 0 m
point.



17. Tsawwassen Rd.
Transect (No.9)
0 m point, taken
from road.

Length of transect:
600 m

18. Tsawwassen Rd.
Transect (No.9)
600 m point,
looking toward
0 m point.

19. Beach Grove Transect (17A Ave.)
(No. 10)
0 m point, taken
from beach.

Length of transect:
250 m

20. Beach Grove
Transect (No.10)
250 m point,
looking toward
0 m point.

21. 72 St. Boundary
Bay Transect
(No. 11)
0 m point, taken
from dike.

Length of transect:
450 m

22. 72 St. Boundary
Bay Transect
(No. 11)
450 m point, looking toward 0 m
point.

23. 80 St. Boundary
Bay Transect
(No.12)
0 m point, taken
from dike.

Length of transect:
250 m

24. 88 St. Boundary
Bay Transect
(No. 12)
250 m point, looking toward 0 m
point.

Appendix 3. Estimated contribution of particulate organic matter to the waters of the Georgia Strait.

Source	Form	Estimated contribution (t $year^{-1}$)	Authority
Rivers	Particulate organic	200,000	Seki et al (1969)
Rivers	Total organic	$1\text{-}2 \times 10^6$	Seki et al (1969)
Wood	Activity of *Bankia setacea* upon stored wood	15,000-300,000	Perkins[a]
Wood	Harbour structures, trees on the seas margin	⩾(15,000-300,000)	Perkins[a]
Wood	Wood pulp industry - as fibre	31,000	Perkins[a]
Wood	Toilet paper, sanitary towels disposablennapkins, etc.	4,000	Perkins[a]
Sewage	Faecal waste	>23,000	Perkins[a]

[a] Estimates by Perkins (1963) derived from information by Trussell (1959, 1967), I.D.D., British Columbia Hydro and Power Authority Survey (1966), U.S. Department of the Interior Report (1967) and by his personal enquiry.

Appendix 4. Conversion tables for British and metric measure.

The figures in the central of the three columns in each table represent either one or the other of the two side columns, as required, e.g. 1 kg = 2.205 lb, 1 lb = 0.454 kg, 100 ha = 247.105 ac, 100 ac = 40.469 ha. Temperature conversion formula: $^{o}C = 5/9\ (^{o}F - 32)$.

WEIGHT

Kilograms	kg or lb	Pounds (lb)
0.454	1	2.205
0.907	2	4.409
1.361	3	6.614
1.814	4	8.819
2.268	5	11.023
2.722	6	13.228
3.175	7	15.432
3.629	8	17.637
4.082	9	19.842
4.536	10	22.046

AREA

Hectares	ha or ac	Acres
0.405	1	2.417
0.809	2	4.942
1.214	3	7.413
1.619	4	9.884
2.023	5	12.355
2.428	6	14.826
2.833	7	17.297
3.237	8	19.769
3.642	9	22.240
4.047	10	24.711

LENGTH

Centi-metres	cm or in.	Inches
2.540	1	0.394
5.080	2	0.787
7.620	3	1.181
10.160	4	1.575
12.700	5	1.969
15.240	6	2.362
17.780	7	2.756
20.320	8	3.150
22.860	9	3.543
25.400	10	3.937

WEIGHT/AREA

kg/ha	kb/ha or lb/ac	lb/ac
1.121	1	0.892
2.242	2	1.784
3.363	3	2.677
4.484	4	3.569
5.605	5	4.461
6.726	6	5.353
7.848	7	6.245
8.969	8	7.138
10.090	9	8.030
11.211	10	8.922

APPENDIX 1. Map to show the vegetational areas and location and vegetation of the line transects (No. 1-14) for the whole study area, 1974.

Legend:

1 - Point Grey Transect
2 - Iona Island Transect
3 - Sea Island Transect
4 - Westminster Hwy. Transect
5 - Francis St. Transect
6 - Steveston Hwy. Transect
7 - Reifel Island Transect
8 - 34th St. (Superport) Transect
9 - Tsawwassen Rd. Transect
10 - Beach Grove Transect
11 - 72 St. Boundary Bay Transect
12 - 88 St. Boundary Bay Transect
13 - 112 St. Mud Bay Transect
14 - Crescent Beach Transect

Carex lyngbyei
Distichlis stricta
Salicornia virginica
Scirpus americanus
Scirpus paludosus
Scirpus validus
Triglochin maritimum
Typha latifolia
Drift wood