A RESOURCE ASSESSMENT OF GOULDSBORO BAY, MAINE

Report to the

National Oceanic and Atmospheric Administration

MARINE SANCTUARY PROGRAM

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Project Interim Report #2

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INTRODUCTION

This is a final report for work initiated under grant No. NA81AA-D-CZ076 and now being continued under contract. While some of what is reported here is essentially in final form and is now in preparation for publication, other aspects are still under investigation. It is requested that no reference be made to information in this report without a notation as to its preliminary form. It is anticipated that field work will be completed in October, 1982, and a final report will be ready for distribution early in 1983.

The purpose of this study is to develop a resource assessment of Gouldsboro Bay in Washington County on the eastern coast of Maine. The assessment is in part descriptive of geological, hydrological, chemical and biological elements, but its primary focus lies in a systems-type analysis of bay function. With the resource assessment being developed herein, a management strategy will be prepared that can be applied to marine sanctuaries formed either in Gouldsboro Bay and its off-lying waters, or in any similar setting on the Maine Coast.

This investigation as a whole will rely heavily on the 1980 Fish and Wildlife Service six volume review treatise, "An Ecological Characterization of Coastal Maine", as a working base. No attempt is made to determine or list all of the taxa of the bay and reference is made to volume four of the above indicated set for a species list for the Maine Coast. Ecologically, this report deals primarily with the major elements of trophic and community structure.

The field work for this report was primarily carried out during the late summer and autumn of 1981. A two-week winter field session was completed in February-March 1982, but little of the results of that work are included here. A preliminary attempt is made to determine some aspects of critical management strategy at this time. However, considerable research and analysis remains to be accomplished, and these attempts must be regarded as tentative.

PERSONNEL

The following individuals have participated in the development and presentation of the study reported herein.

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GEOGRAPHY

Gouldsboro Bay is located on the boundary line between Hancock and Washington Counties, Maine on the north central coast of the Gulf of Maine at Lat. 44° 27' N and Long. 67° 58' W (Fig. 1). This is a submerged coast, generally consisting of a plethora of islands and bays (Figs. 2 & 3). The outermost islands are rocky and tend to be rather barren and wave beaten (Fig. 4); the inner portions of the bays are quiet and have mud flats (Fig. 5) and occasional salt marshes (Fig. 6). Most of the coastal area (90%) is in spruce-fir and mixed hardwood forest, which generally extends to the shore (Fig. 7). The population level is generally low, 40-100 persons per square mile (depending largely upon season). A large part of the local population is self-employed, subsisting on a mixture of fishing and small scale forestry.

Gouldsboro Bay itself (Figs. 8, 9, 10) is oriented roughly on a north-south axis; it is approximately 6.5 nautical miles (9.5 statute miles; 13 km.) long, and its main section is one nautical mile (1.2 statute miles; 2 km.) wide. The maximum depth of Gouldsboro Bay is 70 feet (23 m.). Although a few shallow basinal areas are present, the bottom generally slopes gradually from the upper end to the mouth of the bay. Fresh water streams entering the bay are generally quite small in size and, except near the mouths of the streams, the salinity ranges from 30-32%. The tide range is roughly 8-12 feet (2.5-4 m). The shores are generally rocky, although mud flats and sandy silts dominate the upper reaches and the floor of the bay. A few small marshes are present in the upper reaches. The shores of the bay are generally forested. Corea (Fig. 12), a small fishing village of about 400 people, lies just off the southwestern corner of the bay, and Steuben (Fig. 10), a town with a population of about 970 people, lies on Tunk Stream at the northeastern corner of the bay. Small homes occur scattered along the shores of much of the bay. Lobster fishing and clamming is extensively practiced, largely by individual fishermen, in Gouldsboro Bay. Three semi-permanent fish weirs for herring are present in the bay. However, Gouldsboro Bay is not generally regarded as a good bay for herring, and catches are generally small. During the winter, scallop dragging is sporadic but sometimes intensive.

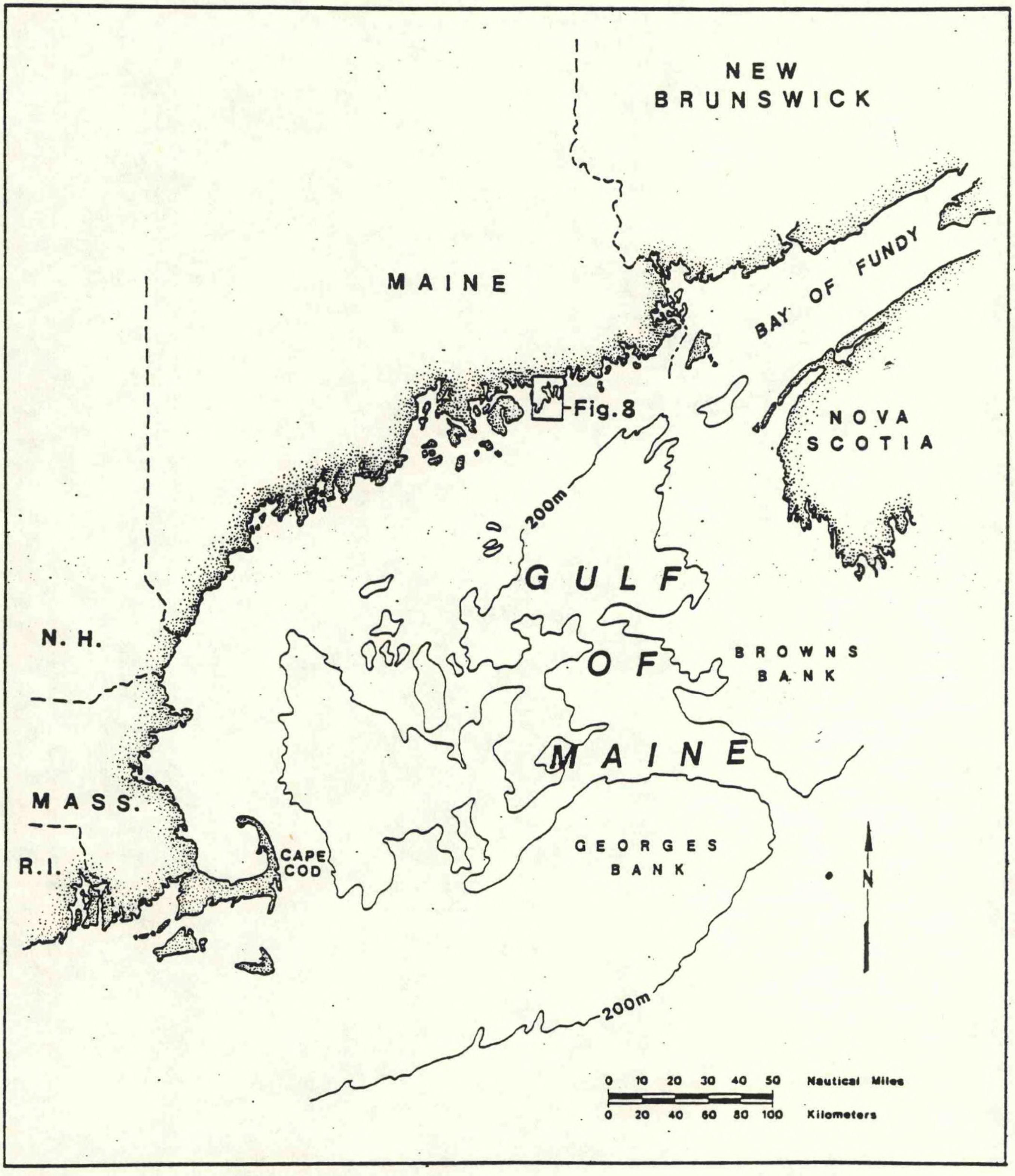


Figure 1. The Gulf of Maine showing the Gouldsboro Bay area and indexing the base map shown in figure 8.

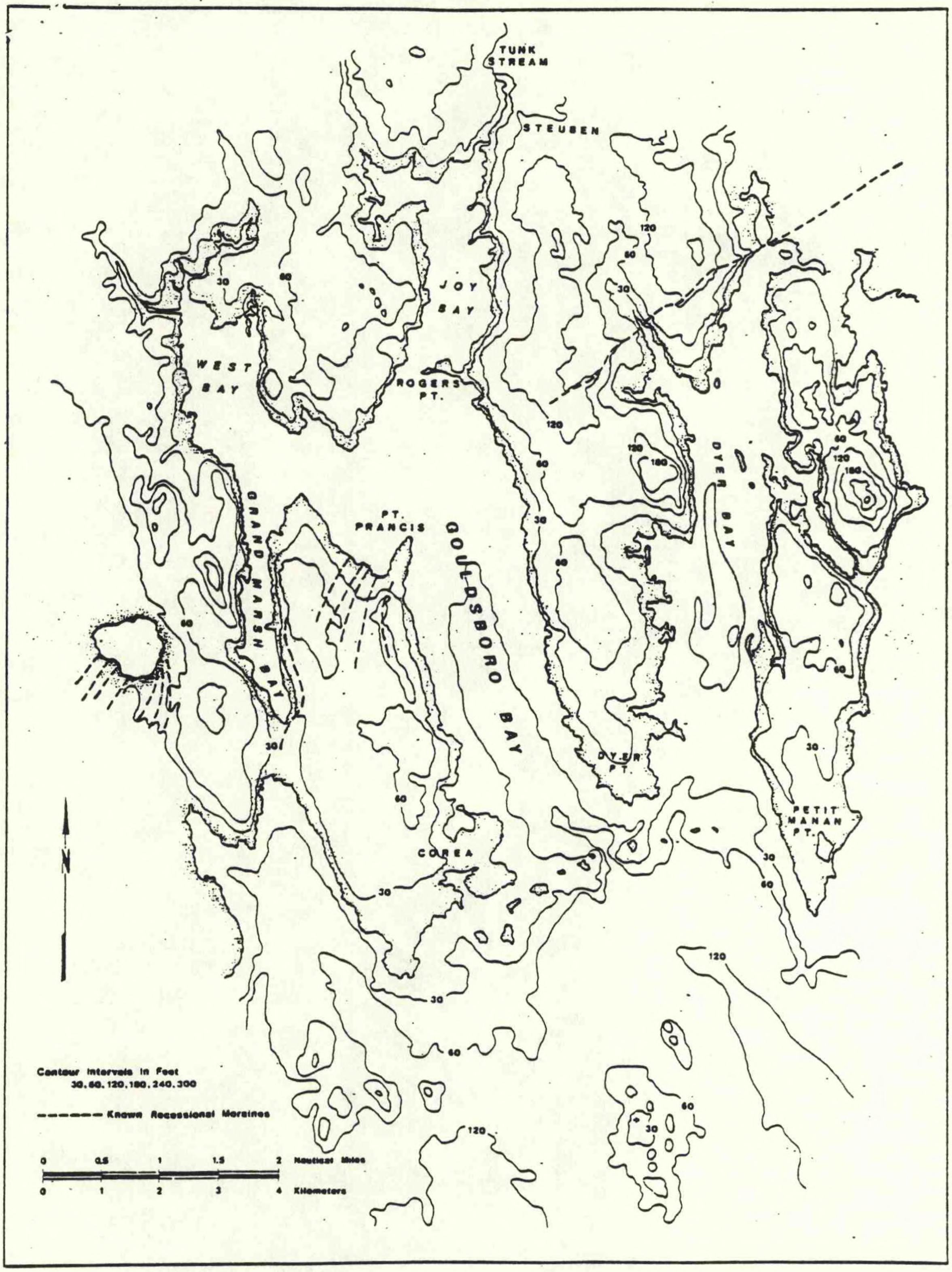


Figure 8. Topographic map of Gouldsboro Bay area.

MATERIALS AND METHODS

Most of the field work for this investigation was undertaken during the summer and fall of 1981 from small boats based from the Marine Systems Laboratory (MSL) research vessel, "Marsys Resolute" (Figs. 13-15). Underwater work was primarily accomplished through the use of SCUBA (Figs. 15-17). Mapping is based on NOS nautical chart 13324 and a low tide photomosaic made from 9x9 black and white aerial photographs taken on May 16, 1944, by the former Coast and Geodetic Survey. Station locations for the 1981 summer session are shown in figures 18&19. Several aerial observation and aerial photographic missions were flown using the MSL Albatross amphibian (Fig. 13).

Geological studies are based on aerial survey, surface reconnaisance, gouge augers (Figs. 20-21), vibracores (Figs. 22-23) and seismic profiling. Surficial sediment samples were collected with a Van Deen-type grab. A Blutworth ES-130 precision depth recorder and an Alden OSR 19T seismic profiler were used to delineate surface and subsurface depth and stratigraphic information. Suspended sediments were collected with a Niskin water sampler and filtered through a 47mm diameter 0.45u pore size Millipore membrane filter.

Temperature/salinity data were taken using a Beckman RS5-3 induction salinometer (Fig. 24). The tide gauges are Leopold and Stevens Model A-71 (Fig. 25). Current information was obtained using arrays of General Oceanic 2010 film recording current meters. Nutrient data was collected by freezing water samples and returning them to the MSL laboratories in Washington, D.C. for calorimetric analysis.

Soft bottom benthic samples were taken with a box core (Fig. 26). A 1/16m^2 tossed quadrat was used for all hard bottom benthic population and biomass sampling. At each station/bathymetric level, 5-10 quadrats were thrown.

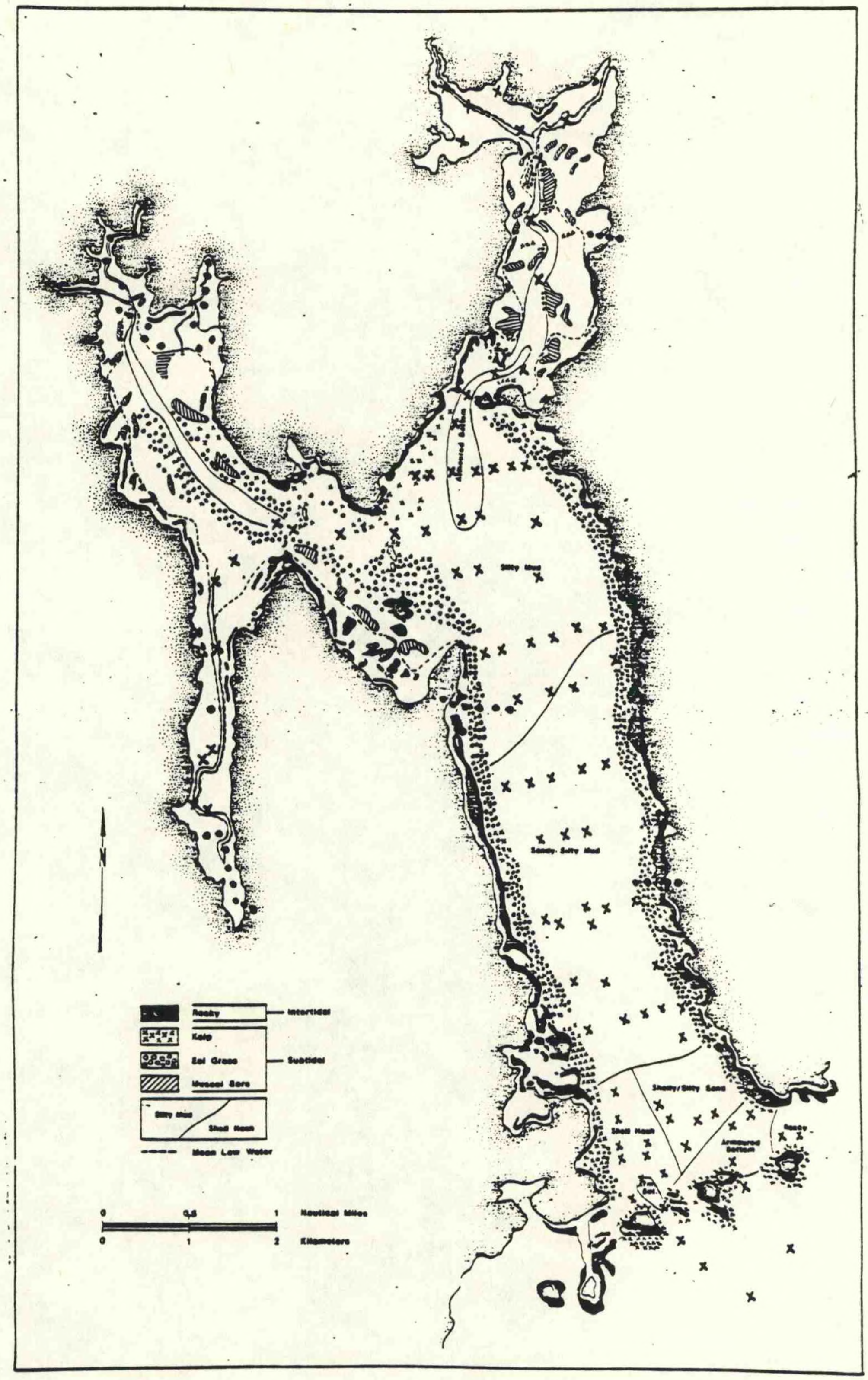


Figure 18. Base map of Gouldsboro Bay showing geological stations.
Sediment samples X; Cores ●

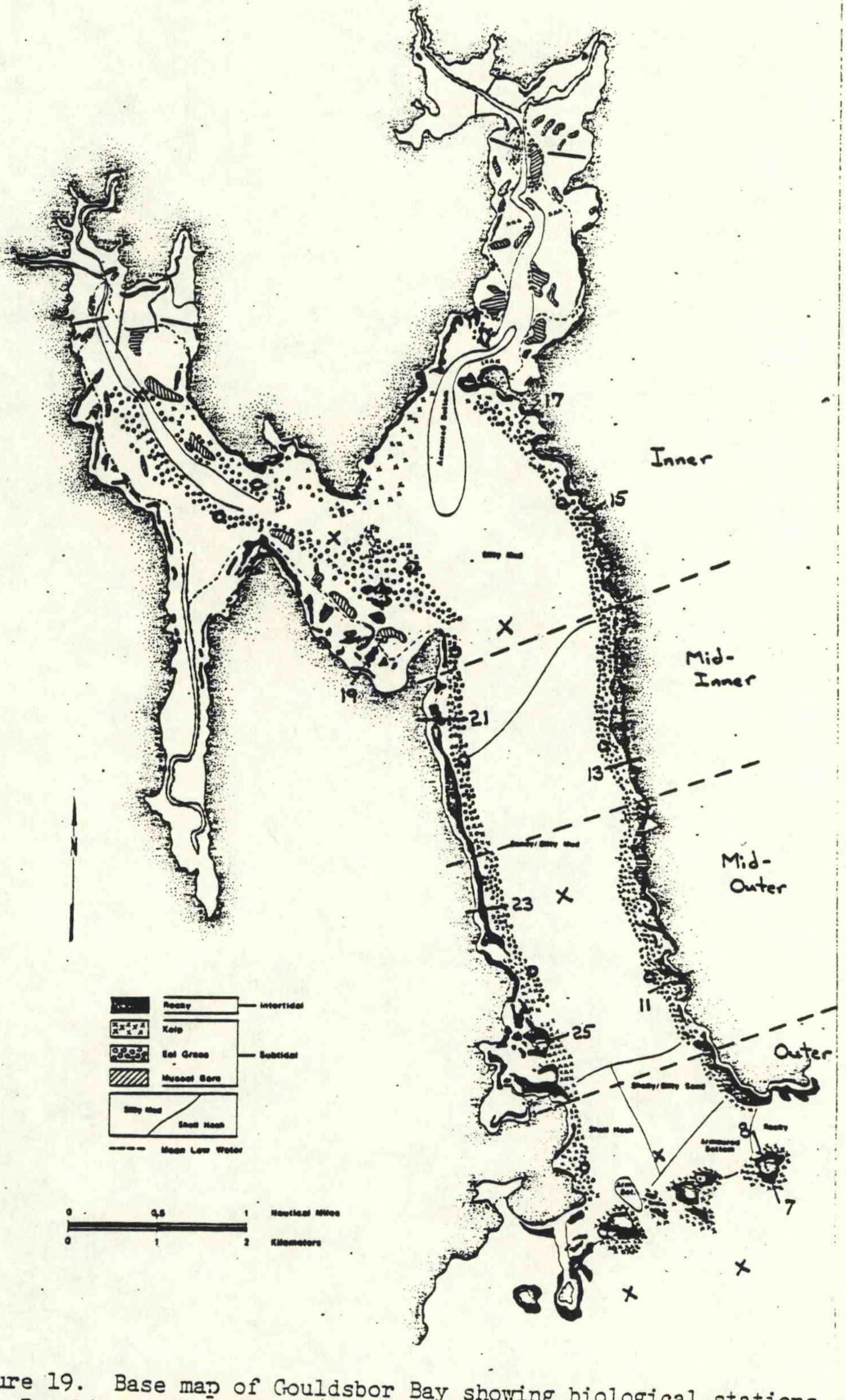


Figure 19. Base map of Gouldsbor Bay showing biological stations. Benthic transects ——; *Zostera* stations O; Plankton stations X.

