A Comparative Study of Salt Marshes in the Coos Bay Estuary

A

National Science Foundation

Student Originated Study

summer 1976

WYLAND/JOHNSON

A COMPARATIVE STUDY OF SALT MARSHES IN THE COOS BAY ESTUARY

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INTRODUCTION

John Hoffnagle

Salt marshes, the areas of vascular plants which are subject to tidal flushing, constitute a unique habitat along the Oregon coast. Being neither terrestrial nor marine, they have qualities of both environments. They occur from mean tide level to extreme tide level, which may be construed to be the spruce/alder vegetation line, and in this study have been further restricted to those areas subjected to tidal flooding of at least 2 parts per thousand salinity during the growing season (Jefferson 1974). Soil on which salt marshes are located is usually poorly drained and poorly aerated (Akin and Jefferson 1973). Starting from slightly elevated tideflat, pioneer plants, once established act as a trap, collecting more and more sediments. In time, drainage channels become more distinct and with more species of plants invading, due to now different conditions, the salt marsh rises above the drainage channels and surrounding tideflat (Redfield 1972). With each new plant species, more roots collect sediments and organic matter from plant decomposition and in time, perhaps hundreds of years, a mature salt marsh configuration two to three meters above the surrounding tideflat is formed.

Salt marshes occur world-wide in sheltered locations such as protected bays, estuaries, on the landward side of offshore islands and on low energy coastlines (Chapman 1960). In Oregon, estuaries and sheltered bays are the only place where salt marshes may be found due to the high energy of waves on the Pacific coast. On the East coast offshore barrier islands shelter the coast enough to provide coastlines capable of supporting great expanses of salt marsh vegetation.

Why salt marshes have been so intensely studied on the East coast in recent years is a question answered by their contribution to the estuarine environment. The estuary is one large ecosystem broken peculiarly into several subsystems. In a terrestrial system one thinks of primary production (photosynthesis) and herbivory as occurring at the same location. Cows grazing in a field break down the grasses' high energy carbon compounds into more simple components yielding energy which is utilized for growth, maintenance, and eventually for consumption further up the food chain. In the special case of the estuary, primary production occurs in several forms. Although eelgrass communities and salt marshes may be directly grazed upon as diatoms and algae often are, a much more significant contribution comes from their incorporation into the detrital food web. In this food web excess plant material is broken down into detritus (dead plant material) and along with associated bacteria and fungi responsible for the decomposition process, is shipped into the estuary. Organisms within the estuary, especially filter and deposit feeders, utilize this detritus and associated bacteria as a major energy source (Fenchal 1969, Newell 1965). In the words of Odum and delaCruz (1963)

"Organic detritus is the chief link between primary and secondary productivity, because only a small portion of the marsh grass is grazed while it is alive, the main energy flow between...levels is by way of the detritus food chain."

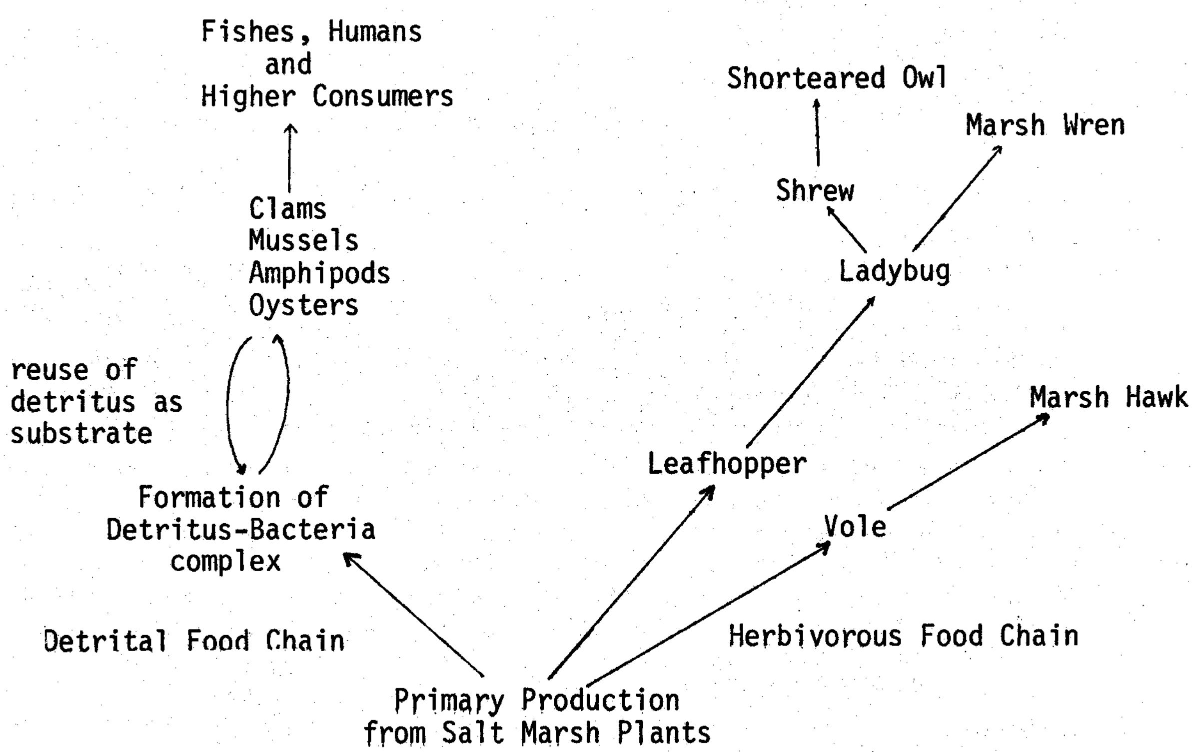

Figure 1. Detrital vs. Herbivorous Food Web.

Other important functions may be ascribed to salt marsh communities due to their special properties and location.

The salt marsh serves as an important settling and filling basin for silt, organic material, and pollutants from marine, terrestrial, and fresh water origin (Johnson 1969). Included in the function of this settling basin are the biological and chemical oxidation and reduction of organic compounds such as secondarily treated sewage into nutrients directly useable by estuarine animals. The fine substrate of the salt marsh has a great sorptive capacity which makes it especially able to trap nutrients (Odum 1970, Ranwell 1964). In this way important nutrients such as nitrogen and phosphorous are returned to the natural system to be reutilized, after having been oxidized by bacteria associated with the salt marsh. In a recent study in Florida a 1500 acre salt marsh was shown to remove all of the nitrogen and one quarter of the phosphorous from the domestic sewage of 62,000 people, putting it into the salt marsh for oxidation and slow release into the system

(Jahn and Trefethen 1973).

At times of flood and storm tides the salt marsh counteracts the effect of high waters, serving as a water storage basin which moderates both erosion and property damage (Akins and Jefferson 1973).

In addition, the salt marsh serves as a breeding and nesting ground for many forms of fish and wildlife (Akins and Jefferson 1973). Salt marshes and associated shallow tideflats serve to moderate temperatures within the bay important to the rearing of juvenile invertebrates of economic as well as natural importance. Certain species of fish are also known to need the moderating temperatures of shallow estuaries for spawning as well as juvenile survival.

Migrating birds utilize the salt marsh areas in Coos Bay. Especially important in this respect is Pony Slough, which serves as a stopover spot for several species of migratory birds when they are forced inland from the coast due to storm waves. Small mammals and non-migratory birds utilize the salt marsh areas for shelter and predator escape as well as nesting and rearing grounds (Johnson 1969).

Biological, physical and chemical factors contribute to make the salt marsh a valuable and precious resource. Social benefits make this area even more important when one considers open-space and aesthetic qualities. In the words of Peter Johnson (1969)

> "...the loss of all types of wetlands in the U.S. has been staggering and tragic. Effective measures are urgently needed to protect those that remain."

Seeing that salt marsh areas serve an important and necessary function in a healthy estuarine ecosystem, how does one approach them from a management perspective? If a great deal were known about the system one would need only to assemble the various contributing factors, attach specific values to them and conclude by listing resource management options and alternatives by developing some set of importance values and seeing how various options apply to salt marsh areas.

In an ecosystem where little is known (Pacific coast salt marshes certainly qualify) the first step towards proper resource management is the collection of baseline data from all available sources both biological and social. The second step is the proper recognition of these resource values within the ecosystem. In the third step, resource management approaches and alternatives may be outlined with proper weight given towards natural and social systems. Our research during the Spring and Summer of 1976 was along these lines. An outline of our rationale is presented.

I. BASELINE DATA COLLECTION
- A. biological
  1. mammals
  2. birds
  3. insects
  4. invertebrates
  5. fish
  6. plant species
  7. primary production
- B. Social
  1. historical
  2. legal
  3. economic
  4. land-use

II. IMPORTANT FUNCTIONS ASSOCIATED WITH SALT MARSHES

A. biological
1. plant disappearance
2. detrital importance
3. bacteria
4. invertebrate feeding experiment
5. insect respiration
6. bird and mammal resource utilization

B. social
1. economic
2. historical
3. legal
4. land-use

III. RESOURCE MANAGEMENT AND ALTERNATIVES

A. Biological importance of salt marshes to estuary
B. Social importance of salt marshes to community
C. Legal perspective of laws affecting salt marshes
D. Management and alternatives

It is our hope that this research will contribute a little towards the knowledge of Pacific coast estuaries and will be a positive influence towards the biological and social well being of these important natural systems. It was towards these ends that our energies were directed.

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SITE DESCRIPTION

John Hoffnagle

Size, Location, Drainage

Coos Bay is the largest estuary wholly within the State of Oregon. Its area is estimated at 12,380 acres (Akins and Jefferson 1973). It is located 260 miles north of San Francisco and 200 miles south of the Columbia River. It is an inverted U, 13 miles long with an average width of 1200 feet at low tide (U.S. Corps of Engineers 1975). It drains an area of 830 square miles (Percy et al. 1974). Uplands consist of 90% forestland with limited crop and rangelands. The upland forest zone is described as the Picea sitchensis Zone, which stretches the length of the Oregon and Washington coast (Franklin and Dryers 1973). This zone is noted for its rich soil, mild climate, and some of the most productive coniferous forests in the world (Fujemore 1971). Principle rivers draining into Coos Bay are the Coos, South Fork Coos, and Millicoma.

Climate

The climate of the area is that of mid-latitude marine with warm summers, wet cool winters, and high humidity most of the year. Average annual precipitation ranges from 50 inches on the coast to 100 inches at the headwaters of the Millicoma River (Oregon State Water Board 1963). Little rain falls in the summer months of June, July, and August. Temperature extremes vary from 16-100°F. In reality these extremes are seldom approached with average January daily temperatures at 45°F and average July temperatures at 59°F. Freezing weather is uncommon and of short duration. Winds are generally from the Southeast during the winter and from the North and Northwest during the summer, responding to the changes in drift of the California Current and the northern movement of the Davidson Current (U.S. Department of the Interior 1971).

Geology

The Coos Bay drainage basin is composed of rugged and highly dissected terrain with unstable slopes. On these slopes the stability of the various soils are rated moderately unstable using the Forest Service's Cutbank Stability rating (U.S. Dept. of Interior 1971). This instability is evidenced in estimates of sediment transported into Coos Bay at 72,000 tons annually (OSU Oceanography 1971). Deposition in coastal streams has kept pace with the rise in sea level along the Southern Oregon Coast (Baldwin 1964). Currently all estuaries in Oregon are silting up from heavy downstream sediment transport as well as marine sediments entering the Bay mouths (Jefferson 1972). This siltation process along with poor logging practices is responsible for creation of marsh areas (termed progradation) in undisturbed tideflat areas in the last century.

Coos Bay is a drowned river mouth bounded on its western side by North Spit, a naturally created spit formed due to the presence of prevailing winds from the North and low flows in the summer dry periods. The remainder of the Bay is bordered by steep coniferous forests or flat marshlands, including area that was once marshland that is now diked or filled.

Population and Industry

Population of the principle towns located on the bay--Coos Bay, North Bend and several smaller communities--was near 32,000 in 1970. Lumber and fishing are the principle employers in the area. Wood and wood products account for nearly 60% of the area work force (Coos Bay Chamber of Commerce 1972). Extreme use of the estuary is made in floating logs to mill sites and in transporting them on ocean-going ships. Fishing accounts for $9,000,000, valued at $1,934,000 in 1971 (Fish Commission of Oregon 1972). Other industries include dairy products, poultry, and cattle.

Salt Marsh Areas of Coos Bay

The salt marsh areas of Coos Bay have been identified as to extent and community structure only in recent years (Akin and Jefferson 1973, Hoffnagle and Olson 1974). Prior to this time no complete analysis of the salt marshes within the estuary was completed. Peripheral mention or mapping of salt marsh areas has been well documented. The first map produced by the United States Coast and Geodetic Survey in 1892, clearly shows distinct marsh areas, but only on the channelward side, since navigation was their principle concern. These maps were drawn out in the field on plane tables and have been shown to be fairly accurate. They have also been the source of some conjecture as to the extent of salt marshes late in the last century and their progradation (Eilers 1974). In 1914, H.D. House collected 13 species of salt marsh plants adjacent to North Slough, but noted that the species present were much more extensive (House 1914). Primarily, vegetational studies have been carried out on the marsh at Pony Slough directly east and adjacent to the airport. Johannesson in 1961 and MacDonald in 1967 and 1969 base data on this marsh (Johanneson 1961, MacDonald 1969). Marsh communities were studied on Bull Island in 1971, but the research was of limited scope (U.S. Dept. of Interior 1971).

Drawing from the work of Jefferson in her Ph.D. thesis (Jefferson 1974), salt marshes along the Oregon coast may be conveniently divided into several marsh "types" based on elevation of marsh, substrate composition and especially plant communities. These marsh types approximate ecological communities in species composition and ecosystem function. Jefferson lists five marsh types of consequence in Coos Bay:

I. Low Sandy Marsh
characteristics:
Located on inland side of baymouths, sandspits or inlands. Substrate is of sandy texture. Marsh surface is only slightly elevated above the surrounding tideflat and has a gentle slope. Almost no channelization occurs.
principle plant species:
Salicornia virginica, Distichlis spicata, Jaumea carnosa, Plantago maritima, and Scirpus americana. Less often Carex lyngbei, Glaux maritima.

II. Low Silty Marsh
Of minor occurrence in Coos Bay.

III. Sedge Marsh
characteristics:
intermediate between low silty marsh and more mature stages or on edge of islands and dikes. Surface may be one foot or more above tideflat.
dominated by Carex lyngbei

IV. Immature High Marsh
characteristics:
Substrate is silty and highly organic. Interrupted by deep dendritic channels. Marsh rises abruptly 2-3 feet above surrounding tideflat. Inundated by many higher high tides.
plant species:
Deschampsia caespitosa, Distichlis spicata, Triglochin maritima, Salicornia virginica, and Carex lyngbei.

V. Mature High Marsh
Of minor occurrence in Coos Bay.

VI. Bullrush-Sedge Marsh
characteristics:
Found along tidal creeks and channels where fresh water dilution is evident. Low, unchannelized surface.
principle plant species:
Scirpus validus, Carex lyngbei.

Based on the above classification scheme, which is somewhat arbitrary and designed principally for management purposes, Hoffnagle and Olson (Hoffnagle and Olson 1974) catalogued the entire Coos Bay Estuary in 1974, finding little difference with Carol Jefferson's much broader work on a state-wide level for the Oregon Coast Conservation and Development Commission (Akin and Jefferson 1973). Using Hoffnagle and Olson's estimates the Coos Bay salt marshes are broken down into the following:

Table 1

Total Undiked Marsh	1951.1 acres
Immature High Marsh	1000.5 acres
Low Sand Marsh	289.1 acres
Low Silt Marsh	71.6 acres
Sedge Marsh	353.8 acres
Bullrush Sedge Marsh	149.8 acres
Mature High Marsh	87.4 acres

On an estuary wide level, the following generalizations may be noted. Scirpus validus occurs most extensively up North Slough while large stands are present up Catching and Isthmus sloughs. Vast acreages of immature high marsh occur opposite the town of Coos Bay, including Bull Island. Expanses of low sandy marsh occur adjacent to and east of the airport at Pony Slough. Fringing marshes occur up South Slough very much similar to the immature high condition. Extensive areas of diked marsh occur throughout the bay estimated to approach 90% of the salt marshes present in 1892 (Hoffnagle and Olson 1974).

The Salt Marshes of Coos Bay in Relation to Other Oregon Estuaries

The salt marshes of Coos Bay are typical of salt marshes occurring in other estuaries along the Oregon coast. It is hoped that findings presented in this report may be applied to other estuarine systems, bearing in mind the individuality of each estuary. Table 2 presents a list of plant species and estuaries in which they were found along the Oregon coast. It is the collected data of several researchers at different time periods and with different competences. The table is taken from Eilers' Ph.D. thesis (Eilers 1974), with data added from Hoffnagle and Olson that supports the notion that the longer time one spends at a study site the more species may be collected. All but three species on the list have been collected in Coos Bay. In addition, several additional salt marsh plant species appear both in our data as well as that of Jefferson (1974). If one chooses only the dominant plant species of the Oregon salt marshes and checks for their presence in these studies (e.g., Salicornia virginica, Deschampsia caespitosa, Carex lyngbei, and Distichlis spicata) an even more homogenous situation appears.

If salt marsh plant communities are in general similar in estuaries along the Oregon coast, man's impact on them has not been. Different sources of man's influence seem to affect salt marsh areas taken from the system to a great extent. Eiler (1974) has constructed a quantitative rating scale in order to assess the disturbance of man in salt marsh systems along the Oregon coast. His system takes into account disturbances such as agricultural fills, road fills, urban industrial fills and others and computes the acreages each has taken from the system. Coos Bay's disturbance rating is a 5 out of 5, while 5 of the 14 estuaries had ratings of 2 or lower. Only the Siletz and Yaquina estuaries had 4 ratings. This points to the fact that while all salt marshes may be roughly similar ecologically, and may have roughly the same function in the ecosystem, they may be much more or much less maligned depending on the estuary they are in, due to man-caused effects.

Study Sites

At the inception of this study eight study areas were chosen for consideration as potential study sites to be used throughout the spring and summer. Criteria for sites included (in order of importance):

Table 2: Plant species reported by Johannessen (1962), MacDonald (1967), and Stock (1972) for Oregon salt marshes. Revised from Eilers (1974), Hoffnagle and Olson (1974) data added.

Species / Location	Coquille River	Coos Bay	Umpqua River	Alsea Bay	Tillamook	Nehalem Bay	Coos Bay (Pony Slough)	Yaquina	Coos Bay (Hoffnagle & Olson)
Agrostis alba	X	X	X				X		X
Carex lyngbei	X	X		X	X	X	X		X
Cuscuta salina		X					X		X
Deschampsia caespitosa	X		X	X	X	X	X	X	X
Distichlis spicata	X		X	X			X	X	X
Elymus triticoides			X						
Glaux maritima							X		X
Hordeum brachyantherum			X						X
Jaumea carnosa	X		X				X		X
Juncus balticus			X						X
Juncus effusus	X								
Juncus tenuis							X		X
Plantago maritima			X						X
Potentilla pacifica			X						X
Salicornia virginica	X	X	X	X			X		X
Scirpus acutus							X		
Scirpus americanus	X	X	X	X	X				X
Scirpus cernuus			X						
Scirpus maritima					X	X	X		X
Spergularia marina	X								X
Trifolium pratense			X						X
Triglochin maritima	X	X		X	X	X	X	X	X

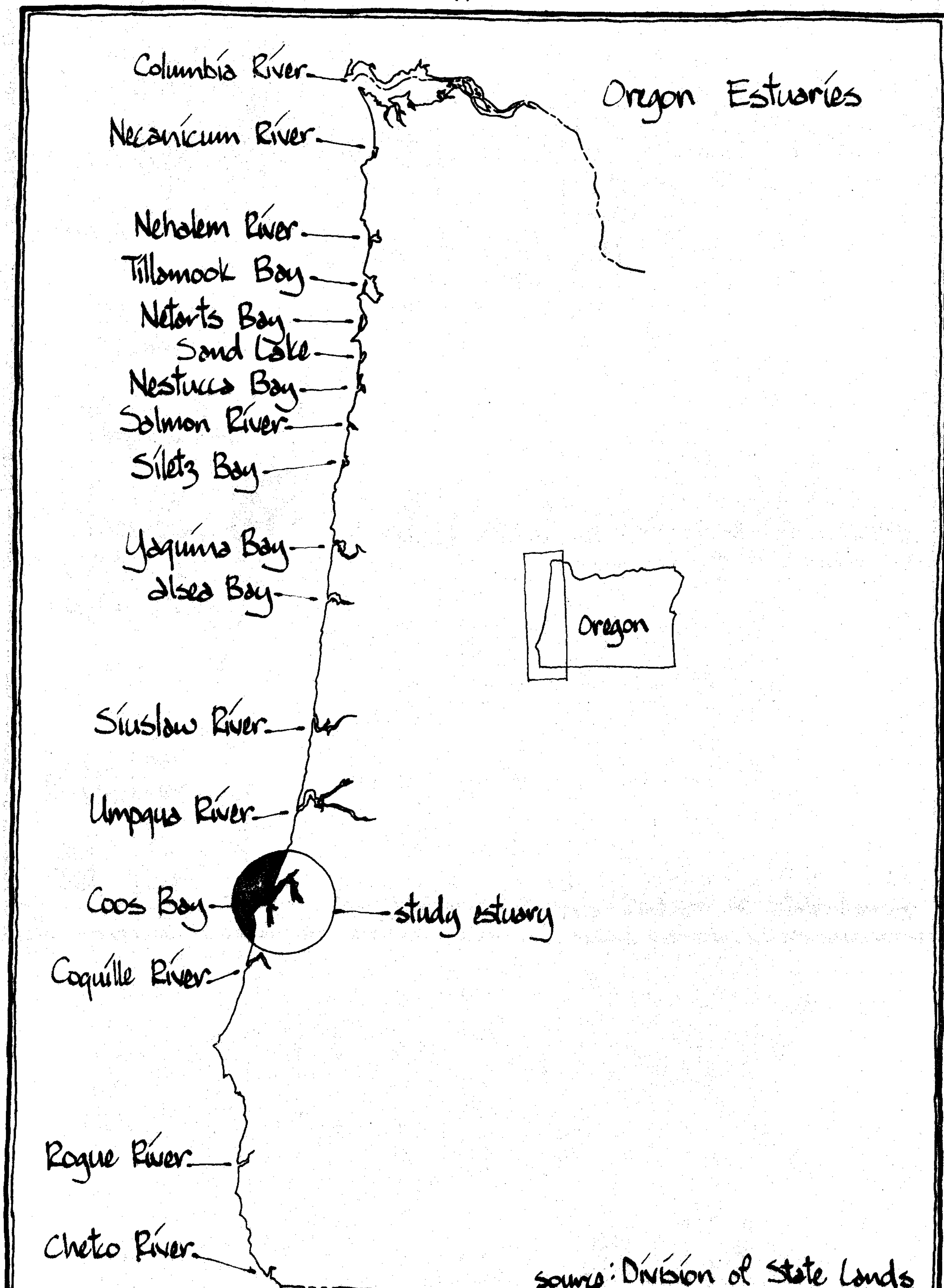

Figure 2. Oregon Estuaries.

1) community type: a wide variety of salt marsh communities were necessary in order to assess the possible function of each marsh type in the system.
2) proximity: two marshes of equal suitability would be chosen by distance from our laboratory.
3) previous studies: any areas having previously been studied would be given priority in order to compare our information with existing information.
4) special natural features: areas with narrow drainage areas would facilitate our detrital studies.

Of the eight potential areas chosen, six were utilized for the final study. Henderson Marsh was not chosen because it has a flora difficult to put into salt marsh classification. Shinglehouse Slough was not chosen because it was far from our laboratory and similar marshes were closer.

The six marshes chosen for study can be classified as follows:

Marsh Name	Initial	Salt Marsh Type	Special Features
South Slough	SO	immature high	minimal human impact
Metcalf Marsh	SA	low sandy	enclosed marsh, one marine channel
Pony Slough	PO	low sandy	close to open bay shorebird migratory area
North Slough	NO	bullrush, sedge	moderately saline, bullrush
Bull Island	BU	immature high	minimal human impact, large marsh area
Coalbank Slough	CO	sedge	semiterrestrial, greatest human impact, septic tank leakage

South Slough Marsh (SO)

The South Slough marsh is located at the end of the South Easternmost arm of South Slough. It is in Township 26 S, Range 13 W, section 24. It is accessible by motorboat only at high tide. A logging road not passable by automobiles goes nearly to the marsh from Highway 101 and is a pleasant hike during the weekends. The salt marsh area has had little human influence except that from logging and limited agriculture much earlier in the century. Remnants of this are hard to find.

The marsh itself is quite extensive with only limited channelization for a salt marsh so high above the surrounding tideflat. Large channels carry the bulk of the waterflow into these upper South Slough marshes, rather than the intense channelization one would normally expect in an immature high marsh. This may be due to the steepness of the surrounding hillsides and the narrowness of the flood plane. Water samples taken during an outgoing tide were highly saline grading to near fresh water, pointing to the contribution of fresh water flow into this marsh.

The vegetation of this marsh is predominantly *Carex lyngbei* with *Distichlis spicata* a subdominant. Channels into the marsh are

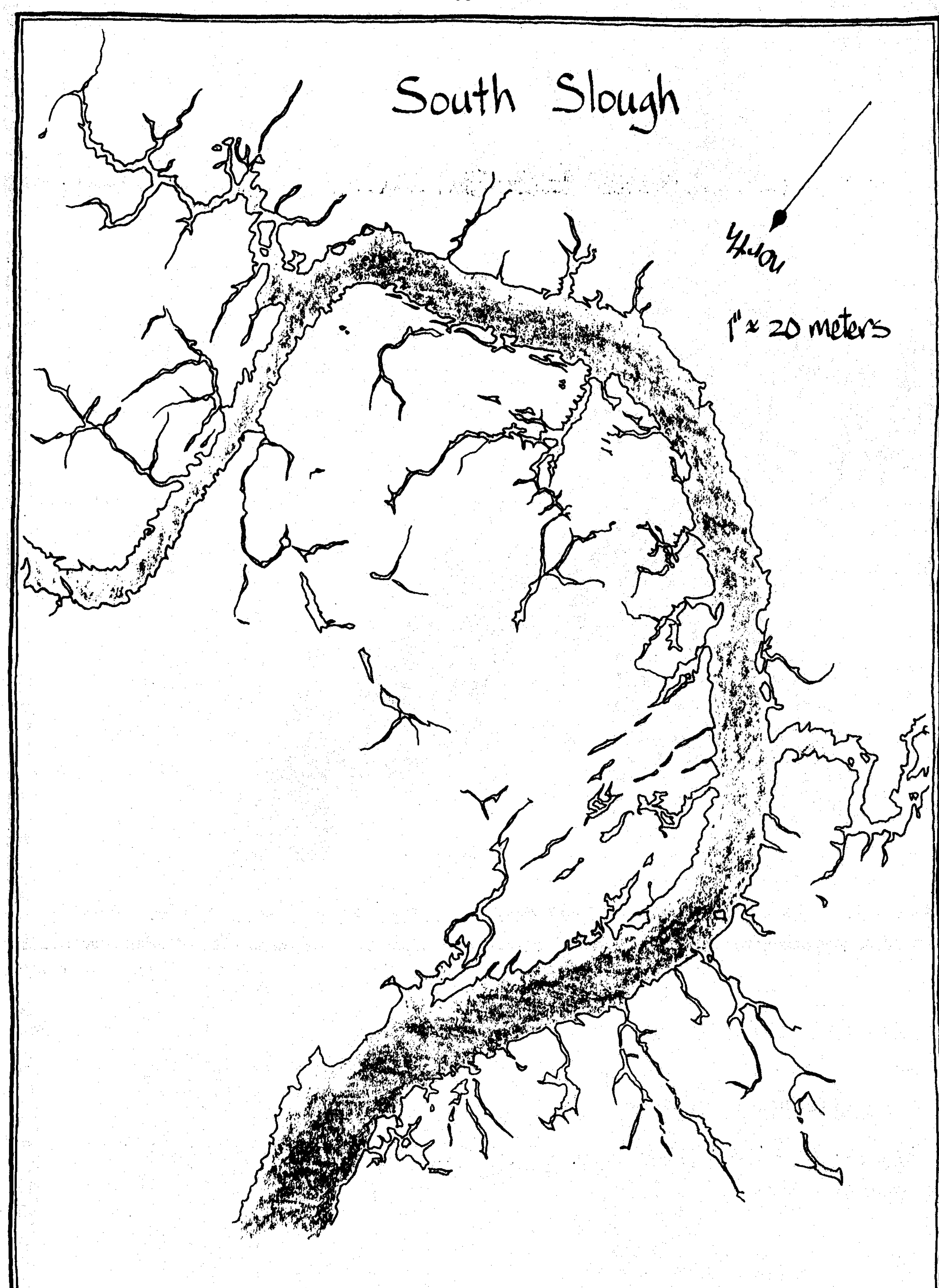

Figure 3. South Slough.

vegetated with the eelgrass Zostera marina. As the channel steeply rises to the salt marsh surface, Salicornia virginica and Triglochin maritima constitute a majority of the cover. At the terrestrial ends of the marsh Agrostis alba, Atriplex patula, and Juncus balticus are seen. Near the terrestrial vegetation line Grindelia integrifolia is present. Carex obnupta can be seen here. At the upper ends of the marsh, fresh water influence can be noted.

Henry Metcalf Estuarine Preserve (SA)

The Salicornia marsh, directly to the east of the docks at the end of Roosevelt Street in Charleston, is unique in several ways. It is completely enclosed by a man-made dike on its seaward side except for a 20 meter channel, through which all water from the marsh must pass. It is also the closest salt marsh to the ocean entrance to Coos Bay and for this reason should be highly marine in nature. It is a low sandy marsh with a substrate of very coarse sand. The man-made dike, which was not present in aerial photographs of the area taken in 1939, is presumed to have altered the character of this marsh immensely. In our sampling of the salinity of the water at this marsh, it was always saline relative to the outer marshes, pointing to limited fresh water inflow. This salinity will, of course, become more dilute with winter rains, as is the case in all salt marshes.

The vegetation of the Metcalf Marsh is undoubtedly the most diverse of our study sites, in spite of the fact that it is also our smallest study site. In the main channels that cut through the marsh, Ulva sp., Enteromorph sp., Cladophora sp., and Ruppia maritima are all very abundant. As one rises into the marsh, Salicornia virginica and Triglochin maritima become dominant. A great amount of Fucus sp. is present as an understory to this Salicornia virginica, pointing to the marine character of this marsh. With increasing distance from the main channel, Distichlis spicata breaks in abruptly occupying the dominant position in this low marsh. At the terrestrial edge, a 15 meter band of Carex lyngbei appears. Within this band is Deschampsia caespitosa, and two species of Juncus, Juncus lasuerii and Juncus balticus. In the highest zone of Juncus lasueurii, Potentilla pacifica and Grindelia integrifolia occur. Plants less abundant include Eleocharis palustris, Plantago maritima, Rumex occidentalis, Jaumea carnosa (quite abundant), Speroularia marina, Cordylanthus maritimus, and Orthocarpus castillejoides. Cordylanthus maritimus has only been cited in two places in Oregon, in North Slough, Coos Bay and in South Slough, Coos Bay. Judging from its abundance this year at the Metcalf, it may be rapidly expanding its range. At the higher zone Agrostis alba and Hordeum brachyantherum are found. Cuscuta salina, a parasitic plant found on Salicornia virginica is common. Its orange color and yellow flowers give a beautiful contrast to the marsh. Scirpus americanus can be found colonizing in channels in the marsh.

Pony Slough Marsh (PO)

The Pony Slough marsh is located adjacent to the North Bend

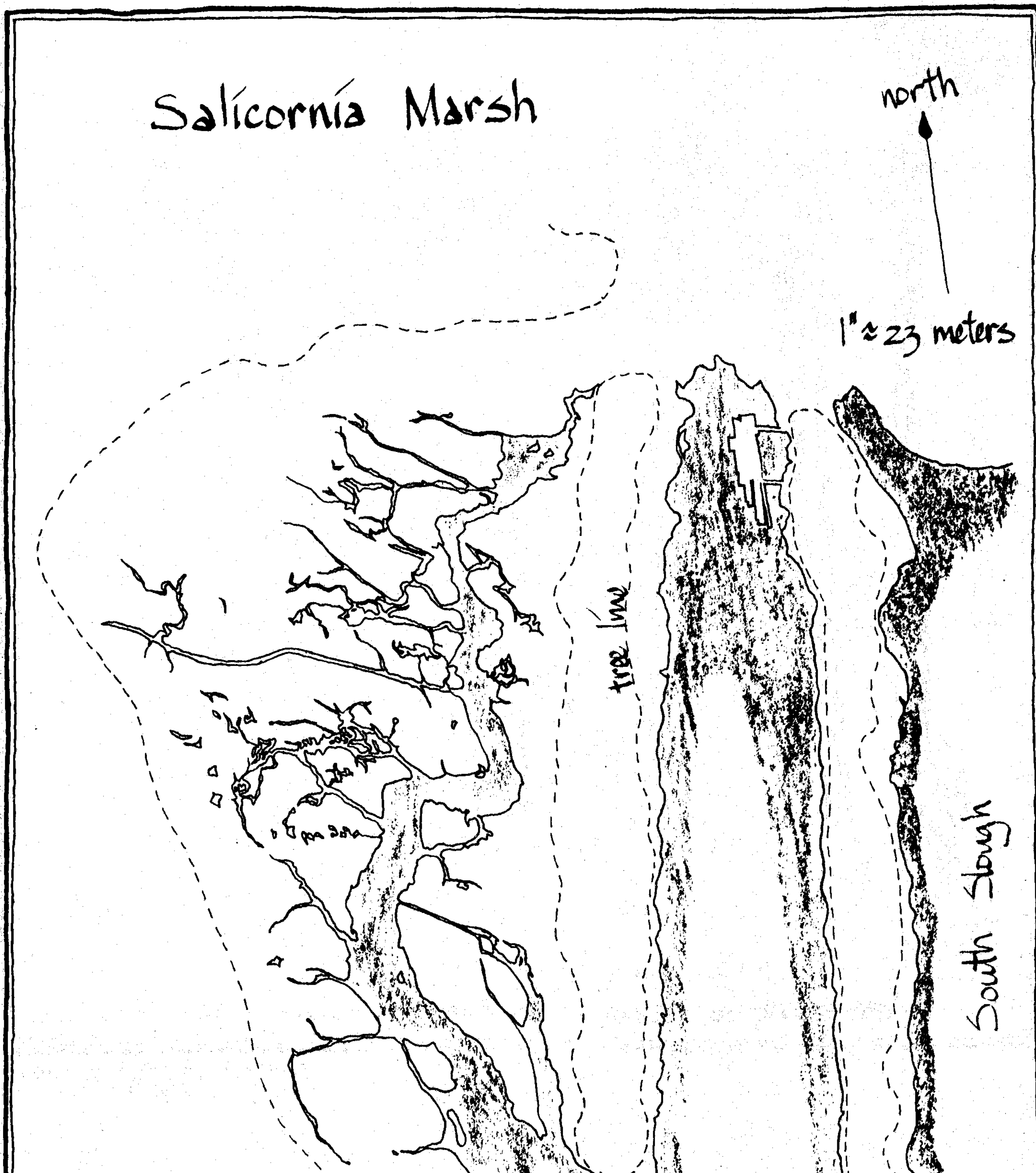

Figure 4. Salicornia Marsh.

airport on its eastern side. It has been severely altered due to the construction of the North Bend airport in the early 1940's. Prior to that time dredge spoils had been piled at the mouth of Pony Slough forcing the channel into this salt marsh to completely change directions. Pony Slough has been recognized as a bird sanctuary by the state since the construction of the airport. It is important to migratory birds seeking shelter from winter storm tides. This very wide, low sandy marsh is next to an expanse of water and is enclosed only on its airport side.

This study site is undoubtedly the most extensively studied in Coos Bay. Carl Johannessen (1961) described the plant species present and Keith MacDonald used this location in 1969 as one of his study sites while surveying marshes on the entire Pacific coast.

The marsh is composed of Salicornia virginica and Distichlis spicata across most of its width. The Distichlis spicata once again changes abruptly with the Salicornia virginica at a junction created by a channel. Deschampsia caespitosa as well as Triglochin maritima may be considered subdominants. Also seen in some quantity is Jaumea carnosa. Glaux maritima and Spergularia marina are less frequently seen. Agrostis alba and Hordeum bracheantherum are seen in the higher half of the marsh. Hodeum brachyantherum is seen, especially on the banks of channels. In the last 10 meters of the marsh Carex lyngbei and Atriplex patula predominate. In the very upper reaches of the marsh Grindelia integrefolia occurs.

Johannessen noted the species composition of Pony Slough marsh in 1961.

Pony Slough Species Composition of Marsh Flora
(Johannessen 1961)

location	Agrostis	Carex	Deschampsia	Salicornia	Scirpus	Triglochin
NW margin of marsh east of airport	trace	5	5	30	45	15
South of first location 300 yd.	--	25	5	25	30	15
S. end of marsh on W. side. S. of above site 700 yd.	--	20	5	30	45	--

It is evident from our studies, to be presented under plant descriptions and zonation, that the composition of the marsh has changed a great deal in 16 years. Carex lyngbei, Deschampsia caespitosa, Agrosis alba, and Salicornia virginica are still present in approximately similar proportions. A great deal less Scirpus americana is present, which makes good sense since it is a colonizer. Of special interest is the complete lack of Distichlis spicata in Johannessen's study, since it occupies dominant position in a great amount of our marsh. Perhaps the Distichlis spicata has invaded at the expense of the Salicornia virginica as the salt

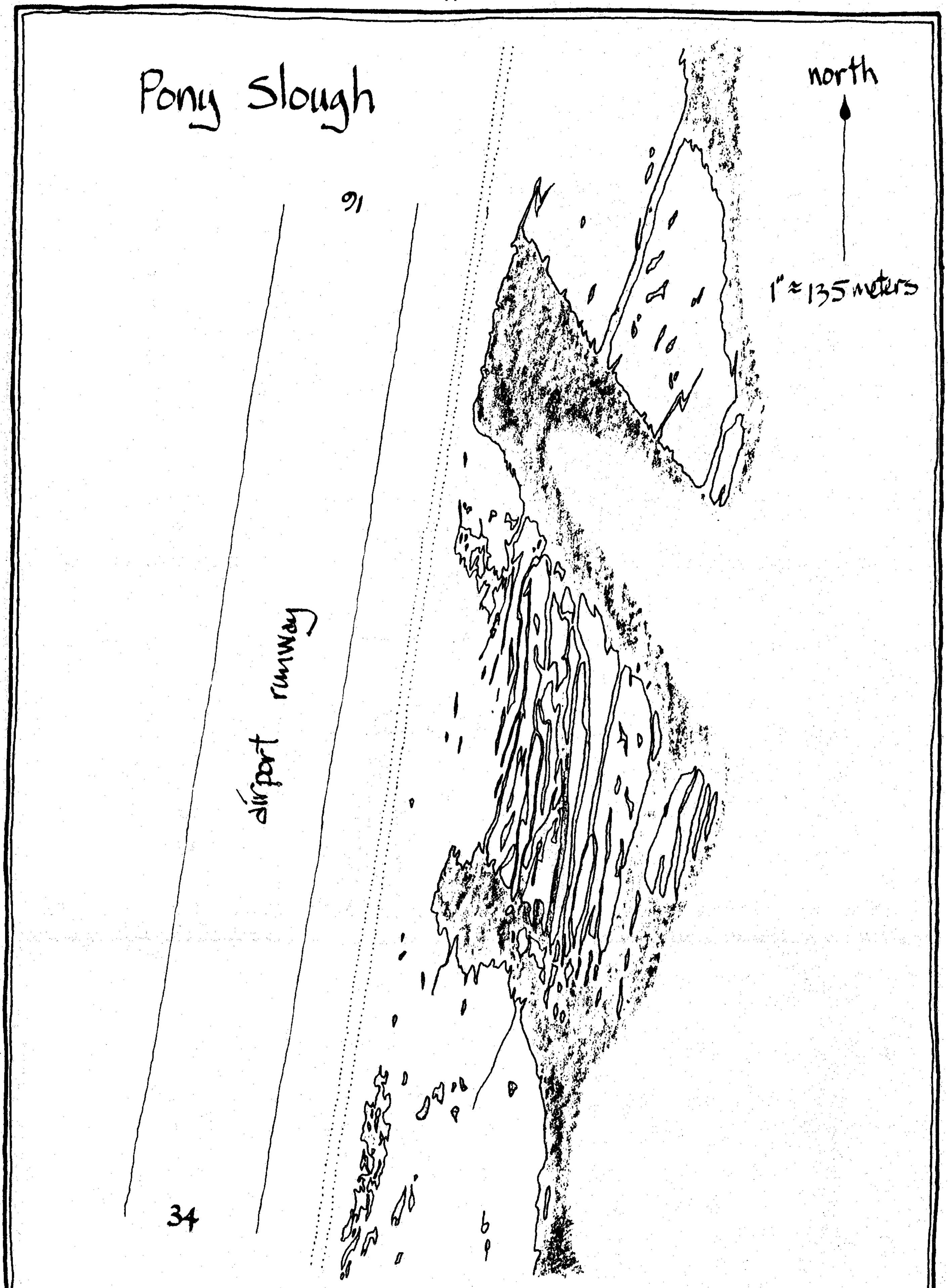

Figure 5. Pony Slough.

marsh has slightly risen.

North Slough (NO)

Located approximately 3.3 miles north of the McCollough bridge, the North Slough study site was chosen for its almost pure stands of bullrush, Scirpus validus. The slough itself is a narrow channel channel trapped between sand dunes forming the beginning of North Spit on the west end and higher cliffs on the east. The 8-9 foot tall Scirpus validus reflects the near fresh water conditions of the salt marsh. A salinity transect taken in midsummer from west to east across the study site reflected a gradient of 4 ppt salinity on the western side to 31 ppt salinity on the eastern side, near the main channel into the marsh. As one grades into this more saline area, Carex lyngbei replaces Scirpus validus. Driftwood piles near the eastern edge of the marsh prevent a salt marsh community from being established up to the dike.

The North Slough study site possesses some of the oddest plants in any of our study locations. Cotula coronopifolia, a South African plant species able to thrive in areas of high wood and bark accumulation, is quite common. Coexisting with the Scirpus validus was Boisduvalia densiflora, a plant not noted as a salt marsh species, but present nevertheless. As one grades to the western side of the marsh, towards the sand dunes and a railroad dike, Juncus balticus and Lileopsis occidentalis appear. Fresh water marsh species are also seen near the railroad dike.

The substate is very much different here than in our other study locations. The soil is very peaty, appearing to be totally organic. An analysis of 1939 aerial photographs shows no signature of Scirpus validus. This complete change in plant communities may have been due to the deepending of the channel next to Highway 101 and the placement of a long narrow dike directly to the west of this channel at some past time.

If one goes south of our study site, North Slough offers some of the most diverse and beautiful salt marshes in the estuary. These marshes were intensively studied by Carol Jefferson (1974).

Bull Island (BU)

In contrast to other salt marshes on the eastern side of Coos Bay, Bull Island is pristine. The salt marsh around these islands has been unchanged by direct human processes in the past 80 years (Herman Lillienthal, personal communication). Not an island at all, our study site is located across from the northernmost island and is next to the road that follows the eastern side of the bay. Although untouched by direct human contact, Bull Island has been shown to be experiencing rapid progradation(Johannessen 1961, Hoffnagle and Olson 1974). Comparing maps of the 1895 Coast and Geodetic Survey with current aerial photographs and aerial photographs of 1939, it can be shown that rapid expansion of salt marsh areas at the expense of tideflat has been occurring. This is thought to be due to increased siltation. Johannessen estimates that the island's extent has increased 50% since 1890. Hoffnagle and Olson show

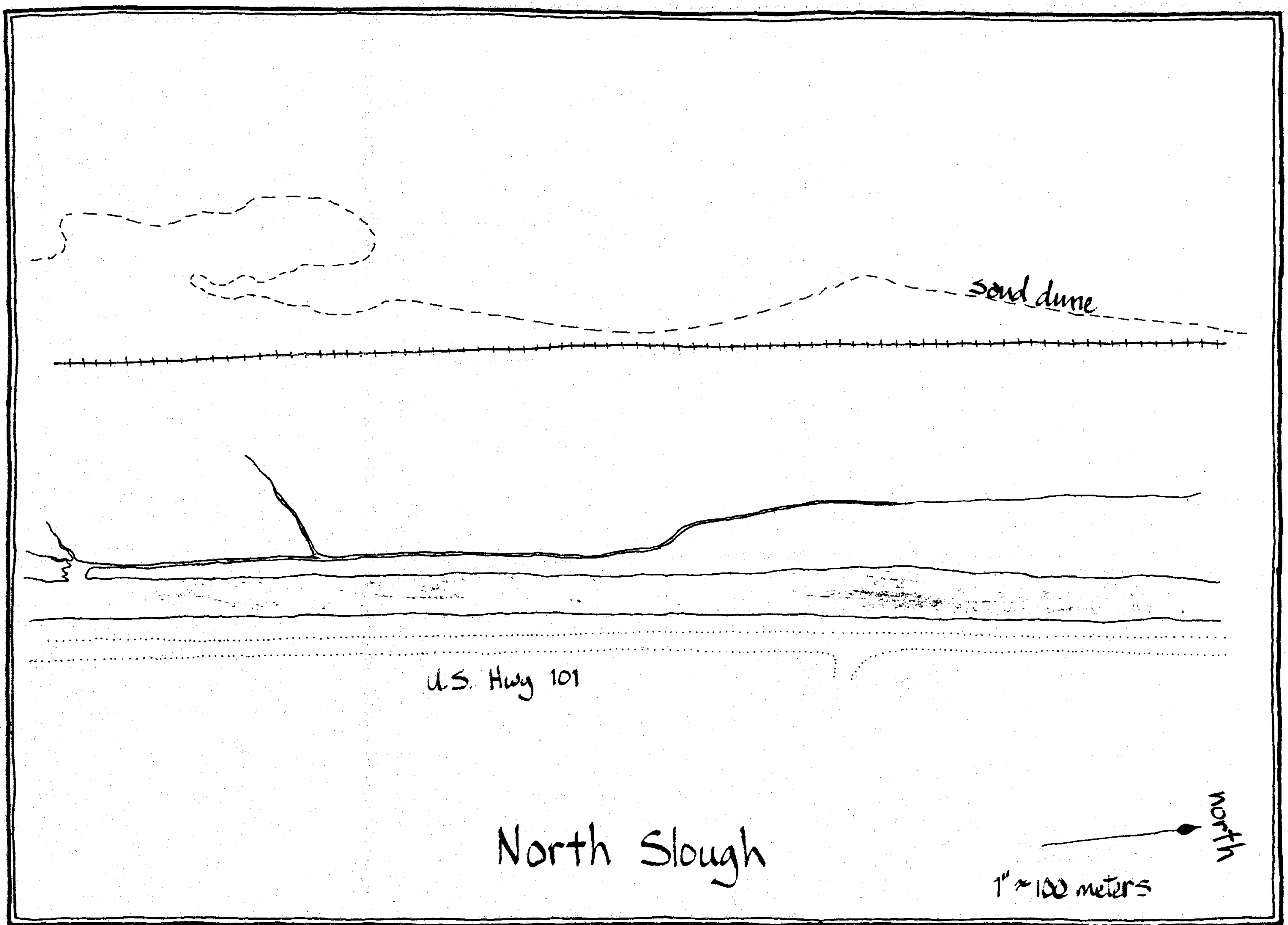

Figure 6. North Slough.

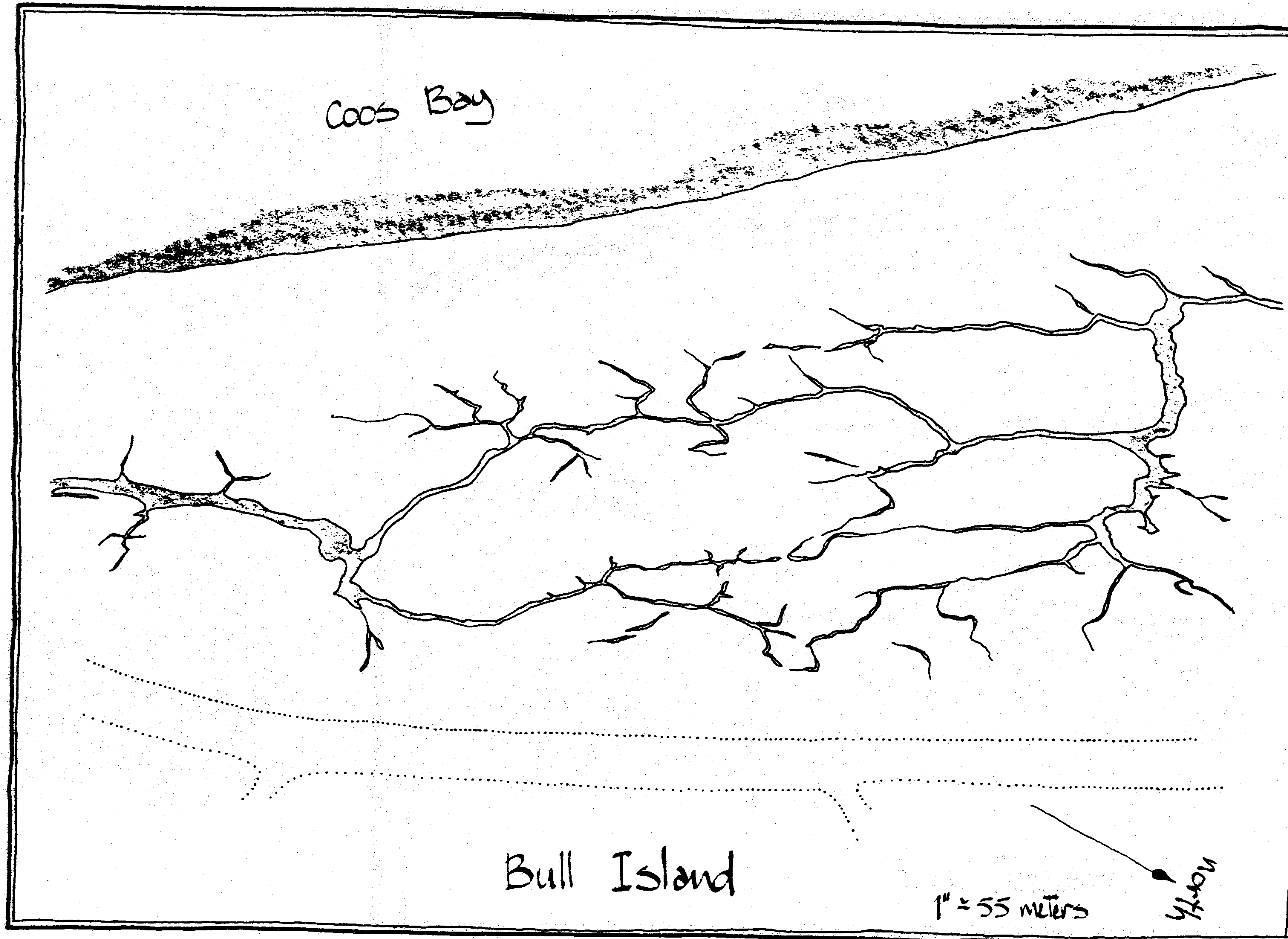

Figure 7. Bull Island.

extreme progradation amounting to 1-2 acres during the period from 1970-1974. These estimates must be tempered due to the obvious inaccuracies involved in comparing navigational charts and aerial photographs. If one looks at aerial photographs taken at different seasons, the late yearly emergence of some salt marsh pioneer plants may be very misleading.

The study site itself is 200 meters wide and is amazingly uniform across this distance. It lies high above the surrounding tideflat and is channelized deeply only at its landward edge. Most of the marsh contains a community of Carex lyngbei, Deschampsia caespitosa, and Triglochin maritima as a subdominant. At the seaward edge, Salicornia virginica and Distichlis spicata have some influence. At the terrestrial edge, Agrostis alba and Hordeum brachyantherum occur. Atriplex patela, Rumex occidentalis, and even higher up Grindelia integrifolia occur. Jaumea carnosa is present in some quantity in the higher reaches.

Bull Island represents the most unchanged of our salt marsh study sites, in spite of its proximity to the industrial pressures of Coos Bay. It is also perhaps the most uniform and unchanging over its wide, 200 meter range.

Coalbank Slough (CO)

The section of Coalbank Slough chosen as our study site is located near KVAL-TV. It is a completely enclosed salt marsh that is connected to estuarine water by a four foot culvert, whose tidegate was removed one year ago after a complaint was filed by the Division of State Lands against Coos County for placement of a tidegate on estuarine salt marsh without a permit. The four foot culvert through a dike constructed in 1973 provides inadequate circulation into the salt marsh and it is becoming terrestrial. In addition to impaired circulation, the salt marsh area seems to be subjected to septic tank leakage, as evidenced by excessive foam in the water coming from the salt marsh and in brown, burnt plant material near the higher reaches of the marsh. The lower, back portion of the marsh is a sedge marsh with a great predominance of Carex lyngbei and a fair amount of Deschampsia caespitosa. The area is separated from our study site by a low dike present in aerial photographs taken in 1939.

On this low dike many higher salt marsh plant species are present. Griddelia integrifolia, as well as Atriplex patula and Rumex occidentalis are present. In addition to these salt marsh species, several terrestrial species occur on this low dike. Vices gigantea, Stellaria calsantha, Plectritis congesta, Cardamine pensylvanica, Cytisus monspessulanus, and Rumex Crispus are all present. As one goes lower toward the main channel, Juncus lesueurii is present, as well as Hordeum brachyantherum and Hordeum jubatum. The main salt marsh level contains a great amount of Carex lyngbei as well as a good amount of Agrostis alba and Deschampsia caespitosa. Distichlis spicata and Salicornia virginica occur near channels and in lower sections of the marsh. Scirpus americanus is present as a colonizer in lower channel regions. Glaux maritima is sometimes found in the marsh. Tolerating

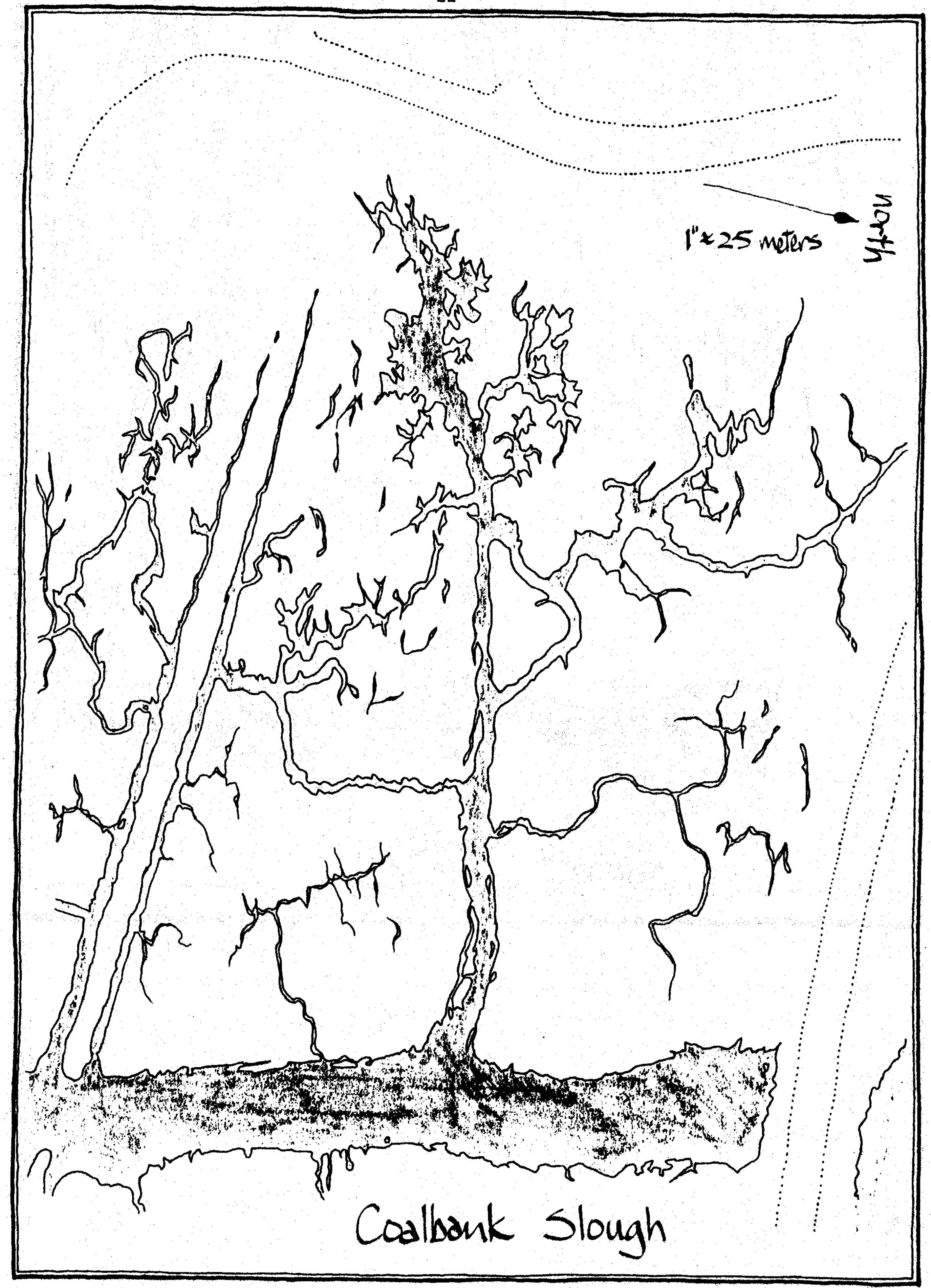

Figure 8. Coalbank Slough.

the lessening salt water conditions and invading into the salt marsh are *Holcus lanatus* and *Boisduvalia densiflora*.

Coalbank Slough is the study site most impaired by man-caused environmental changes. Being the site of a coal mine in the last century, it is surprising that this area had not been developed prior to strict state and federal regulations. With additional culverts and proper sewage disposal there is no reason why this unsightly, low productivity salt marsh could not return to near its natural state.

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Marsh Plants & Zonation...

SALT MARSH PLANTS AND MARSH ZONATION

K.J. VanderZanden

Introduction

The vegetation of salt marshes is universally similar. Ranwell (1972) has suggested that two physical restraints--silt and saline water--control the type of plant growth in marine environments. Given these restrictions, the plant species that can grow in a given area are governed by climate. Whether the plants actually occur depends on the chance factors of migration or introduction.

Climatic factors, especially temperature, may affect the world wide distribution of salt marsh plants. Many maritime plants are sensitive to winter frosts and require summer warmth for successful seed germination (Ranwell 1972). Thus, salt marshes are primarily associated with mid and high latitude regions. In the tropics, salt marshes are replaced by mangrove swamps (Chapman 1960). Maritime marshes tend to occupy narrow fringes bordering raised portions of land or else form, in estuarine waters, extensive tracts several miles wide. Several universal features of salt marsh areas have been noted. Gradation in height from the sea to the land accompanies a change in vegetation. Depressions (salt pans) and winding creeks form the main physiographic features of marshes though in some parts of the world, salt marshes are associated with sand spits or off-shore islands (Chapman 1960).

Salt marshes occur in all the major Oregon estuaries. They form behind sand spits, at river mouths and along shallow bays through the accumulation of organic debris and air or waterborne sediments (Jefferson 1974). Particles rich in nutrients are trapped by plant obstructions, increasing the size of the marsh laterally and vertically (Keefe 1972). Coastal marshes are typified by a small but distinct flora that is tolerant of inundation by saline or brackish water.

Adams (1963) states that the two outstanding characteristics of salt marshes are immediately apparent to the observer: 1) the universal influence of the tides and 2) the zoned pattern of seed plant distribution. Most previous ecological studies have explained the latter in terms of the former. This section focuses on the adaptations of salt marsh plants to their environment with descriptions of species found in our study locations. In addition, a discussion is presented on the various factors affecting the distribution of vegetation--both static zonational and successional patterns--within the salt marsh.

Characteristics of Salt Marsh Plants

Plants that are able to grow in places where there is an excess of common salt or alkali in the soil, whether submerged or not, are known as halophytes. Chapman (1960) defines three degrees of the halophytic condition. Obligatory halophytes require for growth some salt present in the soil during all seasons for growth. Preferential haloophytes supposedly grow best in saline soils but will survive in the non-saline state. However, Eltringham (1971) states that most salt marsh plants do not "need" salt to grow. Recently, Jeffries (personal communication, June 1976) demonstrated that several species of salt marsh plants (Juncus sp., Plantago sp.) exhibit more vigorous growth on soils less saline than their present habitat in the salt marsh and show best growth in non-saline "potting soil." Chapman (1960) goes on to describe supporting halophytes which are capable of living on saline soils but are not aggressively competitive with more tolerant species. Further research is needed to clarify plant strategies in relation to salinity stresses.

It is the salinity of the soil and not that of tidal water that affects the growth and distribution of halophytes. Plants exist that are capable of growing on saline soils containing from .3 to 20 percent salt . Most halophytes grow in soils with salt percentages 2.-6. percent (Strogonov 1962). Average salt content of the open ocean is 33 to 34 parts per thousand, or 3.3 to 3.4 percent. The high salt content in soils increases its osmotic pressure to a value greater than that in normal plant tissues. Therefore, plants are unable to absorb water for respiration and photosynthetic functions. Halophytes have developed various mechanisms for coping with such salinity stresses.

Some plants internalize small amounts of salts into their tissues, thus increasing their own osmotic potential to overcome that of the soil. Other plants, such as Glaux maritima, perform this function by accumulating salts in special glands. Excess salt may be excreted by glands or removed by leaf abscission or root excretion (Strogonov 1962). The water expenditure (transpiration) of plants decreases during the vegetative period with increasing soil salinities. This is accomplished primarily by decreasing the plant's surface area so less area is exposed for evaporation. Thus, many halophytes have round-shaped stems and leaves such as Salicornia and Triglochin. Reduced vegetative parts (especially leaves) also lessens exposed surface area.

Succulence is an important adaptive mechanism for survival on saline soils. The development of special internal water storage tissues has been related to the presence of certain ions, especially the chloride ion, in the soil. Water storage in aerial plant portions overcomes the problems of the extremely high osmotic pressure in the root environment (Chapman 1960). The succulent leaf shape is also better resistant to mechanical damage inflicted by wind and tides (Ranwell 1972). Glaucous stems and leaves (those covered with fine, waxy powder) and those with a coating of soft hairs aid in the external absorption and storage of water. Jaumea and Atriplex exemplify these characteristics (Chapman 1960).

Besides directly affecting plant structure, the conditions created by high salinity concentration in the soil change the relation of the plant to its environment. Such factors as temperature and light, which exert favorable influences under normal conditions, may exert damaging effects in the saline situation (Strogonov 1962).

Salt marshes are often thought of as open habitat. One would then expect a high proportion of annuals in the marsh flora. Two open zones in the marsh are maintained by the high incidence of wave break at MHW of neap tides and the smothering of vegetation by litter at MHW of spring tides. In addition to the pioneer zone of mud flat on the seaward edge, a few species of annuals are abundant in these locations. However, it is mostly perennial species that have adapted to the true salt marsh habitat (Ranwell 1972).

The majority of annuals are members of one family--Chenopodiaceae--characterized by a degree of tolerance for saline and alkaline conditions. Herbaceous perennials such as grasses are the most common. Woody perennials such as Salicornia virginica often have woody rootstocks and stems with succulent or fleshy leaves. Ranwell (1972) describes emergent marsh as new or young salt marsh appearing on the seaward margins of older marsh. Emergent salt marsh species have either dense woody root stocks or highly compacted rhizomatous growth. These characteristics offer a competitive advantage over other marsh species by creating a relatively impenetrable dense growth cover in the emergent marsh as the entire salt marsh becomes more diversified in later stages of succession. On a broader scale, halophytes have a competitive edge over other plants through their ability to grow in a harsh environment. Many of the species present in the salt marsh are not there because conditions favor vigorous growth, but rather that these plants cannot successfully compete in terrestrial habitats (Chapman 1960).

A list of plant species found in our study locations and those previously noted in the Coos Bay salt marshes follows:

Family--POLYGONACEAE

Rumex occidentalis Wats.

Dock is a stout plant with thick, ribbed stems and wrinkled leaves that become reddish in later summer. Flowerparts are in threes. This species of dock, growing in immature high marshes, is also found in the upper zones of other marsh types and in terrestrial habitats. Rumex maritimus is also common in the salt marshes.

Family--CHENOPODIACEAE

Atriplex patula L.

Salt bush is a herbaceous annual with spade-shaped leaves, opposite below and alternate above. Leaves are covered with inflated balloon-like hairs that serve for water storage. Salt bush has separate male and female flowers, with female flowers naked. Plants grow from (1) 2-10 dm, are never found in dense stands, but are scattered through immature high and sedge marshes.

Salicornia virginica L.

Pickleweed or glasswort is one of the most widespread of all salt marsh plants. Jointed fleshy leaves shoot upward from woody stems. Flowers are found in the depressions of joints in fleshy spikes. It is most abundant in low sand marshes; in sedge and immature high marshes, it is found in patches along drainage channels.

The succulent perennial requires salt water for growth; roots, in particular, need aeration and good drainage. See Figure 1.

Family--CARYOPHYLLACEAE

Spergularia marina (L.) Griseb.
Salt Marsh Sand Spurry has five petaled, light purple flowers and opposite fleshy leaves with prominent papery stipules. It grows to 2-3 dm. and is found in low sand marshes. See Figure 2.

Stellaria calycantha (Ledeb.) Bong. var. sitchana (Steud.) Fern.
Northern Starwort has five petaled white flowers borne in cymes with leafy bracts. Leaves are ovate, opposite and sessile. This variety along with Stellaria humifusa Rottb. is found along the coast generally in upper zones of immature high marshes.

Family--ROSACEAE

Potentilla pacifica How.
Pacific Silver weeds has solitary yellow flowers with five parts and pinnately compound leaves. It is unique among salt marsh plants being broad-leaved. Strongly stoloniferous, it resembles a strawberry plant. Pacific Silver weed grows in the higher zones of marshes, rarely submerged during its growing season. It blooms in late May-June.

Family--FABACEAE (LEGUMINOSAE)

Cytisus monspessulanus L.
Resembling the familiar Scotch Broom, French Broom also has light yellow flowers, but they are born in racemes rather than in leaf axils. It is distinguished by hairy seed pods. The terrestrial plant is found on the upper margins of immature high marshes and on the low dike extending through the Coalbank marsh.

Trifolium wormskjoldii Lehm.
Marsh Clover is leafy-stemmed, rhizomatous and flowerheads are axillary on short stems. Flowers are reddish to purple and often white-tipped. It is found on margins of immature high marshes or in interior meadows and streambanks.

Family--ONAGRACEAE

Boisduvalia densiflora (Lindl.) Wats. var. salina (Rydb.) Munz.
Spike Primrose has pinkish flowers with four bi-lobed petals and eight stamens. The fruits are slender, fusiform capsules. The annual herb has softly hairy stems with alternate oval leaves. Not considered strictly a salt marsh plant, it was noted in immature high marshes with Hordeum, Agrostis and Deschampsia, and in the upper zones of low sand marshes.

Family--APIACEAE (UMBELLIFERAE)

Conium maculatum L.
Poison Hemlock is noted by its purple spotted, hollow stem and

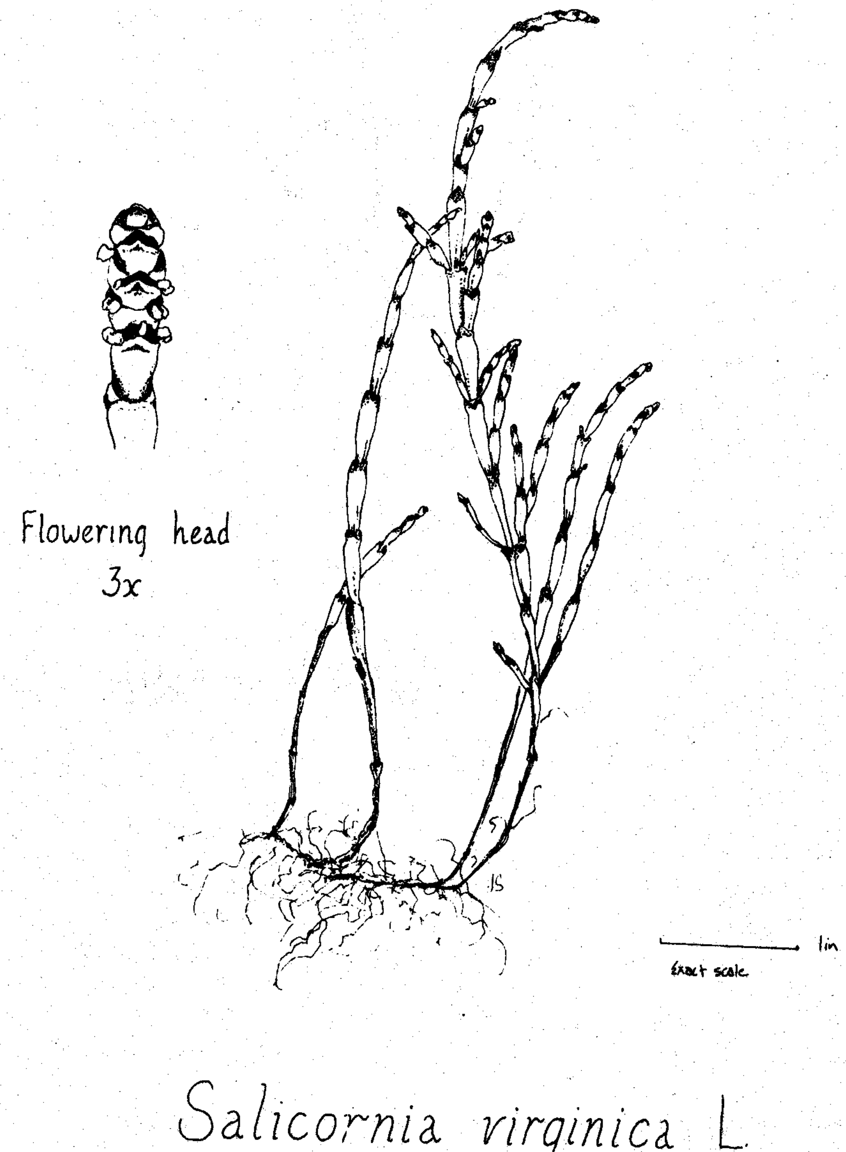


Figure 1. Salicornia virginica L.

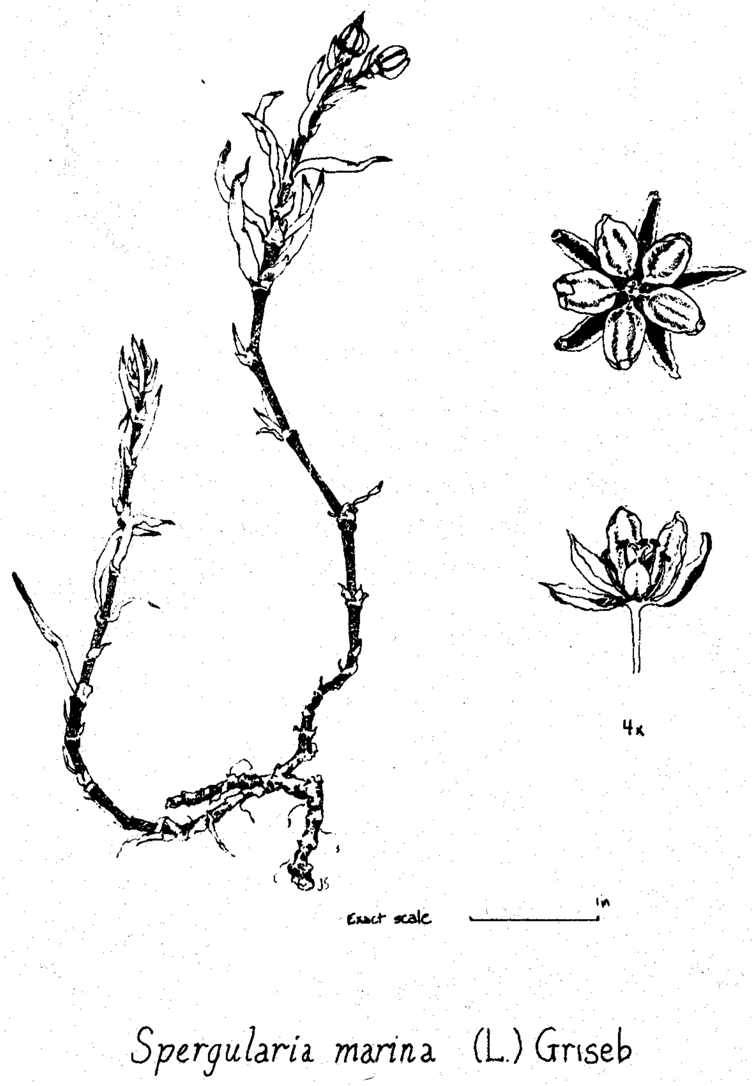


Figure 2. Spergularia marina (L.) Griseb

white flowers borne in compound umbels. A terrestrial plant preferring moist places, it is found in the upper margins of low sand and higher marsh types in association with Juncus and Potentilla.

Lileopsis occidentalis Coult. and Rose

Lileopsis is a small (to 10 cm.) creeping perennial that grows from long rhizomes in clumps. Leaves are reduced to light green, linear structures with transverse partitions. The small white flowers borne in umbels appear from June to August. It is found in low silty marshes or muddy channels within other marshes.

Oeanthe sarmentosa Presl.

Water-parsley is actually a terrestrial plant found in the upper zones of the salt marshes with freshwater influence. Water-parsley is a tall (1-2 m.) plant with pinnate leaves. White flowers are borne in a compound umbel and bloom in August. It was noted on the edge of the North Slough bulrush stand.

Family--PRIMULACEAE

Glaux maritima L.

Sea-milkwort, another low fleshy perennial, has five-merous, bell-shaped flowers with only sepals. The white flowers are single, sessile in leaf axils and bloom in June. Oblong leaves are opposite below and alternate above. It is commonly found in low sand marshes and was also noted in Coalbank Slough.

Family--CUSCUTACEAE

Cuscuta salina Engelm. var. major Unck.

Salt marsh Dodder is an orange colored, leafless parasite that twines around its host sending little knobs ("haustoria") into it to obtain nourishment. The pale flowers have five fused petals and have short pedicels. It is commonly found on Salicornia and infrequently on Jaumea.

Family--SCROPHULARIACEAE

Cordylanthus maritimus Nutt.

Salt Marsh Bird's Beak, a branched annual, grows more or less prostrate and has hairy stems and leaves, some hairs being glandular tipped. The greenish to purplish tubular flowers are approximately 2 cm. long. It is rare in Oregon and is reported in the low sand marsh of North Slough and South Slough. It is more common in Northern California. See Figure 3.

Orthocarpus castillejoides Bent

Paintbrush orthocarpus has clubbed-shaped terminal flowers with four stamens. Bracts surrounding flowers are tipped with white and yellow. The sender annual grows as a single erect stem with upper leaves dissected and lower ones less so. It is found high in low sand marshes with Distichlis, Jaumea and often Juncus and Deschampsia. It is believed to parisitize other plants' root systems.

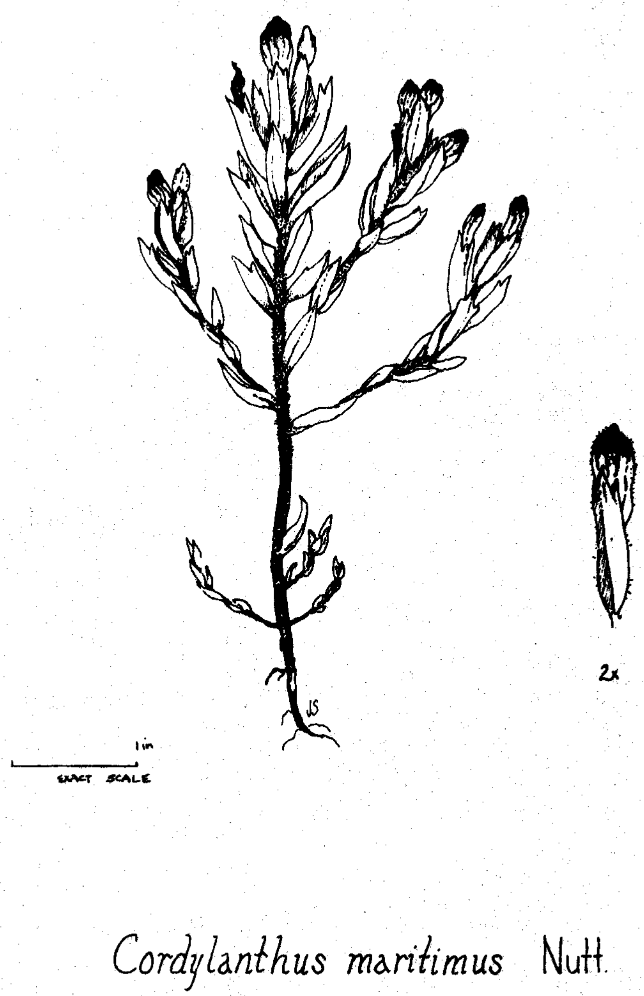


Figure 3. Cordylanthus maritimus Nutt.

Family--PLANTAGINACEAE

Plantago maritima ssp. juncoides Eam.

Seaside plaintain is a small upright plant with flowering spikes borne on leafless stalks. The papery sepals and petals are four-merous. Leaves are more or less linear, seldom 1 cm. wide, and are all basal. It is found in many situations, but mainly in low sand and immature high marshes. See Figure 4.

Family--VALERIANACEAE

Plectritis congesta (Lindl.) D.C.

Rosy Plectritis has five-lobed pink flowers with the corrolla tube spurred and are born in tight clusters. Square stems bear tongue-shaped opposite leaves. Commonly found in moist areas, Rosy Plectritis is found in upper zones of low sand marshes and immature high marshes as well as on the low dike in Coalbank.

Family--ASTERACEAE (COMPOSITAE)

Cotula coronopifolia L.

Brass Buttons has a bright yellow, button-like compact head and leaves (1-6 cm.) entire or with a few coarse teeth. The perennial plant is more or less succulent. It has been introduced from South Africa, and is often found on driftwood in upper portions of high marshes. It is able to survive on substrates that have been impregnated with various chemicals leached from logs during storage.

Grindelia integrifolia D.C.

The Gum Plant is a woody stemmed perennial named for its gummy flowers, with bright yellow petal recurved at the tips. It grows in immature high marshes and on the upper margins of other marsh types. It is reported in coastal marshes from Coos to Monterey Co., California.

Jaumea carnosa (Less.) Gray.

Fleshy Jaumea is a rhizomatous, succulent perennial that grows to 3 cm. It has opposite narrow, entire leaves and yellow terminal flowers that bloom in late July or August. It is commonly found in low sand marshes. Figure 5.

Family--JUNCAGINACEAE

Triglochin maritima L.

Seaside Arrowgrass grows 8-12 dm. in height. The terminal flowering spikes bear green to purplish flowers with parts in three's and six stigmas. The fleshy leaves appear semi-circular in cross section. Triglochin shoots grow close together in clumps with intertwined roots (rhizomes). It often establishes itself on previously unclaimed mudflat and creates circular, elevated hummocks. Senescence strikes center plants as new shoots appear on the outer margins of the clumps. New shoots appear in late April, flower in May and reach full maturity in July. Triglochin lacks strong internal

Figure 4. Plantago maritima.

Figure 5. Jaumea carnosa.

fibers and so decomposes readily. It is frequently found in low sand marshes though often grows in silt, immature high and sedge marshes as well. See Figure 6.

Family--TYPHACEAE

Typha latifolia L.

Flowers of the Cat-tail are borne in familiar brown, cylindrical and terminal, spikelike inflorescences. The tall perennial herbs grow from extensive rhizomes and have alternate linear leaves. Cat-tails grow in slow moving or standing fresh water and usually indicate the boundary between fresh water and salt marshes. Typha was noted in the upper portions of drainage channels in Coalbank indicating considerable fresh water influence.

Family--JUNCACEAE

Juncus balticus Willd.

Flowers of the Baltic Rush are found in a loose lateral panicle on the shoots. Plants grow to 1-12 dm. and are a brighter green than J. lesueurii. New shoots appear from rhizomes in early fall. By April, young plants have grown above the litter and reach maturity in July. The Baltic Rush is found where creek density is high--usually at the headwater of the small drainage channels. Thus, it requires well drained soil with few depressions. It is found on the upper margins of low sand marshes and on the terrestrial edge of the bullrush marsh in North Slough.

Juncus lesueurii Boland.

Rushes can usually be distinguished from sedges and grasses by their often round, non-noded stems; flowers are never in spikes or spikelets. The Salt Rush attains height of 2-6 dm. The hard, dark green stems have a sharp point and many small brown flowers. The lateral inflorescence is sphere-shaped. The Salt Rush grows in dense stands and in immature high marshes and above low sand marshes. Able to successfully compete outside the salt marsh, it is also found forming tight clumps in diked marshes and pastures.

Family--CYPERACEAE

Carex lyngbei Hornem.

Lyngby's sedge is an important constituent of Coos Bay salt marshes. Sedge flowers are much reduced, borne in spikes or spikelets and the stems are usually triangular with leaves W-shaped in cross section. Lyngby's sedge has shorter spikes (1.5-5 cm) than Carex obnupta, which is also reported in upper reaches of the estuary. Spikes are borne on penducles, with the lower ones at least, noding. New shoots of Carex appear in fall but rapid growth is delayed until spring. This species reaches maturity in early July then assumes the color of straw. Seeds are released by late August and early September. Eilers (1975) reports a tall and short form of Carex lyngbei and noted that the tall form found at higher elevations in the marsh becomes prostrate in late summer while the short form remains standing. Carex has a wide salinity tolerance;

Triglochin maritima

Figure 6. *Triglochin maritima*.

the major factor in limiting its distribution is its location on well drained soil. See Figure 7.

Eleocharis palustris (l.) R. and S.

Common Spike-rush has a solitary terminal spikelet. Flowers have two stigmas. The round stems grow to 4 dm. and leaves are reduced to mere sheaths or scales. It grows in upper portions of low sand marshes with Juncus, Carex and Deschampsia. Eleocharis parvula (R. and S.) Link. (Small Spike-rush) grows to 5 cm. and is also reported in low sand marshes.

Scirpus americanus Pers.

Three-square Bulrush has notable triangular stems with concave sides. Spikes are sessile in a cluster. This sedge is a colonizer on bare mud and also appears in the upper portions of drainage channels in low sand marshes in late July.

Scirpus maritimus L.

Salt Marsh Bulrush has a triangular stem and is highly similar to Scirpus americanus. The flowering parts are in a terminal-appearing head rather than lateral spike or spikes. It is also salt marsh colonizer.

Scirpus validus Vahl.

Round stemmed American Great Bulrush has sessile spikes, reddish brown in color. The dark green stems grow to a height of 2 m. or more. This bulrush grows where there is considerable fresh water influence and forms an almost pure stand in the North Slough study location.

Family--POACEAE (GRAMINEAE)

Agrostis alba L. var palustris (Huds.) Pers.

Creeping bentgrass has one flowered spikelet with bent or twisted awns. Spikelets are born in open panicles. The plant grows along the ground sending up thin leaves after some distance (1-1.5 m.). This sod-forming grass is often an important component of pasture lands. It usually joins Carex, Deschampsia and Triglochin at MHW, increasing in dominance at higher elevations. Creeping Bentgrass prefers well-drained soils, areas of high creek density and lesser tidal stress.

Deschampsia caespitosa (L.) Beauv. var. longiflora Beal.

Tufted Hair grass is a tussock and not a sod-forming grass. The spikelets of this grass grow in semi-open panicles that are often glistening or purplish. Awns are twisted or bent. Young blades are folded or curled, 1.5-2 (4) mm. wide and first appear in May. Marked by rapid growth, Tufted Hair grass peaks early in July. Deschampsia becomes established after invaders such as Triglochin have raised the marsh surface somewhat. It often occupies a transitional zone between the lower and upper portions of the salt marsh. Growing to a height of 1-2 m., it forms an upper story on low sand, sedge and immature high marshes.

Figure 7. Carex lyngbei.

Distichlis spicata (L.) Greene

Seashore Salt grass is a rhizomatous perennial (1-2 dm.) with solid stems and open sheaths. Stiff hairs are present at the top of the sheath margins. Terminal spikelets grow in compact, green to purplish panicles and bloom in July. The stiff, two-ranked leaves are rolled in the bud. Distichlis is common in low sand marshes and often forms a dense low mat or is mixed with Salicornia and Jaumea. See Figure 8.

Holcus lanatus L.

Common velvet grass has softly hairy nodes and stems. Spikelets are borne in a whitish congested panicle; awns are hooked. The tufted grass was probably introduced from Europe as a meadow grass but has since become a pernicious weed. A terrestrial grass, it has invaded the Coalbank marsh proper.

Hordeum brachyantherum Nevski

Hordeum sp. have terminal spikes with long awns, open sheaths and short membrane-like ligules. The spikes of Meadow Barley are much longer than broad, often nodding and purple-tinged at maturity. This perennial is found in low sand marshes and infrequently with Carex and Deschampsia in higher salt marshes.

Hordeum jubatum L.

Foxtail or Squirrel tail barley has spikes generally as thick as long. The perennial grows 2-6 dm. in height and is found in immature high marshes in association with Carex, Deschampsia and Agrostis.

Zonation and Succession in the Salt Marsh

Many authors have recognized the distribution of salt marsh vegetation along environmental gradients (Chapman 1960, Ranwell 1972, Jefferson 1974, Eilers 1975). Increase in elevation of the marsh surface, usually expressed as height above MLLW, is often employed as the independent variable in such studies. Elevation itself is not a causative factor in determining plant distribution. Rather, variations in submergence, tidal action, soil salinity, etc., associated with elevational changes directly influence floral zonation. The occurrence of salt marshes and various smaller communities within the marsh have been explained primarily on the basis of inundation or a complex of several factors of which salinity and inundation are considered to be most important (Adams 1963).

H.P. Eilers (1975) in his study of plant community distribution in Nehalem Bay salt marshes, commented on problems inherent in the design of community studies. He believes that if researchers go into the field in hope of finding discrete units of plant associations, the methods chosen will necessarily report the desired information. If one hopes to describe plant communities in a continuum, one will design an experiment to clarify this relationship. Most past work on the Pacific Coast involved plotless methods and observation which tended to support the idea of discrete community units. Vogl (1966) completed a thorough sampling of vegetation in Upper Newport Bay, California, and his results supported the con-

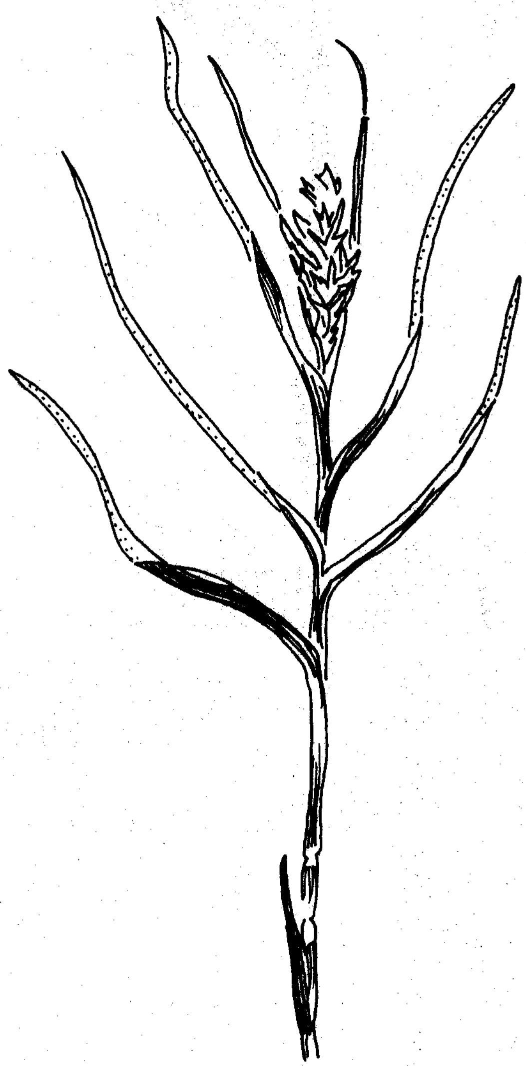


Figure 8. Distichlis spicata.

tinuum philosophy. Jefferson (1974) and Eilers (1975), both working in Oregon estuaries, also reported the blending of communities from lower to higher elevation in the salt marsh as well as in changes in a particular marsh site over time.

Salt marsh organisms are zoned according to the conditions they can withstand, conditions dominated by tides at lower levels and almost independent of them at higher elevation (Ranwell 1972). It is difficult to explain marsh zonation by any one factor. Climatic factors such as temperature, light, rainfall and wind may be altered by tidal inundation. Tidal influences include: intensity and frequency of mechanical disturbance caused by tidal action; the vertical range over which the tide operates which in turn controls the tidal flood depth and the vertical extent of the marsh; the form of tidal cycle which affects the frequency and duration of submergence; water quality--itself determining available light and salinity concentrations (Ranwell 1972).

Climatic effects on a world wide basis were discussed above. Chapman (1959) states that local climatic variability tends to be unidirectional across the marsh surface from seawards to landwards and is a contributing factor to the marked zonation apparent in this direction. Much work has been done on light intensity correlated with plant zonation (Chapman 1930, Adams 1963, Hinde 1964). Ranwell (1972) reports that the effect of reduced light on salt marsh plants is noticeable beneath the shade of overhanging oaks in Hampshire, England estuaries. The growth of Glaux maritima and Triglochin maritima become scraggly and reduced. Little other work has been done on individual species. Not all plants require high light intensities. The turbidity of water covering the lowermarsh and the shade provided by taller plants creates various micro-habitats within the marsh.

It has been difficult to obtain a clear indication of how temperature affects plant zonation. Complex interactions between temperature, photoperiod and salinity obscure absolute effects of this variable (Ranwell 1972). Rainfall influences salinity concentrations especially in the upper zones of the marsh. Chapman (1960) has shown that seed germination of most plants occurs at times of reduced salinity, that is, when low temperatures combine with high rainfall. The effect of wind on salt marsh plants has not been investigated, but Ranwell (1972) believes it must limit the height and extent of plant growth in exposed salt marsh sites.

Mechanical disturbance is greatest at higher marsh levels near MHW of spring tides. Wave presence often persists, prolonged by onshore winds delaying the ebb tide. Tidal litter accumulates here, crushing weak growth and temporarily reducing light supply. Open ground is thus produced near the landward limit of marshes favored by colonists such as Atriplex.

Several studies have shown soil salinities probably do not linearly increase or decrease as one moves landward in the salt marsh. Squiers and Good (1973) suggested that the stunting of Spartina in the higher zones of a Spartina marsh may be due to higher soil salinities caused by increased evapotranspiration due to the decrease in the extent and frequency of tidal flooding. But the highest zone in the salt marsh, marked by terrestrial invaders and semi-halophytes, has much lower soil salinities caused by a high degree of rain and fresh water runoff influence.

Tidal curve, an indicator of the extent of land covered by tidal ebb and flow, steepens as one proceeds upstream in the estuary. Ranwell (et al. 1964) noted that the lower limits of a Spartina angelica marsh in Poole Harbour, England, were higher at successive intervals up the estuary though the differences were small. Boeftnik (1966) has shown on the Scheldt estuary in Holland that different species do retreat to higher levels upstream, apparently in proportion to the steepening of the tidal curve.

The vertical range of the elevational levels of salt marshes is primarily related to the tidal range (difference between the highest high and the lowest low), and secondarily to the turbidity of the water. Highly turbid water thus reduces the potential vertical range of salt marsh plant growth by limiting available light. Marshes contained within large tidal ranges tend to be more steeply sloping, have clearly zoned vegetation and sharper drainage systems that run perpendicular to the shore. Those marshes contained within smaller ranges have less clearly zoned vegetation, sluggish drainage that produces a complex network of winding creeks. Long established mature marshes flatten at the elevational limit where tidal submergence is insignificant and zonation becomes indistinct (Ranwell 1972).

Though plant communities do not exist as discrete units, these zones represent fairly definite ranges of tolerance of certain environmental factors (Jefferson 1974). Eilers (1975) further explains the limits of species' vertical ranges in terms of competition.

> "In general, species inhabiting the upper portion of the elevational gradient are more restricted in vertical range than those of the lower seaward section. This supports the belief that salt marshes exhibit a successional sequence from low to high elevations. Further, the species-elevational curve reveals what might be termed 'elevational niche structure,' that is, even though considerable overlap is present among species, elevations of maximum dry weight are not coincident. This would appear to be an attempt to minimize the competition among species with similar affinities and is perhaps the result of competitive exclusion interactions (Guase 1934, Whittaker 1965)."

Eilers (1975) found that the lower marsh community is less efficient in area utilization in terms of net primary production that the higher communities. With tidal inundation stress greater in the lower zone, a larger portion of the plants' available energy is used for self-maintenance than compared to the amount used by higher zone plants for this purpose. In addition, photosynthetic activity is partially curtailed by submergence.

Observers have questioned whether the static zonation pattern of a salt marsh at a given point in time reflects the same sequences in plant succession. Carol Jefferson (1974) cautioned that zonation cannot be presumed to reflect succession unless the same patterns are also found in plant debris in marsh sediments and validated by a study of community change over time in fixed plots. Her study, involving the examination of soil profiles and the use of C-14 dating, has shown the patterns to be similar.

The type of tide flat sediment and soil salinity determine the initial plant sequence. Algae and species of eelgrass such as Ruppia and Zostera colonize the mudflat. This area is still considered a barren zone and so these plants are not included in a salt marsh species list. On silty soils, pioneer species invade the mud flat, either forming coalescing circular colonies as does Triglochin maritima or sinuous line fronts as in Scirpus americana. Salicornia colonizes sand or sandy silt substrates. Smaller plants with spreading rhizomes and roots begin to anchor the substrate. Plants, characterized by rapid propogation by runners or rhizomes, including Carex and Distichlis, invade the stabilized soil. The die-back of the center portions of circular colonies allows several species such as Deschampsia and Carex to invade these higher barren islands. Juncus lesueurii establishes in the hollows.

As sediments accrete and the drainage patterns become more altered, the marsh changes to allow for the diverse vegetation of a mature high marsh. Salicornia-Distichlis-Juncus is the usual climax community for silty soils, barring diking or a change in the sea level (Jefferson 1974). This relative stability of vegetative cover is rarely attained. Most sea coasts are either rising or sinking and there is no real opportunity for any vegetation to develop that is in equilibrium with the surrounding environment (Chapman 1960).

Diking or other alterations of the tidal flow can cause a marked increase in fresh water influence in upper portions of a salt marsh. In this case, an interruptive community could develop consisting of Scirpus validus, or Typha latifolia. Succession on sandy substrates differs from that on silt. The sequence is again dependent on soil salinity and wave action. Fewer species are involved in the sand sequence. Succession begins with Salicornia and progresses through Distichlis-Jaumea-Triglochin-Plantago communities to a climax community of Juncus lesueurii-Grindelia-Potentilla.

Summary

The world wide distribution of salt marsh plants is largely controlled by climate. Most salt marshes are located in the mid to high latitudes. As halophytic plants capable of tolerating high soil salinities, salt marsh plants exhibit several structural adaptations for coping with their saline environment: reduced surface area, succulence, salt storage and excretion glands, hairy or glaucous vegetative parts. Most salt marsh plants are herbaceous perennials; annuals commonly belong to the Chenopodiaceae family.

The zonation of vegetation from the seaward to landward margins of the salt marsh has been well established and is caused by a number of climatic and tidal factors. The relative importance of individual factors is still debated; however, inundation and soil salinity are probably the most influential. The zoned pattern of plant communities is believed to reflect change in marsh community composition over time. Succession begins with the invasion of bare mud flats and climaxes in a diverse mature high marsh community. Species composition of the successional sequence and climax community is determiend by the initial substrate and soil salinity. Stable salt marsh climax communities are seldom seen,due to the disruptive influence of land and sea level changes, as well as the civilizing effects of man.

Distribution of Vegetation in Coos Bay Salt Marshes

The following vegetational maps indicate the general distribution of plant species within each marsh. The maps were constructed to aid the reader in understanding the location of plant communities and vegetation sampled via the transect method in each marsh. The coded zones do not indicate absolute elevational boundaries of community types.