Community and population content of photosynthetic pigment was determined in the field using calorimetric analysis on a Beckman DU spectrophotometer.

Plankton collections were made by towing nets of 80u and 150u mesh from a small boat. Phytoplankton primary productivity was determined by the C^{14} method using a Packard 2660 Liquid Scintillation Counter.

Although base data are not presented in this preliminary report, they will be included in the final report as appendices and will include appropriate statistical analysis.

Bay export data in the form of fishery landings were obtained by extensive interviews with fishermen, dealers and wardens during both the summer and winter field sessions. Control of the data was based on Maine county fishery landing statistics provided by the Maine State Department of Marine Resources.

A one-hour film for public TV is being developed which describes the ecosystem, the project and the importance of the Sanctuary Program. A Smithsonian film crew worked during several of the field sessions (Figs. 28, 29).

CLIMATE, WEATHER AND BIOGEOGRAPHY

This section is included at this time only for the completeness of the report. It will be greatly expanded and will include considerable data compilation in the final report for the project.

The Maine coast, being a continental shoreline lying at moderately high latitudes in the westerlies and being positioned on the western side of an ocean, is strongly continental rather than oceanic in character. Even though the immediate coast has a near-maritime climate, the temperature is characterized by extremes and the weather by a succession of bi- or tri-weekly lows and fronts moving off the continent. The weather tends to be changeable on a one to four day cycle. Except along the immediate coast, summers tend to be warm with air temperatures generally between 60-80°F (20-30°C). Yearly rainfall is moderate, between 40 and 50 inches, and the drainage tends to be poor due to the till surface and often underlying clay. Bogs, lakes and small streams are abundant and the vegetation is rather lush (Fig. 30). On the immediate coast the autumn is early (Fig. 31), although it is pleasant and long-lived. An occasional intense storm of wind and rain can be expected in November and December, and it can have a strongly modifying effect on the shoreline (Figs. 32, 33). Significant snow and low temperatures usually do not develop until near the end of December; however, January and February can be quite cold with temperatures often well below 0°F (-15°C) (Figs. 34, 35). Also, in the spring, March is generally a winter month; low water temperatures and considerable fog persists through June and into July, and even August (Fig. 36).

The waters of the Coastal Gulf of Maine, like the Gulf of St. Lawrence, are basically characterized by a wide temperature range, with bay surface waters typically reaching temperatures over 15°C in the summer and below 0°C in the winter. The more protected harbors, bays, mud flats and marshes typically develop and maintain several feet (0.3 - 1 m) of ice from January to March (Fig. 37). Mid-bay areas are often characterized by drifting ice packs (Fig. 38) although outside water temperatures are usually 0°C or above and pack ice and shore fast ice in any quantity are absent (Fig. 39). The basic water climate and flora and fauna is subarctic in character, and along with the remainder of the coast from Cape Cod to Newfoundland is closely related to the Okhotsk Sea and western Bering Sea in the north Pacific. On the other hand, the strong tidal character of the eastern Gulf of Maine has a significant influence on the water climate and on the flora and fauna. Tidal mixing tends to reduce the development of stratification in summer and prevent the development of very cold surface water temperatures outside of bays in the winter. Offshore and more eastern areas in the Gulf tend to have narrower temperature ranges, from 0° to 3°C in winter and 10-12°C in summer. Thus, there is a boreal element to the flora and fauna which is matched in southern and eastern Iceland, the northern British Isles and on the outer Norwegian Coast. In addition, the high water temperatures in the southwestern Gulf of Maine and in some inner Maine bays in summer allows for the occurrence of temperate elements from south of Cape Cod as relicts, occasionals or introductions.

Thus, the biogeography of the coastal gulf is complex and includes both boreal and temperate biotic elements. Nevertheless, those elements have been overstressed in the past, probably because of the preoccupation with the plankton and the quite mobile organisms of the fishery, and the basic biogeographic character of the coast is subarctic (Figs. 40, 41).

Gouldsboro Bay, lying well to the northeast in the Gulf of Maine and being in an area of east-west trending shoreline, is influenced by strong tides, winds off the water in the summer and winds off the land in winter. Thus, it is relatively cold and has a relatively narrow temperature range. Based on area coverage

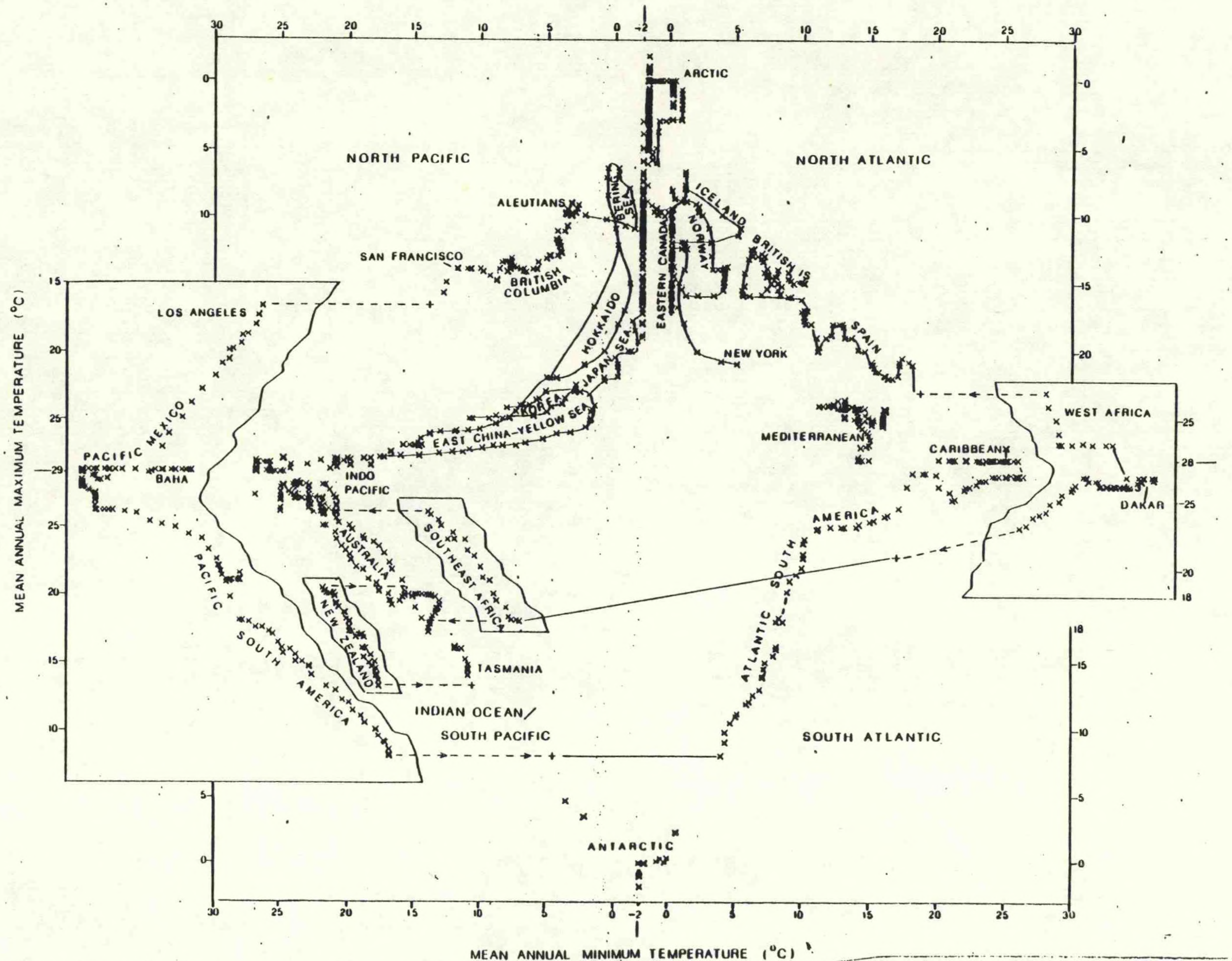


Figure 40. Mean maximum, mean minimum coastal temperature framework for the world ocean. Note that at 12 - 15°C (mean max.) and 0°C (mean min.), Gouldsboro Bay would place in the middle of the eastern Canada shores temperature regime. Winter temperatures in Europe are generally warmer (boreal). After Adey and Steneck, in prep.

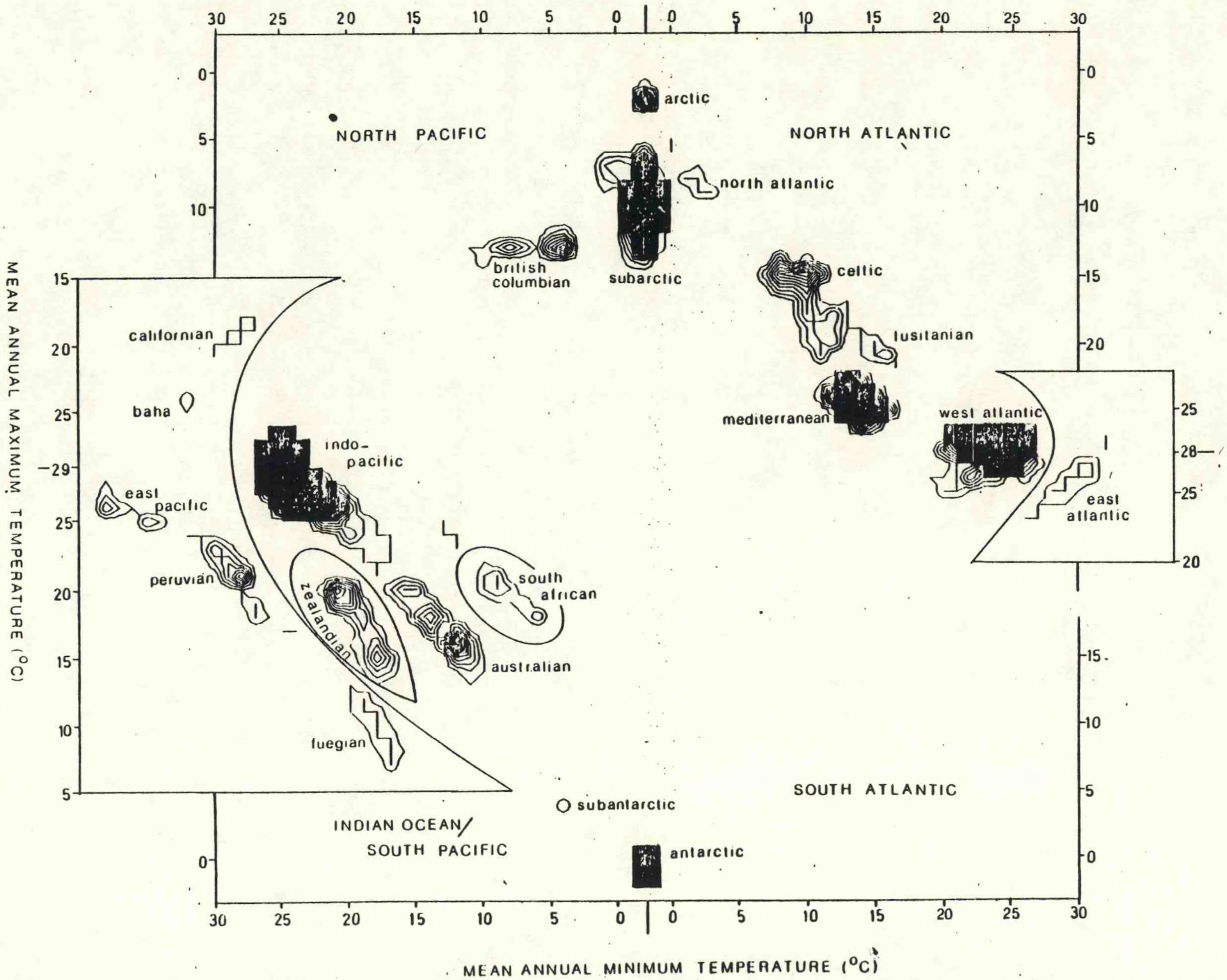


Figure 41B. Mean coastal temperature framework for the Pleistocene. The North Atlantic Subarctic is not a major element. Thus, the eastern Gulf of Maine, along with the Gulf of St. Lawrence, Nova Scotia and Newfoundland is dominated by a (North Pacific) Subarctic biota with a small component of Celtic (boreal) elements.

of the long-lived, sublitteral sedentary coralline flora, the outer coast in this area is about 65% subarctic, 30% boreal and 5% temperate in character. The inner reaches of bays, where a hard bottom exists, are 75% subarctic, 5% boreal and 20% temperate in nature.

GEOMORPHOLOGY AND SEDIMENTOLOGY

In the area of Gouldsboro Bay, the bedrock geology consists primarily of mid-Paleozoic granites and granodiorites that have been smoothed by repeated Pleistocene glaciation. Scattered mafic intrusives occur as dikes in the lower bay and become more abundant and larger in the upper reaches. The dikes do not seem to be a major factor in geomorphic control. Topographic relief is generally less than 300 feet. Although bedrock outcrops are mostly of broadly rounded granites, jointing, fracturing and glacial quarrying is abundant enough to provide a rugged topography on a local scale of tens of feet (Figs. 42, 43). The basic topography is that of preglacial north-south trending stream valleys superimposed on a northwest-southeast trending structural pattern.

A late Pleistocene, Wisconsin glacial till blanket of a few to tens of feet lies over the entire area (Fig. 44). Away from the shoreline only scattered outcrops of bedrock occur. Smaller, often en-echelon recessional moraines are abundant in the area of Gouldsboro Bay and are shown in figure 8. These features are responsible for numerous till bluffs and some smaller points within the bay. The Dyer Neck Moraine, which stretches for about five miles from Wyman, south of Milbridge, nearly to the shore of Gouldsboro Bay, is the largest linear moraine in the area. It appears to be responsible for the shelf-ridge bottom topography of the upper main bay. The Grand Marsh moraine resulted in the blocking and "beheading" of ancient "West Bay" and is the basis for the two-armed shape of modern Gouldsboro Bay.

Along the shore of the bay complex the till blanket has been winnowed by intertidal wave action. The clay, silt and sand sizes have been removed, leaving extensive deposits of cobble and boulder lag lying on bedrock. This process is observable in the lower reaches of West and Joy Bays and becomes more pronounced southward. In topographically lower areas in Gouldsboro Bay, sand and gravel have been deposited by wave action (Fig. 45). To a large degree, the location of these pocket beaches is a function of the jointing pattern of the bedrock (i.e., presence of small-scale headlands and bays) and proximity to a sediment source (i.e., a till deposit). In the southern, more exposed areas of the bay, the lag over bedrock bottom persists subtidally to a depth of 10-15 feet (3-5m). On the outer islands, this type bottom reaches 40-65 feet (12-20m) before disappearing under a soft bottom of gravelly to silty sand.

During Wisconsin deglaciation, from about 12,000-13,000 years BP, a rapid submergence of the present coastal area, by rising sea level, in front of the retreating ice resulted in the deposition of a blanket of sediment over the till. This sediment of clay, silt, and glacial debris is commonly found throughout coastal Maine and has been named the Presumpscot Formation (Bloom, 1963). With the ice removed, rapid upward rebound of the coastal area resulted in re-exposure and a retreat of the shoreline to a position five to ten miles seaward of its present location. Since that time, a slow depression of the crust, accompanied by continued slow sea level rise, has resulted in a general submergence of the coast and a marked "drowned topography" (Fig. 46).

Based on the most recent data (Schnitker, 1974), between 11,000 and 8,000 years BP, sea level would have remained virtually constant at about -55m. Based on the NOS nautical charts and the apparent lower limit of subaerial erosion features, a depth of -55 to -65m seems more likely (Fig. 47). In any case, three thousand years of virtually constant sea level would have been sufficient to produce well-developed shoreline features (exposed bedrock and lag cobble shores, till cliffs, spits, tombolos, and marshes) and define the lower limit of inshore waters. This early Holocene shoreline, besides being the lower limit of abundant irregular topography and near the photic limit, may also be the outer limit

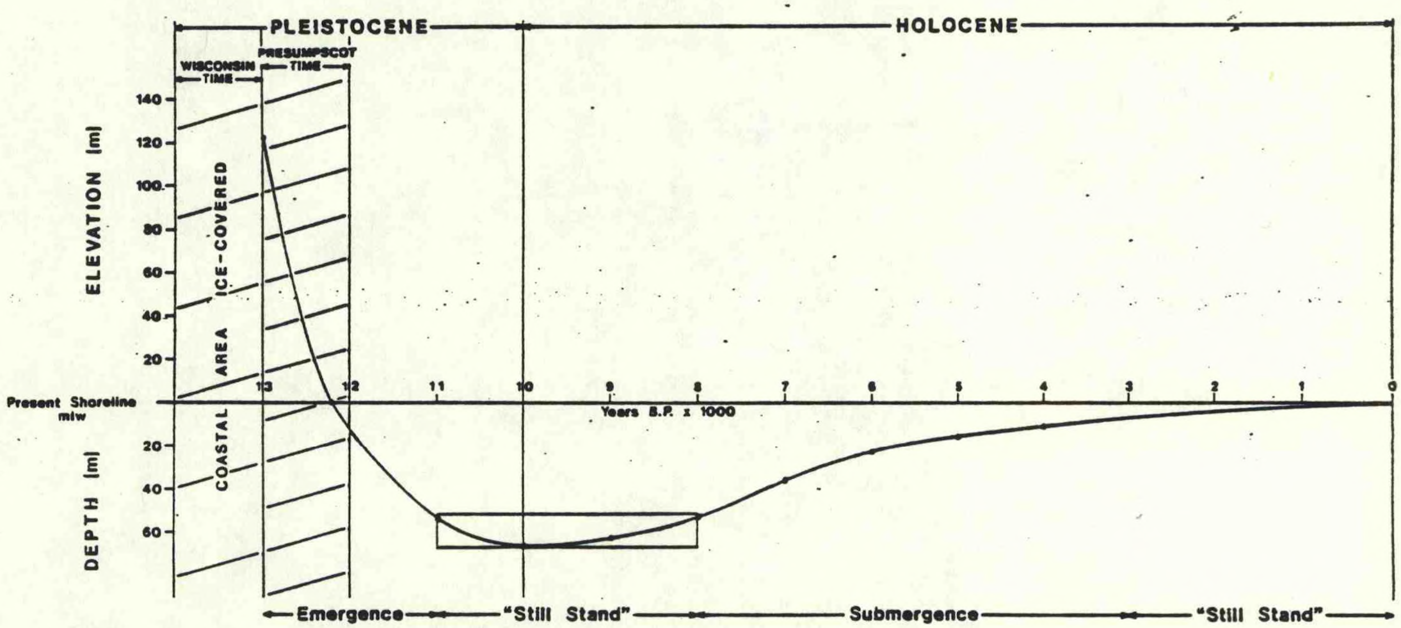


Figure 46. Sea level position, relative to present sea level, over the last 13,000 years.

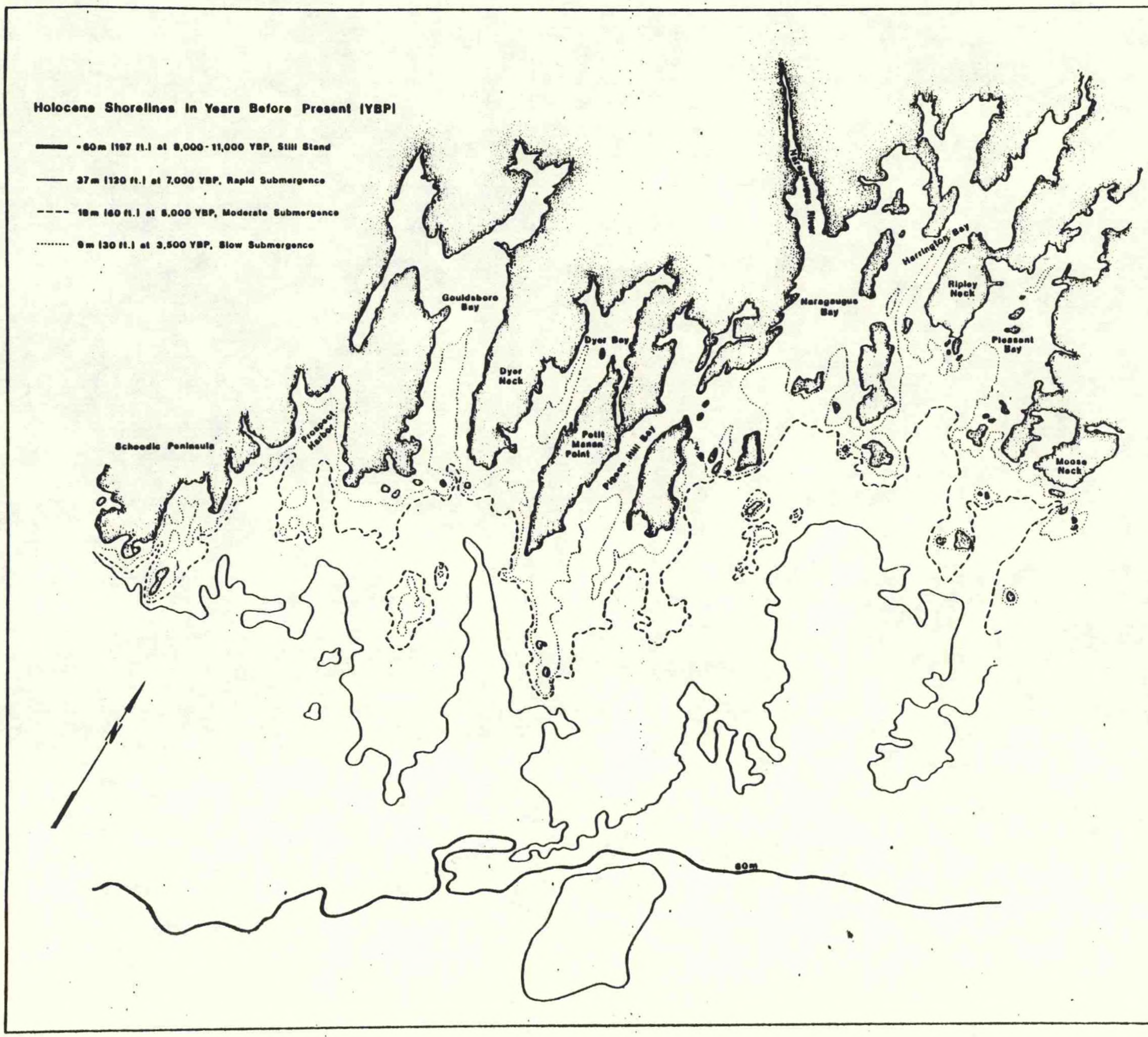


Figure 47. Shorelines of the latest Pleistocene and Holocene in the Gouldsboro Bay area.

for winter lobster migration. Because of its importance in defining the benthic communities in shallow water ecology, and its importance in understanding the Pleistocene history and development of the coastline, considerable effort will be devoted to locating and characterizing in detail this early Holocene shoreline during the summer of 1982.

Beginning about 8,000 years BP, flooding of the inshore shelf began, resulting in the immediate development of a drowned topography and the ancient Gouldsboro and Dyer Bay complex.

From about 8,000-6,000 years BP, the present Gouldsboro Bay was a coastal valley and was probably forested during much of that time. Tunk Stream and its tributaries cut a narrow valley through the Presumpscot clay and into the underlying till along much of the length of the bay. About 5,500 years BP, flooding of the lower bay began through the narrow Eastern Way. By about 3,000 years BP, most of the present main bay had been flooded and yet the openings to the open ocean remained narrow. Thus, for a good part of its modern history (approx. 3,000-6,000 years BP), Gouldsboro Bay functioned like Taunton Bay in Hancock County: a marine pond with little shore erosion and with a strong tidal current through its narrow entrance.

In the last few thousand years, sea level rise has continued at a slow rate (Fig. 48), and at the same time the bay has become more and more open to the effects of open ocean waves. Shoreline erosion of the unconsolidated intertidal deposits progressed in the main bay as silt-sized material removed by wave action became deposited in the upper arms of the bay as mud flats. In small basins scattered along the uppermost reaches of the bay and particularly in the southern part of Grand Marsh Bay, fresh water marshes had developed during the early Holocene. Upon flooding by the rising sea between 2,000 and 3,500 years BP these areas developed salt marsh communities (Figs. 30, 31). The baffling effect of the salt marsh grasses provided for rapid accumulation of silts eroded from the lower Bay and a subsequent building of marsh surface at the same rates as sea level rise. Later, numerous narrow fringing marshes developed along more protected shores in the upper sections of the bay (Fig. 49).

Figures 50-52 show the relationship of the present marine sediments and the late Pleistocene Presumpscot Formation to the underlying till and bedrock. The Presumpscot Formation serves as an excellent marker horizon and for all practical purposes can be used as a boundary between Pleistocene and Holocene. While it may be thin or absent over much of the bedrock ridges lying on either side of Gouldsboro Bay, it is quite consistent beneath the bay and along the shore, wherever it has not been removed by erosion during the past few thousand years. Its frequent absence along the ridges may result from lack of original deposition (due to higher wave energies on the shallower ridges), from erosion during re-exposure of the shore (13,000-12,000 years BP), from recent erosion or re-working by vegetation, or from some combination of all three.

Per nautical mile, the relief on the Dyer Bay, Gouldsboro Bay ridges is 60-120 feet. In the central parts of the bays, the same relief per mile is about 40-60 feet (Fig. 8). Assuming that the continental glaciation had provided a surface of more or less equal relief on the ridges and in the valleys, and that the cover of ground moraine in the two areas is nearly equivalent, the difference in relief suggests considerable post-glacial infilling and smoothing by sedimentation. This smoothing, on the order of 20-40 feet, has apparently been accomplished in part by removal of Presumpscot clay from ridges during the rapid emergence and deposition in the bays. Subsequent erosion on the ridges with deposition of marine sediments in the Bays has continued this process. The difference in relief, the seismic profiles and the cores all indicate that 20-40 feet of post glacial sediments, including Presumpscot clay, a soil or

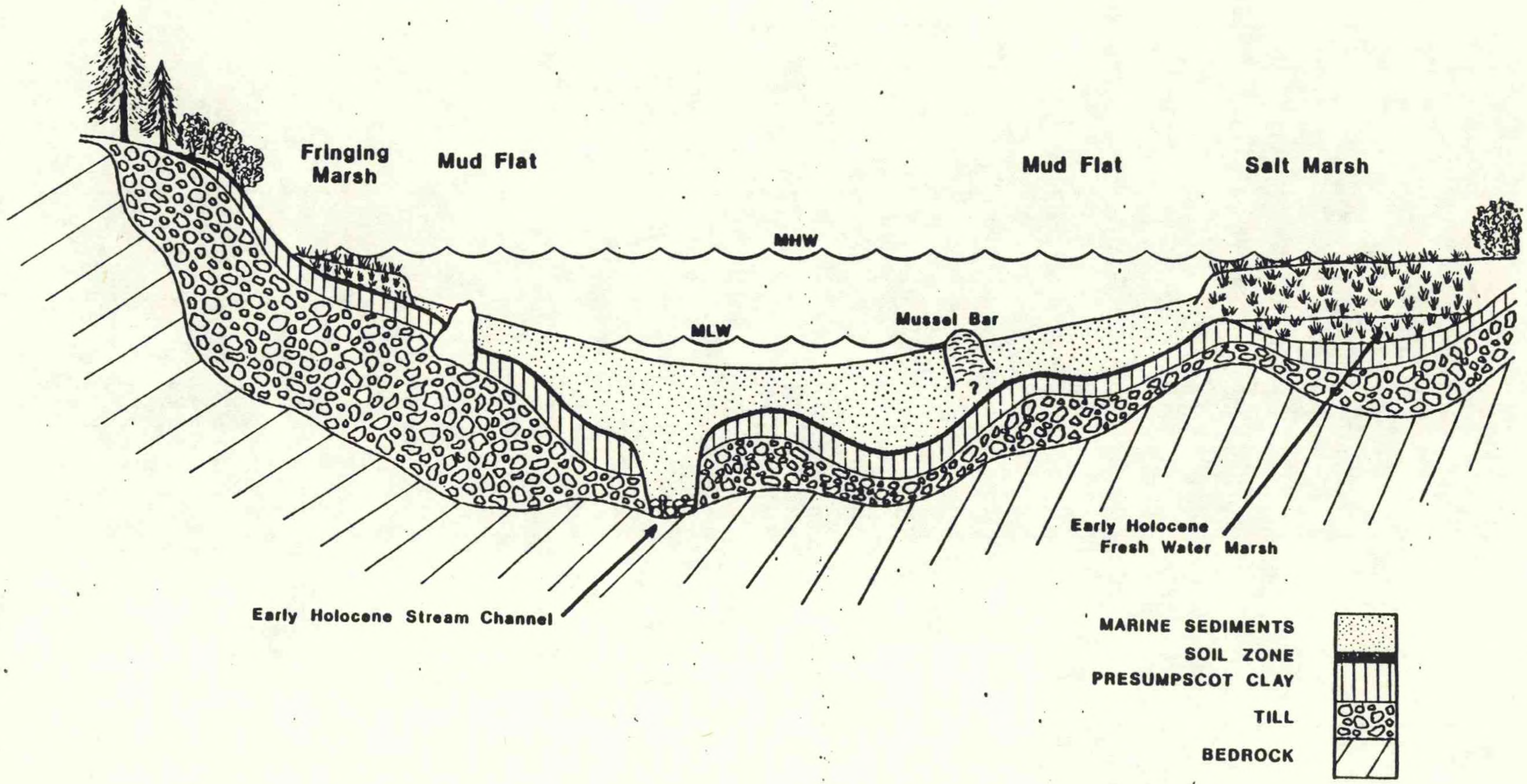


Figure 50. Section across of upper bay showing sub-bottom stratigraphy.

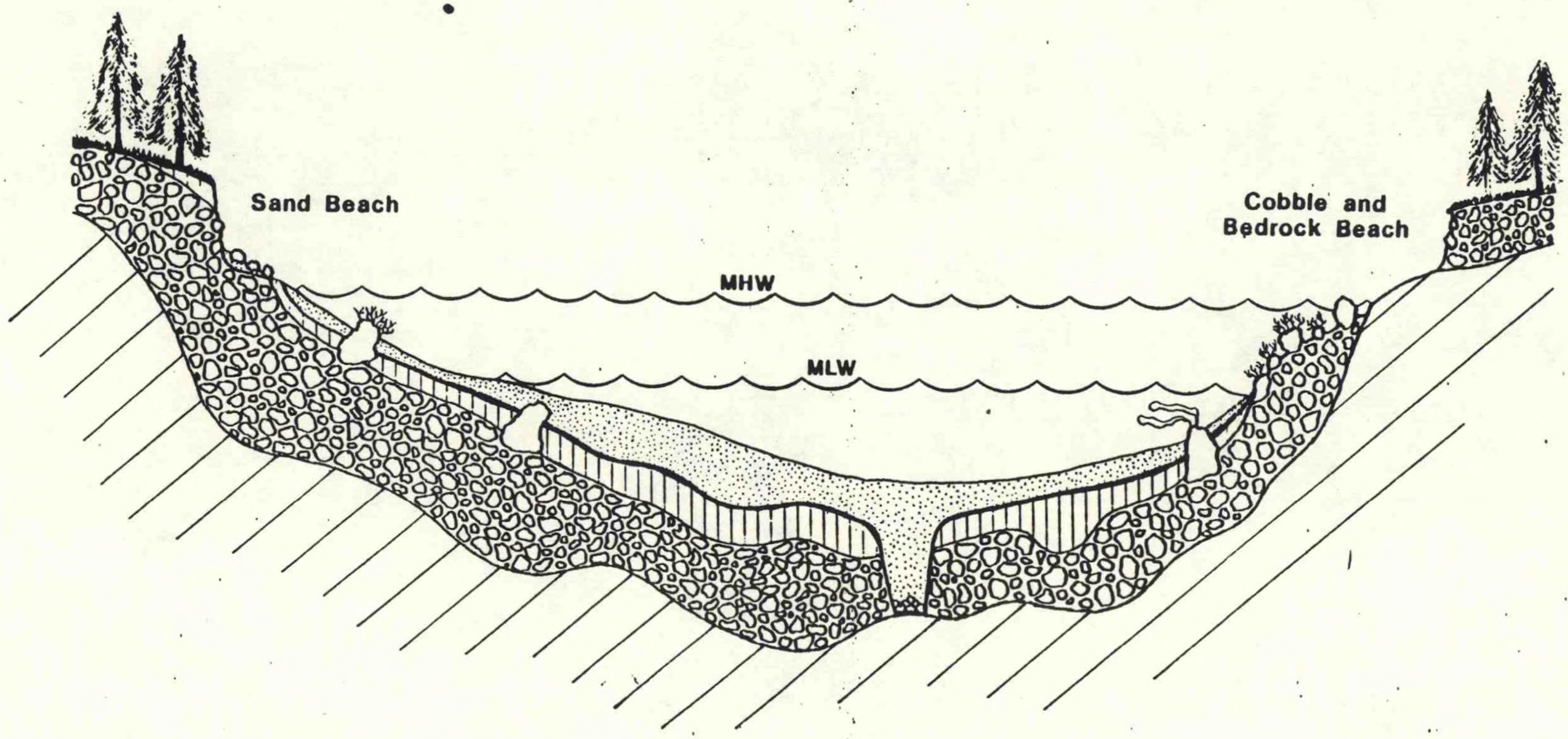


Figure 51. Section across mid bay showing sub-bottom stratigraphy.