Community Code

Distichlis-Salicornia-Triglochin

Distichlis-Salicornia-Triglochin-Jaumea

Distichlis-Salicornia-Triglochin-Jaumea-Deschampsia

Carex-Deschampsia-Distichlis

Deschampsia-Hordeum-Agrostis

Carex

Scirpus validus

Juncus-Grindelia-Potentilla

An elevational cross section (A-A') on each map closely approximates the location of transect lines used for primary productivity studies. The A-A' cross section is graphically portrayed on pages following each map. These cross sections show elevation, location of channels, and changes in plant communities. Elevation is not based on absolute elevation above sea level but rather the maps have been adjusted from a local tide chart so as to indicate the relative contours of each marsh. Plant species are noted as follows:

Agrostis ◉

Alnus ●

Atriplex •

Carex ●

Cenium ○

dead material ▪

Deschampsia ☼

Distichlis ◈

driftwood ▮

Enteromorpha ❂

Glaux ❂

Grindelia ◉

Hordeum ◉

Jaumea ◉

Juncus ◉

Potentilla ◉

Rubus (sp.) ◉

Salicornia ⊙

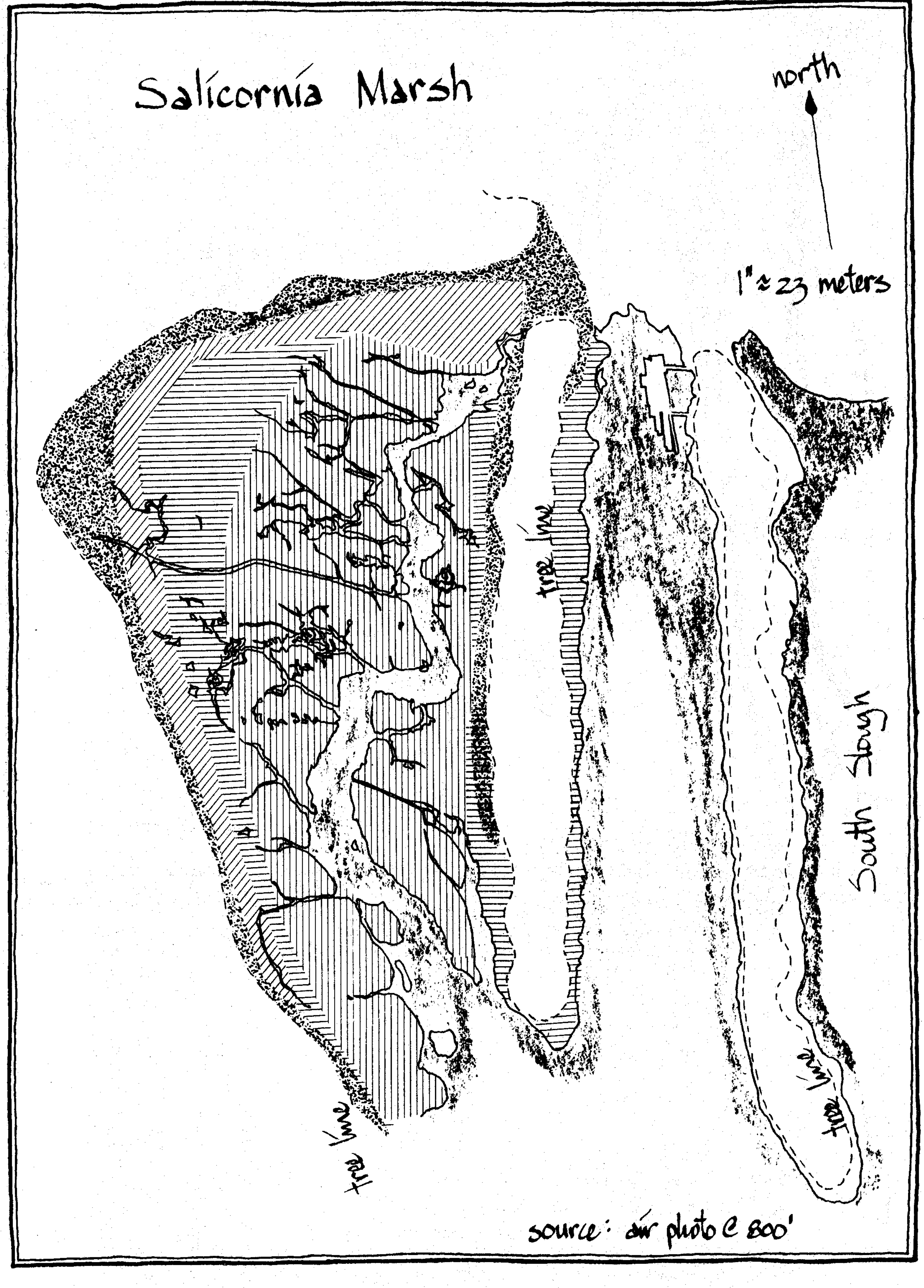
Scirpus ⊙

terrestrial plants ▮

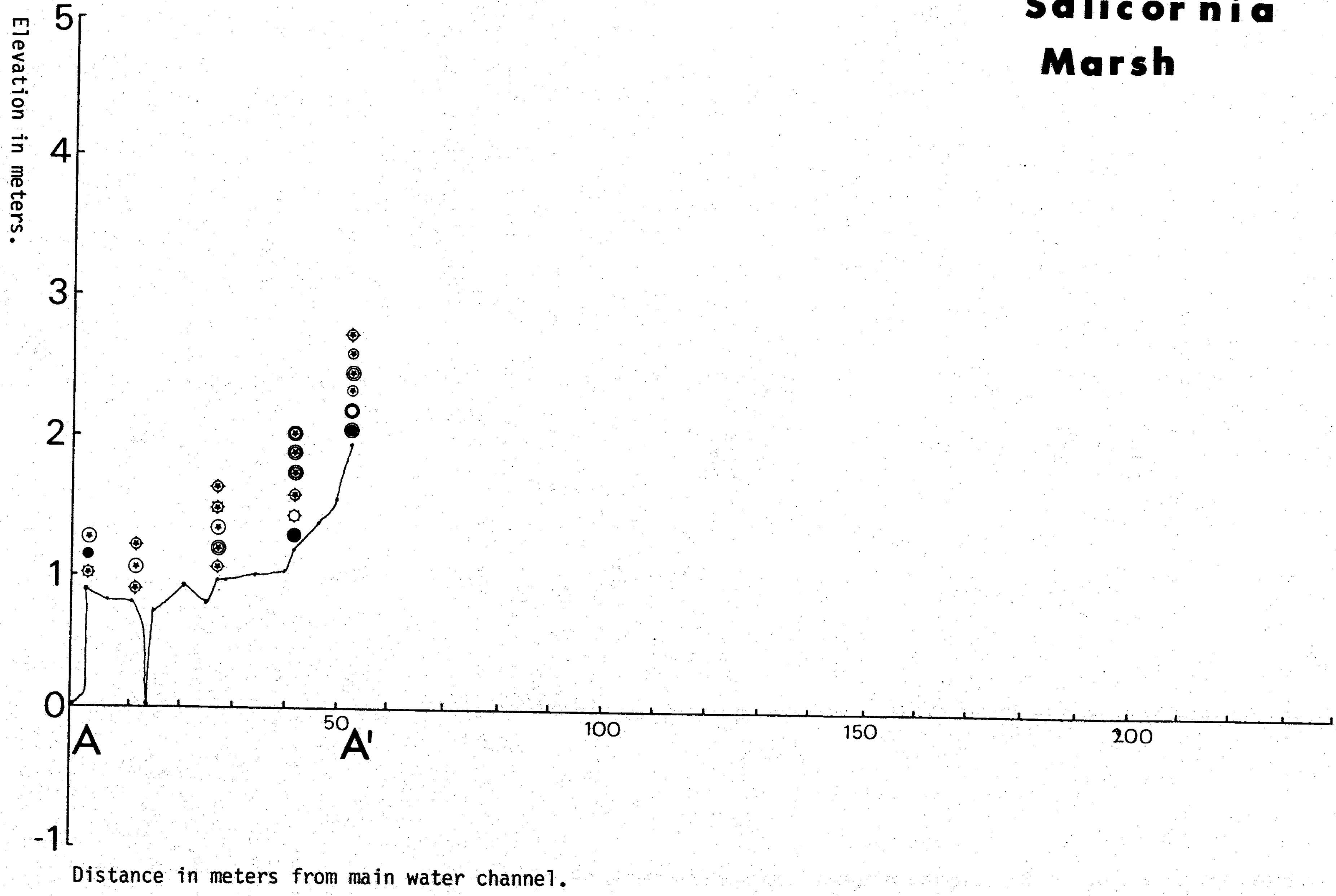
Triglochin ◈

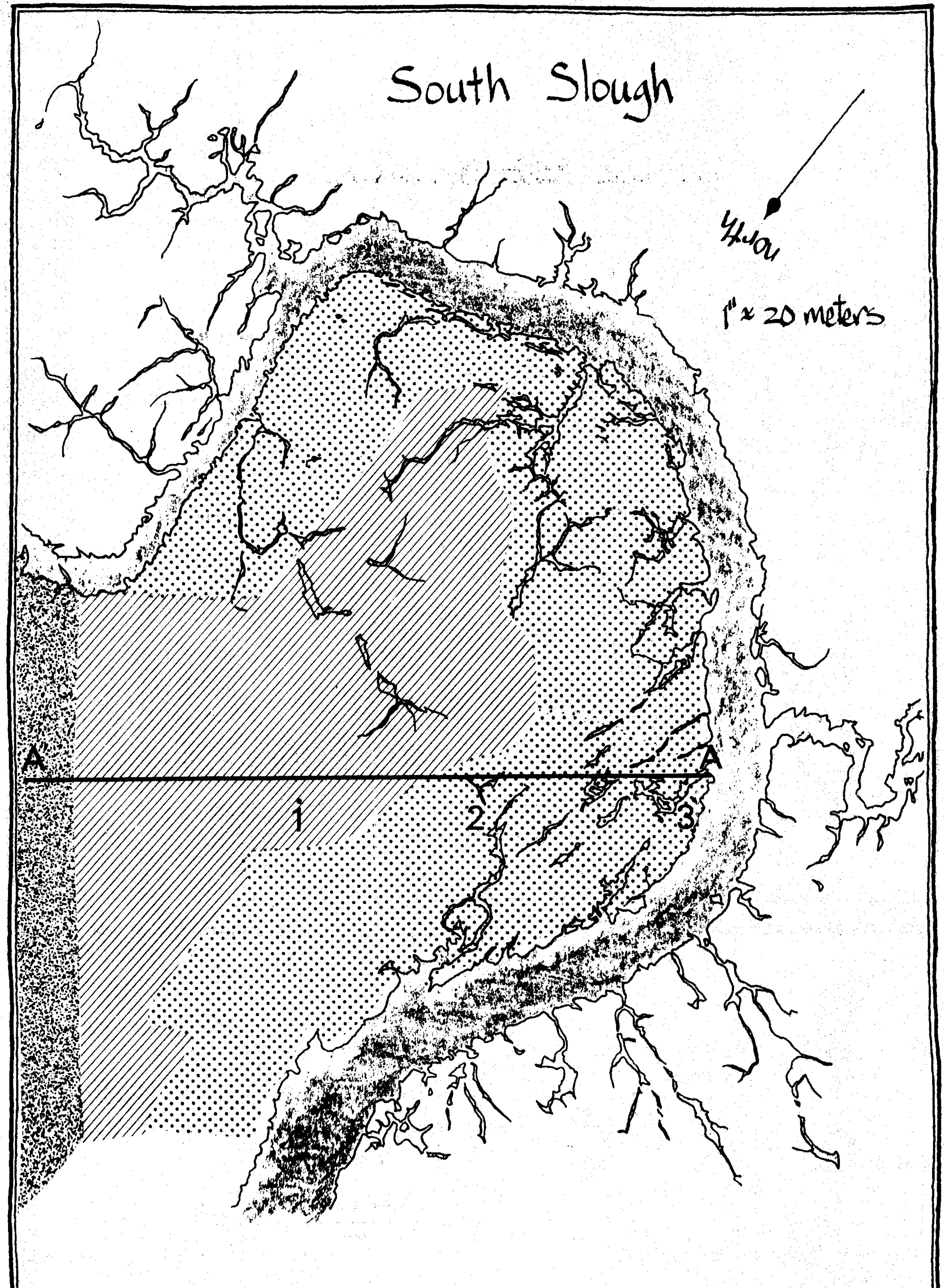
Typha ◉

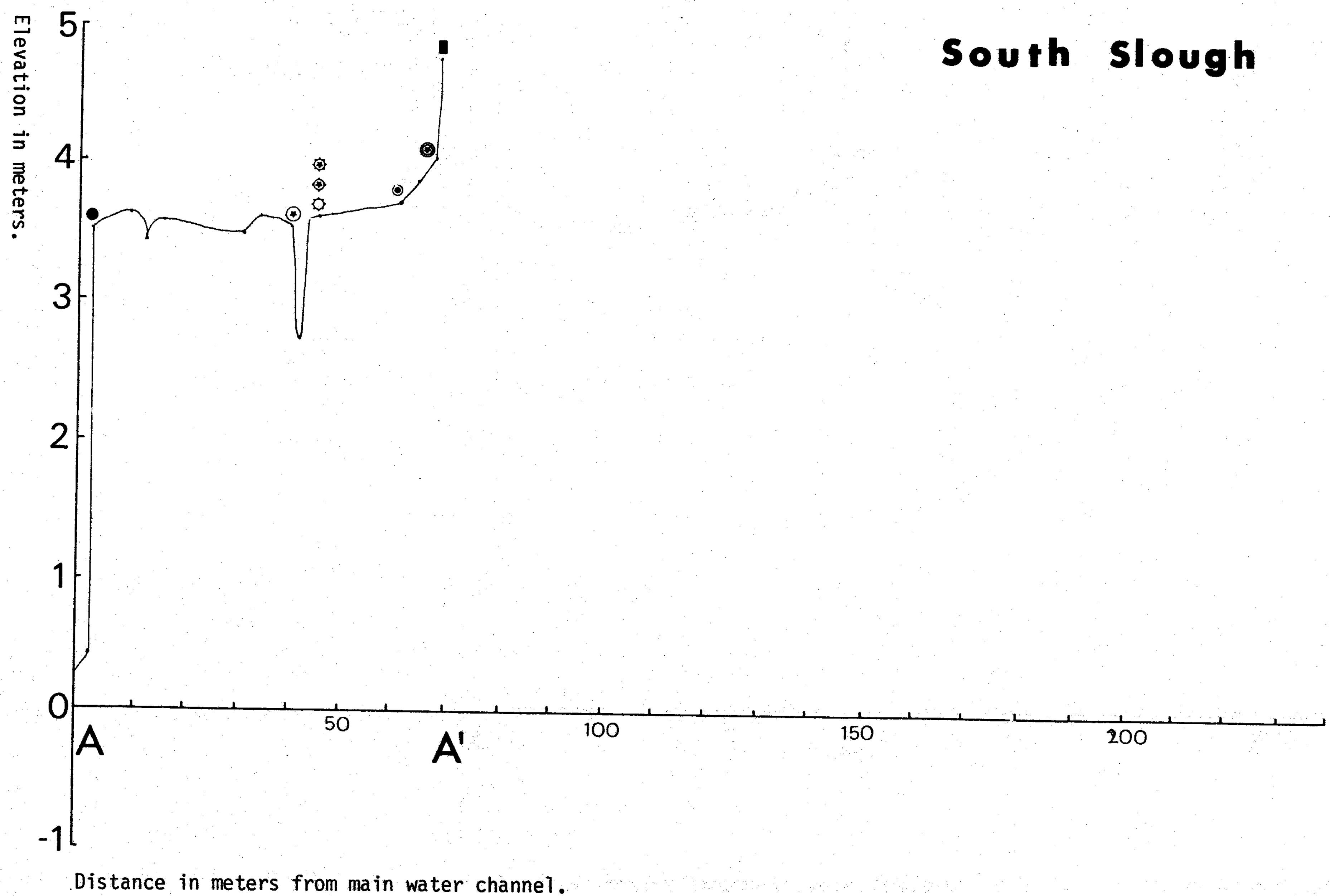
Ulva ●

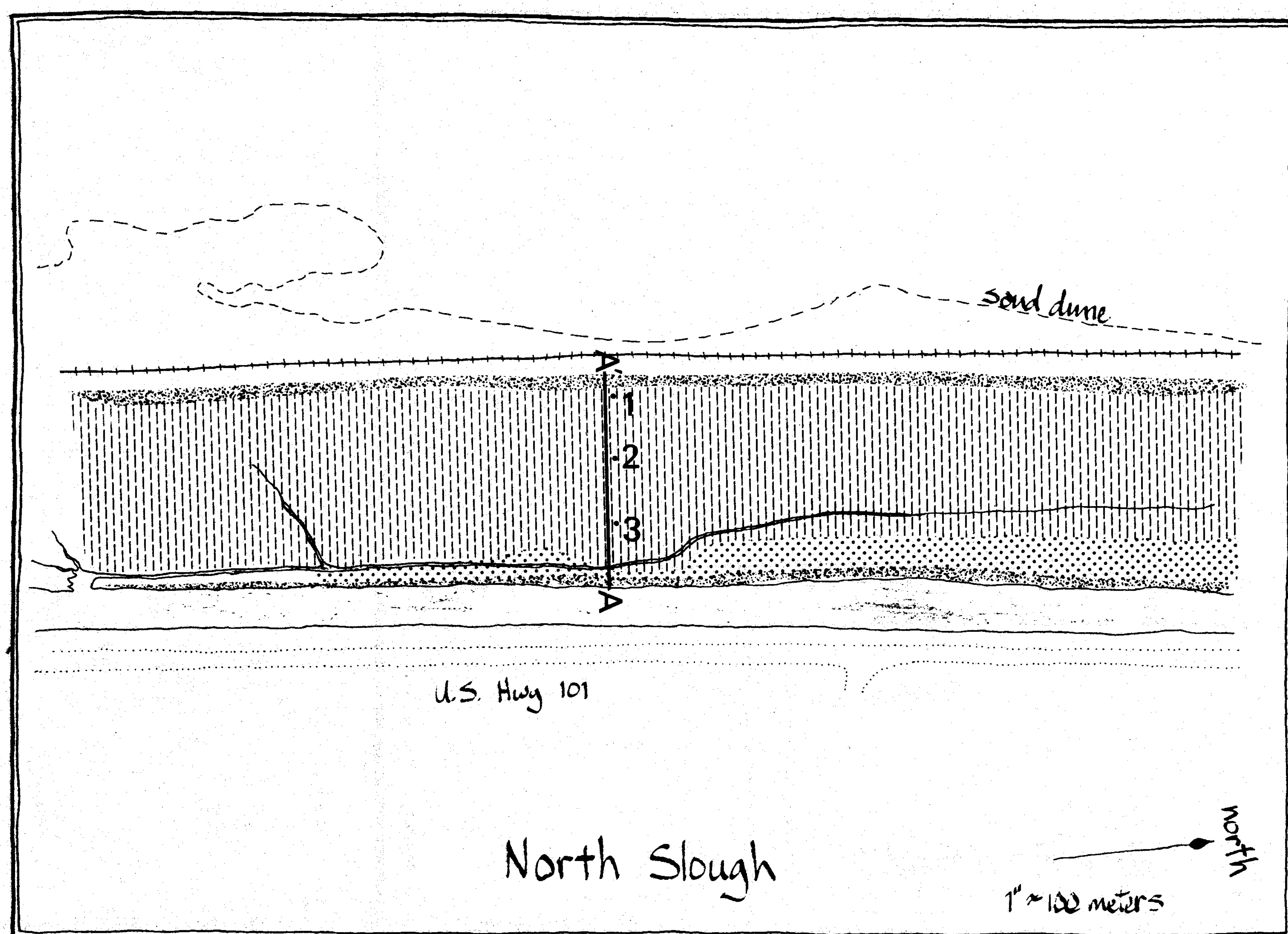

Salicornia Marsh
north
1" ≈ 23 meters
tree line
tree line
tree line
South Slough
source: air photo @ 800'

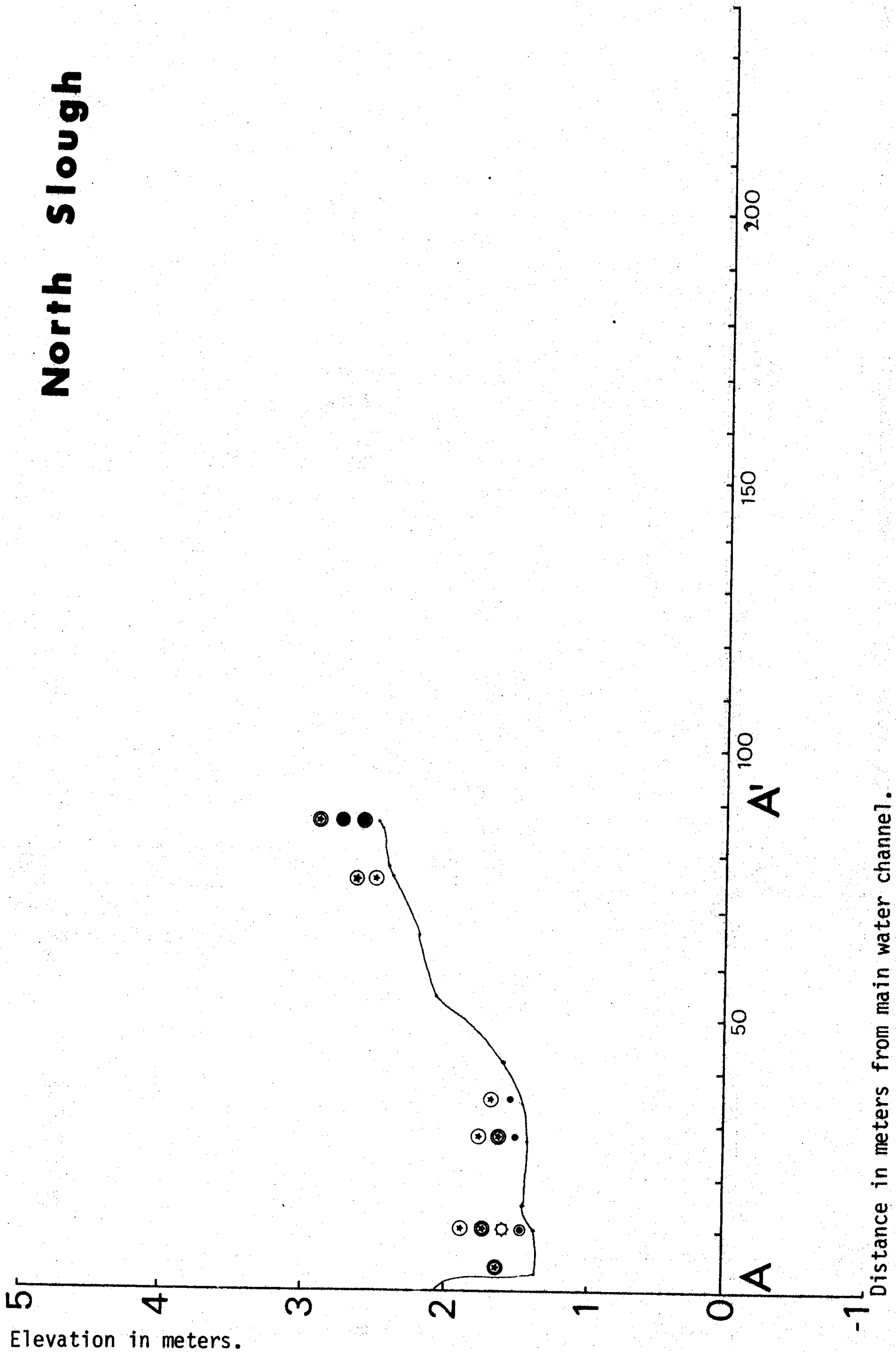
Salicornia Marsh

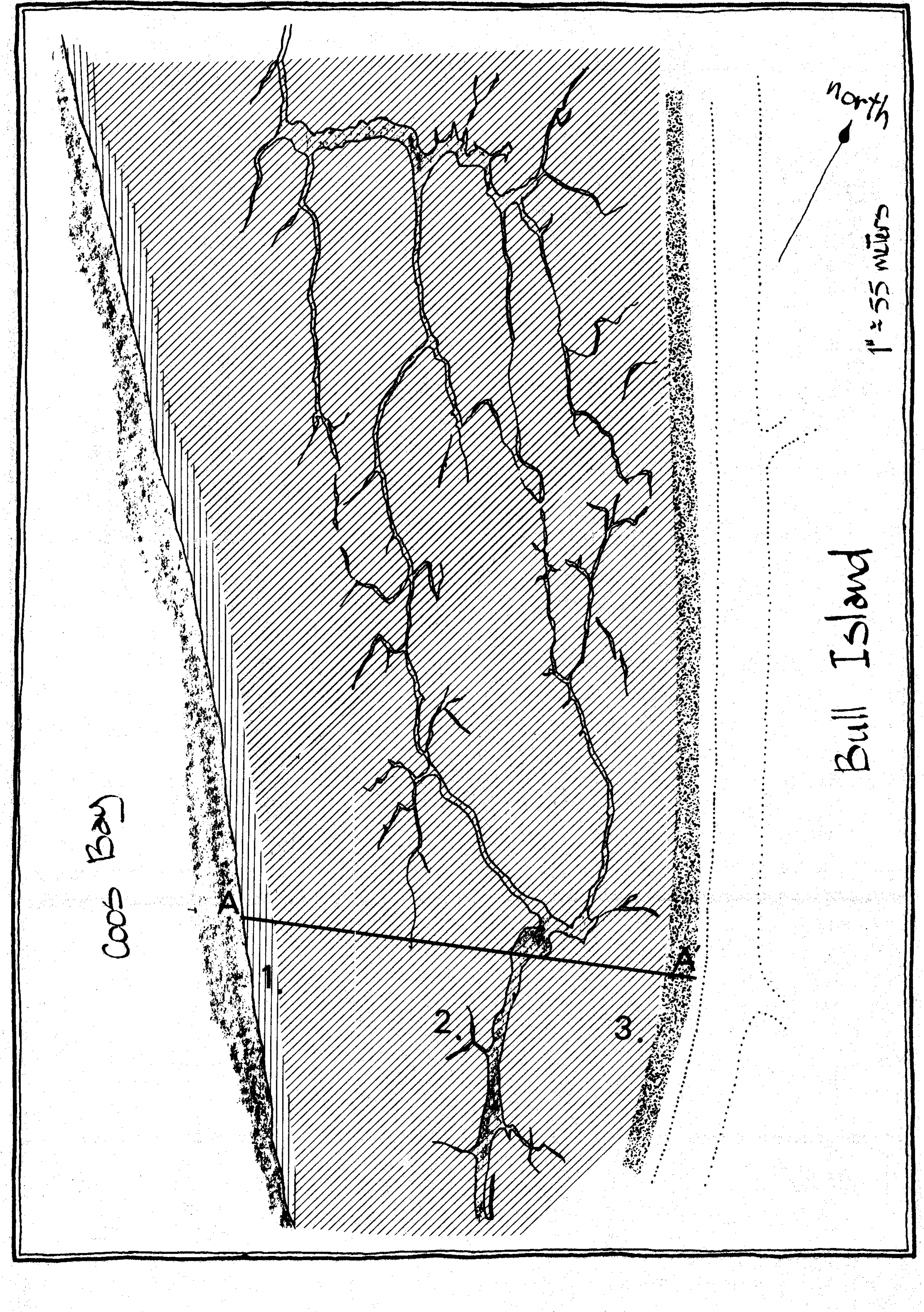


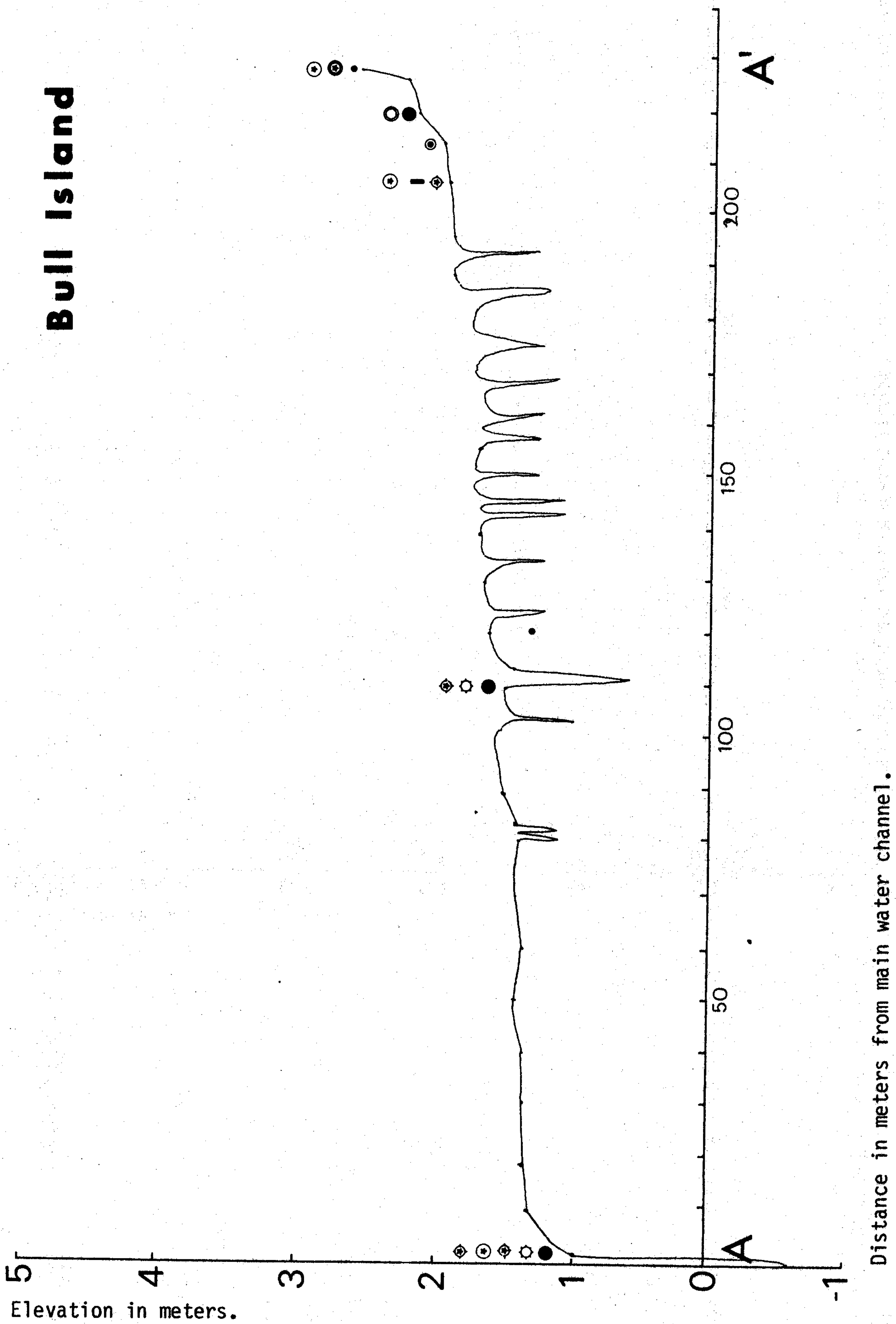

South Slough
1" ≈ 20 meters
A'
A
1
2
3

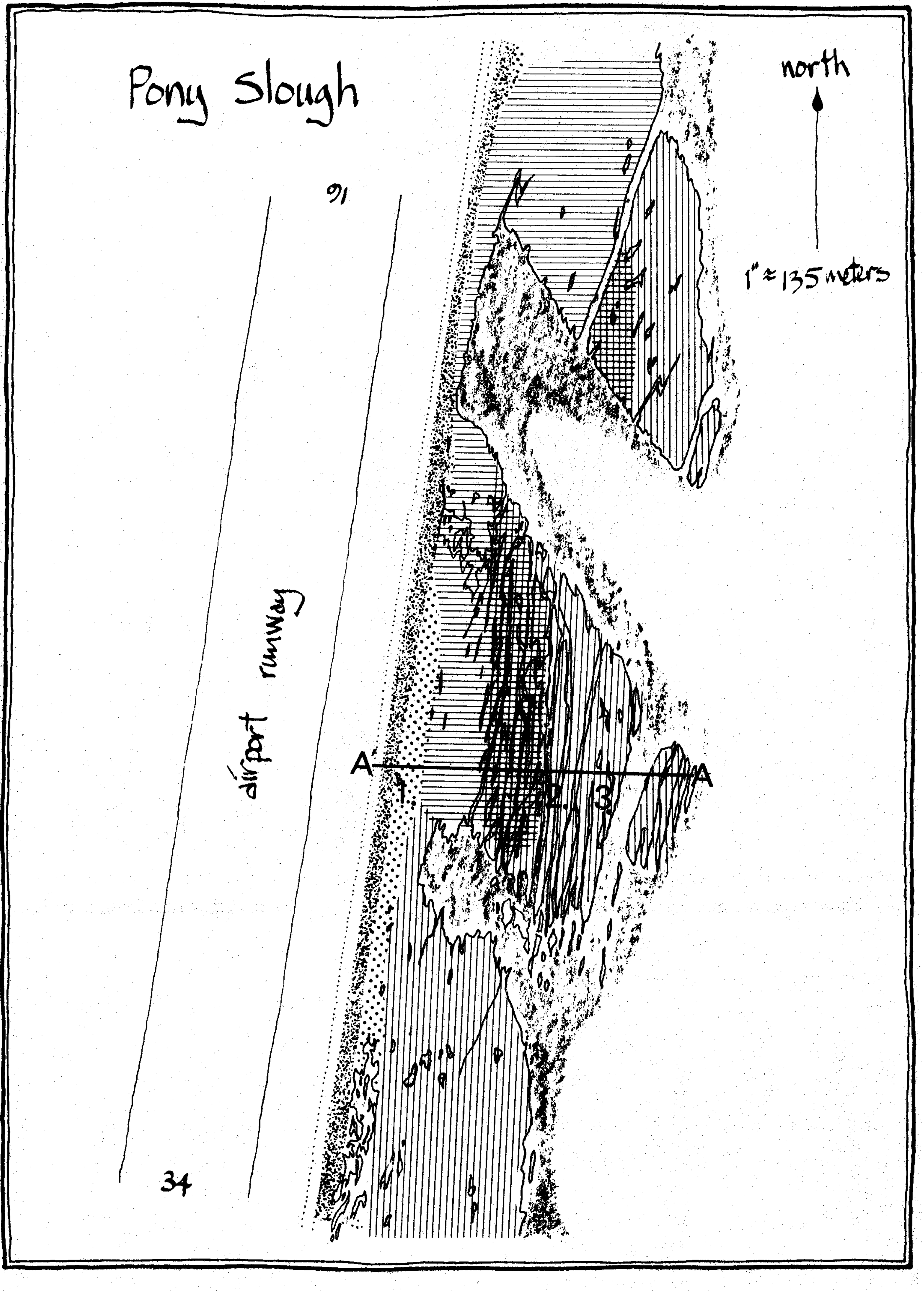

South Slough
Elevation in meters.
5
4
3
2
1
0
-1
A
A'
50
100
150
200
Distance in meters from main water channel.

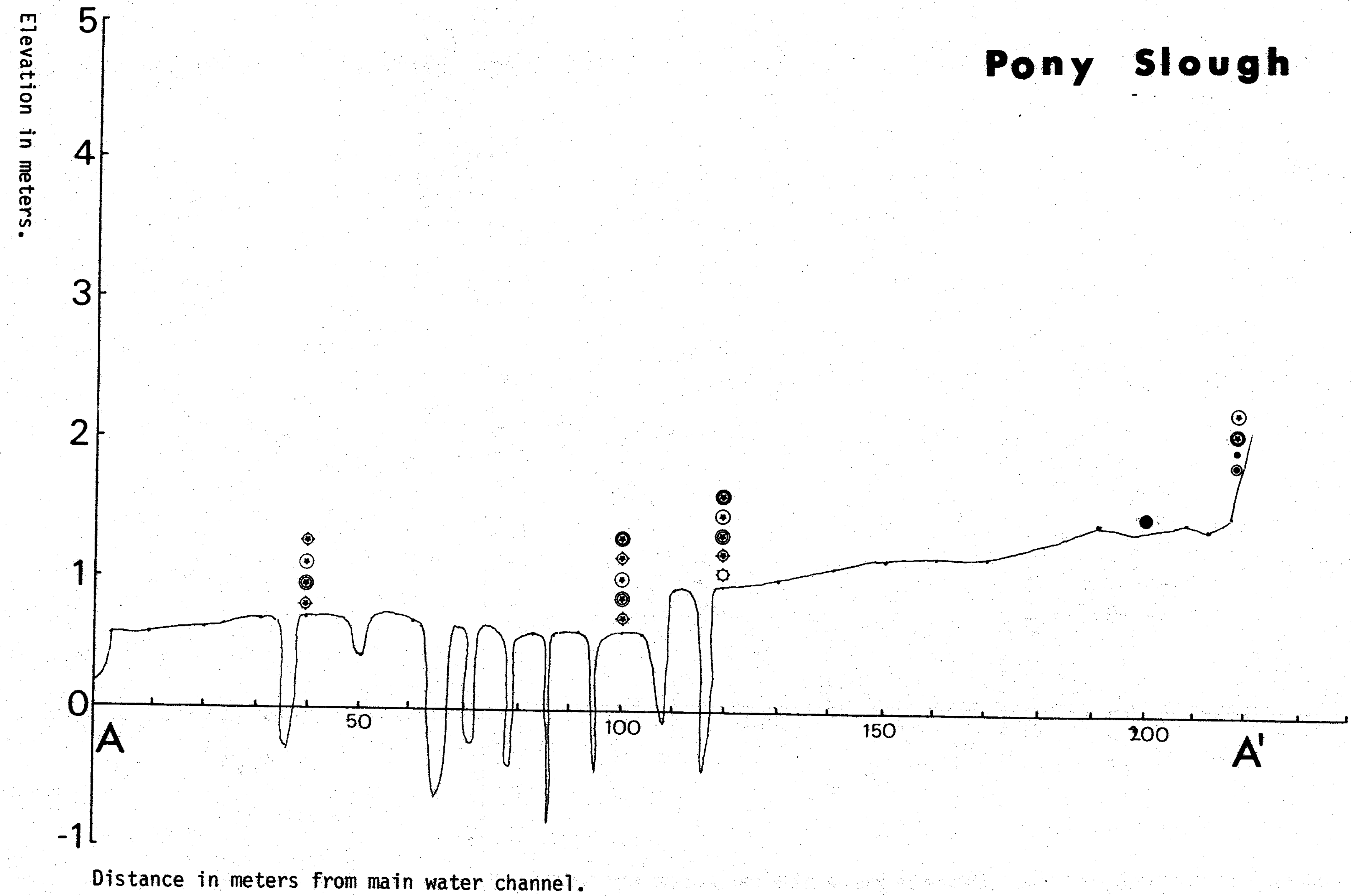

sand dune
A'
1
2
3
A
U.S. Hwy 101
North Slough
north
1" ≈ 100 meters

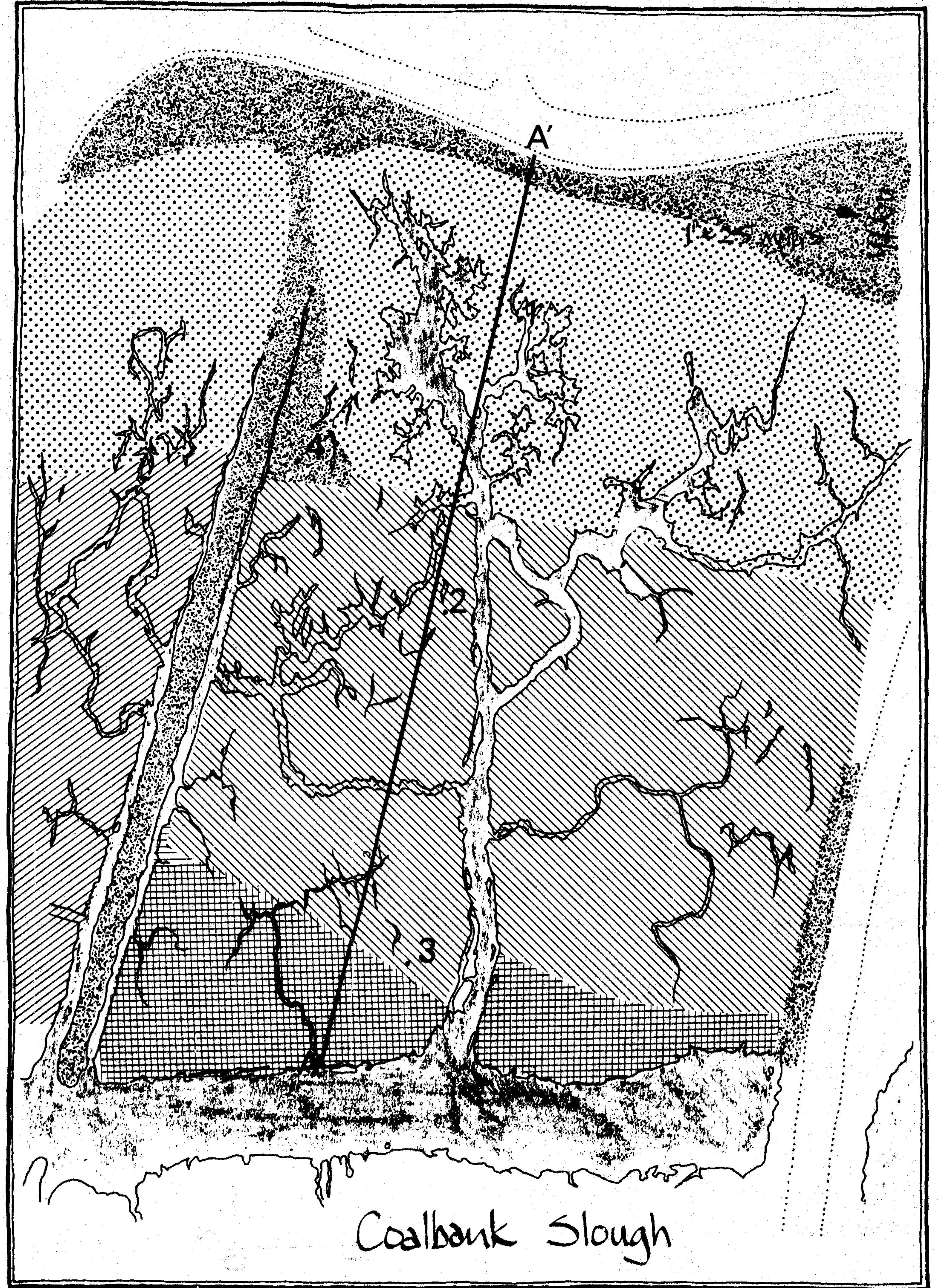

North Slough
A
A'
Elevation in meters.
5
4
3
2
1
0
-1
Distance in meters from main water channel.
50
100
150
200


Coos Bay
Bull Island
north
1" = 55 meters
A
A'
1.
2.
3.

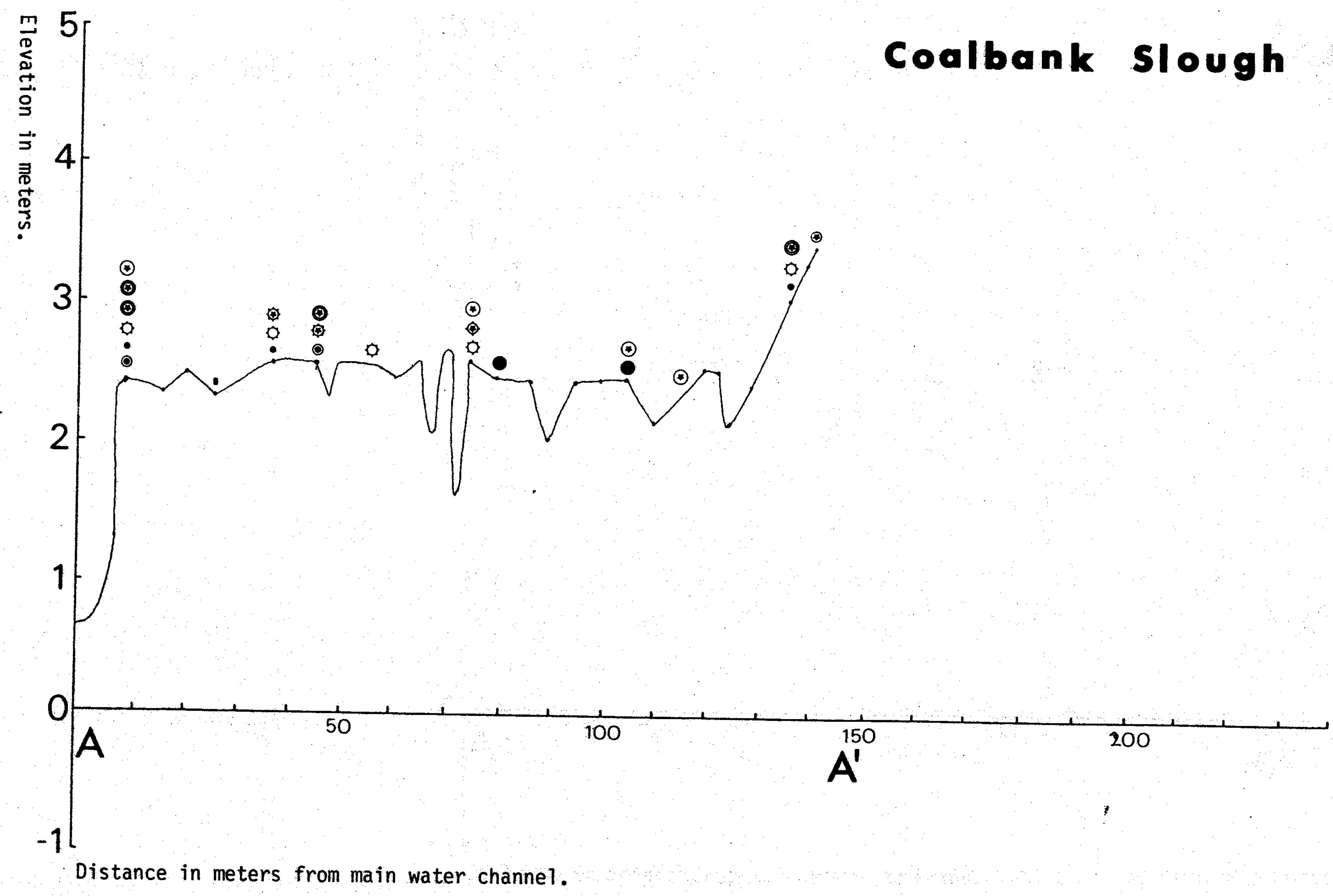

Bull Island
A
A'
Elevation in meters.
5
4
3
2
1
0
-1
Distance in meters from main water channel.
50
100
150
200


Pony Slough
north
1" ≈ 135 meters
91
34
airport runway
A
A
1
2
3


Pony Slough
Elevation in meters.
5
4
3
2
1
0
-1
50
100
150
200
A
A'
Distance in meters from main water channel.


A'
4
1
2
3
Coalbank Slough

Coalbank Slough



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Primary Productivity...

NET PRIMARY PRODUCTION IN COOS BAY SALT MARSHES

K.J. Vanderzanden, Barbie Van Ness,
Melanie Gant, John Hoffnagle

Introduction

All animal life, including that of man, is directly dependent on the growth of green plants. Only these and other autotrophic organisms are capable of the fixation of solar energy through the photosynthetic process and of chemical energy through the chemosynthetic process (Eilers 1975). Light energy is used in photosynthesis by plants to convert carbon dioxide and water into carbohydrates which serve as the ultimate source of "food" for all other organisms.

Odum (1960) defined the primary production of a community, or any part thereof, as the rate at which energy is stored via these processes. The terms biomass (standing crop) and primary production are often confused. Biomass refers to the total weight of organisms in a given area at any one moment. Thus, biomass measurements include a weight/area figure for a certain date or at a certain hour. The concept of increase over time (or rate) is excluded.

In contrast, primary production refers to changes in the amount of energy stored or changes in biomass during a given interval; it is usually expressed as Kcal m^2/day or year or as grams/m^2/day or year. Gross primary production reflects the total rate of photosynthesis including that organic matter utilized by the plant in self-maintenance (respiration) during the measurement period. Net primary production refers to the rate of storage of organic matter in plant tissues in excess of respiratory utilization (Odum 1960).

Methods exist for measuring gross productivity (Eilers 1975). However, since this study is concerned with the amount of plant material available for use by other organisms, we have limited our efforts to determining only the net primary production of the selected salt marsh systems. The production of estuarine plants is especially important. The synthesis of inorganic compounds into organic matter that supplies nourishment and energy directly to terrestrial herbivores, also provides the source of bacteria-rich detritus utilized by estuarine filter feeders. Such organisms are in turn eaten by higher order consumers such as fish (Udell, *et al.*, 1969).

Net production figures are universally used to compare ecosystems or communities. Thus, if cautiously used, they can be helpful indices for resource managers. They do not reflect the total vigor or diversity of a community but only indicate comparative amounts of energy made available by the floral component. Salt marshes have been shown to be highly productive; more productive than the open ocean or forest bounding the marshes, more productive than crop land currently used by man for agricultural purposes (Hoffnagle & Olson 1974).

Annual Net Primary Production Estimates
of Selected Ecosystems

Plant Community	Net Primary Productivity g/m^2/yr	g/m^2/day
wheat (areas of highest yield)	1250	3.43
corn (world average)	412	1.13
hay (areas of highest yield)	940	2.58
forest (pine during years of most rapid growth)	3180	6.0
forest (deciduous, same as pine)	1560	3.0
Spartina salt marsh (Georgia)	3300	9.0
infertile open ocean	182	.5
shallow inshore waters (Long Island)	1168	3.2
	(from Odum 1960)	
eelgrass (Zastera marina) Humboldt Bay, California	4500	5.17
	(from Harding, et al. 1970)	

Several factors unique to the estuarine environment contribute to high salt marsh productivity. The moderating effect of ocean waters on marine climates and locally on the micro-climate of the salt marsh allow a longer growing season (Keefe 1972). Salt marsh plants have adapted to the hostile environment of anaerobic marsh soil and their ability to compete for growth space is best in saline marsh (Keefe 1972). The vertical orientation of the leaves of most marsh plants reduces intense heating (Palmer 1941). In addition, vertical orientation enables the plant to expose maximum leaf surface to sunlight over the day and minimizes mutual shading (Jervis 1964).

Due to the high water table in marshes, soil water is abundant and can be directly used by plants, holding nutrients in a dissolved state in the sediments. The high nutrient content of marsh soils and waters helps maintain high primary productivity. As fresh water flows into the marsh, topsoil silt from upstream is trapped by the marsh plants and later utililized as soil (Ranwell 1964). In addition, the tide moves nutrients from other locations onto the salt marsh (Aurand 1968).

The watery marsh environment hastens the decomposition of organic matter. The high concentration of organic matter in the soil leads to the formation of colloids that absorb exchangeable ions necessary for plant growth (Keefe 1972).

Most research on salt marsh ecosystems has occurred on the East Coast of the United States. Numerous studies have been performed on Spartina sp. and Juncus sp. stands in New Jersy, Delaware, Georgia and Florida (Aurand 1968, Squiers & Good 1973, Boyd 1970, 1971, Udell et al. 1969, Nixon & Oviatt 1972).

Studies on the West Coast are more limited (Barbour & MacDonald in Reimold 1974). A reconnaissance of Oregon salt marshes was made in the early 1960's by C. Johannessen. Johannessen concentrated his efforts on aerial photography, mapping and species description to support his theory that Oregon coastal marshes are prograding (Johannessen 1961). His conjectures have recently been questioned (Hoffnagle & Olson 1974).

For her thesis study, Carol Jefferson surveyed all major estuaries in Oregon in order to describe salt marsh floral communities, develop a model for salt marsh succession and design a classification system for salt marsh types according to physical characteristics and plant cover (Jefferson 1974). Information from her thesis has been utilized by the Oregon Division of State Lands in a publication entitled Coastal Wetlands of Oregon (1975).

H.P. Eilers conducted a study on the West Island marsh in Nehalem Bay. He investigated the distribution of plant communities, diversity, density and primary productivity along an elevational gradient. His work is exhaustive and most similar to our productivity research and thus, is often cited.

In the summer of 1974, Hoffnagle and Olson investigated marsh acreage, land ownership and classification of Coos Bay salt marshes. They also conducted vegetational sampling and their standing crop figures for aerial and root growth serve as bases for comparison with our results.

Our primary productivity study was conducted from April 15 through July 15, 1976, in six salt marshes contained within the Coos Bay estuary. The overall objectives of the botanical studies were two-fold: 1) To identify the plant species found in the six different marshes and their general distribution within each marsh, and 2) To determine the yearly net production of plant material in each marsh.

The first goal is discussed under the section entitled "Marsh Plants and Marsh Zonation." The second objective has been further subdivided into the following study goals:

1) To determine the monthly growth pattern in terms of average aerial biomass for ten salt marsh plant species.
2) To determine the monthly change in aerial biomass and ash-free dry weight for five plant species in each of five marshes.
3) To compare the monthly changes in biomass and carbon content for six species.
4) To determine changes in the biomass of dead standing plant material during the four month interval for each marsh.
5) To determine the change in root biomass during the four month interval.
6) To calculate the average net aerial production for ten marsh species.
7) To calculate the net aerial production for each of the six marshes.
8) To determine if a difference exists between monthly standing crops in salt marsh zones located in proximity to the main water source and those near the terrestrial edge.
9) To determine the changes in plant height over time.

Site Description

The physical descriptions and location of the study locations are contained in the first section of this report. In addition, "Marsh Plants and Marsh Zonation" contains information pertaining to the general distribution of plant species in the six marshes (see vegetational maps). The A - A[1] cross sectional line on the vegetational maps approximates the area covered by transects used for plant sampling each month. Stakes marked #1, #2, #3 indicate the location of plants used to monitor increase in plant height.

Methods and Materials

Several methods exist for estimating net primary productivity. Existing techniques include the use of radioactive isotopes to monitor the CO/O_2 balance, measurement of chlorophyll pigment change and determination of plant biomass change over time. Because the first methods mentioned require highly technical knowledge and expensive equipment, the latter technique, known as the harvest method, has been chosen.

Harvesting and weighing vegetation is a widely used method of determining net primary productivity. It has been traditionally used by farmers to report annual crop analyses. The harvest method is well suited to annual or perennial non-woody vegetation which exhibits seasonal growth and die back of aerial shoots (Eilers 1975).

Because productivity figures include the concept of rate, it is not sufficient to cut vegetation once a year. Milner and Hughes (1968) state that samples should be cut at appropriate intervals throughout the growing season. Successive samples should be taken from the same general area. Our samples were cut on the 15th of each month from April to July. No samples were taken at South Slough in April due to the difficulty in locating the site. Primary production of salt marshes consists of aerial and root production. Each of these will be considered separately.

Net Aerial Primary Production

In order to sample aerial growth, a quadrat 0.5 x 0.25 meters (encompassing 0.125 m^2) was constructed with an open end to facilitate placing it in dense herbage (Thilenius 1966). Eilers (1975) found the rectangular quadrat shape most conducive to sampling representative vegetation. Quadrat samples were taken along a transect line constructed in each marsh from the terrestrial edge to the main saline water source during an ebbing tide. Sampling along the transect enabled us to obtain a representative sample of salt marsh plant species and to collect along an environmental gradient (elevation or distance from water) (Eilers 1975, Benton & Weiner 1958). Sample points were located at constant intervals in each marsh (five, ten or fifteen meters, depending on marsh width). There was some variation in interval length where creek channels coincided with the sample point. In this case, the point was shifted to the nearest bank. Because only one transect was located in each marsh, not all species were adequately sampled. In his more comprehensive study of one salt marsh, Eilers employed six transects to cover the entire study area more completely (Eilers 1975). Our main purpose, however, was to determine salt marsh productivity on a broader scale; the cross sectional transect served to sample plants in terms of relative abundance.

All standing plant material with stems contained within the quadrat was clipped as close to the ground as possible (within 2 cm.). Material clipped from each point was stored in a plastic bag and labelled. Plant bags were kept in a refrigerator to minimize weight loss caused by fermentation and respiration as recommended by Boyer (1958) and Milner and Hughes (1968). Each bag of aerial cuttings was sorted according to live and dead material of each species. Such subsamples were then dried to a constant weight at approximately 100 degrees C. A dry weight figure (g/m^2) for each species (live and dead standing shoots) at each point in a marsh was thus obtained.

To determine the ash-free dry weight of each species, small samples of dry plant material were ignited at 600° C. The minimum time required for complete combustion was determined by weighing the ash of samples burned for 24 hours, then burning new samples for shorter time periods until a change in ash weight was noticed. Two hours proved to be the minimum time needed for combustion of all plant species. The ash weights were subtracted from the dry weights of the burned samples in order to determine percent ash-free dry weight for each species each month for six marshes (Boyd 1971).

In accordance with their suggestion that plant samples be taken over intervals of time, Milner and Hughes (1968) presented the classic formula for determining net primary productivity:

$$PN = \sum_{n=1}^{N} (Bn - Bn\text{-}1)$$

where PN equals net primary productivity and Bn is the above ground standing crop at the nth sampling period. Through successive sampling, biomass is monitored and its maximum for a given area determined (Eilers 1975). However, this method was criticized by Wiegert and Evans (1964) who state that losses or gains in biomass before or after peak standing crop is attained was not considered. Therefore, they presented a better approximation of net primary productivity:

$$PN = \sum_{n=1}^{N} (Bn - Bn\text{-}1) + L + Pa + G$$

where L represents plant losses from death and shedding, Pa is biomass added after peak biomass accumulation and G is loss of standing crop due to consumer organisms. Methods for calculating these variables are discussed in "Results" below.

In order to determine if biomass differed between salt marsh zones closest to the saline water source and those near the terrestrial edge (or "road"), a comparison of monthly mean biomass figures for water and road zones was made. The water zone constituted 40% of the distance from the water to road or edge that was closest to the water. The "road" zone comprised 40% of the distance closest to the terrestrial edge. Those sample points falling within those two areas were averaged to obtain a mean biomass figure for each. A comparison of two means analysis was used to determine if a significant difference existed.

Root Biomass

Root biomass at each month's sampling date was determined by removing a core of roots at each point along the transect. A galvanized pipe (4 cm. inside diameter) was driven into the soil 40 cm. After the pipe was in the ground, the top was sealed by hand to help keep the root core inside while the pipe was being withdrawn. The core was then pushed out of the pipe by a close-fitting rod into a plastic bag and labelled. The method used is identical to that described by Hoffnagle and Olson (1974).

Root cores were stored under conditions similar to those for plant bags. Cores were rinsed by hand over a wire screen, 60 meshes to the inch, under tap water. A screen 35 meshes to the inch was used for cores from Salicornia marsh to allow the passage of coarse sand characteristic of this marsh's soil (Hoffnagle & Olson 1974). Root cores were then dried to a constant weight, weighed and ignited similarly to the procedure for aerial plant samples. The root biomass (g/M^2) for each month was then calculated and recorded.

Plant Height

In an effort to monitor the change in plant height over time, seven to ten plants of the dominant species in each marsh were labelled with colored plastic beads in a numerical code. Heights of the individual plants were first recorded April 29. Subsequent measurements were made on the 28th or 29th day of May, June and July. Plant height was correlated with increase in time for each marsh.

Results

Not all salt marsh plant species attain their average peak standing crop at the same time. Table 1 reports the biomass (g/m^2) of ten plant species found in the six salt marshes studied. (See Table 1.) Our data reported only Scirpus validus (bulrush) in North Slough, though other species are noted in different sections of this marsh. Nine of the species' biomasses were averaged over five marshes with Scirpus validus' values being drawn solely from North Slough. Figure 1 compares monthly standing crops of seven of the ten species (see Figure 1).

Agrostis alba, a sod forming grass, is late to start seasonal growth and reportedly does not reach maximum standing crop until September (Eilers 1973). Scirpus americanus, a colonizer on bare mud, did not appear until late June. All species continued to increase in biomass from April to July, except Carex and Deschampsia, which peaked in June. Table 2 shows variation in the time of species' peak standing crops between marshes (see Table 2).

Ash-free dry weights and % ash-free figures are also listed in Table 2. Scirpus validus and Deschampsia caespitosa appear to have slightly higher ash-free dry weights than the other four species listed. The ash-free dry weight represents the weight of organic material in plant tissues. Approximately 45% of the ash-free dry weight is carbon (Keefe 1972). Approximate carbon content has been plotted against time and compared to monthly biomass figures for five marsh species. Highest percentage of carbon content for all

Table 1: Monthly changes in plant biomass for ten species.

species	April g/m^2	May g/m^2	June g/m^2	July g/m^2
Atriplex patula	0*	No data**	.32	2.0
Salicornia virginica	106.64	126.00	162.56	184.16
Triglochin maritima	4.72	84.4	115.68	129.92
Juncus sp.	7.6	9.92	45.84	65.44
Carex lyngbei	28.88	156.28	206.	178.39
Scirpus validus	45.92	204.96	717.12	795.36
Scirpus americanus	0	0	No data	22.48
Agrostis alba	0	13.2	37.52	153.2
Deschampsia caespitosa	1.34	17.96	105.84	43.36
Distichlis spicata	8.96	13.04	58.08	71.6

* presence not noted in marshes

** presence noted in marshes but not collected in sample

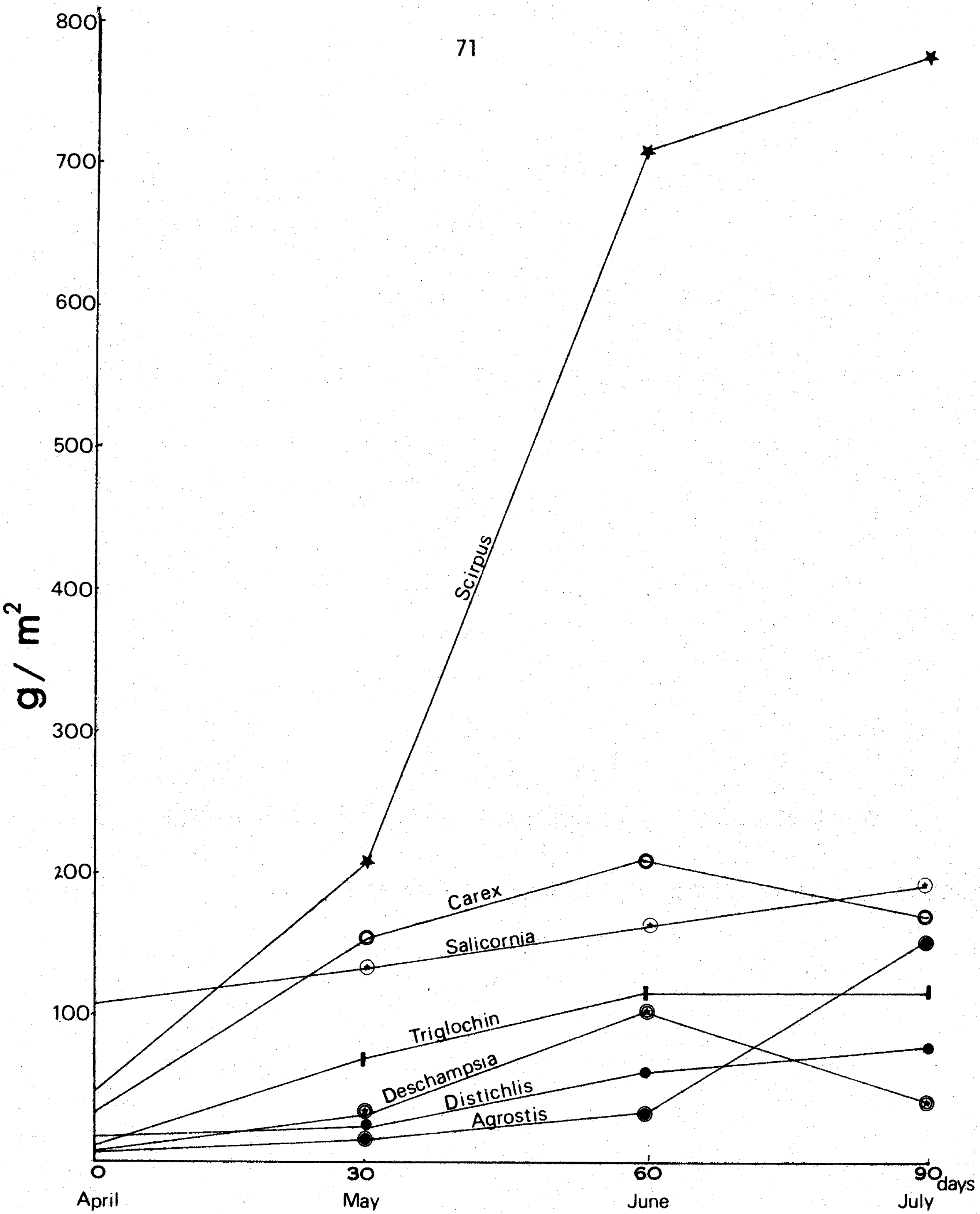

Figure 1: Plant biomass of seven species vs. increase in time

Table 2: Major species' standing crops in six marshes.

	APRIL dry wt. g/m^2	APRIL ash-free dry wt. g/m^2	MAY dry wt. g/m^2	MAY ash-free dry wt. g/m^2	JUNE dry wt. g/m^2	JUNE ash-free dry wt. g/m^2	JULY dry wt. g/m^2	JULY ash-free dry wt. g/m^2
Bull Island								
Triglochin	.56	.40 (72%)	62.96	50.78 (80.66%)	206.08	154.03 (75.1%)	236.96	227.86 (96%)
Salicornia	8.16	6.16 (75.56%)	46.72	38.03 (81.41%)	44.4	36.94 (83.2%)	104.24	99.45 (95.41%)
Distichlis	No data*		1.44	1.36 (94.44%)	16.	14.17 (88.6%)	23.44	11.58 (96.34%)
Deschampsia	0**	0	65.68	62.41 (95.03%)	227.92	204.44 (89.7%)	56.48	54.94 (97.29%)
Carex	57.76	50.02 (83.70%)	79.84	73.35 (91.87%)	261.84	233.82 (83.92%)	209.92	205.04 (97.7%)
Coalbank								
Triglochin	No data		No data		No data		2.56	2.54 (99.24%)
Salicornia	No data		No data		41.16	25.56 (62.1%)	15.84	14.29 (92.76%)
Distichlis	No data		No data		7.12	5.55 (78.%)	17.84	16.91 (94.81%)
Deschampsia	6.72	6.04 (90.%)	11.12	10.36 (93.24%)	42.	35.74 (85.1%)	138.56	129.17 (93.6%)
Carex	5.52	4.88 (88.51%)	78.32	72.88 (93.06%)	90.32	74.33 (82.3%)	38.72	37.03 (95.68%)
Salicornia marsh								
Triglochin	9.52	7.71 (80.98%)	70.8	64.88 (91.64%)	140.24	106.16 (75.7%)	138.48	128.87 (93.06%)
Salicornia	256.03	234.06 (91.42%)	341.12	293.15 (85.94%)	252.24	200.78 (79.6%)	292.4	270.52 (92.52%)
Distichlis	24.48	16.16 (67.85%)	31.52	28.31 (93.%)	120.16	110.78 (92.2%)	25.28	207.23 (96.26%)
Deschampsia	0	0	No data		4.8	4.2 (88.%)	No data	
Carex	9.76	8.29 (85.%)	40.	36.8 (92%)	67.2	6.142 (91.4%)	146.88	140.45 (95.65%)

* presence noted in marsh but not collected in sample

** presence not noted in marsh

Table 2: (cont.)

	APRIL dry wt.	APRIL ash-free dry wt.	MAY dry wt.	MAY ash-free dry wt.	JUNE dry wt.	JUNE ash-free dry wt.	JULY dry wt.	JULY ash-free dry wt.
South Slough								
Triglochin	No data		231.44	192.09 (83.%)	67.92	50.53 (74.4%)	86.32	83.32 (96.53%)
Salicornia	No data		No data		147.6	107.6 (72.9%)	No data	
Distichlis	No data		3.04	2.72 (89.47%)	121.44	94.72 (78.%)	215.28	208.95 (97.06%)
Deschampsia	0	0	3.44	2.28 (92.86%)	219.84	196.98 (89.6%)	17.76	17.19 (96.83%)
Carex	(59.76)	50.02 (83.70%)	452.4	292.04 (86.88%)	460.08	386.01 (83.9%)	454.72	432.89 (95.2%)
Pony Slough								
Triglochin	13.52	9.83 (72.69%)	57.12	46.38 (81.2%)	164.4	121.98 (74.2%)	185.52	175.33 (94.51%)
Salicornia	268.96	231.17 (85.95%)	242.16	199.17 (82.25%)	326.88	261.5 (80.%)	508.16	484.02 (95.25%)
Distichlis	30.32	16.83 (82.84%)	29.2	26.43 (90.5%)	25.12	22.4 (89.2%)	69.44	63.85 (91.96%)
Deschampsia	0	0	9.6	9.06 (94.44%)	34.64	30.89 (89.2%)	69.44	63.85 (91.96%)
Carex	96.	81.6 (85.%)	130.88	119.10 (91.%)	150.4	138.22 (91.9%)	144.	137.08 (95.2%)
North Slough								
Scirpus validus	45.92	42.53 (92.63%)	204.26	190.08 (92.74%)	717.92	656.17 (91.4%)	795.36	700.25 (93.73%)

species is attained in July, though the slight peak is probably not significant (see Figures 2-7).

Biomass figures for standing live and dead shoots were calculated for each marsh on a monthly basis (see Table 3). Figures 8 through 11 compare marsh biomass figures for each month. Salicornia marsh and Pony Slough lead in live standing crops in April, but Salicornia marsh drops to a median position in July while Pony Slough continues to lead. Coalbank biomass figures remain low throughout the growing season (see Figures 8-11).

No plant or root core samples were collected in April for South Slough due to the difficulty in locating the marsh. Since Bull Island and South Slough contain highly similar vegetation (predominantly Carex lyngbyei), the Bull Island April biomass has been projected for South Slough. The reader must note that this figure is an estimate only.

Coalbank, Salicornia marsh, Pony Slough and North Slough all increase in live shoot biomass from April to July. Bull Island and South Slough show rapid growth from April to June, reaching their maximum standing crop in the latter month. July figures reflect decreases in live biomass. North Slough makes the largest gain in four months -- from 45.92 ± 53.13 g/m^2 to 795.36 ± 204.32 g/m^2. July biomass figures reveal the following order from greatest to least accumulation: North Slough, Bull Island, South Slough, Pony Slough, Salicornia marsh and Coalbank. (See Figure 11.)

Estimates of net primary production should include an indication of root biomass change over time. However, problems exist in determining this rate; it is nearly impossible to separate live and dead root stocks, yet alone those of individual species. In addition, a representative sample of roots may not be attained by the pipe method. Hoffnagle and Olson found no significant difference in the dry weights of root biomass for samples taken 40 cm. and 50 cm. below the ground surface. Therefore, the major portion of the roots is probably contained within the top 40 cm. of soil (Hoffnagle & Olson 1974).

Root productivity was not calculated because our figures would have reflected a negative production rate for most marshes. Instead, biomass figures have been substituted. Table 4 lists monthly root biomass and ash-free dry weight for each marsh. Root biomass was correlated with increase in time. Table 4 shows a decrease in root biomass during several intervals for all marshes (see Table 4). Root biomass significantly decreased with time for Bull Island ($r = .96$ $t = 17.00$ $p < .001$), Coalbank ($r = .87$ $t = 5.13$ $p < .001$), Pony Slough ($r = .98$ $t = 34.75$ $p < .001$). Lack of significant correlation for North Slough, Sough Slough and Salicornia marsh could be due to sampling error or small sample size. Decrease in root biomass with time proved almost significant for Salicornia marsh--the scatter plot is given. (See Figures 12-15.)

Table 3: Live and dead shoot standing crops.

	Marsh	April	May	June	July
Live	<u>Salicornia</u>	337.36 ± 320.64	422.24 ± 286.72	491.2 ± 320.8	560.24 ± 256.88
	Pony Slough	287.76 ± 123.36	324.16 ± 152.4	516.72 ± 151.2	689.12 ± 217.68
	South Slough	(63.86 ± 17.52)	571.2 ± 199.6	699.76 ± 148.	550.96 ± 183.68
	Bull Island	63.36 ± 17.52	236.72 ± 83.52	687.28 ± 196.2	596.32 ± 160.4
	North Slough	45.92 ± 24.4	204.96 ± 100.	717.92 ± 235.04	795.36 ± 204.32
	Coalbank	40.16 ± 53.13	56.96 ± 55.36	151.68 ± 153.2	205.2 ± 143.84
Dead	<u>Salicornia</u>	208.8 ± 166.24	162.96 ± 123.52	136.48 ± 112.42	295.28 ± 322.56
	Pony Slough	62.4 ± 92.48	35.28 ± 31.94	90. ± 53.12	120.08 ± 73.76
	South Slough	(106. ± 135.92)	104. ± 5.92	134.72 ± 133.36	126. ± 86.88
	Bull Island	106. ± 135.92	101.68 ± 108.4	283.68 ± 201.04	107.04 ± 90.32
	North Slough	316.08 ± 84.4	261.44 ± 146.	325.12 ± 98.48	524.45 ± 119.6
	Coalbank	480.16 ± 408.16	76.16 ± 67.68	98.3 ± 134.64	71.84 ± 71.92

Monthly changes in biomass and % carbon for six plant species

- Average plant biomass, g/m^2

- % carbon content

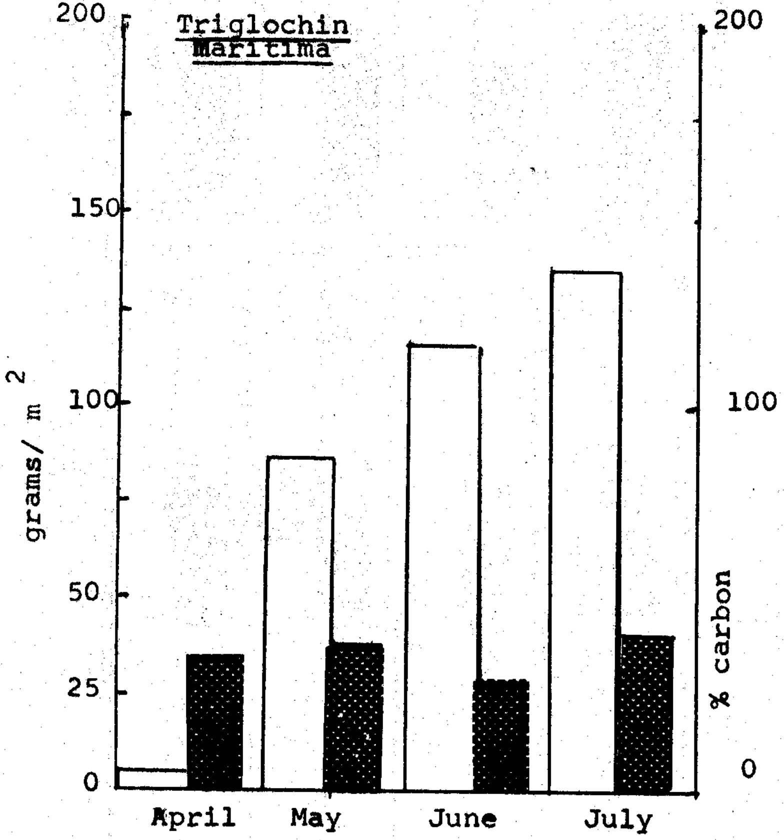

Figure 2: Biomass and carbon content vs. incrase in time

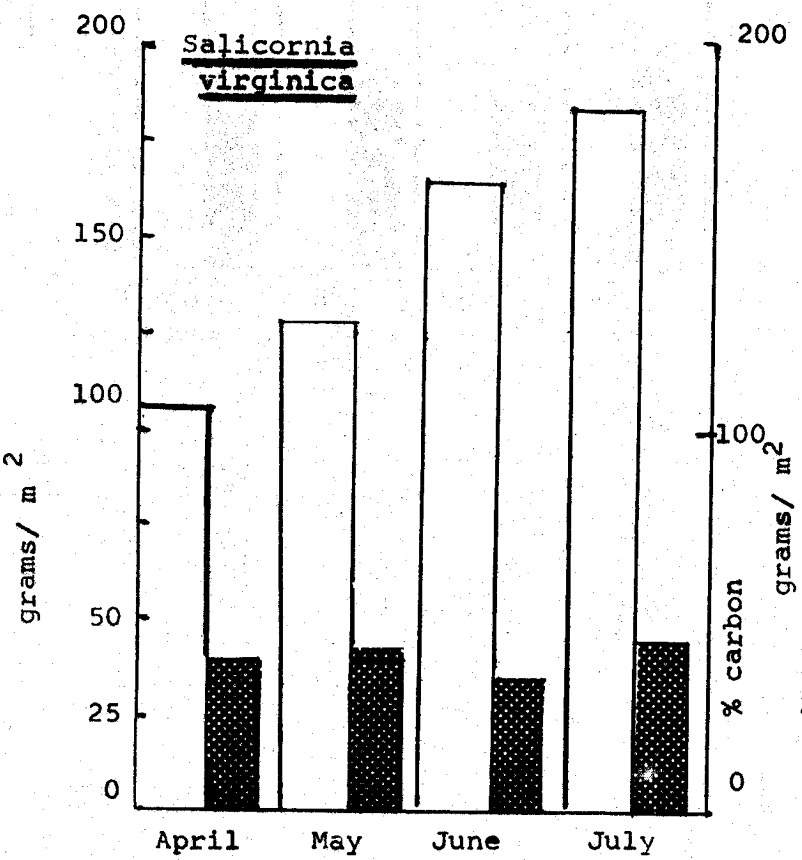

Figure 3: Biomass and carbon content vs. increase in time

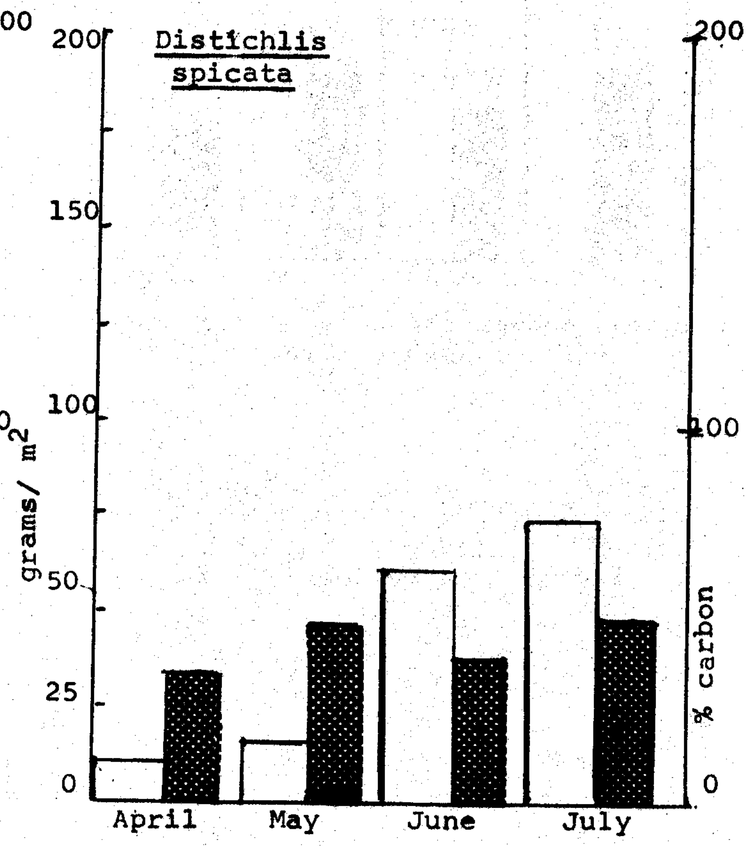

Figure 4: Biomass and carbon content vs. increase in time

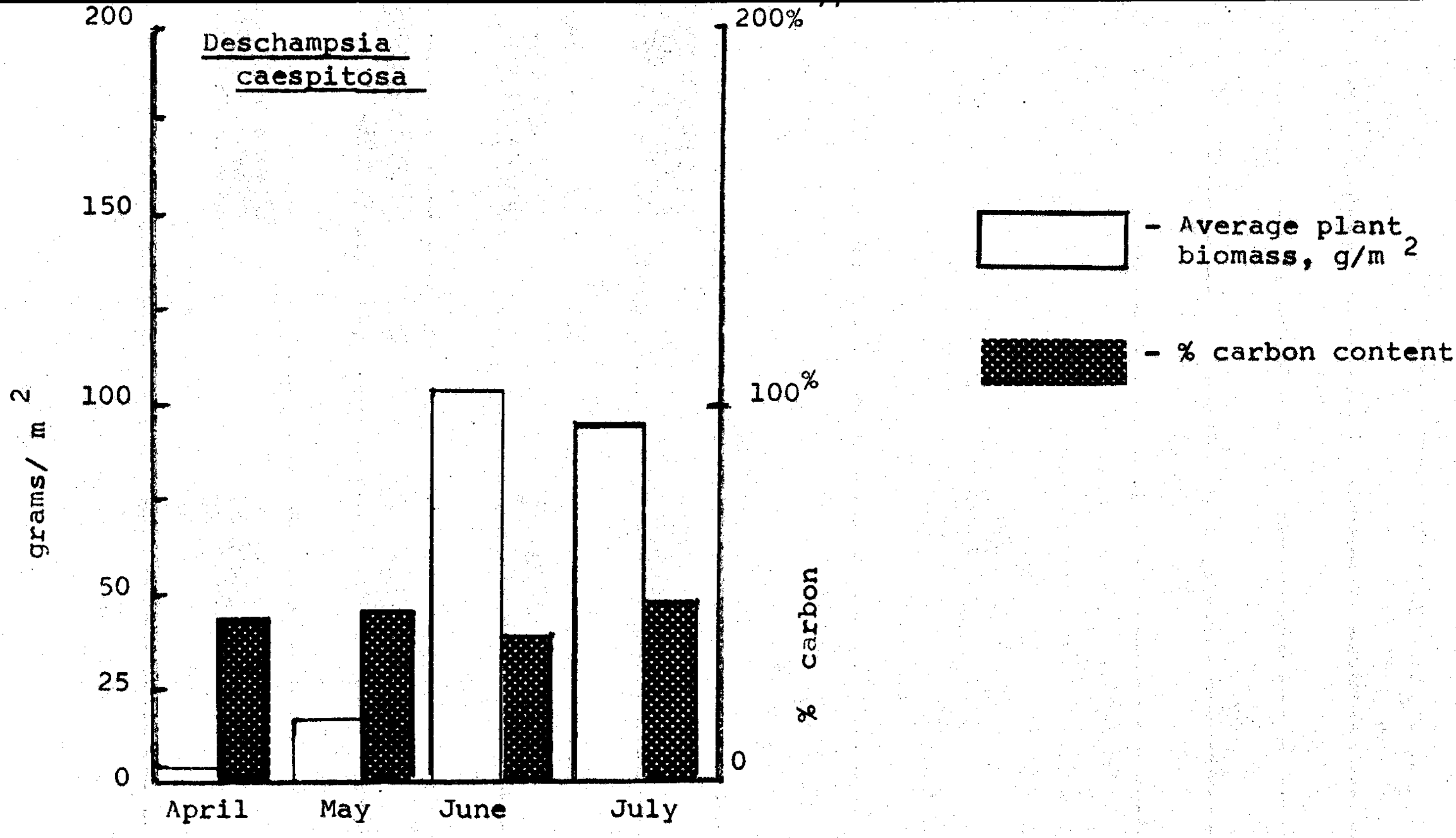

Figure 5: Biomass and % carbon vs. increase in time

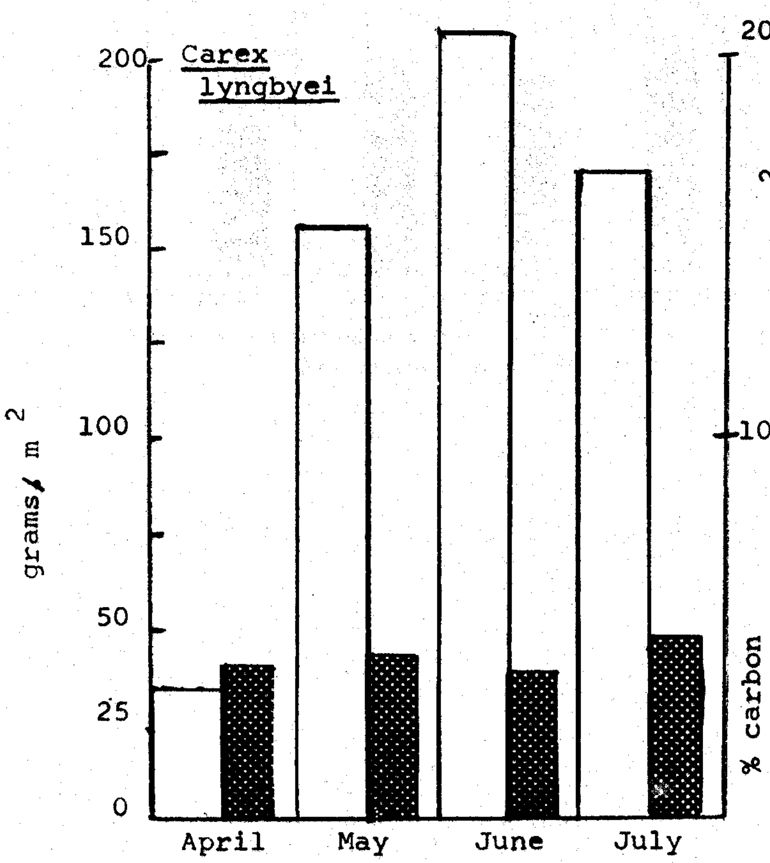

Figure 6: Biomass and % carbon vs. increase in time

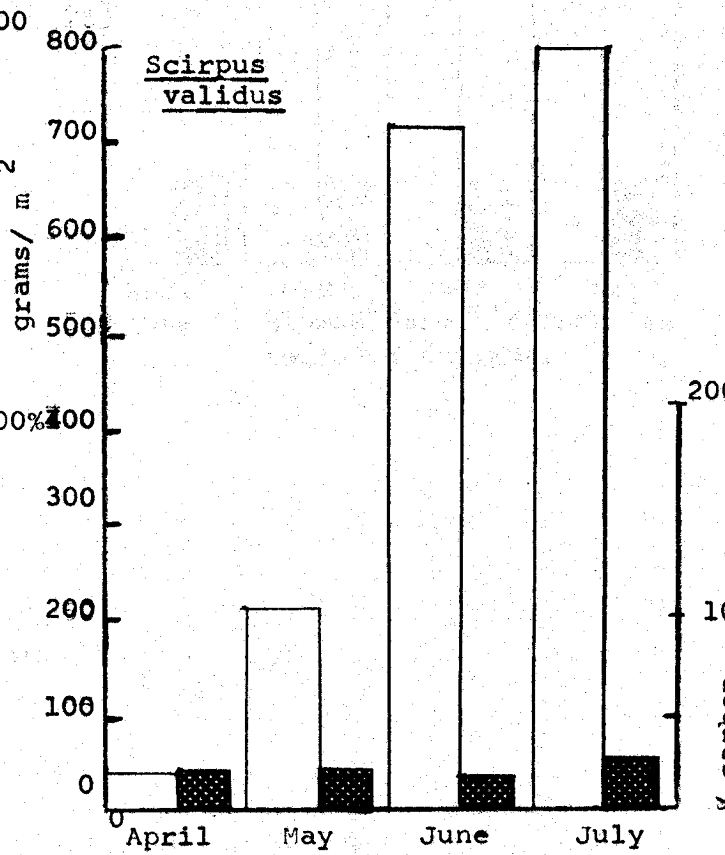

Figure 7: Biomass and % carbon vs. increase in time.

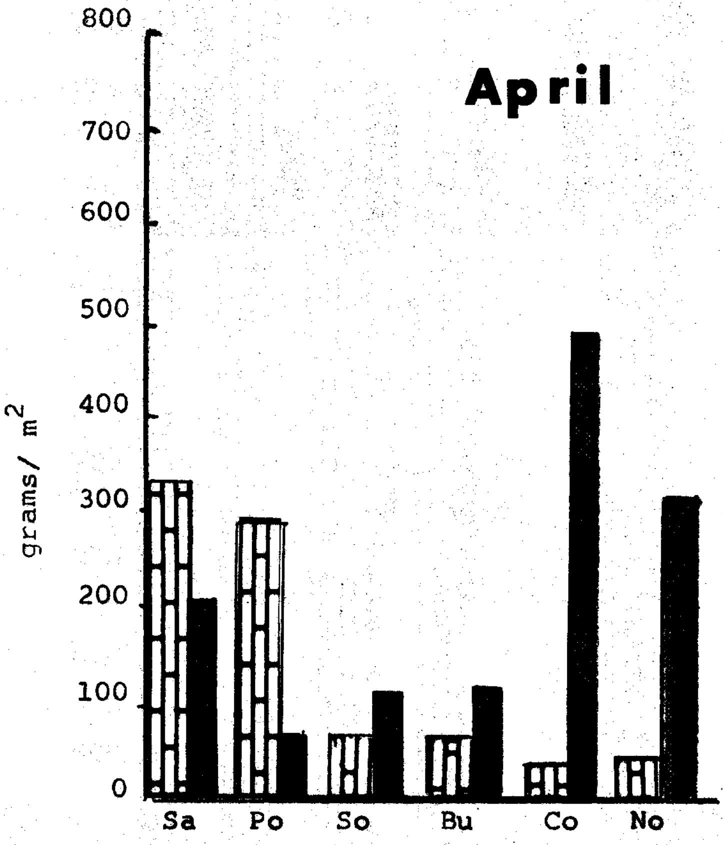

Figure 8: Plant biomass for six marshes

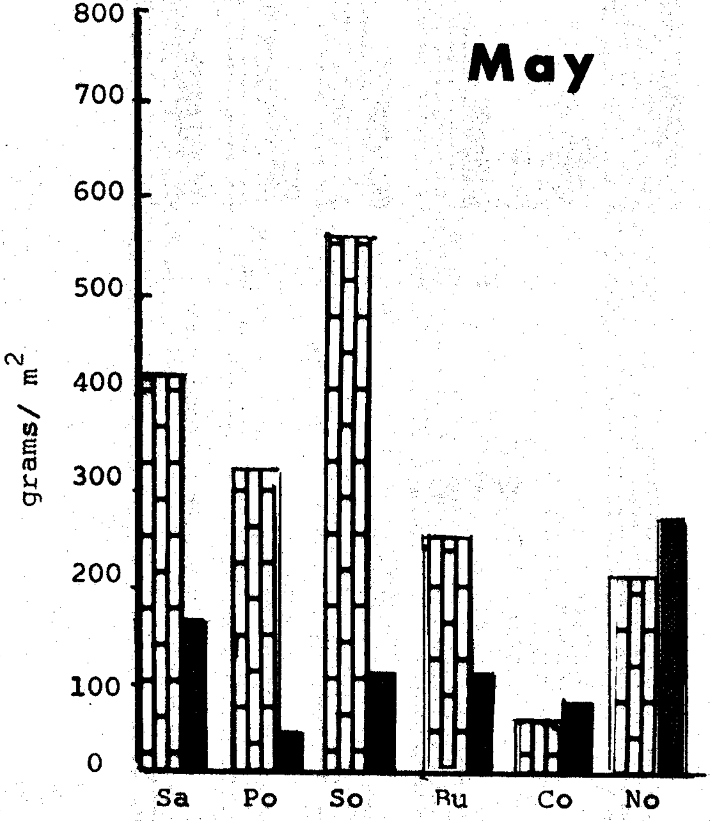

Figure 9: Plant biomass for six marshes

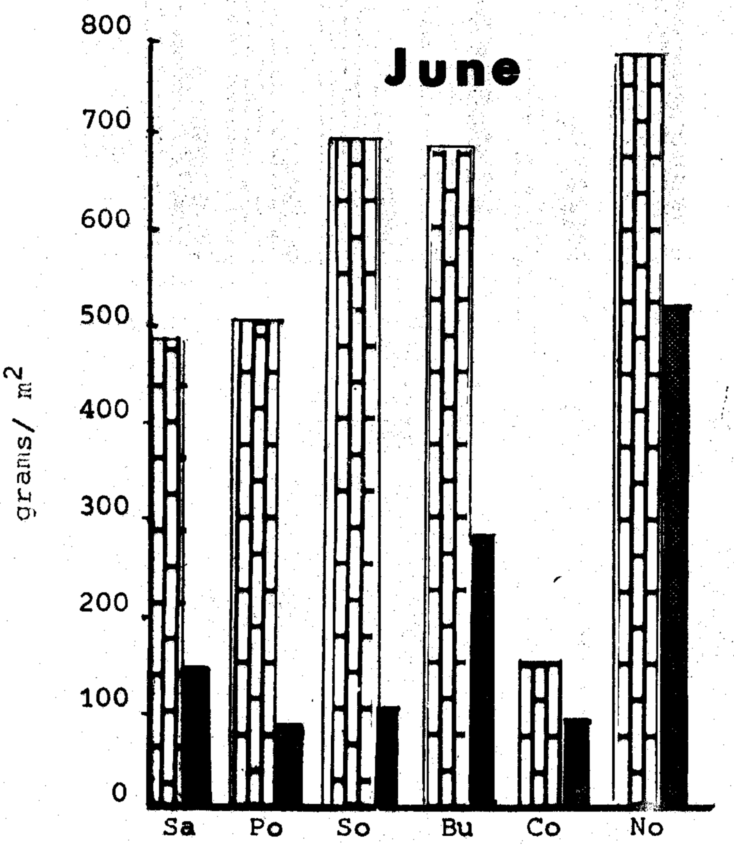

Figure 10 : Plant biomass for six marshes

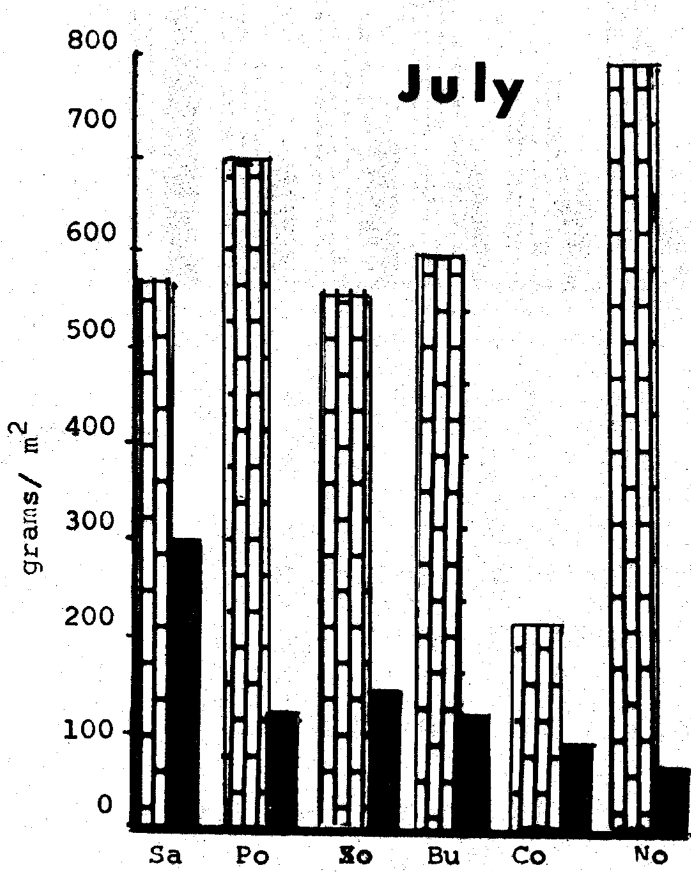

Figure 11: Plant biomass for six marshes

Table 4: Monthly changes in root biomass for six marshes.

Marsh	April dry wt. g/m^2	April ash-free dry wt. g/m^2	May dry wt. g/m^2	May ash-free dry wt. g/m^2	June dry wt. g/m^2	June ash-free dry wt. g/m^2	July dry wt. g/m^2	July ash-free dry wt. g/m^2
CO	38232.08 ± 30063.38	18198.95 (47.6%)	19179.73 ± 9056.66	12213.25 (47.22%)	12213.25 ± 5390.07	8549.27 (70.%)	13375.66 ± 4697.4	11733.13 (87.72%)
NO	20915.38 ± 7762.66	13825.06 (66.1%)	9124.11 ± 1441.07	7517.35 (82.39%)	8877.29 ± 5206.96	7261.62 (81.8%)	6305.66 ± 2364.52	5745.9 (91.14%)
SA	34474.16 ± 12133.63	10535.3 (30.56%)	11552.43 ± 4697.4	5750.79 (49.78%)	10827.91 ± 4522.24	7200.56 (66.5%)	9370.92 ± 5437.84	8905.18 (95.03%)
SO	No data		7205.34 ± 1950.62	4908.48 (68.12%)	5374.14 ± 3152.83	4245.57 (79.%)	7937.81 ± 3869.29	7513.13 (94.65%)
PO	12125.64 ± 6226.05	8329.1 (68.69%)	15549.2 ± 6329.55	8241.08 (53.%)	13329.49 ± 5326.39	9503.92 (71.3%)	9155.95 ± 3264.29	8419.81 (91.96%)
BU	11233.95 ± 3192.6417	5028.32 (44.7%)	13853.36 ± 2794.56	5991.58 (44.%)	10748.29 ± 1291.05	8296.18 (77.%)	9554.04 ± 3821.62	9033.34 (94.55%)

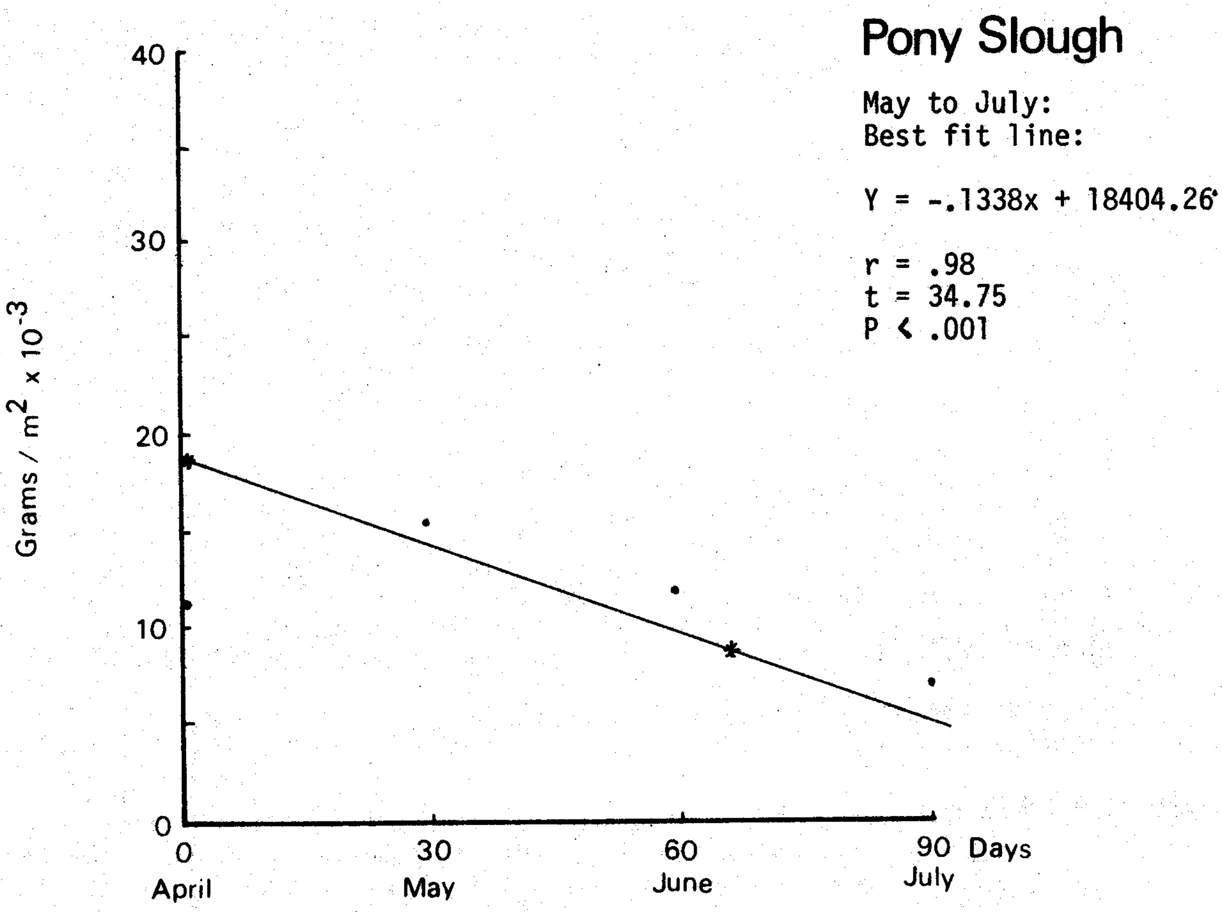

Figure 12: Root biomass vs. increase in time.

Net Aerial Production

Net primary production must include the concept of rate. Biomass is not a satisfactory indicator. As stated above, we have chosen the net primary production formula modified by Wiegert and Evans (1964) in order to calculate marsh productivity:

$$PN = \sum_{n=1}^{N} (Bn - Bn\text{-}1) + L + Pa + G$$

In his study of West Island Marsh, H.P. Eilers sampled vegetation in May, July and September of 1974. Eilers noted that new green growth was already present at the time of the May sampling date. His monitoring of species' biomass accumulation also revealed that different marsh plant species peak at various times throughout the growing season.

In order to overcome these variables, Eilers substituted the sum of each species' maximum standing crop for the (Bn - Bn-1) figure. He reasoned that the maximum standing crop would include all growth incurred during that year's growing season and it was probable that little new growth would occur after the peak. His modified formula is presented:

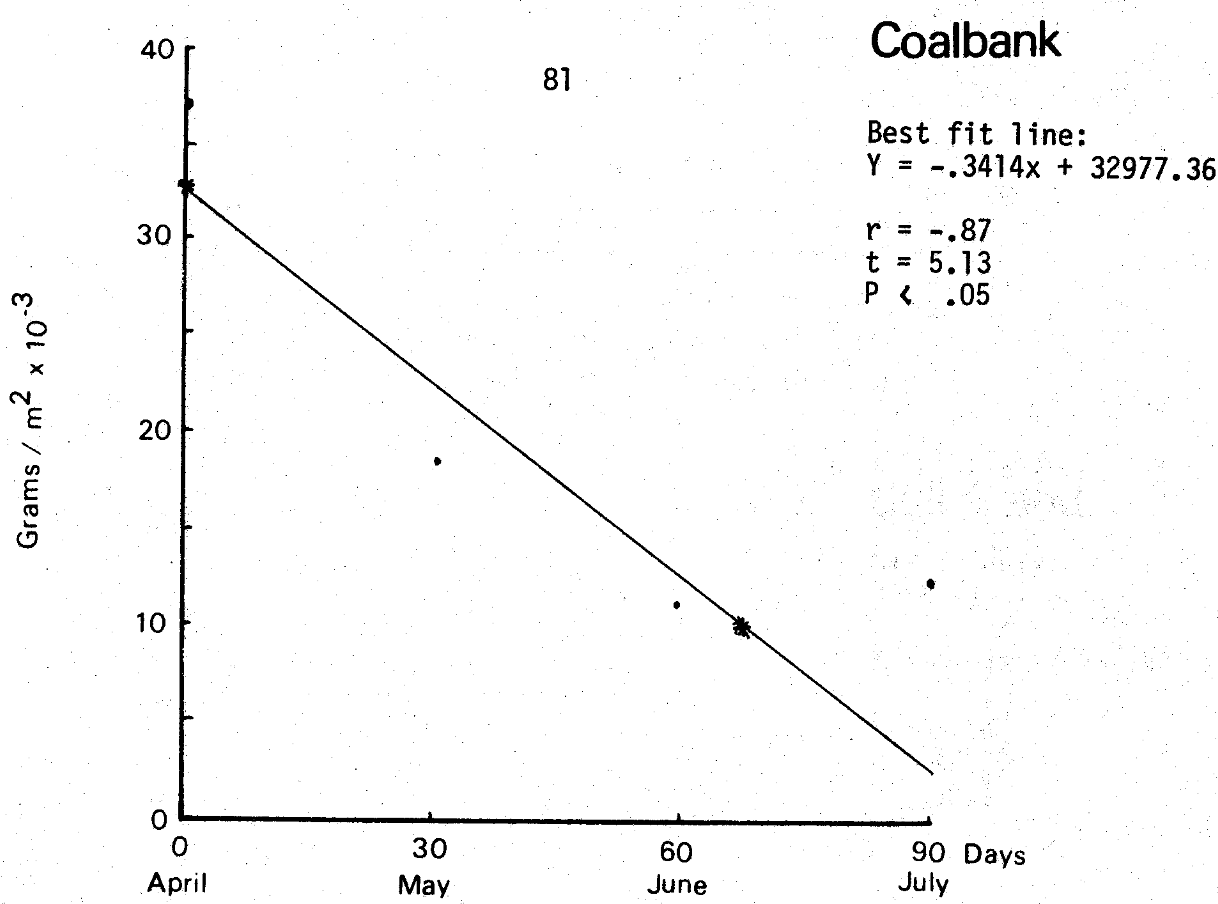

Figure 13: Root biomass vs. increase in time.

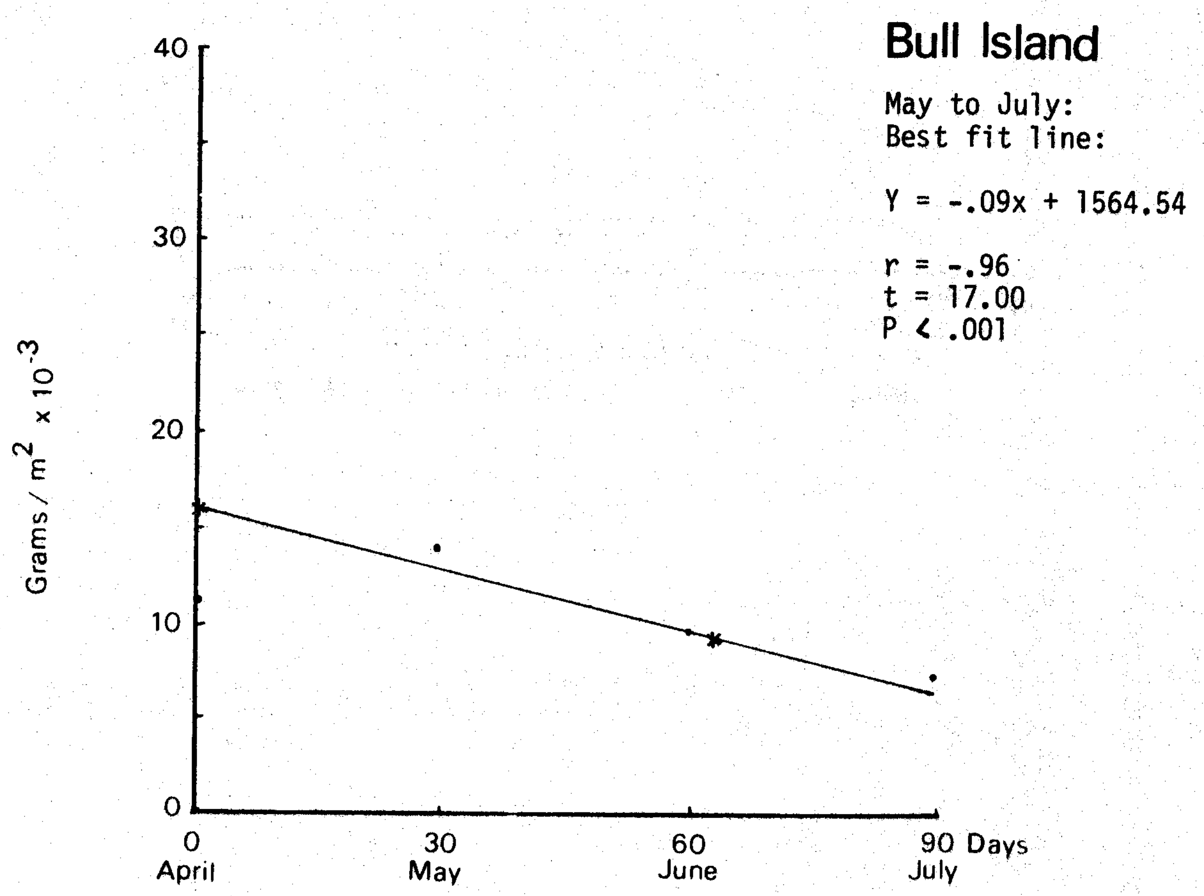

Figure 14: Root biomass vs. increase in time.

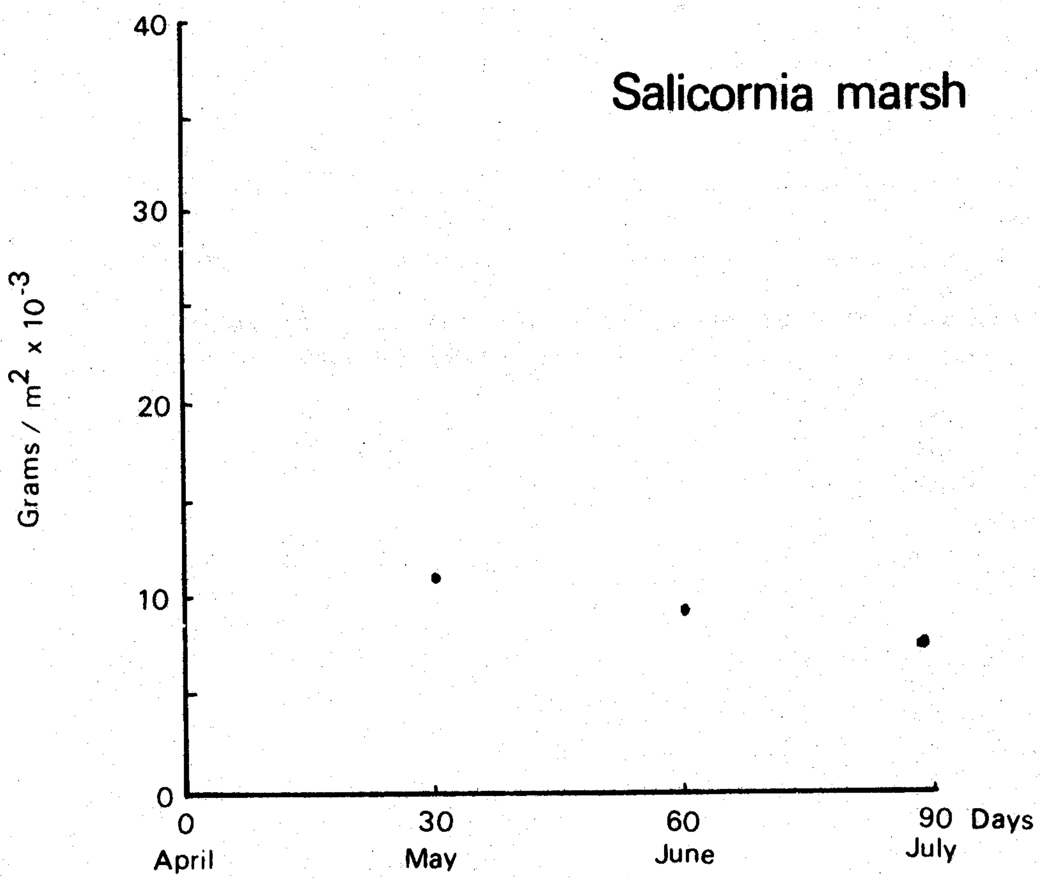

Figure 15: Scatter plot showing decrease in root biomass vs. increase in time.

$$PN = \sum S + L + Pa + G$$

where S is the species' peak biomass (Eilers 1974).

Our data for aerial biomass shows the presence of green growth in April. Two important salt marsh species also reach their maximum standing crop before July. Therefore, any yearly production figures calculated as Bn - Bn-1 or July biomass-April biomass would be underestimated. We were unable to sample marsh vegetation in September. Therefore, it might be argued that July biomass for each species may not represent peak accumulation. However, with only two exceptions, Eilers reports that Nehalem Bay plant species also found in the Coos Bay marshes peak in July. Distichlis spicata and Agrostis alba both peak in September (or perhaps in August) (Eilers 1975). These plants constitute a small percentage of the monthly biomass (Bull Island--.02%, Coalbank--.09%, South Slough--.17%, Pony Slough--.18%, Salicornia marsh--.38% and North Slough .0%). The productivity of those marshes containing the two species will therefore be underestimated. No values for Scirpus validus are listed in Eilers. Biomass accumulation seems to level off in North Slough between June and July (see Figure 1) and a reconnaissance of the site in early August revealed a great deal of die-back in live shoots.

Salicornia virginica, a woody perennial, presents a unique problem for using species' peak biomass figures in the production formula. A large portion of the biomass present in April has been accumulated through many season's growth (some plants may be fifty years old!--Jeffries, personal communication, June, 1976). We found it necessary to subtract the April biomass from each succeeding month's figure in order to obtain a more accurate picture of the current season's growth in Salicornia. Again, marshes containing Salicornia will have slightly underestimated production values due to the errors involved in this method. It would be most advantageous to obtain September biomass values for this perennial to be compared with figures obtained a year later in order to more accurately gauge yearly growth.

The three remaining variables--L, Pa, and G have yet to be discussed. Several methods have been designed to estimate the loss of biomass due to death and shedding. Wiegert and Evans (1964) used a paired plot method and a variation of the litter bag technique to calculate the rate of disappearance from the site. Eilers (1975) collected the "litter" (dead standing and all non-humus plant parts) contained within each quadrat. Samples were dried and weighed. Since most species peaked in July, he considered only the additions to the litter (loss to production) between May and July. Once a species has reached its peak, it will contribute more heavily to the litter. If additions to the litter are considered after the peak of accumulation, such materials would be counted twice.

Eilers states it is necessary to answer three questions in order to estimate "L": How much litter remains on the plot from the previous growing season? How many days are necessary to exhaust this supply? How much litter is attributed to the current season's growth? Eilers designed a set of formulas to determine "a"--the amount of litter accrued from this season's growth. Use of the complete set of calculations involves sampling litter in September (Eilers 1975). Since this study's design did not involve sampling in September, Eilers' formulas and concepts have been adapted in order to utilize the information at hand. A decrease in dead standing material was noted for all marshes between April and May. Present prior to a significant increase in this year's new growth, this material likely represents last year's crop.

Eilers assumed that the rate of disappearance of dead material to be constant (Eilers 1975). Realistically, winter storm tides probably inflict greater damage on standing vegetation. If a constant rate is assumed, however, the amount of dead material, derived from the previous season's growth, that remains during the peak of biomass accumulation can be estimated graphically. Figures 16-21 represent estimates of dead standing plant material. The rate of removal (slope of the line) is projected beyond the month of lowest dead shoot biomass. If the "removal" line intercepts line CB, the amount of dead material remaining from the previous season is represented by AB. This season's crop loss due to death and shedding (L) is calculated: CB - AB = L. Note that for Coalbank and Pony Slough, the value of AB is zero and L = July or June's dead shoot biomass, respectively (see Figures 16-21).

Biomass added after peak biomass accumulation (Pa) can be ignored by use of the peak standing crop for each plant species. Only for those marshes containing large crops of <u>Distichlis spicata</u> and <u>Agrostis alba</u> will Pa be of import. Therefore, for our purposes, Pa = 0.

It is also important to consider the plant material lost to herbivore grazing. As Eilers mentions, no extensive work has been done on the West Coast to determine the percent of peak biomass lost to consumers. Smalley (   ), working on <u>Spartina</u> marshes in Georgia, found that all insects grazed approximately 10% of the total biomass. Our entymologist did study the assimilation of plant tissue in one species of leaf hopper (order Homoptera) using <u>Distichlis spicata</u> from <u>Salicornia</u> marsh. His intake estimates range fom 10-15% with 5% of the plant energy being assimilated (see "Insects" section). However, since efforts were limited to the intake rate of one insect species of one plant, these figures will not be used to directly adjust net primary productivity for each marsh. We will follow the course of Eilers and assume the effect of herbivory to be zero (Eilers 1975). Thus, the final net productivity figures presented below should be 10 to 15% greater.

Individual equations have been written for each marsh or order to calculate yearly net primary production (see Table 5).

Net primary production has been determined for each marsh during the four month sampling interval (April to July) and is also presented in Table 5. Calculations were based on the formula (Wiegert & Evans 1964):

$$PN = \sum_{n=1}^{N} (Bn - Bn\text{-}1) + L + 0 + 0$$

Species' production was determined by averaging the values of g/m^2/4 mos. individual plant species over five marshes. <u>Scirpus validus</u> production is identical to that of North Slough since it was the only plant sampled on that site. Since rate of disappearance

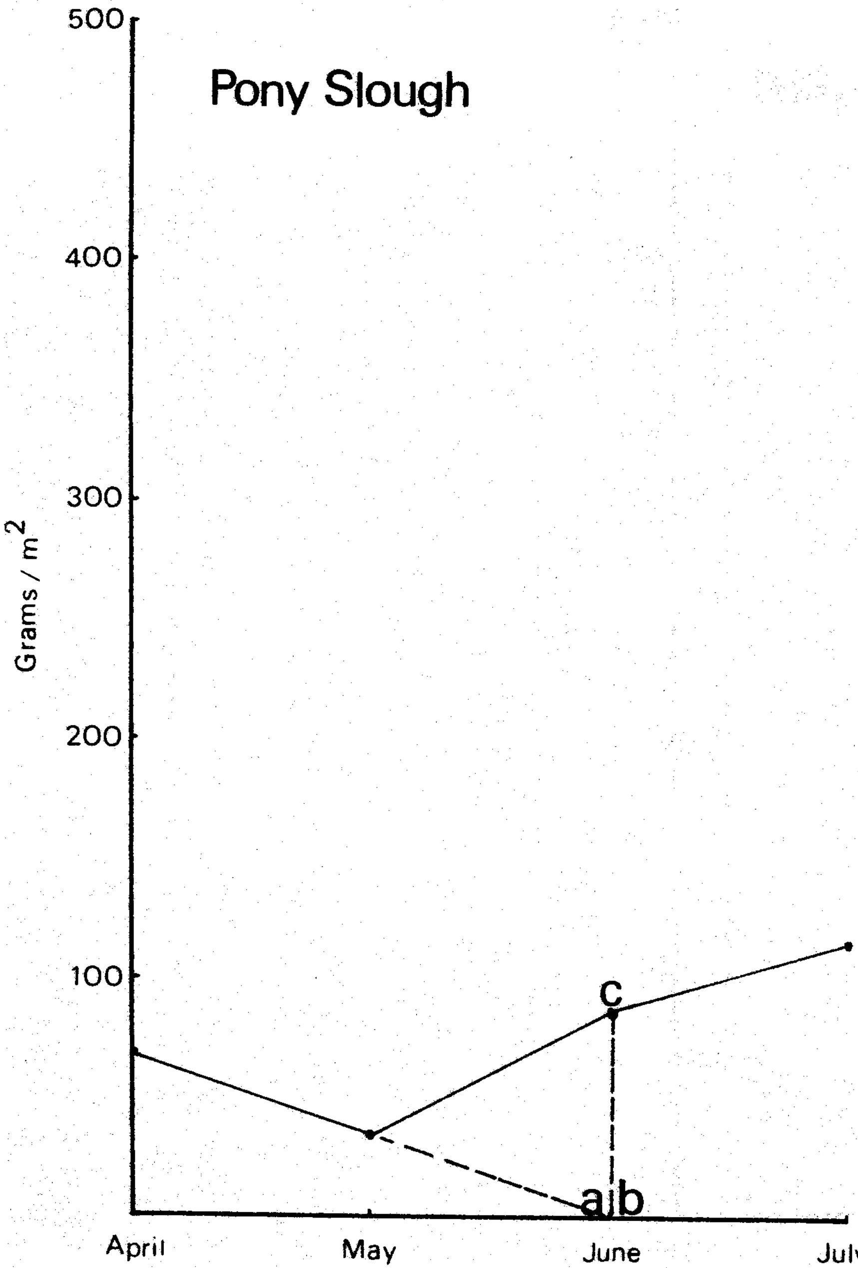

Figure 16: Changes in dead standing biomass from April to July. Estimated portion of dead shoot material (CB) derived from previous growing season.

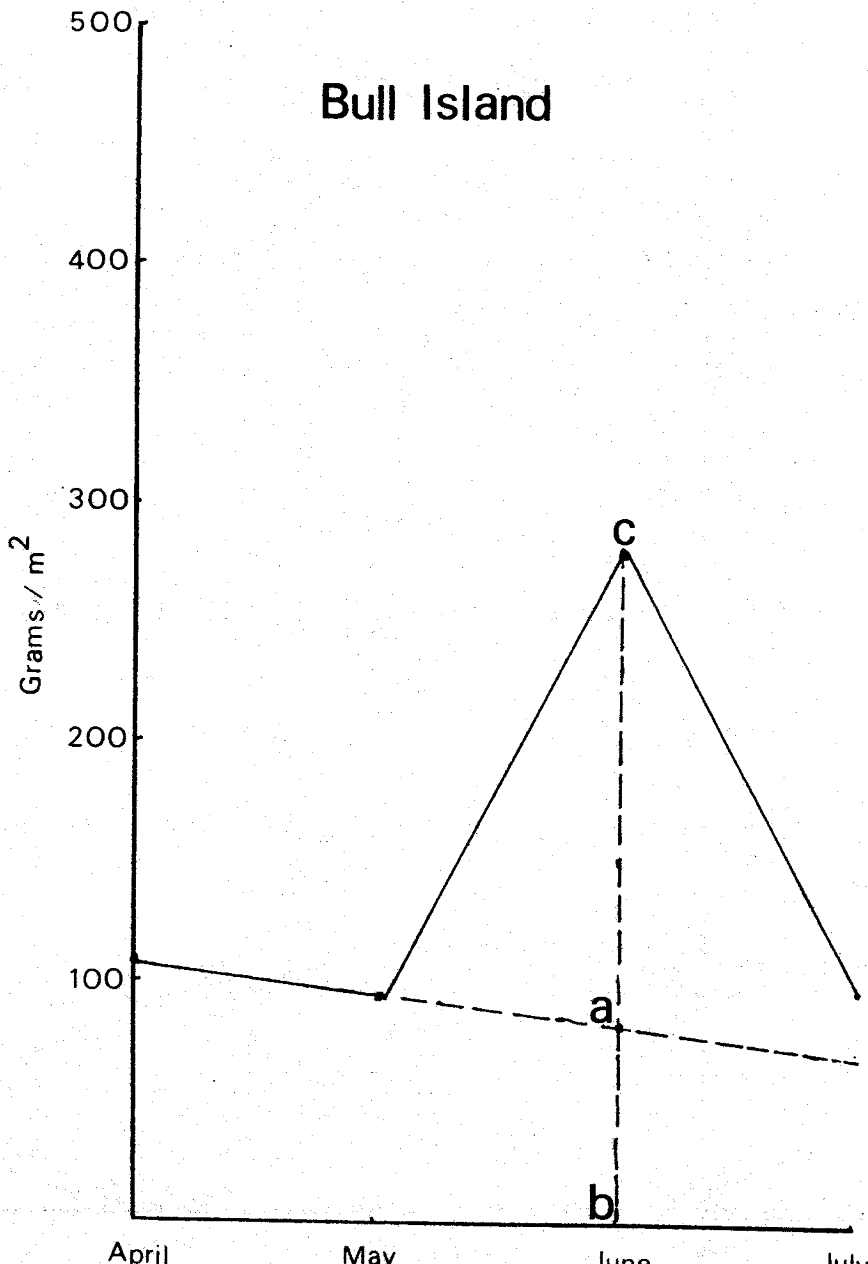

Figure 17: Changes in dead standing biomass from April to July. Estimated portion of dead shoot material (CB) derived from previous growing season (AB).

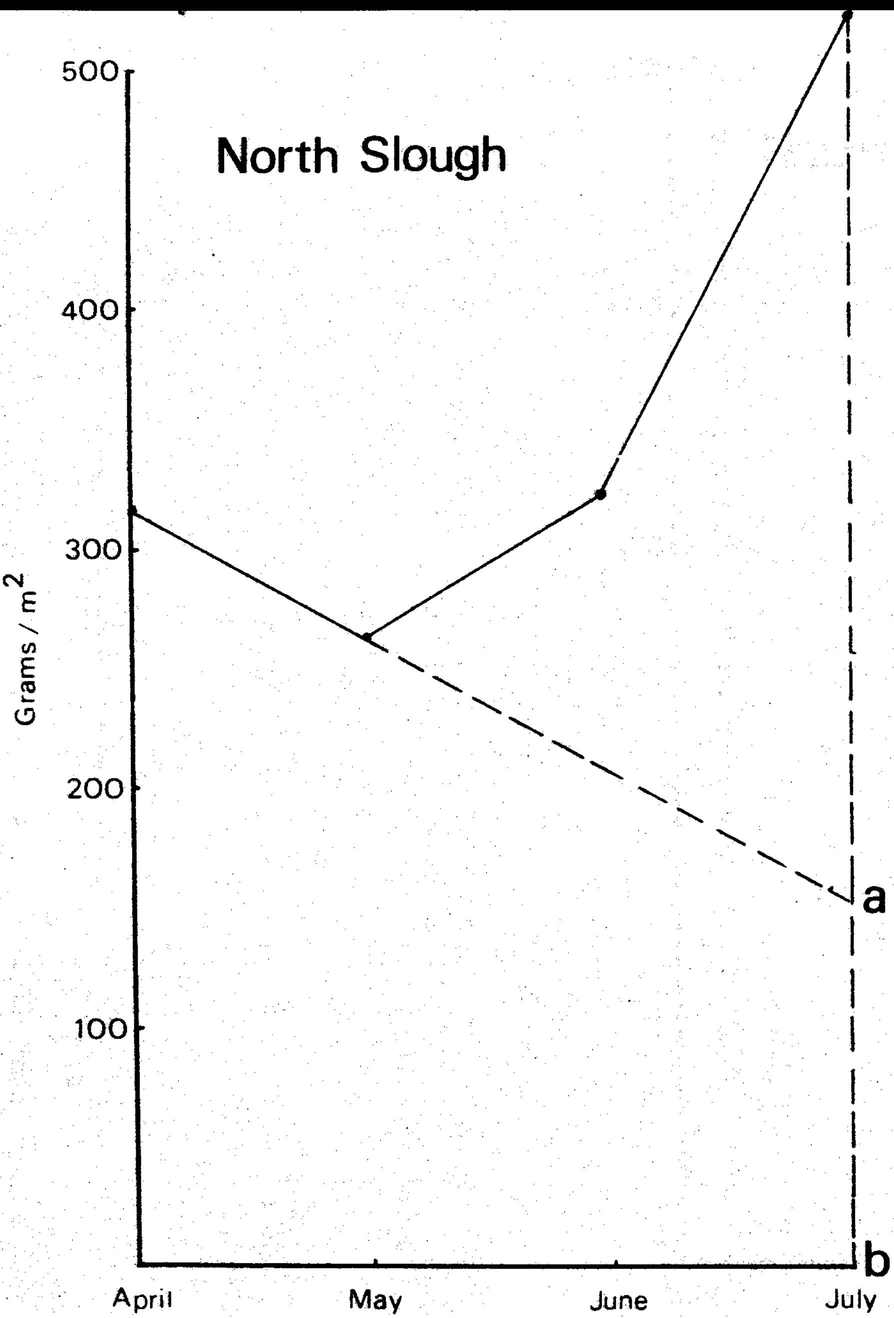

Figure 18: Changes in dead standing biomass from April to July. Estimated portion of dead shoot material (CB) derived from previous season's growth (AB).

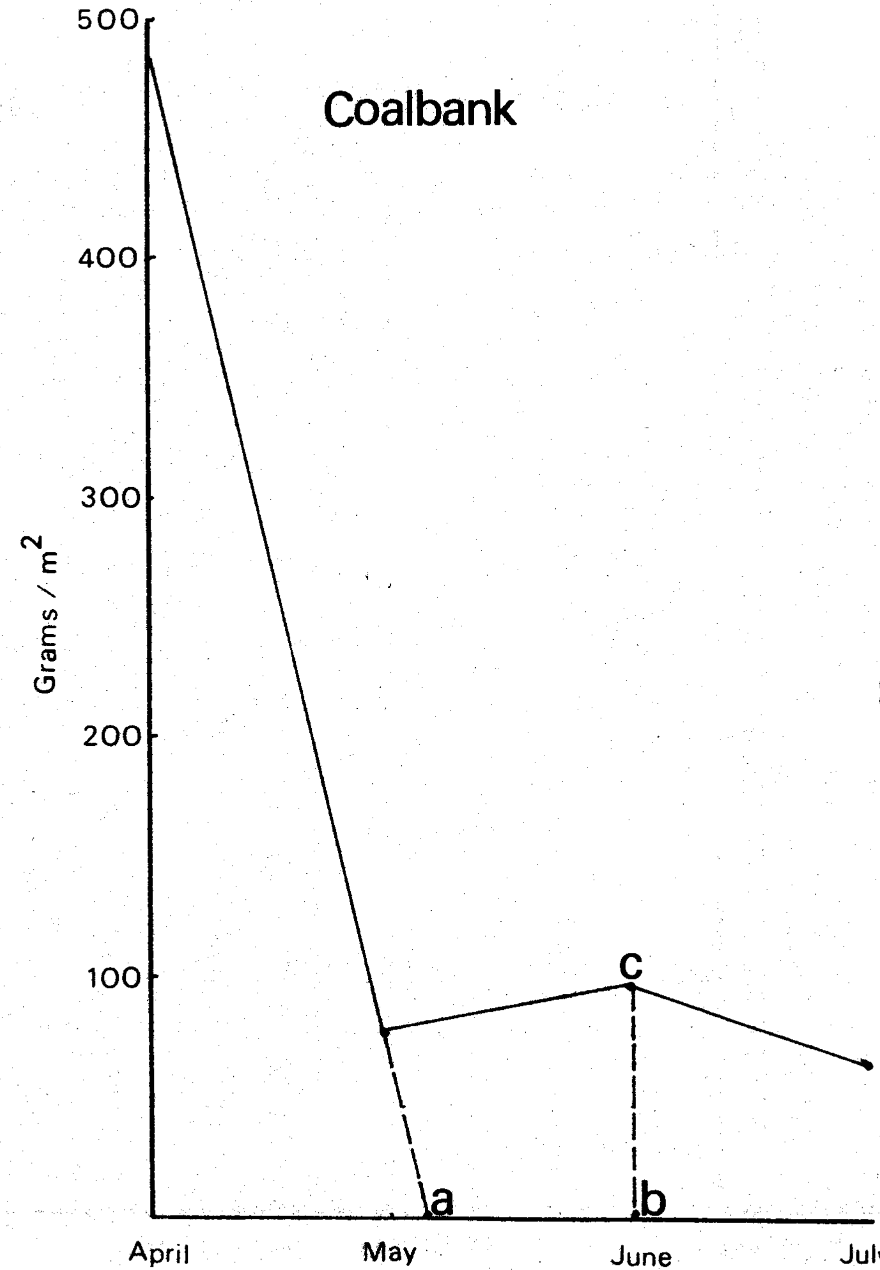

Figure 19: Changes in dead standing biomass from April to July. Estimated portion of dead shoot material (CB) derived from previous growing season.

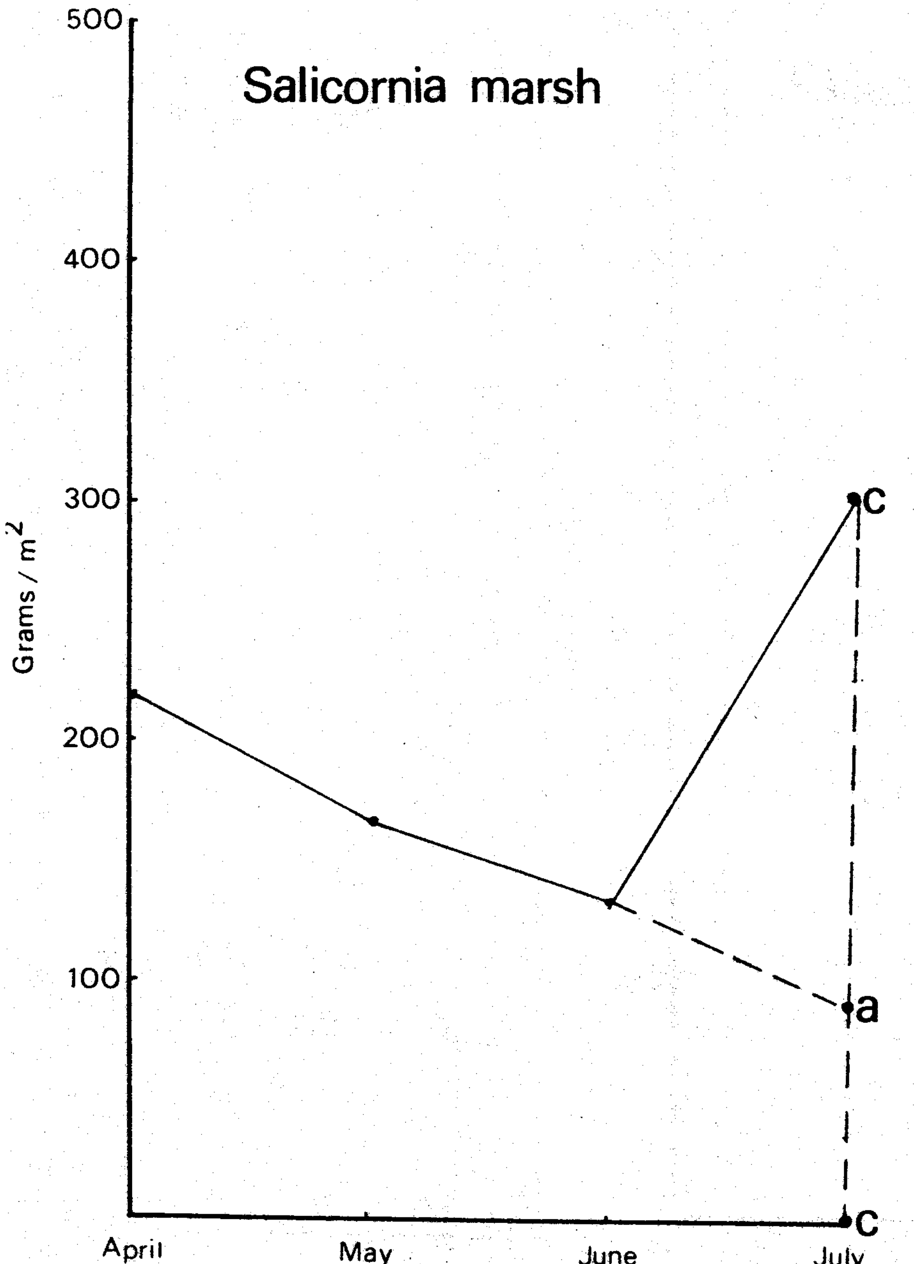

Figure 20: Changes in dead standing biomass from April to July. Estimated portion of dead shoot material (CB) derived from previous season's growth (AB).

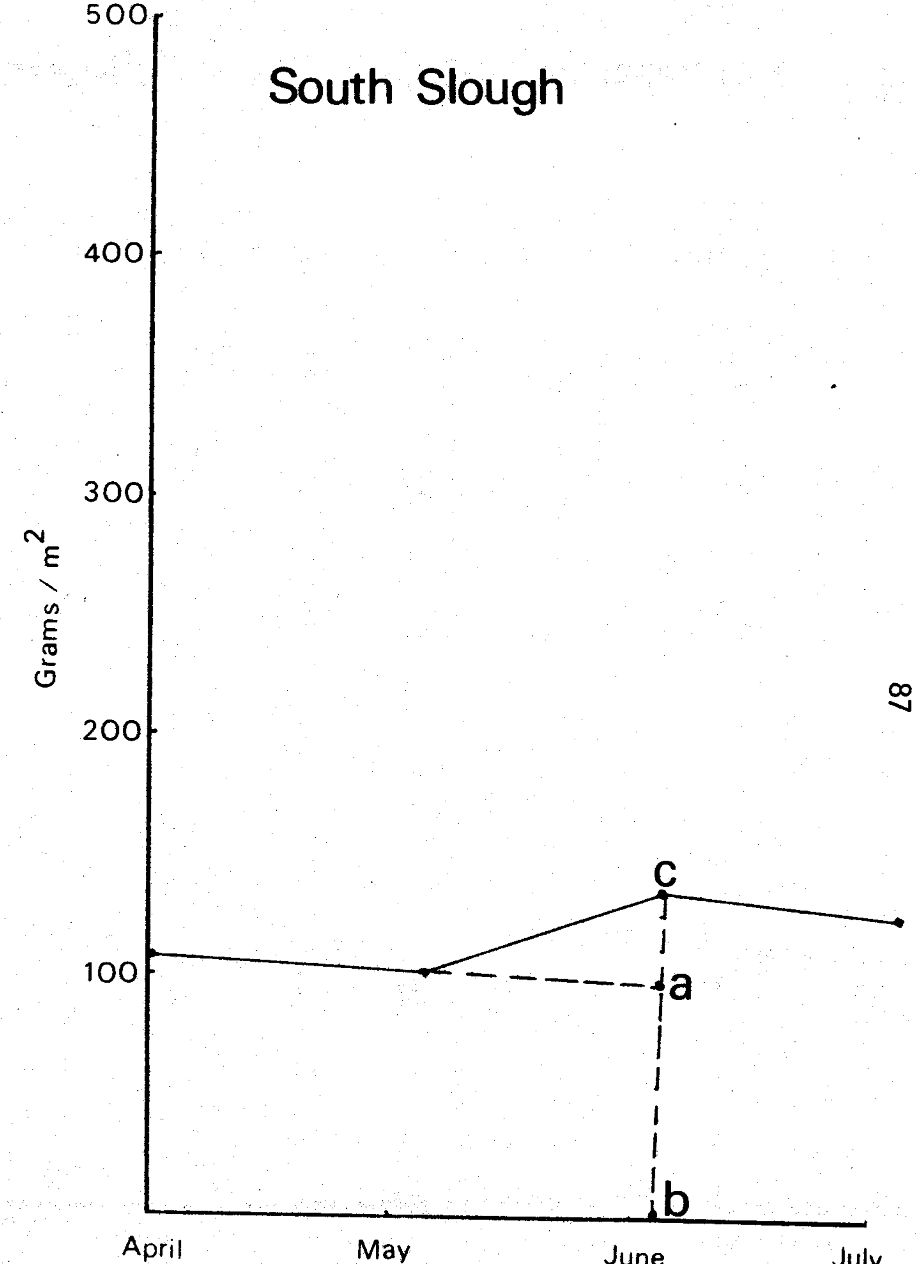

Figure 21: Changes in dead standing biomass from April to July. Estimated portion of dead shoot material (CB) derived from previous growing season.

Table 5: Net primary production in six salt marshes.

Marsh	S	+	L (g/m²)	+	Pa	+	G =	Net Primary Production g/m²/year	Net Primary Production g/m²/4 mos.
North Slough	749.44	+	369.45	+	0	+	0 =	1118.89	
	749.44	+	369.45	+	0	+	0 =		1118.89
Bull Island	815.184	+	192.68	+	0	+	0 =	1007.86	
	623.92	+	192.68	+	0	+	0 =		816.60
South Slough	734.81	+	30.00	+	0	+	0 =	764.81	
	634.4	+	30.00	+	0	+	0 =		664.40
Pony Slough	479.023	+	120.08	+	0	+	0 =	599.103	
	418.18	+	120.08	+	0	+	0 =		538.56
<u>Salicornia</u> marsh	360.066	+	200.28	+	0	+	0 =	560.346	
	222.88	+	200.28	+	0	+	0 =		423.16
Coalbank	280.567	+	98.3	+	0	+	0 =	378.867	
	165.04	+	98.3	+	0	+	0 =		263.34

** Net primary production has been determined for each marsh during the four month sampling interval (April to July) and is also presented.

for individual species was not calculated no adjustments have been made for loss due to death and shedding. Average maximum standing crop figures are also listed in Table 6. These should closely approximate yearly production of each species (see Table 6). Scirpus validus is by far the most productive, followed by Carex lyngbyei. Despite its large total biomass, the current season's crop of Salicornia virginica is among the lowest of the six species listed.

Data for the mean biomass of dead and live shoots in zones located close to the water and those near the terrestrial edge is represented in Table 7. Though figures for live shoot biomass in the two zones appear to differ for South Slough, Salicornia and Bull Island, none of these differences proved to be significant. Implications for differential zone production and a comparison with other studies will be discussed below. Differential disappearance of dead material in water and road zones for Salicornia marsh and Pony Slough will be discussed in the "Detritus" section of this report.

Plant Height

Plant heights increased from April to July. Values were calculated by averaging heights of plants at all three locations in a marsh to obtain an average monthly height. Sets of Salicornia beads in Pony Slough were lost in June; therefore, no data is available for this component. Plant height was correlated with increase in time and was found to significantly increase for Carex--Bull Island ($r = .95$ $t = 13.40$ $p < .001$), Distichlis--Pony Slough ($r = .96$ $t = 17.00$ $p < .001$), Carex--South Slough ($r = .09$ $t = 6.68$ $p < .05$), Scirpus validus--North Slough ($4 = .98$ $t = 34.75$ $p < .001$), Juncus--Coalbank ($r = .99$ $t = 70.$ $p < .001$). Only Salicornia did not increase significantly in height (see Figures 22-26).

Discussion

Spring and summer growing months constitute the growing season for most salt marshes in the United States, though Boyd (1971) found that the fall standing crop of Juncus effusus was greater than the spring's. The decline in biomass during late summer may be related to a temperature conditioned increase in respiration in relation to photosynthesis or a loss of dead or drying lower leaves through breakage or tidal action (Talling 1961). For the remainder of the year, marshes appear to be brown, mucky, wastelands. But the salt marsh community is not stagnant. Tidal action scours the surface, exporting dead plant shoots to the estuary proper. Marsh plants, then no longer palatable to terrestrial consumers, can form the first link in the detrital food chain.

That plant species found in the salt marsh attain their maximum standing crops at different times is readily apparent. Conditions favoring the growth and reproduction of each species varies from the wet, cold March months to the considerably drier days of late summer. The senescence and death of each species is likewise distributed. Decomposing plant tissues and nutrients are thus exported in intervals throughout the growing season.

Biomass differs each month for the six marshes. Pony Slough and Salicornia marsh biomasses remain relatively stable throughout

Table 6: Net production of six species.

Species	Maximum Standing Crop	*Net Production/ April-July
Triglochin maritima	129.92 g/m^2	125.2 g/m^2/4 mos.
Salicornia virginica	77.52 g/m^2	77.52 g/m^2/4 mos.
Distichlis spicata	71.6 g/m^2	62.64 g/m^2/4 mos.
Deschampsia caespitosa	105.84 g/m^2	Not sufficient data.
Carex lyngbei	206.00 g/m^2	177.12 g/m^2/4 mos.
Scirpus validus	795.36 g/m^2	749.44 g/m^2/4 mos.

*No adjustments made for plant biomass loss to death and shedding.

Table 7: Monthly plant biomass in two marsh zones.

Marsh	April water	April road	May water	May road	June water	June road	July water	July road
CO	59.84 ± 84.48	28.64 ± 18.24	36.58 ± 41.04	84.08 ± 68.56	228.16 ±234.88	12.37 ± 6.15	189.52 ± 79.2	36.09 ± 10.35
SO	No data		660. ±218.88	408.08 ± 72.08	828.72 ±121.52	574.24 ± 60.	646.88 ± 90.96	197.36 ±379.44
SA	685.92 ±285.35	496.24 ± 34.4	430.4 ±372.6	331.36 ±121.	740.08 ±332.32	335.76 ±126.4	550. ±359.2	475.52 ±177.2
PO	289.84 ± 85.52	283.29 ± 86.64	235.44 ±107.28	368.08 ±141.52	576.16 ± 82.56	527.04 ±181.2	622.56 ±197.84	669.52 ±153.44
NO	56.6 ± 12.32	64.64 ± 18.24	221.36 ±123.92	125.52 ± 24.8	592.32 ±454.32	601.04 ±222.48	761.52 ±210.08	762.08 ±137.04
BU	57.28 ± 12.32	64.4 ± 16.	267.6 ± 92.16	234.4 ± 93.36	704.08 ±236.64	660.48 ±158.08	664.8 ±158.24	500.16 ± 36.09

Live shoots

Table 7: (cont.)

Dead Shoots

Marsh	April water	April road	May water	May road	June water	June road	July water	July road
CO	939.58 ±490.96	372.88 ±133.2	98.48 ± 59.92	50.8 88.	142.08 ±167.36	102.24 ±108.24	76.48 ± 84.24	76.24 ± 71.12
SO	No data		13.64 ± 9.28	6.96 ± 1.6	27.68 ± 14.32	180.56 ±175.12	184.48 ± 18.96	134.55 ± 96.
SA	10.64 ± 18.48	347.28 ± 75.6	108.48 ±133.44	160.56 ± 51.52	54. ± 43.52	203.75 ±141.04	101.84 ± 60.16	266.8 ± 32.
PO	27.92 ± 34.32	35.36 ± 25.6	34. ± 37.36	34.72 ± 28.48	34.72 ± 72.08	122.32 ± 71.95	81.82 ± 58.56	150. ± 91.36
NO	375.36 ±108.	135.68 ±124.	233.28 ± 26.4	46.16 ± 71.94	348.16 ± 72.08	307.44 ± 71.95	319.68 ±130.72	278.94 ±137.04
BU	68.32 ±152.72	135.68 ±124.	125.44 ±117.6	46.16 ± 71.84	241.44 ±160.72	307.44 ±285.36	194.4 ± 76.8	52.8 ± 39.2

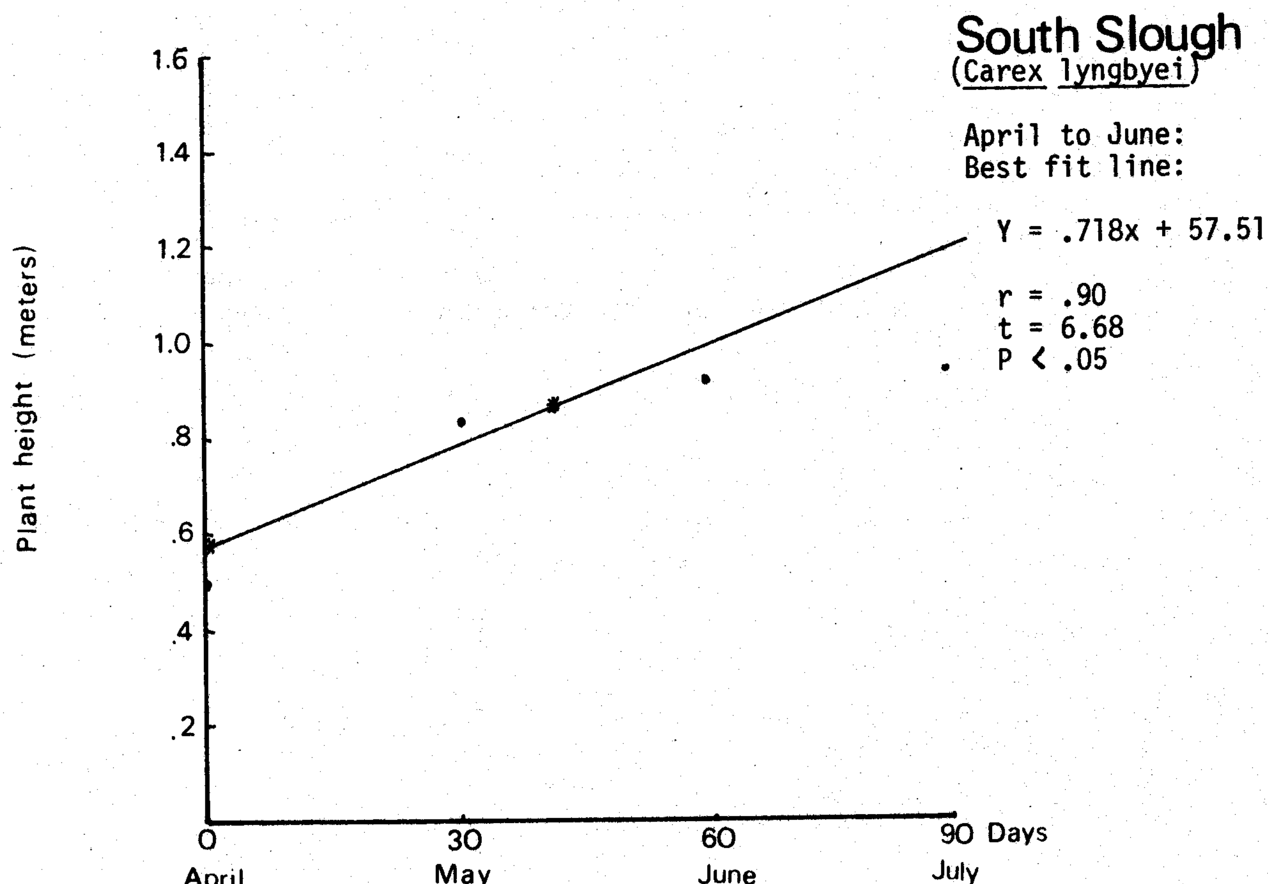

Figure 22: Plant height vs. increase in time.

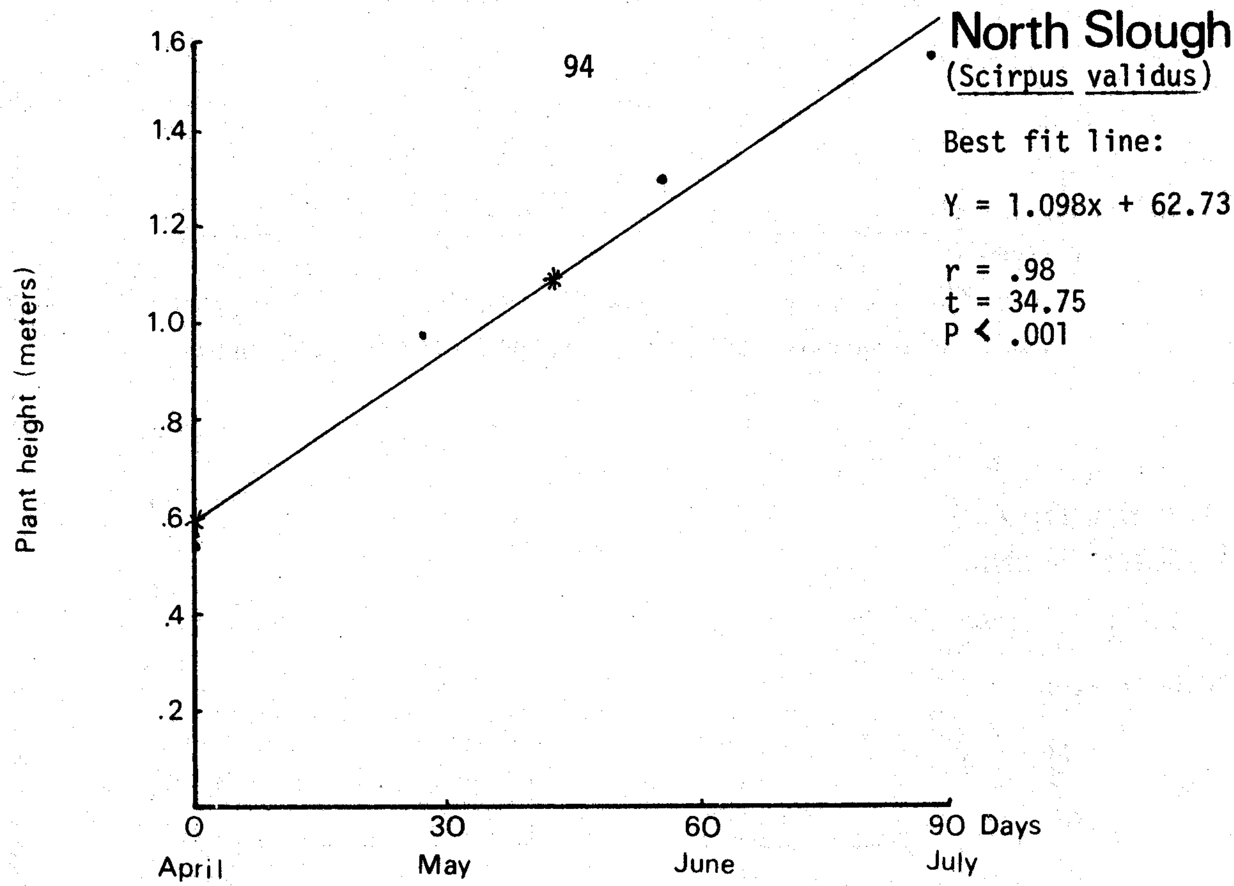

Figure 23: Plant height (meters) vs. increase in time.

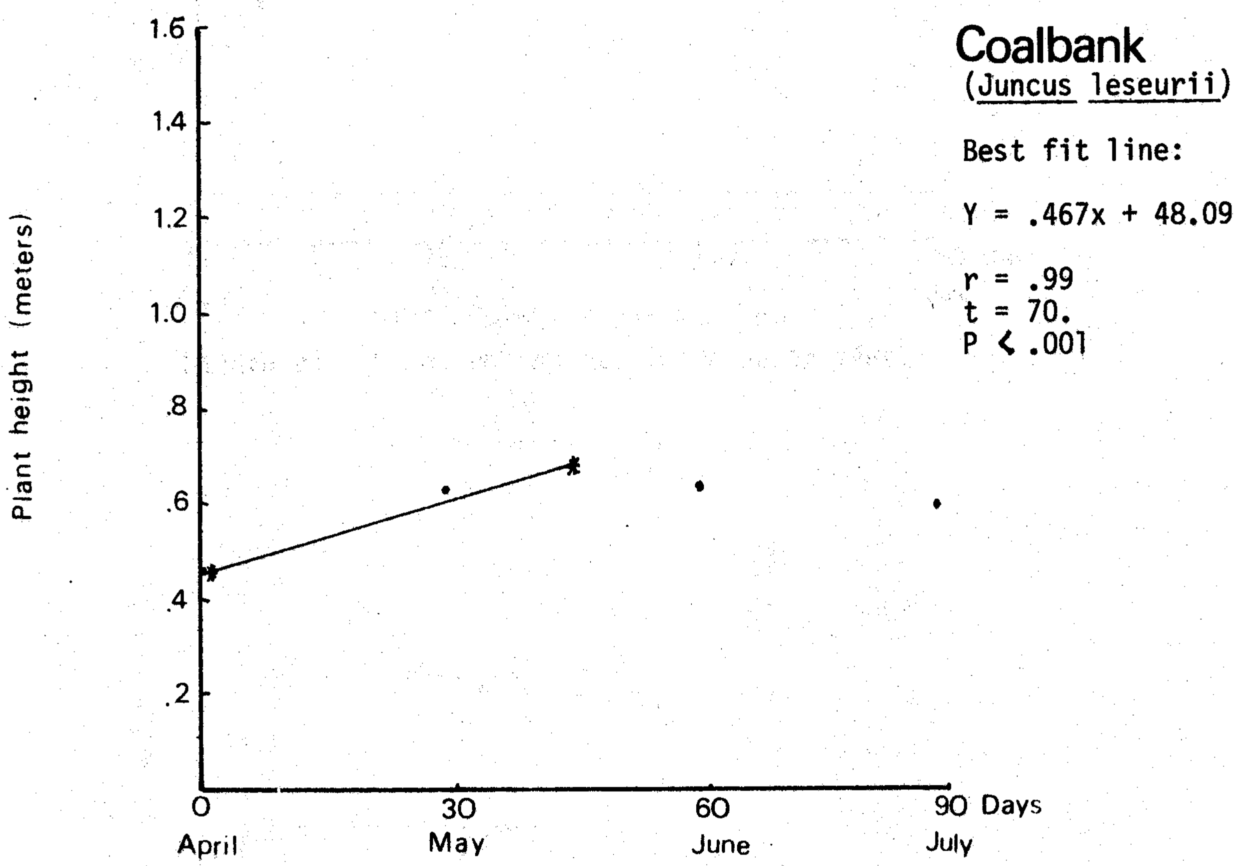

Figure 24: Plant height vs. increase in time.

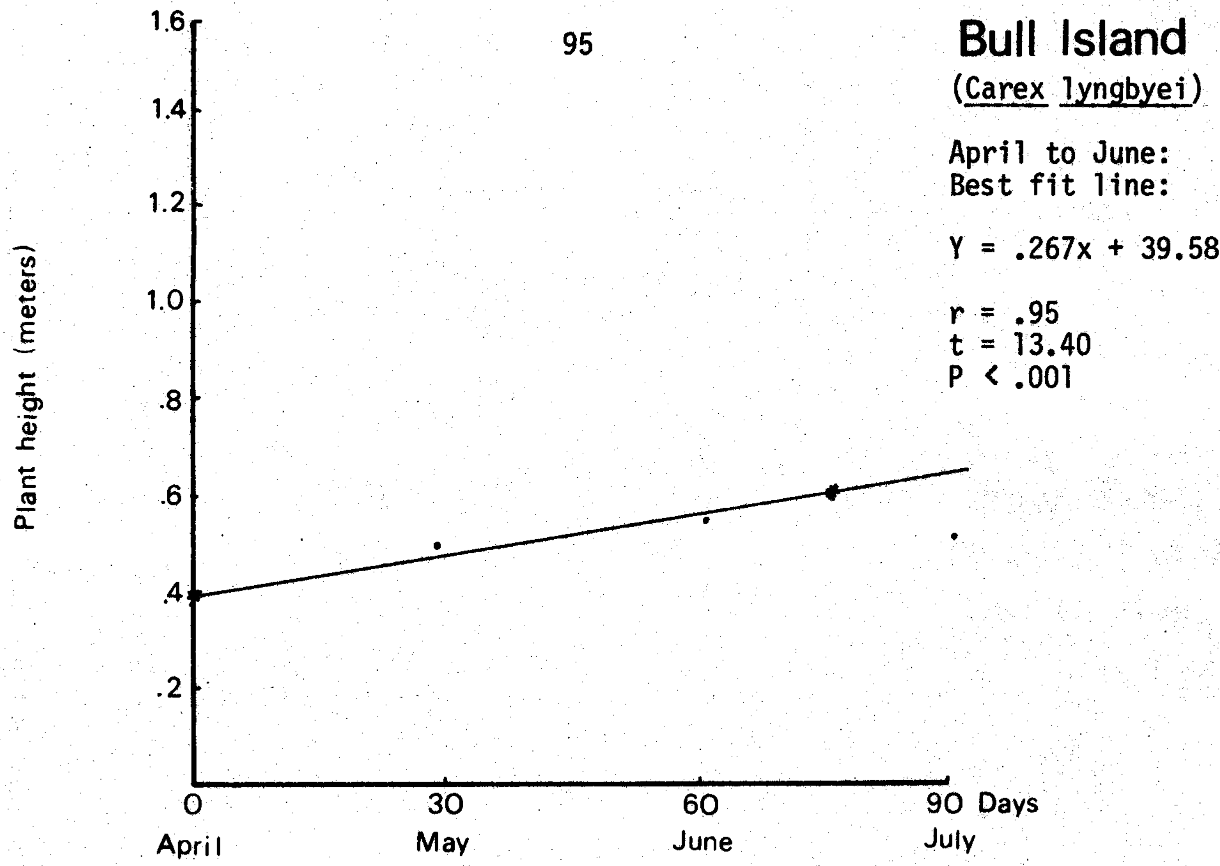

Figure 25: Plant height vs. increase in time.

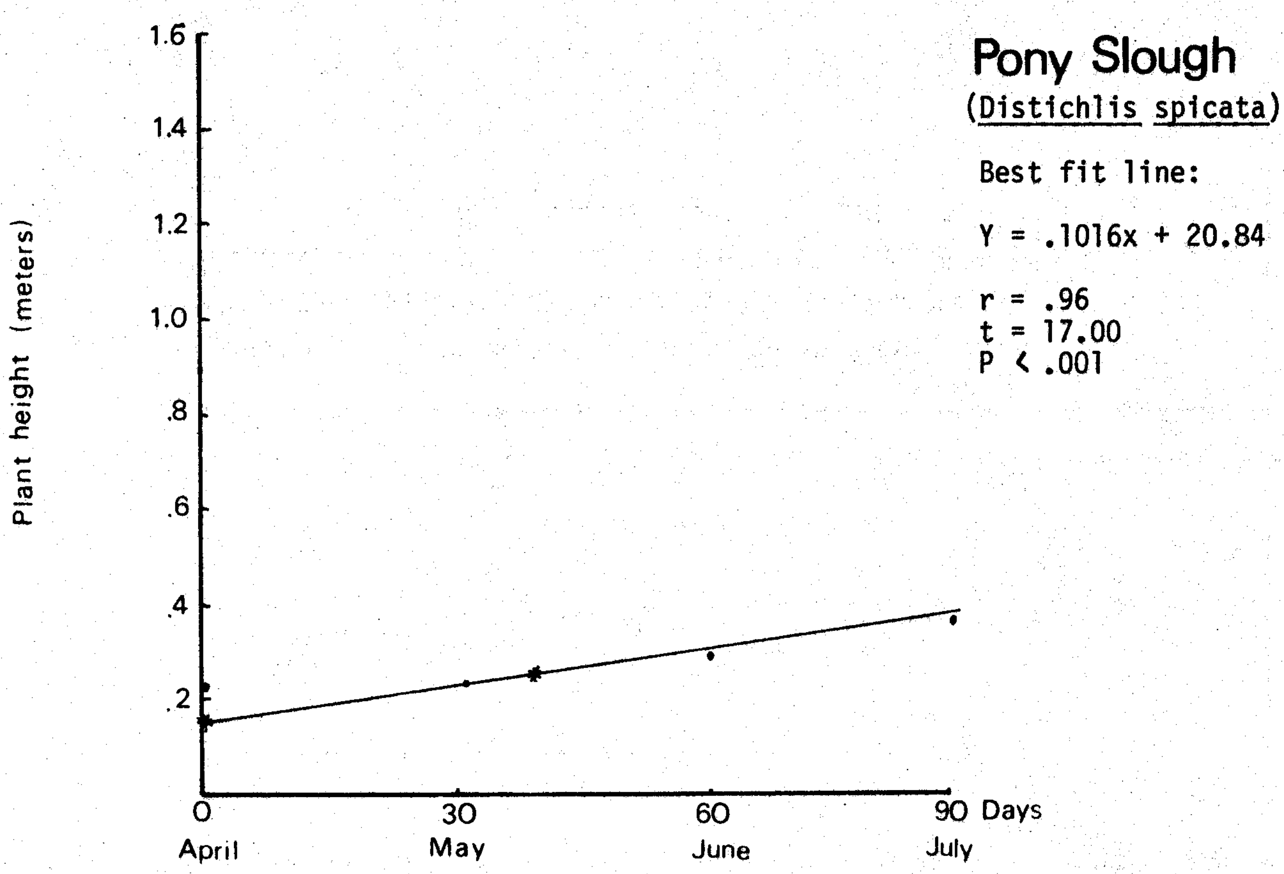

Figure 26: Plant height vs. increase in time.

the April to July interval. High biomass values in early spring and lack of great increase over time may be explained by the dominance of the perennial, Salicornia virginica, in these marshes. However, Pony Slough contains more Deschampsia and Carex than Salicornia marsh; this is reflected by the surge in marsh biomass between May and June. The sharp increase in plant matter during the April-June interval for South Slough and Bull Island is most likely also a function of the "boom" like growth of Carex during these months (Eilers 1975).

The significant decrease in root biomass for three marshes during the sampling period is of interest. Though values did not prove significant for the other marshes, all July root biomass figures are lower than April's (see Table 4). Hoffnagle and Olson (1974) report similar findings for root measurements taken in June and early August at Coalbank. The decrease in root biomass correspond with a period of aerial growth. Plant's probably expend more energy on aerial shoots than in root system maintenance; moreover, energy stored in roots may be released to facilitate growth. South Slough, consisting almost entirely of Carex, shows an increase in root biomass in July. The early die back of Carex may recircuit energy stores once again to the root system. Greater plant diversity in the Bull Island marsh may obscure this tendency. It would be beneficial to sample roots in all marshes in September to clarify this pattern.

Comparison of aerial and root biomass figures for each month illustrate that by far the greatest portion of the plants' biomass lies underground. Root biomass is nearly eight to ten times greater than the aerial. Jeffries (personal communication, June, 1976) has suggested that the large root system provides a strategy storehouse for coping with a harsh, changing environment.

Figures 16 and 19 show a rapid rate of disappearance of dead standing shoots in Pony Slough and Coalbank. Pony Slough, classed as a low sand marsh, is indeed the lowest in elevation of the marshes studied. Squiers and Good (1973) in a study on the production of tall and short forms of Spartina patens, found that the tall form grew in lower more regularly flooded areas and exhibited a steady decrease in litter after September. The short variety grew higher in the marsh and had a more irregular pattern of litter disappearance. Frequent inundation probably loosens and exports dead shoots easily.

The extremely high figures for Coalbank's dead shoot biomass in April is most likely a miscalculation or caused by errors in sampling. This biomass is larger than the live standing crop produced. It has been noted that Coalbnak does not receive good tidal circulation--the water from the main channel rarely floods the entire marsh. Furthermore, Hoffnagle and Olson reported a 280 gram/m^2 difference in July litter standing crop between the open Coalbank sedge marsh and the diked marsh we studied. They estimated that neraly 59,000 lbs. of dead material was not exported from diked Coalbank to the estuary and thus lost to consumers (Hoffnagle & Olson 1974).

Plant growth increased significantly over time for all marsh species exhibiting seasonal growth and die back of shoots. Only

Salicornia virginica proved not to significantly increase in height. This plant forms a mat-like cover with new succulent shoots branching from an older stem. Growth appears to be concentrated in lateral spread rather than increase in vertical height. Scirpus validus showed the greatest increase in height (from .5 to 7.5 meters) corresponding to the greatest increase in biomass over time.

The six marshes studied produced over 1,053,630.94 g/acre/yr. of plant material for the Coos Bay estuary. Again, production figures are underestimated for several reasons: 1) Maximum standing crop figures for several species are not available. 2) Adjustments for the loss of plant biomass to herbivory have not been made. 3) Accurate yearly production figures for Salicornia virginica are not available. 4) Changes in root biomass over a yearly period have not been monitored. 5) A portion of plant material is lost in the processes of collection and sorting.

Production seems to vary according to the marsh type, which itself is determined by elevation, drainage patterns and characteristic vegetation (Jefferson 1974). Factors mentioned in the "Introduction" of this article have varying degrees of influence on each marsh's production.

Coalbank's productivity is exceedingly low. This may reflect the consequences of diking a salt marsh. The Coalbank marsh system has been altered several times in recent years. Once flushed by a free-flowing channel, it was then diked and tidegated for road construction. The tide-gate was removed in 1974 in order to restore the natural properties of the salt marsh. It appears, however, that the culvert is preventing adequate tidal flushing, which should allow the inflow of estuarine nutrients and the export of litter. Large amounts of litter on the ground surface also testify to the fact that dead material is not being removed. In addition, the marsh zone nearest the terrestrial edges are marked by splotches --brown from apparent septic tank leakage.

Hoffnagle and Olson (1974) sampling in summer months were able to report only biomass figures for several marsh types within Coos Bay. Their paper states that the peak standing crops of different marsh types are similar. But they also reported 100-200 g/m^2 higher biomass values for low elevation marshes such as Pony Slough than for the sedge and immature high marshes (South Slough and Bull Island). However, their high July biomass figures for low marshes have ignored the complication caused by Salicornia. Thus their figures include not only this year's crop of Salicornia but also that of many previous season's. Since our maximum standing crop figures were adjusted for this species, our data is a better indication of differential marsh productivity.

Low salt marshes appear to be the least productive and the marshes containing Carex, more productive. Hoffnagle and Olson (1974) have also suggested that higher salt marsh plants may be more valuable as detrital food resources. In contrast, our study has shown Salicornia virginica as one of the most conducive to bacterial/fungal growth and grazing (see "Bacteria" section).

Hoffnagle and Olson's July biomass figures for the marshes included in our study are 100-200 g/m^2 higher than our data (Hoffnagle & Olson 1974). H.P. Eilers reported a net primary production of 1364 g/m^2/year for the West Island marsh in Nehalem Bay (Eilers 1975). This figure should be most comparable to Bull Island data as both marshes are classed as immature high (Atkins & Jefferson 1975). Productivity was determined using similar techniques in all three studies. The comparatively lower productivity values for the 1976 study could be attributed to unusually dry summer conditions in the Coos Bay area. Greatly reduced rainfall could alter available soil moisture and thus the overall vigor of plant growth.

Eilers (1975) completed an extensive comparison of the Nehalem Bay marsh productivity to that of East Coast salt marshes. Nixon and Oviatt (1972) have proposed that East Coast salt marsh productivity increases with decreasing latitude. Nehalem Bay far exceeds the production of Delaware and Rhode Island marshes, which are found at lower latitudes. The less severe winter conditions, rarity of ice rafts, warmer water and a longer growing season may contribute to the high productivity of Pacific Coast salt marshes. Eilers suggests that for the Pacific Coast, salt marsh productivity may decrease with decreasing latitude due to increasing summer drought (Eilers 1975). This theory then would explain the lower productivity of Coos Bay marshes located 190 miles south of Nehalem Bay on the Oregon coast.

Adequate flushing is deemed necessary for healthy salt marsh growth (Keefe 1971). Because a greater proportion of new shoots, especially for Salicornia, were noticed near the main water source in the marshes, it was decided to test for a significant difference in marsh zone biomass. Though values for the zone closest to the water are higher than the road zone values in most marshes, the differences did not prove significant. The large standard deviations probably reflect variability within the vegetation cover present, density, as well as sampling error.

Distance from the water can also be correlated with elevation. Eilers' study focused on vegetational distribution along an elevation continuum.

> "It is at once clear that the plant species characteristic to the West Island marsh have well defined elevational ranges. Triglochin maritima, Carex lyngbyei, Juncus balticus and Agrostis alba occur throughout broad elevational ranges while Salicornia appears more restricted." (Eilers 1975)

He found that production actually increased with increasing elevation (distance from water).

Eilers described two broad floristic units--intertidal and extratidal--and listed plant species for each. The channel bank elevation of West Island marsh is very similar to that of Bull Island, 1.2-2.22 m and 1.76 m, respectively. He reported a rapid increase in productivity with elevation in the intertidal zone, a slight drop in the transitional zone, and a stabilizing increase in the extratidal. Analysis of Eilers' vegetational descriptions of the Nehalem marsh, indicate Coos Bay study locations contained little extratidal marsh. Cotula coronopifolia, Grindelia integrefolia and Atriplex patula, characteristic of the extratidal marsh, are found only in extremely narrow belts adjacent to terrestrial vegetation.

Our transects, then, were located in marsh sections equivalent to Eilers' intertidal and transitional zones with one sample point, at most, in the extratidal. Such a comparison reveals that our theory is not inconsistent with Eilers' productivity findings.

Eilers' also noted an increase in plant diversity with greater elevation (Eilers 1975). Though diversity was not calculated in our study, the greatest species number/samples was noted for the point closest to the terrestrial edge. This phenomenon reflects the mixing effect of ecotonal areas in which one community grades into another.

Seasonal Changes in Nutrient Values

Boyd (1971) and Boyd and Hess (1970) questioned the adequacy of biomass net primary production (or caloric equivalents) figures for determining the value of a particular marsh system. They present data which indicates a fundamental difference between the quantity and quality (chemical composition) of primary production. Chemical analyses have been made on several marsh species (Straskiaba 1966, Lawrence 1968, Boyd 1968, 1970, 1971). Data is used to estimate amounts of chemical constituents per unit area of plant and to compare nutrient values of different plant species. Because nutrient analyses were not performed on plant samples in our study, a brief summary of the literature on the nutrient content of all salt marsh plants is presented below.

The ash-free dry weight of Coos Bay salt marsh plants did attain slightly higher values in July than in April, though the differences are not significant. Squiers and Good (1973) reported no seasonal variability in ash-free dry weight of *Spartina* from June to November though highest values were attained in early July.

The caloric content is a function of the live plant standing crop (Squiers & Good 1973). There is little difference in the caloric content between live and dead plants (de la Cruz & Gabriel 1974). The caloric content of the leaf, stem and inflorescence show a slight significant seasonal increase that may be attributable to higher percentages of structural carbohydrates or the high fat content of seeds. Squiers and Good (1973) concluded that organisms using *Spartina alterniflora* as a food source consumed an amount of total energy that is roughly proportional to the quantity of dry matter intake.

Nitrogen, carbon and calcium peak at the time of maximum standing crop (Boyd 1971). Our estimated carbon contents reached slightly higher values at this time. Nutrient concentration (P, K, Mg, S) peak within two weeks of peak biomass (Boyd 1970, 1971, Stake 1967, 1968). Total quantities of nutrients/m^2 decline faster than dry matter in late summer (Boyd 1969, 1970). But nutritive values of plants based on crude protein did not peak at the time of maximum standing crop (Boyd 1971). Squiers and Good (1973) also reported highest protein values in April decreasing to mid-summer. Similar patterns of protein levels have been reported for forest herbs (Kieckheger 1963) and alpine species (Hadley & Bliss 1964). Boyd and Hess (1970) suggest that this pattern reflects environmentally regulated differences in protein synthesis that is not related to peak standing crop. Boyd goes on to explain,

> "...that plants absorb a store of this potentially limiting nutrient at the beginning of the growing season and then use it as needed when growth conditions are optimum. This implies that nitrogen is limiting during the summer, or that some other factor, such as high salinity, inhibits the plant's ability to synthesize protein or accumulate it in the above-ground parts rapidly enough to keep pace with growth." (Boyd 1970)

Once dead material begins to decompose, nitrogen values change rapidly. Both Boyd (1971) and de la Cruz (1974) noted a marked increase in nitrogen and a decrease in carbon as material begins to decompose. This is easily understandable in light of detrital food chain processes. Carbon plant tissues are metabolized by bacterial and thus converted to protein-rich food for consumers. This bacteria, Protozoa grazing on detritus creates a better, more nutritious food than the living plant from which it was derived (Odum 1969). This concept will be more fully discussed in the following section.

Summary

Different species of salt marsh plants reach their maximum standing crops at various times throughout the growing season. Most species peak in July, while *Carex* peaks in June and *Agrostis* and *Distichlis* in September. *Scirpus validus* and *Deschampsia* have slightly greater ash-free dry weights (and thus possibly higher carbon contents) than the other marsh plants. The perennial habit of *Salicornia virginica* affects the seasonal picture of plant growth in *Salicornia* marsh and Pony Slough. Though both marshes show very high monthly biomass figures, these salt marshes actually produce less net plant material in one growing season than do the other four marshes studied. North Slough (pure bulrush stand) proved the most productive (1118.89 $g/m^2/yr.$) with Bull Island (1007.86 $g/m^2/yr.$), South Slough (764.81 $g/m^2/yr.$) Pony Slough (599.103 $g/m^2/yr.$), *Salicornia* marsh (560.346 $g/m^2/yr.$),and Coalbank (378.867 $g/m^2/yr.$).

Scirpus validus (bulrush) had the greatest net primary production of five major plant species. *Carex* was also highly productive and those marshes dominated by this plant (Bull Island and South Slough) likewise reflect a large increase in plant biomass over time. Productivity figures are underestimated for the several reasons discussed above.

Though none of the differences in mean biomass for "water" and "road" zones within one salt marsh proved significant, comparison of our data with other studies suggest that salt marsh growth is vigorous on the seaward side. It sharply increases in the narrow transitional zone and drops to the lowest values in the less frequently submerged portions of the upper marsh.

The significant decrease in root biomass over time in several marshes may reflect a re-direction of energy to aerial shoot growth with less energy available for carbohydrate storage in underground organs. Except for Salicornia virginica, plant height significantly increases over time. Growth of this perennial appears to be concentrated in lateral spread rather than an increase in vertical height.

As primary producers capable of fixing the sun's energy, salt marsh plants exist as valuable components of the estuary ecosystem. However, any comparison of salt marshes on the basis of productivity alone would be highly dangerous. Too little is known about the functional interactions within the marsh, between the marsh and water, between the marsh and land.

Much more work is needed, especially of longer duration, in order to determine the roles of the salt marsh system throughout the year. North Slough, containing large stands of Scirpus validus, is highly productive. Yet the palatability to consumer organisms and efficient export of Scirpus has been questioned (Hoffnagle & Olson 1974). Though the low marshes such as Pony Slough and Salicornia marsh appear to be the least productive, the dominant plant, Salicornia virginica, is a highly important detritus resource. Furthermore, the woody plant's mat-like growth habit performs a year-long function of soil stabilization.

It is hoped that those involved in resource management will proceed with caution with decisions affecting the future of this unique resource--the salt marsh.

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Detrital Production...

DETRITAL PRODUCTION IN COOS BAY SALT MARSHES

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Detritus plays a central role in estuarine ecosystems, yet there is so little information concerning it, that its importance is often totally neglected, or is mentioned only cursorily. The function of detritus within the estuary has been elucidated on the Eastern seacoast (Darnell 1961, 1967a, 1967b, Odum and dela Cruz 1967), but no conclusive studies concerning the importance of detritus to estuarine organisms have been conducted on the Pacific coast.

Darnell (1967) defines detritus as all types of biogenic material in various stages of microbial decomposition which represent a potential energy source for consumer organisms. This strict definition excludes microbiota, primarily bacteria and fungi. Most studies concerning detritus use a looser definition, which includes the organisms associated with the plant fragments, simply because the two are virtually impossible to separate. The distinction seems to be of fundamental importance since a number of investigators have shown that invertebrate filter feeders assimilate, primarily, associated bacteria and fungi, leaving the detrital materials unaltered as they pass through their feces. This implicates detritus as both a reuseable substrate and as a source of nutrition for associated bacteria and fungi.

Material concerning detritus and its associated organisms and their importance in the ecosystem will be found primarily in three sections in this study. This section deals with plant disappearance and the entry of detritus into the estuarine system. The bacteria section deals with the microbiota associated with the detritus and nutritive aspects of detritus. The invertebrate feeding section deals with detritus and its associated organisms as an energy source for various estuarine invertebrates.

Plant Disappearance

Our purpose in measuring plant disappearance was to measure the rate of breakdown of several species of salt marsh plants common to the Oregon coast from whole plants down to particulate form and to monitor the entry of this particulate material into the estuary. In approximating the amounts of breakdown material entering the estuary one is taking the first step in measuring energy flow through the salt marsh-estuary ecosystem.

Methods

Litter Bag Rate of Disappearance

In situ decomposition of several species of salt marsh plants was measured using the litter bag method. The species included *Carex lyngbei*, *Triglochin maritima*, *Salicornia virginica*, *Juncus lesueurii*, *Deschampsia caespitosa*, *Distichlis spicata*, and *Juncus validus*. In each case plant material was collected and dried to constant weight at room temperature (22°) for 36 hours. With each species equal weights of plant material were placed in hair nets in replicates of 6 or 12 to allow for monthly collection April through September. These nets were tied with fishing lines to permanent wooden stakes set approximately in the low, middle, and high portions of each study area. Bags were allowed to rest on the surface of the marsh in order to simulate natural conditions, although this caused problems with collection of mud and silt in some samples. Other studies have suspended litter bags above the marsh surface near the line of mean water (Boyd 1971), but this seems to simulate standing dead decomposition rather than litter decomposition. Hair nets had openings of 1.3 cm. This large opening size was chosen with reference to the work of investigators in Florida salt marshes (Heald 1971), but has been criticized by dela Cruz and Gabriel (1971) for allowing whole plant fragments to escape. Wiegert and Evans (1964) believe that small openings(1.5-2.5 cm) do not allow litter and mud invertebrates to enter the nets and begin the decomposition process.

Bags were collected monthly from each location and were rinsed gently with water only if excessively dirty. Samples were dried to constant weight at 112°C for 12 hours and sub-samples were combusted in a muffle furnace at 1000°C for 2 hours. Weights were compared with the April sample which had been weighed and muffled initially as a control.

In order to differentiate between mechanical action and bacterial decomposition, a similar in vitro experiment was conducted. This work is presented in the Bacteriology section.

Whole Plant Export

Individuals of several common salt marsh plant species were tagged with small colored beads organized in a roman numerical code that were attached to the plant's central stock with thread. Measurements were taken monthly from April to August of the length of the longest leaf and of the general condition of the plant. Although this method may be criticized as being injurious to the plant, all plants experienced rapid growth during at least a portion of the growing season and several flowered. Comparisons with other unlabelled plants showed normal heights at different locations. This method has been used successfully in other marsh studies to note the general condition of individual plants (Boyd 1971).

Dead Standing Crop

In order to ascertain whether the litter bag and labelling methods were successful, a third method was employed. In conjunction with the primary productivity study all dead standing material was collected from 1/16 m^2 quadrats along transects of 50-200 meters through each study area. Material was placed in a plastic bag and refrigerated prior to sorting and drying. Samples were dried to constant weight at 100°C for approximately 12 hours. Comparisons were made of monthly differences as well as differences from quadrats close to the water and close to the upland each month. This is not to be confused with the work of Eilers (1975) in which all material, including litter, was collected. Our dried material was collected as standing dead material. Litter lying on the ground was not collected. This method was an estimation of the appearance of standing dead material, which is related to the growing season of the plant in each salt marsh. Eilers' method is more directed towards the entry of detritus into the estuary, a different question. Williams and Murdoch use a similar rate of disappearance approach in an eastern coast salt marsh (1972).

Suspended Particulate Material

In order to calculate the exportation rate of detritus into the estuary, two methods modified from Odum and dela Cruz (1967) were used. The material referred to as detritus should properly be referred to as seston, since it contains detritus, phytoplankton, zooplankton, and sediments. To obtain a complete picture of detrital export throughout a complete tidal cycle (12 hours), water samples were taken hourly at the channel entrances to the Coalbank and Salicornia study sites during a neap and a spring tide. Predicted tidal heights for these tides were July 7: 7.1--0.3 ft. and July 30: 6.1-0.2 ft. In order to sample a representative portion of the water column in these relatively shallow channels, the following arbitrary system was used. When the depth of the channel was less than 1/2 meter, one liter sample was taken at 10 cm below the surface. When the water in the channel was between 1/2 and 1 meter in depth, two samples of one liter were taken, one 10 cm below the surface and one near the bottom.

Results

Litter Bag Decomposition

Figures 1 and 2 and Table 1 show the rates of decomposition of seven species of salt marsh plants from April to August 1976, a 120 day period. Originally all sets of replicate bags were of a different weight, but have been presented as a percentage of their April weight for comparison. The decomposition rate is the average of the high, low, and middle decomposition bags from each salt marsh because few trends were noticed from low-middle-high locations within a single salt marsh.

The rate of decomposition of different species is very interesting, and in large part unpredictable. *Triglochin maritima* seems very succulent and without much rigid internal structure. This is borne out by its rate of decomposition, which is nearly 90% in only 90 days. *Carex lyngbei*, on the other hand, seems hearty and would not be expected to rapidly decompose, yet it lost nearly 70% of its weight in a 90 day period. *Scirpus*

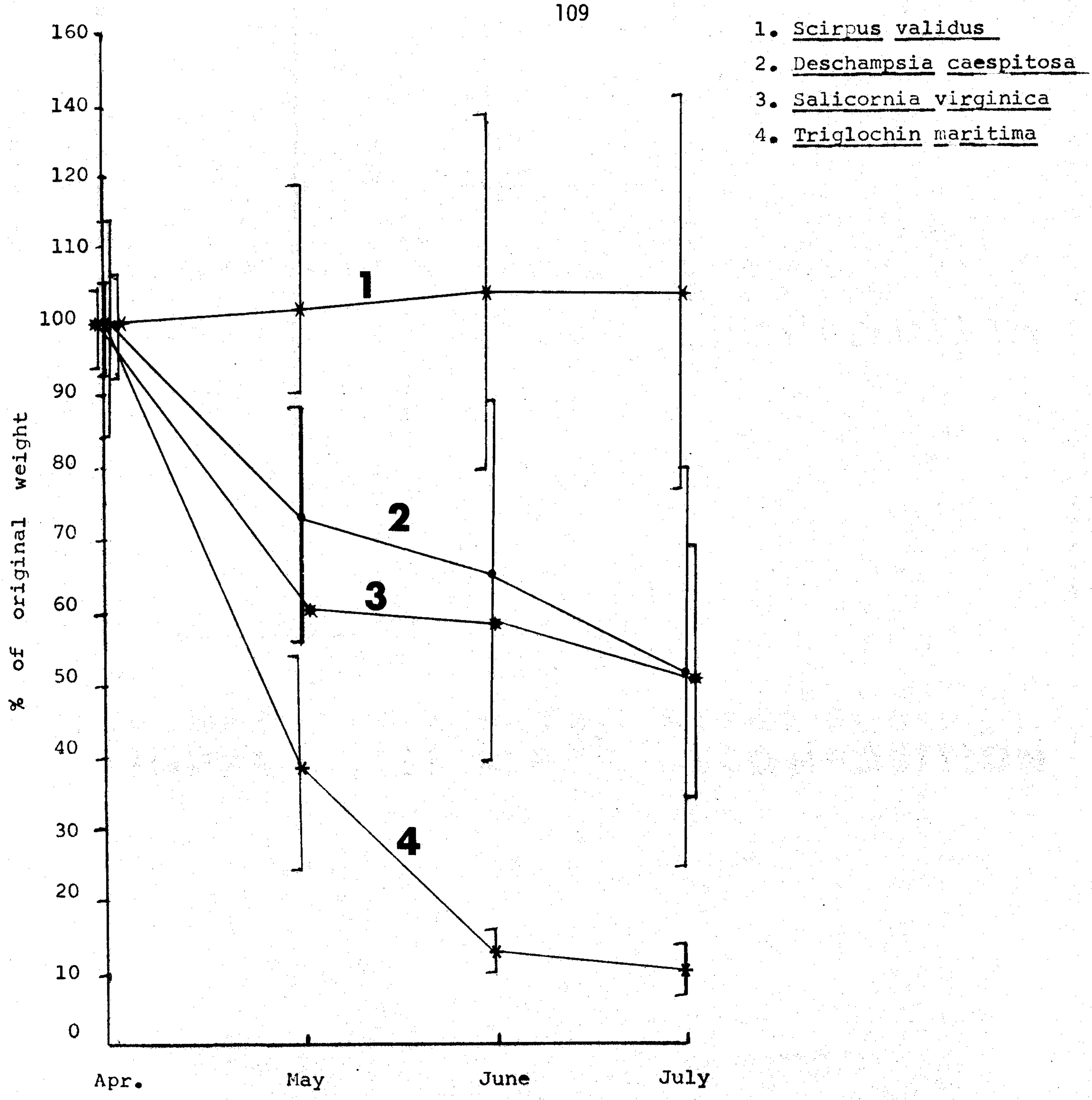


FIGURE 1: LITTER BAG DECOMPOSITION

Note: Vertical lines equal ± one standard deviation

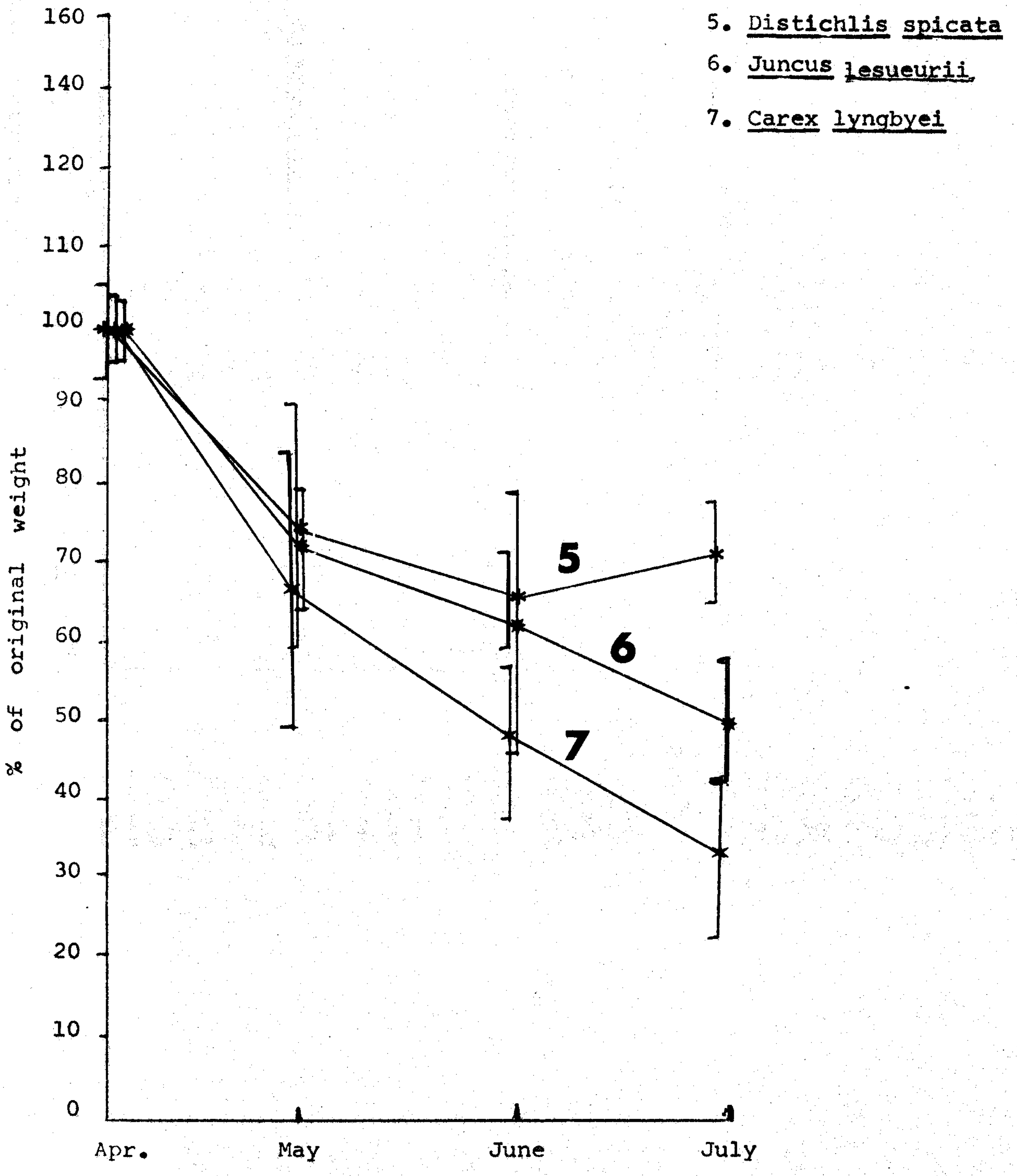


FIGURE 2: LITTER BAG DECOMPOSITION

Table 1: Disappearance of material from litter bags.

	April	May	June	July
North Slough				
Scirpus validus				
dry wt. (gms)± std. dev.	3.28±.5	3.37±.42	3.49±.83	3.46±.87
ash-free wet. %	92.5	91.1	89.0	84.7
Coalbank Slough				
Deschampsia caespitosa				
dry wt.	7.62±.5	5.56±1.3	4.96±2.	3.85±2.12
ash-free wt.	94.4	81.7	89.0	84.7
Juncus lescurii				
dry wt.	16.5±.5	11.9±1.5	10.4±2.5	8.5±1.2
ash-free wt.	94.9	93.1	88.2	79.8
Salicornia				
Salicornia virginica				
dry wt.	10.4±.5	6.2±1.0	6.1±1.4	6.9±2.3
ash-free wt.	90.6	92.2	92.0	89.2
Pony Slough				
Distichlis spicata				
dry wt.	8.3±.5	6.2±1.2	5.5±.4	5.9
ash-free wt.	92.6	91.7	85.7	87.7
Salicornia virginica				
dry wt.	17.4±.5	10.3±1.6	10.8±1.1	8.35±1.8
ash-free wt.	89.5	89.4	86.2	86.2
Bull Island				
Triglochin maritima				
dry wt.	9.12±.5	3.69±1.4	1.24±.4	1.06±3.2
ash-free wt.	84.1	69.4	67.6	53.7
Carex lyngbei				
dry wt.	14.4±.5	9.6±2.6	6.8±1.4	4.9±1.4
ash-free wt.	90.6	84.2	70.9	63.3
South Slough				
Carex lyngbei				
dry wt.	14.0±.5	6.2±2.0	7.9±2.4	3.0±1.4
ash-free wt.	91.0	80.2	67.9	57.9

validus exhibits another trend. This tough, fibrous plant did not show any decomposition over the 90 day period and actually gained some weight due to accumulated mud and silt that collected. This is supported by our finding that large amounts of Scirpus from last year are present in April, undecomposed from the previous growing season. This is something that one does not expect to see in a salt marsh situation.

Salicornia virginica, Deschampsia caespitosa and Juncus lesueurii exhibit a pattern similar to studies with Juncus roermerianus on the East coast. Dela Cruz and Gabriel (1974) state that this rate of decomposition observed was 24% in 100 days, and that this rate was quite rapid when dealing with Juncus roemerianus. Annual rates of decomposition of 35%, 47%, and 37% have been reported by dela Cruz (1965), Waits (1967), and Heald (1969) for the same species. These rapid rates of decomposition have been attributed to soluabilization and leaching of nutrients from within the plant by Boyd (1970), although Kirby (1971) finds mechanical fragmentation a more reasonable factor in such rapid decomposition. It is interesting to note that our species decomposed 60% in 90 days on the average. This is very rapid decomposition, which may be due in part to the large mesh of our litter bags, or to the season in which our study took place.

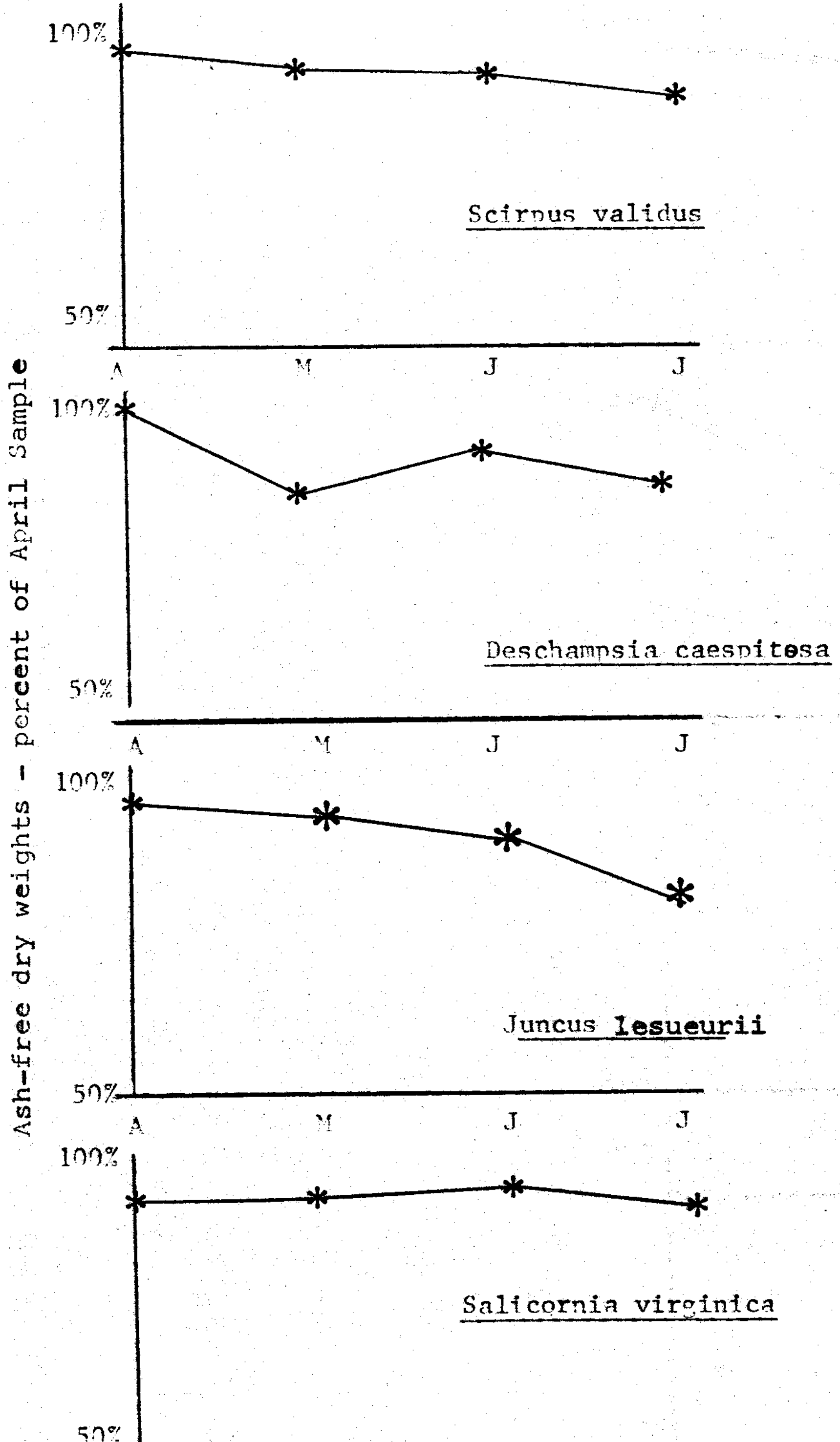
The ash weights presented in Figure 3 show trends reinforcing our litter bag decomposition figures. The Triglochin maritima remaining in the hair net loses a great deal of its carbon in the first month and large portions in following summer months. Carex lyngbei, surprisingly, loses much of its carbon (40% in 90 days), while other species remain much more intact throughout the summer. All other species, including Salicornia virginica, show very little degradation of carbon compounds throughout the sampling period. Salicornia virginica data from figures 1 and 3 point to it as a plant that degrades internal substances slowly, yet loses relatively large amounts of material initially through the export of large fragments.