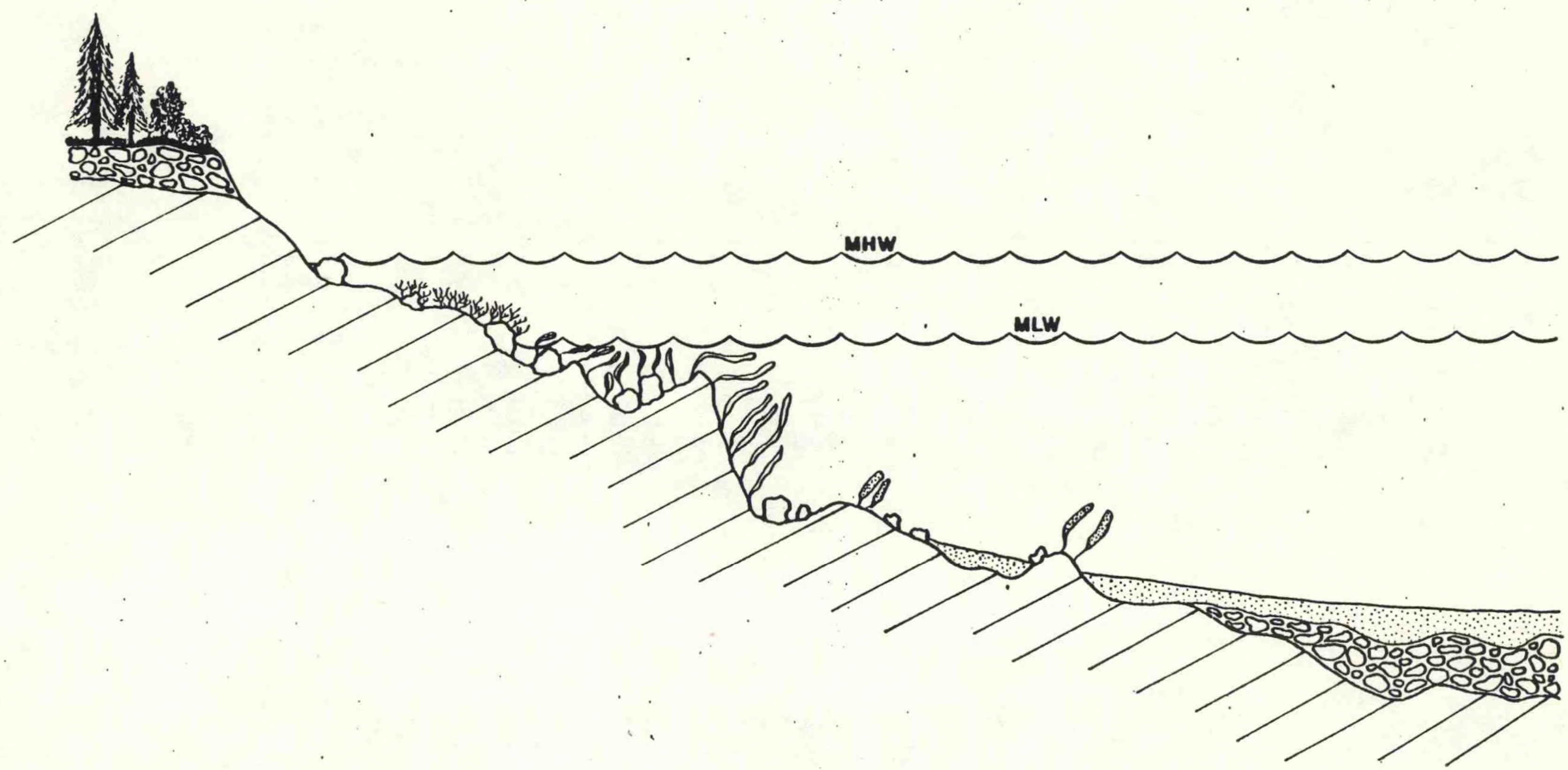


Figure 52. Section of outer shore showing sub-bottom stratigraphy.

Table 1

Biological Communities
of Gouldsboro Bay

	Area (10^6 m^2)	Subtotal (10^6 m^2)	% Total
Benthic			
Intertidal			
Rocky (Ascophyllum/Fucus/Balanus)	1.94		9.1
Mud on Sand Flat (Zostera)	3.3		15.6
Marsh (Spartina)	0.34		1.6
Mussel Beds (Mytilis)	0.32		1.5
Subtidal			
Shallow (plant dominated)			
Rocky (Laminaria)	0.56		2.6
Soft (Zostera)	0.68		3.2
Deeper (animal dominated)			
Armoured (Placopecten/Modiolus/Lithothamnium/Asterias)	1.9		9.0
Shell hash (Echinarachnius)	1.0	14.0	4.7
Sandy Silt (Astarte)	5.6		26.5
Silty (Nereis)	5.5		26.0
Planktonic			
Open Water/Outer Bay (Calanus)	est. 9	14.0	42.6
Inner Bay (Eurytemora)	est. 5		23.7
		21.14	99.8

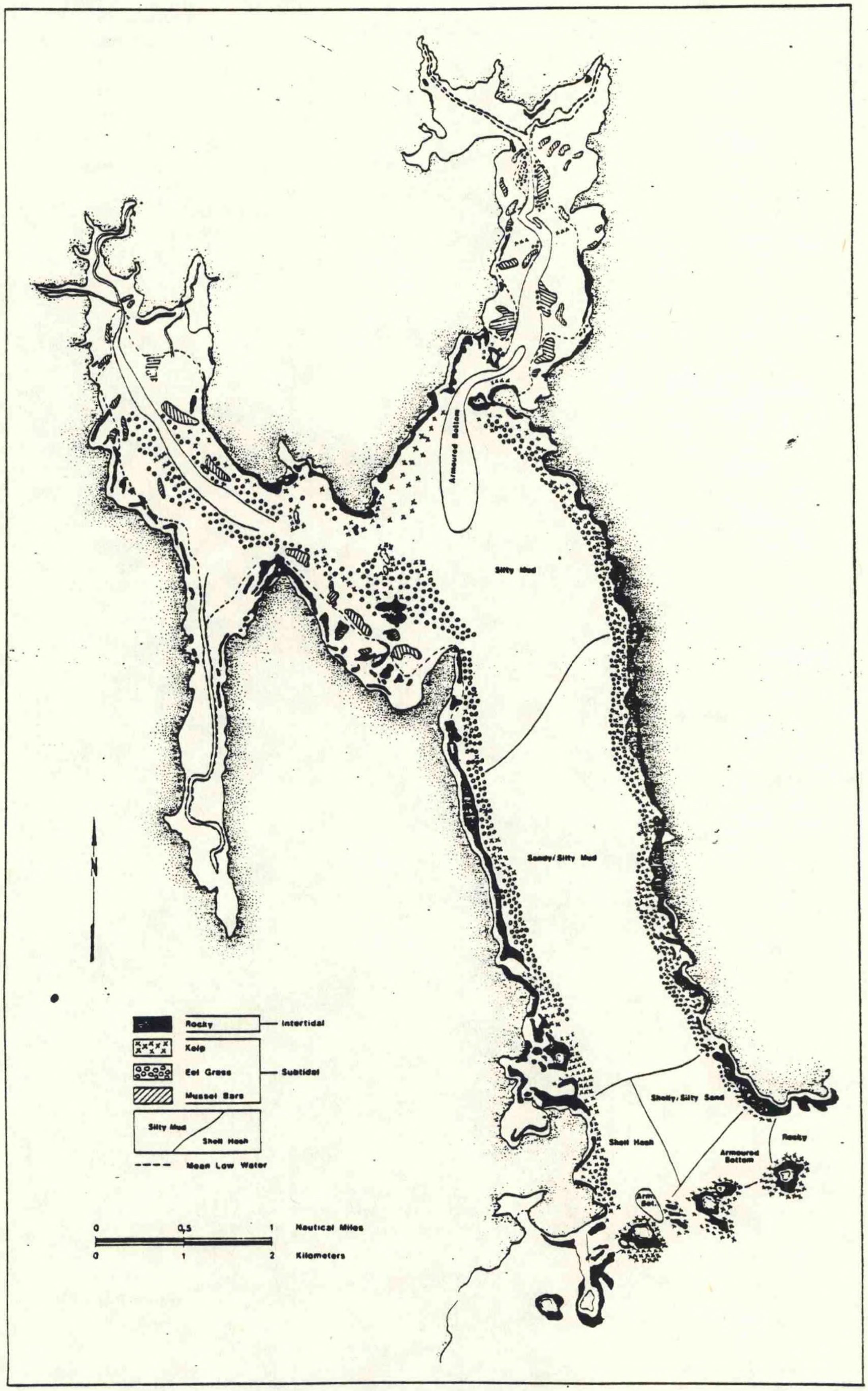


Figure 53. Aerial extent of the biological communities of Gouldsboro Bay.

peat zone, and dominantly silty marine sediments, are present in the central part of the bay.

The nature and distribution of biological communities are largely determined by the character of the substrate; this characterization is listed below in table 1 and shown in figure 53. Sediment character in terms of grain size and percentage composition of organic and mineral components is presently being analyzed and will be treated in detail in a later report. The most striking character of the preliminary analyses is the regular and consistent increase of organic percentage in the bottom sediments from values of less than 2% near the mouth to over 10% on parts of the flats at the head of the bay. Primary productivity is very limited in the flats, and the source of these organics must come from further down the bay, either as plankton and/or macroalgal detritus. Since the latter is by far the dominant source of organics within the bay (Table 9), it seems likely that rockweed is the primary source and that there is a hydrographic mechanism forcing the fine organic detritus to the head of the bay and depositing it on the flats.

HYDROLOGY

The tides in Gouldsboro Bay are semi-diurnal and display a moderate diurnal inequality (up to 0.4m). Mean tidal range at the entrance of the bay is approximately 3.2 meters and spring tides may exceed 4 meters. The regular geometry of Gouldsboro Bay is significant in determining characteristics of the tidal wave.

In plan view (Fig. 8), Gouldsboro Bay proper is rectangular and width remains nearly constant along the axis. West Bay and Joy Bay are shallow, irregular extensions of Gouldsboro Bay, but combined they include less than 10% of the total volume of the system. The cross-section of Gouldsboro Bay is sub-rectangular along the seaward half. Here, depth decreases headward in a gradual and linear manner. Along the upper half the cross-section of the bay becomes more V-shaped and depth decreases abruptly from 11 to 5 meters (MLW) between 6 and 7 kms headward of the mouth.

Predicted and measured tidal range at the head of Gouldsboro Bay correspond closely with predicted range at the mouth. Amplification of the tidal wave due to geometry effects and alternation from frictional energy dissipation are minimal and approximately in balance. This is typical of deep and geometrically regular bays along the Maine coast. Tidal shore relationships along Gouldsboro Bay indicate that the tidal wave is largely a standing wave-type. Highwater at the headward end is only 1.5° out of phase (3 minutes later) with highwater at the mouth. Maximum tidal currents are therefore 90° out of phase with tide-level fluctuation, occurring approximately at mid-tide.

Total water volume in Gouldsboro Bay at mean tide-level is approximately 1.9×10^8 m^3. The mean tidal prism is 5.2×10^7 m^3 or approximately 27% of the bay volume. Maximum tidal prism at spring tide is 6.5×10^7 m^3 and approaches 35% of the bay volume. Mean tidal discharge is approximately 1200m^3/s. Discharge at maximum ebb and flood exceeds 3000m^3/s. Local tidal velocities may reach 80cm/s near the surface and 20cm/s near the bottom at maximum tidal flow.

Several small, freshwater streams enter the Gouldsboro Bay system at the headward end in Joy Bay and West Bay. Freshwater influx from these streams is very small compared with tidal discharge however. Flow measurements taken in the early fall indicated that combined freshwater flow of all streams did not exceed 5m^3/s. Gouldsboro Bay is therefore tide-dominated and generally well-mixed. This is reflected in a high dispersion coefficient and relatively long flushing time. A calculated dispersion coefficient based on the mean tidal prism, an average bay cross-section and freshwater discharge of 5m^3/s is approximately 1.2m^2/s. Assuming a mean bay volume of $1.9 \times 10^8 m^3$, freshwater volume of $2.8 \times 10^7 m^3$ in the bay and 5m^3/s freshwater influx, the flushing time is approximately 32 days. Actual flushing time probably varies between 15 and 60 days depending on tidal range and variations in freshwater supply. Also, storm effects on circulation, mixing and flushing are probably significant, but have not yet been observed.

Despite strong tidal effects and low freshwater influx, weak, vertical and longitudinal salinity gradients persist in Gouldsboro Bay (Fig. 54). An intensive two-week survey of salinity and temperature structure in the bay from neap to spring tide shows a slowly varying system. Weakest vertical stratification (0.1 to 0.4 ppt) occurs near the mouth of the bay (Figs. 54a, 55a). The largest vertical gradients occur along the headward third of the bay and range from 0.4 to nearly 1 ppt. Temperature distribution closely parallels salinity structure (Figs. 54b, 55b).

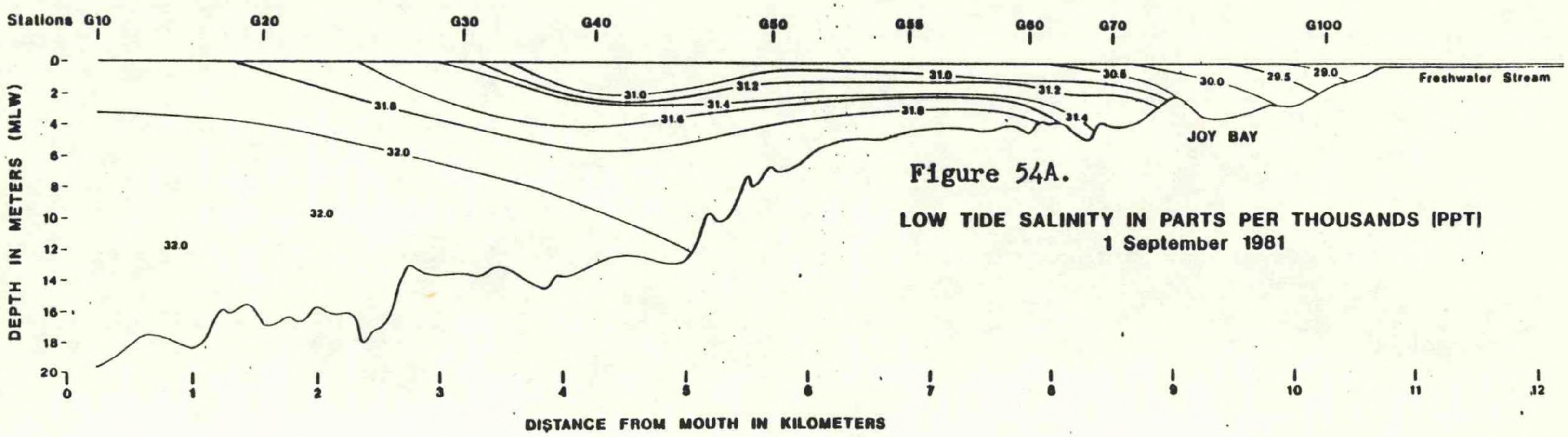


Figure 54A.

LOW TIDE SALINITY IN PARTS PER THOUSANDS (PPT)
1 September 1981

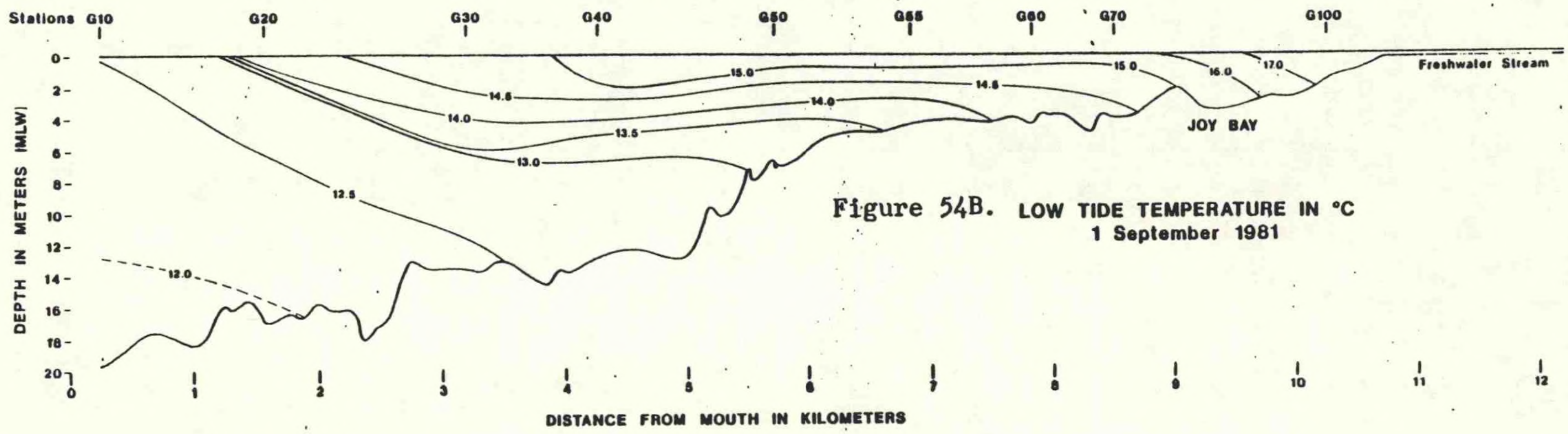


Figure 54B. LOW TIDE TEMPERATURE IN °C
1 September 1981

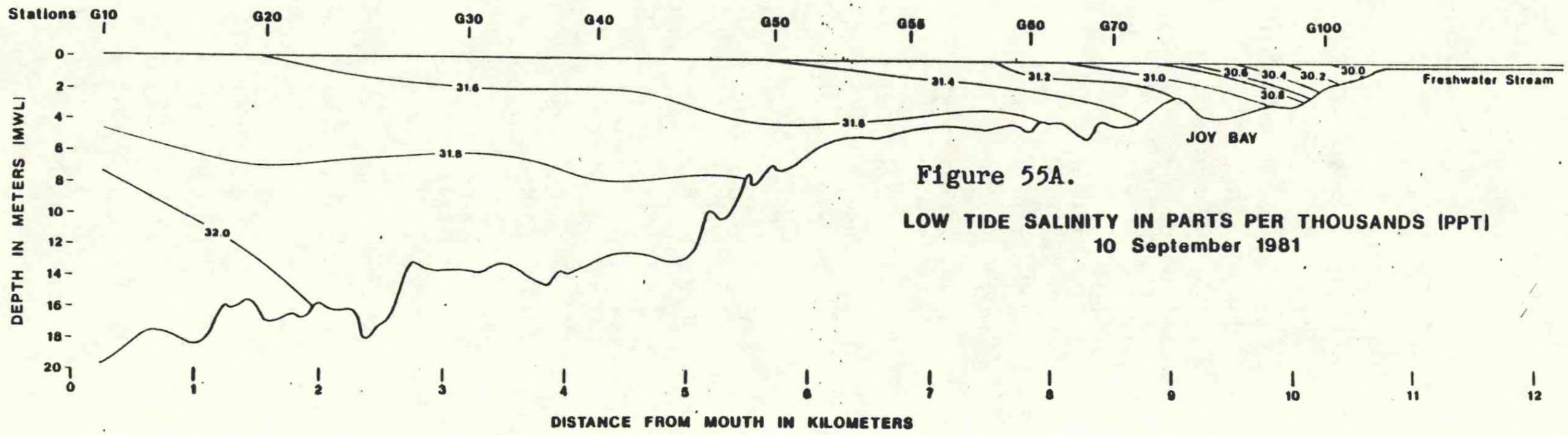


Figure 55A.

LOW TIDE SALINITY IN PARTS PER THOUSANDS (PPT)
10 September 1981

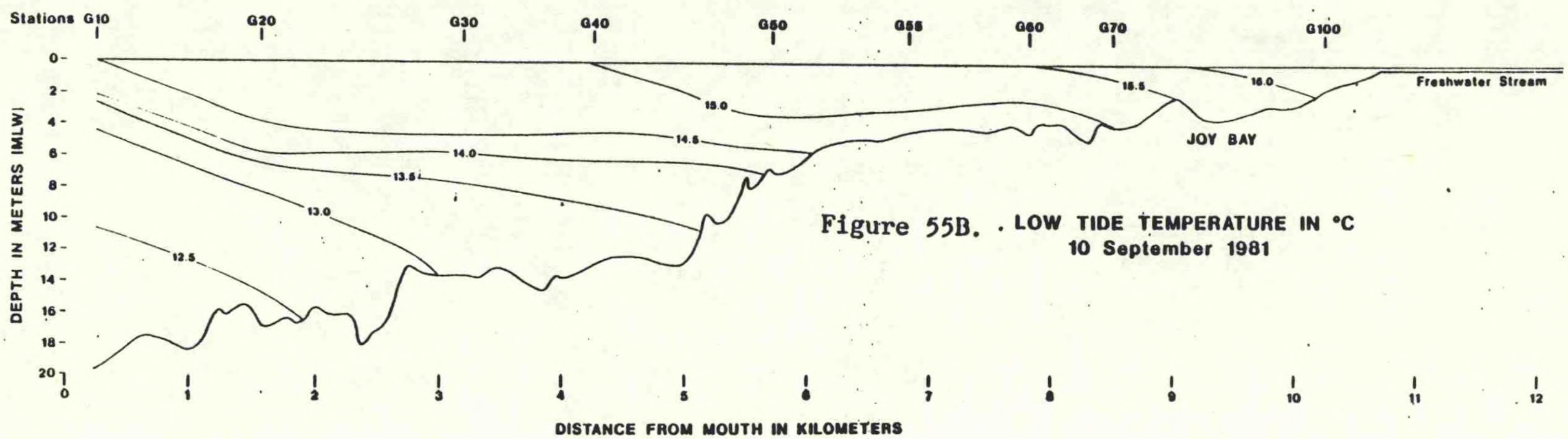


Figure 55B. . LOW TIDE TEMPERATURE IN °C
10 September 1981

In general, Gouldsboro Bay is laterally well-mixed (Figs. 56, 57), but lateral salinity distribution shows a significant feature. Salinity near the mouth of the bay is consistently greater on the east side. This could be due to a Coriolis effect, but is more likely due to a weak tidal pumping system through the restricted bay entrance. Inertial effects at the multiple entrance may cause one or more inlets to be either flood- or ebb-dominated.

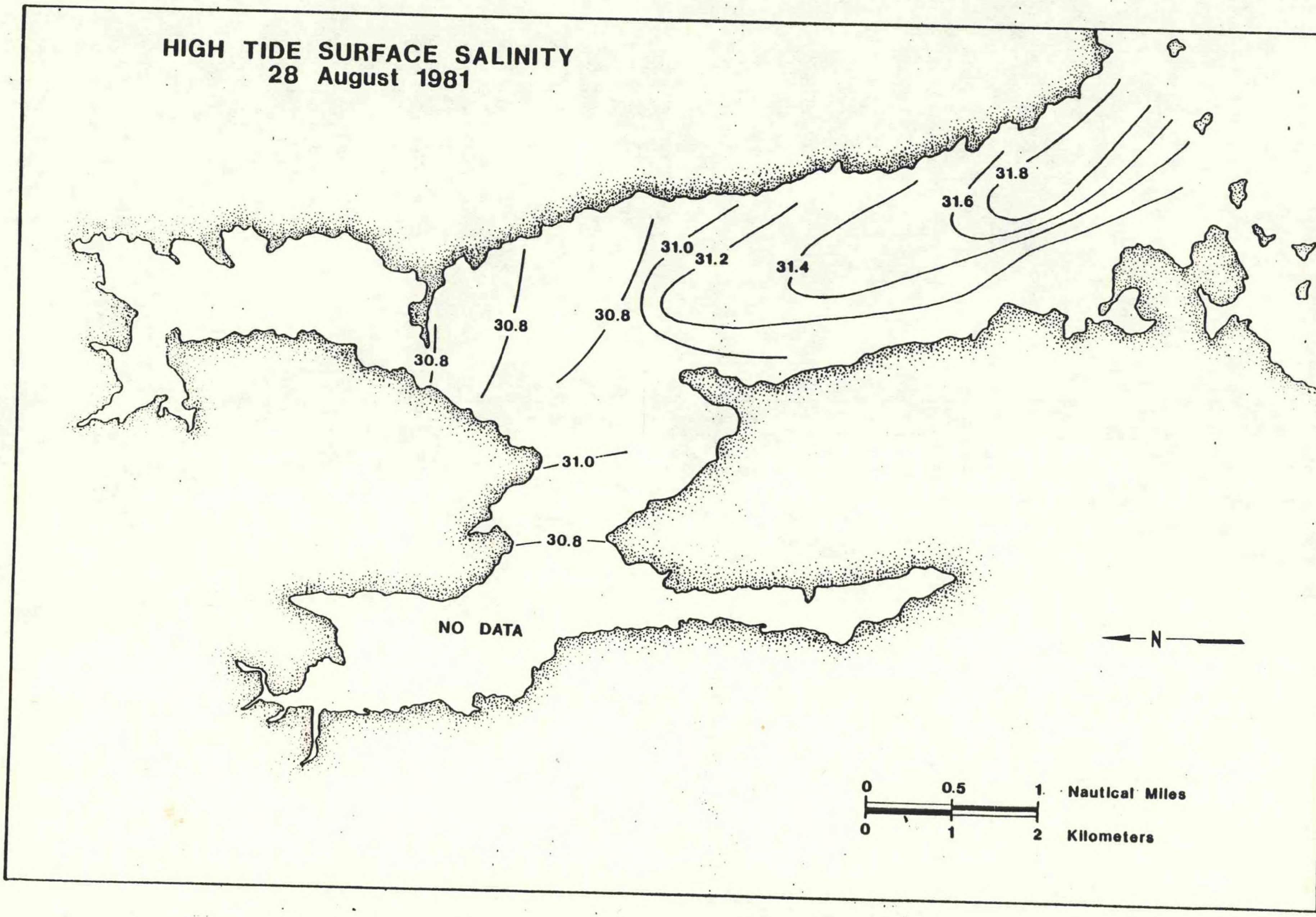


Figure 56. Surface high tide salinity, August 28, 1981.

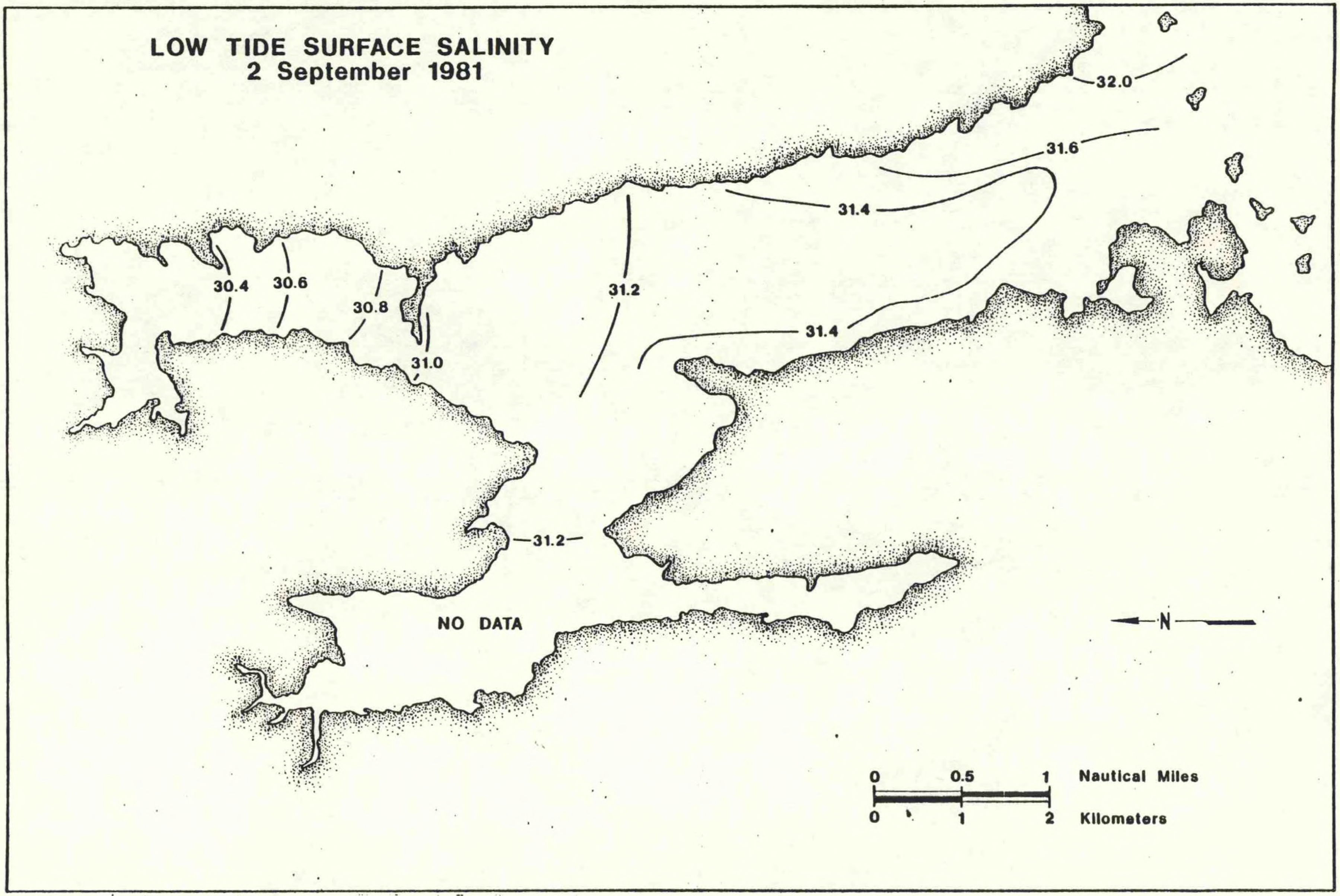


Figure 57. Surface low tide salinity, September 2, 1981.

BIOLOGICAL COMMUNITIES

A characterization of the biological communities of Gouldsboro Bay is shown in figure 53 and outlined in table 1. Study of some communities is well along and each of these is discussed at some length. Study of the remaining communities has only been initiated and only a brief discussion is attempted at this time.

Benthic studies were carried out with $1/16m^2$ quadrats at high (2-3m mlw), mid (0.5-1m mlw), and low (-1 - 0 mlw) tide levels and in the subtidal at 2.5, 5 and 10m below mean low water. Station locations were shown in figure 18. Generally, 16 quadrats were thrown per station/depth level, although as few and as many as 6-28 were used at some locales.

All of the dominant macroalgae and invertebrates were tabulated, along with biomass at each locale. Also, by a variety of means, discussed below, primary productivity in terms of biomass increase for the benthos and C^{14} for the plankton was determined. The emphasis of this report is on primary productivity. Although a wide range of algae and invertebrates are briefly discussed, our treatment centers on the dominant benthic primary producers *Ascophyllum nodosum* (rockweed), *Laminaria saccharina* and *Laminaria longicuris* (kelp) and *Zostera marina* (eel grass).

Intertidal

Rocky Intertidal

The rocky, algal-covered intertidal shore is a primary feature of Gouldsboro Bay, as well as much of the Maine shoreline (fig.53, 58, 59). Generally, the proportion of soft bottom increases from the outer areas to the inner, more protected reaches. Nevertheless, it is only in the upper arms, Joy Bay and West Bay, that the rocky intertidal is largely replaced by marshes and mud flats. Aerially, the rocky intertidal occupies only about 10% of the total surface of the bay. However, its high level of primary productivity (over 60% of the total for the bay) makes it the most important single community in terms of total bay function.

Ten intertidal stations were extensively sampled on the shores of Gouldsboro Bay. Those stations were grouped into four regions of the bay from its outer to inner reaches (Fig. 19), and at each station lower, middle and upper intertidal were sampled with $1/16m^2$ quadrats. The patterns of biomass and demography of the dominant primary producers and the macro invertebrates were determined from those samples. Tables 2&3 show the algal community structure in terms of algal groups, or habit forms, and the distribution of biomass within those groups. As can be seen from the table, the biomass is concentrated in algal group 5, the leathery macrophytes. Within the bay intertidal, the rockweed Ascophyllum nodosum heavily dominates this group in terms of biomass (Table 3; Fig. 61), and it is the biomass and demography of this algae that we will concentrate on in this report.

The age and biomass of Ascophyllum steadily increases up the bay (Fig. 60; Table 4). In addition, Ascophyllum productivity, as measured by weight increase of growing tips, also markedly increases up the bay (Fig. 60). In general, the trend in growth from the outer to the inner regions of the bay was one of a reduced number of growing tips per unit area of substratum but an increase in growth rate per tip. The number of tips per/kg also decreased moving up the bay. The rate of biomass accumulation for the summer increased up the bay, as did the net annual biomass accumulation. The latter increased more slowly than the former.

Table 2 Algal functional groups as used in benthic analysis

	FUNCTIONAL GROUP	REPRESENTATIVES	HABIT	ANATOMY cross-section	GRAZING DIFFICULTY
1	MICROALGAE	• diatoms blue-greens	50µm	50µm	
2	FILAMENTOUS ALGAE	*Cladophora* *Ectocarpus* *Acrochaetium*	1mm; 300µm	50µm	
3	FOLIOSE ALGAE	*Ulva* *Porphyra*	5cm	40µm	
4	CORTICATED MACROPHYTES	*Bryothamnium* *Chondria* *Acanthophora*	5cm	250µm	
5	LEATHERY MACROPHYTES	*Laminaria* *Fucus*	50cm; 10cm	200µm	
6	ARTICULATED CALCAREOUS ALGAE	*Halimeda* *Corallina*	1cm	500µm	
7	CRUSTOSE ALGAE	crustose corallines *Ralfsia* *Peyssonelia*	3cm	50µm	

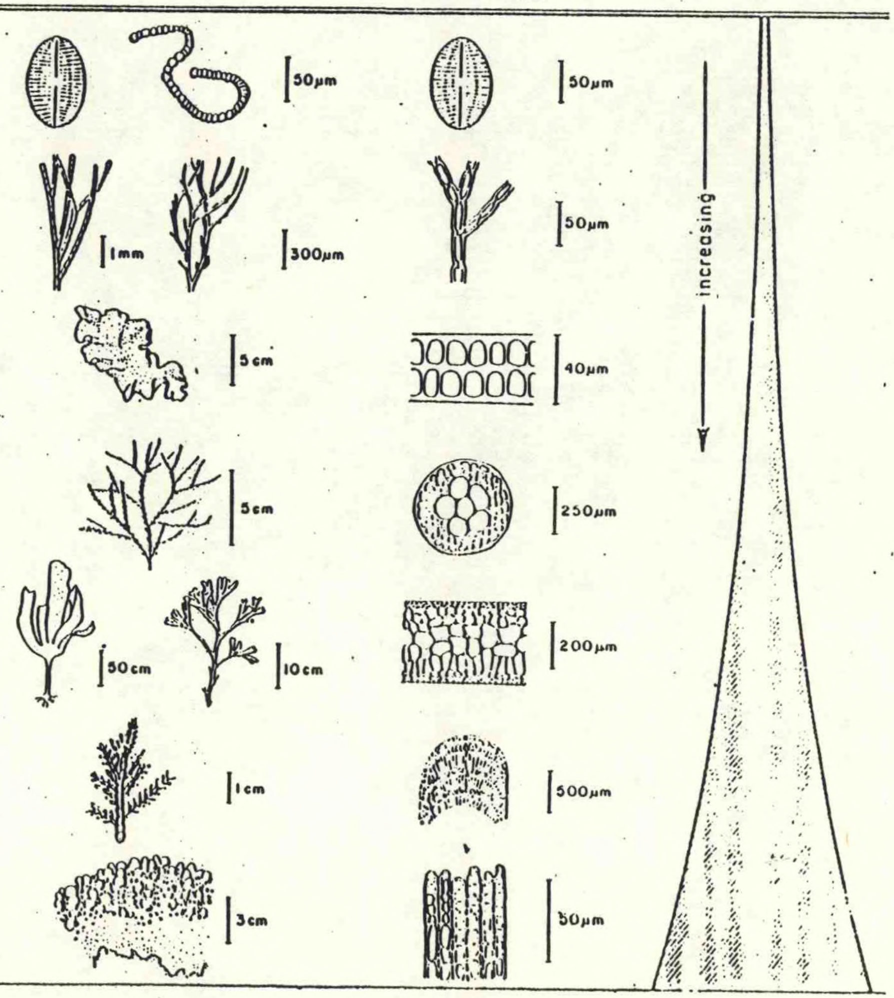


Table 3 Algal biomass (g) of the hard bottom benthic communities of Gouldsboro Bay