Our ash weights, along with the litter bag data for the summer months, point to Kirby's (1971) conclusion that mechanical fragmentation is responsible for the large plant losses in the first month for Salicornia, but for Carex and Triglochin both processes seem to be occurring since leaching of substances within the plant cannot account for the large weight loss shown by the two species.

Whole Plant Export

Looking at Table 2, all marked individual plants showed rapid growth throughout the first three months of the study. (Using our method of labelling, it is impossible to label a plant much smaller than 30 cm. For this reason initial growth rates have not been reported.) Notice how Salicornia and Carex start out in May at similar heights and in July Carex has grown 20 additional cm while Salicornia has not grown appreciably.

Fragmentation appears to be a significant factor in vascular plant energy contribution to the estuary. Although we were certainly not looking at the height of the export season, which must be in



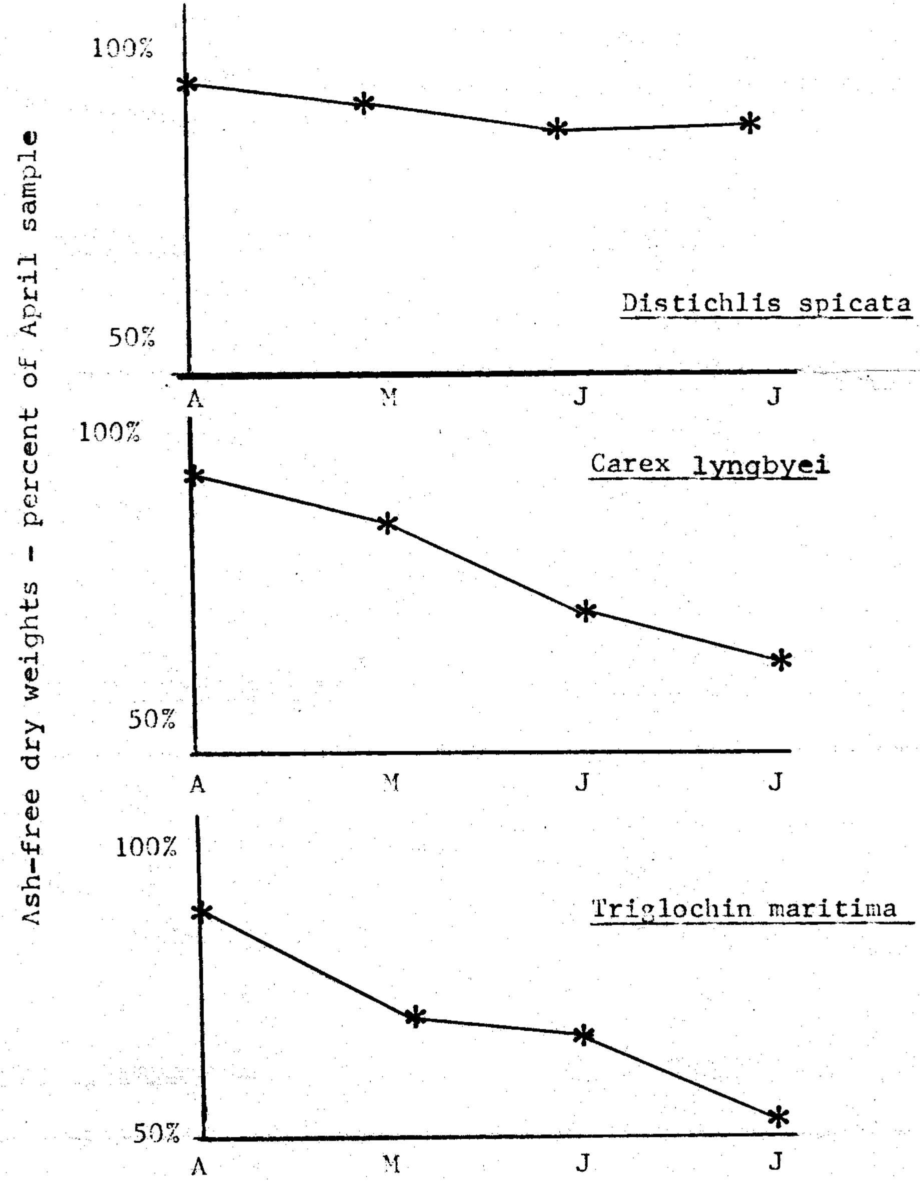


Figure 3: % ash free dry weight of litter bag material

Table 2: Plant growth and fragmentation of three plant species along longest axis from May through August (in cm).

	May	June	July	August
Carex lyngbei				
1.	31.3	45.2	53.3	52.0
2.	33.5	50.4	59.2	60.6
3.	29.5	44.6	51.1	52.0
4.	26.5	40.1	51.2	50.5
5.	28.5	43.7	55.1	55.0
6.	33.2(F)	42.2	41.1	37.0(d)
7.	18.6	33.6	46.1	45.0
8.	37.6	53.2	57.5	58.0
9.	35.3	50.0	-	-
10.	29.4	44.5	47.9	43.0
Salicornia virginica				
1.	35.0	34.5	32.5	32.0
2.	40.3	33.3	49.0	40.5
3.	35.5	38.8	40.0	42.5
4.	35.7	35.7	36.0	37.6
5.	33.0	33.5	34.3	33.5
6.	33.0	33.7	34.4	34.6
7.	26.0	26.7	26.0	26.8
8.	30.7	30.3	26.5	26.4
9.	28.1	24.3	29.0	29.0
10.	25.1	24.7	30.0	27.4
Scirpus validus				
1.	55.0	107.3	167.7	186.8
2.	42.0	45.0	148.5	40.2(d)
3.	72.2	118.2	154.0	170.5
4.	23.7	78.0	151.9	-
5.	69.5	109.0	127.5	127.2
6.	84.1	130.3	142.0	147.9
7.	37.0	87.9	146.8	173.2
8.	74.5	121.1	149.2	168.2
9.	50.2	102.9	148.9	159.5
10.	41.9	94.9	153.0	112.7

the fall and winter, fragmentation, measured by the shortening in length of the plants, was noticed. Sixty percent of the Carex lyngbei, 50% of the Salicornia virginica, and 30% of the Scirpus validus experienced some shortening by August. These rates must increase dramatically in the fall and early winter.

Whole plant export, surprisingly, occurred in 15.2% of our samples. Subtracting the chance that an observer might miss counting a beaded plant by looking at "rediscovered" plants/# plants counted, one gets an exportation figure of 12%. It is difficult to get a credible estimate of this process, however, since we have seen beads that have fallen off intact plants. Based on our collected data, a whole plant disappearance rate of less than 5% between the period of May and August would probably be an over-estimate.

Dead Standing Crop

Table 3 and Figure 4 show dead standing crops for each study site, both near the water and near the terrestrial vegetation line for the months April-July. An M next to a number indicates that the month's live standing crop figure was the maximum live standing crop during the growing season. Dead standing crops seem, in general, to be coincident with peak live standing crops, or in some cases occur the month following peak live standing crops. Notice in Pony Slough and Salicornia marshes that dead standing material increases throughout the growing season. This is not the case with Bull Island and South Slough, where a certain amount of dead material from the previous growing season is still present in April. Dead standing crops finally reach a minimum in May and then increase with increasing plant growth and subsequent death throughout the summer. In North Slough and Bull Island the dead standing material near the water has already peaked in April, although the quadrats near the road have not. This points to a greater mechanical breakdown of plant materials near the mean tidal ranges. This conclusion is supported by several authorities (Ranwell 1964). These findings are also in agreement with Eilers (1974) finding that litter accumulation decreases with lower elevation within a marsh.

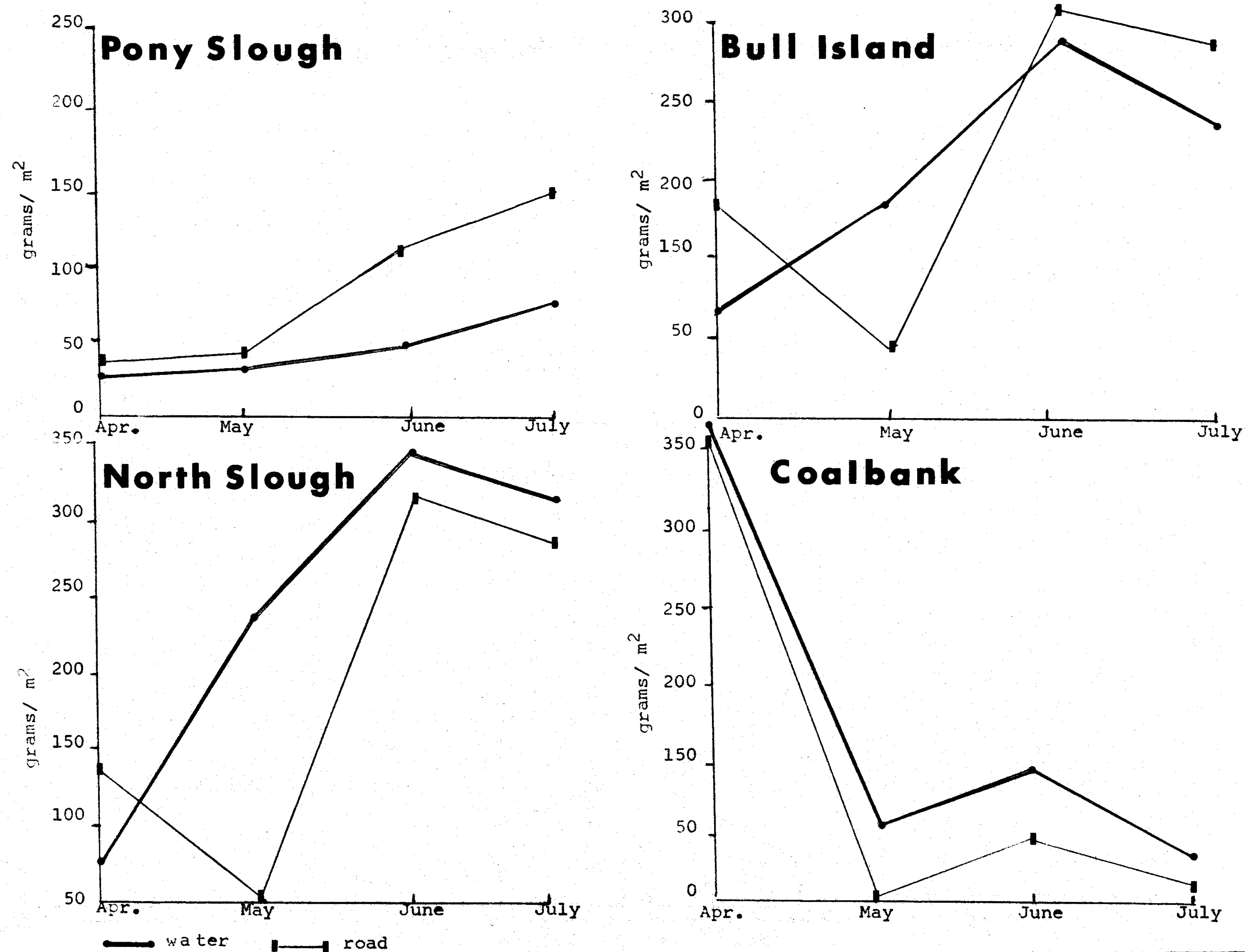
Coalbank Slough, which experienced a stunted plant growth this season, seemed to follow the reverse pattern, although it is really only the same pattern with a large lag period. Instead of increased dead material with plant growth, dead material from last season was still disappearing as late as May at a much greater rate than in our other study sites. This is reasonable in light of the impaired circulation in this salt marsh, which makes the mechanical action of the tides unable to effectively transport plant materials into the estuary. The increasingly organic soil is purely a function of dead plant material standing in place rather than being exported into the estuary.

It is unfortunate that our experimental design did not include litter collection as in Eilers (1974). This would have given us some indication of the amount of material leaving the salt marshes and entering the estuary, rather than just the amount of dead standing material present.

Table 3: Dead standing crop for six study locations, April-July.

Location	April Water	April Terrestrial	May Water	May Terrestrial	June Water	June Terrestrial	July Water	July Terrestrial
Coalbank	939	372	98	50	142	102	76	76
std. dev.	490	133	59	88M	167M	108	84	71
South Slough	-	-	13	7	27	180	184	134
std. dev.	-	-	9	2	14M	175M	19	96
Salicornia	10	347	108	160	54M	203	101	266M
std. dev.	18	75	133	51	43	141	60	32
Pony Slough	28	35	34	34	48	122	81	150M
std. dev.	34	25	37	28	34	48	58	91
North Slough	75	135	233	46	348M	307M	319	278
std. dev.	108	175	26	71	72	71	130	137
Bull Island	68	135	125	46	241M	307M	194	53
std. dev.	152	124	111	71	160	286	76	39

M indicates peak live standing crop for 1976.


Pony Slough
Bull Island
North Slough
Coalbank
grams/ m²
Apr.
May
June
July
250
200
150
100
50
0
300
350
water
road

Suspended Particulate Matter

Table 4 shows the average of the import and export of seston from Salicornia and Coalbank study sites on two different dates.

Table 4
Average Incoming and Outgoing Detrital Weights
(height x weight)

	Average Incoming	Average Outgoing
July 7		
Salicornia	3.14 mgM	1.02 mgM
Coalbank	0.0405 mgM	0.03466 mgM
July 30		
Salicornia	1.63 mgM	8.83 mgM
Coalbank	2.059 mgM	2.06 mgM

Data has been weighted by multiplying tidal height by the weight of the samples on the millipore prefilter in order to get an indication of the volume of water present when the sample was taken. Although this is a crude estimate of the volume of water actually passing the sampling location, it gives us an idea of the relative importance value of the sample. Figures 5 and 6 show both the tidal height and the weighted seston values. Note that the two axes are independent. One could be moved without affecting the other. Only curve shapes and relative minima and maxima are important. Seston weight closely follows tide height. Notice how the July 30 neap tides are more variable than the July 7 spring tides. This is especially true at the Salicornia study location.

In order to verify whether height may be a good indicator on velocity, simultaneous height and flow readings were taken on July 20 at the Coalbank study site. Seston weight times flow seems a much more accurate indicator of the actual material imported and exported. Notice the large minimum during slack tides as well as the relative minimums at mid-ebb and mid-flow. These (seston weight x flow) readings seem a good indicator of tidal exportation of suspended materials.

The particle size of the seston determined from our 6 liter samples taken at mid-ebb and mid-flow are shown in Table 4. Percentage values of 6.9% for the coarse fraction, 5.6% for the fine fraction, and 87.7% for the nannofraction show similar composition to Odum and dela Cruz's studies on the East coast (1968). They reported collections using nearly the same techniques with values of 1%, 4%, and 95% respectively. Odum and dela Cruz went further and measured oxygen consumption rates of the three fractions and found that the nanno fraction is consuming oxygen at five times the rate of the other fractions. This points to the active bacterial metabolism in this smallest fraction.

Determining the composition of the seston was exceedingly difficult. Particles counted under a compound microscope at 20X seemed, in general, to be amorphous with the exception of rare diatoms occurring 1-2% of the time. Other particles seemed to be either too small to be accurately identified, or in

Figure 5: Changes in detrital weights* during a tidal cycle

*weighted by height of tide - see "Results"

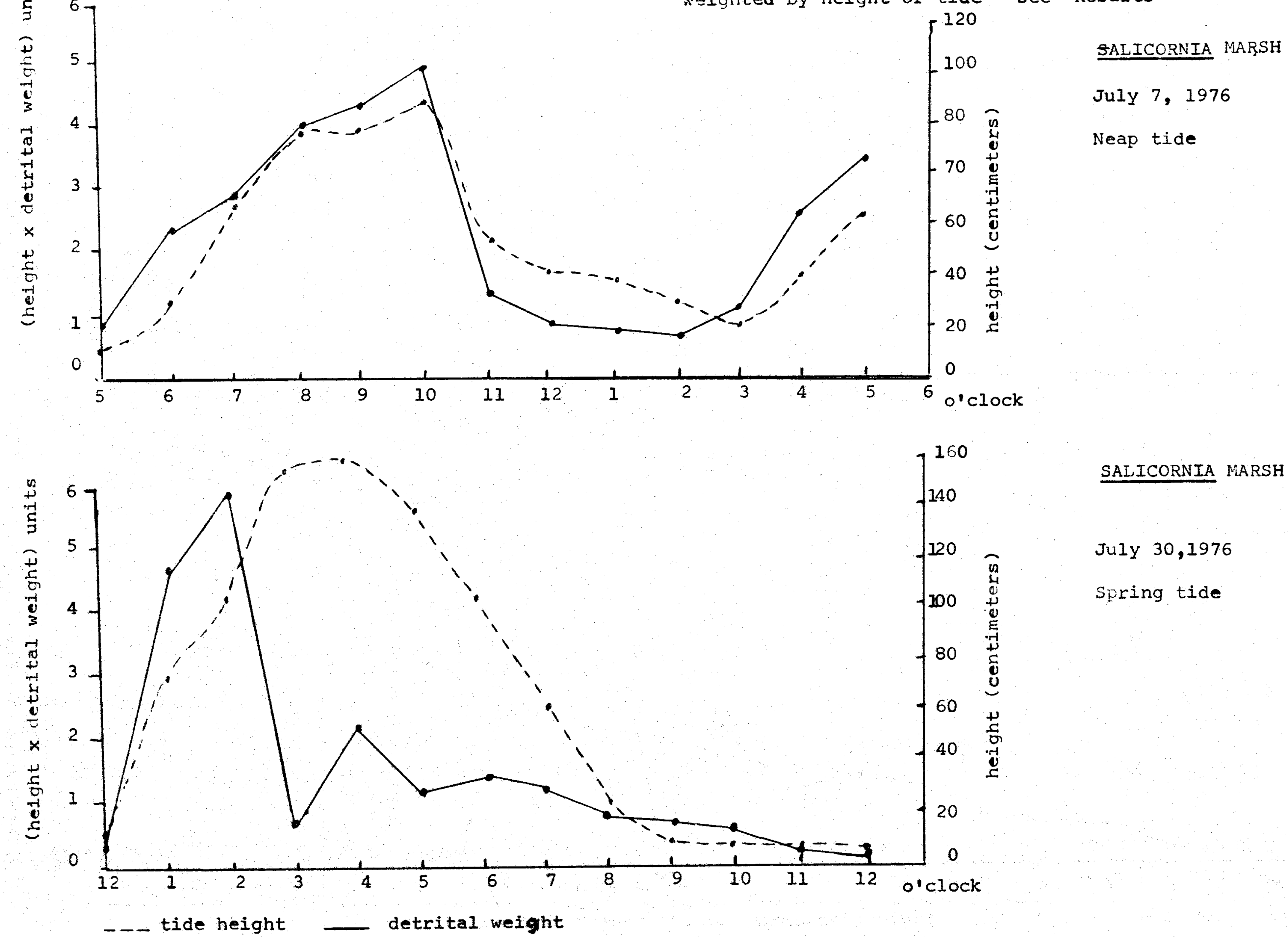


Figure 6: Changes in detrital weights* during a tidal cycle

* weighted by height of tide - see "Results"

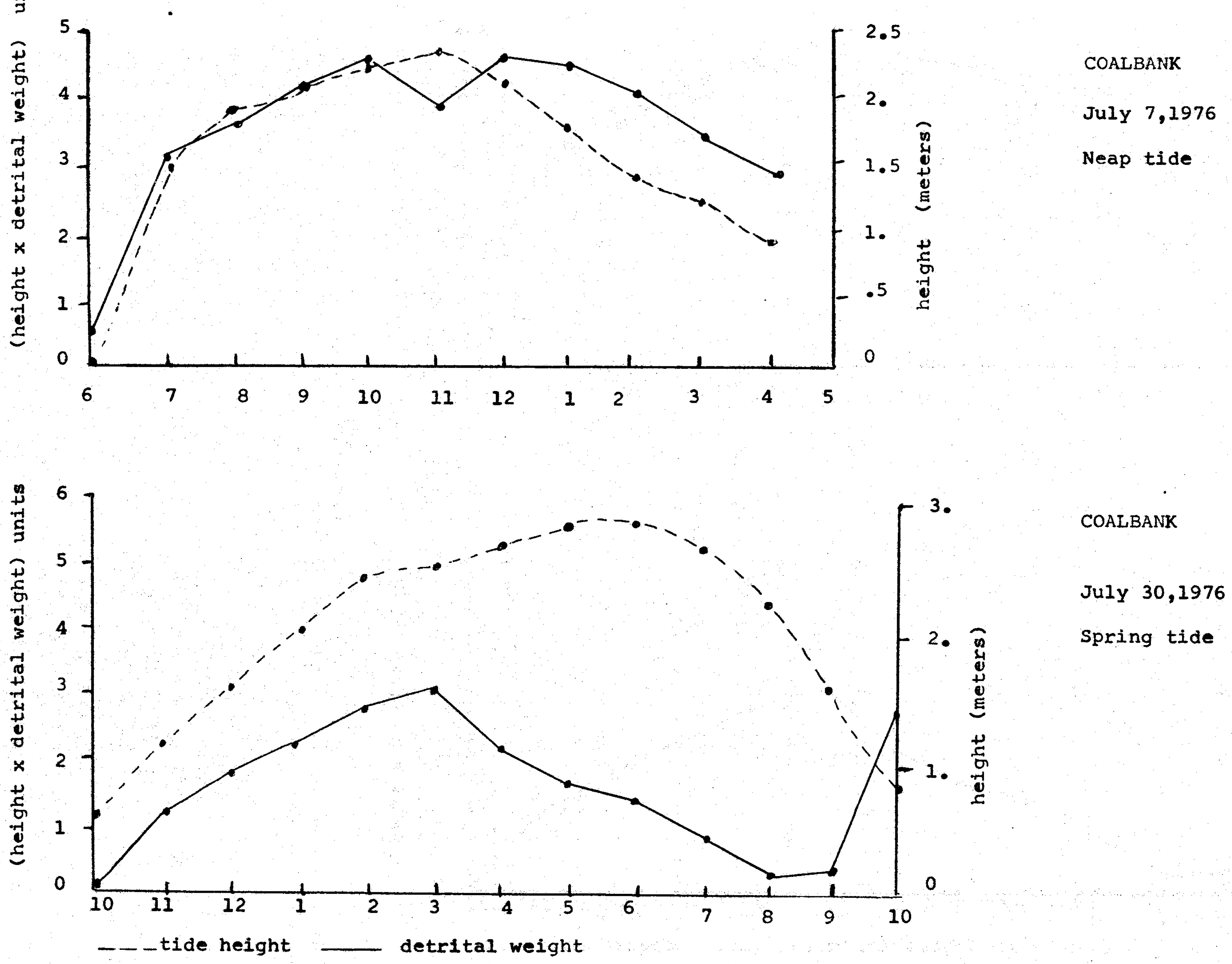


Figure 7: Height and flow as detrital export indices

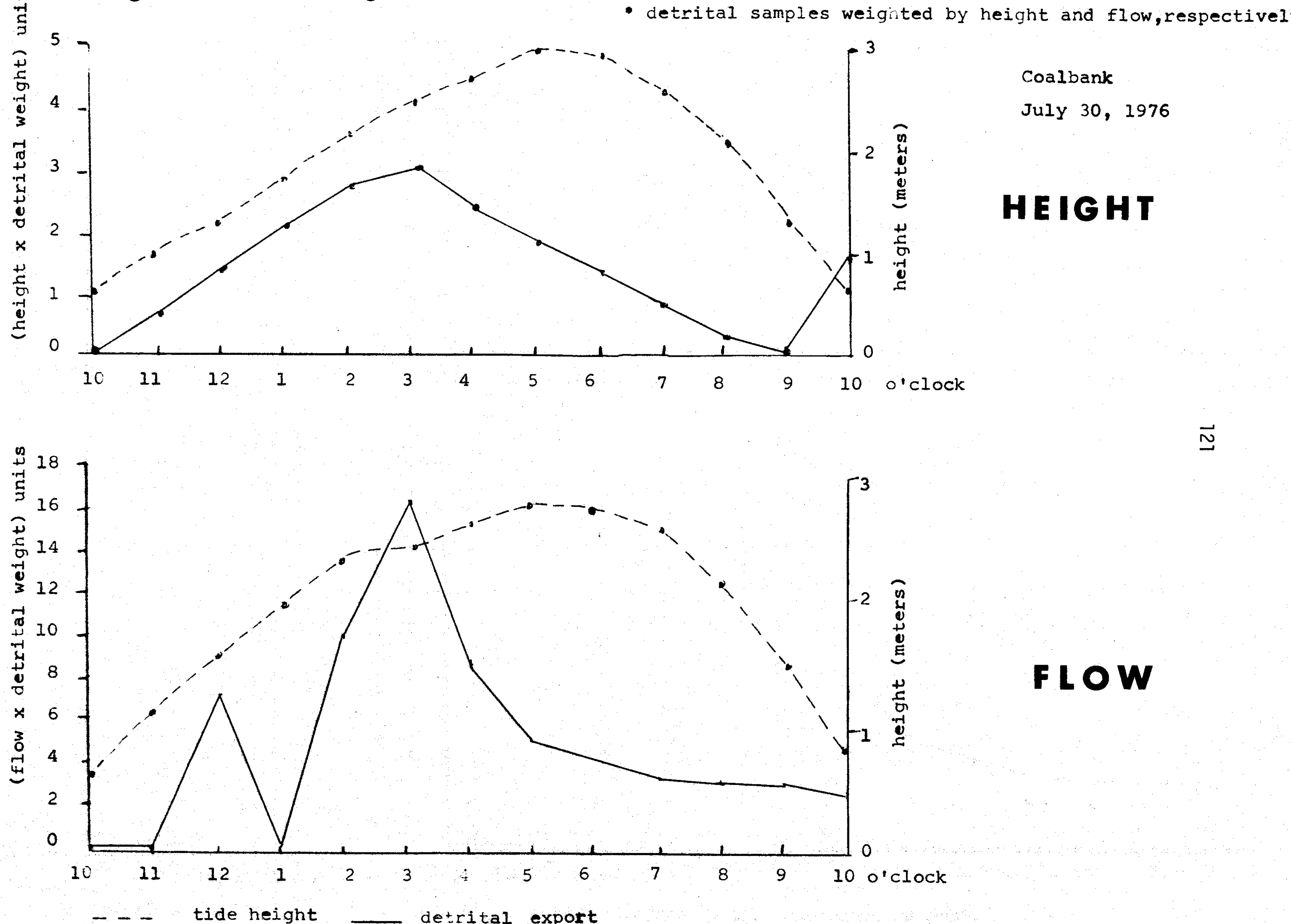


Table 5: Weights and percentages of Detritus in coarse, fine, and nannofraction.

marsh	date	time	tide	Coarse (mg)	Fine (mg)	Nanno (mg)	% Coarse	% Fine	% Nanno
SA	070776	8:15	midflow (Neap)	13	10	348	4	2	94
SA	070776	2:15	midebb	33	15	738	4	2	93
CO	070776	9:15	midflow (Neap)	9	5	223	3.8	2.1	94.1
CO	070776	1:15	midebb	2	15	490	.4	2.0	96.7
SA	073076	6:10	midebb (spring)	2049	259	1366	55.9	6.8	37.2
SA	073076	1:20	midflow	133	148	1552	7.2	8.1	84.7
CO	073076	1:30	midflow (spring)	114	158	1419	6.7	9.3	83.9
CO	073076	9:15	midebb	341	178	997	22.5	11.7	65.7
Average				80.6 (2049 excluded)	97.6	891.6	6.9	5.6	87.4

most cases seemed to be squarish pieces of vascular plant detritus on the order of a few cells in size. Odum and dela Cruz found the following in their East coast study (1968):

Table 6
Odum and dela Cruz's Mean Particle Composition

	Particles/Liter	Detritus	Phytoplankton	Zooplankton
Mid-flood	5,185	4,660(89.9%)	444(8.5%	81(1.6%)
Mid-ebb	24,615	24,038(97.7%)	422(1.7%)	155(0.6%)

These values seem credible in our system, except that no zooplankton was noticed in any of the samples. It is unfortunate that Odum and dela Cruz did not explain their methods more clearly. More recent studies use burning upon ignition in order to separate the relative amounts of sediment and living and dead organisms in sea water samples (Cruz and Orozco 1970, Mulkana 1968, 1969). It seems that some kind of stain would make it easy to identify vascular plants and separate them from algae and phytoplankton, but none was identified as a potential candidate.

Weir Net

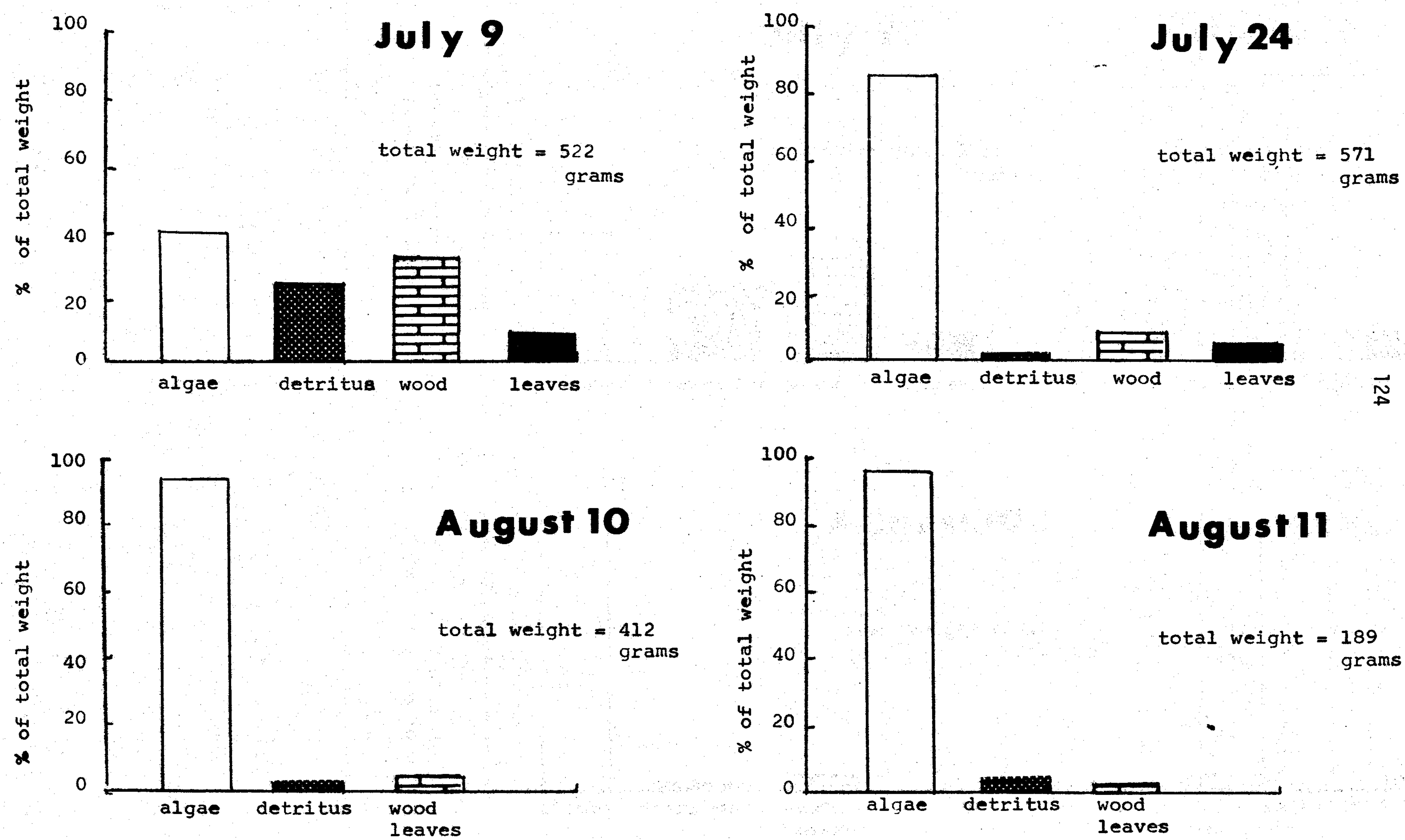
Estimates of detrital export from our macroseston net show interesting trends. The Salicornia marsh is highly marine and highly saline, as well as being relatively small. These facts are reflected in our findings. The relative components collected are shown in Figure 5. Algae, which made up the bulk of the material collected, was primarily Ulva sp., Enteromorph sp., Cladophora sp., Fucus sp., and Zostera marina. Detritus was primarily Salicornia, with some Carex and Jaumea being found occasionally. Alder leaves and alder catkins made up the terrestrial plant category. Floating bark, looking well weathered and coming presumably from the bay, was separated in some cases for clarity.

Incoming tides captured great amounts of Enteromorph sp. while outgoing tides captures Ulva sp. This may be due to the ease of capturing floating Enteromorph at higher tides. The Weir net data points to the importance of algal component in the salt marsh-estuarine ecosystem.

Conclusion

Energy flow within the salt marsh-estuarine ecosystem is one of the most complex imaginable. In addition to production and consumption processes being separated in time, they are also separated spatially. Any measurement of detrital standing crop is a product of complex events separated in time and space. Material produced decomposes at a fluctuating rate; some is exported to the estuary and some returns to the salt marsh soil. Putting any one event in this complex web in perspective requires knowing something about many events, and we do not have this knowledge. With these limita-

Figure 8: WEIR NET COMPOSITION



tions in mind, the following seemingly contradictory findings must be addressed in order to give us a general view of the salt marsh-estuarine ecosystem.

1. Plants decompose rapidly, both in weight and in internal substances.
2. Fragmentation accounts for the loss of some live plant material.
3. Whole plant loss is not a large factor in summer decomposition.
4. Dead standing crops do not completely decompose until the following year. By July, dead material is accumulating in salt marshes that will not be completely decomposed until the following April.
5. Less material was collected near the estuary than the terrestrial vegetation line.
6. Net imports of primarily small (2-6 micron) material in both neap and spring tides occurs throughout the summer.
7. Huge excess of algal material account for the largest amounts of material in some estuarine waters during the summer months.

The salt marsh ecosystem may experience two general seasonal phases. The production component occurs in the spring and summer and is characterized by high productivity of vascular plant materials and little export of these materials into the estuary. Low rates of fresh water runoff and relatively low tides as well as warm days account for this. During this time seston may accumulate within the salt marsh areas leading to some deposition of materials. Macroalgal components, *Ulva*, *Enteromorph* and eelgrasses experience growth and consumption during this time.

The second phase is the consumption phase. During the fall, winter, and into April, estuarine organisms utilize the dead material and associated bacteria from the past growing season in order to exist when production of algae and vascular plants is at a standstill. During this time, high winter tides and great amounts of fresh water runoff wash accumulated litter from the salt marshes into the estuary. This mechanical action accounts for smaller dead standing crops near the water in the summer months as well as in the winter months. Odum and dela Cruz (1968) state that slower decomposition rates in the winter, when peak detrital standing crops occur, help to balance the import of detritus into the estuary. Smaller detrital import in summer months is offset by faster decomposition rates.

Due to the shortness of the study period, this detrital section is at best inconclusive, but it is hoped that the questions generated and the techniques developed may be utilized in an annual study that may provide much sorely needed information on detrital inflow into the estuary.

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Bacteria...

A COMPARATIVE STUDY OF HETEROTROPHIC MICROBE-MEDIATE DECOMPOSITION RATES AND NUTRITIVE VALUES OF VARIOUS SALT MARSH PLANTS

Laura Stunz

Introduction

Microbes play an important part in the ecology of salt marshes. Bacteria in the sediments, particularly those of the sulfur cycle, are important in the recycling of nutrients and in the regulation of estuarine pH (Wood 1967). Additionally, heterotrophic bacteria are present at virtually every trophic level of the salt marsh ecosystem (Paviour-Smith 1955). The focus of this particular study has been those heterotrophic microbes which comprise the second trophic level, those which feed directly on plants.

The implications of microbial decomposition of salt marsh plants are of great significance in terms of estuarine energy flow. First, salt marsh plant breakdown rates are accelerated by microbial action, and aided by this the nutrients trapped in the plants are made available to the estuary. Secondly, microbial decomposition of plants converts plant materials, including cellulose which is virtually unusable by most estuarine animals, into utilizable microbial protein (de la Cruz 1965, 1974; Heald 1969; Gosselink & Kirby 1974). It is the seston, decomposing plants plus associated microbes, which forms a nutritionally rich diet for many of the estuary's filter feeders (Baier 1935).

The purpose of this portion of the study has been: (1) to establish that microbial action is important in the breakdown of plants found in the salt marshes of the Coos Bay estuary, (2) to determine relative _in vitro_ microbe-mediated decomposition rates for _Carex lyngbei_, _Salicornia virginica_, _Scirpus validus_ and _Zostera maritima_, and (3) to investigate the relative nutritive importance of these different plants.

Materials and Methods

Plant Decomposition

Green, growing _Carex lyngbei_ was collected from the field and dried at 100°C for 24 hours. The dried plant material was ground in a Waring blender and the resulting particles were separated via passage through screens of various mesh sizes. The particles which passed through a 60 mesh/inch screen but were retained by a 230 mesh/inch screen were collected, weighed into paper packets and autoclaved. Special attention was paid to the uniformity of particle size because of the findings of Gosselink and Kirby (1974) which indicate that bacteria utilize different-sized particles with differing efficiency.

Acid-washed 250 ml erlenmyer flasks were filled with 50 ml filtered seawater and sterilized. The contents of the paper packets were poured into the flasks, weights of the flasks being measured before and after to determine the actual weight of plant material added. The flasks were sealed with a sterile cotton plug.

A freshly collected sample of decomposing Carex was used to initiate a culture of bacteria on Difco nutrient agar made with seawater. The plate was incubated at 25°C for three days and then 0.60 gm of the mixed bacteria were added to 25 ml of sterile seawater, and 1 ml aliquots were added to each experimental flask. No bacteria were added to the control flasks.

Three of the controls were filtered immediately through a large-pored Buchner funnel lined with gravimetric grade filter paper. The recovered Carex sample was then transferred to a beaker and dried at 100°C for six hours. The remaining flasks were incubated at 25°C in the dark on a rotary shaking table. Three inoculated flasks plus one control were removed at intervals with the last four samples being removed on Day 14. Weight loss of samples was attributed to bacterial metabolism and to decrease of particle size due to microbial action. The controls were for the purpose of discerning whether mechanical action was causing particle size decrease, but they became contaminated.

A second variation of the above experiment was used to determine breakdown rates for samples of Salicornia, Zostera, and Scirpus, following closely the method of Burkholder and Bornside (1957). The differences lie in the method of inoculation, the processing of the samples, and the controls. Inoculate consisted of 1 ml of finely filtered (filter of 4.5-5.0 μ size), aged estuarine water. The controls were the time zero samples. The tared flasks plus samples were removed from the shaker table at approximately two day intervals, dried at 100°C to constant weight, cooled in a desiccator, and weighed. Loss of weight was attributed to microbial metabolism. Additionally, three flasks containing just 50 mls of seawater were dried and weighed in the same manner as the samples to determine the amount of residue left by the water. The average salt water residue value was subtracted from the final weights.

Nutritional Experiment

The methods used for this section follow closely those of Burkholder and Bornside (1957).

Plant media were prepared by weighing out 15 g of dried plant material which had been ground in a Waring blender and passed through a 230 mesh/inch screen, mixing the powder with 500 ml seawater, boiling the mixture for 5 minutes, filtering the mixture through Whatman biological grade glass fiber filter paper, and autoclaving the filtrate.

Mud samples were taken at 10 meter intervals along lines transecting each of the three marshes: Salicornia, Bull Island and North Slough. Equal portions of mud mixtures from each marsh were mixed together to total 20 gm, diluted with filtered seawater to 100 ml, boiled 5 minutes, filtered through glass-fiber paper and a scintered glass filter of pore size 4.5-5.0 μ . The filtrate was autoclaved.

Crude mud bacterial samples were obtained by mixing 10 ml sterile filtered sea water with 15 g mud samples, centrifuging the mixture and retaining the supernatant. A crude mud bacteria sample was amde from the mud of each of the three marshes. Salicornia marsh is hereinafter referred to as Low Marsh, Bull Island as Middle Marsh, and North Slough as High Marsh (as in the introduction to this report).

The bacterial mixture used in inoculation was obtained from samples from the decomposition experiment which had been plated on Difco nutrient agar made with seawater. 0.05 g of bacteria were mixed with 50 ml sterile filtered seawater.

A fifth bacterial source for this experiment was finely filtered, aged estuarine water.

The reaction vessels were acid-washed, autoclaved 50 ml erlenmeyer flasks. Two concentrations of plant extract were used, one consisting of 20% plant extract and 80% sterile filtered seawater, and the other consisting of 10% plant extract and 90% seawater. 20 ml samples were used, with 1 ml of bacterial source being added to each one. The mud extract was used in just one concentration, 80% seawater to 20% mud extract. Thirty-five reaction vessels were used altogether, two concentrations of each plant extract inoculated with each bacterial source, and one concentration of mud extract was inoculated with 1 ml of each bacterial source. The reaction vessels were sealed with parafilm and kept in the dark at 25°C between readings. Changes in turbidity were read at 620 $m\mu$ on a Perkim-Elmer spectrophotometer. Increases in turbidity were attributed to the increasing numbers of bacterial bodies present. Readings were made at time zero and every four hours for 48 hours, rather than just once, as in Burkholder and Bornside's experiment (1957) in response to a criticism by Gosselink and Kirby (1974). Optical densities of samples without bacteria added did not vary significantly from beginning to end of the 48 hour period.

Results and Discussion

Decomposition Experiment

The results from the *Carex* experiment are shown in Figure 1. *Salicornia* is in Figure 2, *Zostera* in Figure 3, and *Scirpus* in Figure 4. The points shown are the averages of the results from three flasks, and the vertical bars denote $\pm$ 1 standard deviation. It is interesting to note that the *Carex* experiment shows the smallest standard deviations overall despite the increased amount of mechanical manipulation involved in the method used. The large standard deviations are usually due to the unexplained aberrant high or low reading from one of the three samples.

Examination of the graphs shows that in every case an increase in weight occurred between the first and second readings. After the initial increase, the plants showed regular loss of weight with the exception of *Scirpus*, which continued to gain weight.

Carex (Figure 1) showed a gross loss of 31.62% in 14 days. This value cannot very well be compared to the others because the difference in recovery technique would tend to prejudice the results to read in favor of a more rapid breakdown rate.

Final values for the other three plants for 9-10 day periods show gross losses of 19.46% for *Salicornia* (Figure 2), 21.20% for *Zostera* (Figure 3), and 18.59% for *Scirpus* (Figure 4).

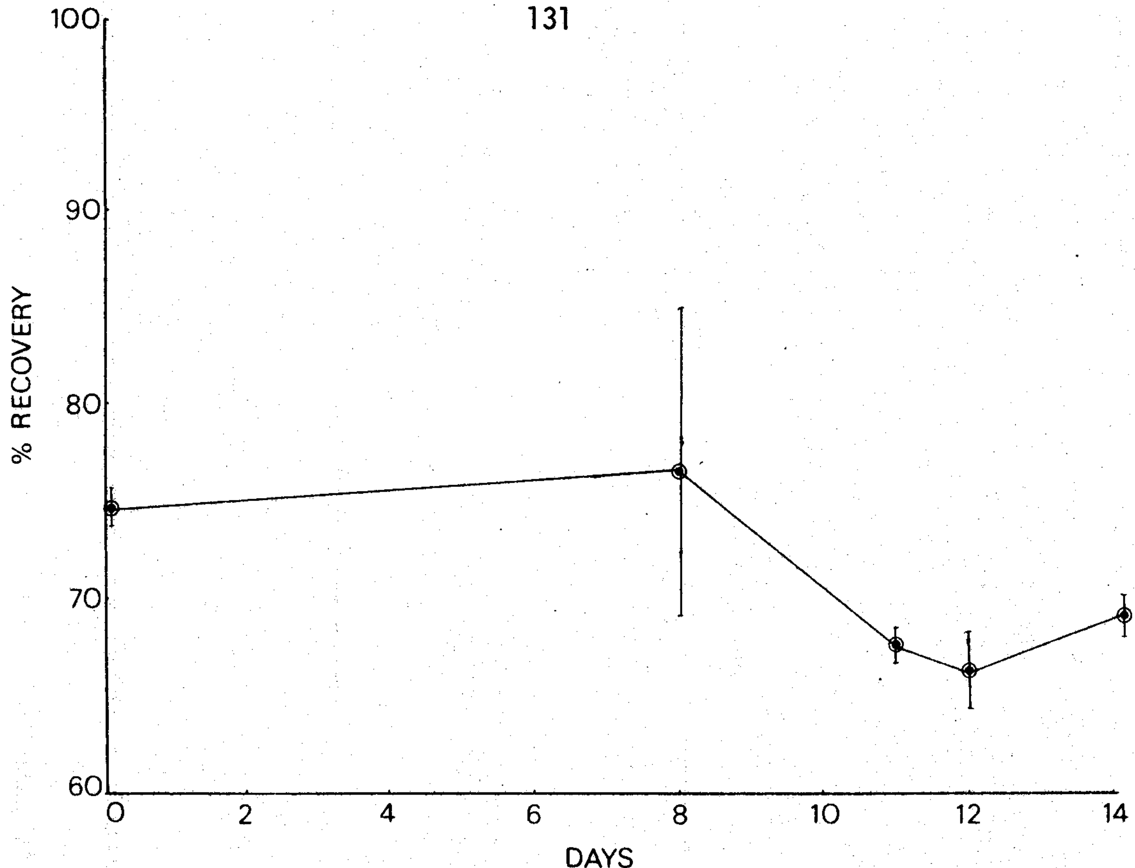

Figure 1. Carex decomposition.

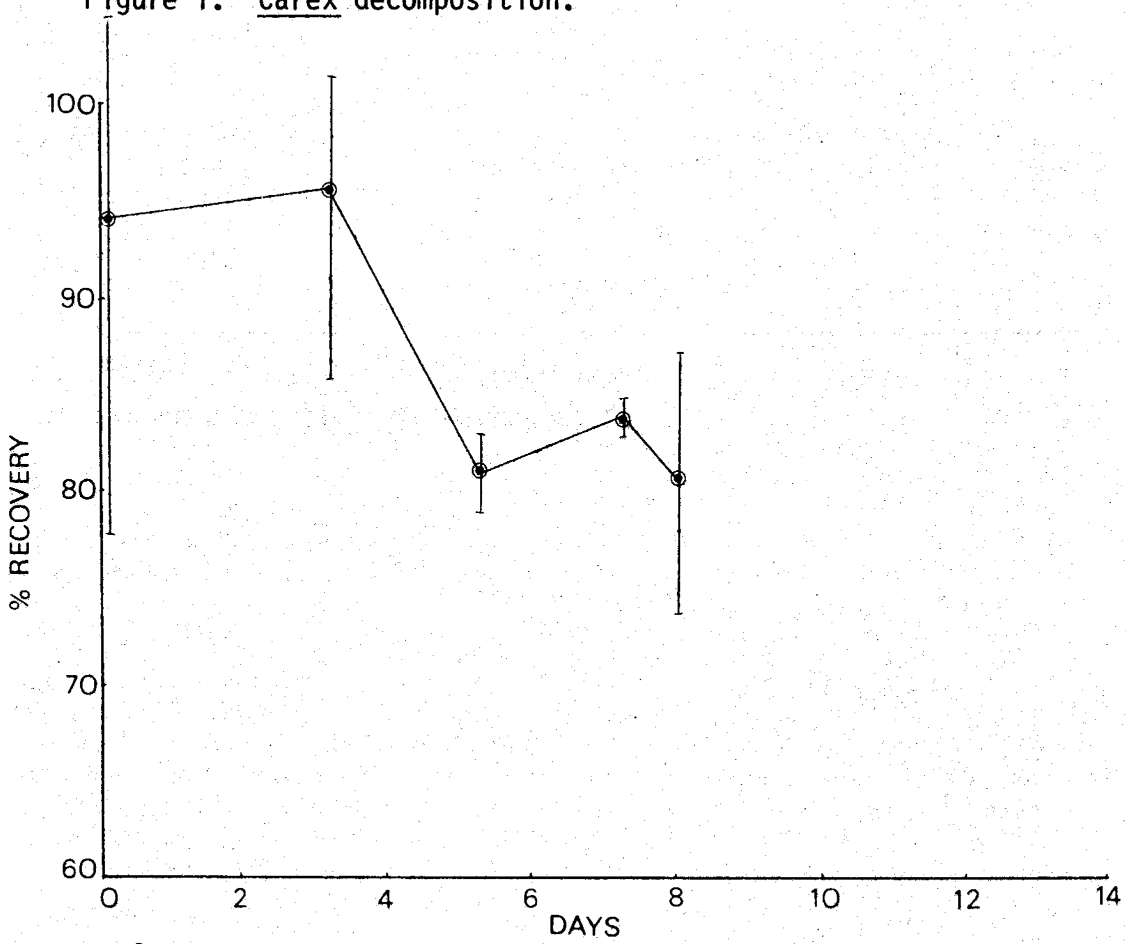

Figure 2. Salicornia decomposition.

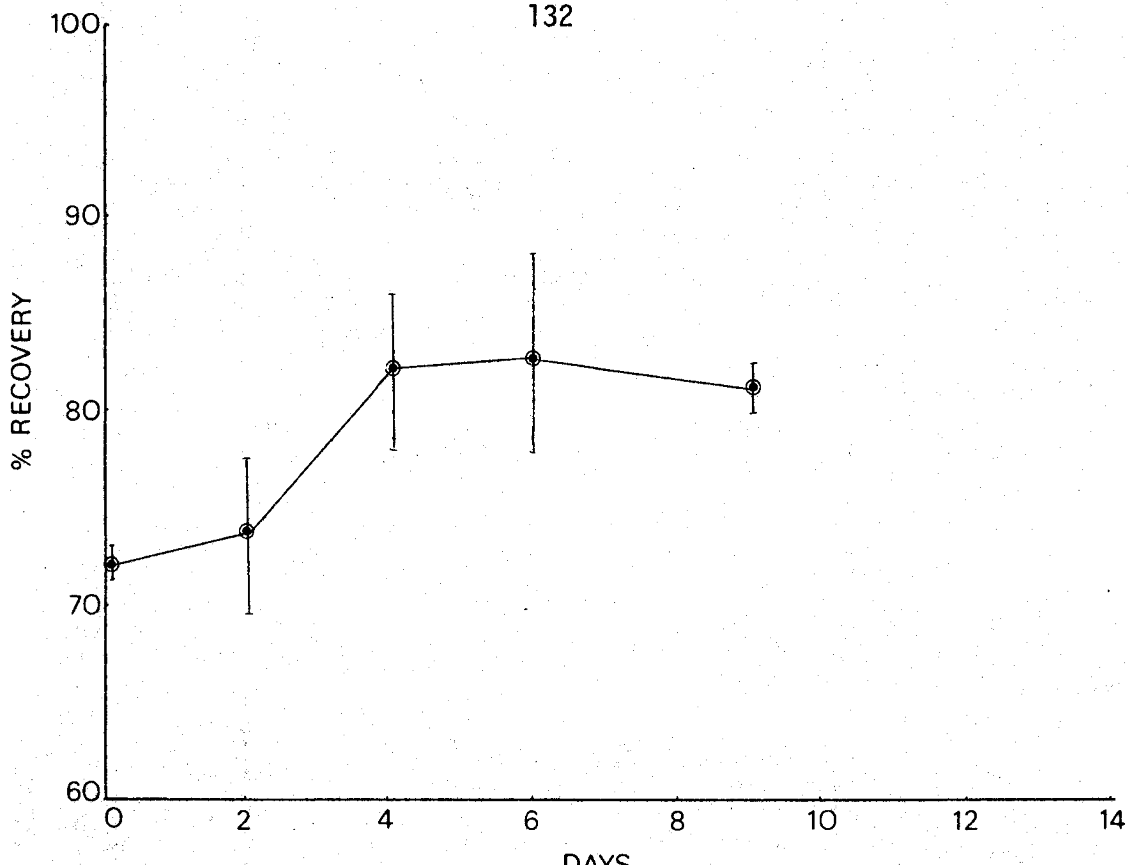

Figure 3. Scirpus decomposition.

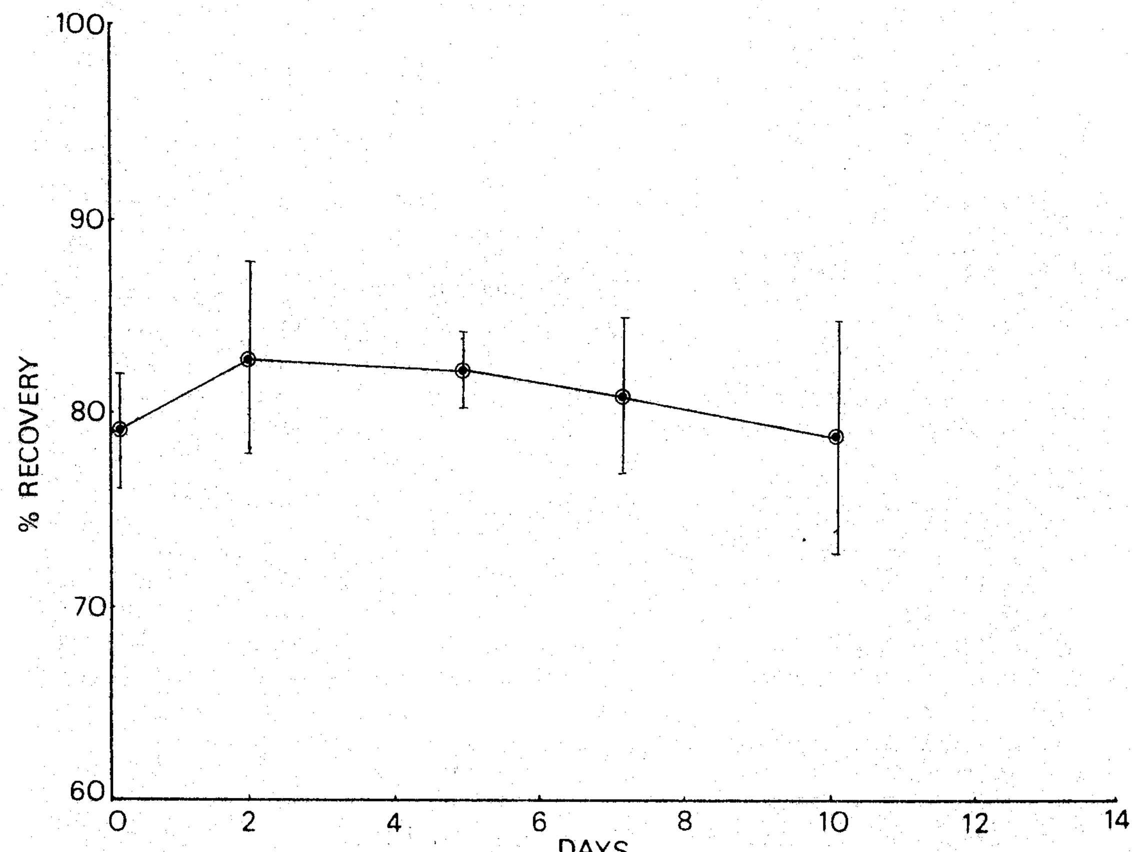

Figure 4. Zostera decomposition.

Net losses using the second reading as a starting point show the following results: Salicornia, 13.83% (6 days), and Zostera, 4.29% (8 days). The Carex value should be valid for comparison in this case as it is a net value. Carex shows a loss of 7.60% in 6 days, but this loss started with the eighth day of incubation. Up until the eighth day, Carex showed a net gain of 8.97% for the length of the run. It is possible that both Scirpus and Carex have a lag period before they begin to decompose. Both of these plants are quite fibrous and initial breakdown could be difficult.

For the short time span involved in the experiment, it appears that Salicornia and then Carex are quickest to decompose via microbial action. Comparing the in vitro figures to those obtained in the field (See Detritus Section, Figures 1 and 2), Scirpus in both cases showed a small gain in weight, Salicornia showed a 40% loss in the first month, levelling off after that, and Carex showed a 35% weight loss over the first month with the rate of loss being sustained over the summer. Thus the in vitro experiments are comparable to those done in the field.

Gosselink and Kirby obtained a gross loss of 25% in seven days in an in vitro decomposition of Spartina alterniflora (1974). De la Cruz and Gabriel obtained a gross loss of 25% in ten days in a similar experiment with Juncus roemerianus. These similarities are encouraging, but no real conclusions can be drawn from this sort of comparison due to the variability of techniques.

Another area of interest in this set of experiments is the initial solubility of each plant type. Carex showed a 25.14% initial weight loss. Again, this value is probably high compared to the others due to differing techniques. Salicornia showed an average loss of only 6.42%, with a wide variation among the samples. Zostera showed a loss of 21.19%, not surprising in light of the papery, brittle quality of the dried plant. Scirpus showed an initial solubility loss of 27.56%. A comparison of these values to the gross loss values indicates that Salicornia is very possibly broken down largely by microbial action. By the same reasoning, microbial action appears to be comparatively unimportant in Zostera breakdown, and of intermediate importance in Carex decomposition. Again, the results are baffling, but simple observation in North Slough reveals there such a dense Scirpus litter layer that the results obtained in vitro are not surprising.

Nutritive Experiment

The results from the nutritive experiment appear in Table 1. The mud samples show the least change in optical density. This agrees with the results obtained by Burkholder and Bornside (1957). The mud results coupled with the fact that bacteria are growing on the plant samples is evidence in support of the hypothesis that microbes from the mud are subsisting on something supplied by the plant.

Concentration effects are intriguing. The second number in each box in Table 1 corresponds to the reaction flask with the higher concentration of plant extract. The Salicornia reaction flasks definitely showed the presence of a limiting concentration of some substance which discouraged bacterial growth. Concentration

Table 1. Maximum changes in optical density over a 48 hour time span for plant and mud extract samples inoculated with bacteria from various sources. Low and high extract concentrations of plant extract are given for each inoculant source.

		Carex	Salicornia	Scirpus	Mud
Low Marsh Bacter	low conc.	0.056	0.147	0.028	0.020
	high conc.	0.058	0.090	0.135	
Middle Marsh Bacteria	low conc.	0.043	0.172	0.050	0.015
	high conc.	0.060	0.070	0.075	
High Marsh Bacteria	low conc.	0.060	0.150	0.095	0.015
	high conc.	0.063	0.103	0.055	
Bacterial Culture	low conc.	0.060	0.170	0.041	0.022
	high conc.	0.080	0.078	0.085	
Salt Water	low conc.	0.126	0.196	0.040	0.015
	high conc.	0.155	0.115	0.072	

effects were not so noticeable in the figures for the other extracts which suggests that the bacteria had an ample amount of food.

The salt water was consistently the source of the most proliferate bacteria. The reaction vessels contained mostly salt water and it could be that this environment was most conducive to salt water bacteria growth.

On the whole, examination of Table 1 shows the Salicornia medium to have been the most productive. This could have been due to a comparatively high nutritive value but not enough information is available to confirm this hypothesis. Carex, with Scirpus following closely, were not as productive media as was Salicornia, but both were still more productive than mud extract.

Conclusion

The results of this study cursorily point out some of the differences in microbial breakdown rates and provide support for the reasons behind them. Carex lyngbei can be characterized as a plant which breaks down moderately slowly but continuously to provide nutrition to the estuary, from the time of its summer peak production well into the winter. Salicornia virginica is a plant of lower peak productivity than Carex (See Primary Production section), but which continues to produce plant matter throughout the winter. The apparent high nutritive quality of Salicornia and its rapid decomposition rate, as well as the frequency of Salicornia marsh inundation indicate that Salicornia could well be of importance to the estuary in providing a constant source of utilizable food. Scirpus validus is highly productive, is of moderate nutritive value and decomposes very slowly. It is a high marsh plant which is washed into the estuary only at times of very high water.

Zostera maritima is highly soluble, constantly available, and may well be a year-round nutrient source although its immediate microbial breakdown rate is negligible.

The diversity of these plants' nutritive values and decomposition rates indicates that the salt marsh plants provide a nutrient pool which can provide the estuary with food year round. Bacteria, when associated with the decomposing plant matter as seston, serve to dramatically increase the rate of release of nutrients and improve the nutrient quality of the plants' contribution.

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Invertebrates...

THE NUTRITIVE VALUE OF SALT MARSH DETRITUS FOR ESTUARINE INVERTEBRATES

Robin Hall

Introduction

The invertebrates in an estuarine ecosystem form a major step in the detrital food web, not only for quaternary consumers such as salmon, but ultimately for humans as well. The role taken by such seemingly insignificant animals is essential in a complete study of salt marshes and their utilization. Mac Ginite (1932) and Baier (1935) were among the first to hypothesize that it is the bacteria involved in plant decomposition which are associated with detritus particles that form the mainstay of the diet of plankton and detritus feeders. As they die, salt marsh grasses may be used by the heterotrophic community in at least four ways: (1) dissolved organic substances ⟶ micro-organisms ⟶ higher consumers (2) dissolved organic substances ⟶ sorption on sediment particles ⟶ higher consumers (3) plant material ⟶ higher consumers (4) plant material ⟶ bacteria and fungi higher consumers.

Of the methods above, the first two depend on the rapid loss to the environment of the water-soluble organic compounds contained in the plant. These substances may be used by bacteria and other micro-organisms directly from the water. or they may become sorbed on other organic or inorganic particles in suspension, or in other sediments. These particles may then be ingested by invertebrates or fishes and the organic substances removed in the digestive tract and assimilated. The third method of degradation of salt marsh plants is immediate direct ingestion by higher consumers, and although this does occur, large plant peices appear to be more an accidental food of scavengers than a primary food source. Finally, the last route of energy exchange to be considered which is also hypothesized to be the most important in a detrital system, depends upon bacteria and fungi to break down the plant substances that are not digestible by most higher organisms.

The primary aim of the invertebrate study has been to determine if certain higher consumers can indeed utilize salt marsh plant detritus with its associated micro-organisms as a single source of nutrients. A second goal was to take a survey invertebrate species living within and in close proximity to various salt marshes, and it is this aspect which will be considered first. Since this is a major undertaking in itself, this survey was limited to a single transect in each of three major types of marsh.

Invertebrates Frequently Occurring in Three Major Salt Marsh Types, the Tidal Creeks That Disect Them, and Immediate Adjacent Areas

Three of the salt marshes were chosen for this survey as being representative of all marsh types in Coos Bay. These include the *Salicornia* Marsh, the major plants being *Salicornia virginica* and *Distichlis spicata*; the Bull Island Marsh, dominated by plant species

Carex lyngbei, Deschampsia caespitosa and Triglochin maritima; and the North Slough Marsh , essentially containing only Scirpus validus. A detailed analysis of the plant communities of each salt marsh may be found in the Site Description and Primary Production sections of this report.

One transect was run in each marsh perpendicular to the line of terrestrial vegetation out to the main salt water channel feeding the marsh. Samples were taken every ten meters, the first being located at the terrestrial edge. The study area was determined by placing over the vegetation a quadrat 0.5 x 0.25m (encompassing $0.125m^2$) constructed of wood with an open end to facilitate placing in dense herbage (Thilenius 1966). The site was then carefully observed for signs of invertebrate life. After capture of the less elusive of these animals, the plant cover was removed to within a few centimeters of the substrate. Once again, any animals observed were collected. Finally, a sample of the substrate $0.10m^3$ was collected and placed in a plastic bag. The various samples were then returned to the lab and, when appropriate, stored under refrigeration until identification could be confirmed. In the lab, substrate samples were wet sieved through two sets of screens, the first confining large animal and plant debris, the second retaining the small specimens while allowing most of the sediment to be washed away. The portion of sample remaining in the sieves was carefully examined for both living and dead faunal material.

The distribution of species due to the effect of increasing elevation was found to be insignificant due to the small sample size. An important environmental factor is the structural form of the vegetation on the marsh surface. The size and growth forms of marsh plants, the density of plant cover and the presence or absence of an algal mat, plant detritus or tidal flotsam all modify the environment (Macdonald 1969). The significance of these factors to the salt marsh invertebrates are mainfold: protection from predatory animals, presence of an adequate source of food, and the buffering effect of wave action that would otherwise prevent inhabitation of the area. Other, more direct effects such as "shading" may modify relative humidity, air temperature or dessication rates (Chauvin 1967). Therefore, a comparison of invertebrate distribution between marsh types is of interest (Table 1).

It should be noted that insect species are treated separately in a following report. However, it was observed that although insects were found in all marshes, a much larger number was found in the North Slough Marsh, where noticeably fewer other salt marsh invertebrates were collected. Perhaps this is an indication that this particular marsh is further on its way to becoming terrestrial than the other marshes considered. Although soil composition analyses were not conducted in this study, the substrate of this marsh contained considerably more decaying humus matter than the other marshes. For example, the Salicornia Marsh substrate is sandy-clay and mud, with a 40 cm reducing layer, while the Bull Island Marsh consists of coarse mud and sand with a 13 cm reducing layer and a layer of wood chips occurring in the tidal creeks about 10 cm under the water-sediment interface (Interdisciplinary Study of Coos Bay, 1970).

Obviously, not all invertebrate species from any marsh are represented in Table 1; however, it is believed that the comparison between relative numbers of species is accurate. The salt marshes

Table 1: Occurrence of various invertebrates in representative salt marshes.

Invertebrate Species	*Salicornia* Marsh: Marsh	*Salicornia* Marsh: Area	Bull Island: Marsh	Bull Island: Area	North Slough: Marsh	North Slough: Area
Phylum Cnidaris						
Class Hydrozoa						
Polyorchis sp.		+				
A. equorea sp.		+				
Class Anthozoa						
Nematostella sp.			+			
Phylum Nemertea						
Class Anopla						
Carinoma (rubia) mutatalis		+				
Lineus ruber		+	+			
Class Enopla						
Tetrastemma nigrifrons		+				
Phylum Annelida						
Class Polychaeta						
Nephtys californiensis		+				
Nephtys caecoides		+				
Platynereis agassizi		+				
Nereis vexillosa		+				
Nereis limncola			+			
Nereis brandti		+		+		
Hesperonoe complanata		+				
Pista pacifica		+				
Abarenicola pacifica	+	+				
Heteromastus feliformes	+	+	+			
Glycera americana		+				
Lumbrineris zonata		+				
Phylum Arthropoda						
Subclass Crustacea						
Class Malacostraca						
Hemigrapsus nudis		+				
Hemigrapsus oregonensis	+	+				
Cancer magister	+	+		+		
Cancer productus		+				
Pagarus hersulesculus		+				
Pagarus samuelis		+				
Pugettia producta		+				
Pinixia faba		+		+		
Callianassa californiensis		+				
Upogebia pugettensis		+				
Loihynchus cinspatus		+				
Crago francescorum			+			
Subclass Pericarida						
Order Isopoda						
Ligia pallasii		+	+	+		
Idothea wasnasenskii		+				
Gnorimosphaeroma oregonensis lutea	+		+			

Table 1: (cont.)

Invertebrate Species	Salicornia Marsh		Bull Island		North Slough	
	Marsh	Area	Marsh	Area	Marsh	Area
Order Amphipoda						
Orchestoidea corniculata		+	+		+	
Orchestia traskiana	+	+				
Amphithoe valida		+				
Corophium sp.			+	+		
Atylopsis sp.			+		+	
Subclass Cirripedia						
Order Thoracica						
Balanus sp.				+		
Phylum Mollusca						
Class Lamellibranchia						
Cryptomya californica		+				
Mya arenaria	+	+	+			
Macoma nasuta	+	+	+			
Protothaca staminea		+				
Tellina salmonea	+	+	+			
Clinocardicem nuttallii		+				
Mytilus edulis		+				
Class Gastropoda						
Littorina planaxis		+	+			
Acmaea sp.		+				
Hermessenda crassicornis						
Littorina scutulata	+		+			
Assiminea californica			+			
Phylum Bryozoa						
Alcyonidium sp.		+				
Phylum Echinopermata						
Class Asteroidea						
Pycnopodia helianthoides		+				
Pisaster ocraceous		+				
Evasterias troschelii		+				

of Coos Bay, and the tidal creeks that dissect them display a characteristic community structure; one or two species are common throughout one particular marsh, while the remaining species are randomly distributed and few in number. This is in agreement with Macdonald (1969) who found in a survey of Molluscs in eleven west coast marshes, that in each set of marsh or creek samples two or three species contributed over 90% of the live animals collected.

Laboratory Feeding Experiments
Materials and Methods

Feeding preference studies were carried out in the laboratory to determine whether particular species of salt marsh plant detritus are more condusive to growth of certain invertebrates than others. Three faunal species were chosen for these tests on the following criteria: suitability to life under laboratory conditions, availability, and potential commercial importance. *Mytilus edulis*, the bay mussel, was collected off floating docks in the bay and was therefore not habituated to daily tidal fluctuation. At the time of collection, the age of these pelecypods was approximately 3 months (Fox & Coe 1943). The Japanese oyster *Crassostrea gigas* was obtained in cultchless form (to facilitate growth measurements) from Oregon State Marine Science Center, Newport, Oregon, at an age of 4 months (Malouf, personal communication). Adult *Corophium sp.* were included in this study since they are a principal food of *Oncorhynchus kisutch*, a commercially important salmon. (Holliday, personal communication.) This species was collected with large amounts of substrate in plastic bags and returned to the lab where the animals were separated out by careful washing through a sieve.

Detrital food particles were prepared from four main salt marsh plants: *Salicornia virginics*, *Carex lyngbei*, *Distichlis spicata*, and *Scirpus validus*. In addition, a mixture of these four plants was prepared. Along with the marsh grasses, a common mud flat plant *Zostera marina* was included as a food source for comparative purposes. Live samples of these grasses were collected and dried at 100°C for 24 hours. This material was then broken down in a Waring blender with sea water which had been filtered through filter paper to remove most particulate matter, while allowing the passage of bacteria.

The sludge thus formed was coarsely filtered through a 240 meshes/cm nylon net in an aspirator apparatus. This filtrate was filtered once more through a five micron mesh Gaf filter to a size ingestible by all species. Jorgensen and Goldberg (1953) have shown that graphite particles of 2-3μ are completely filtered from water of the oyster *Ostrea virginica* and 80% or more of particles 1-2μ are passed through the gills. *Mytilus edulis* almost completely strains from the water graphite particles 1-2μ in diameter. Jorgensen (1954) further states that particles 1-2μ can be ingested by filter feeding copepods. The prepared food solution was placed in flasks and kept covered at room temperature in the dark in an attempt to prevent photosynthesizing organisms from dominating the culture. The detritus-water mixtures were cultured at least two days before being fed to the experimental animals, to allow adequate time for bacterial association and regeneration. In addition to these food sources, phytoplankton was collected from the surface of the bay in a net which retained particles larger than 10μ. This source was included in an attempt to represent the natural food of these invertebrates.

The amphipod Corophium builds small tubes in muddy sediments, so it was necessary to provide this species with a substrate, ideally one which would not contain an additional food supply. Since even autoclaved mud contains the nutrients of the bacteria originally living within this substance, it was decided that a substrate of detritus from the four salt marsh plants and Zostera would be prepared. The procedure used was the same as for the food solutions, except that ground plant material was filtered through a sieve; the supernantent was then removed by aspiration through the nylon net so that particles 30 to 70μ in size were retained. This material was placed in 1000 ml beakers to a depth of 1 cm. Filtered sea water was then added so that the total volume was 700 mls. Ten individuals were then added to each of the six beakers. Survival was used as an index to determine whether this species ingested various food sources, since size and weight measurements vary only slightly among individuals, and it is known that they must eat almost steadily to maintain themselves. Corophia were fed the food solution corresponding to the appropriate substrate every other day.

The initial length of each oyster was recorded along with the total weight of the ten individuals which were placed in each of eight 1000 ml beakers containing filtered sea water. These animals were fed approximately 0.04 gm of the Salicornia, Distichlis, Carex, Scirpus or Zostera solutions; another beaker was fed the same amount of phytoplankton; and finally as a control, the animals in the eighth beaker were not fed. The water in each container was replaced, and the animals were fed every other day for the entire 42 day experimental period. After this time, the wet weight, dry weight, and ashed weights were determined for the Crassostrea. The body tissues and shells were treated together, since separation at this age is nearly impossible. The animals were measured with a calibrated hand lens, accurate to 0.01 mm, dried at 100°C for approximately 12 hours to a constant weight, then ashed in a muffle furnace at 600°C for 24 hours. These figures are reported in Tables 4 & 5.

Mytilus edulis was raised in a similar manner; however, each individual was color coded with enamel paint so that growth of individuals could be recorded. Ten mussels were placed in each of eight four-liter containers with 1500 ml of filtered sea water. Each jar of animals received about 0.04 gm of the detritus-bacteria mixture: either Carex, Distichles, Salicornia, or Scirpus, a mixture of these, Zostera, or phytoplankton. The animals in the eighth jar served as a control and were not fed. The water was changed and the mussels fed every other day. This was observed to be the amount of time necessary for Mytilus to filter all of the water (Fox and Sverdrup 1937). At the termination of the feeding experiments, the mussels were weighed (wet weight), the animal tissues separated from their shells and each was dried to constant weight at 100°C for approximately 24 hours. Finally, both tissues and shells were ashed in a 600°C muffle furnace for 24 hours. The tabulated results of these processes appear in Table 3 .

Results

Mytilus edulis

The feeding experiments on Mytilus were conducted for 42 days, and after 30 days none of those fed on Scirpus or Zostera had survived. At the end of the period, only 10% of the mussels fed on phytoplankton remained; 30% of those raised on a mixture of the marsh grasses survived; 50% of the Salicornia-fed lived; 70% of the Mytilus that were fed Distichlis remained, and of those raised on Carex and those that were not fed, 80% survived. Figure 1.

Overall, the experimental Mytilus decreased slightly in length. However, they were still somewhat larger than 50 field animals picked at random from the same location at the end of the summer. The initial average weight for the experimanetal mussels was slightly higher than for the field animals, but the average final weight of the experimentals had dropped substantially. For mussels fed on two of the marsh grasses, Scirpus validis and Salicornia virginica, a decrease in length and weight was observed. Mytilus raised on Scirpus decreased significantly in weight ($0.05 < P < 0.025$) and those fed Salicornia show a highly significant weight loss ($0.02 < P < 0.01$). Mussels raised on Carex decreased in weight ($0.5 < P < 0.4$) as did those feeding on phytoplankton ($0.005 < P < 0.001$). When these animals were fed Distichlis, a mixture of the four marsh plants, or Zostera, no significant weight decrease was observed. Most intriguing was the weight gain of Mytilus which were raised for the entire experimental period without food. Table 2.

The percentage of water and ash in the tissues of Mytilus edulis was determined for each food source as was the percentage of ash in the shells. Table 3.

Crassostrea gigas

The experimental oysters, Crassostrea gigas, exhibited an overall average decrease in length and a slight increase in weight. Over the same period, 50 "field" oysters were raised in an open beaker in an outdoor laboratory with a steady flow of unfiltered sea water. Various algaes became associated with the container and were removed twice during the 42 day period. These "field" animals were, on the average,somewhat smaller than the experimentals, but each grew approximately a millimeter in length. A small gain in weight was also noted. Table 4.

Crassostrea which were fed Scirpus, Carex, a mixture of the 4 marsh grasses, Zostera, and those which were not fed, showed a small decrease in length. Those fed Distichlis, Salicornia and phytoplankton exhibited a slight increase in length. Those oysters which gained a substantial amount of weight include those raised on Scirpus, Distichlis, and Salicornia. Oysters which were fed on phytoplankton increased slightly in weight, and those fed Carex and the control

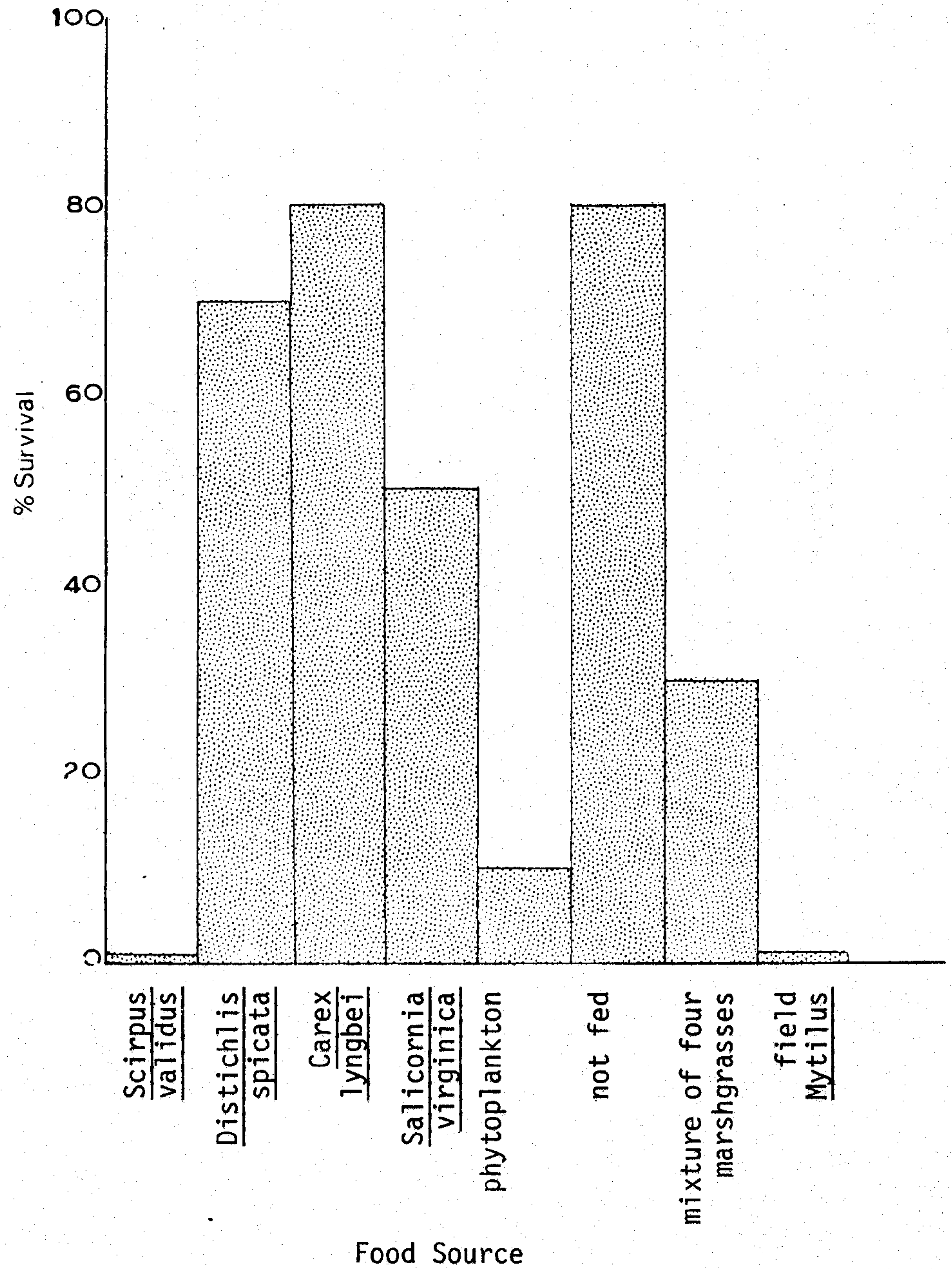

Figure 1: Percent survival of experimental Mytilus edulis fed on various food substances.

FOOD SOURCES	AVERAGE SHELL LENGTH (MM)		AVERAGE WET WEIGHT (GM)	
	Initial	Final	Initial	Final
Scirpus validus	21.5	21.4	1.17	0.5
Distichlis spicata	21.3	21.4	1.12	1.11
Carex lyngbei	21.8	22.3	1.14	1.03
Salicornia virginica	23.9	22.4	1.28	0.91
phytoplankton	20.3	20.3	1.14	0.67
none	21.6	22.3	1.25	1.39
mixture of four marsh plants	21.3	22.3	1.14	0.99
Zostera marina	21.7	--	1.17	--
field mussels	20.52	21.46	1.01	1.10

Table 2: Growth of *Mytilus edulis* as a function of seston food source.

			Tissues			Shells	
Food Source	Number of Individuals	Average Shell Length	Percent Water	Dry Weight Gms.	Percent Ash	Dry Weight Gms.	Percent Ash
<u>Scirpus validus</u>	2	2.14	69.20	0.018	27.78	0.328	92.53
<u>Distichlis spicata</u>	7	21.4	57.92	0.191	10.74	0.454	71.83
<u>Carex lyngbei</u>	10	22.3	48.08	0.062	43.92	0.432	92.20
<u>Salicornia virginica</u>	10	22.4	53.87	0.054	54.38	0.439	92.11
phytoplankton	7	20.3	72.41	0.031	26.83	0.394	88.67
none	8	22.3	43.86	0.191	5.43	0.416	89.56
mixture of 4 marsh plants	4	22.3	54.18	0.036	9.86	0.502	91.09
field animals	50	--	43.83	0.050	7.37	0.431	94.43

Table 3: Composition of shell and tissues of <u>Mytilus edulis</u> as a function of seston food source.

Food Source	Average Shell Length (MM)		Average Wet Weight (GM)	
	initial	final	initial	final
Scirpus validus	5.29	5.19	0.023	0.031
Distichlis spicata	4.89	4.91	0.016	0.023
Carex lyngbei	5.31	5.08	0.025	0.022
Salicornia virginica	5.24	5.19	0.016	0.025
phytoplankton	5.02	5.24	0.025	0.028
none	5.58	5.34	0.025	0.023
mixture of 4 marsh plants	5.46	5.41	0.022	0.014
field oysters	5.58	5.02	0.020	0.014

Table 4: Growth of *Crassostrea gigas* as a function of seston food source.

Food Source	Average Shell lgth	Dry Weight	Percent Water	Percent Ash	Percent Organic
Scirpus validus	5.19	0.140	45.16	85.00	15.00
Distichlis spicata	4.91	0.116	64.44	90.52	9.48
Carex lyngbei	5.08	0.154	70.00	78.57	21.43
Salicornia virginica	5.19	0.118	59.00	89.83	10.17
phytoplankton	5.24	0.104	52.00	90.38	9.62
none	5.34	0.174	75.65	91.95	8.05
mixture of 4 marsh plants	5.41	0.130	92.86	91.54	8.46
Zostera oysters	5.02	0.123	87.86	91.87	8.13
field oysters	4.77	0.017	94.32	94.04	5.96

Table 5: Composition of whole *Crassostrea gigas* as a function of seston food source.

group which was not fed decreased slightly in weight. The Crassostrea which decreased substantially in weight include those fed a mixture of the four marsh grasses, and Zostera.

The per cent of water, ash and organic material for each food source is shown in Table 5. The average per cent water for the experimentals was 68%, and for the field animals 94%. The average per cent ash for the experimental oysters was 89% and for field oyxters 94%. The per cent organic materials as determined by ashing was found to be 11% for experimentals and 6% for field Crassostrea.

Discussion

The probable fate of marsh plant debris is that its carbon is gradually diminished by a population of micro-organisms (further discussed in the Bacteria section of this report) which are in turn periodically digested by various invertebrates (Baier 1935). It has been demonstrated that bacteria have the capacity to survive and multiply on substrates at concentrations of one part in ten million (Zobell & Grant 1942, 1943). In such considerations, the importance of adsorbing surfaces is evident. Bacteria which aggregates on large masses of minute particles of detrital substances are the lytic agents responsible for the derivation of organic solutes from such material. An important source of food for estuarine invertebrates is marine detritus, existing in finely divided, partly even colloidal condition. To become utilizable by a multicellular organism such as the mussel, organic solutes (e.g. amino and other organic acids, monosaccharides, and dissolved nitrogenous waste products) must first be convertable into particulate matter by bacteria and other microorganisms, which assimilate the raw materials into protoplasm (Fox & Coe 1943). This population of micro-organisms is digested during passage through the gut, so that fecal material is returned to its original composition, except that there has been a slight loss of carbon through the activity of the associated bacteria and fungi. This was demonstrated in experiments by Newell (1964) which reveal that the original percentage of carbon is slightly reduced during culturing but remains constant during passage of the material through the gut. The nitrogen percentage, however, rises rapidly during culturing, irrespective of illumination, and falls off rapidly during passage through the gut. From this he concluded that the nitrogen represents a population of bacteria and associated microorganisms which abstract nitrogen from the sea water (and also possibly from the air) and oxidise the carbon of the fecal pellets thus obtaining necessary energy.

Mytilus Edulis

Mytilus edulis is a mucus feeder and secretes sheets of this substance over the gills, which entraps all microorganisms and detritus particles drawn by the action of cilia into the mantle cavity. This material is then either ingested or rejected as pseudofeces from the mantle cavity. Examination of the stomach contents, digestive diverticula and feces of the mussels reveal that the digested material includes dinoflagellates, bacteria, flagellates and other protozoans, other microorganisms, invertebrate ova and spermatoza, unicellular and filamentous algae, algal zoospores together with detritus consisting of chloroplasts, fragments of cellulose, granules of starch and glycogen, oil globules and protein particles from the disintegrated cells of dead animals and plants (Coe & Fox 1942). As further proof of the actual digestion of seston (detritus with its associated microorganisms), Zobell and Landon (1937) have demonstrated the presence of digestive enzymes which lyse bacteria.

Feeding experiments on both species of Mytilus (californianus and edulis) have been attempted with varying degrees of success. In 1937 Zobell and Landon reported that in a nine month study they observed a 12.4% weight gain on coccus-fed Mytilus californianus, bacillus-fed mussels gained an average of 9.7% and the fasting controls lost an average of 6.8%.

Scheer (1949) found that California mussels raised in aerated vessels supplied with various artificial diets, including one group fed on a pure culture of the diatom Nitzschia, invariably showed a loss of tissue weight after a month or more. The loss was smallest on those mussels fed on this diatom.

Fox and Coe (1943) carried out extensive feeding experiments on this same species, including in one group as nutritional sources Ulva, corn meal, mussel flesh, and calcium carbonate in various combinations, and they observed at the end of a three month period no growth in length (or change in shell weight) and a 6% loss of tissue weight. Control animals living in their natural habitat gained an average of 22 mm in length over the same period.

In a second experiment, freshly ground eelgrass (Phyllospadix) and Eisenia arborea, a brown kelp and calcium carbonate were used in differing amounts as foods and decreases in tissue weights of 47.2%, 51.7%, and 42.4% were reported with no change in shell weight. In this study a control group was kept in aerated water only, without food or added calcium carbonate, and these mussels sustained smaller losses in tissue weight than any of the other groups. This fact was attributed not only to a failure to use the provided materials as food but that from them decomposition products were formed which were actually harmful.

In the feeding experiments conducted on the Coos Bay salt marsh plant detritus, a similar result was obtained: the control mussels had a high survival rate and small loss of weight. It is possible that these animals go into some form of "hibernation", (slowing all life functions) under the unfavorable conditions imposed by the experiment.

In a third study by Fox and Coe (1943), Mytilus were fed mixed cultures of diatoms, scrapings from surface mud containing algae and associated microscopic organisms and detritus, with occasional additions of living spermazoa, crushed ova and ground desiccated annelid and mussel tissues. The water in the containers of these animals was replaced each day, allowing for only eight hours of feeding. In this experiment, which lasted three months, there was an average monthly increment in length of about 2 mm. In a control group without artificial feeding, there was no perceptible growth.

Starvation experiments were also carried out by Fox and Coe (1943) and they reported a loss of from 54.5 to 83% of the dry weight of the mussels over a 4-1/2 to 6 month period. For the Mytilus edulis of my study, a 1 to 10% weight loss was observed over a 42 day period, indicating that while growth was not usually evident, these mussels were far from starvation. According to White (1937), about 83% of the substance of normal living tissues consists of water. In this study, the average water content was 57% for the experimentals, which is still higher than the 44% determined for the field mussels. Fox and Coe use percent water as an indication of health, with higher percentages indicating a poor condition, but their numbers are more similar to that reported by White. The dry weights and percent ash of both shells and tissues are similar to those reported by Fox and Coe (1943).

The ecological effects of Mytilus relate to the organisms which are secured as food and those the mussel supplies with food. The latter include such animals as birds, fishes, Molluscs, Crustaceans, and Echinoderms, which feed directly on the mussels; and those which benefit from the metabolic activities of the mussel through its discharge of waste products and more particularly its sexual products (Fox & Coe 1943).

Crassostrea gigas

The oysters feed in a manner similar to that of Mytilus, sheets of mucus are produced and are used to strain out small particles of food from the water. The frontal cilia move these sheets to the labial palps which "feed" the material into the mouth. Oysters and other bivalves react to a variety of disturbing factors by stopping the secretion of the mucus sheets, so that actual feeding is interrupted (Korringa 1952). The gills, however, may continue to pump water, so it is evident that the rate of pumping is not a measure of feeding as has often been the case reported in the literature.

Loosanoff (1949) has demonstrated that the food of oysters is not limited merely by size and shape. Yeast cells are rejected as pseudofeces even when mixed with plankton of the same size which is known to be readily ingested. This has led to the belief by this author that chemoreceptors are located on the labial palps which are capable of recognizing inimical organisms.

Efforts of various research groups to fatten oysters for commercial production have often failed, and Lossanoff and Engle (1947) found that there are definite concentrations above which the density of microorganisms begins to interfere with the rate of pumping. This has not been caused merely by the clogging of the gills, leading to suffocation, but is believed to be the result of the build-up of toxins produced either by the plankton or bacteria which are associated with the seston. The exact point between feeding the experimental systems sufficiently and overfeeding to the point of killing from the build-up of these toxins is difficult to establish. However, in my experiments, neither of these two extremes was reached.

Although the food source of oysters is still in hot debate, a lot is known about growth. Shell growth occurs periodically and has been found by Malouf (personal communication) to have an optimal temperature of 17°C. This was, therefore, the temperature used throughout this study of feeding in invertebreates. Other factors influencing growth include presence of sunlight, leaner animals result from growth in the dark. In my experiments, the temperature control box was not lighted, nor was it open to room or sunlight. The "field" oysters were, however, in the daylight continuously. Another parameter affecting growth is water circulation (Kerswill 1949). In the estuarine system, the positioning of trays holding oysters has an effect on shell production. In the laboratory, aeration (which was occasionally faulty) was the only means of water circulation.

A probable cause of the "negative growth" which was observed has been reported by Korringa (1952). The oysters excrete measurable quantities of lactic acid, which free CO_2 from the animal's shell. Further, excessive handling of each oysters was necessary during the replacement of water (every other day), and very small fragments of shell broken off the growing shell edge.

Corophium sp.

The Corophia raised in sediments prepared from Carex, Distichlis, Salicornia, Scirpus, a mixture of these marsh grasses and Zostera survived only six days. This is best explained by the problems posed by the sediments themselves. Finely ground plant materials do not pack together to form a firm substrate, rather they remain partially buoyant and do not allow these Amphipoids to build the tubes necessary to support their fragile bodies.

The nature of the substrate and the salinity have been found to be the two main factors leading to the localized distribution of Corophium (Hart 1930). These Amphipods are common in coarse, alkaline muds where small puddles cover most of the surface at low tide. They form burrows or tubes (in soft muds) which are usually less than 5 cm deep, and are U-shaped with two openings. They are common in South Slough of Coos Bay, and do not occur in black muds or in association with Zostera. Hart (1930) has attempted raising these organisms in the laboratory on sterile mud, seived mud and mud from their natural habitat; the Corophium lived 2, 6, and 7 weeks respectively. From this and the negative results of feeding experiments involving Ulva, Enteromorpha, and decaying deciduous leaves, he has concluded that these amphipods, like other detrital deposit feeders common in estuarine muds demand a diet of seston for survival.

Corophia are, in turn, ingested by other animals further up the food web, including flounder, salmon, wading birds and gulls.

Summary

The feeding expeirments carried out on Mytilus edulis, the bay mussel, indicate the relative order of importance of those salt marsh plant detrital and other food sources in order of decreasing animal survival, as follows: Carex lyngbei, Distichlis spicata. Salicornia virginica, a mixture of the four marsh plants, phytoplankton, Scirpus validus, and Zostera marina (Figure 1).

Similar experiments on the oyster Crassostrea gigas indicate in order of decreasing experimental importance: Salicornia, Distichlis, phytoplankton, Scirpus, Carex, mixed marsh plants and finally Zostera marina.

In summary, the detritus, which may consist of an entire 2.5 m Scirpus plant or particles a few microns in size, is attacked by various microorganisms which begin oxidation, hydrolysis and assimilation of its basic carbon structure. During the process of microbial breakdown, the bacteria are continuously grazed upon by protozoans. The complex thus formed, seston, is of great potential nutritive value, and it is this community which may be ingested by larger organisms such as mussels, oysters and fishes. Most of the bacteria, fungi and protozoa are digested off the particle. In addition, there may be intestinal microbes which further reduce the particle and provide the host organism with nutrition in the form of excreted organic substances or the body of the microorganism itself. Once the particle, or fragments thereof, is released as fecal matter into the water, the entire process begins again. A single particle may be ingested and reingested in this manner by a number of different detritus feeders with the size of the particle decreasing with the completion of each cycle. Eventually it reaches a very small size and becomes joined together with a number of like particles to form a conglomerate, and the process begins again.

The invertebreates of the estuarine society comprise a major portion of the detrital food web, and link the bacterial and fungal microorganisms to other species which we recognize to be commercially important. These include such invertebrates as clams, mussels, shrimp and crab; and such vertebrates as salmon and tuna, which will be dealt with in the next section of this report.

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Insects...

DISTRIBUTIONS, TROPHIC RELATIONSHIPS, AND ENERGETICS OF SALT MARSH INSECT POPULATIONS

Joe Schrag

Introduction

Energy from the salt marsh is dispersed into two different ecological systems. Some energy is exported into the bay, and some is used by terrestrial organisms. The insects are among the consumers in the terrestrial system and, therefore, must be considered in assessment of the importance of the salt marsh to the entire estuarine system.

Few studies have been done on salt marsh insects, particularly those of west coast marshes. Much of the work which has been done has focused on insects found in Spartina marshes (Davis and Gray 1966, Smalley 1959, 1960, Teal 1962, Marples 1966). Spartina, however, is a plant species which does not occur in the present study sites. The objective of this study is to determine both the taxonomic make-up and the energetics of the insect communities in this area. This will aid in evaluating the importance of the salt marsh and will provide information for the comparison of insect assemblages in east and west coast marshes and for comparison of different marsh types.

Materials and Methods

Sampling Procedures

Coverage of a large area is necessary in order to efficiently describe the insect fauna. This study was limited in time, so the sweep net method of sampling was chosen. This method allows coverage of a large area in a relatively short time and is a good method for comparison of populations (Beall 1935). Though Menhinick (1963) has shown that weather conditions can affect the results of sweeping procedures, it was felt that an adequate description of the community could be attained. Weather conditions at the time of sampling were recorded to minimize bias. A Turtox/Cambosco net as used. The muslin bag was supported by a heavy metal ring and was 50 cm deep and 30 cm in diameter. The handle was 65 cm long and 3 cm in diameter.

Each of the marshes was divided into three zones. Where possible (Pony Slough, Metcalf Est. Pres.) the zones were determined on the basis of dominant plant cover. Typical zonation consisted of a low Salicornia stand, a Distichlis stand in the middle of the marsh, and an upper sedge stand. Where plant cover was somewhat uniform (South Slough, Bull Island) the zones were separated on the basis of distance from the bay.

Three sets of 25 sweeps were taken at each sampling station. Stations were established in each marsh zone. A step forward was taken after each stroke to prevent overlap. It was necessary to move upwind to insure that the bag was open throughout the stroke. The catch was taken to the lab and specimens were keyed to family from keys found in Borror, DeLong, and Triplehorn

(1976). These samples were supplemented by samples from the transects done to determine the invertebreates present in the marshes (see Invertebrate section for methods).

Energetics

Ingestion Rate

The leafhoppers (Homoptera: Cicadellidae) were found to be among the dominant herbivores and were, therefore, chosen as subjects for the energetics studies. Groups of ten individuals were weighed and cultured on a known weight of Distichlis at room temperature (22-24°C). This plant was chosen as a food source because the largest numbers of leafhoppers were found in Distichlis stands, indicating its use as a food source in the natural system.

The plant material was weighed daily, the difference in weight being attributed to consumption by the insects and water loss. Three controls were used to account for the dessication. Plant samples with weights similar to those being used as a food source were placed in culture bowls and weighed daily. Dessication was the only source of weight loss, as nothing was allowed to feed on these samples. Consumption was computed from the equation:

$$C=I_e-F_e\left(\frac{I_c}{F_c}\right)$$

where C is consumption, I_e is initial weight of experimental samples, F_e is final weight of experimental samples, and I_c and F_c are initial and final control weights, respectively (Reichle 1967). The average value from the three controls was used.

The experiments were carried on for two days. A longer time was desired, but problems were encountered which cut the experiment short. The mortality rate of the specimens was high, dessication being the suspected cause. Placing wet paper towels on the bottom of the bowls reduced, but did not eliminate, the problem. Consumption per gram per hour was computed by using the weight of the individuals remaining alive at the end of the 24 hour feeding. It was assumed that the consumption by the individuals dying in this time was negligible.

Respirometry

After determining the ingestion rate, it became necessary to estimate the rate of assimilation. This was calculated from the relationship

assimilation = respiration + production

Respiration costs include energy used for maintenance of body functions and energy used for activity. Production includes energy used for growth and reproduction. The mortality problem precluded estimation of growth from successive daily weights of experimental specimens. Production was then assumed to be 25% of the respiration costs (Teal 1958, Slobodkin 1960).