Depth		Intertidal High		Intertidal Middle					Intertidal Low						2.5m				5m				10m			
Algal Groups		3	5	1,2	3	4	5	6,7	1,2	3	4	5	6	7	1,2	3,4	5	7	1,2	3,4	5	7	1,2	3,4	5	7
Bay Location	Sta																									
	7			145	145	280	13,420	0	167	1926	3098	3182	58	2	31	73	10,323	16	285	2136	11,819	40	72	54	142	120
	8		ND	112	136	551	11,651	0	41	118	2265	5067	7	1	37	86	12,144	16	224	448	10,528	118	33	8	210	118
Outer	x			128	140	416	12,536	0	104	1022	2672	4124	32	1.5	34	80	11,233	16	255	1292	11,174	79	52	31	176	119
	sum					16,965						4955.6					11,363									
	11			4.3	0	91	22,605	0	51	0	1020	11,606	0	25	420	2280	3300	86								
Mid-Outer	25		ND	3.3	0	98	10,841	0.9	37	0	745	12,849	12	49	183	527	1582	144	2	9	207	96				
	23			56	0	203	24,524	23	14	0	434	15,609	0	11												
	x			21.2	0	131	19,323	81	34	0	733	13,355	4	28	302	1404	2441	115	2	9	207	96				
	sum					19,483						14,151					4262									
	13		ND	129		47	38,760	0	0	0	198	13,990	0	17												
Mid-Inner	21		14,560	36		195	24,574	0	11		415	16,190	0	1												
	x			82		121	31,667	0	6	0	306	15,094	0	9												
	sum		14,560				31,870					15,415														
	15	285	8117	0		68	50,514	0	7		288	21,867	1	20												
Inner	19	2300	8627	24		84	68,313	0	7		31	20,159	0	0												
	17	0	31,760	61		197	34,898	18	9		376	23,473	0	54												
	x	1185	16,168	42		116	51,242	6	8		232	21,833	.3	25												
	sum		17,363			51,624						22,098														

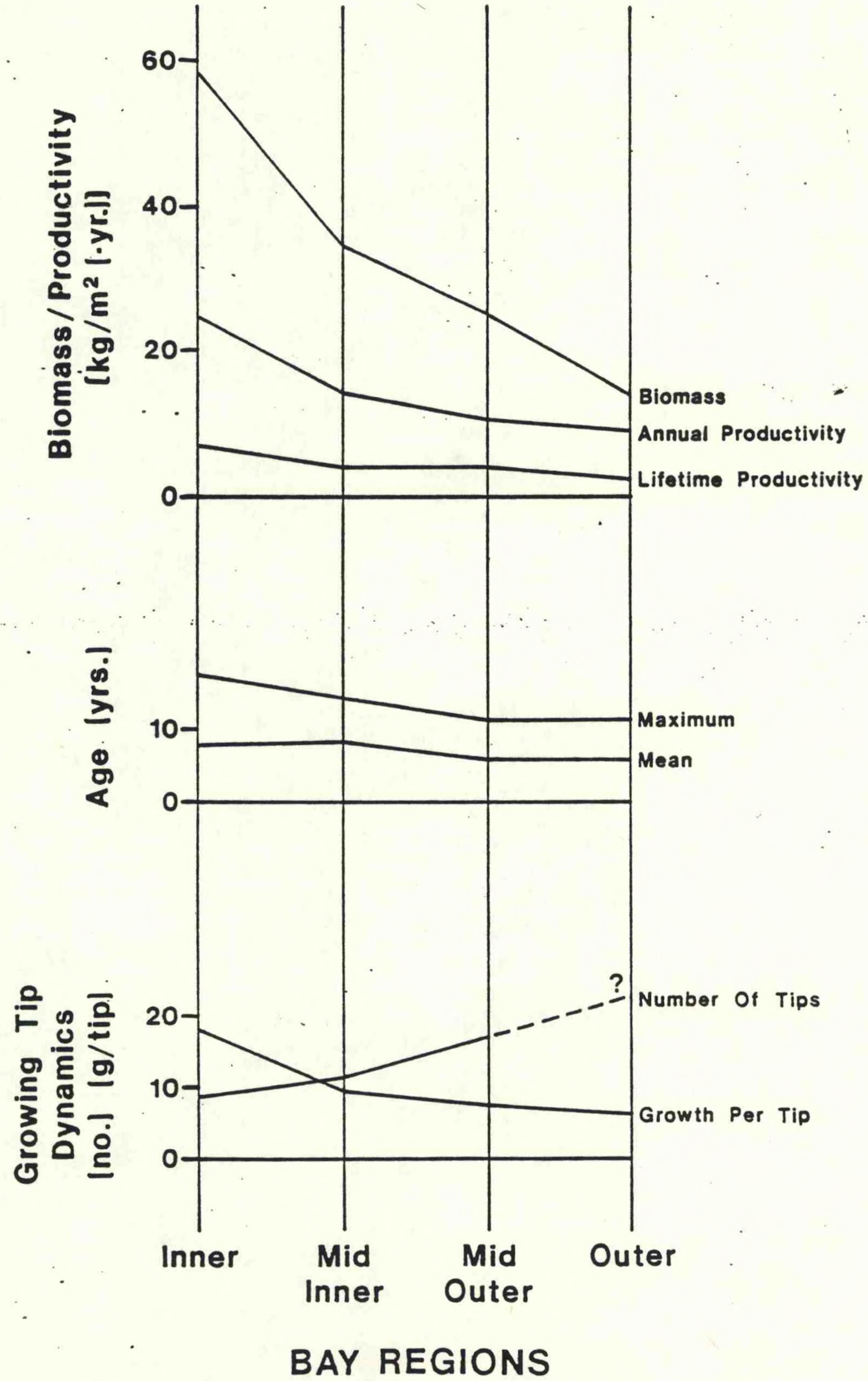


Figure 60. Biomass and productivity (harvest) of Ascophyllum nodosum in Gouldsboro Bay.

Table 4 Demography of *Ascophyllum nodosum* in Gouldsboro Bay, Maine. Mid intertidal zones.

Regions (stations)	A Biomass (kg/m^2)	B Age (yrs) max	C mean	D Growing tips ($No./m^2$)	E Growth per tip (g/yr)	F Annual Prod. (ExD) (kg)	G Annual Prod. (Direct Weight) (kg)	H Tips per biomass (No./kg)	I Prod. per biomass (G/A) (kg/kg·yr)	J Amount of total biomass *Ascophyllum* (%)
Outer (7,8)	12.5	12	6.2	ND	0.72	ND	9.8	ND	0.78	73.7
Mid Outer (11,23,25)	19	11.7	6.0	17,008	0.8	13.6	13.0	667	0.68	97.5
Mid Inner (13,21)	32	15	8.2	12,032	1.04	12.5	13.2	349	0.41	99.4
Inner (15,17,19)	51	15.3	8.2	10,096	1.8	18.2	22.8	173	0.44	99.3

The trend in productivity increasing up the bay is unexpected since both water motion and light penetration (turbidity) decrease in that direction. Also, both phytoplankton productivity and subtidal benthic productivity decrease from outside to the inner reaches of the bay. It is likely that the "inverse" pattern we see is more the result of disturbance than it is a true productivity gradient.

Constant wave induced disturbance including loss of plant parts, is considerably more important on the outer portion of the bay than it is in the more protected areas. The breaks tend to occur on the distal portions of the plant which facilitates branching as they heal their wounds. This probably causes the increased number of tips per quadrant and tips per unit biomass. Experimental study is desirable to establish the following. At the moment it is a working hypothesis.

Ascophyllum plants live longer in the inner reaches of the bay. As a result, they grow to a larger size. Since all of the surface of the plant is photosynthetic, and little increase in girth occurs, increased size provides more photosynthates for growth at the tips. Crowding and shading result in a proportionally lower productivity per unit biomass (i.e., a four times increase in biomass only doubles the total productivity - Table 4). Thus, the complex growth form and shape of Ascophyllum is well-suited for maximizing the productivity potential of the intertidal in quiet waters. Unlike the kelps, it is not capable of handling intense wave action as it grows to larger sizes.

Wave induced disturbance decreases up the bay, but herbivore abundance, size and diversity increases, probably as a result of reduced wave action (Figs. 62, 63). However, herbivore abundance, size and diversity is somewhat misleading in that the most abundant herbivores in the intertidal (Littorina littorea) are incapable of grazing Ascophyllum. Littorina littorea is effective at removing fouling epiphytes and other functional groups of algae. In effect, the herbivores

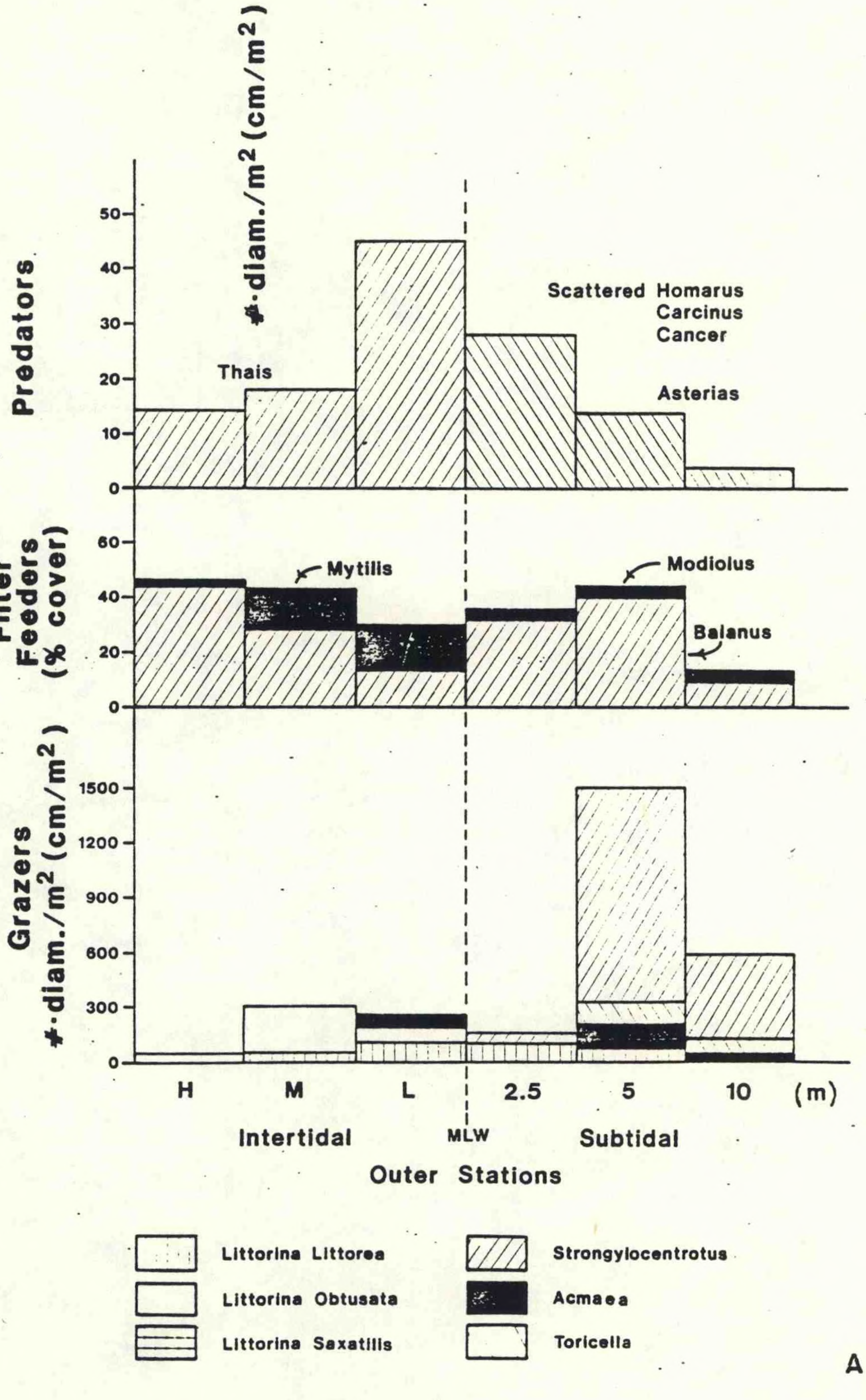
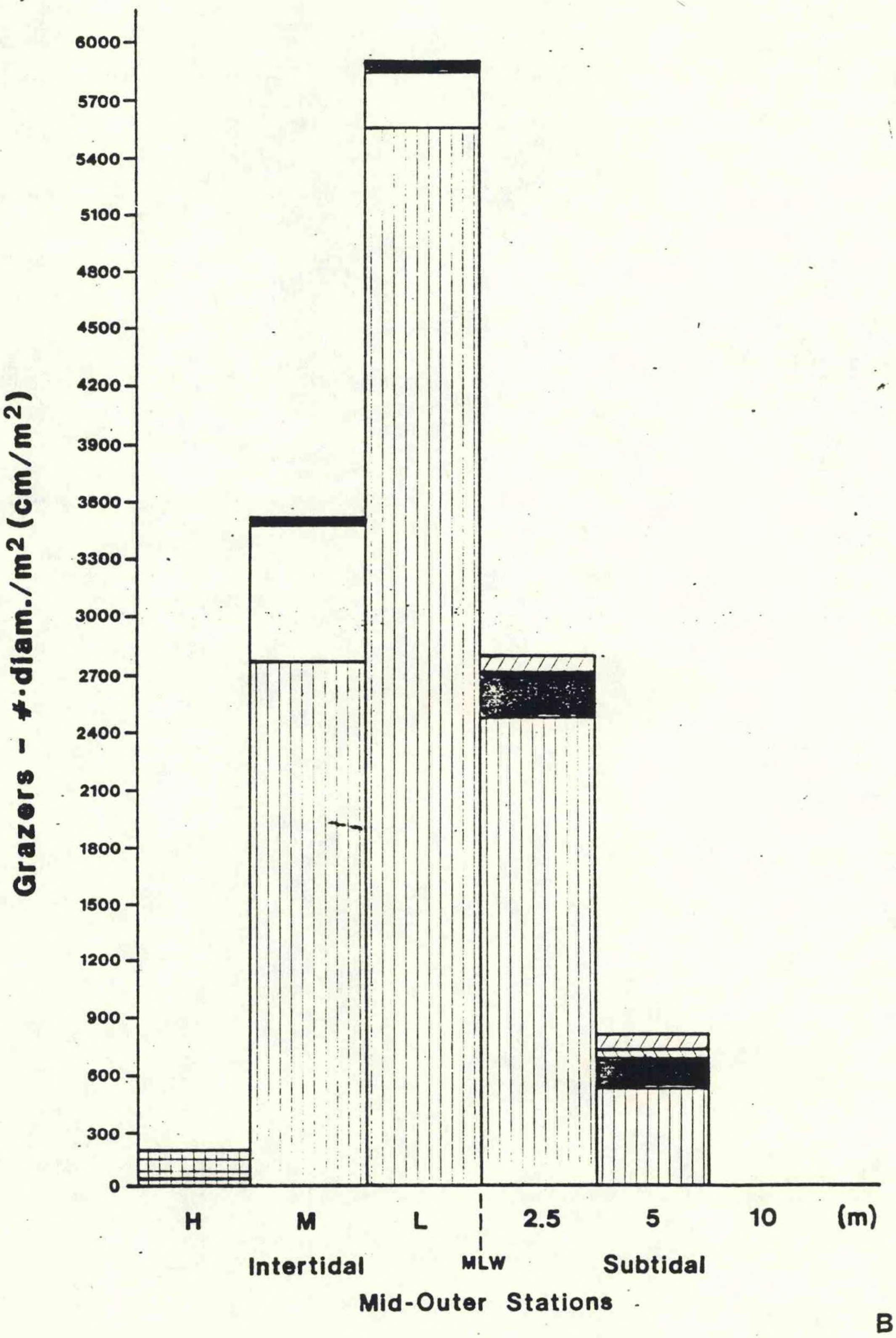
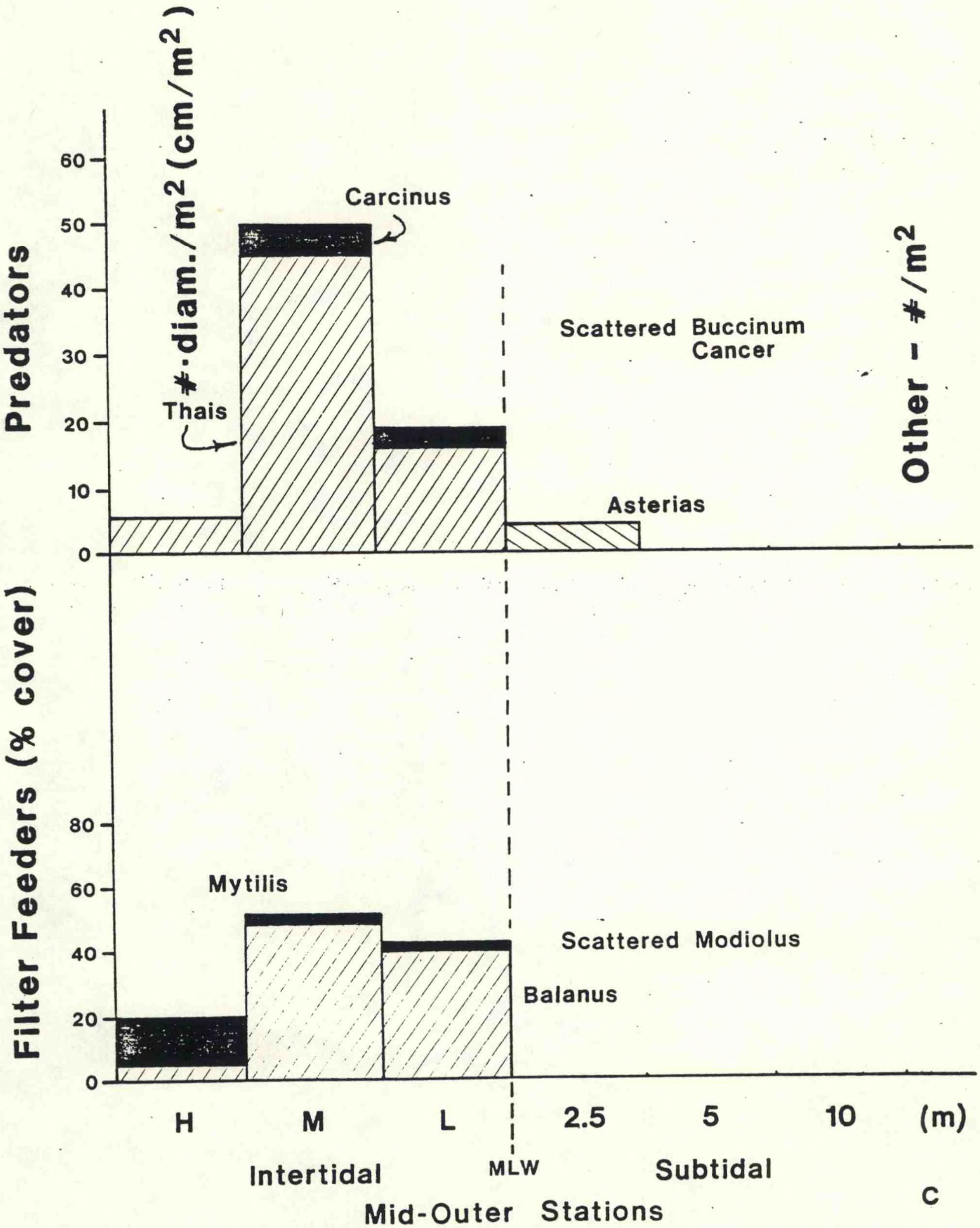