Determination of the metabolic rate provided an estimate of the energy cost of respiration. Specimens were weighed and placed in a 15 ml reaction vessel. A piece of filter paper 7.0 cm in diameter was quartered and one section was saturated in 5% KOH and placed in the vessel. The vessel was then sealed and a pipette graduated in 0.01 ml was attached. Water was used as manometer fluid and fluctuations in the volume of water in the pipette indicated the amount of oxygen being consumed (Weigert 1964, Engelmann 1961). For determination of the basal metabolic rate the flask was darkened by wrapping with paper towels to reduce activity. The temperature was kept at 23°C.

The RQ was not calculated, but was assumed to be 0.82 for the EMR (Roeder 1953) and 1.0 for the active insects. Oxygen consumption was calculated in ml/g-hr and converted to calories/g-hr using conversion factors of 4.825 cal/ml O_2 for resting metabolism and 5.0 cal/ml O_2 for active metabolism. The sum of active and basal respiration is equal to the total respiration cost.

Calorimetry

Consumption was calculated in grams Distichlis/g-hr. Conversion to calories/g-hr was necessary in order to calculate assimilation efficiency, making the determination of the caloric equivalent of a known weight of the food source essential. A bomb calorimeter was not available, so a simple calorimeter was constructed for a crude estimation of this value.

A 10 ml beaker was placed inside a 50 ml beaker, with 20 g (20 ml) of water being used as insulation between the two. A small sample of Distichlis was burned in the small beaker and the temperature of the beakers and the water were monitored. The amount of heat lost by burning the sample was equal to the heat gained by the apparatus. This value was calculated from the equation:

$$H=c_1m_1\ t+c_2m_2\ t+c_3m_3\ t$$

where H is heat lost by the sample; c_1, c_2 and c_3 are the specific heats of the two beakers and the water; m_1, m_2 and m_3 are the respective masses; and t is the change in temperature. The specific heat of water is 1.0 and that of the beakers was found to be 0.20 (Morey 1938). The mass of the small beaker was 8.44 g and of the large beaker was 27.18. The equation thus has the form

$$H=8.44(.20)\ t+27.18(.20)\ t+20(1.0)\ t$$

Three samples were burned and the average value was used.

Results and Discussion

Distributions of Insects

A total of 27 families representing seven orders (Diptera, Homoptera, Hemiptera, Hymenoptera, Coleoptera, Lepidoptera, and Orthoptera) were collected by sweeping. Only the first four orders listed were consistently collected. Though never collected, members of the order Odonata were observed in the marshes. Collembolans were collected in the invertebrate transects.

The Diptera and Homoptera consistently comprised the majority of the catch, a result also found by Davis and Gray (1966). Table 1 shows the percentage composition of the insect populations at the different study sites. The Diptera were first in abundance at seven of the thirteen stations sampled and the Homoptera at five. The Hemiptera were second at five stations, the Homoptera at four, and the Diptera at two. The Hymenoptera were frequently collected, but were seldom found in large numbers.

Figures 1 and 2 show the distributions of the common insect families in different marsh types. Figure 1 shows the distributions of insects in low marshes (Pony Slough and Metcalf Est. Pres.). Figure 2 shows the distribution in immature high marshes (South Slough and Bull Island). The frequency is determined by the number of samples in which the family was present. The density is the number of individuals in each sample.

The Diptera, represented by eight families, were common in all zones of the marsh. The Dolichopodidae were by far the most common family, comprising 48% of the fly population. The Chloropidae were frequently collected, but never in large numbers. The other six families (Muscidae, Ephydridae, Sciomyzidae, Otitidae, Sciaridae, and Tephritidae) were only occasionally collected.

The Homoptera demonstrated the most nearly zonal pattern of distribution. Large numbers were found in the lower zones of the marsh and few were collected in the upper zone of the marsh (Fig. 1 and 2). This pattern was also found by Davis and Gray (1966) on the East coast. In view of the fact that similar distribution patterns were found in differing marsh types, it is probable that the organisms were responding more to distance from water than to plant cover.

The Cicadellidae were the most common Homopterans. They were present in large numbers until the middle of August. A similar decline in abundance was also found by Marples (1966). Other families represented were the Delphacidae and the Aphididae. Spittlebugs (Cercopidae) were observed on the seed pods of Triglochon in mid June. They disappeared by late June and adults were never collected. Perhaps this is associated with the seasonality of the plant species (see Primary Production).

Four families of Hemiptera were collected. Large populations of shore bugs (Saldidae) were found near channels or on mud flats. They eluded the net effectively and are under-represented in the data. The Miridae were most common in the middle of the marsh (Fig. 1). The Nabidae were present in all marsh zones, but were never found in large numbers. They were also collected in the transects. The Gerridae were represented by a single capture near a channel in the upper zone of the marsh.

Most of the common Hymenoptera were parasitic. The Ichneumonidae were the most common and showed no zonal pattern of distribution (Fig. 1 and 2). The Perilampidae were also collected frequently. The ants (Formicidae) were most commonly found in the higher portions of the marsh. Families occasionally

Stations	Percentage Composition				
	Diptera	Homoptera	Hemiptera	Hymenoptera	Other Orders
Low Zone					
Pony Slough	69.9	9.6	13.7	2.7	4.1
Metcalf	21.1	73.7	0.0	5.2	0.0
Bull Island	6.3	78.1	9.4	6.2	0.0
South Slough	25.0	28.6	7.4	10.4	28.6
All Stations	42.1	35.5	9.9	5.3	7.2
Middle Zone					
Pony Slough	52.5	4.9	39.4	3.2	0.0
Metcalf	10.0	73.3	17.7	0.0	0.0
Bull Island	56.2	18.8	18.8	6.2	0.0
South Slough	12.9	54.8	0.0	9.7	22.6
All Stations	34.8	32.6	23.2	4.3	5.1
High Zones					
Pony Slough	52.6	0.0	3.5	21.1	22.8
Metcalf	25.0	25.0	8.3	8.3	33.3
Bull Island	85.7	0.0	7.1	7.1	0.0
South Slough	47.1	29.4	0.0	17.6	5.9
Coalbank Slough	76.2	11.9	0.0	7.1	4.8
All Stations	59.8	9.2	2.8	14.1	14.1

Table 1. Composition of insect populations from samples taken in summer, 1976.

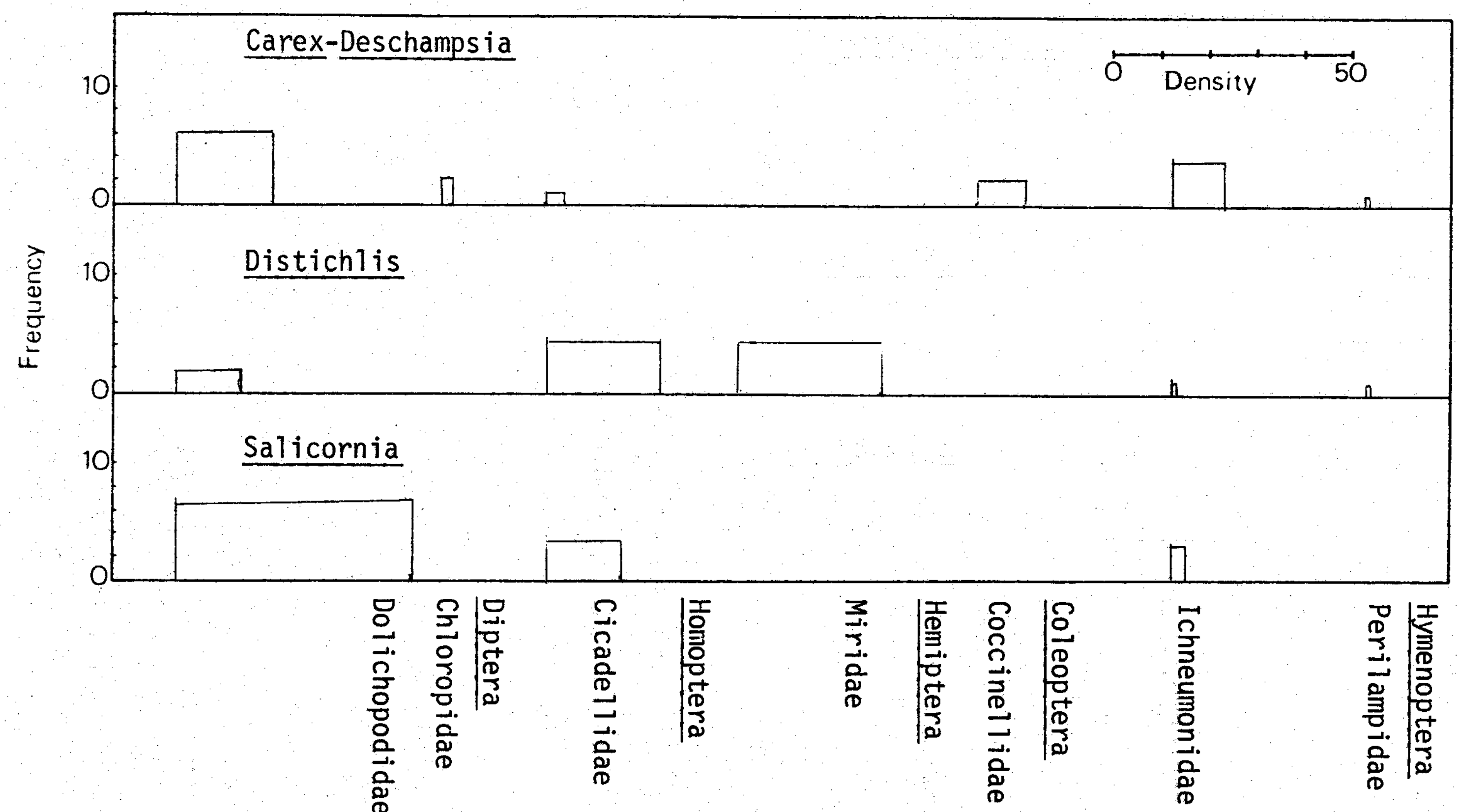


Figure 1. Frequency-density diagram of the common insect families in low marshes.

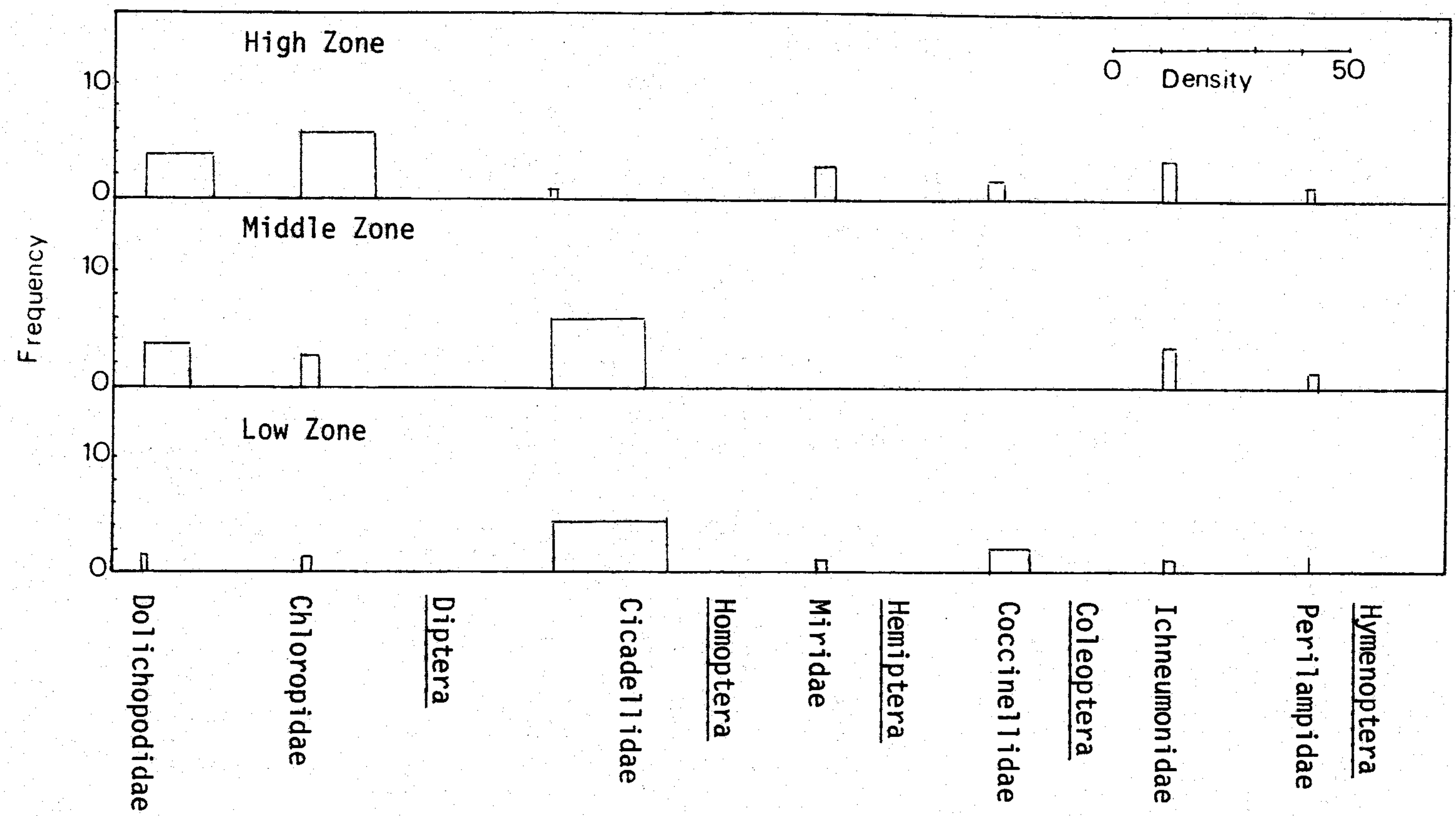


Figure 2. Frequency-density diagram of insects in immature high marshes.

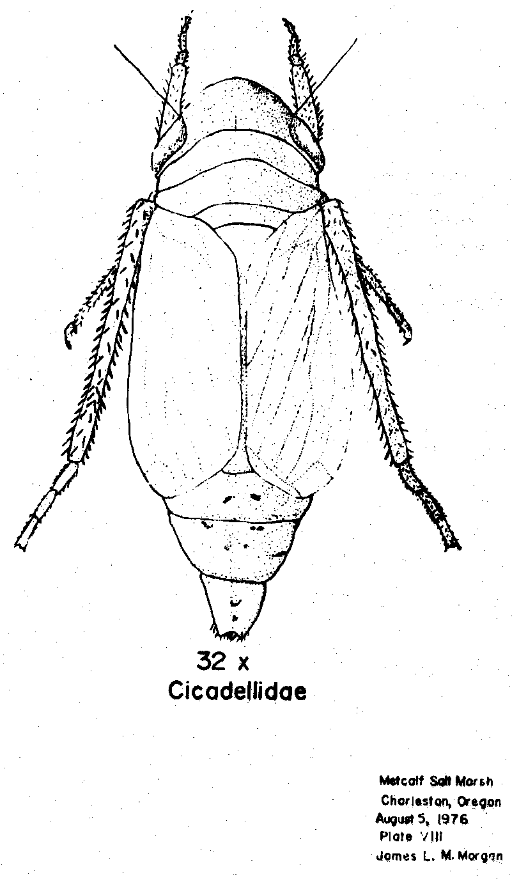


Figure 3. Cicadellidae.

collected included the Diapriidae and the Colletidae (sub-family Hylaenae).

The remaining three orders (Coleoptera, Lepidoptera, and Orthoptera) seemed to be rather scattered in their distribution. The beetles were the most common of the three and the Coccinellidae were the most frequently collected beetles. Many of the beetles were found in Carex and Deschampsia stands. Families represented include Canthariidae, Helodidae, Lathridriidae, and Staphylinidae. Staphylinids were also collected in the transects.

Two families of Lepidoptera (Ctenucidae, Gelechidae) and one family of Orthoptera (Tettigoniidae) were found. Adult Ctenucids were collected in the marsh, but the pupae were found in sedge stands. The larvae feed on grasses and it was assumed that they were using the marsh in this manner. The Orthopterans were collected in sedge stands, but were also observed in other marsh zones.

Seasonal distribution patterns could not be studied, but Davis and Gray (1966) report thatmost species of Orthopterans, Coleopterans, ants, parasitic Hymenopterans, Hemipterans, and Dipterans are absent in the winter. A few species of Dipterans and some of the Delphacids are present throughout the year.

Trophic Relationships

Salt marsh insects display three distinct feeding habits. The phytophagous insects feed directly on the standing crop of plants, either by sucking plant juices or by chewing plant tissues. Saprophagous forms feed on detritus and zoophagous forms are predaceous, often on other insects. Parasitic insects are also zoophagous.

Marples (1966) has shown that there are four dominant herbivores in Spartina marshes: Orchelimum fidicinium (Orhoptera; Tettigoniidae), Prokelisia marginata (Homoptera; Delphacidae), Trigonotylus sp. (Hemiptera; Miridae), and Ischnodesmus sp. (Hemiptera; Lygaeidae). The Delphacids, Mirids, and Lygaeids suck plant juices and the Orthopterans chew plant tissues. At the present study sites the Cicadellids and Mirids were found to be the dominant herbivores and Delphacids and Orthopterans were also present.

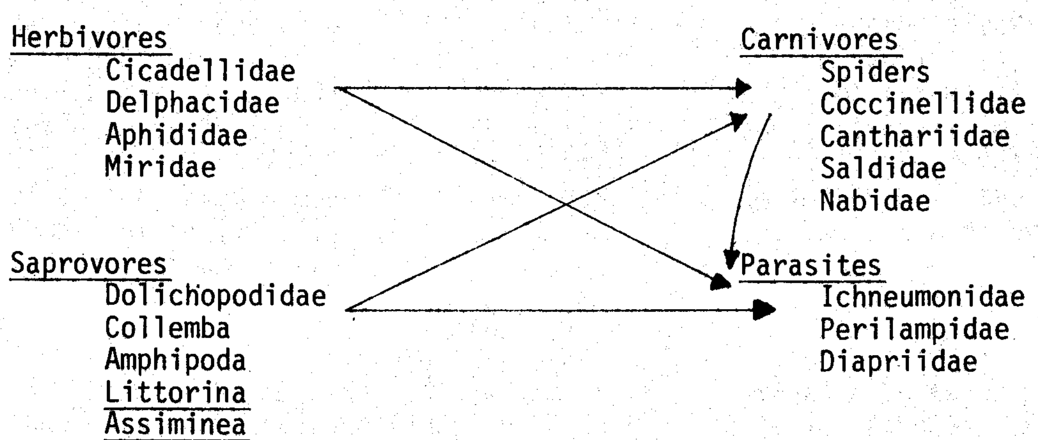
Littorina irrorata has been shown to be one of the most important detritus feeders in the marsh (Odum and Smalley 1959, Marples 1966). Two species of snails, Littorina scutulata and Assiminea californica, were found in the transects and probably also feed on detritus. Dolichopodid and ephydrid flies, amphipods, and Collembolans have also been shown to be detritus feeders (Paviour-Smith 1956, Marples 1966). Amphipods and Collembolans were found in the transects and both families of flies were present in the sweep net samples.

Marples' studies show that spiders are the principle carnivores in the salt marsh system. Three families were located in the marsh (Lycosidae, Clubionidae, and Tetragnathidae). Many predaceous insects also inhabit the marsh, though Barnes (1953) has shown that spiders outnumber carnivorous insects. Nearly all of the Coleopterans (Coccinellidae, Canthariidae, Helodidae, and others), the Hemipteran families Saldidae, Nabidae, and Gerridae, and the dragonflies (Odonata) prey on other insects. Berg, Karlin, and Mackiewica (1955) have shown that scyomizid larvae feed on snails and snail eggs. *Littorina* and *Assiminea* may both be attacked by these flies.

The Hymenopterans found in the marsh were mostly parasitic forms. Ichneumons are known to attack nearly every kind of insect and some spiders. The specific parasite-host relationships of the species found in these marshes are not known. The Perilampids are Hyperparasites and probably attack the Ichneumons. Other parasites include Dipterous larvae, which bore into plant stems (Davis and Gray 1966).

Figure 3 is a representation of the food web involving the insects and invertebrates which were found in the marsh. Birds and small mammals are the primary consumers of insects and invertebrates. Swallows and shrews are both insectivorous and were commonly found in the marsh.

Figure 3
The Trophic Relationships of the Primary Terrestrial Consumers of Marsh Energy



Cameron (1972) has shown that insect diversity is related to the availability of the food source being utilized. Herbivore diversity is positively correlated with standing crop biomass, saprovore diversity with litter accumulation, and predator diversity with prey diversity. The first two correlations are significant. An increase in standing crop biomass (or litter accumulation) is followed by an increase in herbivore (or saprovore) diversity with a two-three week time lag. The increased diversity is the result of an increased number of species rather than an increase in the number of individuals per species. The predators exhibit a diversity increase of the latter type.

Energetics

Table 2 shows the caloric intake and respiration costs of the leafhoppers (Cicadellidae) used in the energetics studies. From the average respiratory cost figures, production was calculated to be 70 calories/g-hr. Total assimilation (respiration + production) was found to be 350 cal/g-hr and assimilation efficiency was 27.5%.

Table 2
Consumption and Respiration Rates of Leafhoppers (Cicadellidae)

	Ingestion		Respiration			
			Active		BMR	
Caloric Equivalent	1582 cal/g *Distichlis*		5.0 cal/ml O_2		4.825 cal/ml O_2	
	cons./g-hr	cal/g-hr	ml/g-hr	cal/g-hr	ml/h-hr	cal/g-hr
Group 1	0.976	1544	50.14	251	3.78	18
2	1.170	1851	51.32	257	2.85	14
3	0.439	694	48.43	242	2.72	13
4	1.089	1723	61.54	308	3.87	19
5	0.352	557	--	--	--	--
Average	0.805	1273	52.80	264	3.30	16

To estimate the amount of energy used by the entire leafhopper population, the production of Distichlis was found for the period between June 15 and July 15 and the absolute density of the specimens was estimated. In this time period 95.12 grams (209 cal/m^2-hr) of *Distichlis* was produced. One sweep of the net covered an area approximately one meter long and 0.25 meters wide (0.25 m^2). The average catch in 20 sweeps (5.0 m^2) was about eight individuals 0.060 g). From this the density was estimated to be about 0.012 g/m^2. At this density and the ingestion rate reported in Table 2 (1273 cal/g-hr), 15.28 cal/m^2-hr or 7.27% of the *Distichlis* production was being consumed by the leafhoppers. Only 2% (4.2 cal/m^2-hr) of the production was assimilated.

Similar values have been reported for insects in other marsh types. Odum and Smalley (1959) have reported that *Prokelisia* assimilates 6% of the *Spartina* production. Smalley (1960) reports that *Orchelimum* ingests 2% of the *Spartina* production and assimilates less than 1% with an assimilation efficiency of 27%. Teal (1962) estimates that herbivorous insects assimilate 4.6% of their potential food.

Teal (1962) discusses two possible reasons for the limited use of marsh energy by the insects. MacArthur (1955) has reported two methods of attaining stability in an ecological system: 1) a community in which many species have restricted feeding habits, and 2) a system in which few species have broad diets. The latter arrangement is found in the marsh and is less efficient than the former. This results in utilization of smaller amounts of energy by the consumers. Teal also points out that a large portion of the marsh production is exported into the estuary and removed from the insects.

Summary

The salt marshes in this area were found to have insect assemblages similar to those on the eastern seaboard. The Diptera and Homoptera were the most prominent orders in both systems. Homopteran populations were concentrated in the lower marsh zones. Hemipterans and Hymenopterans were also commonly collected.

The dominant herbivores were the Cicadellidae and the Miridae. Common saprovores were the dolichopodid flies and the snails *Littorina scutulata* and *Assiminea californica*. Spiders were the dominant carnivores, but predaceous insects, primarily Coleopterans and Hemipterans, were also collected. Ichneumons and Perilampids were the primary parasitic forms.

The energy flow through different marsh types appears to be quite similar. The leafhoppers were found to consume 7.27% and assimilate 2% of the *Distichlis* production with an assimilation efficiency of 27.5%. Similar values have been reported for insects in other marsh types.

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Fishes...

FISHES ASSOCIATED WITH THE SALT MARSHES THE COOS BAY ESTUARY

Introduction

Salt marshes provide aquatic and terrestrial wildlife habitats which are unique. This study consisted of a general survey of fish species and their distribution in six marshes of the Coos Bay estuary including: *Salicornia* Marsh, Coalbank, Pony Slough, North Slough, Bull Island and South Slough. Additionally, gut analyses of representative individuals were conducted in an attempt to determine the feeding habits of common fish species and their position in the detrital food web.

Materials and Methods

Sampling was conducted in the major tidal creek which supplies each marsh. Since these channels vary considerably in width, population samples were taken using both large and small seine nets. In some instances it was necessary to use both nets in conjunction to adjust for channel size or configuration. Representative fish were injected with a 5% formalin solution immediately upon capture to arrest digestion processes and allow for laboratory analyses of stomach contents.

Results

Percent composition by species of the fish captured by seining for each salt marsh is presented in Figure 1. The number of fish caught is also noted. Figures 2 and 3 are length-frequency distributions for the two dominant fishes of the marshes, *Cymatogaster aggregata* and *Leptocottus armatus*, respectively. Table 1 summarizes the results of gut content analysis from the six study sites.

Discussion

The sampling procedures used are not completely unbiased. As a result, the size distributions (Figures 2 and 3) and the percent compositions (Figure 1) are admittedly low estimates of the true salt marsh populations. The size-frequency distributions do suggest that resident fish populations include more juveniles than adults. Similar findings are reported in Coastal Rivers Investigation Reports 70-11 and 74-11: "Fish in Coos Bay, Oregon, with Comments on Distribution, Temperature and Salinity of the Estuary," and "Numbers of Fish Captured in Beach Seine Hauls in Coos River Estuary, Oregon, June through September, 1970." These observations verify the often held claim that estuaries are essential nurseries for ocean and river fish species, and the salt marshes provide the most protected beds within estuarine systems.

Analysis of gut contents is a standard method of determination of ingested nutrients (e.g., *Pacific Fishes of Canada* by J.L. Hart,

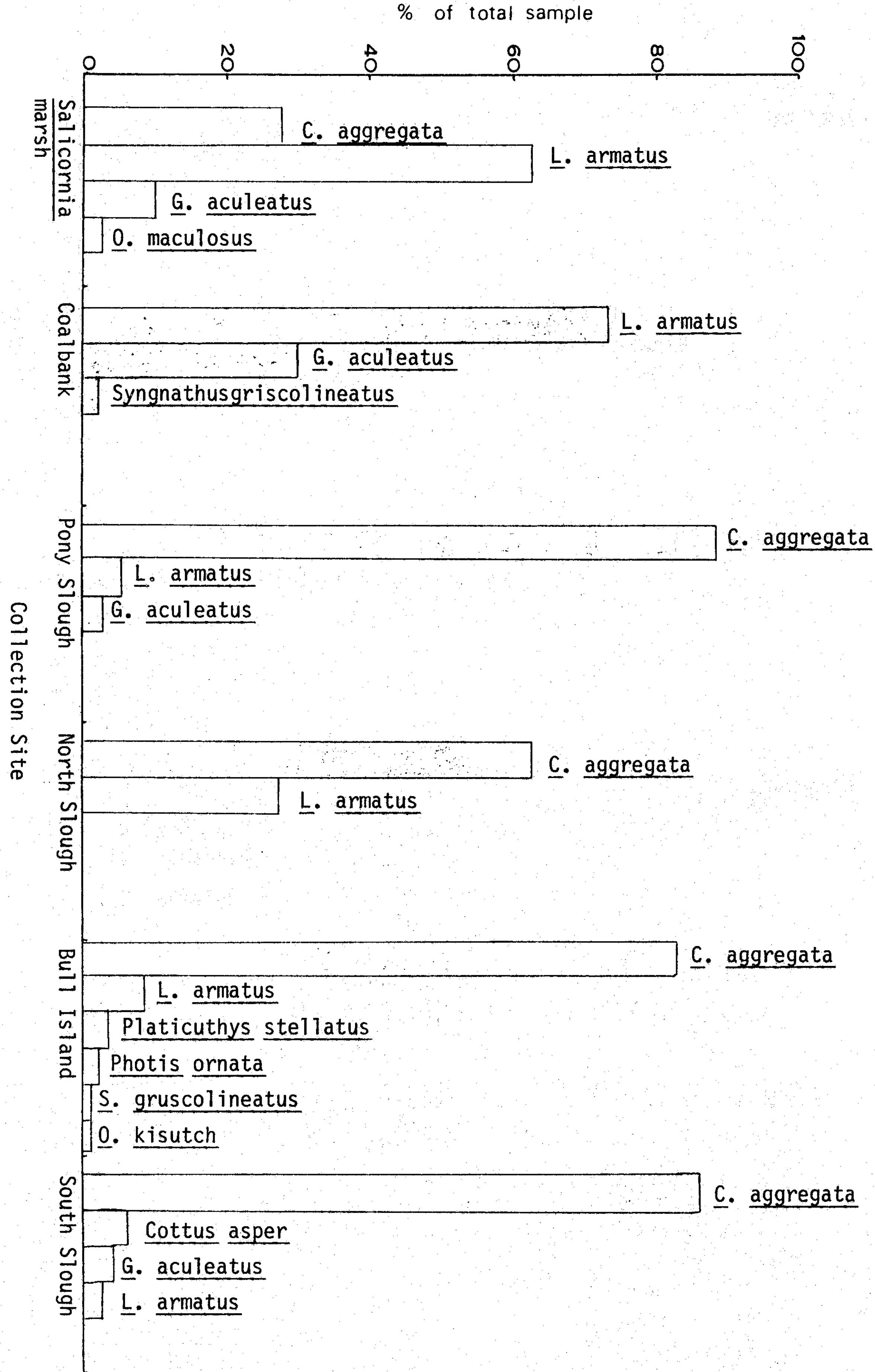

Figure 1. Percent composition by species for each study site.

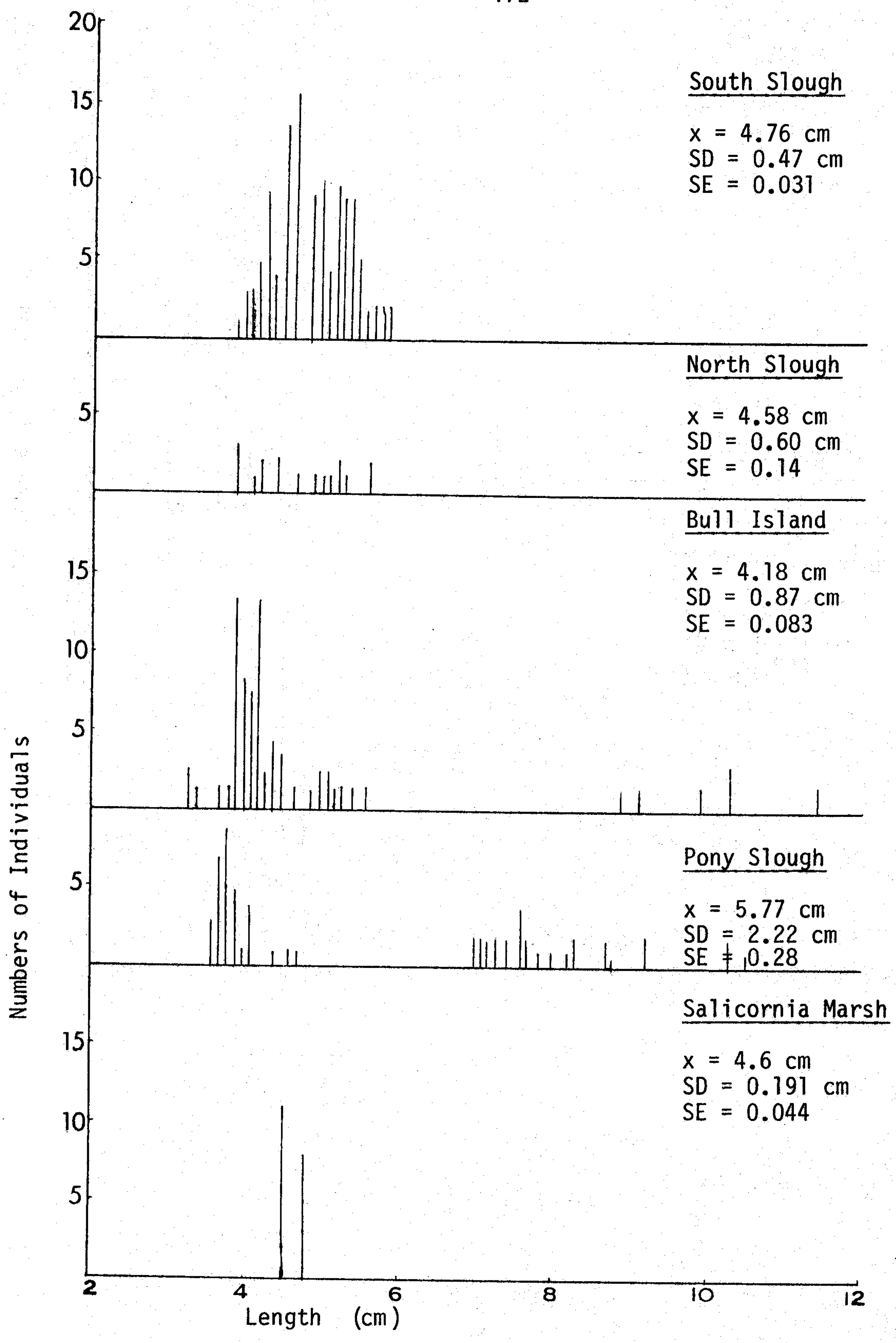

Figure 2: Length-frequency distribution of *Cymatogaster aggregata*.

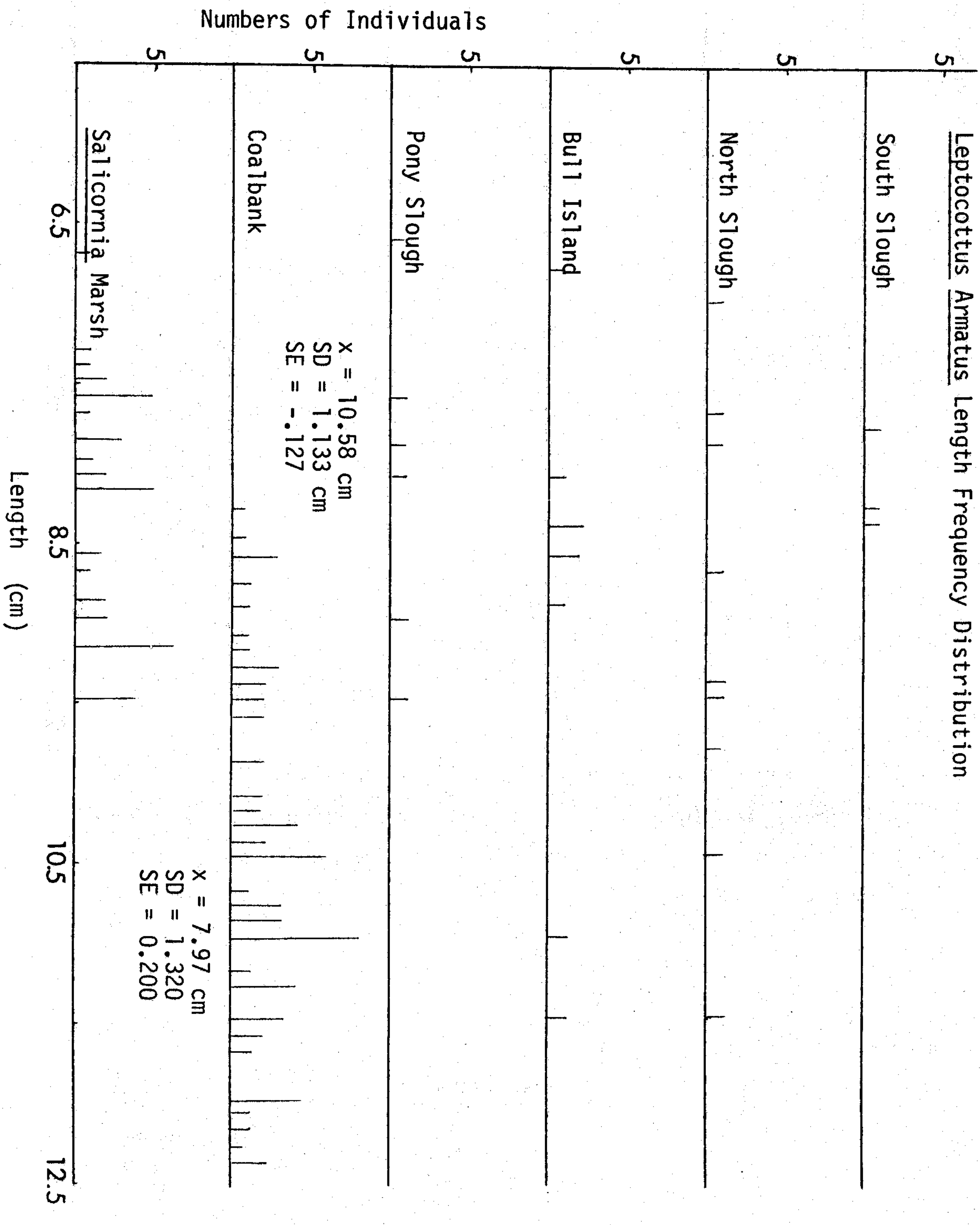

Figure 3: Length-frequency distribution of Leptocottus armatus.

Site	Salicornia				Coalbank			Pony Sl.			North		Bull Island						South Sl.			
SPECIES	C. aggragata (J)	L. armatus	G. aculeatus	O. maculosus	L. armatus	S. griseolineatus	G. aculeatus	C. aggregata	L. armatus	G. aculeatus	C. aggregata (J)	L. armatus	C. aggregata	L. armatus	P. stellatus	S. griseolineatus	P. ornata	O. kisutch (J)	C. aggregata	G. aculeatus	L. armatus	C. asper
# fish exam.	5	7	0	0	12	0	3	3	5	3	5	3	4	4	2	1	2	1	1	2	3	3
Ph. Annelida							8			6		1										
Ph. Molluska Cl. Gastropoda								50														
Cl. Bivalvia	41							2			63				5	7	28					
Ph. Arthropoda C. Arachnida O. acarina	7							7														
Gnorimosphæroma sp.	23	48			4			18				1					5					
O. Amphipoda unidentified							11	28	68	17						76	4			1	4	
SO. Gammanidea unidentified		8			79							5	67				7					7
Corophium sp.		258			648			3			25	64	97	24	105		31	2	6	27		27
SC. Copepoda O. Harpacticoida	*									6	197					30						
O. Coleoptera	9													2				2				
Unidentified insect larvae	8				10					3	79											
Ph. Nematoda**					1		2			3											4	
Unidentified eggs	*	45			150		5															10

* Hundreds, ** Probably parasites.

J Juvenile.

1973). In this survey, a good correlation between ingested invertebrates and those invertebrate species observed and studied in this project was found. For example, the Amphipod Corophium, which is known to feed on seston formed by salt marsh plants, is ingested by several very common species of fish, including the commercially important silver or coho salmon (Holliday, personal communication).

Conclusion

1. Leptocottus armatus dominate the observed fish populations at the Salicornia and Coalbank sites.

2. Juvenile Cymatogaster aggregata comprise the dominant species at South Slough, Bull Island, North Slough and Pony Slough sites.

3. Amphipods, especially Corophium sp., are the primary food source of Leptocottus armatus for all marshes sampled.

4. All species sampled are predominantly carnivorous; plant materials observed in the analysis of stomach content are assumed to be the result of random ingestion and insignificant in the overall diet.

5. Harpactacoid copepods appear to be an important food item for juvenile Cymatogaster aggregata, while Amphipods become increasingly important for mature individuals.

6. In general, juvenile fish dominate the study sites.

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Birds . . .

SURVEY OF BIRD SPECIES IN AND AROUND THE SALT MARSHES OF THE COOS BAY ESTUARY

Craig Magwire

The salt marshes of Coos Bay are of particular importance to the many species of birds which are residents or regular visitors to the bay and adjacent lowlands. Marshes provide shelter and nesting habitat, and serve as the primary source of food in both the detrial and terrestrial food chains.

A survey was conducted to determine what birds use the different marsh types. Observations were made on the abundance and behavior of these birds. Because of the short duration of this study, observations could not be made on the entire yearly cycle of bird populations in the bay. This seasonal information will be provided by combining the past observations of persons in Coos Bay.

Marsh Birds

During this study data were collected in each of the six study marshes, representing the four marsh types. Due to the time limitations of this study, observations could only be made from April through the middle of August. While taking bird observations, a path was always walked which traversed each marsh from the higher terrestrial edge to the mud flat. This enabled the observer to note the different zones within the marsh in which birds are located. This method also allows the observer to see or hear the less conspicuous birds which are often concealed within the tall grass, and drainage channels of the marsh. The marsh area was divided into six observation zones, which lie parallel to the terrestrial edge of the marsh (Figure 1). Species were rated according to the following scale:

- A -(abundant) species seen in numbers of 50 or more birds per day/observer.
- B -(common) species seen in numbers between 1 and 50 per day/observer.
- U -(uncommon) species present but not always certain to be seen each day.
- R -(rare) species not observed every year.

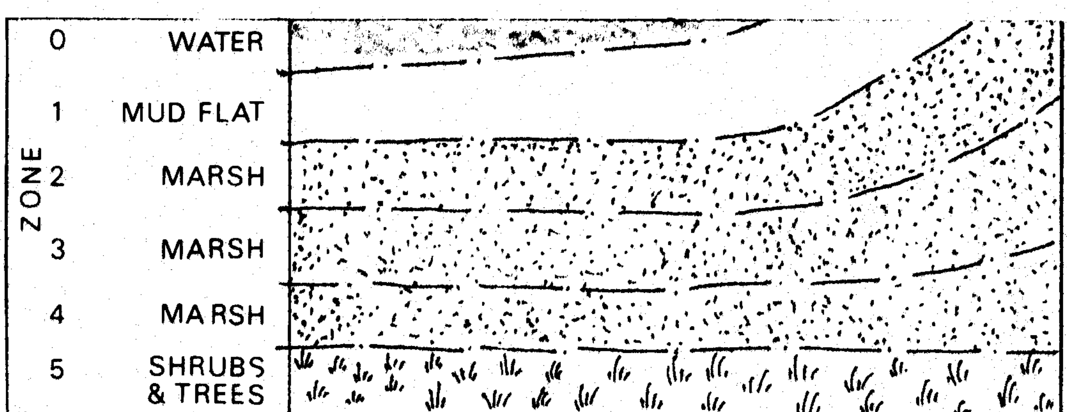

Fig. 1. Six zones used in recording bird observations.

The species observed, their abundance, and the zones in which they are most commonly found in each study marsh have been summarized in Table 1. Only birds making use of the marsh proper, or the air space over the marsh are listed. (See Table 1.)

During the course of the study, 28 species of birds were observed to make use of the marsh. This total does not include birds found only in the shrubs and trees on the higher terrestrial side of the marsh. Birds found solely along the mud flats and in the water are also excluded from this total. The most common marsh users are the swallows, great blue heron, song sparrow and long-billed marsh wren. Other typical marsh species, the rail and marsh hawk, were not abundant during our rather short period of observation. Finches also made a few interesting appearances in the marsh.

Five different species of swallows (barn, cliff, rough-winged, violet-green and tree) made extensive use of the air space over the marsh, adjoining mudflat and water. These migratory birds are locally common during the spring and summer months, generally from April through August. Their large mouths and long whiskers are specially adapted allowing them to catch flying insects over the marsh and neighboring areas. The barn swallow, a species found in all marshes studied, collects the mud at the edge of the marsh, to build it home, usually under the eves of buildings. All five species of swallows build their nests outside the marsh.

The great blue heron is common to the estuary and is usually seen in marshes having a substantial adjoining mudflat. This bird will often seek refuge in the marsh to restore preen feathers. Herons hunt for invertebrates and fish in channels and shallow water around the marsh. Nests are constructed outside the marsh in large rookeries. They are build predominantly in sitka spruce and hemlock groves (McMahon, 1974).

The song sparrow was by far the most common bird using the marsh surface during our period of observation. One could always count on seeing this bird flying back and forth from the brush just outside the marsh, to the marsh grass and mudflat areas. Song sparrows probe the ground in the marsh and marsh channels, in search of insects and worms. This bird has a wide distribution and is common to many different habitats. It has been known to nest in the dense marsh grass, and on snags and debris found in the marsh.

The long-billed marsh wren is another bird which nests and feeds on the marsh. Though not as widely distributed as the song sparrow, this bird is common only to marshes with taller vegetation, as found in the higher marsh types. The long-billed marsh wren uses this vegetation to support its nest, which is built one to two feet above the marsh surface, to avoid the flooding of high tides. Nests are made of different types of grass woven into a small spherical nest. This bird feeds on insects, spiders and snails found on the ground and on marsh grass (Beal, 1907).

The less common virginia rail was a species found in this study only at the North Slough and South Slough marshes, near sources of fresh water. Their thin bodies and muscular legs allow them to run quickly through reeds and grasses. Because they are so elusive, their numbers are difficult to estimate. Their nests

Table 1. Summarized bird observations in six study salt marshes, 15 April 1976-15 August 1976.

Location	NO		BU		CO		SO		SA		PO	
Species		zone		zone		zone		zone		zone		zone
Mallard					C	0-1						
Turkey Vulture			U	0-5								
Marsh Hawk			O	2								
Red-tailed Hawk			U	3-5								
Great Egret			O	1								
Great Blue Heron			C	0-4	U	1-5	C	1-4	O	0-4	C	1-5
Green Heron					U	1-5						
Virginia Rail	0	2-4					O	0-4				
Killdeer			O	1							U	1
*Peep Sandpipers			U	1-2	O	1					C	1
Band-tailed Pigeon			O	4-5								
Common Nighthawk							U	0-4			O	0-4
Belted Kingfisher			O	2	O	0	O	0				
Barn Swallow	C	0-4	C	0-4	C	0-4	U	0-4	C	0-5	C	0-5
Cliff Swallow			O	0-4	O	1-5					O	4-5
Rough-winged Swal.									O	0-4		
Violet-green Swal.	0	0-4	U	2-3	O	0-4			C	0-4		
Tree Swallow	0	4-5			C	0-4			O	0-4	U	0-4
Common crow											U	1-3
Long-billed marsh wren	C	2-4	C	2-3			C	2-4				
Robin							U	2-5				
Starling			O	2-4							O	1-5
Yellow Throat	0	3										
Red-winged Blackbird	0	3										
Purple Finch									O	3		
American Goldf.	0	3-5									U	3-5
Song Sparrow	C	4-5	C	1-5	C	4-5	C	1-5	C	1-5	U	2-5

*Peep sandpipers include: western sandpipers, least sandpipers, white rumped sandpipers and Baird's sandpiper.

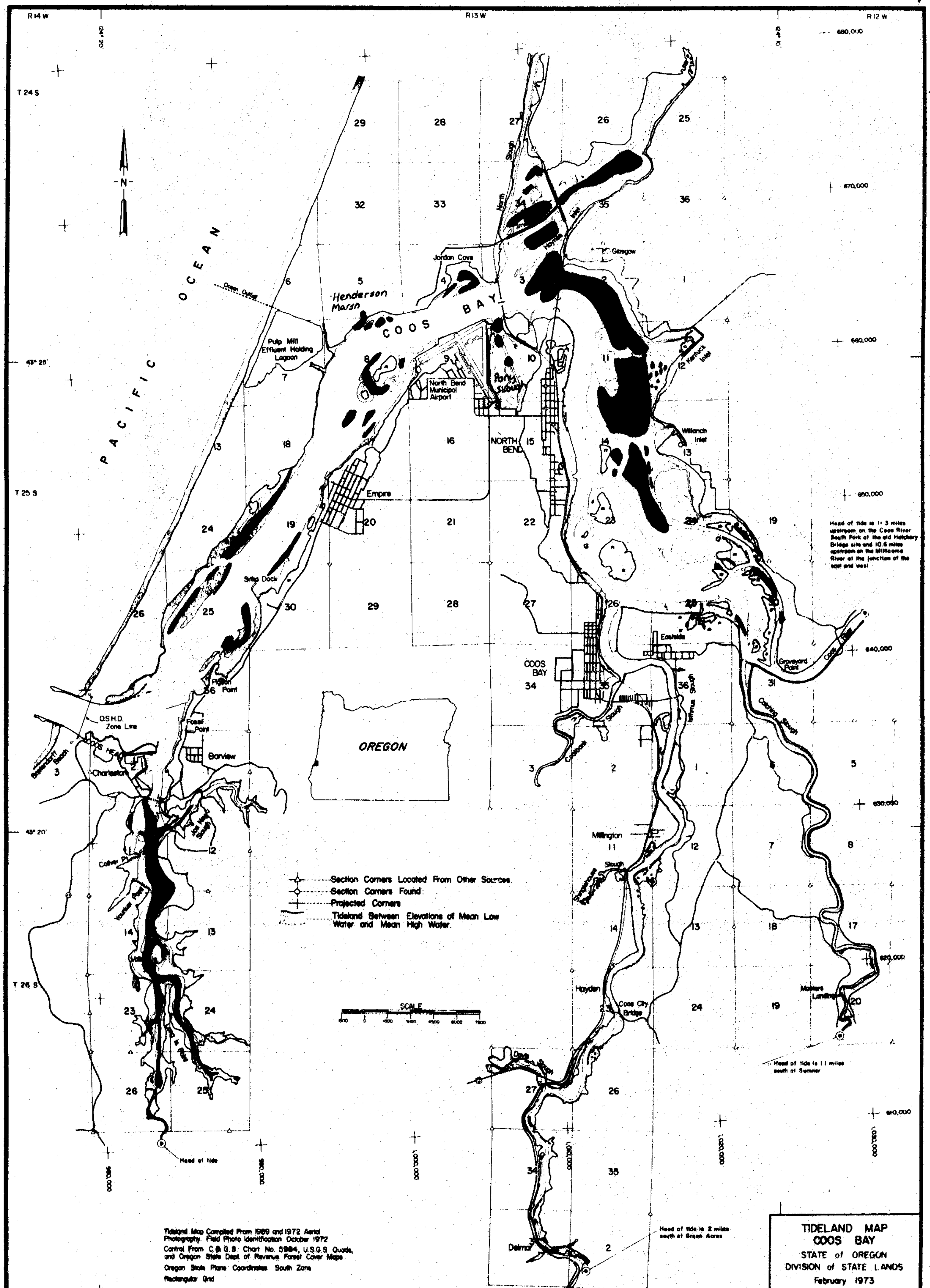

Figure 2. Eelgrass beds in Coos Bay.

are built close to the ground and are well concealed. One virginia rail's nest, which contained as many as five eggs, was located at the North Slough marsh. The young are active when hatched and leave the nest immediately, before their down is dry. The long curved bill of the rail probes the mud for worms and insect larvae. Slugs, snails, caterpillars, small fish, beetles and occasionally grass seeds, comprise their diet.

Sora rails have been observed by others in marshes of the bay. Four sora rails, which are larger than the virginia rail, were sighted at Jordan Cove (Hilda Richer, Coos Bay ornithologist). They were also sighted on occasion in Henderson Marsh (Gorman, 1972).

Two different types of hawks (the marsh hawk and the red-tailed hawk) were sighted during this study. The marsh hawk, which hunts over grassland and marsh areas, was sighted only twice during this study at Bull Island. It is apparently a common species at the Henderson marsh (Gorman, 1972). This species makes a slow, deliberate search for small mammals, hovering only a few feet above the marsh surface. It typically nests in marshes, building its nests directly on the ground. A red-tailed hawk, would occasinally soar over the Bull Island Marsh from its more common hunting grounds outside the marsh.

Finches were found in the marsh on relatively few occasions. However, when present they would feed on nothing but the seeds of *Triglochin*. This behavior was observed from two types of finches (American Goldfinch and purple finch), in both the low sandy marshes.

Salley (1976) has also reported goldfinches feeding on *Triglochin* seeds in a South Slough marsh.

Three other typical marsh species which have been seen are the American bittern (Richer per. comm., June 1976); the common snipe (Ben Fawver, Professor Southwestern Oregon Community College); and the short-eared owl (Gorman, 1972).

Birds of the Estuary

Salt marshes are particularly important to migratory waterfowl, and many other birds of the Pacific Flyway (Thompson & Snow, 1974). The bay provides a resting place, feeding area, and important wintering ground for an important segment of the migratory bird population (U.S. Department of the Interior, 1971). Because of the limited duration of this study, only a small segment of the yearly bird cycle on Coos Bay was observed. Past studies and other observers (Wampole, 1959; Faurver & Wampole, 1971; McGee, 1976; Hilda Richer per. comm. June 1976), have noted these annual population changes. The observations made by these people have been combined to provide information on the seasonal bird populations in several areas on Coos Bay in Table 2. The location of these areas on the bay is shown in Figure 2. The same abundance rating scale is used here as was used for Table 1. The winter season is defined to be October through March. Summer refers to observations made from April through September. It is important to note that observations include sightings on water, mudflat and marsh areas. (See Table 2.)

Table 2. Abundance of summer and winter bird populations at seven locations on Coos Bay.

Location	Haynes Inlet		Pony Slough Reserve		Empire		Pigeon Pt. to Fossil		Salicornia		Coos Head		Other	
Seasonal Status	W	S	W	S	W	S	W	S	W	S	W	S	W	S
1. Yellow-billed Loon												R		
2. Common Loon	C	0	C	0	C	0	C	0	C		A	C		
3. Arctic Loon					U		C	U	C		0	U		
4. Red-throated loon	0	0			0				0		0	0		
5. Red-necked Grebe			0		C		0							
7. Horned Grebe	U		C		C		C		C	C				
8. Eared Grebe	C	0	0	0	0		C		C			0		
9. Pied-billed Grebe	0	0	0						U		0	R		
10.[1]Brown Pelican											0	0		
11. Brandt's Cormorant	0	0	C	C	C	C	C	C	C	C	C	C		
12. Double-crested Cormorant	0	0	C		U		A		U		C	U		
13. Pelagic Cormorant	0	0			0	0	0	0	0	0	A	A		
14.[2]Whistling Swan			R											
15. Canada Goose											0			
16. Black Brant	A				R		A	A	U		0			
17. Emperor Goose									R					
18. White-fronted Goose			R											
19. Mallard	A		A	C										
20. Pintail	A		A	C										
21. Gadwall			A											
22. American Widgeon	A		A											
23. European Widgeon			R											
24. Shoveler			C											
25. Green-winged Teal	A	0	A	C										
26. Redhead			0											
27. Canvasback	C		A											
28. Ringed Neck Duck			R											
29. Greater Scaup	C		C		C		C		C		U	0		
30. Lesser Scaup	C		C		C		C		C					
31. Common Goldeneye	U		R		U				R		0			

Table 2: (cont.)

	Haynes Inlet		Pony Slough Reserve		Empire		Pigeon Pt. to Fossil		Sali-cornia		Coos Head		Other
	W	S	W	S	W	S	W	S	W	S	W	S	W S
32. Bufflehead	C		R		U		C		C		0		
33. Harlequin Duck	R		R								0	0	R
34. Oldsquaw											0	R	
35. Common scoter					R								
36. White-winged Scoter			U	U	A	A	A	C	A	A	A	U	
37. Surf Scoter			U	U	S	S	S	C	S	S	S	U	
38. Ruddy Duck	A		C	0	0		C						
39. Common Merganser	R												
40. Red-breasted Merganser	U		U		C	U	U				0	0	
41. Hooded Merganser		R											
42. Turkey Vulture	0										0	U	
43.[3]Marsh Hawk			0									0	Hend.
44. Bald Eagel	R										R	R	
45.[4]Osprey	0	0										0	
46. Great White Egret			U										Jordan Ross
47. Snowy Egret			R										North S.
48.[5]Great Blue Heron	C	C	C	C	U		U	U	C	C	U	U	
49. Green Heron				0									
50.[6]Virginia Rail													
51.[7]Sora Rail													Hend.
52. American Coot	A		C		C	C	C	C	0		U	0	Jord., Ross
53. Black Oyster-catcher											U	0	
54. American Golden Plover			R										
55. Black-bellied Plover			C	U					R		R		Kentuck, Jordan
56. Simpalmated Plover			U	U	U								
57. Killdeer	U		C	C	C	C	0				U	U	Ross, Larson
58. Long-billed Curlew			U										
59. Whimbrel													Pony, South Kentuck
60. Marbled Godwit			0										
61. Spotted Sand-piper				U								0	
62. Wandering Tattler											0	U	
63. Greater Yel-lowlegs			C	0									Jordan, Ross, Larson
64. Short-billed Dowitcher		0	C	C									
65. Surbird											C	0	

	Haynes Inlet		Pony Slough Reserve		Empire		Pigeon Pt. to Fossil		Sali-cornia		Coos Head		Other
	W	S	W	S	W	S	W	S	W	S	W	S	W S
66. Ruddy Turn-stone						R							
67. Black Turn-stone					C	U					C	U	
68. Rock Sandpiper												O	
69. Pectoral Sandpiper			R										
70. Dunlin			A	A	C	C							
71. Sanderling			O		C	C							
72. Peep Sand-pipers			A	A	C	C	C	O	O	O	O	O	
73. Red Phalarope													
74. Northern Phalarope			R										South S.
75. Common Snipe			U										Jordan, Ross
76. Glaucous-winged Snipe	O				C								
77. Western Gull	C	U	U		C		C		C	C			
78. Herring Gull			C		A	A					O		
79. California Gull			R										
80. Ring-billed Gull	U	U	C	C	C	C							Ross
81. Mew Gull			C	O	C	O					C	U	Ross
82. Herman's Gull		O									O	U	
83. Blacklegged Kittiwake											O	O	
84. Bonaparte's Gull		O		O		O					C	U	
85. Common Tern				R								R	
86.[8] Forster's Tern												R	
87. Caspian Tern				R								R	South S.
88. Common Murre				U	O	U					U	A	
89. Pigeon Guillemot				U		U		U		C	U	A	
90. Belted King-fisher			C	C	U	U			C	C			Larson, Ross, Kentuck
91. Common Crow	C	C	C	C	C	C			C	C			Jordan, Larson
Seasonal Total	31	17	55	28	34	21	21	18	24	11	37	40	
Total # of Species	34		62		37		22		25		46		

Notes

1. Seen August through November. Six Brown Pelicans were seen at Pony Slough August 10, 1938. Six White Pelicans were observed January 18, 1933 at Pony Slough (Richer).

2. Three hundred Whistling Swans were observed at Pony Slough February 30, 1933 (Richer).

3. Two Marsh Hawks were observed at Jackson Cover March 17, 1933.

4. An Osprey nest on the north side of Haynes' Inlet was occupied in 1955 and in 1959.

5. Observed at North Slough bullrush marsh, Henderson marsh, South Slough sedge marsh, and Jordan Cove in numbers less than five.

6. Observed at Henderson Marsh and Jordan Cove in numbers less than five.

7. One seen in South Slough in July.

The shorebirds, waterfowl and various other birds which frequent the bay have a variety of feeding, nesting and migrational patterns. A useful descriptive profile has been given by Robbins, Bruun and Zim (1966) on the patterns characteristic of several major groups of these birds found in Table 2.

Order Gaviiformes

Loons (family Gaviidae) are birds specialized for swimming with powerful legs positioned far back on their body. They feed on fish, crustaceans, and some marine vegetation. Four species are found within the bay (species 1-4, Table 2). The common loon is most often observed, and is most numerous during the winter. These birds summer on northern tundra lakes.

Order Podicipediformes

Grebes (family Podicipedidae) are swimming and diving birds, which feed on fish. Spending their winters along the coast, they summer on inland and northern marshes and lakes. Five species of grebes have been found within the bay (species 5-9, Table 2). The western grebe is particularly common in a cove just south of Pigeon Point (Fawver & Wampole, 1971, Figure 2).

Order Peliconiformes

Cormorants (family Phalacrocoracidae) are primarily fish eaters. They are well-adapted to swimming and diving for fish with their webbed feet. They nest in colonies or rookeries on the sides of rock cliffs. These rookeries are usually found on the large rocks that dot the coastline. Three species are found in the bay (species 11-13, Table 2).

The term waterfowl refers to aquatic birds with webs between their front three toes. Unlike the loons, grebes, and cormorants they have flattened bills with small peg or toothlike structures that act as strainers. They are classified by one order and family (Anseriformes Anatidae) and seven subfamilies. Six of these subfamilies are found in Coos Bay.

Order Anseriformes, Family Anatidae

Geese (subfamily Anserinae) are heavy bodies birds with long necks. They feed on grass, grains and marine vegetation. Four species of geese have made use of Coos Bay during the winter months. They summer to the north in Canada and Alaska. The black brant is the only species common to the bay. Brant, which feed primarily on eelgrass (Thompson & Snow, 1974), make use of the large eelgrass beds in the bay. In the winter they are particularly common in an area between Pigeon Point and Fossil Point (Fawver & Wampole, 1971, Figure 2).

Surface-feeding Ducks (subfamily Anatinae) have shorter necks and are smaller than geese. They feed on aquatic vegetation by tipping forward and submerging their head and upper body. They have also been known to eat mollusks, insects, and small fish. There are seven species of surface feeding ducks found in Coos Bay (species 19-25, Table 2). All but two species (European widgeon and shoveler) are abundant in the winter.

Bay Ducks (subfamily Athyinae) dive from the surface and swim under water to obtain their food. They are primarily carnivores compared to the more herbaceous surface-feeding ducks. Mollusks, mainly small clams, mussels and snails, were found to constitute the main diets of these ducks (California Dept. of Fish and Game, 1965). Seven of the eight species of bay ducks have been found to winter in Coos Bay (species 26-32, Table 2).

Sea Ducks (subfamily Athyinae) have shorter necks and are larger than most other ducks. These diving ducks also feed on mollusks. Seldom found inland, sea ducks winter along arctic coasts and northern tundra. Two species (the white winged-winged scoter, and surf scoter) of the five species found in the bay are common both summer and winter (species 33-37, Table 2).

Stiff-tailed Ducks (subfamily Oxyurinae) are small diving ducks. One of the two species has been sighed in Coos Bay. This species, the ruddy duck, is most abundant at Haynes Inlet during winter.

Mergansers (subfamily Merginae) differ from most waterfowl in having long slender bills. These bills are specialized for catching fish. All three species occur in the bay, though they are not all sighted every year, and only the red-breasted merganser is common (species 39-41, Table 2).

Shore birds and gulls belong to the order Charadriiformes. This order is comprised of a varied group of wading and surface birds. Shorebirds are migratory, long legged birds which feed along mudflats, rocky intertidals and sandy beaches. Two families in this order contain the majority of the shorebirds found in Coos Bay.

Order Charadriiformes

Plovers (family Charadriidae) have shorter necks and tails than other shorebirds. The four species found in the bay can be seen probing mudflats and sandy beaches for food (species 54-57, Table 2).

Sandpipers (family Scolopacidae) vary in size from 5" to 19" in length. They have long slender bills and legs. There are 17 types of sandpipers listed in Table 2 (species 58-72). Both plovers and sandpipers within the bay feed principally upon small clams, insects, snails, polychaete worms and other small invertebreates. Logically, there is a strong connection between available food and the diets of shorebirds and several types of ducks (Calif. Dept. of Fish and Game,1965).

Gulls (family Laridae), are common heavy bodied birds, which scavenge in many areas of the bay. Scavengers aid in the recycling of the energy contained within dead organisms. Nine different species of gulls have been sighted within Coos Bay (species 76-85, Table 2).

Summary

The marsh lands, mudflats, and bay water are prime habitat for bird populations. The larger, more diverse marshes support the greatest variety and numbers of marsh birds. Marshes are used for nesting, feeding and refuge by marsh species, including rails, marsh wrens, and herons. Exposed mud flats are rich with invertebreates upon which a diverse grup of shorebirds feed. The open water is used by loons, grebes, cormorants, geese, ducks, gulls and other birds. Collectively, the marshes, tidelands,and water areas support large seasonal bird populations.

Waterfowl of the Pacific Flyway make extensive use of the food and shelter provided by the bay during winter months. As many as 5,000 pintail ducks have made use of the Pony Slough Reserve at one time (Fawver & Wampole, 1971). Haynes Inlet and in particular the Pony Slough Reserve are used a great deal by migratory waterfowl and shorebirds.

Each type of bird found in Coos Bay has its own migration pattern, nesting habits, and feeding mode, and performs a unique function in the estuarine ecosystem.

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Mammals...

MAMMAL POPULATIONS OF THE COOS BAY SALT MARSHES

Craig Magwire

Introduction

In attempting to gain an insight into the salt marsh community, a better understanding of the mammals which affect the marsh is desirable. Past studies (Fisher 1961, Shure 1970, 1971, Hackaway & Newman, 1971) have provided some information on the roles of mammals in east coast salt marshes and salt marshes of the San Francisco Bay. Little is known, however, about the mammal populations in the Coos Bay marshes. This study is aimed at providing information as to the composition, distribution, and function of mammals in the salt marshes of the Coos Bay region.

The main energies of this study and report are directed toward a small mammal trapping survey of these marshes. Some mention will also be made of the larger mammals which frequent the marsh.

Large Mammals

In conducting the small mammal survey, evidence was found of larger mammals in the Coos Bay salt marshes. Tracks of the raccoon, Procyon lotor, were found in muddy areas at a majority of the marsh sites. This animal is an omnivore, feeding on fruits, fish, invertebrates, small mammals and other small vertebrates and eggs. A raccoon is believed to have taken eggs from the nest of a marsh bird in the North Slough marsh. Of the larger mammals, the raccoon appears to be the most common visitor to the marsh. The black-tailed deer, Odocoilous hemionus columbianus, was sighted at the edge of the South Slough marsh. Its' tracks were found at both South Slough and North Slough marshes. This animal browses in brush areas, mainly outside the marsh. From the extensive tracks and large areas of matted grass in the marsh, it is apparent that the black-tailed deer has used the South Slough marsh for refuge. Beaver, Castor candensis, were also found living at the edge of the South Slough marsh at a point where fresh water enters the estuary. This animal feeds on the bark of primarily deciduous trees found at the edge of the marsh.

Additional large mammals have been reported by others to use the salt marsh areas. In addition to the species already mentioned, muskrat (Ondatra gibethica), mink (Mestela vison), river otter (Lutra canadensis), and weasels (Mustela) were also reported to exist in adjacent marsh and lowlands of Coos Bay in a 1971 publication of the U.S. Department of the Interior. The muskrat is an herbivore while the mink, otter and weasel are carnivores. Only the weasel is not primarily aquatic. Shott (1974a) found evidence of raccoons, river otter, grey fox, Urocyon cinereoargenteus, and coyote Canis latrans, in the marshes of the South Slough region. He found the raccoon to be most abundant, with the river otter, grey fox and coyote being relatively rare. The scarce river otter has a potential economic value (Shott 1974b) as it feeds mainly on rough fish, which feed on the eggs of game fish (Walker et al. 1968). Salley (1976), also working in the South Slough region, found black-tailed deer, muskrat, and a strong population of beaver in a diked and predominantly fresh water marsh area. Duran (1971) and Gorman (1972) observed these same species reported by Salley at marsh, in addition to raccoon and bobcat, Lynx rufus. Henderson marsh is predominantly salt water at this point, although parts of it have been diked and fresh water in the past. This extremely large and varied marsh supports an extremely diverse wildlife population.

These large mammals serve as primary consumers and predators in the marsh community. In general, they are not restricted to the marsh area. For many of the mammals mentioned, the marsh is probably only a part of the animals' total range. For this reason, the many factors of the area surrounding the marsh play a major part in determining the abundance of these animals. Vegetation, fresh water resources, and especially the proximity of human populations are undoubtedly important factors to be considered. This is seen by examining the relative abundance of the larger animals in the rather isolated South Slough, and Henderson marsh areas, as compared to their scarcity in the more urban marsh areas of the bay.

Small Mammals

The main effort of this study was directed toward a small mammal survey. Systematic trapping was carried out in the 6 study marshes, in an attempt to determine the abundance and distribution of small mammals in the 6 different marsh types.

Methods

The trapping sessions for this study were conducted from 15 June 1976 through 10 August 1976. Each study marsh was sampled by 2 trapping sessions during this period. A trapping session consisted of 3 consecutive nights of trapping.

Trapping grids of 20 to 60 traps were used. Single trap lines were used on two occasions. One side of each grid was always placed at the edge of the marsh where marsh vegetation ends, and higher terrestrial vegetation begins to dominate. Most grids also extended to the opposite edge of the marsh where the mud flat begins. The grids were composed of points spaced at 10 meter intervals. Each trap was placed no further than one meter from its point on the grid. This allows traps to be placed where they will most likely result in a capture. Traps were checked once a day, except for a few occasions when they were checked twice daily.

Sherman live traps (2" x 2-1/2" x g-3/4") and Havahart traps (3" x 3-1/4" x 10") were used throughout the study. Peanut butter and oatmeal served as bait. Animals captured were marked by either toe clipping or permanent ink on the dorsal side of the tail.

Results

Species Composition

Trapping results indicate strong populations of small mammals present in the 6 salt marshes studied. Ninety individuals were captured in a total of 1571 undisturbed trap nights, for an overall rate of 5.7 captures per 100 trap-nights. One trap, set in the evening and checked the next day constitutes 1 trap night.

Six species of small mammals were captured. The most abundant species trapped, comprising 71% of the captures, was the vagrant shrew Sorex vagrans. The deer mouse Peromyscus mariculatus, was moderately abundant, totalling 23% of all captures. The majority of these were the subspecies. P.M. rubidus. The Oregon meadow mouse Microtus oregoni, the western red-backed mouse Clethrionomys occidentalis, the black rat Rattus rattus, and the Trowbridge shres Sorex trowbridgii were captured on rare occasions. The total numbers of each species captured are listed in Table 1.

Table 1: Small mammal capture results for each study marsh.

study marsh	trap nights	species capture totals Sor.	Per.	Mic.	Cle.	Rat.
No	180	0	11	1	0	0
Bu	255	14	5	0	1	0
Co	407	28	3	1	0	0
So	255	9	1	0	1	0
Sa	195	5	1	0	0	1
Po	279	8	0	0	0	0
Totals	1471	64	21	2	2	1

Distribution

Six different salt marshes, representing 4 main salt marsh types, were sampled during this study. The data from all trapping periods was pooled, thus averaging any temporal changes which might have occurred.

Figure 1 illustrates the mean captures per 100 trap nights, of the 2 major salt marsh mammals species (the vagrant shrew Sorex vagrans and the deer mourse Peromyscus maniculatus) in each marsh type. The data were combined from the 2 immature high marshes, Bull -Island and the previously diked Coalbank marsh. There was no significant difference between the mean captures of either Sorex or Peromyscus in these 2 marshes.

Trapping results were combined for the 2 low sandy marshes, the Salicornia and Pony Slough. There was no significant difference between the Sorex or Peromyscus captures in the 2 low sandy marshes.

Peromyscus is most abundant in the high marsh. The number of Peromyscus captures drops quickly at the immature high marsh and then less severely in the lower, sedge and low sandy marshes (See Fig. 1). A similar trend of decreasing capture rate with decreasing marsh height, exists for Sorex, in the lower 3 marsh types only. Instead of increasing captures of Sorex in the high marsh, the rate drops to zero. The differences in capture rates between high and immature high marshes were found to be significant for both Peromyscus and Sorex captures. ($z = 2.7$, $p < .007$; $z = 6.6$, $p < .0001$), respectively.

In all marsh types there was a significant difference between

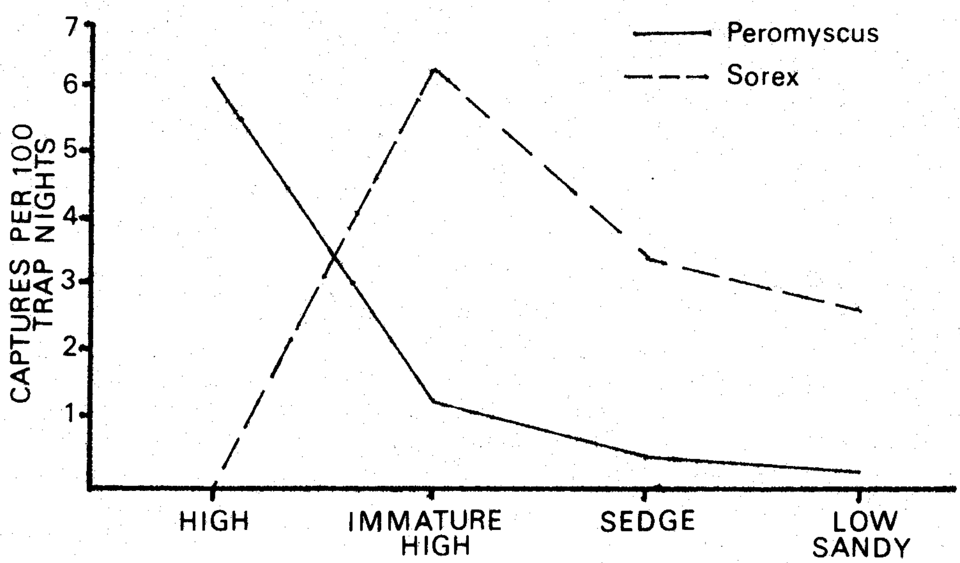

Fig. 1: Captures of Peromyscus and Sorex U.S. salt marsh type.

Sorex and Peromyscus capture rates (see Fig. 1). In the lower 3 marsh types, immature high, sedge and low sandy, the number of Sorex captures was greater than Peromyscus ($z = 4.86$, $p < .0002$; $z = 2.54$, $p < .01$; $z = 3.24$, $p < .001$). Peromyscus was more abundant in the high marsh as no Sorex were captured there ($z - 3.43$, $p < .0006$).

The deer mouse Peromyscus maniculatus and the vagrant shrew Sorex vagrans were observed to have different ranges within the salt marsh. Peromyscus captures were associated primarily with the higher terrestrial side of the marsh. The number of Peromyscus captures decreased significantly, with increasing distance into the marsh from the higher terrestrial side. Seventy meters was the greatest distance Peromyscus was found to venture from the higher edge of the marsh. Sorex, on the other hand, was observed throughout the marshes in which they were found. There was no correlation between the number of Sorex captured and the distance into the marsh. Sorex were found as far as 210 meters from high land at Bull Island, and 190 meters from high ground at Coalbank.

There are some features in salt marshes, however, which do affect the distribution of the vagrant shrew Sorex vagrans. At the Bull Island marsh, more Sorex were captured in the vicinity of logs and snags which litter the marsh, compared to open areas with no debris. Sorex were also associated with a strip of high ground which traversed the Coalbank marsh. This strip of land rises approximately 1 meter above the level of the marsh, and is nearly isolated by channels on both sides. This strip is covered with vegetation similar to that of the surrounding marsh. The number of captures of Sorex was found to be significantly greater on this mound than on the connecting marsh area ($z = 2.68$, $p < .008$; see Fig. 2).

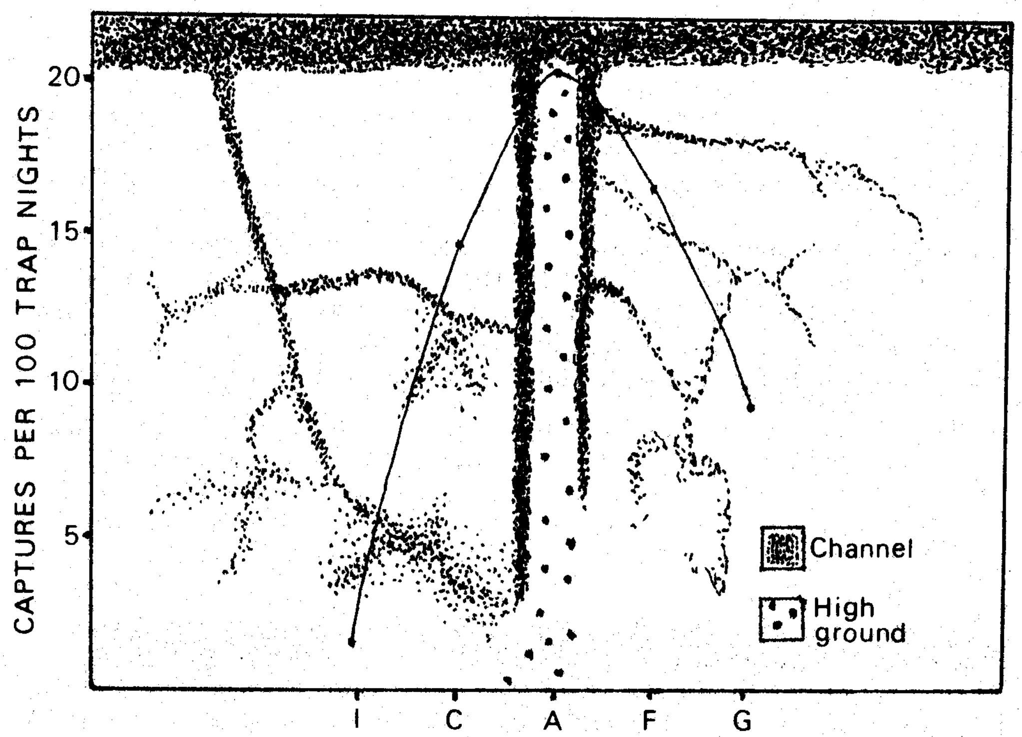

Fig. 2: Mean capture rates of vagrant shrews Sorex vagrans in the vicinity of high ground at Coalbank Slough.

The western red-backed mice, the Oregon meadow mice, and the Trowbridge shrew were all captured between 30 meters and 120 meters into the marsh. The black rat was captured at the higher terrestrial edge of the Salicornia marsh. Because of the small numbers in which these animals were captured, little can be sound about their distribution in salt marshes.

Discussion

The small mammals found in the Coos Bay salt marshes serve as primary and secondary consumers in the terrestrial food chain. The most abundant small mammal overall, the vagrant shrew S. vagrans, is an insectivore feeding upon mature insects, their larvae and pupae, as well as arachnids, snails, and worms (Ingles 1974). The deer mouse P. maniculatus, a common mammal on the terrestrial side of the marsh, is an omnivore. This animal feeds largely upon the fruits, seeds of various plants (Williams 1959). It is also known to feed upon Lepidopterus larvae and other insects in the spring (Johnson 1963). The 2 species of small mammals from the subfamily microture, the Oregon meadow mouse M. oregoni and the western red-backed mouse C. occidentalis, are herbivores which comprised only 4.4% of all captures. They eat solely the vegetative parts of plants. Usually these are grasses and forbs (Jameson 1955). The single black rat, R. rattus, captured, eats a variety of foods, and is commonly found along seaports in the vicinity of buildings (Ingles 1974). The Trowbridge shrew, S. trowbridgii, has similar feeding habits as the vagrant shrew S. vagrans, eating insects and their larvae.

Other studies have found a different composition of small mammals in salt marshes. Shure (1970) found a greater predominance of Microtus in a New Jersey Spartina salt marsh, with 23 Microtus per 100 trap nights, as compared to 0.13 observed in our study (see Table 2). This could be because of differing vegetation, trapping technique, or other factors. There is a possibility that the Microtus population of Coos Bay salt marshes was underestimated by our study. Feeding platforms which are constructed by Microtus (Harris 1953) were often found in South Slough, Coalbank, Pony Slough, and occasionally at the edge of the North Slough marsh. Our trapping methods were virtually the same as those used by Shure. Errors due to unequal sampling of different species trapping methods were not tested.

Table 2: Small mammal captures per 100 trap nights for a New Jersey Spartina marsh and representative salt marshes of Coos Bay.

	capture rates				
	Per.	Mic.	Sor.	Mus.*	Cle.
New Jersey	0	32.3	0.5	0.4	0
Coos Bay	1.4	0.13	4.0	0	0.13

*house mouse Mus musculus

Many factors affect the success of small mammals. Vegetation, tidal inundation, and topography have been found to influence the distribution and relative abundance of small mammals in salt marshes. Our results indicate that both vagrant shrew Sorex vagrans, and deer mouse Peromyscus maniculatus populations change with different salt marsh types, and with certain features found within those marshes.

The relatively low capture rates of the vagrant shrew Sorex vagrans, in the low sandy marshes, dominated by the low growing Salicornia virginica, and in the high marsh, dominated by the sparse Scirpus validus, may be due to the lack of cover provided by these plant species. Fisher (1961), studying salt marshes in the San Francisco Bay region, and Shure (1970) at a New Jersey salt marsh, both reported on association of some small mammals (primarily Microtus), to the greater cover of dense herbaceous areas. This association appears to hold true for Sorex in Coos Bay marshes. This would also explain the increasing rate of Sorex captures in the sedge and immature high marshes. The vegetation in these marshes is dense and tall, as well as more varied in the case of the immature high marsh.

The deer mouse Peromyscus maniculatus was found to be greatly associated with the higher terrestrial edge of the marsh. The dense trees, shrubs and vines which are found just beyond this edge of the marsh provide an excellent habitat for the Peromyscus. This area provides thick cover, varied nest locations, and ample food in the form of seeds and berries. Peromyscus have been associated in past studies with increased shrub cover (Stickel & Warbach 1960) and food availability (Pearson 1958). Pony Slough is the only marsh where Peromyscus was not captured. This marsh is backed on the terrestrial side by a narrow strip of scotch broom Cytisus scoparius, a road, and then an open field, providing almost none of the ideal habitat found at other marsh sites.

Tidal inundation also plays an important role in the distribution of small mammals (Shure, 1971). During inundation Sorex vagrans was reported to stay within its own locale in the marsh, by climbing up the emergent vegetation, and by sifting of floating debris (Johnston 1957). At Bull Island and South Slough, several pieces of wood lightly covered with small mammal feces were found in the marsh at several locations, indicating that they had probably been used for refuge during high tide. Johnston (1957) also reported that Sorex vagrans would swim when the tops of the emergent vegetation was inundated, or when forced to flee by predators. On several occasions during high tides at the South Slough marsh, small mammals were observed to dive into the water from the emergent vegetation when approached. Sibley (1955) and Fisher (1961) reported increased patrols by marsh hawks Circus hudsonius and short-eared owls Asio flammeus flammeus during tidal inundation. As expected, small mammal mortality due to predatory birds increases during high tides (Johnston 1957). The fact that the immature high marsh is inundated less often than the lower marsh types (Akins & Jefferson, 1975), and provide more cover particularly during tidal inundation, helps account for the greater abundance of Sorex in this marsh type.

Unlike the Sorex, the deer mouse Peromyscus maniculatus were observed to seek higher ground during tidal inundation (Hadaway & Newman 1971). This, along with a preference to shrub cover helps explain the association of Peromyscus with the terrestrial side of the marsh, where high ground and preferred habitat are close. The effects of inundation no doubt also play some part in the increasing capture rate of Peromyscus with increasing marsh height. The extremely high capture rate of Peromyscus in the high marsh at North Slough may be a bias from our particular study marsh and trapping method. The marsh used is relatively narrow, and is bordered on 3 sides by higher terrestrial vegetation, with no mud flat area. Traps were set no further than 50 meters into the marsh, in an area which has been found to have the highest Peromyscus density. The capture rate would be expected to be high under these conditions.

Nesting is a special problem for small mammals in salt marshes. The vagrant shrew Sorex vagrans nests within the salt marshes placing its nest directly on the ground. Johnston (1957) observed Sorex vagrans to build only 3 nests out of 45 at an elevation less than

6 feet below the mean tide height. The Sorex then seeks not only higher marshes with good cover, but tries to find higher places within those marshes in which to build nests. This relationship was observed in our study with a significantly higher capture rate of Sorex, on the strip of high ground which traverses the Coalbank Slough marsh. The deer mouse Peromyscus moniculatus, which moves to higher ground during inundation, builds its nests in rotten logs, and dense vegetation, usually just outside the marsh. The western harvest mouse Reithrodontomys ravaventris of the San Francisco Bay salt marshes, builds its nests by roofing over old song sparrow nests located high in the vegetation (Johnston 1957). A similar nest, found at the North Slough marsh, was occupied by a Microtine. The few Microtus which were captured in this study and reported to stay within the marsh during inundation (Harris 1953), and build nests on the ground as Sorex does.

In additionto finding adequate nest locations, salt marsh small mammals have the unique problem of finding fresh water (Fisler 1962). Fisler found that a deer mouse, Peromyscus maniculatus, from a mountain region could not survive on a diet of dry food and sea water, whereas a Peromyscus captured from a salt marsh region lived indefinitely on this diet. However, L.L. Getz (1966) observed that salt marsh Microtus are unable to tolerate water one-half the salinity of sea water for even short periods of time. Microtus do have the ability to obtain needed moisture for short periods, from the vegetation they consume (L.L. Getz 1966). The most common sources of fresh water for salt marsh small mammals is dew, precipitation collecting on vegetation and fluids from food.

Summary

Mammals serve as primary consumers, predators and scavengers in the energy and food chain of the salt marsh community. A variety of larger mammals frequent the Coos Bay salt marshes. For most of these animals, the marsh is only a part of their total range. Their abundance depends primarily upon how remote and undisturbed the community is.

Several species of small mammals have been shown to exist within the salt marshes of Coos Bay. Sorex vagrans was most abundant, with Peromyscus maniculatus being less abundant. The abundance of Sorex, a resident of the marsh, is enhanced by a combination of increased herbaceous cover, higher marsh elevation, and refuge. Peromyscus, an apparent visitor to the salt marsh, is more abundant on higher marsh types, and does not venture far from high ground and shrub cover at the terrestrial edge of the marsh.

These hpyotheses about the relationships between small mammal distribution and features of the Coos Bay salt marshes have, in general, resulted from the data collected during this study. Samples independent of the present study should be taken in order to determine if there is a real basis for their support.

It is difficult to assess and understand the value of these mammals to the salt marsh and neighboring community. In discussing the Peromyscus Ingles wrote:

> Certainly a mammal that is so numerous must play an important part in the ecology of any biotic community in which it lives. (Ingles 1973).

All these animals have a role in the delicate estuarine system, which we still know so little about.

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Legal Aspects...

REGULATIONS AFFECTING THE MANAGEMENT OF OREGON'S ESTUARINE SALT MARSHES[1]

Bonnie Cherick

As the body of this report indicates, salt marshes have gained wide recognition for their value as major sources of marine food production, natural flood retention basins, recreational areas and as sites for education and research.[2] All of this attention has stimulated such a vast array of federal, state and local regulations that even minor coastal projects now require massive amounts of paperwork and patience. In spite of the numerous regulations, however, harmful work is still permitted. Because of these problems, this analysis will: 1) discuss the existing federal, state and local law affecting salt marshes; 2) discuss some of the legal terms used in salt marsh cases of hearings; and 3) provide a basic checklist of steps to spotting and stopping environmentally harmful activities.

Existing Federal, State and Local Laws

Federal

The federal government has been regulating activities in the coastal area primarily under two acts: 1) the River and Harbor Act of 1899,[3] and 2) the Federal Water Pollution Control Act Amendments of 1972.[4]

1. The River and Harbor Act of March 3, 1899 (30 Stat. 1151; 33 U.S.C. 401)

The River and Harbor Act of March 3, 1899 (1899 Act), contained several sections (9 through 20) concerning the protection of the nation's waterways. Congress was concerned over the proliferation of uncontrolled developments along the nation's waterways and harbors and the 1899 Act acted to bring these developments under control, designating enforcement responsibilities to the Secretary of War (now the Secretary of the Army), all in the interests of protecting and enhancing the nation's interestate commerce, which is based upon the Commerce Clause of the Constitution.[5] The 1899 Act applies to "navigable waters of the United States."

The term "navigable waters of the United States" has been administratively defined to mean those waters that have been used in the past, are now used, or are susceptible to use as a means to transport interstate commerce landward to their ordinary high water mark up to the head of navigation as determined by the Chief of Engineers, and also waters that are subject to the ebb and flow of the tide shoreward to their mean high water mark (mean higher high water mark on the Pacific coast).[6] This defines the current jurisdiction of the Corps of Engineers in administering the 1899 Act. Court decisions concerning the 1899 Act have been liberal in applying it to a broad area. However, this jurisdiction would include only those salt marshes below the mean higher high water mark--any salt marshes above that line would not be protected by the Section 10 permit requirement of the 1899 Act.

A. Section 10 (33 U.S.C. 403)

One of the most important sections of the 1899 Act is Section 10, which contains three general proscriptions:

1) Any obstruction, not affirmatively authorized by Congress, to navigable capacity of any of the waters of the United States is prohibited;
2) the construction of any structure in or over any navigable water of the United States is unlawful unless the plan has been recommended by the Secretary of the Army; and
3) it is unlawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of any navigable waters of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of the Army.

The Secretary of the Army has authorized the Chief of Engineers or his authorized representatives to issue or deny permits for construction or other work in or affecting navigable waters of the U.S. pursuant to Sections 10 and 14 of the 1899 Act. The instrument of authorization is designated as a Department of the Army permit or letter of permission. Activities requiring a Department of the Army permit include, but are not limited to, piers, docks, wharves, bulkheads, piling, floats, dolphins, excavations, dredging and filling operations, jettys, breakwaters and groins.

The Corps of Engineers' wetlands policy influences the issuance or denial of permits. It identifies wetlands as those land and water areas subject to regular inundation by tidal, riverine, or locustrine flowage. Generally included are inland and coastal shallows, marshes, mudflats, estuaries, swamps, and similar areas in coastal and inland navigable waters. It also recognizes that these are environmentally vital areas and constitute a productive and valuable public resource, the unnecessary alteration or destruction of which should be discouraged as contrary to the public interest. This wetland policy requires *denial* of a permit for work in wetlands unless the public interest requires otherwise. This policy, promulgated under formal rulemaking procedures and now applicable to it as a matter of law, provides that:

1) the *benefits* of the proposed alteration outweight the damage to the wetland resource, and
2) the proposed alteration is necessary to realize those benefits.

In determining whether a particular alteration is *necessary*, the Corps is required to primarily consider whether the proposed activity is dependent upon the wetland resources and whether feasible alternatives are available.

Department of the Army Permits. Since 1899 the factors considered on the issuance or denial of DA permits have changed from a pure evaluation of effects upon navigation to a full public interest review. In 1968, the full public interest review was incorporated into permit evaluations.[8] Recent administrative interpretations, judicial decisions, and laws have required and encouraged inquiry into the potential environmental impacts of projects requiring a DA permit.[9] The Corps' regulations have included as factors in the public interest review: conservation, aesthetics, general environmental concerns, historic values, fish and wildlife values, flood damage prevention, land-use classifications, navigation, recreation, water supply, water quality, and in general, the needs and welfare of the people. General criteria considered in each evaluation are:

1) the relative extent of the public and private need for the proposed structure or work;
2) the desirability of using appropriate alternative locations and methods to accomplish the objectives of the proposed work or structure;
3) the extent and permanence of the beneficial and/or detrimental effects that the proposed structure or work may have on the public and private uses to which the area is suited; and,
4) the probable impact of each proposal in relation to the cumulative effects created by other existing and anticipated structure or work in the general area.[10]

No permit will be granted unless its issuance is found to be in the public interest.

Penalties for Violations of the 1899 Act. The penalties and remedies for violations of Section 10 are established by Sections 12 and 17 of the 1899 Act (33 U.S.C. 406 and 413). Violators are deemed guilty of a misdemeanor and fined not less than $500 nor more than $2,500, or imprisoned up to one year, or both, in the discretion of the court. Also, violating obstructions may be removed by injunction proceedings and the court may order restoration to the original condition. The injunction provision has been particularly useful in salt marsh cases,[11] and has on occasion been expanded to require appropriate remedies to be fashioned when violations occur.[12]

Effectiveness of Section 10 (1899 Act) to Protect Salt Marshes.

1) Jurisdiction

Under the 1899 Act, federal jurisdiction extends only to the mean higher high water mark on the Pacific coast--thus many salt marshes are not covered by the Act. However, if they fall within the area described, the Corps of Engineers will deny permits unless there are overriding national interests which require their alteration. Ecological factors would weigh heavily in the decision to deny permits.[13]

2) Injunctive Remedies

On April 8, 1974, the Corps revised its regulations[14] to provide that no after-the-fact permits will be issued until the judicial proceedings have been accomplished. When work has been started or even completed without the necessary authorizations, the District Engineer immediately issues a cease and desist order and simultaneously begins an investigation of the facts surrounding the alleged violation. If the District Engineer's investigation reveals that work was started or completed without proper authorization, he must submit his report of the facts and his recommendations to the U.S. Attorney for appropriate legal action. The District Engineer is prohibited from accepting and processing any permit application until final disposition of all prescribed penalties and fines and/or the completion of all work ordered by the court. If this Corps' cease and desist order is not obeyed, then a U.S. District Court cease and desist will be obtained to stop all work until the facts are obtained and the activity is found to be legal or illegal.

B. Section 9 (33 U.S.C. 401)

This section prohibits the construction of any dam or dike across any navigable water of the United States in the absence of Congressional consent and approval of the plans by the Chief of Engineers and the Secretary of the Army. For intrastate navigable waters of the United States, the dam or dike may be built under the authority of the state legislature with prior approval of the location and plans by the Chief of Engineers and the Secretary of the Army.

C. Section 13 (33 U.S.C. 407)

Section 13 makes it unlawful to throw, discharge, or deposit refuse matter of any kind, except liquid sewage, into any navigable water of the United States or tributary thereto without a permit. It is commonly known as the "Refuse Act." Permit authority under this Act is now given to the Administrator, Environmental Protection Agency under Sections 402 and 405 of the FWPCA (33 U.S.C. 1342 and 1345).

2. The Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1251 et seq; Supp IV, 1974)

The FWPCA was enacted "to restore and maintain the chemical, physical and biological integrity of the nation's waters" by prohibiting the discharge of pollutants into the "navigable waters."

The term "navigable waters" under this Act does not define the same jurisdiction as the term "navigable waters of the U.S." of the above-mentioned 1899 Act. "Navigable waters" does include the traditional definition "those waters which are presently or have been in the past, or may be in the future susceptible for use for purposes of interstate or foreign commerce."[15] However, this definition was found inadequate in light of congressional intent, and the court called for its expansion in the leading case of *Natural Resources Defense Council v. Callaway*.[16] Subsequent to that decision, the Corps published regulations which describe navigable waters jurisdiction for purposes of Section 404 of the FWPCA. According to these regulations, "navigable waters" means waters of the U.S., including the territorial seas with respect to the disposal of fill material...and includes:

1) coastal wetlands that are navigable waters of the U.S. subject to the ebb and flow of the tide, shoreward to their mean high water mark (mean higher high water mark on the Pacific coast); and
2) all coastal wetlands...and similar areas that are contiguous or adjacent to other navigable waters.

"Coastal wetlands" includes marshes and shallows and means those areas periodically inundated by saline or brackish waters and that are normally characterized by the prevalence of salt or brackish water vegetation capable of growth or reproduction.

In essence, then, Section 404 prohibits the *discharge* of dredge or fill material except by permit at specified disposal sites. It does not cover dredging activities in the newly expanded jurisdiction. It is valuable through the use of the permit procedure but it confuses matters by covering fill activities separately from dredging activities and by operating over a broader jurisdiction than the 1899 Act. Dredging activities above the mean higher high water mark are still not covered.

The Army Corps of Engineers is responsible for the authorization of Section 404 permits. Issuance of a permit is generally based on an evaluation of the probable impact of the proposed structure or work and its intended use on the public interest.[17] This means that the benefits which may reasonably be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. The factors which may be considered relevant are conservation, economics, aesthetics, general environmental concerns, historic values, fish and wildlife values, flood-damage prevention, land-use classifications, and in general, the needs and welfare of the people. The four general criteria for issuance of a Section 10 permit[18] are also considered in the evaluation.

When applicable, the Corps will also consider some specific policies in evaluating permit applications. One such consideration is whether the project will cause undue interference with adjacent properties or water resource projects.[19] The regulations state that a landowner's general right of access to navigable waters is subject to the similar rights of access held by nearby landowners and to the general public's right of navigation on water surfaces.

In addition, certain Environmental Protection Agency regulations affect the issuance of Corps permits. For instance, the EPA has guidelines for evaluating proposed discharges of dredge or fill material in navigable waters. Title 40 part 230.1(a)(2) makes it clear that no discharge of dredged or fill material will occur at a proposed disposal site in a navigable water if the Administrator determines after notice and opportunity for a public hearing and consulting with the Secretary of the Army, that such discharge will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas, wildlife or recreation areas. Part 230.4 presents some approaches for technical evaluation of discharges of dredged or fill material for the District Engineer. Generally 230.4 says that the effects of discharges of dredged or fill material on aquatic organisms and human uses of navigable waters may range from insignificant disruption to irreversible change at the disposal site. More specifically, the degradation or destruction of aquatic resources by filling operations in wetlands is considered *the most severe environmental impact*... The guiding principle in evaluating such an operation is that destruction of a highly productive wetlands may represent an irreversible loss of a valuable aquatic resource. Finally, wetlands are considered to perform important functions if they:

1) serve important natural biological functions, including food chain production, general habitat, and nesting, spawning, rearing and resting sites for aquatic or land species;
2) are set aside for study of the aquatic environment or as sanctuaries or refuges;
3) are contiguous or adjacent to the above two lands, and would harm natural drainage characteristics, sedimentation patterns, salinity distribution, flushing characteristics, current patterns...; or
4) are significant in shielding other areas from wave action, erosion or storm damage;
5) serve as valuable storage areas for storm and flood waters; and
6) are prime natural recharge areas.

Part 230.5 explains the considerations that will be given to permits that affect water quality standards. Generally selection of disposal sites and conditioning of discharges of dredged or fill material is based upon consideration of municipal water supply intake, shellfish, wildlife, recreation activities, threatened or endangered species, minimizing the damage to benthic life, the presence of wetlands, and the size of the disposal site.

Each of the above-mentioned considerations is weighed by the Administrator in determining whether to:

1) allow the proposed discharge with appropriate conditions to minimize unacceptable effects on the aquatic environment,
2) deny it, or
3) request additional information where necessary.