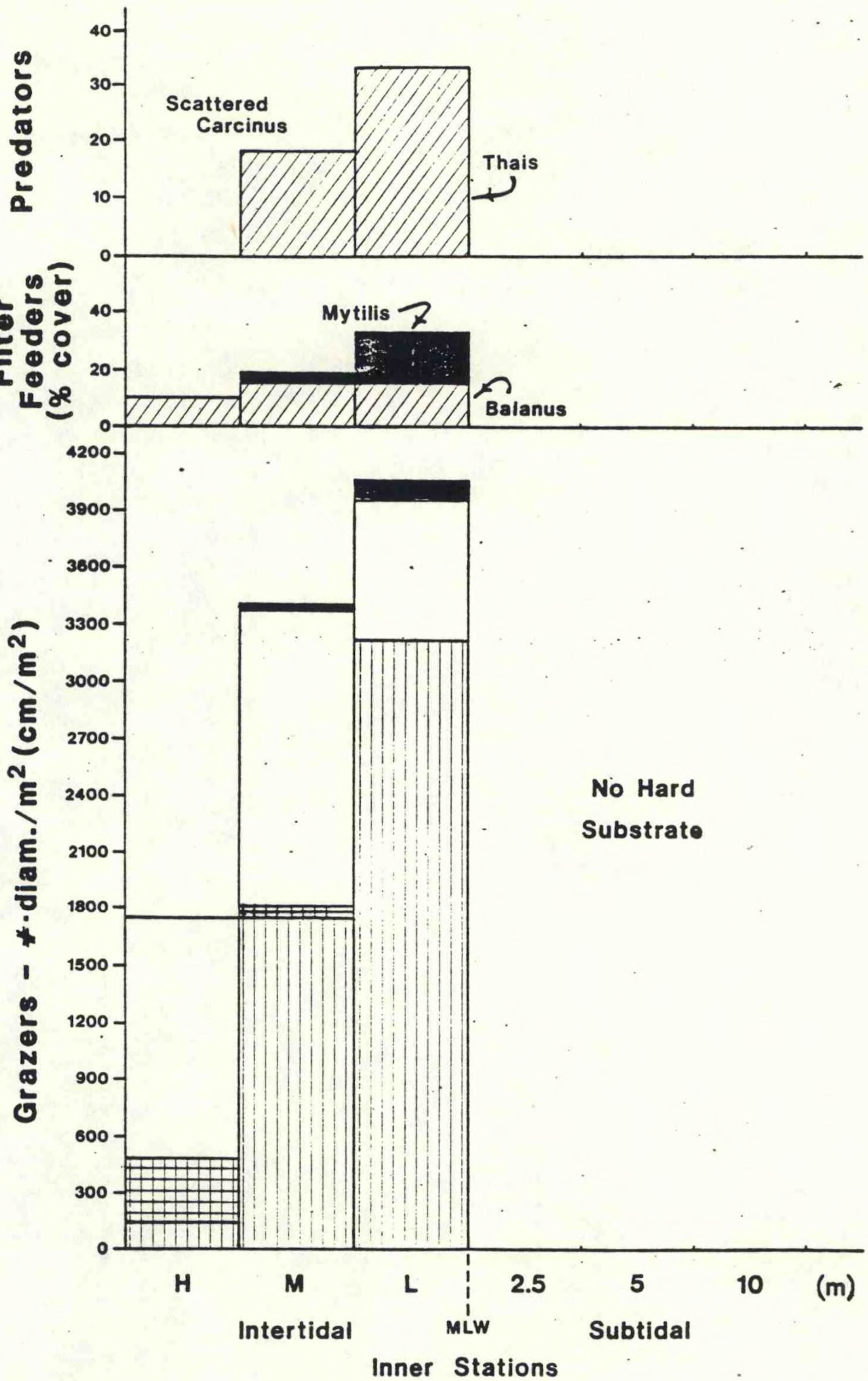
Figure 63. Invertebrate populations, rocky intertidal and subtidal of Gouldsboro Bay.



Grazers - #·diam./m² (cm/m²)
6000
5700
5400
5100
4800
4500
4200
3900
3600
3300
3000
2700
2400
2100
1800
1500
1200
900
600
300
0
H
M
L
2.5
5
10
(m)
Intertidal
MLW
Subtidal
Mid-Outer Stations

B


Predators
#·diam./m² (cm/m²)
Other - #/m²
60
50
40
30
20
10
0
Carcinus
Thais
Scattered Buccinum
Cancer
Asterias
Filter Feeders (% cover)
80
60
40
20
0
Mytilis
Scattered Modiolus
Balanus
H
M
L
2.5
5
10
(m)
Intertidal
MLW
Subtidal
Mid-Outer Stations
C


Predators
Scattered Carcinus
Thais
Filter Feeders (% cover)
Mytilis
Balanus
Grazers - #·diam./m2 (cm/m2)
No Hard Substrate
H
M
L
2.5
5
10
(m)
Intertidal
MLW
Subtidal
Inner Stations

D

reduce interspecific competition from fouling algae, which may additionally contribute to the increased productivity of Ascophyllum towards the inner reaches of the bay.

Our discussion has centered around the dominant plant Ascophyllum nodosum. The rockweed Fucus vesiculosus and a variety of filamentous and leafy green, brown and red algae, as well as a scattering of several red crusts, also occur in the intertidal, particularly in the more exposed areas. It seems likely that Ascophyllum possesses a decided growth advantage over these other species, but is slow to recover and recolonize from a damaged or removed state.

Based on productivity data relative to algal group from the literature (Doty, 1971), we have calculated a potential productivity for each algal group for each station and depth zone. The results, based on the standing crop for each group (Fig. 64), suggests that at all intertidal station depth zones, except the outer region, Ascophyllum provides over 95% of the total primary productivity. At the outer station, leafy and fleshy small macrophytes dominate the lower intertidal. As a result, the proportion of the total productivity of outer stations attributable to Ascophyllum is just under 70%.

It is our intention to examine the potential productivity of filamentous, leafy and small macrophyte algae in more detail during the coming summer. However, at this writing it would appear that most of the intertidal productivity of Gouldsboro Bay is centered in the algae Ascophyllum, and our preliminary discussion of energy flow in the bay system is based on this information and our extensive understanding of this species. Whether it matches the magnitude of primary production in Ascophyllum or not, the trophic pathway of small algae/litterinids/dog whelks/birds in the intertidal is an interesting one and will be focused on in the future.

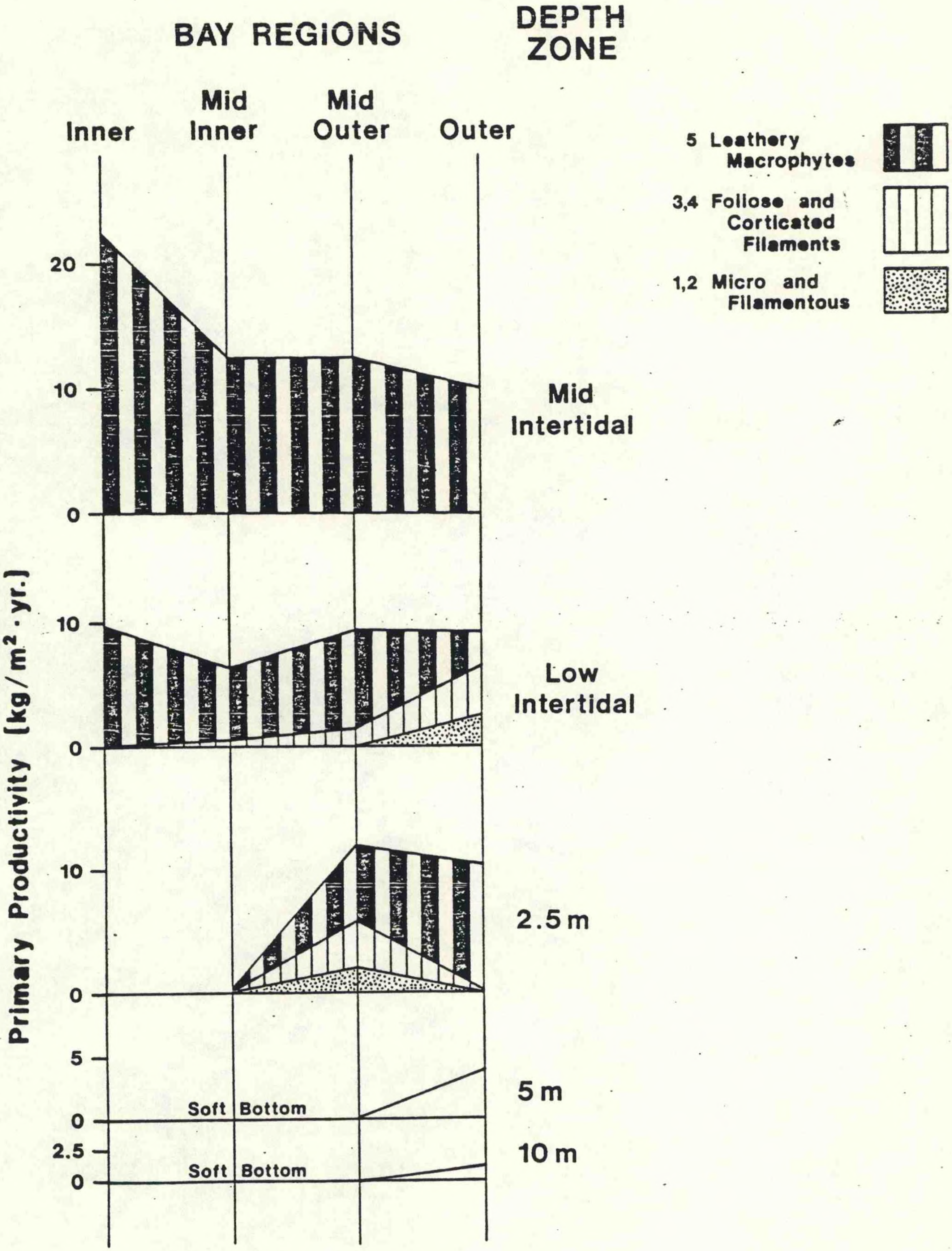


Figure 64. Estimated productivity of filamentous and foliose algae of the rocky inter- and subtidal.

Mud Flats

No attempt has yet been made to study the animal community structure, or the secondary productivity of the mud flats of Gouldsboro Bay. A major effort will be undertaken on the animal communities of soft bottoms during the summer of 1982. Our emphasis here is on primary productivity. The muddy intertidal (Fig. 65) occupies most of the upper reaches of the bay and, next to open water and subtidal soft bottom, is areally the largest bay community at about 15% of total bay area. Nevertheless, in spite of the large area, because of the nature of the substrate and the severe winter conditions, primary productivity is quite low on the flats. The percentage of organic material in the upper layers of the flats is quite high. Our analyses are underway at this time and preliminary results show that it is at least over 5% and probably closer to 10%. As discussed at several points in this report, much of this organic material is undoubtedly detritus derived from macroalgal breakdown.

Algae (*Enteromorpha* and diatoms) occur as primary producers on these flats. However, algal productivity is greatly outweighed throughout the summer by that of *Zostera marina* (eel grass) (Figs. 65, 66). *Zostera* colonizes the mid-zone of the mud flats during the spring and grows through the summer. By late summer and early autumn, the flats have a dark green color from the air, and the *Zostera* at low tide provides an almost continuous cover over the mid-tide range of the flat. During January, shore fast ice along the flats gradually builds seaward, eventually covering most of Joy and West Bays during cold winters (Figs. 34, 37). On very cold nights, at low tide, the *Zostera* is frozen into the ice sheet. With tide rise, the plants are pulled from the mud. By early spring, as the ice melts off, no trace can be found of *Zostera* on the flats. Thus, these flat communities are a highly productive component of the bay, especially considering their large area. However, growth of standing crop is renewed each spring, the plants are yearlings and enter the detritus food chain as drift along the shore (see below, Primary Productivity). Mud flats are very likely dominantly consumer communities living on the primary productivity of the water column and the rocky intertidal.

Large mussel bars (Figs. 67, 68) occur in Joy Bay and to a lesser extent West Bay. Although these features form the smallest biological community recognized in this study, they are particularly interesting both because they are the only organisms that significantly change the substrate aspect of their environment (like tropical reefs) and because of their potential economic value.

Marshes

Areally, marshes are a relatively small component of Gouldsboro Bay, as they also are for most of the Maine coast. However, they form a particularly interesting community and will be studied intensively during the summer of 1982. The largest marsh in Gouldsboro Bay is Grand Marsh, at the southern end of West Bay (Figs. 30, 31). Fringing marshes, a few meters wide, are abundant around the upper reaches of West and Joy Bays (Fig. 49), and Little Marsh is developed at the northeastern corner of West Bay (Fig. 69). However, these structures are very small in area as compared to Grand Marsh.

Subtidal

Hard Bottoms

Next to a rocky, algal-covered intertidal, colder shores of both the northern and southern hemisphere are characterized by "reefs" of very large algae, typically kelps. Although very limited in areal coverage, the kelp community is known for its high productivity and its high diversity of organisms (Figs. 70 -72).

Typically in the eastern Gulf of Maine, the subtidal kelp community is limited by a lack of abundant hard substrate in the protected parts of bays. However, even where substrate is not a factor, kelp extends from low water springs to various depths ranging from a very few meters to 15-20m. The lower limit appears to be generally controlled by urchin grazing, which in turn is principally limited in shallow water by wave action. In the large bays, such as Frenchmans, Blue Hill, and Penobscot, where substrate is not limiting and open ocean swell is virtually absent, urchin grazing limits the kelp community to very shallow depths and often removes it entirely. When the kelp is absent, a rocky bottom, at depths of 15-30m, depending on turbidity or often distance offshore, is occupied by a coralline-urchin community which often contains abundant mussels (Modiolus modiolus), starfish (Asterias forbesi) and sea cucumbers (Cucumaria frondosa). Corallines are very low level primary producers as compared to kelps. Urchin abundance is probably limited to some degree by crab and lobster abundance. It is likely that heavy fishing of these crustaceans has some influence on the productivity of subtidal rocky shores.

There is considerable depth zonation among the larger algae in the kelp community (Figs. 70-72). Alaria esculenta, a mid-ribbed species, is the dominant plant in the upper meter on wave beaten shores; it is often absent in bays. Laminaria saccharina and Laminaria longicuris are the characteristic kelps of the mid-zone. At the lower end of the zone, the mid-ribbed and perforated Agarum cribosum, tends to dominate. The latter is quite resistant to urchin grazing and probably contains noxious compounds.

Subtidal algal biomass, productivity and herbivore population structure throughout the rocky areas of Gouldsboro Bay were studied in this project. The subtidal zone showed a number of demographic trends opposite to those found on the adjacent intertidal zone. Although scattered subtidal rocks and patches of kelp occur up the bay into the mouths of both Joy and West Bays, as a continuous subtidal community, the kelp (or its replacement coralline) community is largely limited to the mid-outer and outer regions (Fig. 53). Both inland along the bay and with depth, on the outer shore, the total plant biomass (Table 2) and kelp productivity decrease (Fig. 64). This is to be expected as a result of light limitations due to increasing depth and increasing turbidity.

At the outer stations, there is a marked increase in abundance of the green urchin with depth, very few animals at 2.5m and a number of larger animals at 5m and to a slightly lesser extent at 10m (Fig. 63A). At the mid-outer stations, only a few animals were found in the subtidal zone. Thus, it would seem that, unlike in the larger bays and in more exposed locales, turbidity and substrate are far more critical in limiting the kelp community than Strongylocentrotus droebachiensis.

As discussed below, it is critical to extend this project into the more exposed waters lying off Gouldsboro Bay. This will provide an opportunity to examine in detail the urchin/kelp interaction and particularly how it relates to coastal productivity.

Soft, Shelly and Armoured Bottoms

Primary productivity is limited on all these bottom types. Although grab samples have been taken, and sediment analysis is now underway, intensive biological study will not be carried out until the summer of 1982.

In areas of strong current, primarily Eastern Way, at the mouth of the bay and off Rogers Point at the mouth of Joy Bay, fine sediments, sand and silt are swept away by water turbulence and flow. These areas are characterized by abundant pebbles, covered with coralline algae and by deposits of mollusc shells. Although an active area for sea scallops, armoured bottoms are limited in area in Gouldsboro Bay (Fig. 73). A related area, lying in a "wave shadow" of the islands, lies at the southwestern corner of the bay. Small, broken shells, particularly fragments of barnacles from the wave exposed islands at the mouth of the bay, collect in large quantity in this area. The sand dollar Echinarachnius parma is abundant on this bottom (Fig. 74).

A very large part of the bay is occupied by a fine-grained, almost soupy mud, a sandy silt with limited animal populations (Fig. 75). Although this bottom has been cored and grab sampled, no effort has been yet made to work up animal community structure.

The percentage of organic material in the bottom sediments increases from less than 2% near the mouth of the bay to 3-5% in the mid-upper bay, finally reaching 5 to over 10% in the mud flats. Since the primary source of that organic content in primary productivity lies in the mid and upper bay, dropping off markedly in Joy and West Bays, it seems highly likely that there is a shoreward transport and retention mechanism for fine organic materials as well as fine inorganic sediments.

Planktonic

Investigations of the phytoplankton, primarily diatoms, of Gouldsboro Bay (Fig.76) are underway and will be reported on at a later time. Primary productivity studies in the water column are discussed below. In this section we will discuss studies in zooplankton populations currently underway.