Penalties for Violation of the FWPCA. The enforcement provision of the FWPCA is described in 33 U.S.C. 1319. This Section provides the EPA Administrator with the authority to find a violation, give 30 days notice, and then issue a compliance order or bring a civil or criminal action. Civil actions include any appropriate relief. Criminal actions are dependent upon willful or negligent violations of the water quality standards.

Implementation Phases of Section 404. The program for implementing Section 404 is divided into three phases. July 1, 1975, the Corps' dredge and fill permit jurisdiction along the coast extended to all coastal waters subject to the ebb and flow of the tide, to their mean (higher) high water mark and also to contiguous or adjacent wetlands....[20] September 1, 1976, the Corps' jurisdiction will be extended to include primary tributaries and fresh water wetlands. Finally, effective July 1, 1977, discharges of dredged or fill material into any "navigable water" (as broadly defined) are scheduled to come under the Corps' jurisdiction.

Problems. As noted, Section 404 does not apply to removal projects and the Section 10 jurisdiction which does is more limited. Moreover, Section 404 has been the subject of controversy in the courts and in Congress. There are currently amendments[21] in Congress which seek to substitute a new definition of navigable waters for the provision now in Section 404--in order to retain more state control. It seems that many states already have programs to regulate the disposal of dredged or fill material and therefore they consider Section 404 an unnecessary encroachment on state authority.[22] On the other hand, some states want to retain Section 404 strengths either because their coastal management programs are inadequate or because they feel a double permit system is doubly protection.[23] In view of Oregon's position that "...any expansion of the Corps' permit jurisdiction should be delegated to the State of Oregon,"[24] Oregon's regulations affecting wetlands will be analyzed after some additional laws affecting salt marsh management are discussed.

Miscellaneous Laws Affecting Salt Marsh Management

1. The Water Quality Improvement Act of 1970[25] (the FWPCA of 1972)

The WQIA is the forerunner of the FWPCA of 1972. Its provisions were transferred to the later, more comprehensive, enactment. The Act is generally administered through the EPA. The provisions with particular effect on salt marshes are as follows:

Section 1252 requires the Administrator to prepare and develop a comprehensive program in cooperation with federal agencies, state water pollution control agencies, interstate agencies, and the industries involved for preventing, reducing, or eliminating pollution of the navigable waters and ground waters. Certain investigations are authorized by this section as are administrative grants to governors. Planning agencies receiving such grants are required to develop a comprehensive pollution control plan for the basin (including estuaries) which "...(c) recommends maintenance and improvement of water quality..."

Section 1255(n) states that the Comprehensive Plan for Water Pollution Control should also "study the effects of pollution *including sedimentation in the estuaries and estuarine zones, on fish and wildlife...*" and on other beneficial purposes. Such studies shall "also consider the effect of demographic trends... land and industrial development, navigation, flood and erosion control, and other uses of estuaries and estuarine zones upon the pollution of the waters therein." (Estuarine zones are defined as including salt marshes, coastal and intertidal areas, etc.)

Section 1342 delegates most permit authority over discharge of pollutants to states which have adequate programs. In Oregon the delegatal agency is the Oregon Environmental Quality Council. However, the Secretary of the Army retains a veto over permits which he judges would impair the anchorage and navigation of any navigable waters.[26] Further, if the state is not meeting its approved program, the Administrator may withdraw his approval of the state program if, after a hearing, corrective action is not taken. This delegation section should be compared to Section 1344.

Section 1344 is the statutory section which governs federal permits over the deposit of dredged or fill material into navigable waters. In this paper it has been discussed as Section 404 of the DWPCA. Basically, the Secretary of the Army is given authority to issue permits using "guidelines...applicable to the territorial seas, the contiguous zones and the ocean" (including the effect of disposal of pollutants on marine life and...changes in marine ecosystem diversity, productivity and stability.[27] As discussed above, this section has been broadly interpreted in the federal regulations.

2. The National Environmental Policy Act[28]

This congressional declaration of national environmental policy strives for cooperation between federal, state and local governments, and other concerned public and private organizations, "to use all practicable means and measures..., in a manner calculated to foster and promote the general welfare..." It further declares it the responsibility of the federal government to improve and coordinate federal plans, functions, programs and resources to...

(3) attain the widest range of beneficial uses of the environment without degradation...,

(4) preserve important historic, cultural, and natural aspects of our national heritage, and to maintain, wherever possible, an environment which supports diversity and variety of individual choice.

Section 4332 then requires the development of methods and procedures, in consultation with the Council on Environmental Quality (CEQ) to insure that environmental values will be given appropriate consideration in interpreting the policies, regulations and laws. Most importantly, Section 4332(c) requires, for every record or report on proposals for legislation and other *major federal actions significantly affecting the quality of the human environment,* a detailed statement by the responsible official on:

(i) the environmental impact of the proposed action,

(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,

(iii) alternatives to the proposed action, etc.

The above requirements are essentiall procedural--ensuring that the agencies following the procedures will be aware of the impact of their decisions when made. It is still unclear what constitutes a "major federal action..." but federal proposals as well as federal decisions have qualified as such.[29] It may also include any action permitted or approved by an agency.[30]

3. The Coastal Zone Management Act[31]

This Act declares the national policy:

"a) to preserve, protect, develop, and where possible, to restore or enhance, the resources of the Nation's coastal zone...

b) to encourage and assist the states to exercise effectively their responsibilities in the coastal zone through the development and implementation of management programs to achieve wise use of the land and water resources of the coastal zone giving full consideration to ecological, cultural, historic, and esthetic values as well as to needs for economic development,

c) for all Federal agencies engaged in programs affecting the coastal zone to cooperate and participate with state and local governments and regional agencies...and

d) to encourage the participation of the public..."

The Act specifies that "coastal zone" means the coastal waters and adjacent shorelands...and includes...salt marshes, wetlands and beaches.[32]

In order to encourage each state to develop a program, the CZMA first describes a Federal Management Development Program grant which requires:

1) a boundary identification,
2) definition of permissible land and water uses having a direct and significant impact on coastal waters,
3) inventories and designations of coastal areas of particular concern,
4) identification of state means of exerting control over the land (and relevant law),
5) broad guidelines on priority of uses, and
6) organizational structure for implementation.

The second phase of the CZMA is the administrative grant, which requires, among other things...

1) having a coordinated local area-wide and interstate plan with a continuing mechanism for consultation;
2) meeting the regulations and policies of the Act;
3) meeting the governor's review and approval;
4) holding public meetings, and generally enabling implementation of the plan.

The effect of the CZMA is to put the primary responsibility for planning on the states. However, it also requires that some of the traditional local rights be modified in the interests of the nation and the region.[33]

Local activities subject to national interest modification as listed in the comment to the CZMA Approval Regulation 923.15 include:

1) energy production and transmission;
2) recreation (of an interstate nature);
3) interestate transportation;
4) production of food and fiber;
5) preservation of life and property;
6) national defense and aerospace;
7) historic, cultural,aesthetic and conservation values; and
8) mineral resources.

Section 307 of the CZMA provides that federal permits of licenses issued will be consistent with the approved state program and that the state must certify applications for federal permits and licenses for such consistency. Further, federal agencies shall not approve applications for federal assistance except where consistent with the program or necessary in the interest of national security.

A separate consistency standard relates to federal development projectsin and federal activities affecting the states' coastal zone. These projects and activites "shall be consistent with the state's program to the maximum extent practicable."

Finally, it should be noted that the federal-state coordination under the CZMA is generally dependent upon a process called A-95 review.[34] This procedure does help identify potentially conflicting federal actions but does not establish a mechanism for resolving conflicts and doesn't specifically address the requirements of the CZMA. Oregon's implementation of the CZMA will be discussed under the section on state laws affecting salt marshes.[35]

4. The Flood Disaster Protection Act of 1973[36]

This Act enables the Secretary of Housing and Urban Development to carry out a National Flood Insurance Program. The Act addresses three key areas: insurance, flood plain management, and local community consultation and appeals procedures.

Under the Act:

1) federal financial assistance for acquisition or construction purposes for projects within special hazard areas previously identified by HUD and made eligible for flood insurance is prohibited, unless the project will be covered by such insurance for its full development cost (less land cost) or the new limit of available coverage, whichever is less; and
2) federal instrumentalities responsible for the supervision of lending institutions must direct such institutions to require flood insurance in connection with their real estate or mobile home and personal property loans in such identified areas, up to the maximum limit or the balance of the loan, whichever is less.

State-owned properties are exempt from these requirements if they are adequately covered under a state insurance fund satisfactory to the Secretary. If flood insurance is available (which depends upon whether federal development standards are met), it must be purchased in connection with federally-related financing of projects in identified flood-prone areas as a condition of the federal assistance.

The Act retains HUD's use of the 100-year flood standard and flood hazard area identification and actuarial rate studies for flood-prone communities. Further, the Act requires HUD to publish information on known flood-prone communities and to notify them within six months of enactment of their tentative identification as such, following which the community must either make prompt application for participation in the flood insurance program or satisfy the Secretary that it is no longer flood-prone. Communities having identified flood-prone areas were required to participate in the flood insurance program by July 1, 1975, or be denied federally-related financing for projects that would be located in such areas.

In Oregon, Coos County and the cities of Coos Bay and North Bend were all identified as being within flood-prone areas, and they are now participating in the "Emergency" Program. Communities entering the program generally do so in two phases. They first become eligible for the sale of flood insurance in the Emergency Program under which only half of the program's total limits of coverage are available and all insurance is sold at subsidized premium rates. This is the phase at which Coos County and the cities are operating. They have passed the regulations requiring permits for building and thus enabled their homeowners to buy subsidized flood insurance. The second phase, the "Regular" Program, cannot be entered into until a community rate study has been completed. The projected completion date for Coos County is November, 1977. Buildings constructed on or before completion of the study, as well as those located outside of the special flood hazard areas, remain eligible for the first half of available coverage (known as "first layer" coverage) at either subsidized rates or actuarial rates, whichever are cheaper. All other buildings require actuarial rates on both layers of coverage. Flood Hazard Boundary Maps are on file within each eligible community--usually the building inspector's office or the city clerk's office. Maps, literature and policy application forms and manuals are available from State Farm Fire and Casualty Company in Salem.

5. The Fish and Wildlife Coordination Act of 1956[37]

This Act is the foundation for the Endangered Species Act of 1973[38] and it set up the National Wildlife Refuge System (the System) which consolidates the authorities relating to the various categories of areas that are administered by the Secretary of the Interior--wildlife refuges, areas for the protection and conservation of fish and wildlife that are threatened with extinction, waterfowl production areas, etc.[39] It also provides that whenever the waters of any...body of water are...controlled or modified for any purpose whatever...by any department or agency of the U.S., adequate provision ...shall be made...for the conservation, maintenance, and management of wildlife resources...and...habitat...including the development and improvement of such wildlife resources....[40] This provision is the one that requires the Corps to consult with the Bureau of Fish and Wildlife before acting. Although the consultation is advisory only, it appears that the use of waters, land or interests supervised by the Bureau is required to be in accordance with general plans approved jointly:

1) by the head of the participating department or agency exercising primary administration in each instance;
2) by the Secretary of the Interior; and
3) by the head of the agency exercising the administration of the wildlife resources in the state.[41]

Finally, the F & WCA provides for the public acquisition of land, waters and interests therein.

6. The Endangered Species Act[42]

This Act seeks to conserve the ecosystems upon which endangered and threatened species depend. In order to do this, the ESA authorizes the "necessary"[43] regulations. Then it provides civil penalties and citizen suits for their enforcement. The Act affects marshes because the term "species" includes any subspecies of fish or wildlife or plants and any other group of fish or wildlife of the same species or common spatial arrangement that interbreed with mature.[44] A species is determined as "endangered" or "threatened" by the Secretary of the Interior, who publishes a list of them in the Federal Register.

State laws which conflict with the ESA are void unless they are more restrictive regarding the "taking" of a species than the exemptions or permits provided for in the ESA. Also, if there is a more restrictive provision in the Marine Mammals Protection Act of 1972,[45] it prevails.

The Secretary of the Interior may utilize the authority of the Fish and Wildlife Coordination Act of 1956,[46] the Fish and Wildlife Coordination Act, as amended, and the Migratory Bird Conservation Act[47] to acquire land as appropriate. Finally, the Secretary is independently authorized to acquire land using Land and Water Conservation funds.[48]

7. The Estuary Protection Act[49]

This Act expresses congressional policy on values of estuaries and need to conserve their natural resources. It authorizes the Secretary of the Interior, in cooperation with other federal agencies and the states, to study and inventory estuaries of the United States, and to enter into cost-sharing agreements with states and subdivisions for permanent management of estuarine areas in their possession. It requires further that the Secretary provide his view and recommendations on all projects which impact estuarine areas and require congressional approval. It appears that the Northwest was treated in a very general fashion and that there were no specific recommendations made for Coos Bay.[50]

8. The Marine Sanctuaries Act of 1972[51]

This Act authorizes the Secretary of Commerce to consult with various other secretaries and then designate marine sanctuaries in certain areas of the ocean waters and of other coastal waters where the tide ebbs and flows. The Secretary determines these sites for the purpose of preserving or restoring such areas for their conservation, recreational, ecological or aesthetic values. The governor of any state may certify to the Secretary that the designation is unacceptable to his state. Also, a provision allows for hearings in coastal areas most directly affected "for the purpose of receiving and giving proper consideration to the views of any interested party." After designating a sanctuary, the Secretary may issue regulations controlling permitted activities. The U.S. Army Corps of Engineers issues these permits. The regulations must be consistent with the purposes of the Act as set out in 33 U.S.C. 1401.

9. Other Related Federal Laws

The Anadromous Fish Conservation Act, as amended (16 U.S.C. 757a-757f).

Forest and Rangeland Renewable Resources Planning (16 U.S.C. 1601 et seq.) and amendments.

Convention between the U.S.A. and the United Mexican States for the Protection of Migratory Birds and Game Mammals.

The Migratory Birds Convention Act (R.S., 1970, c. M-12).

The Marine Mammal Protection Act (1972) (P.L92-522, 16 U.S.C. 1361 et seq.).

State

The states and the federal government have concurrent jurisdictions over navigable waters of the states.[52] The Oregon laws which affect salt marshes are primarily: The Fill/Removal Law,[53] the Submerged and Submersible Lands Law,[54] the state standards for water quality,[55] the Forest Practices Act,[56] the Submerged Lands Leasing Policy,[57] the Dock Policy,[58] and the Land Conservation and Development Commission (LCDC)[59] Goals and Guidelines. In addition, the South Slough Sanctuary,[60] created partially by LCDC, will be discussed here.

1. Oregon's Fill/Removal Law

This Act authorizes the Director of the Division of State Lands to control the removal of material from the beds and banks or filling of the "waters of this state" by requiring the property owner or governmental entity involved to apply for a permit to conduct the activity.[61]

As a matter of policy, the fill/removal law seeks the protection, conservation and best use of the water resources of the state.[62] It further recognizes that streams, lakes and other bodies of water of the state *are vital to the economy and well-being of the state and its people for domestic, agricultural and industrial use and also as habitats and spawning areas for game and food fish, avenues for transportation, and sites for public recreation.* Thus removal/fill projects are regulated:

1) because of the importance of the waters of the state;
2) in order to avoid health, safety and welfare hazards to the people; and
3) in order to avoid interfering with or injuring public navigation, fishery and recreation uses of the waters.

As an additional matter of policy, the Division of State Lands (DSL) must avoid condemnation, inverse condemnation, taking or confiscating property without due process of law.

The Act serves laudable purposes; however, there are several problems with it. First, by definition, "fill" means the total of deposits by artificial means equal to or exceeding 50 cubic yards or more of material at one location. Similarly, "removal" means the taking of more than 50 cubic yards or the equivalent weight in tons of material...in a calendar year. The 50 cubic yard limitation is unnecessary. It may be contended that this limit avoids the time-consuming review process of projects which have minimal environmental impact; however, it confuses property owners because federal laws do not have the 50 cubic yard limitation.[63] More importantly, it makes it possible to block a small stream which has high public resource value without permission from the state.

Another phrase which is unclear is "waters of this state." It is defined as "natural waterways, including all tidal and non-tidal bays, constantly flowing streams, lakes and other bodies of water in this state, navigable and nonnavigable..."[64] This has been interpreted in the Stand Land Board Rules to include estuaries, salt marshes and wetlands, but the authority for this interpretation is not apparent. Fortunately, the legislative history of the statute shows that estuaries were intended to be covered,[65] but the statutory wording would be better if it were either exclusionary (waters of the state means all bodies of water within the state except irrigation ditches...) or if it specified estuaries and salt marshes.

Second, the policy behind the fill/removal law could be stated more strongly. One may infer from the language that the protection or Oregon's natural environs is a primary consideration in determining public benefit, but the policy statement fails to directly state that priority. Also, the requirements of due process are not specified in the policy section, which proscribes condemnation, inverse condemnation, taking or confiscating of property.[66] To date, in the only court discussion of this issue in Oregon,[67] Judge Spencer found that the process of granting or denying a permit (which includes four criteria on which the Director bases his decision and a hearing and appeal) met the due process standard and was therefore constitutional.[68] However, since the defendant had not applied for a permit and not gone through the process, the issue of whether a permit denial would constitute a "taking" was not ruled upon.

In addition to the taking challenge, the language describing a conditional permit has caused some problems.[69] It says the Director "may impose such conditions as he considers necessary to carry out the purposes of [the statute]." It is not clear whether the Director is limited in the types of conditions which may be imposed, whether work on an unrelated site could be required, or whether the conditions imposed must be closely related to the permit activity and in mitigation of its effect. The latter interpretation appears to be the most reasonable,[70] but the question has not yet arisen in an Oregon case.[71] The authority of other state agencies is also made clear in this section. The Director may consult with the various state agencies' representatives in considering a permit--their recommendations are only advisory.

Violations of the fill/removal law may be handled by penal enforcement proceedings or by the Director of the Division in proceedings to abate alleged public nuisances at law or in equity--but not until the defendant has had an opportunity to be heard. This means that the state may not have a temporary restraining order to restrain the defendant until the propriety of granting an injunction can be determine--instead, the state must wait until the defendant has been heard. Essentially, this provision denies the state the customary rights of a civil litigant and enables violations to continue until a hearing has been held.

The Division of State Lands needs a more effective enforcement tool to support the fill/removal law. In 1973, Senate Bill 37 was proposed to provide the DSL with authority to initiate civil proceedings for the removal of unapproved artificial fill or deposit. This legislation, however, was defeated, largely because of its projected fiscal impact.[72] Another alternative would be a civil penalty of from $200-$500 for a permit violation. This type of enforcement would be less costly, and probably more effective than the right to sue a violator would have been. Such a penalty would, of course, be subject to review and appeal.

Another controversial provision is ORS 541.665, which says that if the Director issues a permit to fill, it *shall be presumed* that such fill does not infringe upon the public rights of navigation, fishery or recreation, and the public rights to lands created by the fill shall be considered extinguished. This language was used in order to remove possible clouds on titles to filled lands. The language has been interpreted as a presumption which may be rebutted by contrary evidence in the appeals process. In this regard, it is to be hoped that the importance of the public right of use--navigation, commerce and fishery--will be recognized as it has been in the Oregon Admissions Act,[73] the Tidelands Sales Act,[74] and Oregon case law.[75] Prior to this section, the public had been presumed to retain its rights in lands granted by the state unless clear and special words gave the public right of use away.[76] It now may be argued, in light of the wording of the statute, that in permit cases, special wording in state permits must preserve the public right.[77] If the presumption is necessary in order to remove clouds on title to filled lands, the statute should at least state that the presumption is rebuttable or that it does not affect tidelands.

In sum, Oregon's Fill/Removal Law serves a good regulatory function but certain sections of it are not clear and the policy statement could be strengthened. Also, it should not be confused with a comprehensive coastal management plan. The issuance of a Fill/Removal permit only indirectly considers such factors as water quality or the effect on adjacent lands.[78] It does not project a plan or goals for the management of the coast.

2. The Submerged or Submersible Lands Law

This law prohibits the filling of submerged or submersible lands without the *owner's* approval. Since most submersible lands are privately owned, the state only has power under this law when submersible lands are concerned. However, if the private owner's approval of the fill is obtained, a fill still cannot be undertaken until a permit is obtained pursuant to the fill/removal law. Such a permit may not be granted by the DSL where the filling would unreasonably interfere with existing public rights in or uses of navigable waters.[79] This interpretation is supported by the presumption that a permitted fill or removal does not affect the public rights,[80] and the criteria for issuing a permit,[81] and the policy of the fill/removal law.[82]

3. State Standards for Water Quality

Oregon's water quality standards are set and monitored by the Department of Environmental Quality (DEQ) as approved by the federal Environmental Protection Agency (EPA).[83] DEQ has adopted special water quality standards to supplement the general water quality standards for protecting the beneficial uses[84] of specified waters of the state and to conserve the waste assimilative capacity of the waters so as to accommodate maximum development and utilization of the resources of the state.[85]

As a matter of policy, the DEQ strives for the highest and best practicable treatment and/or control of wastes, activities and flows so as to maintain dissolved oxygen and overall water quality at the highest possible levels.[86] DEQ also seeks to keep water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor and other deleterious factors at the lowest possible levels.

In order to achieve these goals, general and specific water quality standards have been established. The Special Water Quality Standards for the Marine and Estuarine Waters of Oregon apply to Coos Bay salt marsh management.[87] These standards state that "no wastes shall be discharged and no activities shall be conducted which either alone or in combination with other wastes or activities will cause:

1) Of upwelled marine waters naturally deficient in DO, DO concentrations to be less than 6 milligrams per liter for estuarine waters, or less than saturation concentrations for marine waters.
2) Organisms of the Coliform Group. (MPN or equivalent MF using a representative number of samples).
    a) (For marine and shellfish growing waters). The median concentration of coliform bacteria of sewage origin to exceed 70 per 100 milliliters.
    b) (For estuarine waters other than in shellfish growing areas). Average concentrations of coliform bacteria where associated with fecal sources, to exceed 240 per 100 ml or to exceed this value in more than 20% of samples.
3) Hydrogen Ion Concentration (pH). pH values to be outside the range of 7.0 and 8.5 over shellfish growing waters.
4) Turbidity. (Jackson Turbidity Units, JTU). Turbidities to exceed 5 JTU above natural background values except for certain short-term activities which may be specifically authorized by the Sanitary Authority under such conditions as it may prescribe and which are necessary to accommodate essential dredging or construction where turbidities in excess of this standard are unavoidable.
5) Temperature. Any significant increase above natural background temperatures, or water temperatures to be altered to a degree which creates or can reasonably be expected to create an adverse effect on fish or other aquatic life."[88]

Unless an activity directly affects water quality, the DEQ acts only in an indirect capacity. That is, DEQ frequently gives technical responses in an advisory capacity to permits circulated throughout agencies and organizations. Specifically, DEQ may comment on Department of Geology and Mining Resources reclamation plans, DSL removal/fill permits, Corps of Engineers navigable waters projects, State Forestry projects, county and city government projects and Council of Government undertakings.

In Coos Bay, the Department plans also to establish a Section 208 (of the FWPCA) waste management program which will be an area-wide waste treatment management tool concentrating on non-point sources affecting water quality. Currently such programs are being developed for eastern Oregon, but it will be about two years before such a program starts in Coos Bay.[89]

The Department of Environmental Quality's log-handling policy also has an impact on salt marsh management. At this point, the policy is very weak. The policy recognizes the adverse affect which bark debris and leachate releases resulting from dumping, storage and millside handling of logs in public waters can have on water quality; therefore, it proposes a state permit for log-handling operations on public waters where problems exist or are likely to occur.[90] The draft permit requires easy letdown of logs and is tentatively scheduled to go into effect in 1977.

4. The Forest Practices Act

The FPA was enacted in 1972. Its policy is to encourage forest practices that maintain and enhance:

1) social and economic benefits such as the jobs, products, and tax base of the forest industry, and
2) resources such as the forest tree species, soil, air and water resources and habitat for wildlife and aquatic life.

Coos Bay is located in the Southwest Forest Region. The salt marshes are mainly affected by the Oregon Forest Practice Rules[91] which interpret the Act--specifically, those relating to harvesting and stream protection[92] or the siltation caused by road construction and maintenance.[93]

The rules relating to stream protection during and after harvesting operations require maintenance of stream beds and stream-side vegetation in as near a natural state as possible in order to maintain water quality and aquatic habitat. To do this they list several rules:

1) Avoid tractor skidding in or through any stream...
2) Avoid cable yarding through any Class I[94] stream. When yarding is necessary, do it by swinging the yarded material free of the stream bed and banks.
3) Cable yarding through Class II streams should be avoided. When unavoidable, it shall be done to minimize stream-bank vegetation and channel disturbance.
4) Provide the shading, soil stabilizing and water filtering effects of vegetation along Class I streams by one of several means....[95]

5) Leave stabilization strips of undergrowth vegetation along all Class II streams in widths sufficient to prevent washing of sediment into Class I streams below.
6) Keep machine activity in beds of streams to an absolute minimum.

The Road Construction and Maintenance rules seek to establish minimum standards for forest practices that will provide the maximum practical protection to maintain forest productivity, water quality and fish and wildlife habitat during road construction and maintenance. In order to do this, the rules list factors which should be considered in locating, designing, constructing and maintaining a road. Among the location criteria the rules say, "where practical alternatives exist, avoid...marshes...." A relevant road design factor is "Design culvert installations to prevent erosion of the fill." Also, "Where justified by the volume of traffic, grade or type of soil over which the road is built, use roadside ditches and relief culverts."

Clearcutting Legislation. It is appropriate to note here there are several bills currently pending in Congress containing a wide variety of proposals which, when enacted, will affect only the national forests.

5. Oregon's Leasing Policy for Submerged and Submersible Lands

Ownership of the Lands. When Oregon became a state in 1859, title to the lands underlying navigable waters passed to the state.[96] The state title, as such, is complete and state ownership rights are subject only to the paramount power of the U.S. to control such waters for purposes of navigation in interstate or foreign commerce. In the 1870's, the state made and repealed some grants to these lands, but since then, the only way the state has parted with its title to these lands was by sale, or lease, of its tidelands prior to 1963, or by sale, lease or exchange of its submerged and submersible lands after 1963.[97] Submersible lands are defined as lands lying between the lines of ordinary high and low water of all navigable waters held by or granted to this state by virtue of her sovereignty....[98]

Public Trust. The state holds title to its submerged or submersible lands in trust "for the people of the state that they may enjoy the navigation of the waters, carry on commerce over them, and have liberty of fishing therein freed from the obstruction or interference of private parties."[99] Theoretically, this means that everyone should have an equal opportunity to use and enjoy these lands. Therefore, rather than prohibiting the use of the lands for commercial purposes, the state requires people to pay a royalty for the use of materials contained in the beds and banks and this money goes into the Common School Fund. Thus, no one can use state-owned land, except through a lease stipulating a royalty. The lease is issued by the Division of State Lands, the administrative arm of the State Land Board.

State Land Board Regulations. The State Land Board formulates state land policy and issues regulations which interpret and apply the statutory authority given to the Division of State Lands to lease portions of the beds of navigable waterways for uses other than royalty leases for mineral extraction. The goal of the State Land Board is to obtain the greatest benefit for the people of the state, consistent with the conservation of the resources under sound techniques of land management.[100] The State Land Board recognizes that the public's navigable waterways constitute a resource of great value and utility to all but that the resource is limited, therefore the leasing regulations are designed to allocate the land to private use as fairly as possible without interfering with the use of the waterway as a highway for public navigation, commerce, fishing and recreation.

Annual Rentals. In order to allocate the private use of the lands, the State Land Board determines annual rentals for all leases of the state-owned submerged and submersible lands according to use classifications.[101] If the rental is for the *extension of an upland use*--such as a floating restaurant or a pile-supported building unnecessarily located over water, the annual rental is calculated by multiplying the number of acres to be leased by six percent of the per acre appraised value of the land.

On the other hand, if the property use is *water dependent* (requiring location on or over water), the annual rental of marinas and moorages is calculated as three percent of the number of boat-slips or tie-ups times an Occupancy Factor (the percentage of slips filled year around). Log storage and handling operations constitute another water dependent use which is calculated at $150/acre per year for the first acre and $90/acre per year for each additional acre. (This rental rate is subject to a rate study.) Finally, *new, unusual, or hardship uses* are appraised by the Division staff pursuant to OAR 82-030.

6. Oregon's Dock Policy

A Corps of Engineers' section 10 permit is required for any dock which constitutes an obstruction of "navigable waters."[102] When a Corps permit is required, the DSL has the opportunity to comment on its issuance. The DSL restrictions on privately owned moorages in tidewater in coastal rivers and bays are quite limited. These restrictions refer only to the size and placement of the float or combination of floats. They require that the total area of the float be less than or equal to 600 square feet including the area enclosed by a boatslip or boathouse. The maximum length of such float or combination is 50 feet. The shoreward edge of the float is required to be as close to the mean lower low tide line as possible while affording sufficient depth to moor the owner's boat and the riverward edge may not exceed the line of adjacent floats along the same bank. Also, the riverward edge may not extend beyond ten percent of the mean lower low tide width at the point of moorage.

Environmental considerations are noticeably lacking from the above restrictions. It is debatable whether the DSL has the sources; #6 air, water and land resources quality; and #8 recreational needs.

The forest lands goals is to conserve forest lands as forest uses. Forest lands are to be retained for the production of wood fiber and other forest uses. Existing forest land uses are not to be changed unless the change is in conformance with the comprehensive plan. Recognized forest uses include open space, buffers from noise, and visual separation of conflicting uses; watershed protection and wildlife and fisheries habitat; also, outdoor recreational activities and related support services and wilderness values compatible with these uses.... The guidelines for forest lands mention that forest roads should be the minimum width necessary for management and safety and that highways through forest lands should be designed to minimize impact on such lands.

The open spaces goal is to conserve open space and to protect natural and scenic resources. This goal directs that the location, quality and quantity of certain resources be inventoried--including fish and wildlife areas and habitats; ecologically and scientifically significant natural areas; water areas, *wetlands,* watersheds and groundwater resources. If there are no conflicting uses of these resources, they are to be managed so as to preserve their original character. Where conflicting uses are identified, the social, environmental and energy consequences of the conflicting uses are to be examined and a program is to be developed which achieves the open spaces goal.

The sixth goal is to maintain and improve the quality of the air, water and land resources of the state. To attain this goal, state and federal environmental quality statutes, rules and regulations are to be met. Also, present and future waste and process discharges shall not:

1) exceed the carrying capacity of the resource considering long range needs,
2) degrade the resources, or
3) threaten the availability of the resources.

The eighth goal seeks to satisfy the recreational needs of the citizens of the state and visitors. An inventory of the recreational needs of the planning area is based upon an analysis of public wants and desires. The carrying capacity of the air, land and water resources of the area is a major consideration in planning recreation areas.

Other goals which may tangentially enter into planning decisions concerning salt marsh management are the economic goal of diversifying and improving the economy of the state (#9); the transportation goal of providing and encouraging a safe, convenient and economic transportation system (#12); and the energy conservation goal (#13).

<u>Coastal Planning Goals and Guidelines</u>. In recognition of the unique characteristics and circumstances of Oregon's coast, LCDC has drafted specific coastal goals. Draft No. 3 (June, 1976) contains both an estuarine resources goal and a shorelands goal which, if adopted, will act to protect these resources.

1) <u>The Estuarine Resources Goal</u>

This goal specifically aims at recognizing and protecting the unique environmental, economic and social values of each estuary;

authority to deny a dock request which complies with the described restrictions if there is no local law (comprehensive plan or zoning ordinance) which further restricts development. Generally, the State Department of Fish and Wildlife does comment, however, that the proposed moorage should be no larger than necessary for the applicant's needs. It is also possible that the DSL could argue interference with the public right of use in certain cases.[103] In addition, if the Corps denied an application on the basis of a federal wetlands review, the DSL could concur, even though those development standards do not have the force of law. Finally, if the proposed moorage has an effective use area of more than 3,000 square feet or a float, dock, or boathouse use area in excess of 1,000 square feet, then the DSL will require the applicant to lease the submerged or submersible land involved.[104]

7. The Land Conservation and Development Commission (LCDC)

In 1973, Oregon enacted Senate Bill 100, which created the LCDC (a seven member lay body responsible for making land use planning and policy decisions) and the Department of Land Conservation and Development (the administrative arm of LCDC). The purposes of S.B. 100[105] are to insure Oregon's livability, to conserve Oregon's resources and to provide for Oregon's orderly development. In order to achieve these purposes, S.B. 100 mandates that citizens be provided the opportunity to participate in land use decisions throughout the entire planning process. It then provides for a partnership of local and state government to coordinate comprehensive land use plans and administer S.B. 100. Finally, it proposes a single coordinated comprehensive plan among all units of government and state and federal agencies.

S.B. 100 created the LCDC so that it would:

1) adopt statewide land use goals and guidelines,
2) coordinate activities of statewide significant,
3) coordinate state and federal agencies,
4) provide for citizen involvement, and
5) serve as an appellate body to resolve conflicts.

In addition, LCDC may recommend to the legislature that it designate specific geographic areas as "critical areas" requiring special land use management. LCDC reports its activities monthly to the statutory Joint Legislative Committee on Land Use.

Senate Bill 100 also assigns specific responsibilities to the DLCD, cities, and counties, and state and federal agencies and special district. The most important of the responsibilities is the development of the local comprehensive plan--charged to cities and counties. Each comprehensive plan is reviewed by the DLCD for compliance with state-wide planning goals and guidelines and coordinated with other proposed plans.

State-wide Planning Goals and Guidelines, Oregon's Land Conservation and Development Commission (LCDC) adopted 14 state-wide planning goals and guidelines[107] on December 27, 1975. The goals which primarily affect salt marsh management are: #4 forest lands; #5 open spaces, scenic and historic areas and natural re-and to protect, maintain and where appropriate, develop and restore the long-term environmental, economic and social values, diversity and benefits of Oregon's estuaries and associated wetlands. In order to reach this goal, coastal comprehensive plans must:

1) describe environmental, economic and social diversity among estuaries based upon the inventory requirements;
2) maintain the diversity by classification within the comprehensive plan according to the most intensive alteration which already exists or which may occur in that estuary;
3) designate distinct land and water use management classes and practices within each estuary, and establish priorities of use for particular areas which will retain the diversity of estuarine characteristics identified in the inventory. These uses shall reflect and remain compatible with adjacent shorelands characteristics. When classifying estuarine areas into management units, the following shall be considered and included:
   a) biological and physical features and characteristics
   b) social and economic uses and needs
   c) water depth and access to open water or channels
   d) maintenance of biological, social and economic diversity among and with estuaries
   e) water quality, both existing and potential impact of projected management on water quality
   f) adjacent upland characteristics
   g) compatibility with adjacent uses, and
   h) energy costs and benefits; and
4) develop specific implementing procedures, including necessary ordinances, to achieve the intent of the Estuary Goal. These shall indicate how the unique features and valuable resources will be protected, enhanced, or restored.

The Inventory. A very general statement in the Estuarine Resources Goal describes the inventory as a necessary preliminary step for providing information on the nature, location and extent of physical, biological, social and economic resources in sufficient detail to establish a sound basis for land and water use management. The Guidelines explain that the biological inventory should include location, description and extent of:

1) the benthic flora and fauna;
2) the fish and wildlife species, including part-time residents;
3) the important resting, feeding and nesting areas for migrating and resident shorebirds, wading birds, and wildfowl;
4) the areas important for recreational fishing and hunting, including areas used for clamdigging and crabbing;
5) estuarine wetlands;
6) fish and shellfish spawning areas;
7) significant natural areas; and
8) areas presently in commercial aquaculture.

<u>Considerations and Requirements</u>. The estuarine portions of each comprehensive plan...shall be based on the following:

1) Protection of the estuarine ecosystem by maintaining the surface area of the estuary, its flushing capacity, and its water circulation characteristics. Dredge or fill activities which would alter the surface area, flushing capacity or water circulation characteristics shall be permitted only when it is necessary to provide a significant public gain which cannot feasibly be provided in any other manner. When such dredge or fill activities are permitted, another area of similar biological potential shall be provided to insure that the integrity of the estuarine ecosystem is maintained.

It should be noted here that by definition, the estuary includes: a) estuarine waters; b) tidelands; c) tidal marshes; and d) submerged lands. Therefore, the first consideration of maintaining the surface area of the estuary means that the surface area, flushing capacity and circulation characteristics of a salt marsh would be protected. The second consideration mentioned in the Estuarine Resources Goal is:

2) A clear presentation of the impacts of any proposed alteration on the integrity of the estuarine ecosystem, and a careful *demonstration of the public's gain* which warrants such modification or loss.

This means that the burden is on the proponent of change to show that the public will gain from the proposed alteration. Other important considerations include:

3) Provision for appropriate navigation and water-dependent commercial enterprises and activities by designating suitable sites and protecting them from incompatible uses. Interim uses which are not water-dependent may be permitted if they do not conflict with the immediate or long-term use of the sites for water-dependent use....

7) Designation of water storage areas where needed for products of industry and commerce. Land storage for such products shall be provided as a preferable alternative whenever feasible.

8) Restriction of the proliferation of individual single-purpose docks and piers by encouraging *community facilities* common to several uses and interests. The site and shape of a dock or pier shall be limited to that required for the intended use. Alternatives to docks and piers...shall be investigated and considered.

This consideration is particularly good in light of the dock policy of the Division of State Lands which does not restrict the building of docks at all except with regard to size and shape.

9) Identification and protection of estuarine areas and *features of particular biological and scientific importance*, such as critical fish and game habitat, habitat for rare or unique species, important nursery, spawning and feeding sites, and significant natural areas.

10) Identification of appropriate areas for restoration where

> activities have adversely affected some aspect of the estuarine system, and where restoration would contribute... Sample sites would include areas such as abandoned diked estuarine marsh areas....

The above considerations will probably have the most influence on marsh management if the Estuarine Resource Goal is adopted in its present or a substantially similar form. In addition, the Guidelines propose an estuarine classification system which would limit the type and extent of alteration which may occur in each estuary according to the most intensive alteration allowable. This system is to be based on physical features. A second classification system, a Management Classification System, is proposed to reflect limitations imposed by natural resources, including areas of high natural value and hazard areas, as well as social and economic need features. Three types of management classes are proposed:

1) Preservation areas--including at a minimum, major tracts of salt marsh, tide flats, seagrass beds, oyster bars and clam beds...
2) Conservation areas--including smaller tracts of lesser biological importance, of significant habitats. Partially altered areas, or estuarine areas adjacent to existing development of moderateintensity, should also be conservation areas.
3) Development areas--these are divided into shallow-draft and deep-draft navigation areas.

<u>The Shorelands Goal</u>. This Goal also applies to salt marshes since it defines coastal shorelands as including those lands adjacent to all estuaries and adjacent coastal wetlands. The Goal strives to conserve, protect and where appropriate develop and restore the resources and benefits of all shorelands.... It also seeks to reduce the hazard to human life and property, and the adverse affects upon water quality and wildlife habitat resulting from the use and enjoyment of Oregon's coastal shorelands. To achieve these aims, the local comprehensive plan is directed to establish a landward shorelands boundary, identify the specific resources within it, and classify the shorelands into management units which are, among other things, compatible with the characteristics of the adjacent coastal waters. The suggested categories for classification are:

1) Natural areas--these would include major saline and fresh water marshes...
2) Conservation areas--including fresh water marshes, bogs or swamps adjacent to the shoreline...
3) Water-dependent use areas--including shoreland areas especially suited for water-dependent use because of some unique feature of the water-land interface, including but not limited to the following:
   a) areas having physical, chemical, and biological characteristics suitable for aquaculture
   b) deep areas
   c) protected areas subject to scour;
4) Water-related use areas--this appears to be a leftover category which should be assigned only to shorelands

which are suitable for development and which are not otherwise classified. If uncertainty exists concerning the classification of a shoreland area, local government is directed to assign the Conservation classification to that area rather than a Water-dependent or Water-related use classification.

The South Slough Sanctuary. On March 7, 1974, the National Oceanic and Atmospheric Administration (NOAA) proposed guidelines (15 CFR Part 921) pursuant to Section 312 of the Coastal Zone Management Act of 1972 (CZMA) for establishing the policy and procedures for the nomination, selection and management of estuarine sanctuaries.

Under Section 312, the Secretary of Commerce is authorized to make available to each state certain grants up to 50 percent of the cost of acquisition, development and operation of estuarine sanctuaries. These grants are awarded to states on a matching basis in order to provide scientists and students the opportunity to examine over a period of time the ecological relations within the area. The intent is to ensure that a representative series of areas will be available for scientific or educational uses such as baseline studies, studies of natural ecological systems, studies for controls against which the impacts of development might be compared, and interpretive studies. A biogeographic classification system was used for selecting a sanctuary site to reflect the geographic, hydrographic and biologic differences of a variety of ecosystems. One of the first sites selected was the South Slough Sanctuary site in Coos County. This site is now close to approval.

In Oregon, the Land Conservation and Development Commission (LCDC) administers the CZM funds. The management agency is the Division of State Lands (DSL) which operates according to State Land Board policy. In Coos Bay, a technical management team, composed of representatives from state agencies and Commissioners from the Coos County Board is providing technical assistance and policy recommendations to the State Land Board. The team also will advise the sanctuary manager[109] in the management and long-term protection of the South Slough Estuarine Sanctuary. The broad management objective of the management team is to advise in the overall management, research and education programs within the Sanctuary. Finally, a private organization, The Nature Conservancy (TNC), has also played an important role in buying about half the property included in the sanctuary boundaries.[110]

The overall value of the South Slough Sanctuary is estimated at $3.9 million. The DSL is appraising the property under the Federal Relocation Act.[111] Certain properties are still being evaluated for their appropriateness. The evaluation criteria include slope, sewage disposal, soil stability, pristine qualities, existing zoning and existing uses.

After a review of the South Slough Estuarine program, it was determine that protection of the area as a natural unit with full recognition of other public and private interests would be better served by including the entire portion of the watershed in a three-tiered management program. Under this program, Level I is the sanctuary proper and requires fee title control. The Level I boundary must be greater than one-fourth mile from the mean high tide.[112] Level II is the buffer and critical impact control area. It also includes all areas of 30 percent slope or greater. In this area state interests need only control specific acts or uses and fee title control is not required. Finally, Level III consists of the Sanctuary Area Basin. In this area appropriate management will occur by strictly enforcing the existing statutory laws.[113] It should be noted that the boundaries of these Levels have been tailored to follow property lines in order to simplify acquisition problems.

Local

The basic components of local law affecting salt marshes are the comprehensive plan and existing zoning and subdivision ordinances. The local bodies creating such laws are the Coos-Curry Council of Government, the Board of County Commissioners for Coos County, the Coos County Planning Department, the Coos City Planning Department and the Port Commission of Coos Bay.

The Context of Local Law. In accordance with Section 305 of the federal Coastal Zone Management Act,[114] Oregon is developing a management program for the land and water resources of its coastal zone. Oregon's Coastal Zone Management Program is based on Senate Bill 100,[115] the authority of other state statutes, and the achievements of its former Oregon Coastal Conservation and Development Commission. As discussed, S.B. 100 created LCDC and its administrative arm, The Development of Land Conservation and Development, which implements the Commission's policies. LCDC developed Statewide Planning Goals and Guidelines which set forth state policy for land and water resource management, local comprehensive plans and related actions of all levels of government. In addition, LCDC drafted the Coastal Goals and Guidelines which, when adopted, will be used to assess the comprehensive plans of counties on the coast.

The Comprehensive Plan. Each city and county must develop a coordinated comprehensive plan, zoning and subdivision ordinances which are in conformance with the adopted Statewide Planning Goals and Guidelines. Coastal cities and counties will have to comply with the adopted Coastal Goals and Guidelines as well. Also, special district plans and actions must conform with the Goals and the local comprehensive plans.

Both LCDC and the local county governing body review plans and ordinances. Comprehensive plans, zoning and subdivision ordinances are to be in compliance with the Goals and Guidelines within one year from the adoption of the goals. However, planning extensions may be provided by LCDC after a detailed compliance schedule has been submitted by the local government.

Plan Enforcement. When it is necessary to enforce an LCDC Goal, a plan adopted under the statewide goals, or an appealed decision by the LCDC, the LCDC has two courses of action. It can seek injunctive relief in the state courts to achieve compliance, or it can complete all or a portion of the local plan for a community which refuses to fulfill its plan obligations and withhold the county's cigarette and liquor taxes. Coos County does not yet have a comprehensive plan. It does have the estuarine element of its comprehensive plan, but this is being reviewed by LCDC.

Authority of the Comprehensive Plan. The authority of the Comprehensive Plan has been challenged because ordinances, statutes and rules affecting a county often conflict with the plan. In Oregon, however, two leading cases have established its authority. In *Fasano v. Washington County Commissioners*, a requested use failed to conform to the residential designation of plan of development but the Washington County Planning Commission granted a zone change to the landowner. Thereupon, the local homeowners filed a petition for review of that action in the Circuit Court and won. The Oregon Court of Appeals affirmed that decision and then the Oregon Supreme Court reviewed it and agreed that the zone change should not have been granted. In its decision, the Court asserted its authority to review zone changes and it noted that planning commission plans and zoning ordinances are closely related--both intended to be part of a single integrated procedure for land use control. The Court further pointed out that the plan embodied policies and guidelines and the zoning ordinances should give effect to those policies and guidelines.

The second case dealing with comprehensive plans is *Baker v. City of Milwaukie*.[117] In this case, the zoning ordinances of the city allowed a more intensive use in an area than the comprehensive plan did. Baker therefore sought to compel Milwaukie to conform the zoning ordinance to the comprehensive plan, to cancel a variance approval by the Milwaukie Planning Commission, and to suspend the issuance of building permits in areas of the city where the zoning ordinance allowed a more intensive use than that set forth in the comprehensive plan. On April 1, 1975, the Oregon Supreme Court strengthened its position in *Fasano*, supra, stating that the comprehensive plan is the controlling land use planning instrument for a city, that a city assumes responsibility to effectuate that plan and conform prior conflicting zoning ordinances to it and that zoning decisions of a city must be in accordance with the plan.

Authority of the Port Commission. The authority of the port commission of Coos Bay is derived from ORS 777.005 to 777.990. The most important of these statutes and two ordinances made pursuant to them are discussed below:

> 777.105 Bay, river and harbor improvement. A port may improve bays, rivers and harbors within its limits and between its limits and the sea for the width and length and to the depth the port considers necessary or convenient for the use of shipping and as the means at its disposal will allow. It may construct the canals, basins and waterways necessary or convenient for the use of shipping or the extension of the commerce of the port.

The "necessary or convenient" language of 777.105 is broad but since the subject of the statute involves dredging, the port must still obtain a fill/removal permit from the state in order to carry on such activities.

777.120 Port's authority over harbors, wharf lines and navigation. (1) To the full extent the State of Oregon might exercise control or grant to ports the right to exercise control, a port has full control of all bays,rivers and harbors *within its limits*, and between its limits and the sea. As convenient, requisite or necessary or in the best interests of the maritime shipping and commercial interests of the port, a port may, within its limits:

(a) Make, change or abolish wharf lines in bays, rivers and harbors.

(b) By ordinance make, modify or abolish regulations for the use of navigation, or the placing of obstructions in or the removal of obstructions from bays, rivers and harbors.

(2) A port shall have the authority to engage in the control and prevention of river and stream bank erosion, and the prevention of damage from floodwater and sediment, and to make, establish, change, modify or abolish such rules and regulations to preserve natural resources and prevent estuary and stream pollution within the boundaries of the district.

Note that the above statute specifies that the Port shares its control with the State of Oregon. Coos Bay Port Ordinance No. 30 establishes wharf or pierhead lines in the Port and regulates the use of waters therein. It also prohibits the obstruction or impeding of navigation and the projection, building, or maintenance of any building, structure or obstruction in the waters of Coos Bay beyond the wharf lines.

777.132 Authority of ports to distribute water; construct and maintain marina facilities. (1) A port may distribute water for domestic or industrial purposes within or without the port...(2) A port may construct, improve, maintain and operate public marina facilities. Such facilities may include campgrounds or parks which the port may operate and maintain or lease to public or private organizations or persons for operation and maintenance.

777.190 Ordinances for policing or regulating of port property. A port may by ordinance in accordance with ORS 198.510 to 198.600 make, modify or abolish regulations to provide for the policing, control, regulation and management of property owned, operated, maintained *or controlled* by the port. A port, for the purpose of enforcing such ordinances, may appoint peace officers who shall have the same authority, for the purpose of the enforcement of the ordinances, as other peace officers.

The port of Coos Bay enacted Ordinance No. 67 pursuant to the above enabling statute. No. 67 defines Coos Bay Harbor, creates the office of Harbormaster, prescribes his powers and duties, and establishes rules and regulations for the government and control of the navigable waters within the jurisdiction of the Port of Coos Bay. It also provides penalties for violations of the rules and regulations. Navigable waters within the jurisdiction of the Port of Coos Bay are designated as Coos Bay Harbor, but they are not specifically defined. It is assumed by the Port that they would refer to any waters capable of floating a log.

777.210 Port may engage in certain port management activities. A port may:
(1) Establish, operate and maintain water transportation lines in any of the navigable waters of this state and waters tributary thereto, any portion of which may touch the boundaries of the port.
(2) Engage generally in the business of buying and selling coal, fuel oil and all kinds of fuel for watercraft of all kinds.
(3) Acquire, construct, maintain or operate sea walls,jetties, piers, wharves, docks, boat landings, warehouses...canals... bridges...and buildings for the economic handling...of freight and handling of passenger traffic with full power to lease and sell the same, together with the lands upon which they are situated, whether held by the port in its governmental capacity or not.
(4) For the public convenience and the convenience of its shipping and commercial interests, may improve all or any portion of the waterfront of its harbors, rivers and waterways.
(5) Enlarge its tidal area, and construct, excavate or dredge canals and channels connecting its waterways with one another or with other waterways and the sea.
(6) Acquire or construct, maintain or operate airports anywhere within the port.

It should be noted that (3) gives the port authority to construct docks and the Port feels this authority is complete.[118]

The above statutes are applicable to practically all of the Coos Bay salt marshes, because the salt marshes fall within the Port District as delineated in the ordinances. However, Port authority is still subject to the state and federal statutes, rules and policy statements concerning wetlands. Where state authority is asserted, for example by means of the fill/removal law, the Port must participate in the permit process just as a private citizen must.

Terms

This section of the paper is written to aid the layman in reading about or listening to legal problems which may arise concerning the management of a salt marsh. The terms discussed below are commonly used in salt marsh cases but are frequently misunderstood. Many definitions exist for these terms, but it is hoped that these explanations will provide a basic understanding of their meaning.

Eminent Domain. The power to take private property for public use.

Condemnation. The process private property is taken for public use, without consent, but upon payment of just compensation.

Jus Publicum. This term refers to the public right of use--

a right derived from the English common law. In England, title to the water and land beneath the water was in the sovereign. This title was split into the jus publicum (the public right of use) and the jus privatum (the private right of use). In Oregon, the state's title to tidelands between high and low water mark includes both the jus privatum and the jus publicum, but the state can only convey the jus privatum. Thus, privately-owned lands remain subject to the jus publicum which protects such public uses as navigation, fishing and commerce. The Oregon Attorney General's Opinion No. 6861 asserts that ORS 541.625(2) in conjunction with the remainder of Chapter 754 (1971) Oregon Laws codifies the common law concept of the jus publicum in navigable waters.

Navigability. Definitions of "navigability" are used for a wide variety of purposes, and vary substantially between federal and state courts. Primary emphasis must therefore be given to the tests of navigability which are used by federal courts to delineate federal powers. Statements by state courts, if in reference to state tests of navigability, are not authoritative for federal purposes. Likewise, federal definitions do not apply to state laws unless the state has adopted federal tests. The following are federal definitions:

1) General definition of navigability.
   Navigable waters of the U.S. are those waters which are presently, or have been in the past, or may be in the future susceptible for use for purposes of interstate or foreign commerce. A determination of navigability once made, applies laterally over the entire surface of the water body, and is not extinguished by later actions or events which impede or destroy navigable capacity.
2) Geographic and jurisdictional limits of navigability of rivers and lakes.
   Jurisdiction over entire bed.
      Federal regulatory jurisdiction, and powers of improvement for navigation, extend laterally to the entire water surface and bed of a navigable water body, which includes all the land and waters below the ordinary high water mark.
   Upper limit of navigability.
      The character of a river will, at some point along its length, change from navigable to non-navigable. Very often that point will be at a major fall or rapids, or other place where there is a marked decrease in the navigable capacity of the river.
3) Geographic and jurisdictional limits of navigability of oceanic and tidal waters.
   Shoreward limit of jurisdiction.
      Regulatory jurisdiction in coastal areas extends to the line on the shore reached by the plane of the mean of the higher high water on the Pacific coast. Where precise determination of the actual location of the line is necessary, it must be established by survey with reference to the avail-

able tidal datum, preferably averaged over a period of 18.6 years. Less precise methods, such as observation of the "apparent shoreline" which is determined by reference to physical markings, lines of vegetation, or changes in types of vegetation, may be used only where an estimate is needed of the line reached by the mean higher high water.

Bays and estuaries.

Regulatory jurisdiction extends to the entire surfae and bed of all water bodies subject to tidal action. Jurisdiction thus extends to the edge of all such water bodies, even though portions of the water body may be extremely shallow, or obstructed by shoals, vegetation, or other barriers. Marshlands and similar areas are thus considered "navigable in law," but only so far as the area is subject to innundation by the mean high waters. The relevant test is therefore the presence of the mean high tidal waters, and not the general test described above, which generally applies to rivers and lakes. Marshlands are also subject to federal regulation because of the definition of navigable waters which defines the Corps' jurisdiction as including those wetlands contiguous or adjacent to traditional navigable waters.

Navigation Servitude. Public right of navigation for the use of the public at large.

Police Power. The power vested in the legislature by the constitution to make laws which promote the public welfare. It includes the whole sum of inherent sovereign power which the state possesses and which the state may exercise for the promotion of the order, safety, health, morals and general welfare of society. Often such legislation prohibits certain uses of property. If the legislation in question is reasonable, then the landowner does not get compensation. Wetlands regulations present the question of whether a state may use its police power to preserve its exhaustible natural resources. One test of whether the police power is being reasonably exercised is to examine whether:

1) the interests of the public generally, distinguished from those of a particular class, require such interference;
2) the means are reasonably necessary for the accomplishment of the purpose; and
3) the means are not unduly oppressive upon individuals.[120]

Public Rights. Those rights in water which apply to the general public, riparian and non-riparian alike. Generally the public has the right to use water for such purposes as fishing, navigation and recreation.

The Public Trust Doctrine. This doctrine says that the state's title to any lands below navigable waters is a title held in trust for the people of the state. This trust requires the state to manage and control the lands to insure that the public may enjoy navigation, fishing and commerce in the waters without obstruction or interference by private parties. This doctrine is recognized to varying degrees in different states. Generally, the state may grant the use of these lands for purposes in aid of navigation and commerce or when the use does not substantially impair the public interest in the lands and water remaining. However, when a state tries to abdicate control over the lands, this constitutes a violation of the public trust and the state's act is void or voidable.

Section I of Article I of the Oregon constitution sets forth a legal basis for the application of the public trust doctrine in Oregon.

> "We declare that all men, when they form a social compact are equal in right: *that all power is inherent in the people, and all free governments are founded on their authority, and instituted for their peace and safety and happiness;*"

This statement has been viewed as an implicit prohibition against legislative or administrative action that is clearly contrary to the public welfare.[121]

Riparian Rights. Those rights which adhere to ownership of the bank of a body of water. A landowner has the right to gain land by accretion and lose land by erosion; however, title may change if the land shifts suddenly, as when avulsion occurs.

The Right of Fishery. The right to take fish at a certain place or in particular waters. In the United States, the right of fishery over navigable and non-navigable waters generally belongs to the state when a tidal water is concerned; where nontidal water is concerned, and the bed or bank of the water has been sold, the right of fishery usually belongs to the private owner.

Submerged Lands. Lands lying below the line of ordinary low water of all navigable waters within the boundaries of the state regardless of whether the waters are tidal or nontidal. (Division of State Lands.)

Submersible Lands. This generally means lands lying between the line or ordinary high water and the line of ordinary low water of all navigable waters and all islands, shorelands or other such lands held by or granted to the state by virtue of its sovereignty. (Division of State Lands.)

Taking.[122] The Fifth Amendment to the Constitution contains the taking clause, "...nor shall private property be taken for public use without just compensation." There is very little historical evidence to explain this intention of the Founding Fathers in adopting this amendment.

"Taking" might mean that the government cannot actually seize lands but that it may regulate the way lands are used. This interpretation prevailed until 1822--it analyzed purported takings by examining the *kind* of legal activity which made the landowner claim his land was being taken. If the land was physically seized, the government was required to compensate the landowner, but a mere governmental regulation of land use was legal and no compensation was required.

On the other hand, "taking" may include governmental regulation if the regulation limits the use of the land to such a *degree* that the land has been "taken" from the legal owner. Justice Holmes relied upon this principle in *Pennsylvania Coal v. Mahon*,[123] the leading 20th century Supreme Court case on this issue. Holmes's statement that a certain degree of regulation may constitute a taking and thus require compensation requires the court to analyze each case according to its own special facts and circumstances. The categories of regulation that have often generated litigation are those restricting mining, regulations for the preservation of open spaces, regulations which seek to eliminate existing uses, regulations of flood prone areas, wetlands, estuarine and beach lands, and a variety of regulatore deterrents to urban growth.

Regulations for the protection of wetlands or estuarine areas often require the maintenance of a sensitive area in a relatively unspoiled state. To support such a restrictive regulation, there must usually be a strong showing of public benefits which will result from the regulation: flood and property protection and the preservation of natural resources, wildlife, fishing rights and water purity. State Supreme Court cases have split on the issue of whether wetlands regulations constitute a taking.[124]

Steps to Spotting and Stopping Environmentally Undesirable Activities[125]

The most important thing to remember about catching and reporting violations is to be thorough. In order to be effective, one must carefully document what is done and seen.

1) Request the city and county planning commissions to put you on their mailing lists for zone change, conditional use and subdivision plat petitions. These agencies are legally required to send notice only to nearby (or affected) property owners.
2) Find out about newsletters, brochures and reports sent out by private companies; keep up with reports and major decisions made by public agencies (the Port Commission, the Forest Service, the Division of State Lands, etc.).
3) Take notes at hearing or meetings.
4) Keep a regular watch over environmental areas which you are particularly interested in.
    a) Keep a log or diary of site inspections.
    b) Be careful and observant--take pictures and mark your way.
    c) Avoid trespassing--walking on a beach below the mean of mean high water is legal. Entering an open field that is *not posted* is legal. Being anywhere that is open is legal. Taking notes, photographs and sketches from these areas is legal.
    d) If you meet someone (the owner?), use a direct and open approach. Show your personal identification

and ask permission to enter. Do not enter if permission is refused. Do not enter a posted field without permission.

e) If entry is refused, ask the U.S. Attorney to obtain a court order or search warrant. If the request is necessary and reasonable, entry can usually be legally obtained.

5) If you suspect that a permit is being abused, or has not been granted, you may have spotted a violation. Look for activities such as these in

Rivers, Estuaries, Bays, Lakes, and Surf:

a) fills, dredgins, rip-rapping efforts, debris or rubbish;
b) outfalls or dumping of wastes or spoils, siltation from road-building, clearing, or fills;
c) spillovers and other potential contamination hazards, building on unstable ground;
d) changes in abundance or type of vegetation and wildlife;
e) residues collecting on or near the shore, any operation with side effects that might be detrimental to the quality of the water or the character of the shoreland; or
f) sporting activities that might be damaging to the land near the edge of the body of water--dune buggies, etc.
g) Look also for changes in the water itself: discoloration, debris, unusual odors, changes in aquatic life, flow or circulation or increased sedimentation.

Flood Plains, Hillsides, Dunes, Beaches:

a) newly-cleared land, stakes, signs announcing new developments, construction activities, surveyors, etc.;
b) trail-bike paths or other worn areas that indicate damage to soil or vegetation;
c) campfires or brush fires except where specifically permitted;
d) clear-cutting, where erosion would be significant;
e) operations which emit air pollution, excess fumes or noise;
f) any building on dunes, areas prone to flooding or landslides.
g) Look also for more intense uses or expansion of existing activities.

6) When you suspect a violation, find out:

a) Who owns the land, and who is conducting the activity.
b) If the activity requires a permit or other legal sanction--such as a zone change.
   1. If so, from what agencies?
   2. Was this permit or legal sanction obtained properly before the work or activity began?
   3. What are the time, area, operation, and other restrictions under the permit or legal sanction?

c) What is the goal or purpose of the work or activity?

d) How will the work or activity affect the following:

1. Air Quality
   --Will there be foul odors, smoke, chemical fumes or ash emitted? If so, how will this affect the livability of the area, the vegetation and the wildlife?
   --What alternatives are there to the atmospheric discharge?
2. Water Quality
   --Will there be chemicals, solid waste, silt, sediments, or dredging spoils introduced into the water?
   --Is the water muddied or discolored? Have there been changes in water temperature or circulation, or in the abundance of water life as a result?
   --What alternatives are there to the dumping of the substances into the water?
3. Noise Level
   --Will the noise be excessive?
   --Will it affect nearby residential areas?
4. Land Stability
   --Will there be dune or bank erosion?
   --Is the activity or development prone to destruction by flooding, storms, or landslides?
   --Will there be a need for public expenditures to rip-rap or "bulkhead" so that the work or development can continue?
   --How can potential problems be avoided?
5. Wildlife
   --Will the activity affect the movement of wildlife, or alter natural feeding and nesting grounds?
   --What guarantees can be made that the activity will not endanger wildlife, and that damage to marine-life habitats will be minimal?

e) If the activity involves dredging, ask:

1. Is the depth and extent of operation really necessary?
2. What alternatives to dredging are feasible?
3. Where is the dredge spoil to be placed?
4. Is the composition of the spoil toxic?
5. Will the spoil cover marshlands, or other areas of productive marine life? Will it affect water circulation? Will it be deposited where run-off will cause siltation problems?
6. Is there an alternative, less detrimental location or use of the spoil than currently employed?

f) If the activity involves residential, industrial, or commercial real estate development and/or road construction ask:
   1. What is the natural productivity or scenic value of the area, versus the need and practicality of development at that location?
   2. Does the development conform to the comprehensive plan and zoning ordinances? Does it fit in or detract from the surroundings?
   3. Has the development been built on stable ground, safely removed from storm, slide, and erosion hazards?
   4. What steps are being taken to preserve the aesthetic and other natural resources of the area?
   5. What services will be extended to the development? Does the added tax revenue cover the added costs of services that must be provided?
   6. Is the development actually paying for services or is the local government subsidizing this operation with taxes collected elsewhere?
   7. What sewage treatment facilities are planned? If septic tanks are planned, where will the over-flow go, and what are the probabilities of "leaching" problems?
   8. What additional traffic and public use will the development encourage? Will this destroy any fragile areas?

7) Contact the appropriate agency to report violations.
   a) Usually you should contact:
      1. The Division of State Lands, Salem, 378-3763
      2. The Department of Environmental Quality,
Portland, 229-5309
Coos Bay, 756-4244
      3. The Highway Division, 396-3121
      4. The city manager, 269-1181
      5. The Coos Bay Fish Commission, 269-1200
      6. The Soil Conservation Service, Coquille, 396-3121
      7. The Forest Service, Oregon Dunes NRA Office, 271-3611
      8. The Corps of Engineers,
Portland, 221-3775
Coos Bay, 267-6484

8) Remember, when contacting agencies, to make a note of the date of the contact, the complaint, the agency called, and the names of persons notified and their position, and the action promised or taken.

9) Write a letter to the agency involved. Specify permit application number. Send copies of letters to the governor, senators, etc., when appropriate. When commenting on the Corps of Engineers, always be sure to send a copy of your letter to the Division of State Lands. Technically, try to clearly separate your opinions from state-

ments of fact. When listing the facts that support your argument, state whether it is based on your own observations or an accepted scientific finding. If you consult an engineer, biologist, or other specialist, give the name and qualifications of that individual. If your letter is a long one, list the main points at the beginning. Photographs can be extremely valuable if they help to emphasize or document a point. If you include a photo, state where it was taken, the date and time of day. Do not tamper with or write on the photo.

10) Keep a copy of all correspondence sent or received.
11) Notify an environmental organization such as Thousand Friends of Oregon, Sierra Club, Oregon Environmental Council, the Nature Conservancy, or Northwest Environmental Defense Center, if the agency does not take action.

Footnotes

1. The term estuarine salt marsh is used because this paper is primarily a study of Coos Bay salt marshes and they are located on an estuary. Many of the laws relating to their protection, however, refer only generally to tidal wetlands or even wetlands. This paper will use the term used in the law being discussed. For the biological differences see the latest publication by the Fish and Wildlife Service, Dept. of Interior.

2. See National Geographic, June, 1972, "Fragile Nurseries of the Sea: Can We Save Our Salt Marshes?" by Steven W. Hitchcock, p. 729; also, "The Salt Marshes of the Coos Bay Estuary," by John Hoffnagle and Robert Olson. Port Commission of Coos Bay and the Oregon Institute of Marine Biology, August, 1974.

3. 33 U.S.C. Sec. 403 (1970) (hereinafter referred to as the 1899 Act, or Section 10 specifically).

4. 33 U.S.C. Sec. 1251 (1972) (hereinafter referred to as the FWPCA, or Section 404 specifically).

5. The constitutional authority is assumed to be the commerce clause, but cases have also cited the admiralty clause. Cf *U.S. v. Underwood* 344 F. Supp. 486, 489 (M.D. Fla. 1972) to *U.S. v. City of Asbury Park* 340 F. Supp. 444, 452 (C.J.J. 1972).

6. *U.S. v. Republic Steel Corp.*, 362 U.S. 482 (1960). Note also that in tidal waters the Corps' jurisdiction extends to the mean higher high water: *U.S. v. Rands*, 389 U.S. 121, 123 (1967); *United States v. Pot-Nets., Inc.*, 363 F. Supp. 812, 815-17 (D. Del. 1973). The line of the mean higher high water mark has not been mapped in Coos Bay or in many spots on the Coast.

7. 33 C.F.R. 209.120(g)(3).

8. This change is due to legislative enactments and administrative actions which have introduced ecological factors into the determination of whether to grant a Section 10 permit. See the Fish and Wildlife Coordination Act, U.S.C. Sec. 661-666(c) (1964). See also the Memorandum of Understanding between the Secretaries of the Army and the Interior 33 C.F.R. 209.120(d)(ii) (1972).

9. See also the National Environmental Policy Act 42 U.S.C. Sec. 4332 (2)(c) (1970), and *U.S. v. Joseph G. Moretti*, 331 F. Supp. 151 (S.D. Fla. 1971), vacated in part on other grounds, 478 F.2d 418 (5th Cir. 1973). 526 F2d 1306 (5th Cir., 1976).

10. 33 C.F.R. 209.120(f)(2)(i-iv).

11. See *U.S. v. Perma Paving Co.*, 332 F. Supp. 754, 757-58(2nd. Cir. 1964); *United States v. Underwood*, 344 F2d 486, 494 (M.D. Fla. 1972).

12. *U.S. v. Republic Steel Corp*, 362 U.S. 482 (1960).

13. Regulatory authority is strengthened by congressional policy as expressed in the Fish and Wildlife Act, 16 U.S.C. 742a (1967), the National Environmental Policy Act, 42 U.S.C. 4321 (1969), the Coastal Zone Management Act Sec. 307(c), 16 U.S.C. 1456(c)(3) (1972).

14. See C.F.R. 209.120; 39 Federal Register 12115-12137 (April 3, 1974).

15. 33 C.F.R. 209.260(c).

16. 392 F. Supp. 685 (D. D.C. 1975).

17. 33 C.F.R. 209.120(f)(1).

18. See Federal law section of this paper--Section 10--which states the regulations of 33 C.F.R. 209.120(f)(2)(i-iv).

19. 33 C.F.R. 209.120(g)(1).

20. 33 C.F.R. 209.120(c)(2).

21. H.R. 9560 was first introduced by Representative John Breaux (D., Louisiana). Substitute amendments were offered and the Wright Amendment passed the House in July. It eliminates past commercial use as an element of "navigable waters."

22. See letter from Governor Straub, October 13, 1975, to the Chief of Engineers, Corps of Engineers.

23. See reference to letter from the Secretary for Resources, State of California to Senator Alan Cranston (D., Ca.). Conservation Report #16 from the National Wildlife Federation, May 28, 1976.

24. See note 22 above.

25. 33 U.S.C. 1251 et seq (Supp. IV, 1974).

26. 33 U.S.C. 1342(b)(6) (1970).

27. 33 U.S.C. 1343(c)(1)(B).

28. 42 U.S.C. 4331, 4332 (1968).

29. *Sierra Club v. Morton*, 395 R. Supp. 1187, (D.C. 1975).

30. Ibid.

31. 16 U.S.C. 1401-1451, as amended.

32. 16 U.S.C. 1453.

33. See 1455(c)(8), which requires consideration of the national interest when siting facilities of more than local nature; see also 1455(e)(2), which requires a method of assuring that the regulations don't unreasonably restrict land and water uses of regional benefit.

34. For a good discussion of A-95 review, see Real Property Probate and Trust Journal, Volume 10, 1975, p. 670.

35. See State law section of this paper--South Slough Sanctuary.

36. 42 U.S.C. 4001-4151 (1973), as amended.

37. 16 U.S.C. 661 et seq (1934), as amended.

38. See Miscellaneous laws, 6. The Estuary Protection Act, as explained herein.

39. 16 U.S.C. 668dd.

40. Ibid., 663.

41. Ibid., 663(b).

42. 16 U.S.C. 1531-1543.

43. 16 U.S.C. 1544(d).

44. 16 U.S.C. 1532(ii).

45. 16 U.S.C. 1361.

46. 16 U.S.C. 742 et seq (1956).

47. 16 U.S.C. 715 et seq.

48. 16 U.S.C. 1534(b).

49. 16 U.S.C. 1221-1226, as amended (1970).

50. Information from Bureau of Fish and Wildlife, Portland, Oregon.

51. 16 U.S.C. 1431 et seq.

52. *Cummings v. Chicago*, 188 U.S. 410, 431 (1903).

53. ORS 541.605- 695.

54. ORS 274.905-940.

55. As set by the Environmental Protection Agency and the Department of Environmental Quality. 33 U.S.C. 1342.

56. Chapter 316, 1971 Oregon Laws. ORS 527.610-730 and subsection (1) of ORS 527.990.

57. State Land Board Rules for Leasing State-owned Submerged and Submersible Lands 141-82-010.

58. Division of State Lands Memorandum--Restrictions on privately-owned moorages; (July 5, 1974).

59. LCDC was established under the authority of the Coastal Zone Management Act, 17 U.S.C. 1401 (1970).

60. This sanctuary is located in Coos County.

61. ORS 541.610.

62. Ibid.

63. See discussion of the 1899 Act and the FWPCA Section 404 in this paper.

64. ORS 541.605(8).

65. See Senate Bill 224 (1971 OR L 754); Senate Committee on Fish and Game, p. 5.

66. ORS 541.610(2).

67. *State of Oregon v. Saxon*, Lane County Circuit Court; Case No. 74-3147.

68. The four criteria are listed in ORS 541.620. For an analysis of "taking" see 46 ALR 3rd 1422, 1428.

69. ORS 541.625(3).

70. See Attorney General opinion no. 6967; Feb. 26, 1973.

71. The airport hearing in North Bend July 21 and 22 may provide discussion of this question in the resulting rulings.

72. See budget division analysis, January 19, 1973, which established the cist of each civil action at $3-5,000.

73. 11 Stat. 383 (1859).

74. ORS 274.060.

75. *Corvallis Eastern Railway Co. v. Benton*, 61 Or. at 369-370; 121 P. 418 (1874).

76. *Hume v. Rogue River Packing Co.*, 51 Or. 237, 248, 83 P. 391 (1908).

77. See permit application of City of North Bend to extent airport runway. Hearing July 21 and 22, 1976.

78. According to ORS 541.627(3), the Director may consult the State Geologist, the State Wildlife Director, the State Fisheries Director, the State Forester, the Director of the Department of Environmental Quality...etc. These state officials have no veto and are not required to even comment.

79. Attorney General opinion 6861 (Sept. 17, 1971).

80. ORS 541.665.

81. ORS 541.625(a).

82. ORS 541.610.

83. Public Law 92-500 Section 303.

84. Beneficial uses are: domestic water supply, industrial water supply, irrigation, livestock watering, anadromous fish passage, salmonide fish rearing and swimming, resident fish and aquatic life, hunting and wildlife, fishing, water-skiing and skiing, pleasure boating, aesthetic qualities and navigation.

85. OAR 41-030.

86. Ibid.

87. OAR 41-070.

88. Ibid.

89. Discussion with Oregon's Department of Environmental Quality.

90. See proposed permit program in log-handling policy statement adopted by Oregon's Environmental Quality Commission on October 24, 1975.

91. Forest Practice Rules 24-101 to 24-648.

92. FPR 24-446.

93. FPR 24-620 to 24-624.

94. A Class I stream means waters which are important for recreation and/or used by significant numbers of fish for spawning, rearing or migration routes. Stream flows may be either perennial or intermittent during parts of the year. Class II streams are used only by a few, if any, fish for spawning.

95. FPR 24-446(4)(a-c).

96. *U.S. v. Oregon*, 295 U.S. 1, 14 (1935).

97. In 1967, the previous definitions for tidelands, overflow lands, shorelands, tidal flats, and tide islands were incorporated under submersible lands. Ch 421 Section 98.

98. ORS 274.005.

99. *Illinois Central Railroad v. Illinois*, 146 U.S. 387, 452 (1892).

100. Article VIII Section 5 (2).

101. State Land Board Policy Memorandum, adopted December 18, 1975.

102. See definition of "navigable waters" on page 2 of this paper.

103. Where no similar docks are present and where a small water area is concerned.

104. State Land Board rules for leasing state-owned submerged and submersible lands. 141-82-010(2)(a).

105. ORS 197.705 to 197.795.

106. The Coos Bay Comprehensive Plan development will be discussed under Local laws.

107. A fifteenth goal was adopted one year later which addresses the Willamette River Greenway.

108. The LCDC defintions of water-dependent and water-related uses do not correspond to the definitions of these terms in the State Land Board Rules.

109. When the sanctuary is established, a sanctuary manager will be employed by the Division of State Lands.

110. The Georgia Pacific, Bergen and Kunz properties.

111. 42 U.S.C. 4601-4655.

112. Within this level, uses are classified as permitted, restricted, or prohibited. See program requirements for contractual amendment, section 312, Oregon Estuarine Sanctuary Grant.

113. This would include the Forest Practices Act and State Water Quality Standards. It probably also includes enforcement of agency policy statements.

114. See Federal laws--the Coastal Zone Management Act section of this paper.

115. See State laws--LCDC section of this paper.

116. 507 P.2d 23 Mar. 2, 1973.

117. Or. App., 520 P.2d 479, (April 1, 1974) 533 P.2d 772 (April 1, 1975).

118. See discussion of the dock policy of the Division of State Lands, page of this paper. The adoption of the LCDC Coastal Goals would provide the state with authority over docks.

119. Attorney General's Supplement "Definitions of Navigable Waters of the U.S."

120. *Lawton v. Steele* 152 U.S. 133 (1844); *Goldblatt v. Holmstead* 369 U.S. 590, 595 (1962); *Potomac Sand and Gravel Co. v. Governor of Maryland* 265 A. 2d at 716 (1970).

121. "The Public Trust Doctrine in Oregon," by Peter Herman, Department of Justice, Salem, Oregon (Dec. 2, 1971).

122. See The Taking Issue by Fred Bosselman, Dave Callies and John Banta. Prepared for the Council on Environmental Quality (July 9, 1973).

123. 260 U.S. 393 (1922).

124. See *State v. Johnson*265 A.2d 711 (Me. 1970) but cf. *Just v. Marinette County*, 56 Wis. 2d 7, 201 NW. 2d 76 (1971).

125. My sources for this section are "Layman's Guide to Investigating Section 10 Violations," Land and Natural Resources Division, Dept. of Justice, 1975, by Wallace H. Johnson, David W. Jessup and Paul F. Campbell, and "Coastwatch Oregon," by Susan Brody, an intern of Western Interstate Committee for Higher Education, 1974.

Land Use Planning...

LAND USE PLANNING'S EFFECT ON THE USE OF SALT MARSH IN COOS BAY, OREGON

Roderick Ashley

As has been indicated throughout the body of this report, the importance of salt marshes to the estuarine system is immense. "...Landscapes differ in their capacity to support and sustain human activity. Given a particular use or category of uses, some places are more suitable than others."[1] The primary purpose of this work is to identify thoses uses which are presently affecting salt marsh landscapes, review existing land use plans of various levels of government concerned with salt marsh environments, while not losing sight of the impact of these uses and plans upon the entire estuarine system.

> "The existing structure of the land is a resultant of unseen natural process operating over a long period of time. We must respect this structure and work to have our constructions be a continuation of that process, letting the present landscape play an evident role in the determination of suitable form for each place, respecting the impact that any structures have on the land. Similarly, the existing structure of a community is a result of many, often conflicting, processes, and is analogous to organic growth. Again, what we do should be as part of an interacting process which includes and respects what has been done, what there is to do and what there could be to do."[2]

Land use planning should be more than just citing how a piece of land should be used. Hopefully, a description of use is prescribed only after a careful and thoughtful understanding of the land in question has been reached. Only in this way will people have some guarantee as to the future of their land.

Unfortunately, the importance of salt marshes has been greatly undermined, and marshes have been rapidly disappearing from the estuarine environment. "Many of the real values of the marshes are not recognized, or accrue some distance from the marsh itself."[3] By examining the historical development in Coos Bay and comparing this growth to existing uses in the estuary, one should be able to get a feeling for the pressures responsible for the modification of the landscape as seen today and detect those developmental pressures still present today. Once trends of development, existing uses, and ownership of salt marshes have been determined, speculating about the future of salt marshes within the Bay may be done quite accurately.

In 1969, the Oregon State Legislature passed into law a bill requiring all counties, cities and governmental districts to prepare a comprehensive land use plan for their respective areas. A brief look at the history of land use planning in Oregon will help to introduce why salt marshes are viewed the way they are today from a land use legislative perspective. There currently exist several land use plans for Coos County. Although there is some overlapping of concerns, there are specific areas and concerns which are viewed quite differently, posing some problems. Comparing these land use plans with current land use trends should help to identify how salt marshes are viewed in long term planning policies.

Where discrepancies over the use of salt marshes appear in the various plans, these areas will be noted and referred to in an overall, site specific, study of the Bay. In this study, suggestions will be made as to how the area should be used and why, according to the importance of existing salt marshes and the role the area plays in the entire estuary.

Although different marsh types will have been evaluated in terms of location, productivity, habitats provided, and potential developmental use, they will not be viewed separately when planning policies are recommended. The biological system studies of this report have provided much insight into the importances and differences of four salt marsh types. But there is still a lack of real understanding of salt marsh systems in general, to evaluate and prescribe uses for individual marsh types. Because of this lack of understanding, the term "salt marsh" shall be used to represent "land areas where excess water is the dominant factor determining the nature of soil development and the types of plant and animal communities living at the soil surface."[4]

As noted earlier, there has been a rapid disappearance of salt marsh land, or any wetlands, for that matter. Recently there has been discussion as to whether or not salt marshes can be created. If this is the case, that man can induce and witness an increase in salt marshes, then locations throughout the Bay will be suggested for prime salt marsh creation areas. Previously diked areas, no longer in use, will be noted for the possibility of removing the dikes and returning the lands back to estuarine production.

There currently exist two locations within Coos Bay which will set the stage for how land use planners and legislators will view the importance of salt marshes in the estuary. On Coalbank Slough there exist two marshes of considerable size. In 1973, The Coalbank Slough study site (CO) was diked to prepare the land for a subdivision. The Division of State Lands required that the tide gate be removed from that dike, and there has been recent interest in reclaiming that marsh back to its natural state. The second marsh, considered at first for its present zoning, could become important in a recent concept of environmental trade-offs. Both examples are used to help illustrate Oregon state laws concerning environmental quality.

The concept of land use planning at a statewide level is fairly new in Oregon, and has the opportunity and is under pressure to rapidly change. The final portion of this section will address itself to land use planning in general, and the process which must occur for a meaningful policy and plan to be generated. Only through careful and thoughtful planning are our estuarine resources safeguarded against destruction and becoming obsolete. It is hoped that by the end of this study it can be determined how salt marshes can and should be used, rather than preserved or abused.

Developmental History of Coos Bay

"Although the figures vary, some experts figure that more than

40 percent of our marsh lands have been destroyed in the past hundred years."[5] In Hoffnagle and Olson's The Salt Marshes of the Coos Bay Estuary, it is stated that 90 percent of the salt marshes in Coos Bay have been lost for various reasons. (Figure I) To fully understand the pressures responsible for modifying the Coos Bay Estuary, it becomes important to first understand how it evolved and why the Bay is as it is today.

"Wetlands are rarely permanent features of the landscape, even in man's limited time perspective. These areas represent a particular stage in the geologic history of a region."[6] Oregon's estuaries are the result of the rising sea level and the filling of coastal river mouths with sediment being washed down river. After these sediments are worked by tide action and river flow, they are deposited along the banks of the estuary, forming a substrate for wetland vegetation to establish itself upon. Continued sedimentation accounts for the continual rising of tide flats. Once vegetation takes hold in the mud, increasing amounts of sedimentation is trapped by the vegetation.

"The marsh itself is a dynamic community within which an orderly replacement of plants takes place through time, and eventually the process would produce an upland meadow or Sitka Spruce woodland. In Oregon the older high marshes are diked, drained or otherwise modified by man before this transition to an upland community takes place."[7]

Prior to European settlement of the Oregon coast, little is known about the extent of salt marshes. But settlement patterns and use of the land has had an impact upon the expanse of marshland in the estuary. Dr. Carl Johannessen in Some Recent Physical Changes of the Oregon Coast (1961) has stated that coastal marsh margins were relatively stable prior to European settlement. Any shoreline change was due to natural sedimentation, rising sea level, and fires set in estuarine watersheds.

Changes in land use practices caused an increase of sediment load entering the estuary. Logging and great coastal fires ranging from Nehalem to the Rogue River have been responsible for the increased sedimentation. This sedimentation allowed for an increase in elevation of some mudflats, providing the substrate and water conditions necessary for salt marsh to grow. This has been a great factor in the increased expansion of tidal marsh. As Dr. Johannessen has stated, "It is definitely established that the [marsh] vegetation, once started, can greatly accelerate the accretion process and induce changes in the shoreline."

An example within Coos Bay will help to demonstrate this. Kentuck Slough has gone through quite an extensive series of diking. "A semi fluid mud has been floculated in the bay water and laid down in the 'barrow ditch' dug in the mudflat during construction of the levees. The old mudflat has been built up slightly and tidal marsh vegetation is rapidly invading...The amount of marsh in the [Kentuck slough has doubled in the last 22 years according to a resident."[8]

What this demonstrates is that salt marshes can be considered as sedimentary systems, and are geologically active. Once a substrate and tidal cover are provided, marsh plants are given

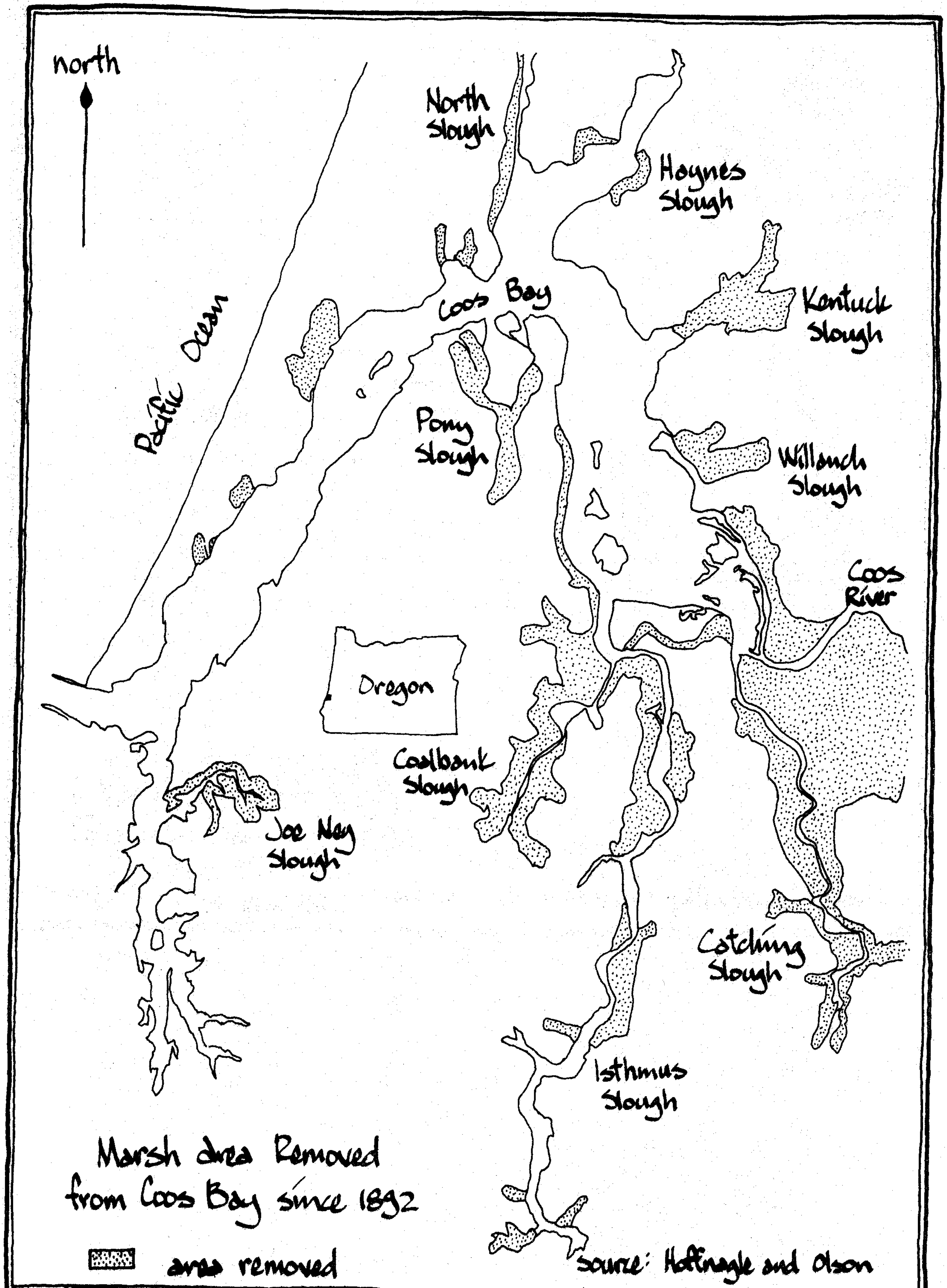

north
North Slough
Haynes Slough
Coos Bay
Kentuck Slough
Pacific Ocean
Pony Slough
Willanch Slough
Coos River
Oregon
Coalbank Slough
Joe Ney Slough
Catching Slough
Isthmus Slough
Marsh area Removed from Coos Bay since 1892
area removed
Source: Hoffnagle and Olson

Figure 1.

the opportunity to grow and expand themselves into larger marsh areas. This might begin to indicate that marshes may not be as old as once thought. "That low salt marsh expansion in Oregon has occurred very rapidly in the past 100 years could be correct, judging by the accretion rates...obtained for low silt marshes and by the large areas of such marshes in the estuaries today."[9] This may be observed by the fringing marshes around recent spoil island deposits. The idea of "growing salt marsh" will be brought up again in this report.

The developmental history of Coos Bay, although relatively recent, reveals a tremendous change in characteristics within the estuary. Before the beginning of white man's interest in Coos Bay, Indian villages lined the east bank of the bay from South Slough to Empire. The resources of the area provided for an abundant life for these people. Although hunters and trappers had visited the area earlier, "the real history of that beautiful sheet of water and its environment dates only to the time that...the Coos Bay Company arrived on the banks of the grand and beautiful bay."[10]

With an abundance of timber resources, fertile agricultural land, and a good natural seaport, it is surprising that the primary reason for early settlement and growth in the bay was due to the discovery of coal. "Within a short time of their [Coos Bay Commercial Company] arrival in Coos Bay in the summer of 1853, they found several dozen veins surfacing in ravines and on hillsides near the harbor. By October they had staked nineteen claims on the mineral lands and anticipated rapid development of their veins. The Coos Bay coal field which these men discovered... extended from North Slough on Coos Bay to Lampa Creek on the Lower Coquille River. Coal production ran between 40,000 and 75,000 tons a year in the period 1880-1890."[11]

Unfavorable rock conditions and a low quality of coal saw the reduction of the coal industry from Haynes and Kentuck Sloughs south onto Coalbank Slough in the Libby area. Mining on Coalbank Slough was one of the first activities to endanger salt marsh land. "The first cargo of coal was mined from a drift in the Boatman Donation Claim. It was transported in wagons a mile and a half to Coalbank Slough, and transferred in scows to Empire City. This cargo was shipped shortly afterwards to San Francisco."[12] Marshes were either filled or structures were built upon stilts which slowed water currents and allowed wood chips and sediments to deposit, in turn filling the land. Salt marshes began to disappear as millions of tons of coal were shipped through Coalbank Slough.

In 1873, the city of Marshfield was incorporated. Much of Marshfield (later to become known as the City of Coos Bay) was built upon "man-made land." In fact, the entire shoreline of today has been created from fill. Although some of the land was formed by the accumulation of sediments around the pilings of buildings, the easiest way of creating land was by diking and draining salt marshes. The transformation of marshes into "usable" land and the construction of buildings on pilings allowed for an easy and rapid growth. Even today, buildings in the downtown Coos Bay area are still built on top of pilings. With a lack of flat land in the area having a direct access to the bay, salt marshes became the ideal "reclaimable land." Since then, dredge spoils have been used to fill much of the low lands around the bay.

Although coal was responsible for early interest in the bay area, timber was soon recognized as the primary resource in the area. In 1858 the first sawmill was constructed at the tip of the Coos Bay peninsula (that area now known as North Bend). Two years later, a mill was built in Marshfield and continued in operation until 1885. "That enterprise, in a measure, built the town. Tons of sawdust had been spread several feet deep upon marshy flats that made it convenient to erect buildings and establish streets over otherwise waste lands."[13]

Because roads were scarce in the area, any navigable waterway became important in shipping this valuable resource. "Catching Slough, which empties into the bay nearly opposite Marshfield is a stream of considerable importance, as it connects Sumner with the bay and millions of feet of lumber have floated down the placid stream. The Coos Bay and Roseburg wagon road passing through Sumner has made the slough a highway that has enabled the traveller to reach the bay sooner and easier than to continue staging, especially in the winter time when roads are at their worst."[14]

Logging has had a tremendous impact upon salt marshes in the past, and these pressures still exist today. "Poorly designed clearcuts, poor road building techniques, large scale slash burning and the use of splash dams in aiding the transport of logs, all encouraged accelerated erosion conditions resulting in sedimentation within the bay."[15] Not only does the harvesting of logs have an impact upon salt marshes, but so does the transporting and storage further act to alter salt marsh characteristics. The Environmental and Economic Impact of Alternate Methods of Log Transportation, Storage, and Handling in the Coos Bay Estuary (1974) states the effects that logs can have upon marshlands and wetlands within the estuary. These include: 1) accumulation of woody debris and bark, 2) increases in the concentration of toxic substances, 3) current and waterflow changes, 4) filling, and 5) physical abuse. The report continues in mentioning that, "in the Coos Bay Estuary all of the above effects can be seen where logs are dumped and stored or debris from such operations accumulates." These effects have further influences upon resident and migratory birds, resident and adromonos fish, smaller animals critical in food webs and mammals dependent on aquatic systems.

With an abundance of timber and the need for increased water transportation of both raw and processed lumber, shipbuilding became an important industry. Along with the interest in shipbuilding and transportation came a concern for the entrance of the harbor. The mouth of the channel was originally at a depth of 26 feet. "The entrance to the bay, shifting its channels each year, did not receive full attention until September 1861, by the United States Coastal Survey...Congressional appropriation for harbor improvements led in 1880 to the awarding of contracts...to construct a jetty to run into the lower bay at Rocky Point near Barview."[16] Improvements have continued within the bay, and today, there is a Deep Draft Navigation Channel dredging operation underway, deepening the main channel to 40 feet. With the removal of dredged materials, areas are needed in which to deposit the spoils. Because of their location, elevation, and often how they have been viewed, salt marshes have been the primary recipients of this spoils material.

Improved transportation also saw the construction of a railroad. "The railroad addition to the town of Marshfield deserves more than a passing notice," writes the Oregon Historian, Orvil Dodge (1898). "It is laid out upon a marsh that has been reclaimed by extensive dykes forming a level grassy plain that is suggestive of a lawn." Once again, great admiration is given to those who can successfully reclaim the "wasted marsh lands."

Filling and logging have accounted for a large loss of salt marsh in Coos Bay. Agriculture, however, has seemed to have taken the greatest toll. Salt marshes, upon being diked, quickly become incredibly rich agricultural lands due to the buildup of nutrients found in marsh plants. Orvil Dodge has written:

> "On Coos Bay there are many tributaries commonly called sloughs, though they are streams coming in from the hills which are met by the tides as they find the sea's level, and the marshes are formed that in many places have been dyked and placed under cultivation yielding prolific crops of vegetables and hay as well as small grain in favored localities."

Dodge goes on to say:

> "On the lower courses of the streams, and particularly in the vicinity of Coos Bay, is a large amount of swamp and over-flowed lands. Much of this can be drained effectively and extensive series of dykes have already been erected to restrain water of the Coos River... The land thus reclaimed is amazingly productive in all varieties of grains and root crops..."

Diking was used for keeping out the brackish waters and for flood control. Lands diked in the late 1800's today "look like normal pasture with levees, but originally tides of a foot or more covered the land... Nine thousand eight hundred hectares of salt marsh in Coos Bay have been filled or diked."[17]

Throughout all the early writings, there is a reminder of how successful farmers have been in reclaiming marsh lands for agricultural purposes. There is never mention, however, of the amounts of marsh present or reclaimed. Catching Slough today shows the effects of reclamation. "Once 1600 acres, Catching Slough proper is now less than 50 acres, located on the very sides of the channel."[18] (Figure 2) Productive salt marsh soon became productive farmland.

Other uses have been responsible for the diminishing salt marshes. The golf course at Kentuck Slough was once 175 acres of salt marsh. Shinglehouse Slough has lost marshland through chip and refuse filling. Water circulation has been cut off to some marshes in North Slough due to construction of the railroad there.

Now that a general overview of the entire bay has been stated, it is interesting to look at the developments within some of the individual sloughs. It is thought that originally South Slough was an estuary of its own, having its own mouth to the Pacific Ocean.[19] In the mid 1800's, a sawmill was constructed at the head of South Slough. A great dam was also built here for obtaining power and to back water to enable floating logs to the mill. Eventually this dam

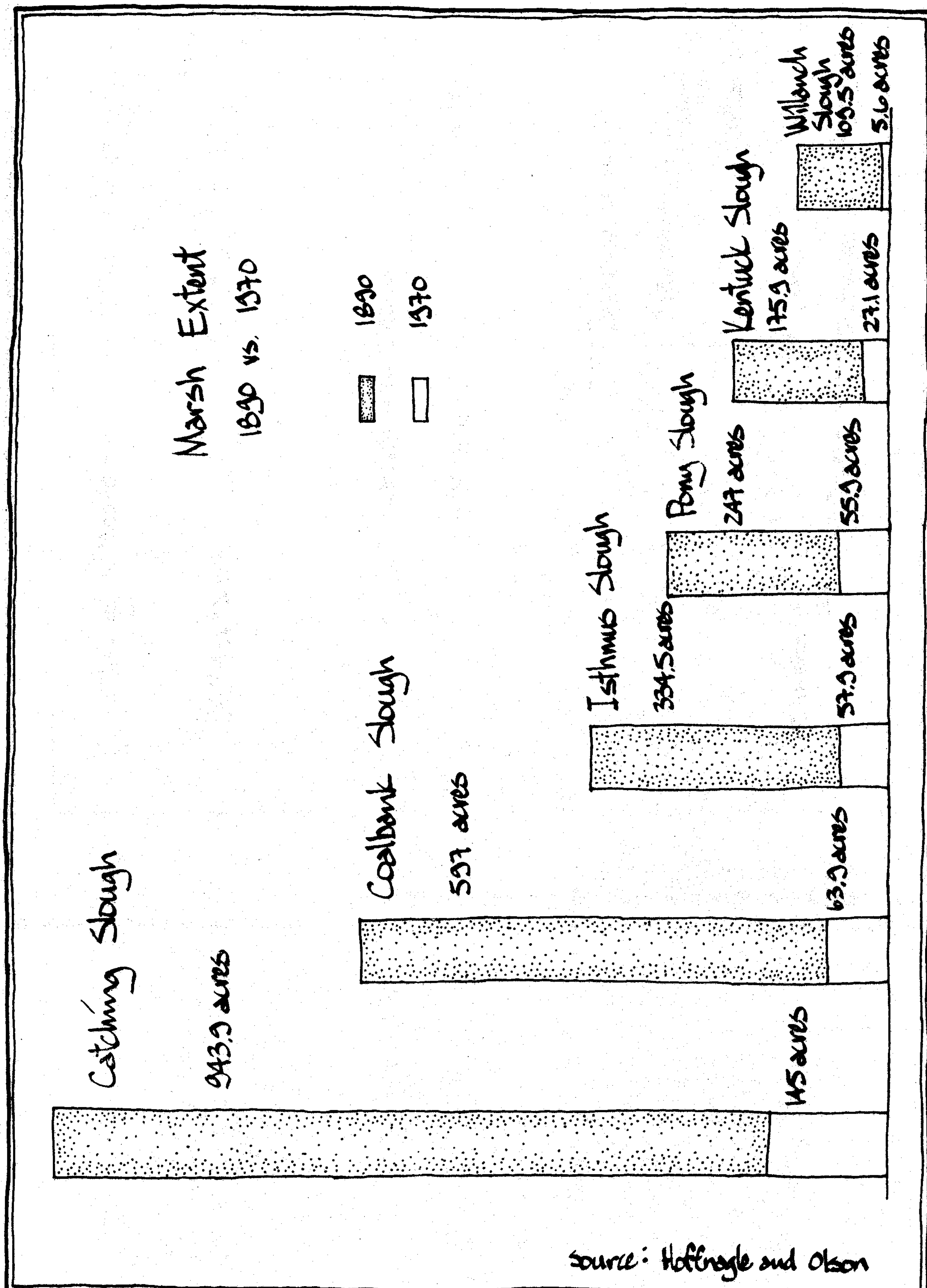

Marsh Extent
1890 vs. 1970
1890
1970
Catching Slough
943.9 acres
145 acres
Coalbank Slough
597 acres
63.9 acres
Isthmus Slough
334.5 acres
57.9 acres
Pony Slough
247 acres
55.9 acres
Kentuck Slough
175.9 acres
27.1 acres
Willanch Slough
105.5 acres
5.6 acres
Source: Hoffnagle and Olson

Figure 2.

was abandoned becuase of leakage and breakage by animals. Much of the diked lands in South Slough either are not in use or have become naturally breached, and are returning back to their natural state. Presently, a South Slough Sanctuary is being prepared for the area south of Valino Island, which would then become a control estuary for research and study. (Figure 3) The eastern end of Joe Ney Slough was diked sometime in the mid 1940's. "The area east of the dike was turned from salt marsh to farmland over a period of several years."[20]

Pony Slough probably provides the most vivid picture of reclamation of salt marsh and tideflat. Once containing almost 250 acres of salt marsh, Pony Slough has dwindled to about 56 acres, and some of this is still in danger of removal. In 1917 about 84 acres of tidelands in the northeast section of the slough were filled to allow for the extension of the Southern Pacific Railroad across Coos Bay. Further filling brought the introduction of industry into the slough. In 1939, 242 acres were filled to allow for the construction of the North Bend Municipal Airport. 1947 saw Pony Slough and adjacent areas sanctioned as a State Bird Refuge, (Figure 3)hosting thousands of birds along the Pacific Flyway. The State Fish and Wildlife Department states that there are no development restrictions for this refuge, and it is only recognized as such. Between 1946 and 1966, the area south of Virginia Avenue was filled. In 1957, the idea for the Pony Slough Shopping Center was introduced. Presently there is a fill permit filed with the Division of State Lands to allow a 32 acre fill to accomodate an extension of the airport runway. This fill will also be discussed later in this work. The City of North Bend also has had a Marina Feasibility Study completed, indicating alternate sites within Pony Slough for the development. "The tidal flat area of Pony Slough has a great deal of value in its natural state from ecologic and conservationist view points, but also possesses an unparalleled value for the City of North Bend as an area for future industrial and commercial expansion."[21]

Coal mining, logging, dredge spoil disposal and agriculture have accounted for the majority of diking and filling of Coos Bay's salt marshes. In nearly every arm of the bay, 90 percent of the marshes once present have fallen victim to one of these uses. Although the future of the remaining 10 percent of salt marsh is uncertain, its productivity and habitat can only continue to increase in value.

Developmental Pressures

Coos Bay Estuary houses the largest sea port between the Columbia River and San Francisco. The State of Oregon Legislative Assembly of 1969 urged the President and Congress of the United States to:

- -Institute a plan to develop the Port of Coos Bay, Oregon, into a major world seaport
- -Coordinate all federal agencies toward development of this plan
- -Provide aggressive but orderly comprehensive development of the port site, the estuarine and ocean resources, industrial potential, and outdoor recreation.[22]

"Western Oregon comprises one of the most densely forested regions in the United States...The Coos Bay drainage [basin] consists of about

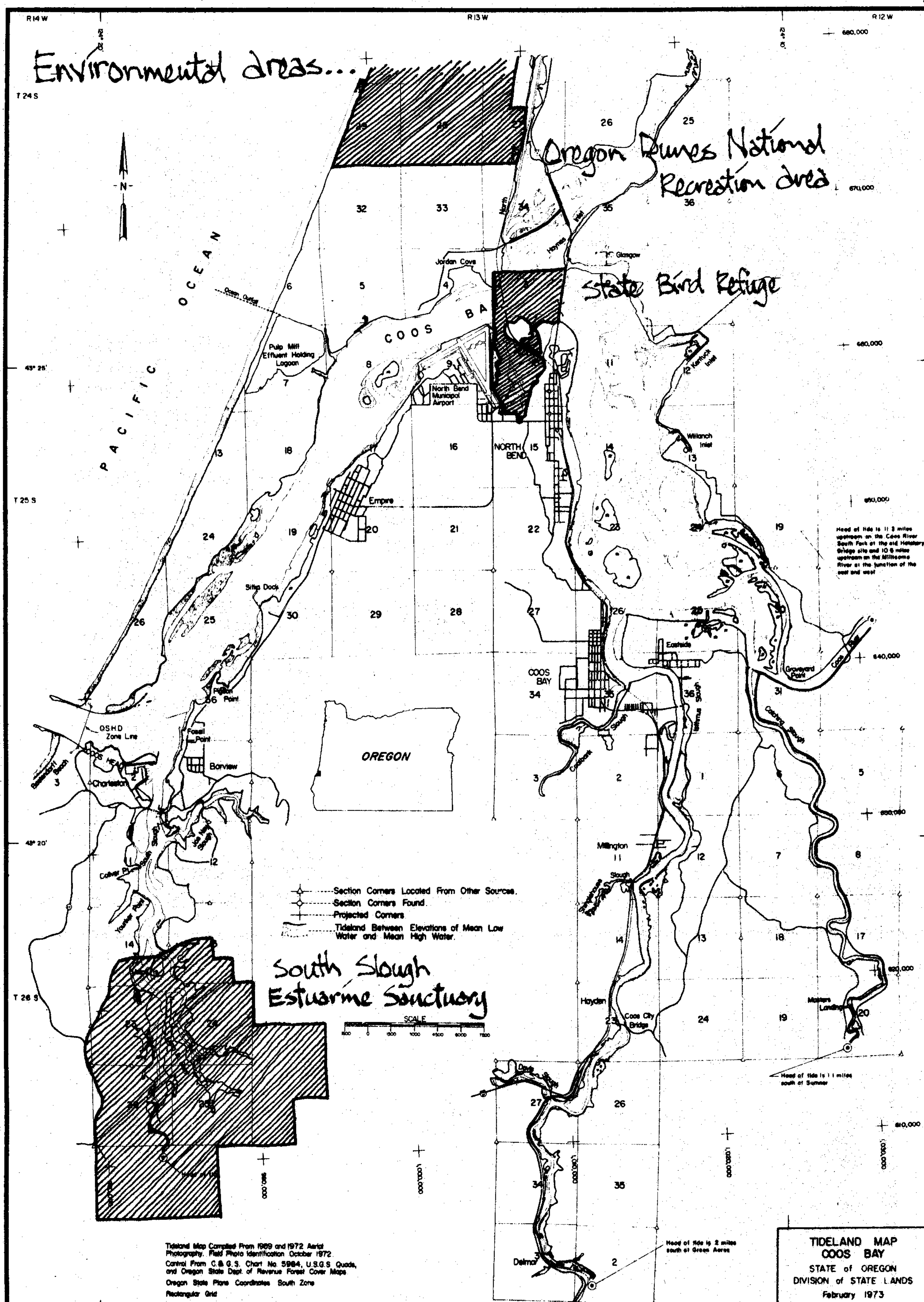

Environmental areas...
Oregon Dunes National Recreation area
State Bird Refuge
South Slough Estuarine Sanctuary
PACIFIC OCEAN
COOS BAY
OREGON
Pulp Mill Effluent Holding Lagoon
North Bend Municipal Airport
NORTH BEND
Empire
COOS BAY
Eastside
Jordan Cove
Glasgow
Kentuck Inlet
Willanch Inlet
Graveyard Point
Catching Slough
Sitka Dock
Pigeon Point
Fossil Point
Barview
Charleston
OSHD Zone Line
Millington
Hayden
Coos City Bridge
Matters Landing
Delmar
Section Corners Located From Other Sources.
Section Corners Found.
Projected Corners
Tideland Between Elevations of Mean Low Water and Mean High Water.
SCALE
Tideland Map Compiled From 1969 and 1972 Aerial Photography. Field Photo Identification October 1972.
Control From C.& G.S. Chart No. 5984, U.S.G.S. Quads, and Oregon State Dept. of Revenue Forest Cover Maps
Oregon State Plane Coordinates South Zone
Rectangular Grid
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

Figure 3.

830 square miles. About 87 percent of this area is forested. These forests are the principal nature resource and are the primary economic base." Of the remaining area, "10 percent is cultivated, 1 percent is in grass and brush, and 2 percent is non-vegetated."[23]

Because of its proximity to a large natural resource base and its sheltered and deep waters, Coos Bay has developed into "the lumber shipping capital of the world." In the lumber shipping industry, logs are first stored and often processed before leaving the area. Log storage and transport has almost always taken place within the estuary, and has added to the lowering of the water quality in Coos Bay.

With an increase in shipping and the size of ships, there has been need to deepen the shipping channels. At this time, a channel deepening project is under way by the Army Corps of Engineers. Although much of the dredge spoil material will be taken and deposited outside of the bay, much will also remain and be deposited as fill. In the past, salt marshs have been one of the primary sites for depositing this material.

Degradation of water quality within the bay due to sewage outfall will only promise to decrease because of the restrictions being placed upon occupants of the bay by Oregon's Department of Environmental Quality. Along with the possibilities of industrial expansion within the bay area, plans have been developed for the construction of a new Marina and the expansion of the City of North Bend's Municipal Airport.

In 1966, the Port of Coos Bay sanctioned a report prepared for them entitled <u>A Comparison of Sites for Industrial Expansion in the Coos Bay Area</u>.

> The report presents information on 14 potential land sites for industrial development, including four sites which could be provided with excellent ocean-going ship docking and cargo handling facilities. Preliminary land development cost estimates and comparisons are made.

Some of the results of that investigation include:

> 1) The entire land area adjacent to Coos Bay located between the Southern Pacific Railroad and the Pacific Ocean on the north shore of the Bay should be reserved for the development of heavy industry. This is the area from Jordan Cove west to the ocean.
>
> 2) The most economical industrial developments can be made on the following sites:
> a) The Henderson Marsh area west of Jordan Cove
> b) The North Point area located just north of North Bend
> c) The Upper North Slough located between Highway 101 and the Southern Pacific Railroad about 4.0 miles north of the City of North Bend
>
> 3) An area of approximately 120 acres lying adjacent to and west of Jordan Cove is now being actively considered for an industrial installation to include ship docking and bulk commodity handling facilities.

The investigation goes on to state that the "Port...is presently filling an area known as Eastside...and should be used for light industrial and commercial developments...The Port should actively pursue the investigation and acquisition of the industrial site designed in this report as the North Point Site."[24]

The sites presented for development included in the report include (Figure 4):

1) Upper North Slough
2) Lower North Slough
3a) Jordan Cove
3b) Dunes Site
4) Henderson Marsh
5) North Point
6a) Pony Slough (West)
6b) Pony Slough (East)
7) Empire
8) Pigeon Point
9) Eastside
10) Coalbank Slough
11) Bunker Hill
12) Millington
13) Hayden
14) Coos City Bridge

The criteria used in selecting the above sites included economic concerns, the degree of existing facilities, proximity to existing transportation modes and routes, and similar considerations. Although not enumerated within the site criteria, mention was made to noise, smoke and odors connected with manufacturing, and stated that these "must not be detrimental to the neighborhood."[25] This was the only environmental or resource criteria used in the selection of the sites.

In the individual site development descriptions, there is no mention as to the resource potentials within the site areas. In the description of the Dune Site, it is stated that "it would be desirable to use a considerable amount of the high sand dunes located on this site for the filling of either the Jordan Cove site or the Henderson Marsh site."[26] The Henderson Marsh site description makes no mention whatsoever about the presence of salt marsh and/or related fauna. The Pony Slough site description states that if any dredging were to occur in Pony Slough for fill of fringing lands, that the central channels should be lowered "in order to prevent the exposure of the mud flats."[27]

Considerations throughout the report seemed to deal only with economic and proximity factors, and dealt with developmental concerns locally with little concern about the impact upon the entire estuarine system. Jordan Cove, Henderson Marsh and Pony Slough were also mentioned as Potential Ship Docking Facilities.

In 1974, another report was prepared for the Port of Coos Bay Commission, entitled <u>The Environmental and Economic Impact of Alternate Methods of Log Transportation, Storage and Handling in the Coos Bay Estuary</u>. Although the report was concerned with both transportation and storage alternatives, storage alternatives pose the possibility of permanent damage to salt marshes due to filling and the raking of the logs over the flora, whereas in transportation alternatives, any damage is not apt to be permenant, as the marshes could be cleaned or transportation methods changed. The

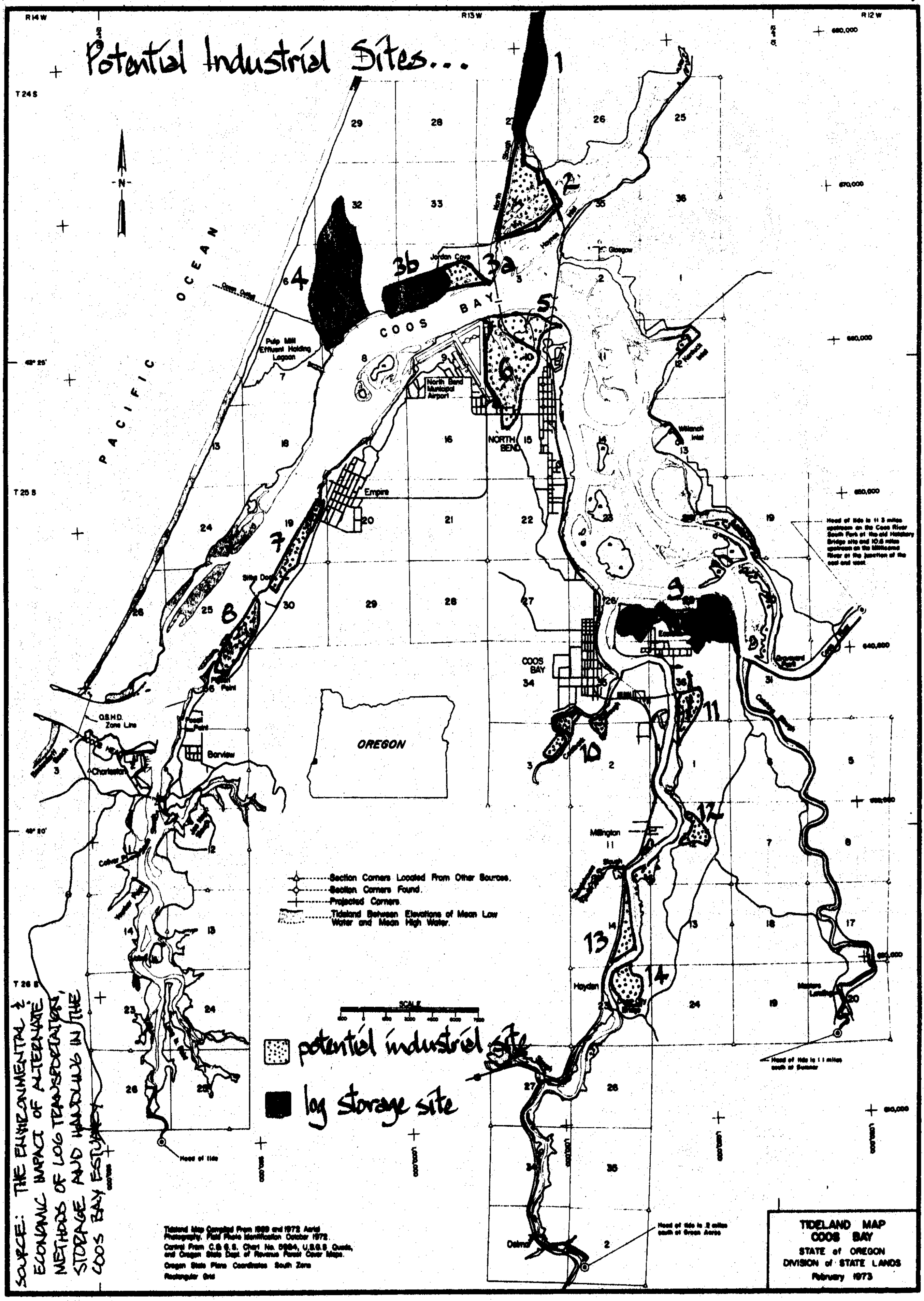

Potential Industrial Sites...
potential industrial site
log storage site
PACIFIC OCEAN
COOS BAY
Pulp Mill Effluent Holding Lagoon
North Bend Municipal Airport
NORTH BEND
Empire
Jordan Cove
COOS BAY
OREGON
Charleston
Barview
Millington
Haydon
Delmar
Section Corners Located From Other Sources.
Section Corners Found.
Projected Corners.
Tideland Between Elevations of Mean Low Water and Mean High Water.
SCALE
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973
Head of tide
SOURCE: THE ENVIRONMENTAL & ECONOMIC IMPACT OF ALTERNATE METHODS OF LOG TRANSPORTATION, STORAGE AND HANDLING IN THE COOS BAY ESTUARY

Figure 4.

report concluded "that there will not be a major shift in the flow of logs into the Greater Coos Bay area in the future...It has been assumed that approximately 200 million cubic feet of wood chips will be exported annually from the area."

After investigating the fourteen sites recommended in A Comparison of Sites for Industrial Development in the Coos Bay Area, four sites were initially selected, with a potential site for a log yard at Pierce Point. The four sites recommended include (Figure 4):

1) Henderson Marsh Site
2) Dunes Site
3) Upper North Slough Site
4) Eastside Site

From the body of the report, "...it is apparent that substantial volumes of logs are stored in the Coos Bay Estuary...The only real alternative is dry land storage, preferably at the user mill." It is particularly significant that none of these sites are adjacent to existing log-using plants. This confirms the generally expressed opinion that "land for the storage of logs is not available alongside existing log processing plants."

Because the Dune Site and Henderson Marsh Site are adjacent to one another and the Dune Site was felt to be less desirable than Henderson Marsh, the Dune Site was dropped from consideration. The Upper North Slough site could not be developed until the Lower North Slough site was first developed, and without relocating the North Slough channel, and was also dropped from consideration.

This study more or less limited the proposed log storage sites to Henderson Marsh and Eastside. Another potential site mentioned is that at Pierce Point. This area has already been mentioned and studied before by a local company. The Coos Bay Estuary Planning Commission has recommended that Henderson Marsh be zoned Industrial, Eastside Spoils Disposal, or Industrial, and Pierce Point as Forest and Grazing, although an Industrial zone was expressed at one time, and the pressure for this zone still remains. The zoning of the Henderson Marsh completely overlooks the presence of a salt marsh and habitat for migratory birds.

The preliminary economic and environmental evaluations of the mentioned sites recommended Eastside as the best storage site. The report also stated that mills should begin converting to gentle let-down rather than dumping logs into the estuary, and that the average log residence in the sloughs be reduced, both of which would continue to improve water quality in the bay. To relocate the industry away from the estuary would almost totally destroy the wood processing industry.

> "The problem of keeping coastal river mouths open for navigation has been of continuing concern to port authorities for many years. For many coastal ports, the navigation channel represents the economic lifeline of the community, for it may provide the only means for inexpensive and efficient transport of goods. This is clearly the case at Coos Bay, Oregon. The economic viability of the Coos Bay region is directly linked to the timber industry, which requires a navigation channel with adequate depths to allow for economical export of forest products from Coos Bay."[28]

The entrance to Coos Bay, as it is presently maintained, consists of two jetties at the entrance to the bay, a 40 foot deep channel across the outer bar, and a 30 foot deep, 300 foot wide channel to the mouth of Isthmus Slough. "The Corps of Engineers, at the request of Congress, prepared plans to deepen the Coos Bay navigation channel to 45 feet over the bar and 35 feet through the remainder of the channel."[29]

"Eight and one-half million cubic yards of sediment and rock will be removed from Coos Bay to construct the proposed modifications. In addition, approximately 1,400,000 cubic yards of overburden, accreted since the preceeding maintenance dredging, will be removed...The 1.4 million cubic yards of overburden to be dredged will be placed at Eastside."[30] Much of the new project dredged material will be dumped at sea, along with dumping at proposed sites within the bay. The increase in required disposal sites is great.

The Coos Bay Estuary Committee has some reservations as to nine disposal sites designated in the Channel Deepening Project. (Figure 5) "The Port of Coos Bay would not oppose the utilization of any of the disposal sites which the Corps is presently entertaining."[31] However, the Port is concerned with slough off and leaching into the bay. Sites 3, 4, 6, 19, 20 and Beach are considered to be conditinally acceptable, providing additional elements are implemented and sites 23, 24, 25 and B were considered to be in conflict with the estuary plan. Five of the six conditionally accepted sites have been proposed to be used during the project, along with seven additional acceptable sites.

Almost any site with in the bay will have at least some effect upon the estuary. North Spit has been recommended by Natural Resource Agencies and conservation groups because it does not encroach upon wetland areas. Although ocean dumping would be the best solution, it is not feasible for the entire project. Any material to be dumped on a proposed site will first require a fill permit from the Division of State Lands, which should help to retain most, if not all, of the proposed wetland fill areas.

The North Bend Airport site is seen as an advantage for filling to allow for the extension of the proposed runway, and yet is a disadvantage because of the destruction of substantial shellfish population and ellgrass beds which will occur. There are several proposed environmental trade-off proposals which now exist, and will be covered later on in this report.

The Coos-Curry Council of Governments has been instrumental in having a water resource management plan prepared. Because of restrictions imposed by the Department of Environmental Quality and the guidelines in the management plan, dumping into the bay is becoming much less hazardous. Dr. Paul Rudy, Director of the Oregon Institute of Marine Biology, has stated, "In the eight years I have been here, the water quality has only improved." This is not to imply that the bay is again healthy, but that measures are being taken to once again see a higher water quality.

The City of North Bend has recently completed a study concerning the construction of a new marina to be located within Pony Slough. Although four alternatives exist, all indicated the removal of some wetland areas, either in the actual marina or the navigation channel.

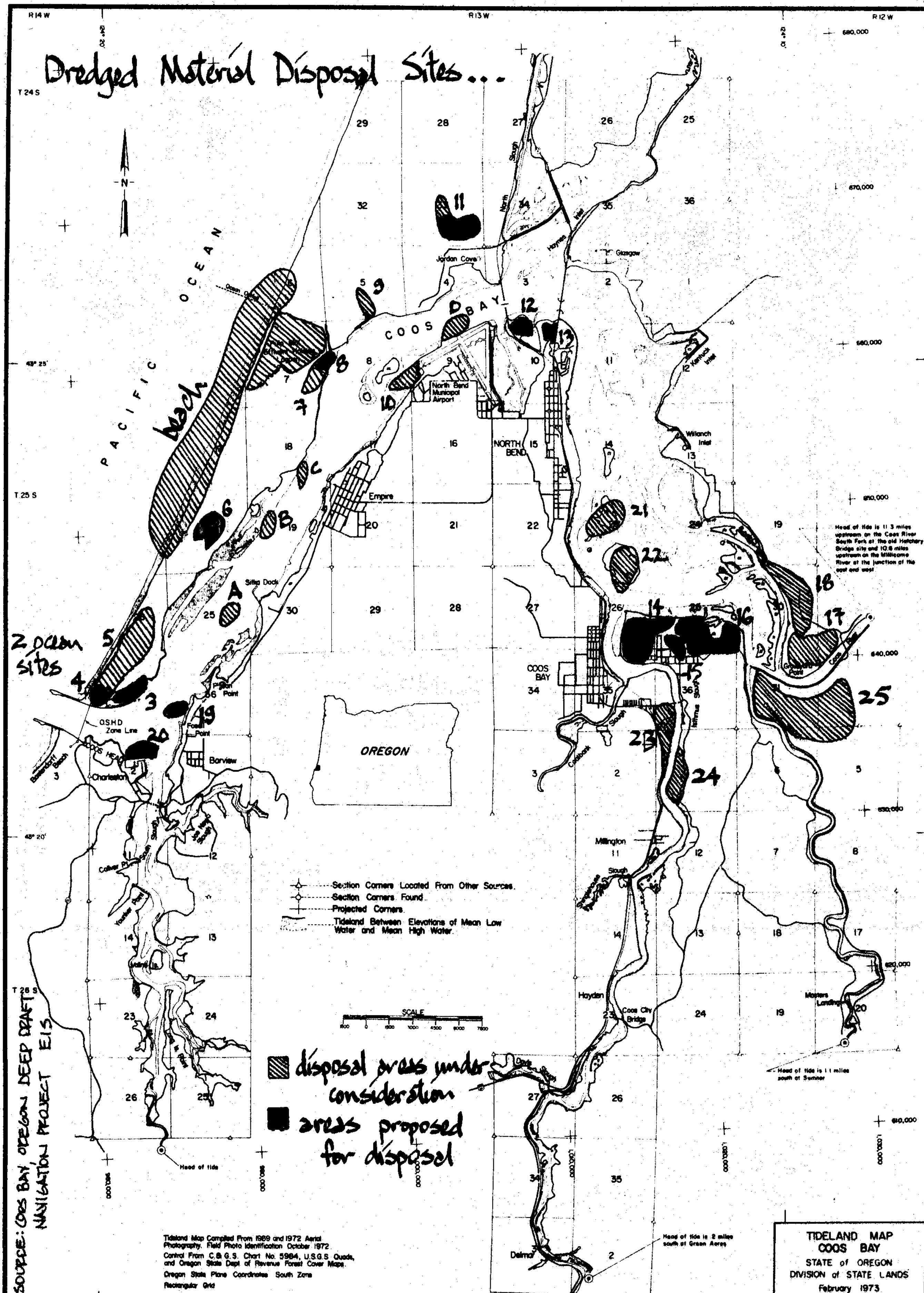

Dredged Material Disposal Sites...
PACIFIC OCEAN
COOS BAY
beach
2 ocean sites
disposal areas under consideration
areas proposed for disposal
SOURCE: COOS BAY OREGON DEEP DRAFT NAVIGATION PROJECT EIS
OREGON
Section Corners Located From Other Sources.
Section Corners Found.
Projected Corners.
Tideland Between Elevations of Mean Low Water and Mean High Water.
SCALE
Tideland Map Compiled From 1969 and 1972 Aerial Photography. Field Photo Identification October 1972.
Control From C.&G.S. Chart No. 5984, U.S.G.S. Quads, and Oregon State Dept of Revenue Forest Cover Maps.
Oregon State Plane Coordinates South Zone Rectangular Grid
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

Figure 5.

Ownership

Most of the uplands of the Coos Bay estuary are privately owned, with the exceptions of North Spit and Pony Slough, which are in public ownership. "The majority of this is in individual private holdings, although large tracts of corporate ownership are located in the Coos River delta, North Slough-Haynes Inlet, and South Slough areas."[32] With the acquisition of the South Slough Sanctuary, 4500 acres of both slough and uplands south of Valino Island have become public in ownership.

Tidelands ownership patterns are much more complex. (Figure 6) City governments of Coos Bay, North Bend and Eastside own tidelands in front of their respective districts. The State of Oregon owns much of South Slough, Haynes Inlet, Shinglehouse Slough, and Catching Slough. Large areas in private ownership include much of the Coos River delta, the Kentuck Inlet-Glasgow portion of the bay, and North Slough. Much of this is owned by lumber companies and is used for log storage either by the respective owner or by a lessee. A more detailed study of ownership patterns and assessment values can be found in Hoffnagle and Olson's The Salt Marshes of the Coos Bay Estuary (1974).

Existing Land Use

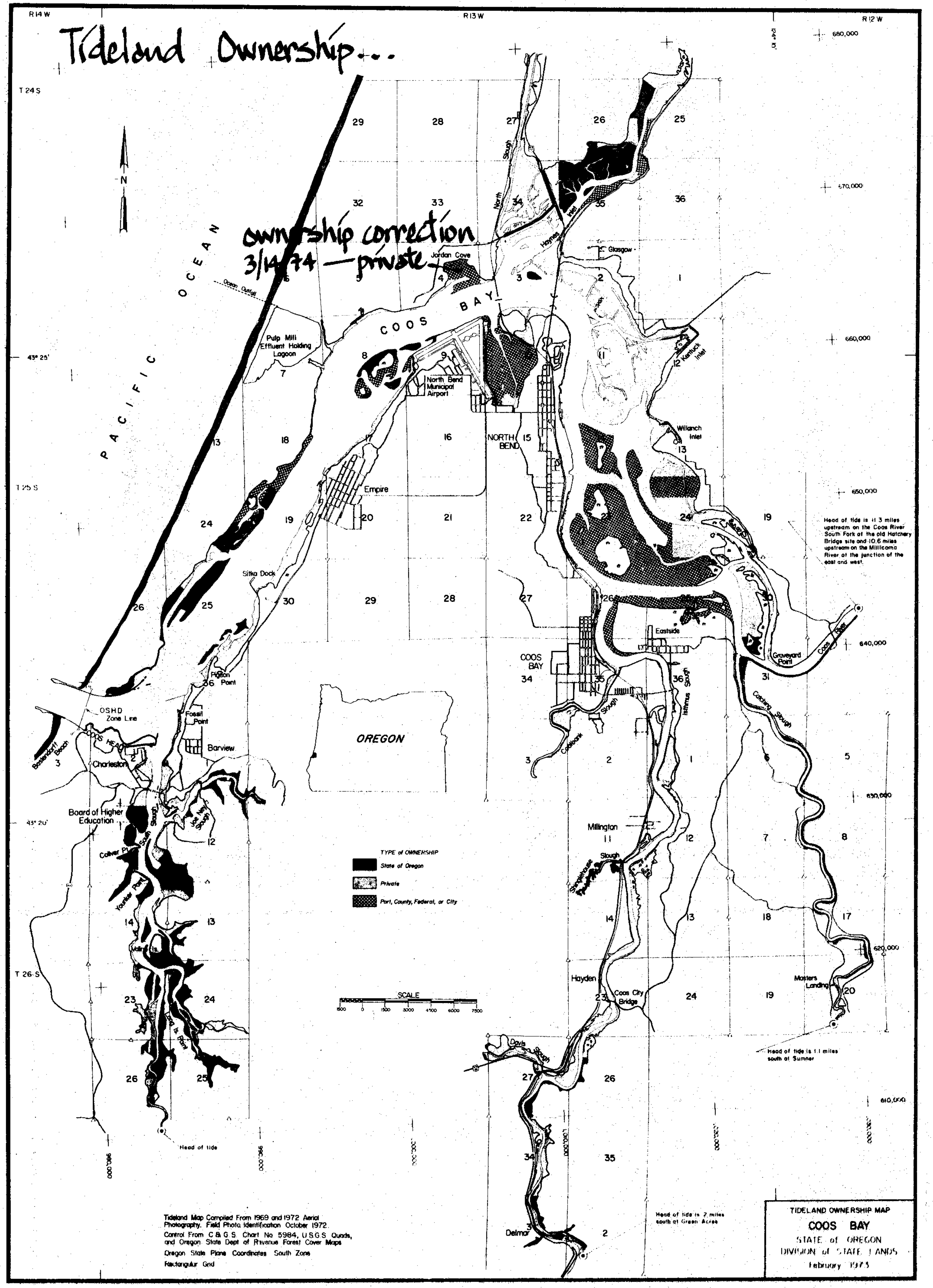
Much of the wetland areas of Coos Bay have been diked and drained for pasture land. Other areas have been covered with fill from dredging operations to allow for development, and large areas of tidelands and marsh are still being used for the storage of logs. With the exception of South Slough, nearly all of the bay has been modified somewhat.

Much of the bay shore is occupied with lumber processing and handling activities, including docking facilities. Isthmus and Catching Sloughs house much of this activity. A refuse dump is located on Shinglehouse Slough. Jordan Cove houses a wood chip and pulp mill operation. The North Bend Municipal Airport is located on the west side of Pony Slough, the only airport servicing the area. Commercial activity is centered in the cities of Coos Bay and North Bend south of Pony Slough. Charleston harbors the area's fishing fleet. Residential areas line the remainder of the bay, with a heavy concentration on the west side of the peninsula. (Figure 7)

Land Use Legislation

No single piece of land use legislation has had as great an impact on the development of western Oregon as the Donation Land Law of 1850.[33] The Donation Land Law gave up to 640 acres per family for simply settling, improving and filing claim to the land.

> "Title to all of the Oregon coast was in Indian hands in 1853. Under directives from the federal government Anson Draft, Superintendent of Indian Affairs for Oregon Territory, had, in the summer of 1851, negotiated treaties of land cession with the Clatsops and Tillamooks. In August and September of that same year, he obtained treaties from the tribes of the Southern Oregon Coast between the Coquille River and the California Border. None of these agreements



Tideland Ownership...
ownership correction 3/14/74 — private
PACIFIC OCEAN
COOS BAY
Pulp Mill Effluent Holding Lagoon
Ocean Outfall
Jordan Cove
Glasgow
Haynes Inlet
North Slough
Kentuck Inlet
Willanch Inlet
North Bend Municipal Airport
NORTH BEND
Empire
Sitka Dock
Pigeon Point
Fossil Point
Barview
OSHD Zone Line
COOS HEAD
Charleston
Bastendorff Beach
Board of Higher Education
South Slough
Joe Ney Slough
Collver Pt.
Younker Point
Valino Is.
Long Is. Point
Head of tide
Eastside
COOS BAY
Isthmus Slough
Coalbank Slough
Graveyard Point
Coos River
Catching Slough
Millington
Shinglehouse Slough
Hayden
Coos City Bridge
Davis Slough
Delmar
Masters Landing
OREGON
Head of tide is 11.3 miles upstream on the Coos River South Fork at the old Hatchery Bridge site and 10.6 miles upstream on the Millicoma River at the junction of the east and west.
Head of tide is 1.1 miles south of Sumner
Head of tide is 2 miles south of Green Acres
TYPE of OWNERSHIP
State of Oregon
Private
Port, County, Federal, or City
SCALE
Tideland Map Compiled From 1969 and 1972 Aerial Photography. Field Photo Identification October 1972.
Control From C & G.S. Chart No. 5984, U.S.G.S. Quads, and Oregon State Dept of Revenue Forest Cover Maps
Oregon State Plane Coordinates South Zone
Rectangular Grid
TIDELAND OWNERSHIP MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

Figure 6.

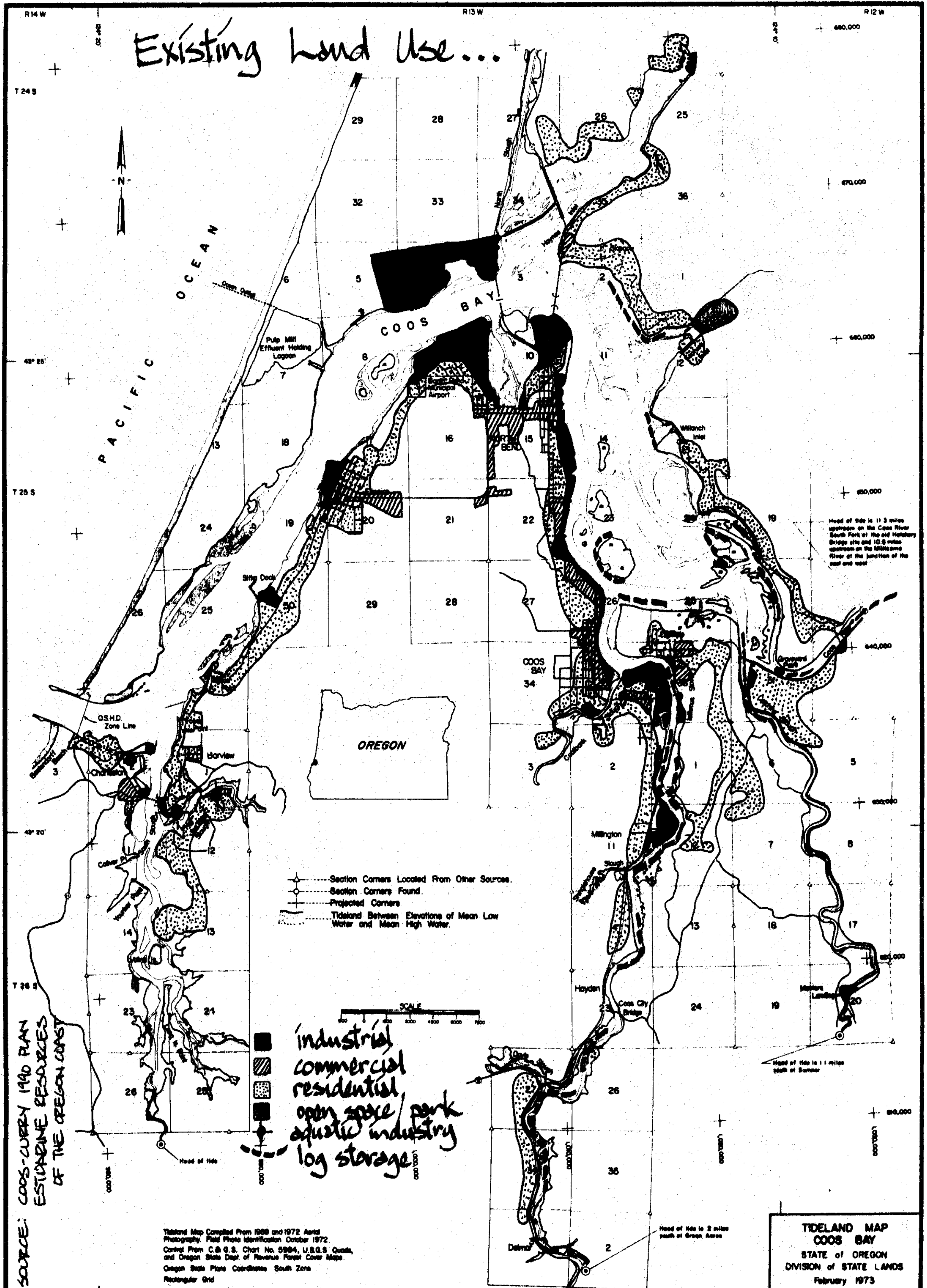

Existing Land Use...
industrial
commercial
residential
open space/park
aquatic industry
log storage
SOURCE: COOS-CURRY 1990 PLAN ESTUARINE RESOURCES OF THE OREGON COAST
PACIFIC OCEAN
COOS BAY
OREGON
Pulp Mill Effluent Holding Lagoon
Charleston
Barview
Millington
Hayden
Coos City Bridge
Willanch Inlet
O.S.H.D. Zone Line
Section Corners Located From Other Sources.
Section Corners Found.
Projected Corners
Tideland Between Elevations of Mean Low Water and Mean High Water.
SCALE
Head of tide
Head of tide is 2 miles south of Green Acres
Head of tide is 1 1 miles south of Sumner
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

Figure 7.

was ratified by the Senate and thus land title remained under Indian control The lands were, excepting small white settlements on the Clatsop Plains, on the Lower Umpqua, and at Port Orford, exclusively in Indian Tenure as well."[34]

In 1849, the United States Congress passed the Swamp Land Act, which granted all swamp and overflow lands to Louisiana. Although unfit for cultivation at that time, the purpose being to help control floods and mosquito-breeding swamps. Oregon was admitted to the Union in 1859 and granted ownership of all the tidelands in the state. In 1860, Congress extended the provisions of the Swamp Land Act to the State of Oregon. "Originally, and for many years after its admittance to the Union, it was a primary conception of Oregon's leaders that the public lands should be sold as a source of revenue for the state...The lands of Oregon were not valued for their future potential worth."[35]

Interest in wetlands was low. Any land unsuitable for cultivation was considered unvaluable. Much of the tidelands were sold for $1.25 an acre, which was considered competitive at the time. Prices eventually advanced to about $7 per acre. However, unlike dry lands which were generally sold without restrictions, the submersible lands of the intertidal coast area were sold under the Act of 1872, and carried a restriction of a public easement, which is in effect to this day. The Act of 1872 provided ways for coastal riparian owners to purchase tidelands abutting their property. Earlier 1870's acts which had granted title of tidelands to adjacent owners were repealed by the Act of 1878. "Laws passed early in the State's history...granting public easements to the common fishery over any tidelands sold by the state, still remain virtually unchanged and have been in continuous effect, though unbeknown to many persons, including tideland purchasers."[36]

General laws of 1891 state "The Board of Commissioners for the sale of State lands was authorized and <u>required to sell</u> the remaining unsold tidelands, including tidal flats in the Columbia River and Coos Bay."[37] This also confirmed all previous grants of tidal flats in the Columbia River and Coos Bay. Other cases of granting and selling tidelands only further exemplifies the state's failure to recognize the importance of tidelands.

The Advisory Committee to the State Land Board in 1872 "found that successive Oregon Land Boards during the past one hundred years had caused the state to divest itself of more than one-half of state-owned estuarine submersible lands. An oddity found was that in some instances the total acreage of tidelands granted or sold exceeded the acreage surveyed as actually existing."[38] This committee also found that "new lands created by filling estuarine tidelands often extinguished the public easement and right to navigation and and the common fishery..."[39]

The state has engaged in the granting of leases for use of state-owned submerged and submersible lands since 1907. Session Laws of 1907 state that "no offshore tidal flats or islands be sold for 10 years following the passage of the Act."[40] Minutes of Land Board meetings indicate that the first offer to lease submerged and submersible lands was in 1909, when a tide island in the Columbia

River was being advertised. Although information as to the materializing of the lease was never found, a protest was filed which led to an injunction. Minutes of 1912 reveal such a lease that does materialize.

In 1909, the Port of Coos Bay was established. 1913 brought the passage of the Oswald Act, which states, "Oregon's beaches between low and high tidelines to be a public highway."[41] Ten year extension of the 1907 Act, prohibiting the sale of tidal flats and islands, were passed in 1917 and 1927. The state, in 1963, recognized coastal beaches as state recreation areas rather than public highways.

The 1969 State Legislature passed Senate Bill 10, which required that all governmental districts within the state prepare comprehensive plans for development within their respective areas. In partial response to Senate Bill 10 and the Coastal Zone Management Act, the Oregon Coastal Conservation and Development Commission (OCCDC) was created by the legislature in 1971 to prepare a natural resource management program for the coastal zone. The OCCDC then spent several years establishing policy topics, conducting public workshops, and developing policies for the use of coastal resources.

The 1973 Legislature enacted Senate Bill 100, which has become known as the 1973 Land Use Act. Senate Bill 100 created the Land Conservation and Development Commission (LCDC) to, "Coordinate comprehensive planning" at a statewide level. (See pages 221-222 in Regulations Affecting Management of Oregon's Estuarine Salt Marshes.) "Although the goals in the 1969 Act (Senate Bill 10) were not mandatory, they were made required interim goals under provisions of Senate Bill 100, Section 48."[42] LCDC was charged "with adopting statewide planning goals and guidelines for land use."[43] Senate Bill 100 also requires the development of coordinated comprehensive plans by local governments, special districts, and state agencies which comply with the statewide planning goals and guidelines.

"Early in 1975, the OCCDC adopted a series of 42 policies, necessary actions, and recommended actions for managing the coastal resources. This completed its legislative charge, and the OCCDC went out of existence."[44] The Oregon Coastal Conservation and Development Association (OCCDA), "...a voluntary association of cities, counties and port officials, was formed in mid-1975, to assist member counties in coordinating planning activities."[45]

Senate Bill 10 set up ten broad goals which districts were to use in preparing their comprehensive plans. Using these goals as a foundation, LCDC expanded each, and added four additional goals, which went before public hearings and were adopted in December, 1974, and went into effect January 1, 1975. Since then a fifteenth goal has been aded, and four Coastal goals are currently in draft form.

"LCDC recognized that the unique characteristics and circumstances of Oregon's Coast should be addressed in specific coastal goals. Before developing such goals, however, the Commission elected to await the final report of the OCCDC which was nearing completion of a four year study of the particular resources, hazards, and land use problems associated with the Oregon Coast."[46] Originally, nine goals were prepared from the OCCDC policies, which have now been cut to four: 1) Estuarine Resources, 2) Shorelands, 3) Beaches, and

4) the Continental Shelf. At this time these four goals and their guidelines are in their third draft and are being circulated for public comment.

It is hoped that these four goals and guidelines will be adopted by the end of 1976. They will then be incorporated into Oregon's Coastal Zone Management Program, which the present draft is based on the draft goals. After adoption, a final Environmental Impact Statement will be prepared and a Federal Review of the Coastal Zone Management Program will take place. This management program is a very large step in assuring both proper utilization and protection of our coastal resources.

Oregon has moved swiftly in the past seven years in planning for its future. The steps it has taken have produced laws and regulations which many Oregonians feel are too restrictive and authoritative. In the General Election of 1976, citizens were given the chance to decide about the future of planning at a statewide level: Ballot Measure 10 was asking for the repeal of LCDC and statewide goals and guidelines. The ballot measure was defeated, and governmental districts must now comply with the laws set up by Senate Bill 100 and carry out the Goals and Guidelines prepared by LCDC. Oregon now has a strict, yet reliable and workable plan for "assuring the highest level of livability for its citizens."[47]

Salt Marshes in General

Salt marshes have been viewed, at least historically, as sore thumbs within the landscape. Because of the lack of flat land surrounding Coos Bay, development oriented itself as close to the bay shore as possible. Marshlands, already flat and semi-terrestrial, have been prime areas to allow for the creation of more developable land. Other marshes, diked and then drained for pasture land, have also created what inhabitants wanted: usable land.

Although filling and diking have been fairly well controlled, if allowed at all, marshes are still subject to log storage, effluents from domestic sewage, and the speculation of their future uses is unclear. With the rising and lowering of the tide, salt marshes and other submersible lands are subject to having their surfaces raked twice a day by logs stored in their vicinities. This raking does not allow any chance for the regrowth of any previous surface covering. Although industrial and commercial sewage pollution is on a decline in the bay, leaking septic tanks are contributing their share of pollutants into the estuary. It is also estimated that up to 15% of livestock wastes eventually reach the estuary. Many of the private land holdings are being kept for future developmental reasons, economic gains, and some for open spaces and views into the estuary. Honest answers concerning the future of individual marshes are hard to find.

There is some concern, at least recently, as to what salt marshes are already providing, rather than what they can become and provide. Marshes are providing habitat for large numbers of waterfowl. Small mammals, other birds and young fish are also found here, as well as shellfish populations in the marsh substrate. Along with providing places for the animals to live, salt marshes are also providing these and other animals within the estuary sources of food, both directly and through the detrital chain. More than just immediate organisms are dependent upon the presence of salt marshes. "It is quite clear that when marsh lands are destroyed, the vast diversity and abundance of life dwindles away."[48]

In addition to providing food and shelter within the estuarine system, salt marshes "are partial cleaning components of the coastal environment. Phosphates and some other pollutants are converted by marshes into nutrients, in essence marshes can be fertilized by certain pollutants. In addition, marshes improve the quality of the marine environment by filtering suspended sediment from water and rendering it less opaque to sunlight, which stimulates floral proliferation. "Marshes act like a land trap," says (Dr. Edgar) Garbisch (of the Center for Applied Research in Environmental Science in St. Michaels, Maryland), and in this way they are an effective barrier against erosion. This attribute also has stimulated the hope that marshes may be a cheap and natural replacement for steel and concrete bulkheads which currently deter erosion in man-made areas."[49]

No longer can we argue that salt marshes are providing only for wildlife. By assimilating phosphates, marshes are helping to control the amounts of pollutants reaching the estuary from domestic sewage and animal runoff from farm lands (phosphates comprise a large percentage of organic waste materials). Some sediments are being trapped by the marshes and are tending to allow light penetration into the waters for richer plant growth. And marshlands are also seen as potential flood control devices. Found within the flood plain, marshes are able to withstand flooding and can retain large amounts of water.

Although we have seen what we can do to salt marsh areas, we are just beginning to see what we can obtain from these lands by allowing them to remain in their natural states. Because research in these areas is new and little evidence presently exists, it becomes extremely important to allow the option to retain salt marshes in case they become much more valuable than previously thought.

Land Use Plans Affecting Coos Bay

The impact and demands of Senate Bill 100 and the Land Conservation and Developmental Commission have been great upon the state, and particularly so upon coastal counties. Understaffed planning departments are feeling the pressures of planning requirements and deadlines. There has been an overwhelming success story in the formation of localized citizen involvement and planning groups. Alterations within the bay have taken place with less impact due to public awareness, interest, and some insight for the future of the area. The outcome of this has been the preparation of several Coos County Land Use Plans, as directed through Senate Bill 100. To date these include Coos County Interim Zoning, Coos County Comprehensive Plan, Coos Bay Estuary Comprehensive Plan, Coos-Curry 1990 Regional Comprehensive Plan and local city plans. At some time in the near future, all of these plans should and will be included in coordinated, comprehensive documents, as required under Senate Bill 100.

Before looking at individual land use plans, it is helpful to first understand some of the concepts that the Land Conservation and Developmental Commission have established. One of the primary functions of LCDC was to set up a series of state-wide standards through which local comprehensive plans could be coordinated and reviewed. Furthermore, the 1973 Land Use Act "mandated active citizen involvement in the on-going land use planning process at all governmental levels."[50] This Citizen Involvement Goal was then adopted as an administrative rule "to assure that citizen involvement would be created throughout the plan review and development..."[51]

The statewide standards which were adopted are known as the Planning Goals and Guidelines. "Goals are intended to carry the full force of authority of the state to achieve the purposes...of the Act. Goals are regulations and the basis for all land use decisions relating to that goal subject. Guidelines are suggested directions that would aid local governments in activating the mandated goals. They are intended to be instructive, directional and positive, but not limiting local governments to a single course of action when some other course would achieve the same result...guidelines are not intended to be a grant of power to the state to carrying zoning from the state level..."[52] All of the goals adopted are of equal importance.

The goals and guidelines are used in the preparation of a comprehensive plan.

> "The comprehensive plan developed...inter-relates all of the functional and natural systems and activities of land and water use. To be comprehensive, these plans must integrate the many separate considerations,...which have traditionally been managed independently of each other. A comprehensive plan must be coordinated and developed into a single document, expressing the public interest regarding the growth and development of an area, including the management of its natural resources. The plan includes a land use map and policy statement."[53]

Fifteen goals and guidelines direct the entire state in planning for the future. Four additional goals are nearing adoption for the coastal counties in the state. Two of the four directly affecting marshes and wetlands are the Estuarine Resources and Shorelands Goals and Guidelines. Much of the text of these goals has been presented in pages 222-26 of this report.

The following is a review of the two coastal goals affecting the use of salt marshes, along with other local plans and their views regarding the importance of marshlands.

Estuarine Resources[54]

The overall statement of the goal immediately recognizes that there exist differences among estuaries and diversity within individual estuaries. Within the discussion of estuaries, "associated wetlands" are referred to. "Estuarine plans and activities shall protect the estuarine system," and non-estuarine related uses will not be allowed in an estuarine location, unless no "alternative upland location exists."

Within an actual comprehensive plan, "uses shall reflect and remain compatible with adjacent shoreland characteristics." The eight considerations included will definitely protect the estuary, while at the same time directing development towards a more natural location (which most often is not immediately the most economical). An inventory will be conducted to provide information necessary for decision making.

A very important consideration in this goal is "maintaining the surface area of the estuary, its flushing capacity, and its water circulation characteristics." Dredging and filling will not be allowed unless they will "provide a significant public gain which cannot feasibly be provided in any other manner," one of the two biggest threats to the destruction of marsh lands (the other being diking and draining). Since salt marshes are considered part of the estuarine environment, and water circulation and surface area cannot be altered, salt marshes are presently in a very protected state "land-use-planning-wise."

If in situations where fill or alteration of estuarine areas is necessary, other "areas of similar biological potential shall be provided to ensure that the integrity of the estuarine ecosystem is maintained." Although this makes sense as to not reducing the volume and area of the estuary, there could develop problems concerning the places where land trade-offs would take place. This will be discussed in a later portion of this report.

Within the inventory of a comprehensive plan, reference must be made as to the location of estuarine wetlands, which includes salt marshes. Also within the management classification system, "limitations imposed by natural resources, including areas of high natural value," (salt marshes) shall be adhered to. Basically, the goal addresses the fact that estuaries have been very much abused as natural resources, and with careful attention and planning, the quality of the resource can be maintained and eventually improved, without halting its development.

Shorelands Goal[55]

The overall statements of this goal refers to "shorelands adjacent...to estuaries and wetlands." The management of shorelands shall be "compatible with the characteristics of the adjacent coastal waters." There is concern for recognition of the flood plain and in minimizing sedimentation in the estuaries. "Important shoreland and wetland biological habitats which are dependent upon the adjacent water body..." shall be inventoried to help form management policies under this goal. "Areas of vegetation cover which are riparian in nature or which function to maintain water quality and to stabilize the shoreline [salt marshes]," shall also be identified in the inventory.

Local comprehensive plans must also "maintain to the maximum extent feasible the vegetative fringe adjacent to coastal waters, to maintain water quality, fish and wildlife habitat, recreational use and aesthetic resources...State and federal agencies should attempt to identify the sources, magnitude, impact, and importance of sedimentation on estuaries..." This goal, along with the Estuarine

Resources goal will restrict the use and place effective controls upon future development in salt marshes.

The LCDC Goals and Guidelines have not been adopted as of yet. Upon their adoption, all coastal comprehensive plans will have to abide by the requirements set within these goals. As far as the planning and zoning of Coos Bay that presently exists affecting salt marshes, there are several plans which must be looked at and considered.

Coos-Curry 1990 Regional Comprehensive Plan[56]

This plan is a "long-range plan serving three basic functions: summarizing socio-economic and environmental conditions and problems; presenting regional plans as well as certifying them for improving socio-economic and environmental conditions and for enhancing the general quality of life in the region; outlining recommended policies and procedures for regional planning and implementation of those plans by assigning and coordinating responsibilities of various agencies." Continual reference is made as to maintaining a regional perspective. In each element, the following concerns are addressed: 1) Human Resources, 2) Economics, 3) Environment, 4) Transportation, 5) Housing, and 6) Land Use.

This plan recognizes that "the longer the shoreline per unit of water area, the greater the potential for actual biological productivity"(shoreline/water area ratio). It also recognizes the importance of marshland and wetlands as "important aspect(s) of estuarine productivity." Included in these aspects are 1) food energy and nutrient cycling, 2) production of fish and wildlife, 3) prevention of siltation and erosion, 4) absorption of pollutants, and 5) moderation of water temperature.

Over 32% of the total area of Coos County is in public ownership. Only .02% of the total area in both Coos and Curry Counties is marshland. "Presently developed land is not developed to its fullest potential and can absorb increases of development. Land use planning in the region will tend to lead development to or adjacent to presently developed areas, and tend to protect open areas."

This plan recognizes that planning is a continuing process and states that "the elements of this plan are in various stages of development." South Slough and Joe Ney Slough have been identified as areas where no further point discharges will be allowed due to the use of this area for drinking water, shellfish hunting, scenic quality, unique natural area, or because the body of water is unable to assimilate wastes. Discharge points referred to in the report have already decreased in numbers due to controls placed on outfalls by the state.

Shinglehouse Slough and Joe Ney Slough are the two prime sites for solid waste disposal sites. This is in compliance with trying to locate one single landfill for Coos County. Also included in this report is a statement on "the potential for a solid waste incinerator to generate electricity." The study concluded "that such a project would be economically feasible and could recycle most of the solid waste produced in the area between Florence and Brookings. The optimal location for this plant would be at Coos Bay, probably in the vicinity of North Spit."

Of special interest is a statement to "encourage resource preservation on a regional basis," which includes "setting aside selected areas for wildlife refuges." Unfortunatley, the present State Bird Sanctuary at Pony Slough is not recognized as a refuge in the area, and many people do not even know that it exists. Also included is the notion to "preserve and enhance the bays, harbors, banks, and their shorelines. This natural resource has unique features giving form and meaning to the region...Develop the bay areas and shorelines in a manner which will minimum problems such as water pollution and flood control."

General Conservation and Development policies for estuaries and wetlands have been established. Although the plan recognizes that "Oregon's estuaries and wetland areas are among the most valuable natural resources of the state," the protection of these "most valuable natural resources" is insured only by stating "uses and activities must be directed to provide for a balance between conservation and development."

Resource Conservation policies propose that "alterations of water characteristics shall be carefully studied to determine the consequences (with adverse conditions being minimized whenever possible) before approval is given. These include:

a) That the proposed uses or activities will be conducted in a manner which minimizes adverse impacts on significant aquatic life or wildlife habitat.
b) That the proposed uses or activities will provide a substantial public benefit.
c) That the alternative locations with less adverse impacts are not practicable.
d) That any alteration be the minimum size necessary.
e) That public rights will not be unjustly minimized.
f) That the proposed use be water related.
g) That the proposed alterations be designed to minimize adverse hydraulic effects and flood hazards.
h) That any subsequent maintenance be taken into account.

Aquatic Life and Wildlife guidelines state that:

a) Production of aquatic life and wildlife shall be considered as one of the beneficial uses in all estuaries.
b) Significant aquatic and wildlife habitats shall be protected to the maximum extent possible.

Basically, all of these guidelines recognize an importance of the estuary and suggest that some understanding of the impacts of a proposed activity be known, although there are no restrictions that might be placed upon uses within the estuary. There is mention made to the fact that alterations be of the minimum size and impact necessary, but several such alterations begin to add up enormously when dealing within a system as fragile as that of an estuary. No mention is made as to how much total alteration and impact may someday occur to an estuary.

Resource Development guidelines include a statement of "maintaining the public benefits derived from the area's [estuary and wetlands] natural resources" when evaluating a proposed development, and continues with a list of factors which should be considered, the last being the "degree of water relatedness, with water dependent uses preferred." Again, not an overly strong stand on water relatedness, and no real measure of protection of the existing estuarine ecosystem; rather just a framework for understanding the justification and effects of an alteration.

Mention is made as to the "improvement of port facilities should keep pace with all other connecting transportation advances." This includes the necessity of deepending the navigation channel, though no mention is made of any policies which should direct the disposal of dredge spoils.

Overall Coos County Land Use Goals were established in 1971:

I) To provide appropriate, well integrated and orderly areas to accomodate the following and anticipated requirements: 1) residential, 2) manufacturing, 3) transportation, 4) utilities, 5) trade, 6) services, 7) professional, 8) cultural, 9) recreational and 10) open spaces.

II) Land that is suitable for more than one use should be categorized to reflect its best and highest use. Priority of uses should be established and land that is suitable for more than one use should be used to accomodate multiple uses when possible.

III) The problems of urban growth must be anticipated.

IV) In order to carry out any goal and properly utilize the land, further studies should be made with regard to regulation of land use, when appropate, since there is no prescribed system suitable for all areas.

Land use planning in the Comprehensive Regional Plan is divided into two levels: 1) Regional, and 2) Local. The regional level is to "establish the broad character of land uses in the region, identify and coordinate regional land use relationships and to coordinate land use planning with the other various planning elements." Local units of government will "conduct long-range planning of defined areas and identify and control specific land use areas." The main intent of the plan is to identify characteristics and coordinate regional plan elements.

The regional plan, Figure 8, is divided into <u>Intensive</u> and <u>Extensive</u> land use categories, which are then further subdivided. Intensive areas "identify appropriate areas for future urban uses." Extensive land use areas are "intended to preserve the basic rural and open character of the region as well as to protect important environmental and economic resources of the region." Nowhere in the plan is there made mention of any estuarine resources that should be preserved or protected, or even have limited developmental rights. Although estuarine resources were mentioned in the planning policies considered, no actual classification of salt marshes or wetlands is made.

"Identification of specific land uses within the guidelines of the regional plan are the responsibilities of the local planning agencies." Local planning throughout the region is in various stages of development. Coos-Curry Council of Governments 1990 Comprehensive

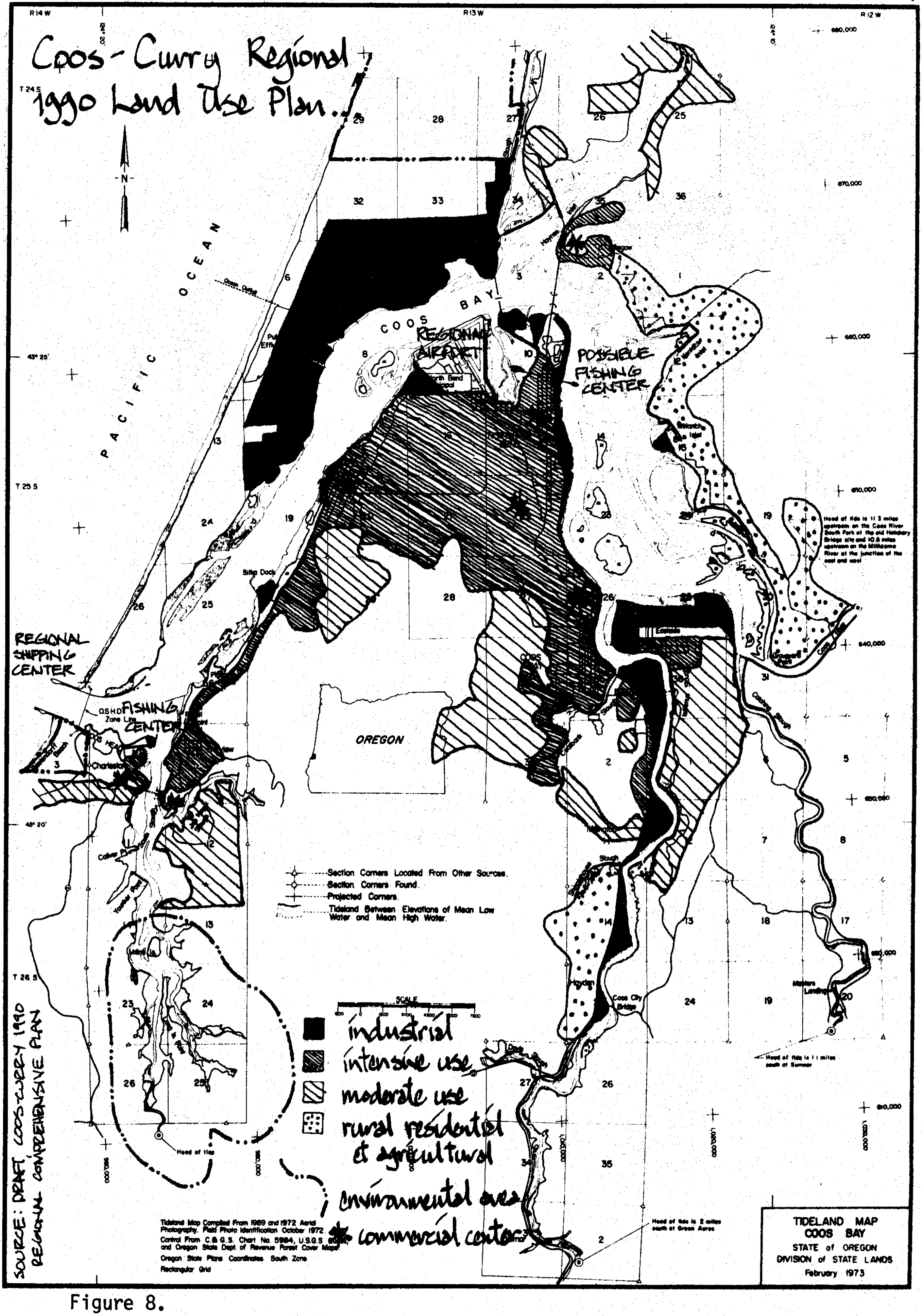

Coos-Curry Regional 1990 Land Use Plan..
PACIFIC OCEAN
COOS BAY
REGIONAL AIRPORT
POSSIBLE FISHING CENTER
REGIONAL SHIPPING CENTER
FISHING CENTER
OREGON
industrial
intensive use
moderate use
rural residential et agricultural
environmental area
commercial center
SOURCE: DRAFT COOS-CURRY 1990 REGIONAL COMPREHENSIVE PLAN
Section Corners Located From Other Sources.
Section Corners Found.
Projected Corners.
Tideland Between Elevations of Mean Low Water and Mean High Water.
SCALE
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

Figure 8.

Plan recognizes the following conditions with respect to their jurisdiction with the following plans.

City of North Bend[57]

An integrated comprehensive plan has finally been completed. "It complies with all regional criteria with one exception; presently the plan provides for an industrial area in Pony Slough. This classification is presently under review by the city, and the city is considering the study to assess the economic and environmental feasibility of developing a marina in the Slough. Rendering the outcome of that study, this would conform to the regional plan."

City of Coos Bay[58]

"A fully integrated plan with no conflict with the regional plan" has been developed. It has also been coordinated with the regional plan. "A new comprehensive plan is pending which also conforms." (Figure 9)

Eastside[59]

A zoning ordinance has been adopted which conforms to the regional plan. An ongoing plan will further refine plans.

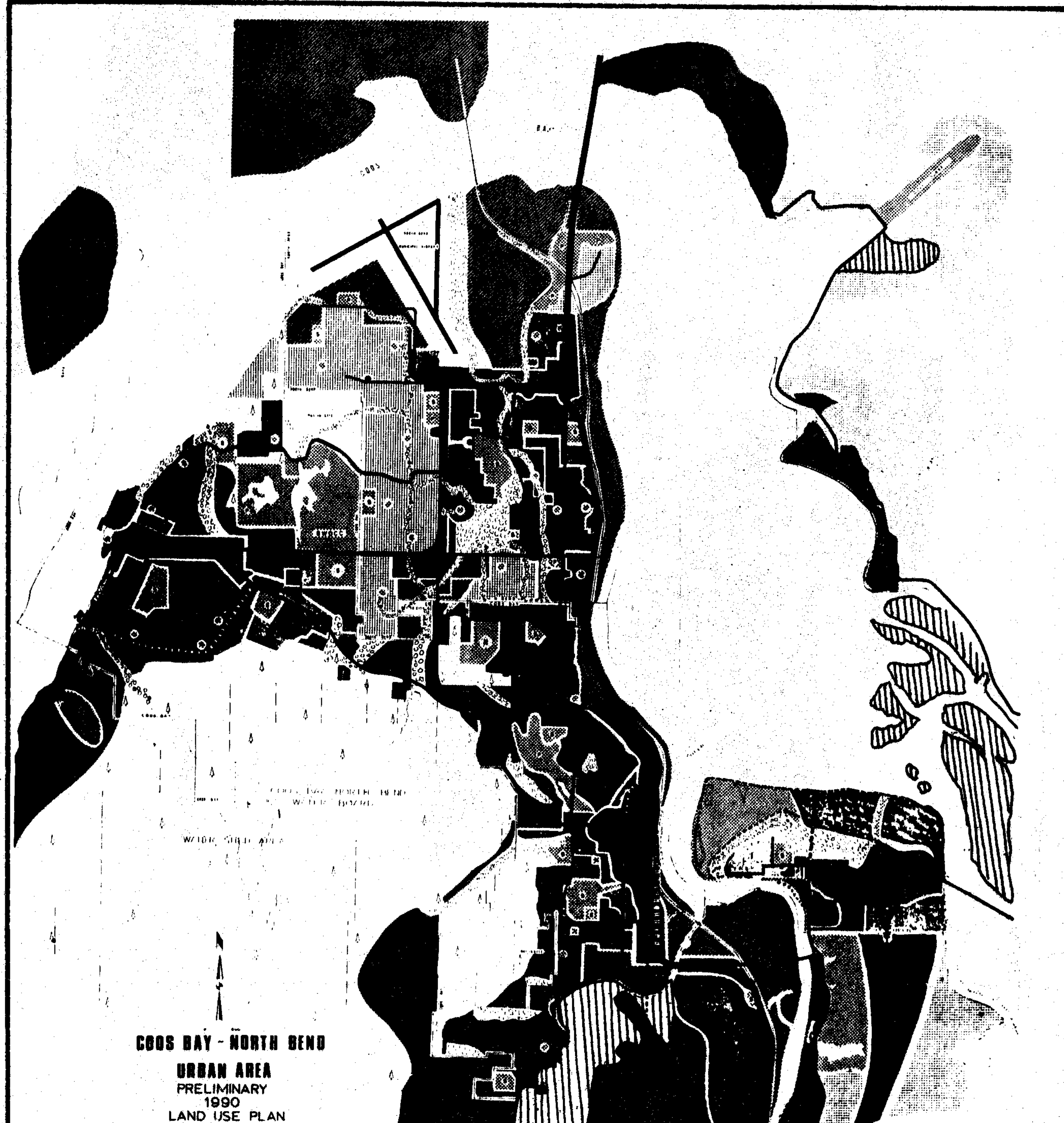
Coos County[60]

At this time Coos County has adopted an interim land use map which "conforms to the general thrust of the regional plan." An Interim Zoning Ordinance has been developed and was adopted in the summer of 1975. "The purpose of this zoning ordinance is to hold present trends in land development until a comprehensive plan can be developed. This ordinance, as it conforms to the regional plan, is certified as an interim land use guide, pending the development and adoption of a complete comprehensive plan." (Figure 9)

Coos County Interim Zoning[61]

This zoning ordinance classifies marshlands and wetlands under an Interim Natural Resource Zone (INR). It is recognized that "intense human activity would significantly damage or destroy the resource value of the area. This zone is further intended to provide for open space lands..." Those uses "permitted outright" in the INR zone include: 1) recreation uses limited to day use..., 2) aquaculture and accessory facilities, 3) wildlife and marine sanctuaries, and 4) management and harvest of forest products. Those uses considered as conditional uses include: 1) solid waste disposal facilities, 2) sanitary land fills, 3) library, 4) museum, 5) public utility facility, 6) communication facility, 7) piers and boat houses, 8) commercial riding stable, 9) accessory facilities for outdoor recreation activities, and 10) overnight camping facilities.

There is no mention in this zoning about the water relatedness



Courtesy of Coos-Curry Council of Governments

Figure 9.

of the proposed conditional uses. Article 8, Conditional Uses, states that, "The conditional use will conform with the Comprehensive Plan or is not reasonably expected to conflict with the proposed comprehensive plan..." Water related activities will become required because of the LCDC goals and guidelines.

Coos Bay Estuary Comprehensive Plan[62]

The Coos County Board of Commissioners had adopted this comprehensive plan, "..an Element of the Coos County Comprehensive Plan." A planning committee was established to develop a plan for water and related land uses in the estuary. This plan recognizes the estuary as a "fragile marine environment" which must be "developed to accomodate the county's economic and transportation needs as a port. Choices to balance these competing concerns in the estuary are limited."

Specific problem areas for study relating to salt marshes included: a) development; b) log storage, water and land storage, accessibility; c) spoil disposal, f) sedimentation in bay; g) life cycle in tidelands; k) sewage-affluent disposal and l) tideland flow alteration. Problems recognized with current uses in the Coos Bay Estuary included:

3) Adequate locations and criteria for disposal of dredged material.
5) Filling of estuarine areas without thorough study and planning which has
   a) significantly reduced the volume of the estuary
   b) reduced tidal flushing
   c) changed the physical characteristics of the shoreline
   d) destroyed large acreages of productive marshlands and tidelands
   e) changed land values and land use patterns in the urban areas.
9) Lack of disposal sites for wood chips from channels and marshlands that have accumulated over the years.
10) Disposal and runoff of domestic sewage into the bay.
12) Reduced vegetation cover at estuarine perimeter.
14) Poor water quality in small sloughs with limited tidal flushing and low fresh water input.
15) Gradual destruction or alteration of nesting, feeding, and resting areas for fish, shellfish, aquatic birds and mammals.

From these concerns, the following goals pertaining particularly to salt marshes were written. These goals should be regarded as policies or recommendations for the planning use and management of the estuary:

2) Establish land development standards at the estuarine perimeter to prevent excessive ground cover and soil removal.
3) Designate dredge spoil locations, priorities and criteria for the disposal at each site.
5) Limit, to the areas indicated in this plan, estuarine filling that will further reduce the volume of the estuary, significantly alter the character and shape of the shoreline,

destroy marshland and tideflats or significantly change land use in an area.

8) Permit burning in certain designated disposal sites for wood debris from channel and marshlands primarily in the East bay and Isthmus Slough area...

12) Limit uses of poorly flushed slough areas to natural production and non-disruptive recreational use.

13) Prevent destruction or alteration of significant natural nesting, feeding and resting areas for fish, shellfish, aquatic birds and mammals.

Using these six goals, along with twelve others, an Estuary Use Plan was prepared, as in Figure 10. "Only those land uses that may produce significant impacts on or are dependent upon the water itself are specifically included." These uses include: a) Marine Industrial, b) Industrial, c) Marine Commercial, d) Recreational, e) Spoils Disposal, f) Converted Areas, g) Uplands and h) Forest and Grazing. Of these categories, those uses which pertain particularly to the use of salt marshes include:

e) Spoils Disposal: Areas where dredge spoils may be placed provided that precautions are used to prevent the return of spoils to the bay and that appropriate State permits are secured. Spoils disposal may also be permitted in other upland categories...

f) Converted Areas: Areas where public benefit may be accrued through the conversion of estuarine areas to upland uses. Such conversion may be accomplished through either diking or filling as appropriate.

Water Use categories in the estuary include: a) Marine Transport, b) Marine Storage, c) Marine Harvest, d) Marine Production, and e) Marshlands. Those goals relating directly to marshlands include:

b) Marine Storage: Water areas where log rafts, vessels or other waterborne obstructions to navigation are regularly placed on either a long term or short term basis. These areas may require maintenance dredging.

d) Marine Production: Tidal areas of valuable biologic natural resources that contribute to the overall estuarine system; no filling or dredging permitted; public recreational uses permitted; certain areas may be re-evaluated for potential designation as Marine Harvest. This designation includes many small marshlands throughout the estuary which are too small to be adequately mapped on the scale presented.

e) Marshlands: Those marsh areas within the main bay and along the tributary sloughs that are vital to the organic, aesthetic and recreational integrity of the estuarine system; no filling or dredging permitted; public recreational uses permitted.

Salt marsh areas designated as Spoils Disposal, Converted Areas, or Marine Storage, although not protected by this plan, will still have to go through the state's fill and removal permit system. Areas of considerable size might also be in question as to the conformance

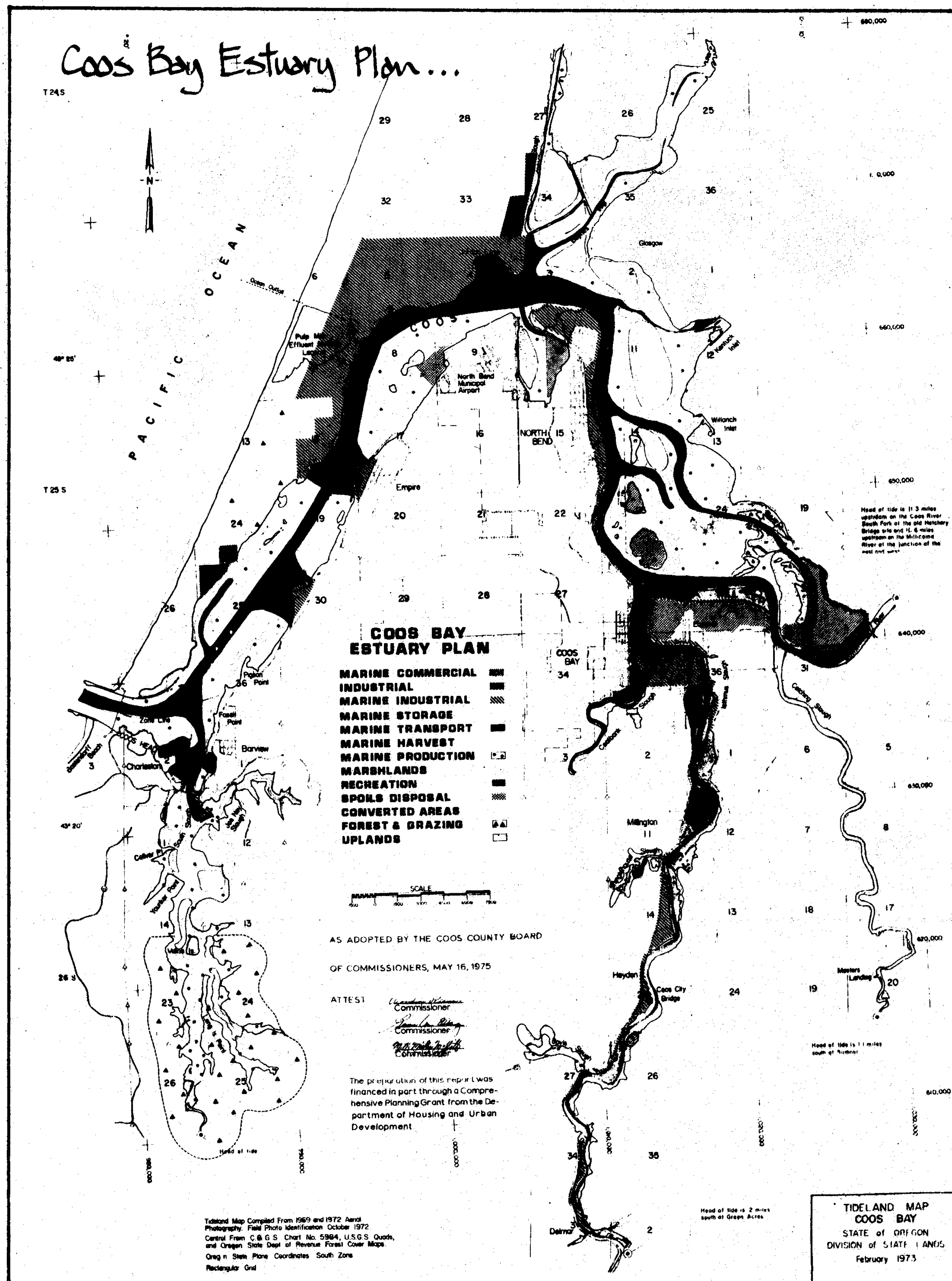

Coos Bay Estuary Plan...
PACIFIC OCEAN
COOS BAY
ESTUARY PLAN
MARINE COMMERCIAL
INDUSTRIAL
MARINE INDUSTRIAL
MARINE STORAGE
MARINE TRANSPORT
MARINE HARVEST
MARINE PRODUCTION
MARSHLANDS
RECREATION
SPOILS DISPOSAL
CONVERTED AREAS
FOREST & GRAZING
UPLANDS
SCALE
AS ADOPTED BY THE COOS COUNTY BOARD
OF COMMISSIONERS, MAY 16, 1975
ATTEST
Commissioner
Commissioner
Commissioner
The preparation of this report was financed in part through a Comprehensive Planning Grant from the Department of Housing and Urban Development
Glasgow
North Bend Municipal Airport
NORTH BEND
Empire
Charleston
Barview
Millington
Heyden
Coos City Bridge
Delmar
Masters Landing
COOS BAY
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

Figure 10.

with LCDC's Coastal Goals and Guidelines. Although these areas are not preserved as natural areas contributing to the estuary, they are still protected under federal and state laws, since salt marshes are considered part of the navigable waters. Any further loss of salt marsh is protected under Marine Production and Marshland categories. The importance of marshlands to the estuarine system has been recognized, and in most cases it has been decided that their importance outweighs any other suggested uses in the same areas at this time.

In January of 1973, the Coos County Planning Commission mailed copies of the Estuary Committee's report for review and comment. After comments were analyzed, eleven areas were cited that "would warrant special review." These eleven areas (Figure 11) along with their special concerns included:

1) North Slough: originally designated Industrial, objections came from using "this area of prime natural resource, aesthetic and recreational value for industrial purposes." The Oregon Dunes National Recreational Area would "preclude industrial use of the area within its boundaries (roughly 1/2 of the total area).

2) Pony Slough: the east 1/2 of the slough designated Commercial, which is presently in tidelands and marshlands. The objection came from a commercial zoning in an area high in natural resource values.

3) North Spit: designated Industrial. Objections stemmed from "the extent of industrial areas designated in light of needs for additional industrial areas."

*4) Kentuck Inlet: a Marine Commercial/Marine Transport designation "with storage and loading facilities at the mouth of the Inlet." Objections came from the proposed dredging and/or filling required for the development and the general industrial intrusion into the area.

5) Bull Island: designated Spoils Area for maintenance spoils disposal and for burning wood debris on the southern end. The big objection came from using a "natural resource area for burning of wood debris and limited spoils disposal, particularly when alternative sites are available."

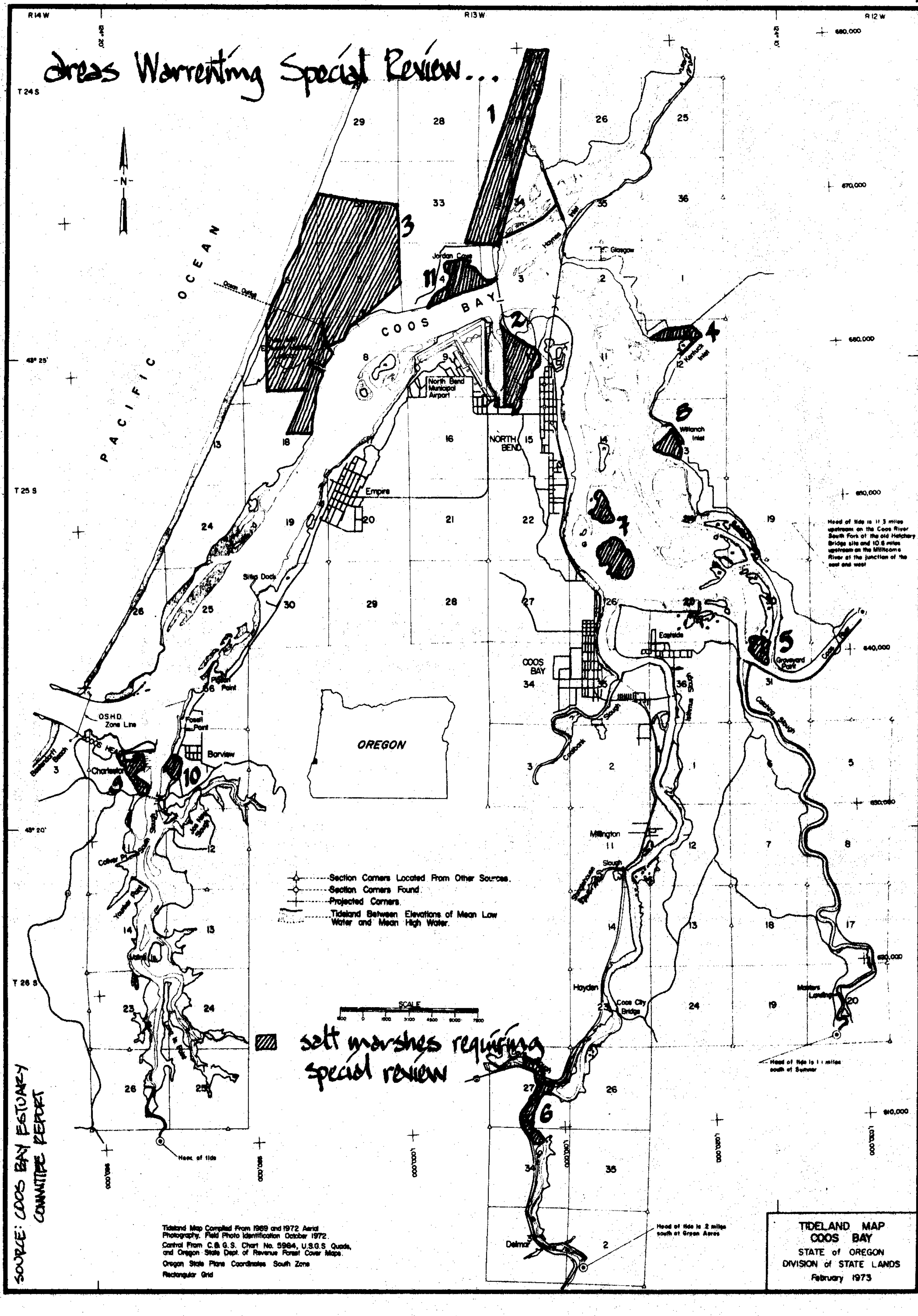
6) Isthmus Slough: Marine Transport/Marine Industrial/Marine Storage/Spoils Disposal/Marshland. Objections came from the continued intensified use of water and marshland areas of limited tidal flushing action.

*7) Spoil Islands: designated as Spoils Disposal, "the continual placement of spoils on these islands where spoils and waste water may escape into the bay."

8) Pierce Point: Industrial/Marine Transport designations require dredging and filling. Industrialization of the east bay was felt to be incompatible.

9) Charleston: the designation of Marine Commercial became like a blanket zone.

10) Barview: Designation of Marine Commercial on "State owned property on the east side of Charleston Harbor." Objections came from "utilizing prime recreational and natural resource area for commercial use."



Areas Warrenting Special Review...
PACIFIC OCEAN
COOS BAY
Jordan Cove
North Bend Municipal Airport
NORTH BEND
Empire
Glasgow
Kentuck Inlet
Willanch Inlet
Graveyard Point
Eastside
COOS BAY
Pigeon Point
Fossil Point
Barview
Charleston
Millington
Hayden
Coos City Bridge
Delmar
OREGON
Section Corners Located From Other Sources.
Section Corners Found.
Projected Corners.
Tideland Between Elevations of Mean Low Water and Mean High Water.
salt marshes requiring special review
SCALE
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973
SOURCE: COOS BAY ESTUARY COMMITTEE REPORT
Tideland Map Compiled From 1969 and 1972 Aerial Photography. Field Photo Identification October 1972.
Control From C.& G.S. Chart No. 5984, U.S.G.S. Quads, and Oregon State Dept. of Revenue Forest Cover Maps.
Oregon State Plane Coordinates South Zone Rectangular Grid

Figure 11.

*11) Jordan Cove: Marine Transport within the Cove. The objection came from a commercial use without specific plans or proposals.

*denotes retention of the original designation.

It should be noted that in all cases, resource agencies were the primary objectors to the designation of uses.

After review of these areas and a public hearing for additional input, the following actions occurred:

1) North Slough: modified the extent of Industrial Area.
2) Pony Slough: changed to Marshland.
3) North Spit: Marine Industrial area modified.
*4) Kentuck Inlet: retained original designation.
5) Bull Island: Spoils Disposal was removed, retained the burning of debris on existing site.
6) Isthmus Slough: no recommendations until a log storage study being conducted through the Port is concluded (remained very similar to original designation).
*7) Spoil Islands: retained original designation.
8) Pierce Point: accepted Industrial designation, but recommended a Forest and Grazing FG-40 during the interim period.
9) Charleston: referred the planning to District #5 Steering Committee.
10) Barview: same as above.
*11) Jordan Cove: retained original designation.

At the time preliminary land use categories were assigned throughout the estuary, there was a 216% increase in Industrial lands (Industrial and Marine Industrial), accounting for 17.2% of the total acreage of land/water use in the Estuary Plan. Salt marshes accounted for 3.5% of this total acreage.

Upon adoption of the Estuary Comprehensive Plan, the following changes were noted from the earlier review and recommendations. Pierce Point was given an Uplands designation, with a clause recognizing the "potential utility of this site for industrial purposes." Bull Island remained a dredge spoil site "if no viable alternative exists to implement the dredge project of the Port of Coos Bay." Although the text does not give it a Spoils Disposal classification, the plan still has it marked that way. The Coalbank Slough marsh site was changed from Converted Area to Marshlands.

A last note is the failure to recognize Henderson Marsh as a salt marsh at all. The entire marsh site has been classified as Marine Industrial, probably anticipating a fill. "In the past, water has been circulated into the marsh by a faulty tidegate which has undergone recent repair, cutting salt water inflow into the marsh."[63] The Oregon Coastal Conservation and Development Commission's Coastal Wetlands of Oregon also fails to take note of this marsh, which "appears to be a high mature marsh."[64] Henderson Marsh does appear in The Salt Marshes of the Coos Bay Estuary by Hoffnagle and Olson. Although many of the plant species at the marsh site are fresh water species, it is still unclear why the omission of this large marsh.

Henderson Marsh is important not only for its size, but it is "the most significant marsh on the Bay's west side."[65]

Salt marshes affected by the adoption of the Coos Bay Estuary Comprehensive Plan include both those marshes protected by the plan, and those which have received other classifications of uses. Of concern at this time are those which have the potential to be developed because of the plan. (Figure 12) These marshes include:

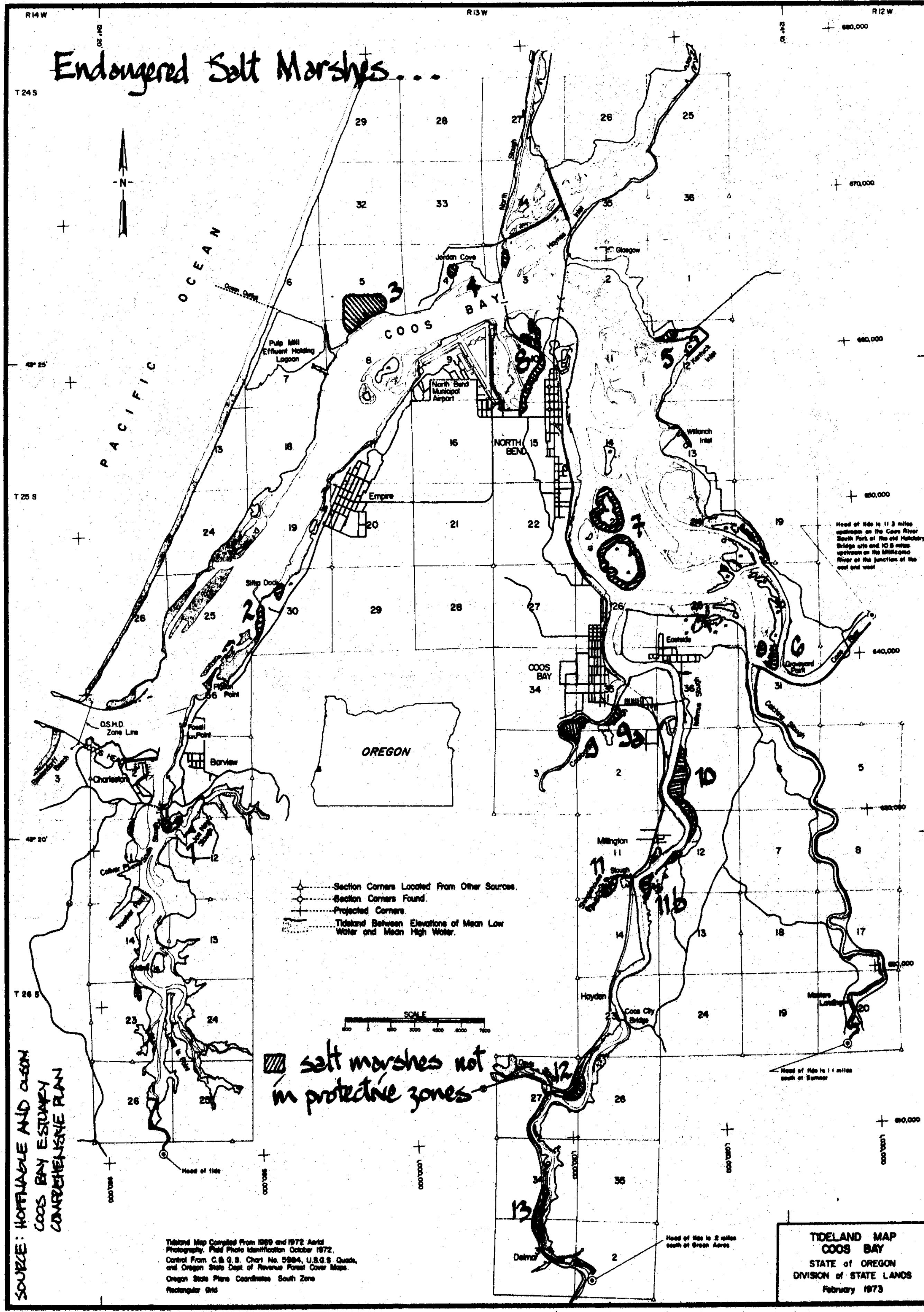
1)	Joe Ney Slough	Marine Storage/Marine Industrial
2)	Sitka Docks	Marine Industrial/Marine Transportation
3)	Henderson Marsh	Marine Industrial
4)	Jordan Cove	Marine Industrial
5)	Kentuck Inlet	Marine Transportation
6)	Bull Island	Spoils Disposal
7)	Spoil Islands	Spoils Disposal
8)	Pony Slough	Marine Commercial/Marine Industrial
9)	Coalbank Slough	Converted Area
9a)	Coalbank Slough	Marine Industrial
10)	Isthmus Slough	Marine Storage
11)	Shinglehouse Slough	Industrial
12)	Davis Slough	Marine Storage
13)	Delmar	Marine Industrial

Although there are several marshes in danger of development, it appears that the future existence of these marshes is fairly well protected. Again, this is because of the Fill and Removal permits from the Division of State Lands required before 50 cubic yards of estuarine lands are either filled or removed.

In general, the Coos Bay Estuary Comprehensive Plan has done a good job of at least designating land use categories and assigning them to areas throughout the bay. The need to develop the bay exists, and the bay is going to have to change to meet these needs. Unfortunately, no plans have recognized that multiple uses might exist in certain areas. It is almost as if a blanket zone was placed on areas, and small and unique characteristics are passed over and soon forgotten.

While reading through the text, one will notice that each statement is preceeded by "The plan recommends." This brings up a final item of concern: the legality of the document. In April of 1972, the Coos Bay Estuary Committee was appointed "for the purpose of conducting studies bearing on the Land Use Regulations in the Coos Bay Estuary."[66] The original intention of the committee was to prepare a recommendation to the Coos County Planning Commission concerning the estuary, and not to prepare a land use plan for the estuary.

Upon adoption of the "recommendation" as part of the Coos County Comprehensive Plan, in 1975, an appeal was brought before the Land Conservation and Development Commission for the review of the Estuary Plan. The petitioners included the League of Women Voters of Coos County, Bay Area Environmental Committee, 1000 Friends of Oregon, and fourteen citizens of the area. Their complaint states, "that the Estuary Plan fails to comply with the interim goals enacted by the 1969 Oregon Legislature...or with the definition of a comprehensive plan as provided by the 1973 Oregon Legislature."[67] Also


Endangered Salt Marshes...
salt marshes not in protective zones
SOURCE: HOFFNAGLE AND OLSON COOS BAY ESTUARY COMPREHENSIVE PLAN
PACIFIC OCEAN
COOS BAY
OREGON
NORTH BEND
COOS BAY
Empire
Charleston
Barview
Eastside
Millington
Hayden
Delmar
Glasgow
Jordan Cove
North Bend Municipal Airport
Pulp Mill Effluent Holding Lagoon
Sitka Dock
Pigeon Point
Fossil Point
O.S.H.D. Zone Line
Willanch Inlet
Graveyard Point
Coos City Bridge
Section Corners Located From Other Sources.
Section Corners Found.
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Tideland Between Elevations of Mean Low Water and Mean High Water.
SCALE
Tideland Map Compiled From 1969 and 1972 Aerial Photography. Field Photo Identification October 1972.
Control From C.& G.S. Chart No. 5984, U.S.G.S. Quads, and Oregon State Dept. of Revenue Forest Cover Maps.
Oregon State Plane Coordinates South Zone Rectangular Grid
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

Figure 12.

included is the violation of LCDC's Citizen Involvement Goal. The adoption of the plan took place at a special meeting without giving appropriate notice to interested citizens.

The appeal, however, does state that "the Estuary Plan represents satisfactory progress...towards compliance with applicable goals."[68] An opinion and recommendation from John H. Clough, Hearings Officer, Department of Land Conservation and Development, states the following: "The Estuary Plan is admittedly an incomplete portion or element of the Coos County Comprehensive Plan and does not comply with the definition of a comprehensive plan." Clough goes on to state: "that elements of comprehensive plans which are adopted on a preconceived basis be construed as interim planning only subject to reconsideration when they are integrated into the comprehensive plan for the county."[69]

A Comprehensive Plan is the controlling land use planning document for a governmental district. In the case of a discrepancy in previous zoning and the comprehensive plan, the comprehensive plan will always be the ruling document, as has been established by Fasano v. Washington County Commissioners and Baker v. City of Milwaukie.

In the case of Coos County, however, there exists a problem with planning for the estuary. Coos County is presently under Interim Zoning (adopted July 1975, after adoption of the Coos Bay Estuary Plan). There exist discrepancies in the Interim Zoning Plan and the Coos Bay Estuary Plan. LCDC recommended that the Coos Bay Estuary Plan be considered as interim zoning until the Comprehensive Plan for the entire county was completed. Which plan would rule in a land use conflict consideration would probably be found out in the courts. At the time this report was being prepared, LCDC did decide that the Coos Bay Estuary Plan was not a comprehensive plan. Until the completion of the Coos County Comprehensive Plan, the Interim Zoning Ordinance would control in land use decisions. However, once the county's plan was completed, the Coos Bay Estuary Plan would become a part of that plan. And this decision could probably be taken to court.

Tidal Flushing in Coalbank Slough

On July 1, 1974, there was a public hearing "in the matter of the application of Coos County to fill a portion of Coalbank Slough and other tributaries of Coos Bay, Oregon."[69] At that hearing, Dr. Carol Jefferson (then referred to as Miss Carol Jefferson) was testifying as to the condition of the particular portion of Coalbank Slough in question (one of this study's marsh study sites). At the time of the hearing, Dr. Jefferson was asked, "With the present tidal gate on the culvert, would that 25 acres now be considered part of the estuary?" To this she replied,"If so, only minimally. And I say that because this morning I witnessed that there was a small amount of leakage across the fill, but as an overall picture, no."

After questioning about specific marsh plant types and the importance of inundation of saline water, Dr. Jefferson was asked what would eventually happen to the marsh if the tidegate were to remain on . Her reply was, "What will happen has already begun to happen...They'll [salt marsh plants] be out competed," along with a change in substrate of the marsh. Reference made to a dike placed on Boone Slough in Yaquina Bay in 1937 revealed that there no longer existed any character of the earlier marsh.

Although Dr. Jefferson did not know if the removal of the four foot tidegate from the culvert would provide adequate flushing, she did indicate that upon removal, and adequate water circulation, "the marsh would recover almost immediately, within the growing season. ...By the end of next summer it would be recovered to where it was, pretty much...But if you left the tidegate on, or obstructed the tidal flow in some manner for 10 years, it doesn't have a chance."

It has been indicated that with the intricate network of channels leading into the dominant one in Coalbank Slough, when the tide moves in and out, it "reaches more portions of the marsh, [and] therefore can bring in more material and carry away more material." A U.S. Department of the Interior study entitled Natural Resources, Ecological Aspects, Uses and Guidelines for the Management of Coos Bay, Oregon states, "that tidal circulation...in Coalbank [Slough], with little or no summer inflow or intertidal storage, is nearly a pulsating or sloshing back and forth of the water mass." After some argument about the input into the estuarine system, it was established that the detritus produced is "going out regardless of whether the tide is a major moving force or not, because as of now, Coalbank Slough has not filled up, and the debris created must be going somewhere."

The final outcome of this hearing was that Coos County was required to remove the tidal gate on the culvert of the particular marsh, so that it may again be inundated with saline water and return back to contributing to the estuarine system.

On Friday, July 30, 1976, two researchers were at the Coalbank Slough marsh study site taking hourly readings of salinity, height of water within the marsh, velocity of water flow into and out of the marsh, and to take water samples to determine amounts of detrital material leaving the marsh and entering the estuary. About half-way through these collections and readings, it was discovered that there was a visible difference in tidal height in the slough and the outlet channel of the marsh.

A small train tressle once bridged the mouth of the channel of the Coalbank Slough marsh. In 1972 this marsh was then diked and a tidegate was put in to help both drain the site and to keep saline water from entering the marsh. Eventually the area would have been put to an agricultural use, or filled and subdivided for development.

The Coalbank Slough marsh in question is a sedge marsh dominated by Carex lyngbei, which, according to Dr. Jefferson, is, "more produtive, acts more as a sponge and is an entire little system,"[70] as compared to other marsh types in the estuary. But with the differences in tidal heights of the marsh channel and Coalbank Slough, it should be questioned as to whether the marsh in question is receiving the same tidal flushing before the diking and installation of the tidegate and after the removal of the tidegate.

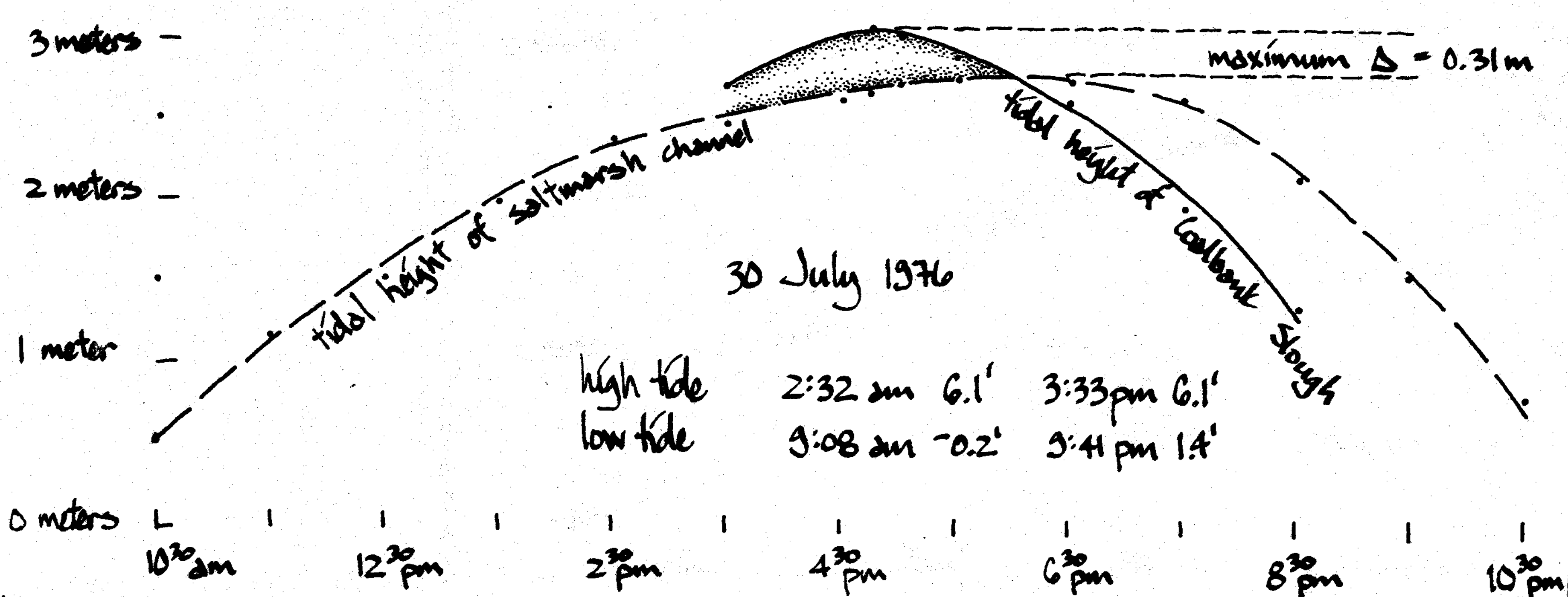
By using a stadia rod and an eye level, a relative difference in tidal height can be calculated. The bottom of the stadia rod is placed at the highest level of water in the marsh channel. By taking a reading on the road using an eye level (at an eye level of about 6 feet, although insiginificant in the relative differences in height) a distance from eye level to the surface of the water can be recorded. Repeating the operation on the Coalbank Slough side of the dike, and sighting the eye level from the same spot, another distance of eye level to water surface level can be measured. The difference between these two readings can then be referred to as the relative difference in tidal heights.

Before and during these measurements, readings were being taken of the actual tide height inside of the marsh, using a 5 meter measuring stick, so that the bottom of the channel in the marsh measured 0 meters, or no height. This record of actual tide height can then be plotted on a graph. By adding or subtracting the measured differences in tidal height, whichever is appropriate for the reading, the height of Coalbank Slough can be calculated and also graphed. (This is assuming that Coalbank Slough and the marsh are the same distance from eye level to their bottoms. Although this is obviously not the case, the theory works in terms of a "tidal prism." A tidal prism can be defined as the "volume of water exchanged during each tidal cycle, equal to the volume within an estuary between high and low tide levels.") Assuming that the bottom of the channel to be the lowest water mark, then this same mark can be used in the Slough for the bottom of the volume of water that will be exchanged (due to water seeking its own level). The volume of water above this mark should theoretically be exchanged in the marsh. By overlaying the graphed readings, any area between the two lines denotes an amount of water which is not circulating through the marsh (assuming that water does seek its own level). (Figure 13)

The visual difference in tidal height was first observed at 3:00 pm and recorded at 3:30 pm along with the other readings. Approaching high tide, readings were taken every 15 minutes. At 4:45 pm. Coalbank Slough reached a relative height of 3.1 meters. At 5:30 pm, the marsh channel reached a relative height of 2.79 meters. This gives a maximum difference in height of .31 meters, or just a little over a foot (12.2 inches). The reason for the lapse in time of maximum heights of the two water bodies is due to the fact that as the tide in Coalbank Slough recedes, and Coalbank Slough's water surface level is higher, the marsh channel continues to fill. Adjusting times and tide heights from the Humboldt District to Coos Bay proper, high tide was to reach 7.1 feet at 5:03 pm. Low tides occurred at 11:11 pm and 10:38 am reaching 2.4 feet and 1.2 feet respectively. These tides are relatively high for any time of the year.

At the time of this study, two years since the removal of the tidegate, biologists have stated that this marsh has not returned to its original state, as Dr. Jefferson said it would with proper circulation. This is probably due to the marsh not receiving proper circulation, as suggested in Figure 13. No studies were made to determine the adequacy of a 48 inch culvert to properly allow water circulation into the marsh. The County was only required to remove the tidegate on the culvert, hoping that the marsh would return to its original state. Because less water is entering the marsh,

Flushing Capability of Coalbank Slough



distance: eye to water level (in meters)	10^{30} am		12^{30} pm		2^{30} pm		4^{30} pm			6^{30} pm		8^{30} pm		10^{30} pm
of channel	—	—	—	—	—	3.0	2.9	2.8	2.75	2.8	2.9	3.3	—	—
of slough	—	—	—	—	—	2.75	2.5	2.5	2.65	2.9	3.55	4.1	—	—
difference (Δ)	—	—	—	—	—	+.25	+.4	+.3	+.1	-.1	-.65	-.8	—	—
channel height	0.52	1.15	1.55	2.0	2.4	2.5	2.65	2.75	2.79	2.78	2.65	2.2	1.6	0.85
slough height (channel + Δ)	—	—	—	—	—	2.75	3.05	3.05	2.89	2.68	2.0	1.4	—	—

Fig. 13.

peripheral marsh vegetation is disappearing, and the marsh is shrinking in size. This also means less detrital material entering into the estuary.

"Some of the worst water quality conditions in the bay occur in deadend channels of Coalbank and Isthmus Sloughs."[71] The Coalbank Slough marsh plays an important role in local water quality conditions. Tim Davison of Oregon's Department of Environmental Quality reported that there were problems with leaking septic tanks in the area due to the unsuitability of the soil. Because of a salt marsh's capability of assimilating organic waste and perform tertiary treatment, this marsh must be playing some role in the assimilation of the local leakage before it reaches the main body of the estuary. At the channel mouth could be seen bits of toilet paper and a brown foamy scum.

It is felt that this marsh has not yet returned to its original state, and yet is still playing some part in producing food and assimilating wastes for the estuary. A letter has been sent to Stanley Hamilton, Waterways Manager, c/o Oregon's Division of State Lands, to see if a complaint need be filed to draw the Division's attention to the matter and request further adjustment in returning the marsh to its original state. Upon receipt and comment of thatletter, further action will then be taken in restoring this marsh.

Mitigation

One of the primary requirements in protecting an estuarine ecosystem is to maintain "the surface area of the estuary, its flushing capacity, and its water circulation characteristics," as recognized in the LCDC Coastal Planning Goals and Guidelines. If these characteristics are required to remain unchanged, then it would seem as though no further alteration could take place within an estuary. But the requirement goes on to read that any activity that would alter these three characteristics "shall be permitted only when it is necessary to provide a significant public gain which cannot feasibly be provided in any other manner." When these "activities are permitted, another area of similar biological potential shall be provided to ensure that the integrity of the estuarine system is maintained." Some compensation is to occur before an activity is to occur.[72] The trading of one biological area for another similar area in compensation for development is known as "mitigation." This measure will assure that Oregon's estuaries will no longer continue to diminish in size and quality.

The City of North Bend has recently applied for a permit from the Division of State Lands to allow a 32 acre landfill for the extension of a runway at the city's Municipal Airport. The permit was returned with several stipulations, including that of requiring mitigation in this case. "The city appealed the original permit because it required the removal of the large spoil island at the end of the proposed fill off the west end of the airport." The Division of State Lands held a contested case hearing in late July from which the Director of the Division will make another decision in early fall. City of North Bend officials feel that no mitigation is required for the landfill. Donald Morgan, representing the City of North

Bend, in a statement to The World of Coos Bay, says, "We're all scrambling around trying to get some expert to tell us what is mitigation... We've talked back and forth about whether or not we can come up with some other kind of mitigation," rather than removal of the island. The Attorney General has stated, "...that there must be total mitigation required in the permit."[73]

The purpose of this work is not to further deliberate upon whether or not mitigation is necessary, but rather take a critical look at the Coastal Goals and Guidelines and indicate the strengths and weaknesses of the mitigation proposal. The goals (although as of yet, have not been adopted) specifically state "areas of similar biological potential shall be provided." In the case of the airport fill, large areas of eelgrass beds will be removed, and so then must somehow be returned to the estuarine system.

What is lacking in this goal is a statement of locations where such trade offs should occur. It would not make sense to allow a development in one area of the bay to be off set with mitigation at the other end of the bay, and expect that the bay will pretty much retain its original characteristics. In 1971, Coos-Curry Council of Governments had a sewerage planning study prepared for Coos Bay. This plan reads, "a preliminary analysis of the various physical zones of marine and estuarine waters within the study area has resulted in the establishment of certain desired goals or standards..." These goals were felt "to be adequate at least through 1980, but should be considered preliminary and subject to modification following completion of the water resource phase."[74]

This plan has proposed six general classifications for the optimal water quality in Coos Bay (Figure 14). "The establishment of specific zones is dependent on several factors: 1) preservation or upgrading of existing water quality; 2) recognition of shellfish reproduction, rearing and harvesting areas; 3) recognition of recreation areas; 4) degree of flushing and low water exposure; 5) navigation and deep water areas; and 6) areas subject to low summer fresh water flows."[75] These, or similar, areas should also be classified as land trade off areas, in which mitigation would have to occur within the same water classification.

Even more specific are the Water Management Units that were established by the Oregon Coastal Conservation and Development Commission in Estuarine Resources of the Oregon Coast. These Management Units represent classifications according to different characteristics within each slough. (Figure 14) Those parameters used in preparing the classifications include: 1) physical type, 2) mixing characteristics, 3) extent of eelgrass beds and tidelands, and 4) the terrestrial and marine biological values. The management of the units would take into account the characteristics of each estuary type.

The following Management Units were assigned to Coos Bay's inlets and sloughs.

Isthmus, Davis, Shinglehouse, Coalbank, Pony and Kentuck Sloughs	Type IV
Coos Bay/Coos River	Type V

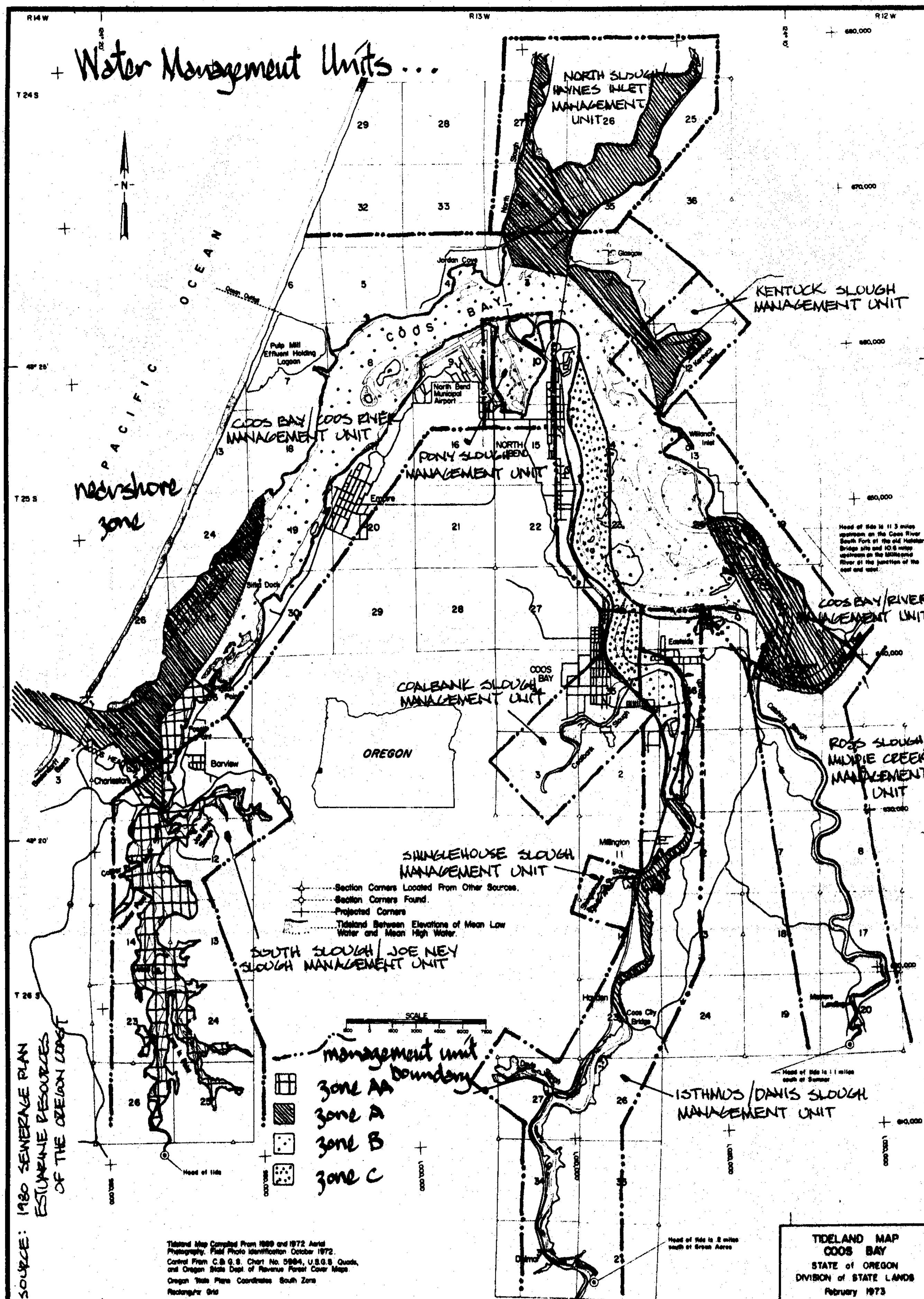

Water Management Units...
NORTH SLOUGH/ HAYNES INLET MANAGEMENT UNIT
KENTUCK SLOUGH MANAGEMENT UNIT
COOS BAY/COOS RIVER MANAGEMENT UNIT
PONY SLOUGH MANAGEMENT UNIT
nearshore zone
PACIFIC OCEAN
COOS BAY
COOS BAY/RIVER MANAGEMENT UNIT
COALBANK SLOUGH MANAGEMENT UNIT
ROSS SLOUGH/ MATSIE CREEK MANAGEMENT UNIT
OREGON
SHINGLEHOUSE SLOUGH MANAGEMENT UNIT
SOUTH SLOUGH/JOE NEY SLOUGH MANAGEMENT UNIT
ISTHMUS/DAVIS SLOUGH MANAGEMENT UNIT
management unit boundary
zone AA
zone A
zone B
zone C
Section Corners Located From Other Sources.
Section Corners Found.
Projected Corners
Tideland Between Elevations of Mean Low Water and Mean High Water.
SCALE
SOURCE: 1980 SEWERAGE PLAN ESTUARINE RESOURCES OF THE OREGON COAST
TIDELAND MAP
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

Fig. 14.

Catching Slough Type VI

North, Haynes, South and Joe Ney Sloughs Type VII

Type IV: Drowned River/well mixed estuaries have low to moderate marine biological value and very low terrestrial value. They have a low to moderate percentage of eelgrass and tidelands.

Type V: Drowned River/well mixed estuaries have low to moderate marine biological value and high terrestrial biological value. They have a moderate percentage of eelgrass and tidelands.

Type VI: Drowned River/well mixed estuaries which have moderate marine biological value and moderate terrestrial biological value. They have a low percentage of eelgrass and a high percentage of tidelands.

Type VII: Drowned River/well mixed estuaries which have moderate marine biological value and high terrestrial biological value. They have a moderate to high percentage of eelgrass and tidelands.

Further description of each type may be found in that report.[76]

If a marsh, or any estuary element, were to be altered in Isthmus Slough, a body of water already considered to be of poor water quality, it would be of little or no value to that Slough to mitigate in South Slough, an already pristine slough, or any other non-adjacent area. Although the bay would essential retain the same size, characteristics and qualities of areas would change quite rapidly.

In case of the airport, mitigation should take place either within Pony Slough itself (Pony Slough Water Management Unit), or zone B, very similar to the Coos Bay/Coos River Water Management Unit. These areas of quality and characteristics become especially important in the smaller sloughs and tributaries due to tidal flushing. The City of North Bend is considering trading some undiked salt marsh for the airport fill, rather than removing the spoil island. Although this puts another salt marsh in a relatively protected state, it does nothing for the eelgrass beds being removed or for the integrity of Pony Slough. Eelgrass beds and salt marshes are far from being biologically similar.

Man-Made Marshes

If it is true that marshes are relatively young geologically, and if provided the right substrate and tidal cover will expand rapidly, then might it not be possible to actually build salt marshes? Although marshland has been reclaimed by the breaching of dikes and allowing tidal inundation, recovery is often slow, if it occurs at all, due to the change in substrate composition and texture. Recently there has been another way of "reclaiming" marshlands, and that has been through the process of building them.

Actually, "man-made salt marshes" are not new. Much of the spoils material which has been dredged out of the bay has been deposited within the bay forming spoils islands. "Marsh often fringes the spoil islands and is also found on older spoil islands not completely above tidal range. These marshes stabilize the spoil, and eventually result in meadow formation."[77] Several of the salt marsh identification and classification studies done on the Oregon Coast and in the Coos Bay Estuary have indicated marshlands fringing spoils deposits. The same holds true with the Pony Slough study site used in the preparation of this report. Filled in 1939 to allow for the construction of the airport, the fringes of the fill on the westward side of the slough are now covered with marsh plants.

In a 1973 article found in Passages, Northwest Orient Airlines Inflight Magazine, there is an article referring to the "building" of salt marshes by Dr. Edgar Garbisch of The Center for Applied Research in Environmental Sciences in St. Michaels, Maryland. In the articles, Garbisch states, "We reestablish the flora, the grasses, and within two years, nature will have provided the rest. There seems to be a magnetic effect; life attracts life." He goes on to say that it might now be possible to reclaim an equivalent of most of the marshes that have been lost.

This same action is now taking place in the Gulf of Mexico. The Army Corps of Engineers is currently converting the "dredgings from ship channels...into lush and productive marshland."[78] Although similar projects have been started elsewhere, the largest of 350 acres is located off the mouth of the Mississippi River. An article in U.S. News and World Report states:

> "Already it is attracting new life. Native grasses--seeded quickly by wind, water and birds--have grown vigorously. There are signs that the new land has been adopted by muskrats and nutria as well as by wading birds and waterfowl."

The Corps is planning to build "as much as 60,000 acres of new wetlands in the Mississippi River Delta over the next decade."[79]

"The Corps of Engineers is planning a man-made marsh near the mouth of the Columbia River between Washington and Oregon that will measure 12,000 feet wide and a mile long."[80] Although these artificial marshlands have been cited to be expensive, they are helping to solve the continual loss of wetlands. Even so, the fact still remains that "wetlands are being lost much faster than they can be artificially created."[81]

A problem that might exist in Coos Bay, as well as in the othe estuaries in Oregon, is the recognition of the unhealthyness of continuing to shrink our estuaries. LCDC's Estuarine Resource Goal states that "the surface area of the estuary" must be maintained. Since marshlands are considered part of the estuary, would an increase in marshlands through filling the estuary reduce the surface area of the estuary, or would the surface area remain constant? Although this possibility is far away and might never happen, the possibility should be brought out now and discussed. The final statement would probably be set again in the courts, since the issue would be new to Oregon.

A final consideration is the fact that only the fringes of spoil islands turn into marshlands. This is because of the elevation of the interiors. Although the interiors are often to be planted, they are now barren deserts of dried and cracked mud. If these interiors were to be lowered, or if new disposal islands were planned to be low in elevation, then the interiors would probably also develop into marshlands. All proposed spoil disposal sites within the bay should be required to be made into environmental habitats rather than barren deserts.

The Planning Process

Land use planning is a relatively new and multidisciplined process. Land zoning has been around for some time, coordinated comprehensive planning has not. Once a field engaged in by a select few, land use planning has developed into an all-encompassing activity involving many disciplines and many more persons.

Upon adoption of Senate Bill 10, the State of Oregon realized and decided that in order to maintain a high standard of livability in the state, and to prepare the state for future growth, comprehensive planning was required. The 1973 Land Use Act and the formation of the Land Conservation and Development Commission was a more aggressive step in planning and regulating growth and development in the state.

Various levels of planning deal with several aspects of planning. After overall planning frameworks and policies are decided upon, ways in which specific areas might be developed or preserved can be discussed. Actual detailed plans and particular developments can then be drawn up and reviewed in relation to the broader framework. This order of action assures a more comprehensive, coordinated and meaningful plan.

Typically, federal, regional and state agencies are responsible for developing a broad planning framework. Intrastate agencies discuss ways in which areas might be developed and the character an area might take on, and local groups write specific proposals for action. When LCDC was preparing the state's Goals and Guidelines, they relied heavily upon public input and criticism. A Citizen Involvement Goal was written "to develop a citizen involvement program that insures the opportunity for citizens to be involved in all phases of the planning process...The citizen invovlement program should be appropriate to the scale of the planning effort..."[82] This Goal was then adopted as an administrative rule to insure that citizen participation would be created all through the plan development and review.

Coos County is divided into planning districts, each with its own Steering Committee made up of local residents. These groups are responsible for the analysis of existing uses, natural systems, and deciding upon the future development of their respective areas. Upon completion of a localized land use plan following broad policies and guidelines, coordination at the county level is made much easier and more meaningful. County plans will eventually be coordinated at a state level, and are guaranteed to be comprehensive because of coming from more localized sources. Review of materials and actual planning is being placed into the hands of the ones who will be affected by the planning. Planning must remain multi-disciplined and must continue to receive more and more input from more and more persons.

The estuary is a unique and extremely small area compared to the entire state or even just the coastal area. Although the estuary itself is small in area, a very large area surrounding it affects the function and integrity of an estuary. Ideal estuary planning should include all of this area, most notably the estuary's drainage basin. (Figure 15) Water areas alone cannot be planned without concern for their surroundings. Water and land uses must be complementary and coordinated to have any meaning at all.

Plans for the estuary, or any area for that matter, should be based on long-range predictions of changing needs and changing availability of resources. This helps to explain that at no time is a plan complete, but rather represents that which is best understood at the time of its preparation. Planning is an ongoing process and must continue to be so to have meaningful impact upon the usage of our land and water resources. Accompanying planning should also be a continual effort to better understand the estuary and account for its needs.

Coastal residents often feel as though their home is "the playground for the rest of the state." They resent interference with their planning interests. Unfortunately for these people, the coast contains very unique and valuable resources that even more than just the State of Oregon relies upon. Plans for coastal activities must be sensitive to the fact that the coast and especially its estuaries are very limited. Coastal plans must be governed by more than just local plans, and must rely upon the direction of state, regional and feceral policies. Only through adequate planning will our estuaries continue to provide for many persons, and adequate planning only stems from a wide range of inputs.

Summary

Coos Bay Estuary has experienced extensive alteration since its discovery by white man in the middle 1800's. Accompanying these alterations has been the continual loss of salt marsh and tidelands. With only 10% of Coos Bay's salt marshes remaining, it becomes extremely important to decide upon how this resource will continue to be used. It is also necessary to insure that this resource will not continue to dwindle away until there are no longer sufficient marshlands to provide for the estuary.

Although early development plans for Coos Bay often cited marshlands as the most economical construction sites, more recent planning measures have been written to insure that at least some degree of protection exists for both marshlands and tidelands. In the case of a plan not recognizing the presence or importance of salt marsh areas, Fill and Removal Permits from Oregon's Division of State Lands are required, for any modification over 50 cubic yards of land. Through comprehensive planning and the State's laws and regulations, the existence of the salt marsh in the future at this time is fairly much insured.

Once smelly and easy to fill pieces of land, we are just beginning to realize and understand the importance of salt marshes to the estuary. Rather than looking for ways in which salt marshes can be "made into" usable resources, we are just beginning to understand what marshes are providing for us already in their natural state. We're just beginning to understand the potential of a salt marsh for assimilating and performing tertiary treatment on organic wastes,

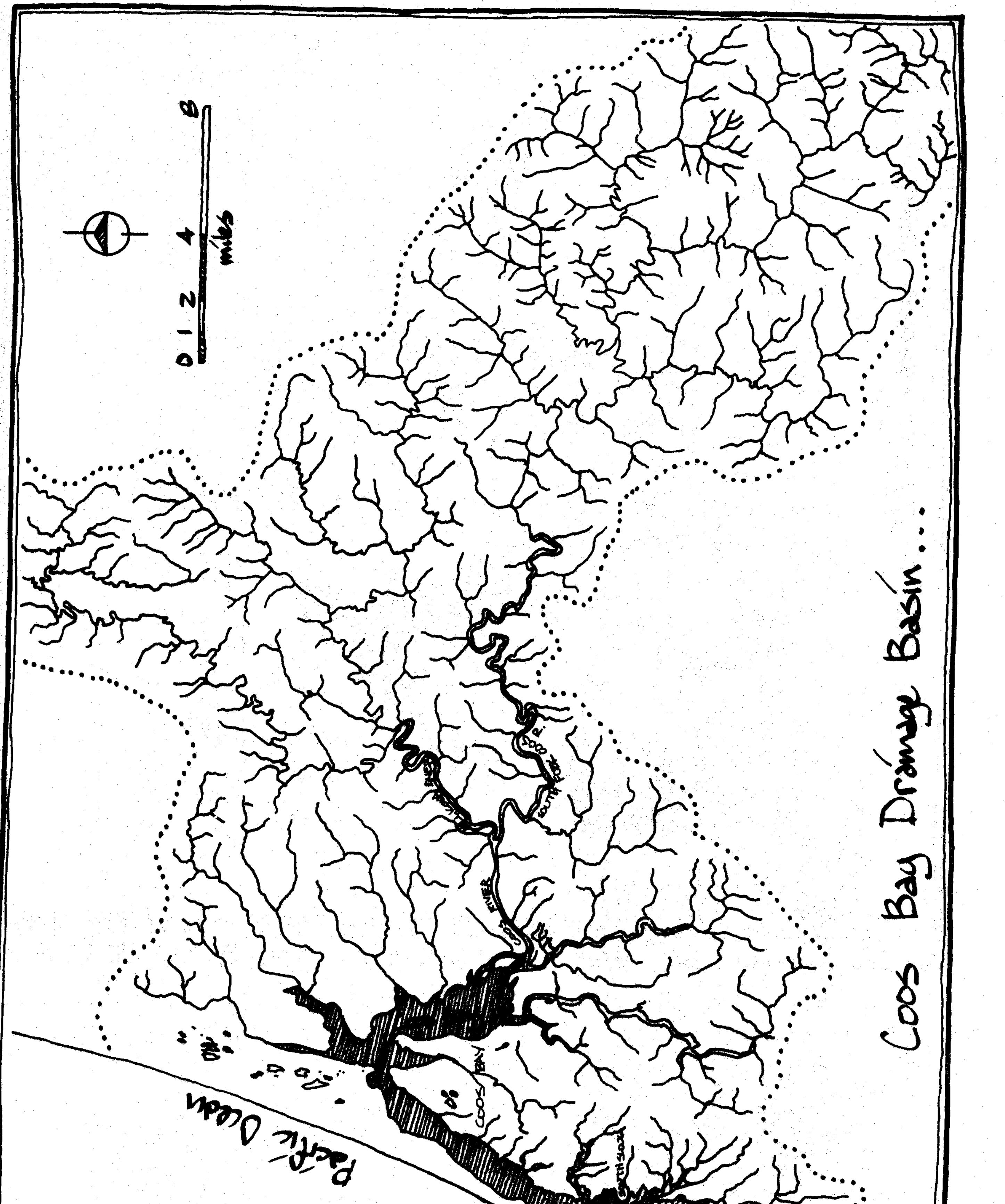

Coos Bay Drainage Basin...
0 1 2 4 8
miles
Pacific Ocean
COOS BAY
COOS RIVER
SOURCE: US DEPARTMENT OF THE INTERIOR, NATURAL RESOURCES...OF COOS BAY, OREGON

Fig. 15.

while we continue to spend millions of dollars trying to build a similar machine. We are just beginning to witness the actual amounts of food contributed to an estuary through a salt marsh, which is phenomenal in itself. Unfortunately, we are only just beginning to fully understand these importances.

But we must make planning decisions today. All the data needed for decision making is not present, and probably never will be. In light of this, options must be allowed to exist for salt marshes to continue their valuable function to both man and nature. As this resource has diminished in size and contribution, its value has continued to increase in the importance of maintaining the estuary's integrity. We cannot rid ourselves today of the remaining 10% of marshlands, only to discover tomorrow their real importance.

"We've all said that estuaries are extremely valuable, probably the most valuable type of land we have. We don't know how they work. What's more, I would suggest that we will never know because man will change them faster than we can study them."[83] Hopefully, this will not be the case. When situations arise that warrant the removal of marshlands, or any ecosystem for that matter, from the estuary, development should only be allowed to occur if mitigation is insured to take place. In this way the estuary will be allowed to change, but now allowed to dwindle away. It is time that "Coos Bay...be treated as a body of water--not as a piece of real estate."[84]

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43. Ibid.

44. Ibid.

45. Ibid.

46. Ibid.

47. Ibid.

48. Jack Rudloe, op cit.

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Economic Aspects...

A THEORETICAL BASIS FOR MEASURING THE SOCIAL VALUE OF SALT MARSH

R. Michael Martin

Abstract

Resource managers, acting as representatives of society, make allocative decisions concerning salt marshes. This chapter is directed towards resource managers with substantial economic training. Although it focuses upon salt marshes, the anlaysis is sufficiently general to be applied to any environmental resource.

In general, the usefulness of this paper derives from its explicit statement of the conditions, necessary and sufficient, to test if society holds too much or too little salt marsh. The precise objective of this research is a rigorous specification of an empirically testable methodology to value, monetarily, the services foregone when society converts a salt marsh to an alternative use.

To accomplish this objective, I define the theoretically efficient salt marsh acreage. Quantifying the efficient acreage requires a general equilibrium model including at least two natural ecosystem production functions. Lacking information to specify the ecosystem production functions, I propose a test of the hypotheses that society hold too much or too little salt marsh. Such a test employs a monetary measure of the social benefits and costs of a marginal change in salt marsh acreage. I focus on formalizing a methodology to estimate the monetary social losses incurred in converting a salt marsh. Making such a monetary valuation is a prodigious and exacting task, therefore, in conclusion, I critically appraise the work of other researchers who have presented simplified valuation methodologies. These alternative valuation schemes, although not as rigorous or exacting, provide some quantitative information helpful in decision-making.

Introduction

Salt marshes are unique natural resources providing society with a vector of services. Salt marshes augment the waste assimilative capacity of the environment, feed the detritus-based estuarine fauna, and dissipate the energy of storm waves. They contribute recreational and aesthetic values by providing wildlife habitat and open space. An opportunity cost of their conversion is the stream of benefits foregone when conversion occurs.[1]

This chapter describes a methodology to quantify empirically the monetary value of the services society foregoes when converting a salt marsh to an alternative use. Using the tools of economic analysis, I define rigorously the necessary and sufficient conditions to value the services of the marginal salt marsh.

Section I reports my original and subsequently revised objectives and motivations for preparing this paper. I define the efficient quantity of salt marsh for society to hold and examine how deviations from the efficient quantity can be evaluated using a marginal test. The section concludes with a discussion of the complicating factors which potentially make the efficient acreage different from that quantity of land allocated to salt marshes by the private land markets.

Section II describes explicitly the analytical methodology, necessary and sufficient conditions, and data requirements to value the stream of benefits foregone when society converts a salt marsh.

Section III provides a critical appraisal of various valuation methodologies which have appeared in the literature.

Section I

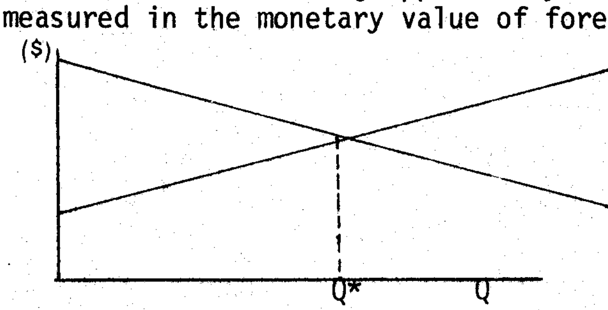
In 1974 three prominent natural scientists, Gosselink, Odum, and Pope, authored a paper entitled "The Value of the Tidal Marsh."[2] This 1974 paper specifies techniques and methods to estimate a monetary valuation of tidal marsh acreage. Reporting data for Atlantic and Gulf Coast salt marshes, Gosselink, Odum, and Pope supply their valuation methodology and estimate value per acre.

My original goal, working as an economist on the SOS team, was to derive a monetary valuation of Pacific Coast salt marsh acreage in the spirit of Gosselink, Odum and Pope, but with a more refined and empirically testable methodology. Due to lack of resources, money, time and data, I could not compete this ambitious project in three months. My revised goal is to describe a rigorously defined accounting methodology which provides, if sufficient conditions are met, a monetary valuation of the services society foregoes when a salt marsh is converted to an alternative use.

The Gosselink, Odum and Pope paper estimates "value per acre."[3] Total value and average value per acre provide information concerning the overall economic impact of a resource upon proxies for the level of social well-being such as incomes and employment. The relevant variable is an efficiency analysis is marginal value. Marginal value is defined as the change in total value which accompanies a unit change in output. The marginal value of additional salt marsh acreage is, therefore, the change in the total valuation of salt marsh services. To manage resources efficiently, society continues increasing salt marsh acreage until the marginal value of the additional salt marsh equals the opportunity cost of that acreage.

The supply price of natural ecosystem output at its origin is zero, however, a primary input into the natural ecosystem production function is land. The resource or opportunity cost of this land is its highest valued alternative use.

If a salt marsh has a positive opportunity cost (the opportunity cost of some acreage may be zero), then what is the efficient quantity of salt marsh services for a society to consume? Assume a diminishing marginal value for successive units of salt marsh services and increasing opportunity costs for salt marsh acreage measured in the monetary value of foregone goods and services.



MC is the marginal cost or opportunity cost of successive acres of salt marsh measured as the dollar value of foregone goods and services. MV is the monetary value of salt marsh services.

salt marsh services

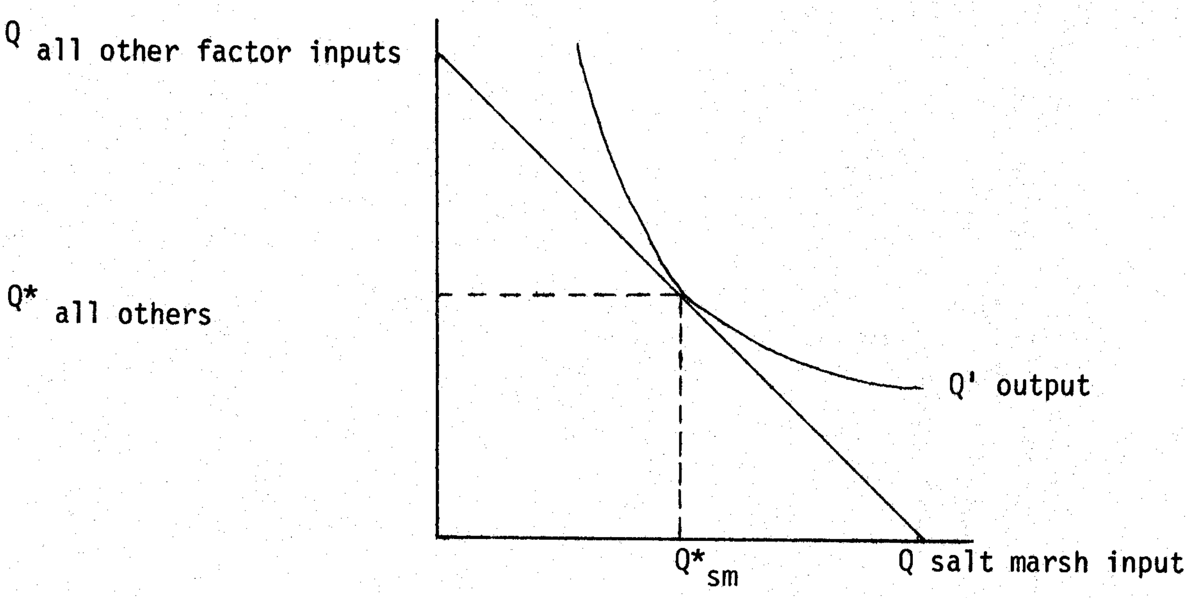
Q* is the efficient quantity of salt marsh services. The declining gains associated with the last unit of salt marsh services just offsets the increasing losses of alternative goods and services.

Society values services. Acreage has social value because it produces a stream of services or benefits. The relevant management variable, however, is acreage, not services, because it is the variable over which society has the greatest policy control. This diagram serves as a basis to test for deviations from the efficient acreage, using a monetary measure of services.

A complete test for deviations from the efficient acreage is beyond the scope of this paper. My goal is to provide a methodology to estimate a social opportunity cost of salt marsh conversion. In the following paragraphs I define the socially efficient acreage of salt marsh.

An exhaustive list of salt marsh services is both long and varied. Examples include flood protection benefits, open space amenities, habitat for both terrestrial and aquatic wildlife, waste assimilative capacity and detritus production. Conceptually, one of my greatest difficulties has been trying to partition the list into either consumer goods or intermediate goods. I assume, hereafter in this paper, that salt marsh services are intermediate goods or inputs into further productive processes.[4] The first order conditions for productive efficiency require thatinput rates of substitution be inverse to the ratio of their input prices. Graphically, this necessary condition implies that isoquants must be tangent to isoclines in input space.

An efficient allocation of resources minimizes the total resource cost of obtaining any given level of output; it puts society on the frontier of the production possibilities curve. Assume the goods and services for which salt marshes provide inputs can be produced with a range of factor proportions. Numerous ratios of salt marsh inputs to other factors produce a given level of output. Factor inputs include capital, labor and other ecosystem contributions.[5] A typical isocline and isoquant in input space follows:

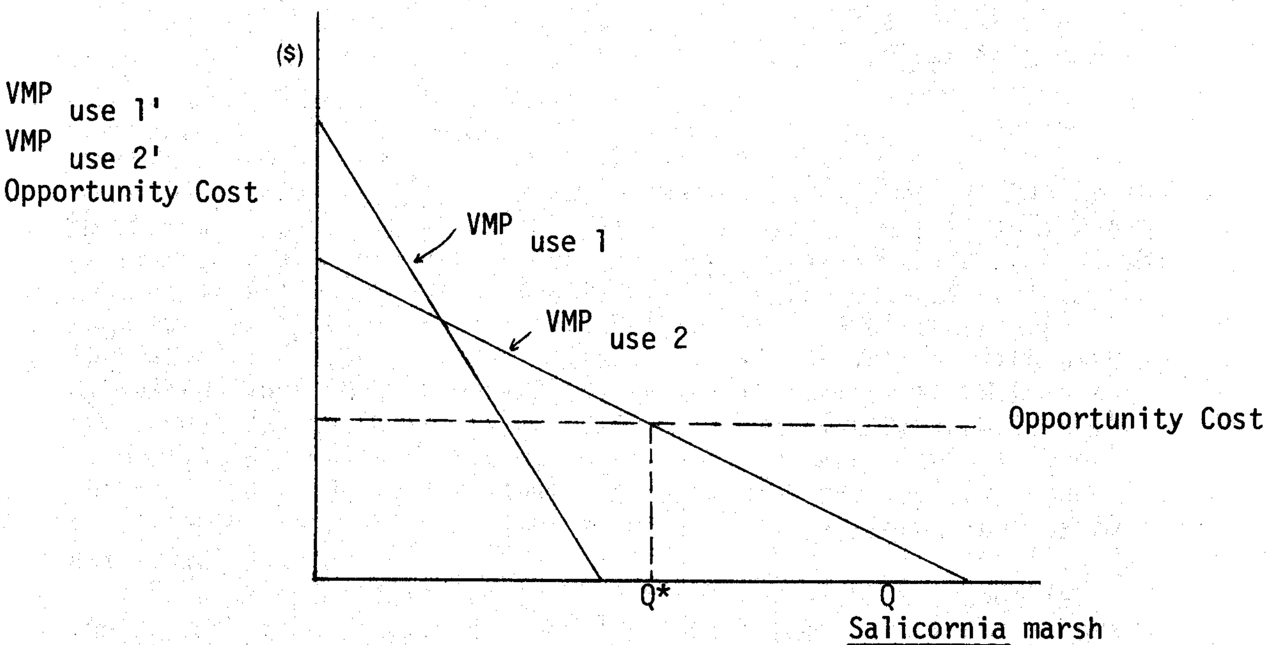


The input combination Q^*_{sm} and $Q^*_{all\ others}$ minimizes the total cost of producing A' level of output. This combination of inputs is both the "least cost" and the "efficient" combination. The exogenous parameters, input prices (opportunity costs) and the production technology, define the least cost combination. A unique least cost combination of inputs exists for each possible Q', the level of output, given sufficient assumptions governing the convexity of the isoquant.

The efficient quantity of salt marsh minimizes the total cost of obtaining the aggregate output level determined by society's preferences given the initial constraints. More explicitly stated, for a given set of individuals' tastes and preferences, a general equilibrium model solves for the set of prices which minimizes total resource cost given the productive technology, aggregate resource base, and initial distribution of resources. The price ratios determined by the general equilibrium model imply a rate of product transformation, a point on the production possibility frontier, and an aggregate output level and mix. The isoquant-isocline model is now complete; the input prices, production technology, and output level have been specified. A unique input combination minimizes total resource cost and specifies the efficient quantity of salt marsh inputs. If salt marsh outputs were produced in fixed proportion to acreage the described exercise would have now specified the efficient acreage.

Salt marshes yield a variety of services. Differentials in location, elevation and water quality produce the many outputs in varying proportions. The theory of joint products allow us to extend the above analysis to determine the efficient mix of salt marsh types and the efficient total acreage. A rigorous welfare application of the theory of joint products necessitates that society keep adding salt marsh acreage of the ith type until the value of the marginal product of the last acre in the production of the jth output just equals the opportunity cost of that acre.

An illustration may help to clarify this point. This management principle requires that society continue adding Salicornia acreage, for example, until the monetary value of the contribution of Salicornia detritus in the production of the commercial and recreational harvest of fish equals the opportunity cost of that acreage. I assume, for expositional purposes, this use demands the most extensive input of Salicornia acreage at a value exceeding opportunity cost. Assume a Salicornia marsh contributes to the production of n outputs. For diagrammatic simplicity assume n equals two; the first use being waste assimilation of inorganic nitrates and phosphates; and the second being a detritus contribution to the fisheries' food web. The value of the marginal product schedules for each input and a positive opportunity cost define the efficient quantity of Salicornia marsh:



This analysis reveals Q* as the efficient acreage of Salicornia marsh. Accomplish this exercise for each type of marsh. A summation over marsh types identifies the efficient total acreage of marshland.

To identify the total socially efficient acreage of salt marsh requires the specification of two natural ecosystem production functions. The first relates natural system parameters, such as elevation, location, water quality, etc., to salt marsh outputs. The second relates salt marsh outputs to other factor inputs in the production of monetarily valued outputs. Salt marsh outputs are intermediate goods; other inputs include labor and capital. Monetarily valued outputs are marketable fish, flood protection, waste assimilation, etc.

Natural scientists lack sufficient information to quantify these production functions. Modeling ecosystems is extremely complex.[6] We often do not have information on the sign, let alone the magnitude of change in system variables due to changes in system parameters.

Appreciate that the foregoing exercise is theoretical. In the absence of a well-specified general equilibrium model, including confidence in the associated coefficients, it is impossible to solve for the efficient quantity of salt marsh. Notice that the parameters of such a model are all functions of time, thereby implying the efficient Q* is likely to be changing with respect to time. I argue, however, that I could test empirically the hypothesis that society holds a quantity of salt marsh acreage in excess of Q*. Alternatively, the same test could be applied to a hypothesis that society holds too little marsh relative to Q*.

A benefit-cost analysis of a small change in marsh acreage performs a marginal test of either of the above hypotheses. Such an analysis compares the monetary value of services foregone by converting a salt marsh (marginal value) with the monetary value of goods and services gained in converting the marsh to an alternative use (marginal cost). Benefit-cost analysis or social benefits analysis is most often applied by economists to public or social investments such as road-building, public education, etc. The marsh analysis rephrased in investment terminology asks, for a given acreage, how the monetary value of services gained through investment in salt marsh (MV) compares with the monetary value of the goods and services gained in its highest valued alternative use (MC).[7] If, for an investment in salt marsh acreage, marginal value exceeds marginal cost (benefits exceed costs for the project), then society holds too little marsh. If, on the contrary, for such an investment marginal cost dominates marginal value (costs exceed benefits for the project), then society holds too much.

Traditionally, markets have performed the function of allocating resources by allowing individual resources owners to make the described marginal test. Economic theory reveals that under certain conditions markets can solve the problem of resource allocation in an efficient manner. In general, the market system relies on prices to signal or reflect the costs of acquiring goods and services. If, for whatever reason, the price of a good is lower than the costs of resources used in the production or provision of that good then an inefficient allocation occurs. Several characteristics of salt marshes disturb allocative efficiency. These characteristics are:

a. Failure of the exclusion principle to apply to public goods (salt marshes provide a vector of public goods); and
b. the lack of consideration of option demand value and preservation value; and
c. zero pricing for the use of public natural resources.

Salt marsh owners are unable to appropriate returns on the factor inputs their resource provides. They are essentially providing a vector of public goods:

Public good	Beneficiary
material input	fishing industry
waste assimilation	general public
aesthetic (open space)	general public
recreational values	participants in specific
wildlife habitat	recreational form
flood protection	general public
preservation value	general public
option demand value	general public

One property of public goods is the failure of the exclusion principle. The exclusion principle is the ability of a resource owner to exclude from receiving benefits from those who do not compensate the resource owner. The resource owner appropriates no revenues from retaining the salt marsh in its natural state.[8] The circle of beneficiaries is difficult to circumscribe. The owner has no defined property rights over these inputs since the contribution of a single salt marsh to estuarine waste assimilative capacity or salmon production is even more difficult to specify.

In fact, salt marsh owners must make expenditures in the form of property taxes to retain ownership.

Individuals in society may derive benefits from retaining the option of consuming environmental amenties. For instance, Midwesterners may be willing to pay to retain the option of someday consuming coastal amenities including salt marshes. Likewise, members of this generation may be willing to forego some alternative consumption to ensure that future generations experience a salt marsh or its derivatives. If a good exists for which there are no close substitutes or should individuals gain a benefit by retaining an option then the good in question may have preservation value and/or option demand value. Indeed, it is likely that the value of man-made assets might well decline overtime relative to the products of nature since the former are becoming increasingly abundant and the latter are becoming increasingly scarce. Compounding this shift in relative output, rising incomes and growing population increase the demand for environmental amenities. I assume the impact of these variables upon demand to be positive.

In the absence of market mechanisms to internalize preservation values, option demand values, and relative changes in future demand, private resource owners are likely to hold fewer salt marshes than the efficient quantity.

The private resource owners' ability to market salt marsh services is further constrained by the pricing policy pursued by public agencies who also own marshland. Public bodies have historically provided the benefits streams from salt marshes at a zero price. Marshland owners, public and private, have responded to these conditions by converting the resource to another scarce but private good, flat land, via filling, diking, or dredge spoils disposal. By conversion to a private good the resource owner can appropriate a stream of revenues.

These characteristics of the salt marsh resouce imply that the private opportunity cost of conversion may be significantly less than the social opportunity cost of conversion. It follows that less salt marsh is held in a natural state than is socially desirable.

Although the above listed characteristics of salt marsh land tend to bias land markets toward retaining too few lands in natural states these conditions are not sufficient to prove that in fact too few such lands are held. The mitigating factor in the analysis may be public ownership of salt marsh land. Public ownership may, indeed, more than compensate for the various market imperfections because the public provides the resource at a zero price.

Public ownership is a somewhat misleading term. In actuality, the areas of public ownership can be divided into areas owned by the federal government, state, county, city and port authorities. The breadth of the constituency to which each of these authorities are responsible varies widely. Public ownership does not imply, therefore, that a consensus has been reached among the differing bodies concerning conversion policy in the estuary.[9]

Further considerations which muddy the analysis include:

1. the uncertainty surrounding how and what impact conversion decisions have upon valuable ecological systems; and

2. the equity impacts of changing the nature of the benefits stream (public trust doctrine) from public to private returns.

The complications added to our theoretical model make it impossible to determine a priori if indeed society holds too much or too little salt marsh. Hopefully, greater insight could be gleaned from an empirical test.

Section II contributes to such an empirical test by defining the necessary and sufficient conditions to measure the social opportunity cost of conversion.

Section II

The social value of land, like any productive asset, is defined to be the discounted present value of its future net benefit stream. The value of land in a competitive market equals the discounted present value of the future net benefit stream appropriable by an owner. I assume the competitive market value has been adjusted for risk and discounted at a rate proportionate to the opportunity cost of capital. It is well established that competitive markets have difficulty in assimilating the impact of external economies or diseconomies in relation to common property resources. Given the discussion of public good externalities which concludes Section I, it is probable that the market value of salt marsh land underestimates its social value. The purpose of this section is to define rigorously a general methodology for valuing the stream of services foregone when society converts a salt marsh. I pursue the social opportunity cost of conversion of, alternatively, the social value of the marginal acre.

I adopt benefit-cost analysis as a methodology to accomplish my objectives. Social benefits analysis, as it is sometimes named, seeks a monetary measure of the net social gains or losses in efficiency deriving from an investment project.[10] Social benefits take two broad forms:

1. to consumers, benefits are reductions in the opportunity cost of obtaining access to goods and services which contribute to their welfare; or
2. to owners of scarce factor resources, benefits are increases in their economic rent.[11]

The social benefits of a given project equals the sum of both benefit types. The highest valued alternative use measures the opportunity cost of resources utilized by a project. The net benefits of an investment opportunity equal the present discounted value of social benefits in excess of resource costs.

Most benefit-cost analyses examine benefits by measuring changes in consumers' surplus. The analyst estimates a demand curve for the commodity using regression techniques, controls for the other demand parameters and estimates a price elasticity. S/he anticipates the change in market price likely to accompany the investment project and forecasts the change in quantity demanded. The differential in consumers' surplus measures the monetary value of the social gain or loss.

In general, this method of measuring social benefits is insufficient for quantifying the social opportunity cost of salt marsh conversion because marsh outputs are intermediate goods and not valued directly by consumers. For some recreational goods, however, this method may be the most feasible empirically.[12] To perform the empirical exercise for recreational elements of marshland conversion, this method requires the following information:

1. the final demand functions for salt marsh services or at least data from which a researcher could estimate them; and
2. a marginal cost of consumption function which relates spatially defined marshes and consumers.

The value of services foregone equals the maximum amount people will pay to have the opportunity to buy the old level of services at the lower price minus the maximum amount people will pay to have the opportunity to purchase the new level of services at the new higher price (the change in consumers' surplus).

Quantifying the value of foregone intermediate goods resembles valuing foregone final demand. I illustrate this by detailing the analysis graphically first for consumer goods then for intermediate goods. The area beneath the demand curve for X measures its social value. In the diagram following, the area beneath the demand curve MB, up to and inclusive of Q^*_x, minus the area beneath the marginal cost curve MC, to the same point, represents the monetary value of the opportunity to purchase Q^*_x units of X.

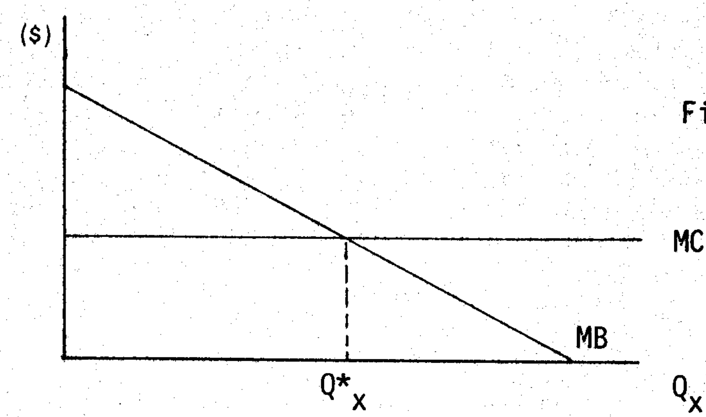


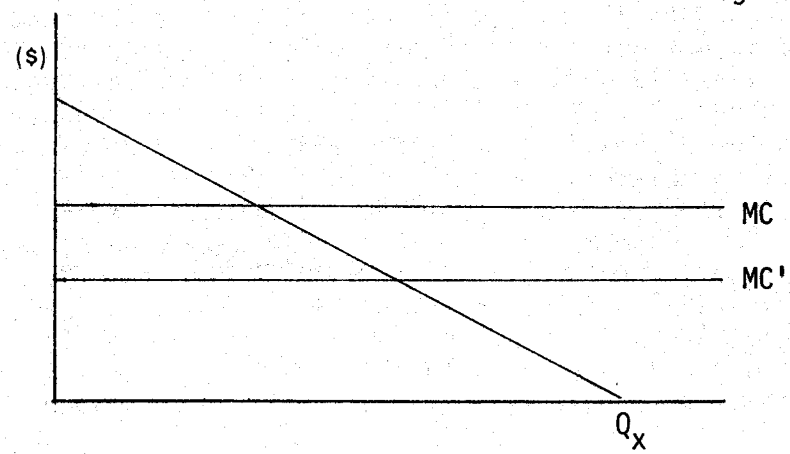
Figure II-1

The shaded region represents the area of consumers' surplus, the benefits in excess of costs of consuming Q^*_x.

A proposed project, which reduces the cost to consumers of obtaining X, produces benefits equal to the change in consumers' surplus. Assume the investment reduces MC to MC'. The area shaded in Figure II-2 estimates the monetary social gain.

Alternatively, to quantify the value of foregone <u>intermediate goods</u> an analyst needs, as a necessary condition the relevant consumers' factor demand functions. The appropriate consumers' surplus measure for an intermediate good is obtained from the correctly

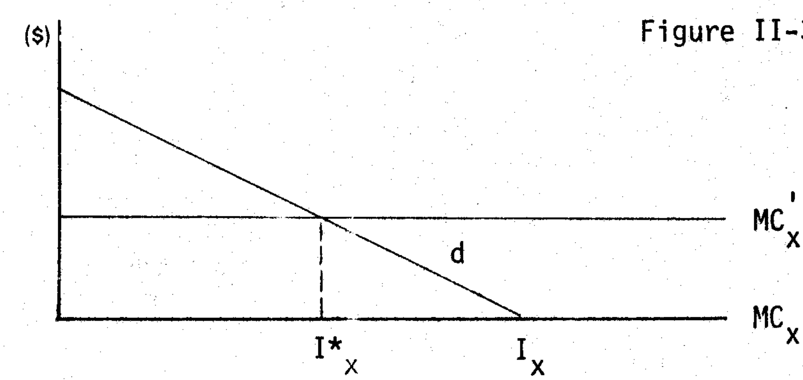
Figure II-2



derived demand curve for that input. The short-run demand curve is obtained by subtracting from the marginal valuation of the nth unit of output the combined cost of all other inputs that enter into the production of this nth unit.[13] I assume that the prices of these other inputs to be fixed and that all inputs are combined efficiently. For instance, the short run demand curve for detritus derived from the commercial salmon industry is obtained by subtracting from the marginal valuation of the nth salmon the combined cost of all other inputs that enter into the production of this salmon, making the same assumption as above. For any factor input, a consumer's factor demand schedule exists for each use in which it is employed. In the case of salt marsh detritus, demand schedules exist for the production of commercial salmon, recreational fishing, recreational clamming, etc.

I will illustrate the monetary value to consumers of producers having the option to purchase a given input at a given price. Assume the production of tennis shoes (Y) require canvas (X) as an input.[14] Production efficiency requires that the input rates of substitution be inverse to the ratio of input prices. Producers, therefore, expand canvas employment until its contribution to total value of the nth pair of tennis shoes equals its marginal cost. Consumers of tennis shoes have an implicit demand function (d) for the canvas in tennis shoes. Assume I add to this demand function for canvas a marginal cost of canvas function (MC_X).

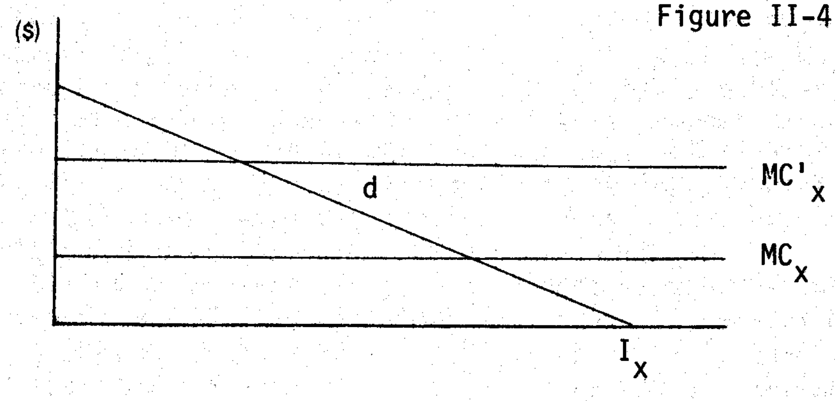
Figure II-3



Producers wish to employ I^*_x units of canvas at MC_x. The shaded region, the area of consumers' surplus, is the maximum consumers of tennis shoes will pay to give producers the opportunity to buy canvas at MC_x.

If a proposed action increases MC_x to MC_x', then the shaded area of Figure II-4 represents the net monetary loss to consumers of tennis shoes.

Figure II-4



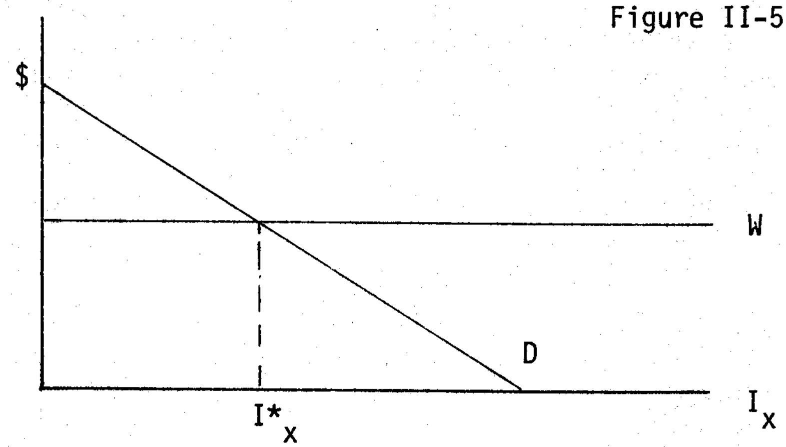
The net monetary loss to society, consumers of all types of canvas products, is the summation of net losses for each use of canvas. The analysis is general and holds for any intermediate good.

A salt marsh analysis fits within this general framework. The fact that the nation's waterways, rivers, estuaries, and oceans are common property resources complicates the analysis slightly. In general, the products and services that issue from the waterways are also common resources. The products are considered "free" goods until someone takes possession of them. In competitive markets, the summation of factor payments exhaust total value. Without ownership common resources require no factor compensation, and thus are attributed no explicit market value. They have neither a market demand curve nor receive factor payments.

Most salt marsh outputs are common property resources (nutrient uptake, detritus production, waterfowl habitat). In general, these marshland outputs contribute to the production of other environmental resources (waste assimilation, fisheries, water fowl). Estimating the demand for waterfowl habitat requires specifying the demand for waterfowl. This condition holds true for each salt marsh output.

In output sectors where demand is not expressed through markets, an implicit demand curve must be approximated. The literature on measuring recreational benefits has demonstrated an implicit demand schedule exists for many recreational resources held in common by society. Quantity demanded varies inversely with changes in transfer costs. Transfer costs are the costs a consumer incurs to obtain access to the resource. The social monetary value of the resource is the excess of benefits over costs of acquisition. I assume the analysis of common resources used as intermediate goods is identical to that presented for other factor inputs. The supply price of the common resource intermediate goods is zero, however, to utilize I_x, requires proximity. W is the opportunity cost of resources consumed in gaining access to I_x or the transfer cost of I_x. In fishing, for example, w is labor, boats, gear, etc., while for recreation w is travel time and transportation costs. D is the correctly derived consumers' demand curve for input I_X.

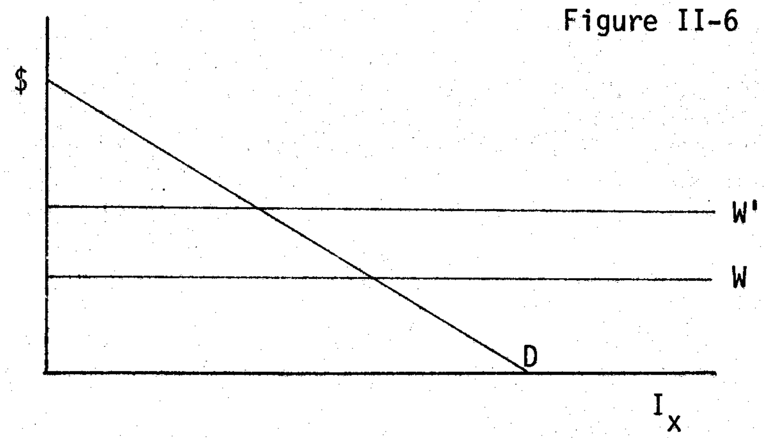
Figure II-5



The shaded area represents the maximum consumers will pay to give producers the opportunity to purchase I^*_X at w.

The monetary value of services foregone when converting a salt marsh equals the net change in consumers' willingness to pay for the producers' opportunity to buy the factor resources. I assume a salt marsh conversion increases the transfer cost of factor inputs from w to w'. The net change or the monetary value of services foregone is the shaded area in the figure below summed over all salt marsh outputs.

Figure II-6



The above analysis has established the theoretical basis for measuring the monetary value of the stream of services foregone when society converts a salt marsh. The exercise reveals the following information is necessary and sufficient to quantify the monetary measure:

1. the correctly derived consumers' demand functions for all salt marsh output utilized in the production of monetarily valued goods and services; and
2. the cost functions which relate spatially defined producers and salt marshes.

Section III

Section II describes the methodology and information required to measure the monetary values foregone in salt marsh conversion. I recognize that such a measurement is, indeed, a prodigious task. Researchers and resource managers have responded to the complexity of specification and identification problems by proposing more simplistic valuation methodologies. Section III reviews two publications which present simplified valuation schemes. The authors and titles are:

1. James G. Gosselink, Eugene P. Odum, and R.M. Pope, The Value of the Tidal Marsh, Publication No. LSU-SG-74-03, Center for Wetland Resources, Louisiana State University, Baton Rouge, Lousiana, May 1974; and
2. John A. Hanson, assisted by Chris Sawyer, William Rabiega, Colleen Acres, and Don Leadroot, A Re-examination of Estuarial Management: Estimated Net Economic Impact of Filling 80 Acres in the Columbia River Estuary, submitted to Port of Astoria, Astoria, Oregon, April 1976.

The authors of these works have examined the foregone values of estuarine conversion. My objective in reviewing the Gosselink, Odum, and Pope paper is to examine the usefulness of their valuation tools juxtaposed to benefit-cost analysis. I submit the Hanson report primarily to focus upon Hanson's attempt to formulate an ecosystem production function. The critical appraisal I offer of these authors' works is humbly appreciative of their efforts.

In 1972 three natural scientists, Gosselink, Odum and Pope (hereafter GOP), authored an original and persuasive attempt at measuring the monetary value of Gulf and Atlantic coast tidal marshes. The authors adopt two broad valuation approaches. The first seeks a monetary measure of the highest valued sum of uses compatible with maintaining the estuary-marsh ecosystem in its natural state. This set of uses must not include uses which are mutually exclusive (i.e., secondary waste treatment and intensive oyster culture). This first GOP schema is analogous to the methodology proposed in Section II. In Section II, I define the social value of the marsh's productivity to equal the highest valued sum of discounted net benefit streams. The benefit streams in any summation must be for a set of mutually compatible uses.

A second methodology proposed by GOP estimates the marsh's social value on the basis of its gross primary productivity per acre.[15] The authors multiply an average marshland figure for gross primary productivity times a conversion ratio from energy to dollars. The energy to money conversion ratio equals the ratio of Gross National Product to National Energy Consumption.

GOP, in several comments, express concern with "conventional" economics and the pricing system's ability to deal with environmental resources in general and land resources in particular. I share their concern, however, hopefully this critique reveals how the tools of economic analysis can be put to service in performing future valuations.

In my estimation, the relevance of the GOP paper resides in its description of the many socially valuable functions tidal marshes perform. On the other hand, GOP's valuation techniques lack a methodological foundation. They fail to discuss production functions, price elasticities, or any of the other determinants of supply or demand. Although prices are mentioned, the authors confuse value in exchange with value in use. The authors consistently estimate social benefits by measuring social costs. Furthermore, GOP show no apparent recognition of the laws of diminishing marginal productivity or diminishing marginal rates of substitution.

For most economists, these criticisms would be sufficient to warrant dismissing GOP's valuation methodology. I choose to extend this critique, however, to analyze four hypotheses which serve as the foundation of the GOP valuation approach. These four hypotheses are:

1. tidal marshland values per acres should equal final product value for all goods and services which utilize the tidal marsh ecosystem divided by the number of acres; and
2. gross expenditures offer an adequate measure of social value or net social benefits; and
3. society should value natural ecosystems at the opportunity cost of the scarce resources society would utilize in performing the same ecosystem functions; and
4. land values should be defined by gross kilocalories per acre.

In examining GOP's analysis of the data, I appraise the four hypotheses.

GOP examine data for commercial fisheries, recreational fishing, boating, hunting, aquaculture potential, and waste assimilation. Although they offer no data, GOP correctly insist that monetary values for flood protection, provision of migratory waterfowl habitat, and element recycling should be included in any valuation methodology.

GOP estimate the contribution of the marsh to fisheries' production to be as follows. Let:

x = total estimated dockside value of fish and shellfish; and
y = value added in processing; and
z = number of acres of coastal marshland.

GOP estimate value/acre to equal $(x+y)/z$.

This analysis exemplifies the use of hypothesis one. GOP offer no rationale why all value, dockside and processing, should be imputed to the marsh other than the fact that "conventional" economics attributes no explicit value to the common-property resource. Secondly, it is unclear why the marsh should receive all value while other environmental resources (fisheries, ocean, atmosphere, etc.) receive none. A conventional economist adequately addressed the issue:

> "Sir William Petty, an early economist, put the matter in this striking way: labor is the father and land the mother of the product. One cannot say which is more important in producing a baby--a mother or a father. So, too, one cannot in most cases hope to demonstrate how much of the physical

product has been caused by any one of the different factors taken by itself. The different factors interact with each other. Usually they reinforce each other's effectiveness, but sometimes they are substitutes for one another and they compete with, rather than complement, each other."[16]

An incorrect train of reasoning goes as follows:

Without the ecosystem, society has no product--true.
Without the primary resources, society has nothing--true.
All value should be imputed to the primary resources (land, labor and capital)--true.
All value should be imputed to a primary resource (land, or labor, or capital)--false.

This pattern of reasoning represents a fallacy becuase, in general, it is impossible to distinguish one factor's productivity in the absence of other factor inputs.

Ecologists should be especially appreciative of interdependencies. The physical reality that system outputs require a combination of system inputs permeates social systems as well as natural ones. Fish, for example, result from a productive process utilizing water, nutrients, dissolved oxygen, a propagating sotck, and a host of other inputs. What value is a propagating stock in the absence of a spawning ground? Alternatively, what value is a spawning ground in the absence of a propagating stock? Similarly, the value of shrimp is lower in the absence of labor just as the value of labor greatly declines in the absence of something to harvest. The call for factor inputs is a joint interdependent demand.

The foregoing appraisal nullifies the first GOP hypothesis, the hypothesis that some lands should be singled out and attributed total product value.

GOP claim that conventional economies assign no explicit value to common-property resources. Instead, all value is credited solely to privately owned labor, capital and management. Although GOP hint that a thorough analysis requires a measure of consumers' surplus, they consistently estimate social value by measuring gross hypothesis two.

In addressing hypothesis two, I demonstrate how economic theory ascribes an implicit monetary value to the common-property resource. The value of a resource, good or service, however, should not be confused with the opportunity cost of acquiring it. Benefits are benefits. Costs are costs and not benefits. GOP consistently confuse the two. It is true that in competitive markets the summation of factor payments (costs) exhausts total product value. In effect, total revenue equals total factor payments and nobody pays the commons because no one owns it. This is not to say, however, that economic theory ascribes common resources zero value. The total social value of any product equals the area beneath the demand curve. Let D represent the demand schedule for canned salmon, in Figure III-1.

The acquisition of this good, however, necessitates the expenditure of scarce resources. Define MC to equal the marginal costs to society of foregone goods and services which could have been produced with the labor, capital, and management expended in the

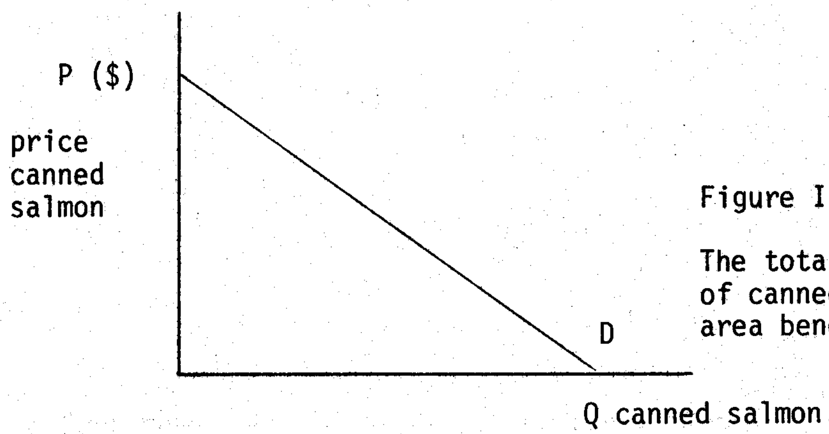
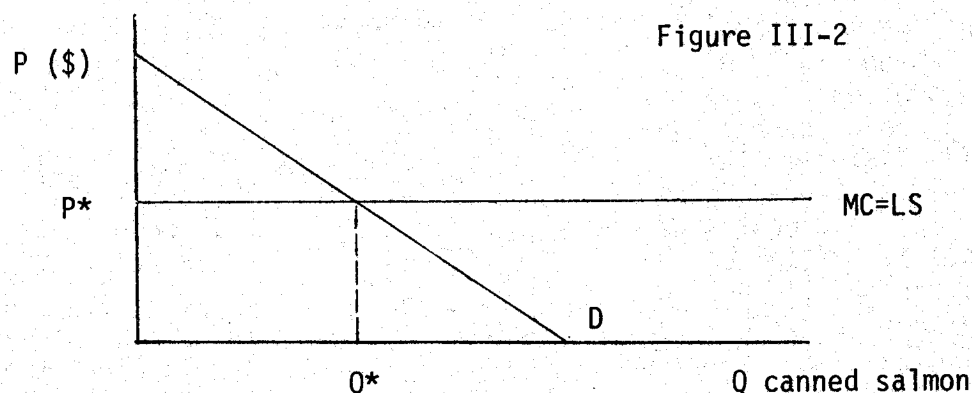


Figure III-1

The total monetary value of canned salmon equals the area beneath D.

production of canned salmon. For a constant cost industry in long run competitive equilibrium, MC defines the long run supply curve.

Figure III-2



Consumers purchase Q* at P* per unit. Total revenue, P*Q*, equals total cost P*Q*. The shaded region in Figure III-2, the area of consumers' surplus, corresponds to the maximum amount of money people would pay rather than go without Q* at P*.

For a factor input, the appropriate measure of consumers' surplus or net social value follows from its consumers' factor demand schedule. In general, for environmental resources, the area beneath the factor demand schedule is equivalent to the area of consumers' surplus for the final product. Economic theory, indeed, credits a monetary value to common property resources. This monetary value equals a summation of the areas of consumers' surplus defined for each final product to which marshlands contribute inputs.

P*Q*, the measure used by GOP, represents the total cost (total revenue, or total expenditures of supplying or buying Q*. Regardless of examining Q* from the demand or supply side, P*Q* is an inadequate measure of total value or net social value. From the supply side, P*Q* is the opportunity cost of foregone goods and services. It values the resources expended in acquiring Q*.[17] Costs are costs. Alternatively, the gross monetary benefits of consuming Q* equals the area beneath the demand curve from the origin to Q*. The net social value of the contributing common property resources (tidal marshes included) equals the area of consumers' surplus. Recall, consumers' surplus is defined as the gross benefits of consumption minus the gross costs of acquisition.

Alternatively, view P*Q* as total expenditures. P*Q* divided by the number of units of an input in existence represents average expenditures per unit input. Such a variable has no theoretical or practical significance except as a descriptive measure such as per capita GNP.

GOP perform an identical valuation procedure for recreational fishing, boating, and hunting as they have done for commercial fishing. Gross expenditures by recreationalists are divided by acres of marshland.

Once again, GOP are subject to the same basic criticisms. Expenditures by recreationalists are transfer costs and not benefits. In general, these expenditures represent the demand for transportation and recreational equipment, and not the demand for the recreational opportunity itself. A measure of the net social value of a recreational resource, for example elk, requires two steps. First, estimate a demand schedule for stalking elk, where stalking elk requires the use of a gun, camera, or binoculars. This schedule measures the demand for the entire recreational experience, including the related by separable phases of anticipation, travel to the site, experience at the site, travel from the site, and recollection. In general, this demand function is characterized by some price elasticity reflecting substitute recreational experiences. Varying transfer costs (entrance fees, licenses, etc.) and recording changes in quantity consumed, generates a demand schedule for the resource itself. The monetary value of the resource equals the area of consumers' surplus beneath this derived demand curve.[18]

Examining hypothesis three further exemplifies the inadequacy of the gross expenditures measure of benefits.[19] This hypothesis argues that the value of a natural ecosystem equals the opportunity cost of the scarce resources society would utilize in providing the same functions ecosystems perform "free" of charge. Economic theory suggests that the demand for most goods, services, or inputs has some price elasticity. This price elasticity reflects a diminishing marginal rate of substituion which in general, is held to characterize all goods and services. There exists, then, for all goods and services a quantity consumed beyond which the marginal value of an additional unit is zero.

Assume D is the demand curve for waste treatment services. MC is the opportunity cost of acquiring any given level of these services. MC is substantially below the "least-cost" alternative method of accomplishing this service. MC utilizes tidal marsh to perform significant amounts of waste treatment. The tidal marshes provide a subsidy to the costs of waste treatment.

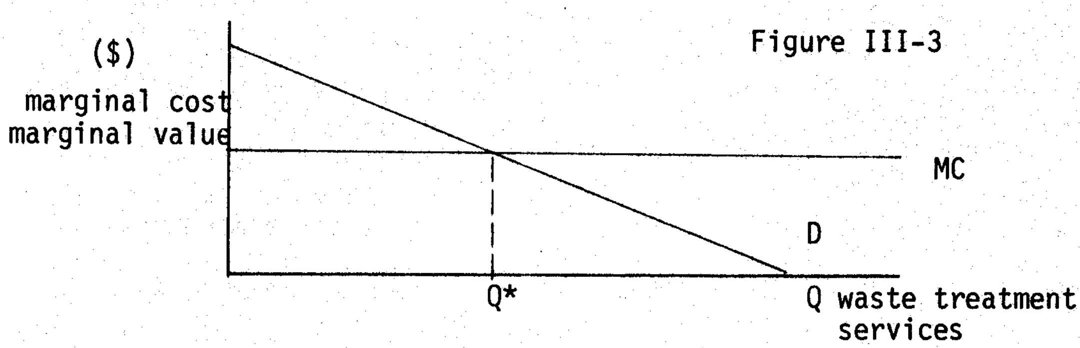
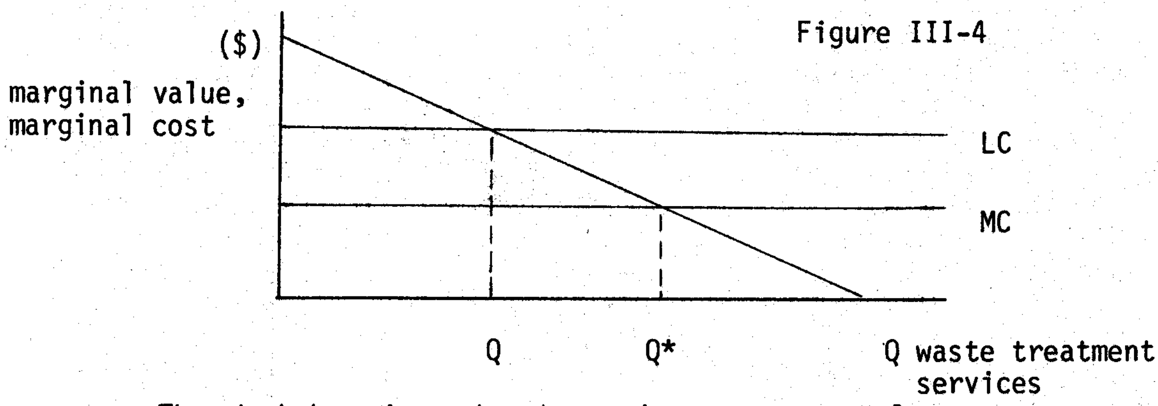


Figure III-3

The area of consumers' surplus measures the net social value of waste treatment services. Define LC as the opportunity cost of society providing the same service exclusive of the tidal marsh subsidy. I assume LC exceeds MC or society would be already performing the function exlcusive of salt marshes.

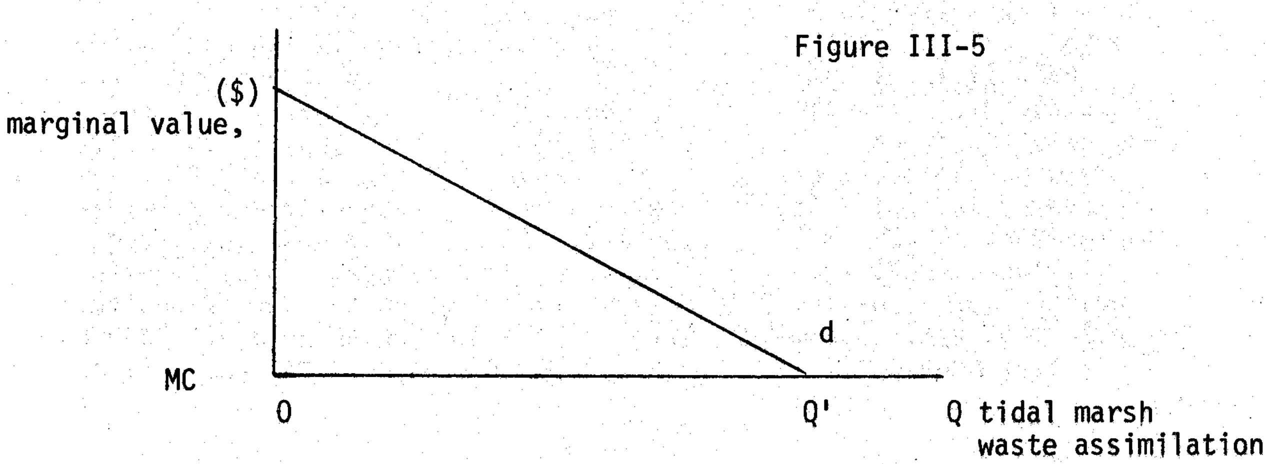
Figure III-4



The shaded region, the change in consumer surplus, measures the monetary value of the waste assimilation which occurs in salt marshes.

The area beneath a consumers' factor demand schedule (d) for salt marsh waste treatment mimics the area of consumer surplus in Figure III-3.

Figure III-5



The area beneath (d) equals the monetary value to society of tidal marsh waste assimilation when overall marginal cost is MC.[20] Q' is the maximum quantity of tidal marsh waste assimilation for which marginal value exceeds zero. GOP and hypothesis three argue that the appropriate measure of value is LC times the estimated total waste assimilation performed by tidal marshes. Although at first intuitively appealing, hypothesis three is analytically incorrect. First, it is likely that tidal marshes are performing waste assimilation in excess of Q' (see Figure III-5). This statement implies thatthey provide waste treatment services for which marginal value is zero. Secondly, the hypothesis neglects the probability that both the consumers' demand function and the consumers' factor demand function have a price elasticity of demand. This condition implies that at a higher price, LC, consumers will demand less total waste treatment and less tidal marsh waste assimilation.

Hypothesis four suggests that land values should be defined by gross kilocalories produced per acre. This hypothesis neglected two important economic considerations:

1. the law of diminishing marginal value; and
2. the economic determinants of value-supply and demand.

GOP estimate gross primary productivity per acre per annum for tidal marsh. Gross primary productivity provides a rough measure of energy flow where energy is measured in kilocalories. GOP divide Gross National Product by National Energy Consumption to arrive at an estimated $/unit of energy utilized in the production of the nation's goods and services. The authors admit GNP is at most, an accounting relationship, a descriptive measure. Multiplying GNP/NEC by average gross primary productivity, GOP arrive at a figure they call the "ecological life support value" of the tidal marsh. Next year, if everyone mows, instead of their own lawn, their neighbor's lawn for a price, GNP goes up, NEC remains the same, and the ecological life support value of tidal marshes skyrockets.[21]

A more fundamental criticism can be levied at the hypothesis; it disregards the determinants of value. Conventionally, scarcity and opportunity cost have determined value, and not kilocalories. Marginal cost and marginal value determine value in exchange. Hypothesis four neglects a conceptual difference between value in use and value in exchange. Economists took almost a hundred years to solve the paradox of diamonds and water, and then, clearly distinguish between value in use and value in exchange.

The paradox:

Water, which obviously has great value in use, has little value in exchange: diamonds have comparatively fewer practical uses but great value in exchange.[22]

The price of a good is its value in exchange. The price of a commodity is <u>determined</u> by the interaction of supply and demand. The <u>total usefulness</u> of a commodity does not determine exchange value, but rather, the usefulness and cost of the last unit consumed. For example, in the aggregate, water is certainly useful to an individual, but since water is relatively plentiful, one more gallon has little use. Water is low in price because it has a low marginal value and a low marginal cost of production. Alternatively, diamonds are high priced because they have both a high marginal value (since they are relatively scarce) and a high marginal cost of production. Value in exchange measures scarcity as reflected through demand <u>relative</u> to the opportunity cost of production. Salt marshes are increasing in social value because of the increasing scarcity and productivity of their services, and not because their gross primary productivity is high.

In supplement to the data GOP examine, monetary values for additional tidal marsh functions may be quantifiable. GOP state, for example, that tidal marshes provide important flood protection benefits. If this hypothesis is true, then the benefits should be measurable. Differentials in premiums for flood protection insurance (now federally required) reflect differences in risk accepted by insurance underwriters. The differences in risk indicate the long-period probability of a flood. Controlling for rainfall, latitude, and other variables, should allow a benefits analyst to test for residual variation in premiums due to the presence of large acreages of tidal marsh.

Similarly, GOP hypothesize that salt marshes reduce channel siltation. Once again, this social value should be quantifiable if the hypothesis holds true. Channel siltation rates should be reflected in the cost of maintenance dredging. Controlling for hydrography should allow a test for variation in channel maintenance cost due to tidal marshes.

My criticism of GOP's valuation methodology has been harsh. I hope this critique can be accepted not as a condemnation of the fine work ecologists and other natural scientists are doing in relating social and natural systems, but instead as an economist's attempt to help these scientists hone their tools of analysis. My goal is to help GOP perform a sound, and analytical defensible argument to protect salt marshes from thoughtless exploitation.

In April 1976, John Hanson assisted by four researchers published A Re-examination of Estuarial Management: Estimated Net Economic Impact of Filling 80 Acres in the Columbia River Estuary. The Hanson report is a benefit-cost analysis of the proposed estuarine fill. While the analysis which is performed should be applauded, it is incomplete. I shall confine my appraisal to the methodology the Hanson team uses to estimate the social value of the fill. A social cost of this project is the monetary value of the natural estuarine productivity foregone by fill.

In essence, the Hanson report performs a trophic analysis. It converts second trophic level productivity of the fill site into pounds of salmon and bottomfish.[23] Performing trophic analysis is an attempt to estimate a crude natural system production function where available food/member of a species is the limiting factor.[24] Hanson nets his gross estimate of pounds of fish by a probability of harvest (both commercial and recreational). He multiplies the netted figure by price per unit (lbs.-commercial, per fish-recreational), assuming the contribution of this site is small relative to the total harvest. This final value Hanson equates to the social cost of conversion, the value of services foregone by fill. While the analysis performed is extremely commendable, Hanson makes no attempt to estimate monetary values for the complementary services this estuary provides. Omitted services include waste assimilation, open space amenities, wildlife habitat, and option demand. Hanson alludes to compensating for these monetary values by consistently overestimating values for the commercial and recreational fisheries. Three conditions imply Hanson has underestimated the social value of the estuarine productivity foregone by fill:

1. the benefit streams are not adjusted for ecological uncertainty, irreversibility, intergenerational inefficiencies, and option demand;[25] and
2. no adjustments are made in the benefit streams to accomodate rising incomes and/or population increases;[26] and

3. the benefit streams are not adjusted for changing price ratios of commodity and amenity resources vs. man-made goods and services.[27]

In addition, the Hanson report fails to verbalize explicitly the changing distribution of the benefit stream. The estuary in its natural productivity, provides a vast array of public goods and common-property resources. These benefits are available to the general public. The fill option changes the benefit stream to one providing private goods rationed among consumers at a market price.

Conclusion

The work accomplished in this chapter has been theoretical. Section I views society trying to allocate resources efficiently. In the absence of a well-specified general equilibrium model, society cannot solve explicitly for the efficient quantity of salt marsh land. I offer the marginal test as a strategy to examine for deviations from allocative efficiency. A vector of externalities makes it impossible to determine a priori if society holds too much or too little of the marsh resource. In Section II, I focus upon a methodology to estimate, monetarily, the values society foregoes in marshland conversion. Finally, Section III critically appraises two land valuations as a theoretical application of the methodology established in the first sections.

Footnotes

1. Conversion of salt marshes usually takes the form of filling, piling, diking, or dredge spoils disposal.

2. James G. Gosselink, Eugene P. Odum, R.M. Pope, "The Values of the Tidal Marsh," publication no. LSU-SG-74-03 Center for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana.

3. The variable they estimate appears to be average revenue per acre. The authors make no distinction between marginal, average, or total values or revenues.

4. Doing so greatly simplifies the exposition, whereas partitioning the list into both categories adds only specification and aggregation problems.

5. Numerous examples of factor substitution in ecosystem output exist. For instance, the rearing of salmon fry in hatcheries, as opposed to the gravel beds of fresh water streams, represents a substitution of capital for land in the production of salmon.

6. See Clifford S. Russell (ed.), Ecological Modeling in a Resource Management Framework, Resources for the Future, Inc., Washington, D.C., 1975, for a discussion of the state of the art.

7. Notice, that for any given acreage, an investment decision must be made in each time period. Even for acreage already in salt marsh, the investment decision requires society to either maintain the acreage as marsh or allocate it to some alternative use.

8. A scarcity rent is capitalized into the land values over time. Flatland is a scarce resource on the Oregon coast, which in many regions must be created through investment. The availability of dredge spoils make the conversion of estuarine tidelands especially attractive.

9. Theoretically, it is particularly important to notice the ability of federal and state agencies, with very broad constituencies, to internalize the external benefits mentioned above without bearing the pecuniary diseconomy. Compare that position with city, port authority and private resource owners who with much narrower constituencies can internalize very few of the benefits while bearing the full burden of the pecuniary externality. As a result, the sides of the "conservation vs. development" confrontation in salt marsh allocation are not clearly drawn between private vs. public owners, but instead between those who can internalize the external benefits and those who cannot. For recent examples see transcripts of Division of State Lands (Oregon) vs. City of North Bend, contested fill permit hearing, July 1976, or Division of State Lands (Oregon) vs. the Port of Astoria, contested fill permit hearing, 1976.

10. A net gain in efficiency is a situation in which a costless redistribution of the monetary gains between gainers and losers could fully compensate losses and leave some net monetary gains.

11. I define economic rent to be any return in excess of the factor's supply price. For an explicit explanation of these concepts see E.J. Mishan, Cost-Benefit Analysis, Praeger, 1976.

12. See, for example, William G. Brown, Ajmer Singh, and Emery N. Castle, An Economic Evaluation of the Oregon Salmon and Steelhead Sport Fishery, Agricultural Experiment Station, Oregon State University; or William G. Brown, Farid H. Nawas, and Joe B. Stevens, The Oregon Big Game Resource: An Economic Evaluation, Agricultural Experiment Station, Oregon State University.

13. E.J. Mishan, Benefit-Cost Analysis, Praeger, 1976, pp. 29-30. This is the consumers' demand for the input, and not necessarily the producers'. The constant returns to scale production function implies factor proportions remain constant for changes in output. This assumption enables me to proceed from Figure II-2 to Figure II-3. Define units of output to be that which utilize one unit of the input.

14. Environmental and common-property resources are special cases of the general consumers' factor demand analysis. I begin with the general analysis for private goods and introduce environmental resources as a special case.

15. For an enlightening discussion of primary productivity, I refer the reader to the section, in this publication, titled Net Primary Production in Coos Bay Salt Marshes. In general, gross primary productivity refers to the energy, in the form of carbohydrates, produced by plants in the photosynthetic process. Plants utilize this energy in growth and respiration (self-maintenance). Gross primary productivity measures a flow variable (grams carbon fixed/unit area/unit time) and must be held in juxtaposition to a stock variable such as standing crop (grams carbon fixed/unit area).

16. Paul A. Samuelson, Economics: An Introductory Analysis, 7th ed., McGraw-Hill, 1967, p. 510.

17. This analysis assumes full employment of factors in competitive markets.

18. William G. Brown, Anjmer Singh, and Emery N. Castle, in An Economic Evaluation of the Oregon Salmon and Steelhead Sport Fishery, working with 1962 data, estimated the area of consumer surplus to be over $5.7 million per year. This value is exclusively attributable to the salmon-steelhead sport fishery. In addition, their estimates were projected to increase by 50% by the year 1972 due to increasing incomes and population.

    The authors (listed as reference) of Multi-disciplinary Study of Water Quality Relationships: A Case Study of Yaquina Bay, Oregon estimate the net economic value of three fisheries, salmon, clam and bottom fish, to be $62,819 per year. This estimate is for Yaquina Bay alone!

    GOP's paper could have been analytically more persuasive if, indeed, they had used the appropriate tools of analysis.

19. Hypothesis three, it turns out, is built upon the fallacious hypothesis two.

20. This area represents the short run monetary value. In the long run, the area beneath d equals the change in consumers' surplus seen in Figure III-4. The short run implies a given MC curve associated with some fixed factor or restricted entry. The long run allows the marginal cost curve to change from MC to LC via the entry and exit of "firms." Firms, in this case, are agents producing waste treatment. The firms of this analysis are salt marshes and waste treatment facilities.

21. Once again, price times quantity overestimates the value of marshland if any of that energy fixed has a marginal value less than GNP/NEC.

22. This section is adapted from Walter Nicholoson, Intermediate Microeconomics and its Application, 1975, by Dryden Press, Chap. 2.

23. Hanson reports that data on gross primary productivity was not available. The Hanson paper bases its analysis upon surveys of second trophic level organisms performed by the Oregon State University School of Oceanography.

24. Other limiting factors could be the size of the propagating stock, dissolved oxygen content of the water, available spawning grounds, etc.

25. See Anthony Fisher and John V. Krutilla, "Valuing Long Run Ecological Consequences and Irreversibilities," Journal of Environmental Economics and Management, 1, 96-108, (August, 1974).

26. See A.C. Fisher, J.V. Krutilla, C.J. Cicchetti, "The Economics of Environmental Preservation: A Theoretical and Empirical Analysis," American Economic Review, LXII, 605-619 (Sept., 1972).

27. See E.J. Mishan, Cost-Benefit Analysis, op cit., p. 285.

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Summary...

STUDY SUMMARY

An 11 person interdisciplinary group was an exceptional first for most of us. Attaining a group consensus on any point of discussion grew exponentially more difficult as our numbers increased. Group meetings, therefore, always promised lively debate. Group discussion often centered on how we felt our results should be interpreted.

The natural scientists insisted, quite correctly, that the project summary should emphasize that our empirical results should not be taken as the final word. The social scientists conceded that the ultimate word in any discipline was not likely to arrive until a future date. At this point in the discussion all disciplines would nod acknowledging that, indeed, more research funds should be devoted to the area of study. The social scientists expressed concern, however, that between now and any final word society must make decisions dictating the fate of selective salt marshes.

As a group, therefore, we discussed the elements which constitute a general methodology for natural resource appraisal. More explicitly, the team had to decide what elements of an ecosystem must be addressed inorder to adequately appreciate its role in the natural and social systems. Secondly, what information must a decision maker have to compelte a thorough appraisal of a natural resource? In other words, what functions must society understand, at least simplistically, before it can justify decisions which significantly modify natural ecosystems? A general methodology for natural resource appraisal consists of the following elements:

1. a thorough understanding of the ecology and energetics of the natural resource;
2. a complete description of the social values this resource contributes;
3. an estimate of the monetary value of the resources;
4. an accurate model of land markets, including quantitative estimates of the allocative inefficiencies resulting from external economies and diseconomies; and
5. numerous flexible policy instruments which enable society to sustain or convert the resource.

Having this information would be <u>sufficient</u> for allocative efficiency. We feel, however, that a cursory examination of these five elements is <u>necessary</u> to make informed resource management decisions. We have applied cur methodology for resource appraisal to Oregon salt marshes. In our appraisal of the marsh resource we have:

1. tried to gain a broad understanding of the ecology and energetics by examining:
   a. net primary productivity
   b. detritus contribution
   c. insects

- d. invertebrates
- e. fishes
- f. birds
- g. mammals

2. described salt marsh's socially valued functions:
   - a. detritus production
   - b. terrestrial and aquatic wildlife habitat
   - c. waste assimilation
   - d. element recycling
   - e. open space amenities
   - f. flood control
3. defined the necessary and sufficient conditions to estimate the monetary value of marsh services by conversion
4. reported the extermal economies and diseconomies particular to salt marsh which distort the efficiency of land market allocations
5. communicated the legal and land-use policy instruments which society has on hand to direct resource allocation

Although this publication should not be regarded as sufficient information to justify land-use decisions, we hope it lays the groundwork for wise resource management.

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