Although quantitiative studies on Gouldsboro Bay zooplankton have only begun, preliminary observations show the same basic generic percentages previously published for the Gulf of Maine (Shermann, 1963). Bigelow (1926) and Fish and Johnson (1937) also indicated that copepods were the most abundant and comprised the greatest volume of zooplankton occurring in the Gulf of Maine waters. These

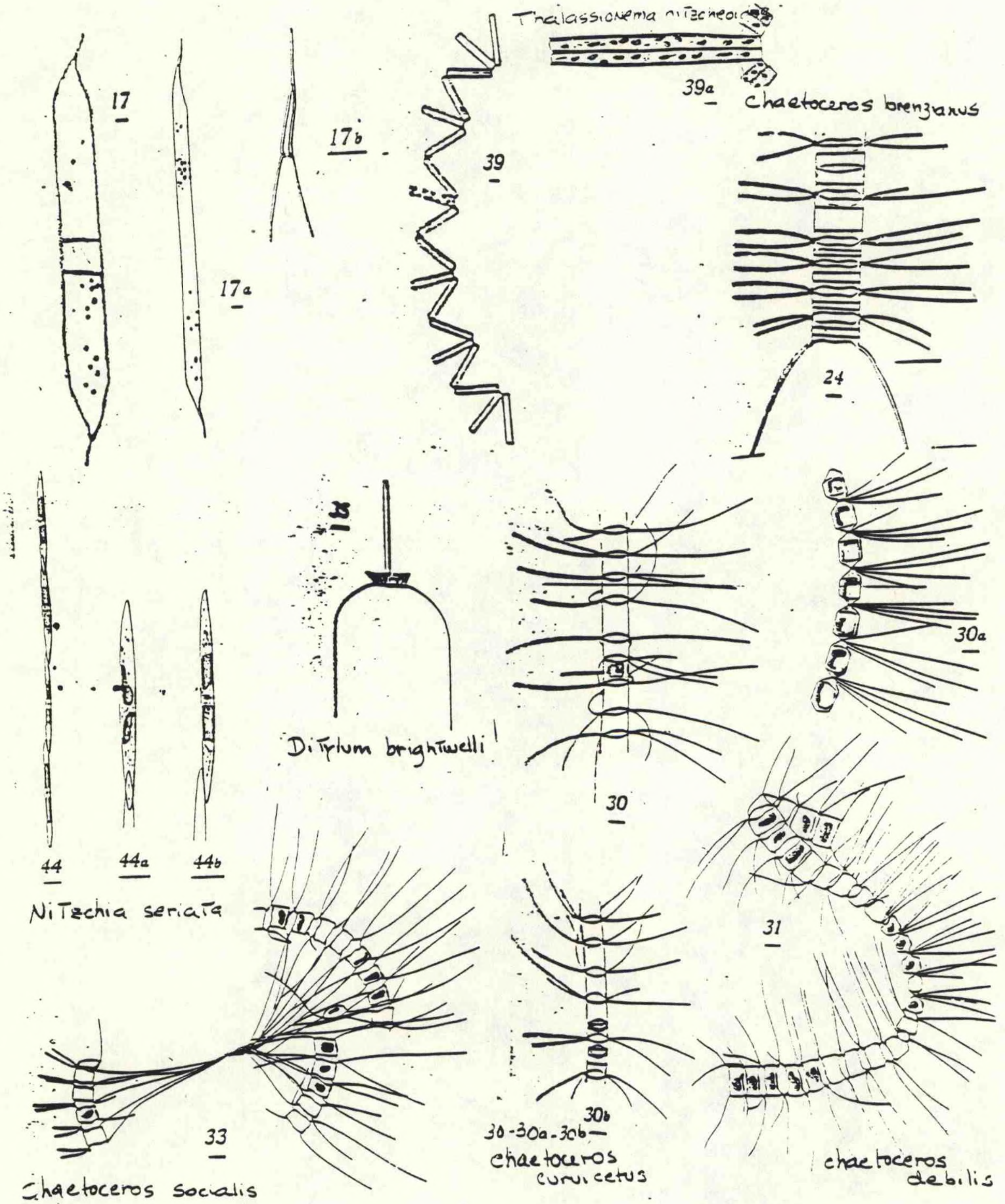


Figure 76. Dominent planktonic diatoms of inner Gouldsboro Bay.

investigators also showed that volumes of these zooplankton were consistently higher west of Penobscot Bay than east of this region. However, while the copepods were the dominant group throughout the summer and early fall, the cladocerans, very abundant in early summer, decrease in numbers and are practically absent by the early fall. The spring and summer decline in percentage composition of copepods is associated with the increase of other abundant zooplankton groups, particularly meroplankton. The abrupt rise in decapod larvae in spring and eggs of many invertebrates during the summer indicate the breeding period of many invertebrate species during warmer months.

Although studies of zooplankton from a line of six stations extending up the axis of the bay are underway, only the outer and innermost stations are compared and contrasted here (Tables 5, 6; Figs. 77, 78).

The summer/fall zooplankton distribution in Gouldsboro Bay follows a typical estuarine pattern, despite only very minor temperature and salinity gradients, as discussed above. The community at the mouth of the bay is comprised of common shelf-dwelling copepods and the cladocerans _Evadne_ and _Podon_. In the late summer of 1981, this was in agreement with oceanographic conditions, a salinity of 32.0% and a temperature of 13.5°C, typifying shelf water north of Cape Cod. The presence of the cold-water shelf calanoids _Pseudocalanus minutus_, _Paracalanus parvus_, _Tortanus discaudatus_ and _Calanus sp._ quite near the mouth of the bay indicates limited mixing of shelf and bay communities. The cyclopoid _Oithona spinirostris_ is an offshore tropical transient probably carried in from the Browns Bank area, along the southwestern coast of Nova Scotia by the intrusion of oceanic water. It is not a typical member of this shelf community.

Of the 12 species of calanoid and cyclopoid copepods that occur at the mouth of the bay, only seven are found in the bay proper. Also, in the headwaters of the bay, a shallow-water estuarine community is developed. In addition to the

Table 5 Species of copepods found outside Gouldsboro Bay and at other offshore northwestern Atlantic localities.

Gouldsboro Bay August - October 1981 44° 25' N	Gulf of Maine 42° 43'N-44°34'N	Woods Hole 41° 30' N
Offshore (station control)		
<u>Calanoids</u>		
Acartia hudsonica	March - June	October - February
Acartia longiremis	March - May	January - May
Calanus spp *1	March - August	December - June
Centropages typicus	Sept.-Nov., March-May	August - May
Centropages hamatus	March-November	June - February
Paracalanus parvus	x	x
Pseudocalanus spp *2	July - August	December - May
Temora longicornis	x	October - December
Temora turbinata	Sept. - November	October - August
Tortanus discaudatus	March - August	June - October December - March
<u>Cyclopoids</u>		
Oithona similis	March - September	August - January
Oithona spinirostris	x	January - February May - June October - December

*1 only juveniles

*2 validity of genus still in question

Table 6 Species of copepods occurring within Gouldsboro Bay and other Gulf of Maine bays.

Gouldsboro Bay August - October 1981 44° 25' N	Penobscott Bay 44° 24' 05 N	Passamaquoddy Bay 45° N
Inshore (station #5)		
<u>Calanoids</u>		
Acartia hudsonica	March - December	May - November
Acartia longiremis	October - March	November - January
Centropages typicus	November - January	July - January
Centropages hamatus	March - November	October
Eurytemora americana	x	x
Eurytemora affinis	March - December	x
Pseudodiaptomus coronatus	x	July - February
Temora turbinata	x	August - January
Temora longicornis	March - January	x
<u>Cyclopoids</u>		
Oithona similis	YR *2	August - January
Oithona spinirostris	x	x
Oncaea sp.	x	x
Saphirella sp. *1	x	x

*1 validity of genus still in question

*2 YR = all year round

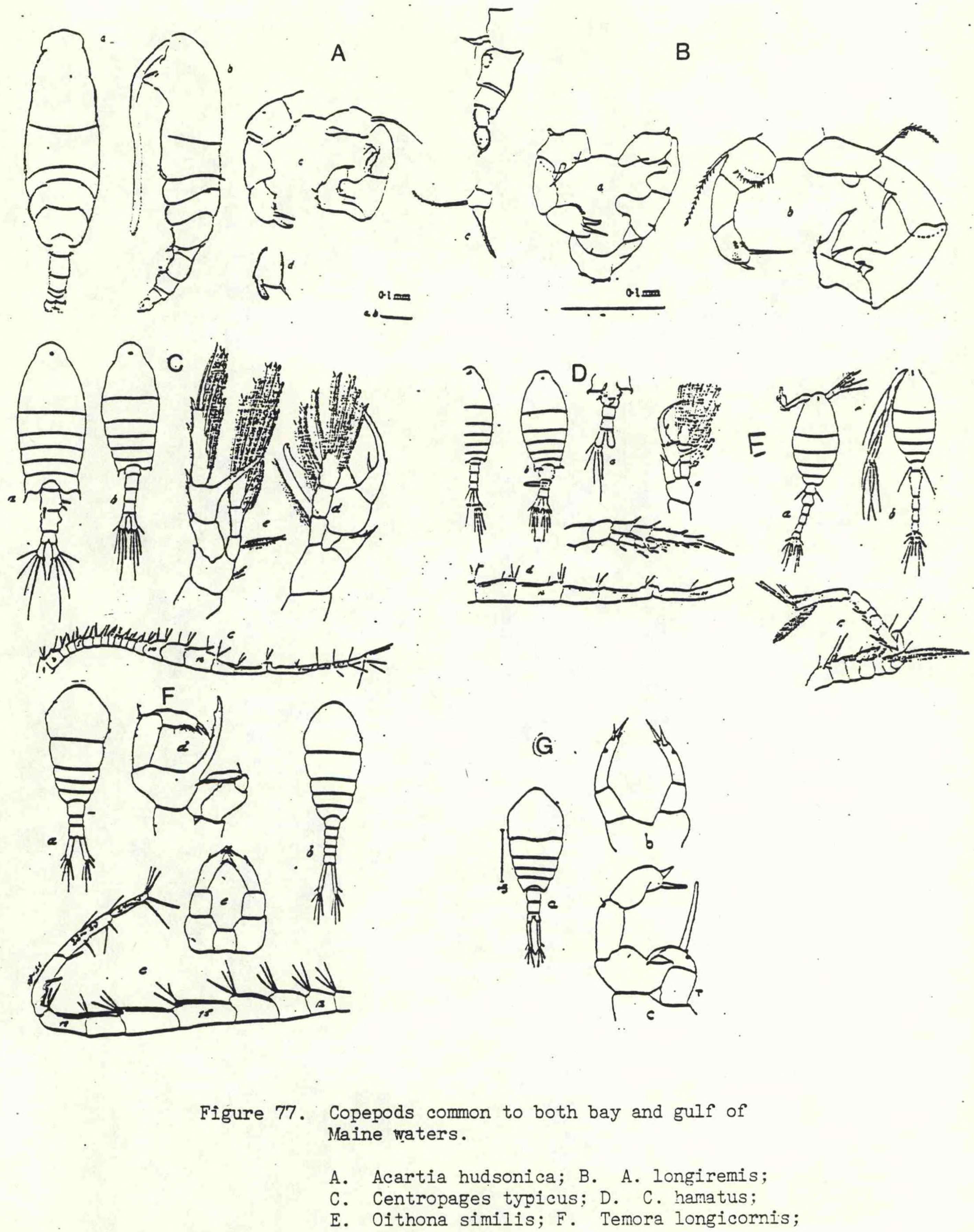


Figure 77. Copepods common to both bay and gulf of Maine waters.

A. Acartia hudsonica; B. A. longiremis;
C. Centropages typicus; D. C. hamatus;
E. Oithona similis; F. Temora longicornis;
G. T. turbinata.

From Bradford, J. (1976); fig. A-B, Wilson, C.B. (1932); figs. C to G

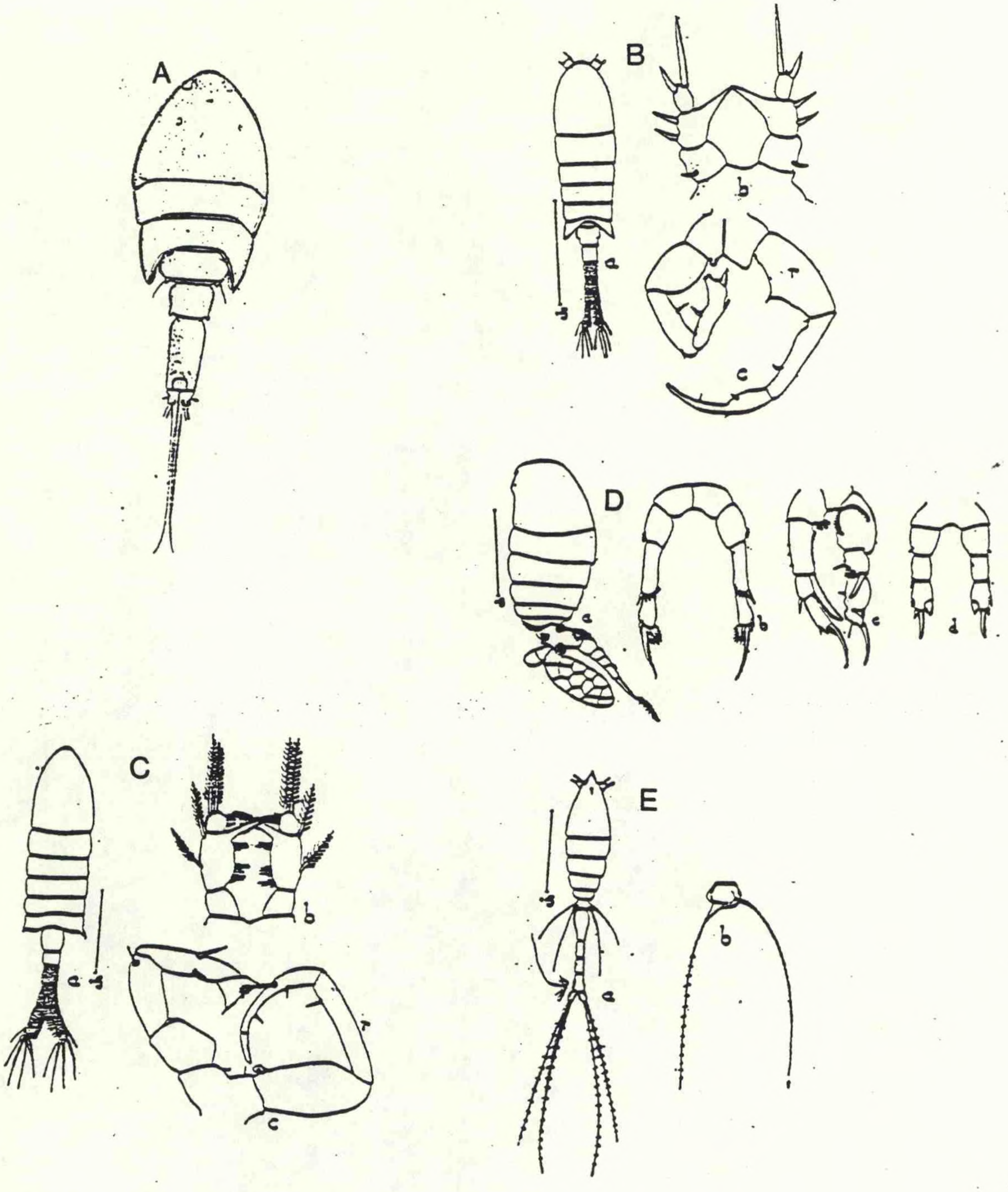


Figure 78A. Copepods occuring only within bay waters of Gouldsboro Bay.

A. *Saphirella* sp.; B. *Eurytemora affinis*; C. *E. americana*; D. *Pseudodiaptomus coronatus*; E. *Oithona apinirostris*.

From Wilson (1932).

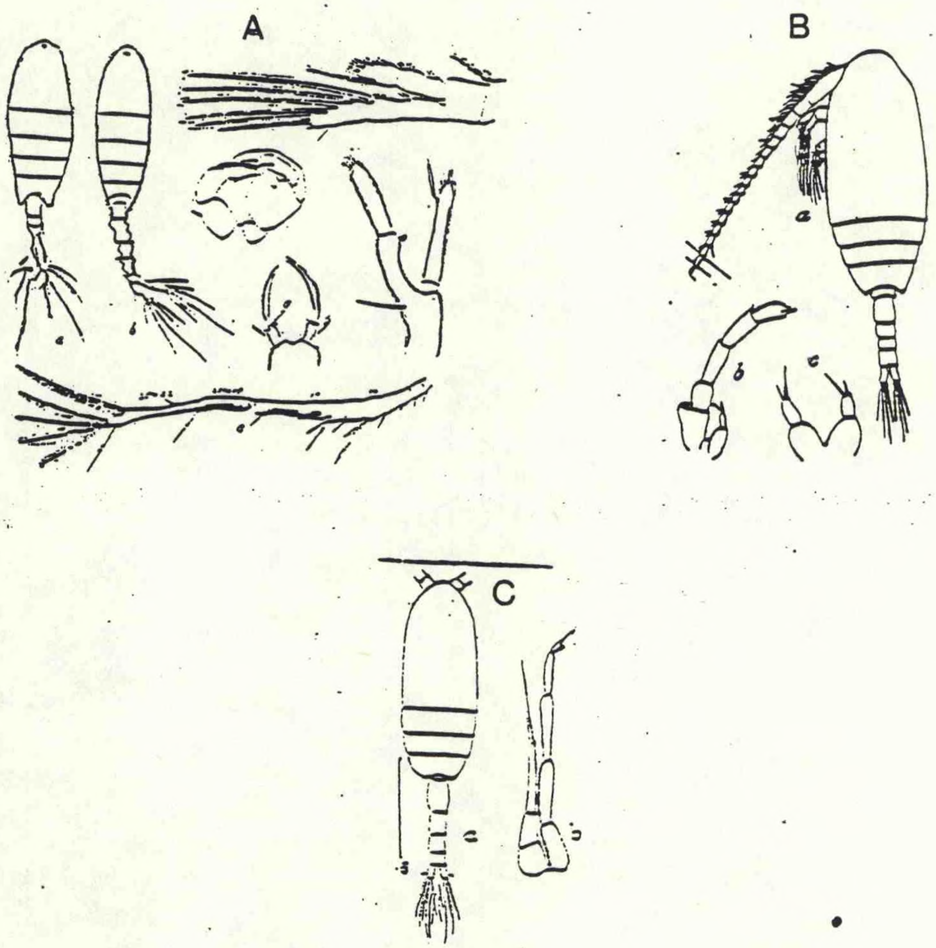


Figure 78B. Copepods occuring in inshore waters outside of Gouldsboro Bay, but not within the bay.

A. Tortanus discaudatus; B. Paracalanus paruus; C. Pseudocalanus minutus.

From Wilson (1932).

seven species of copepods common to the offshore station, five species are unique to the upper stations of the bay. The euryhaline calanoids *Eurytemora affinis*, *E. americana* and *Pseudodiaptomus coronatus* are able to establish populations within the bay, possibly because they are not in direct competition with the shelf species. They are able to survive the physical and chemical conditions of the shelf but cannot feed as efficiently as shelf species. Of the three cyclopoid species found in the bay, only *Oithona similis* is common to the offshore station. *Oncaea sp.* and *Saphirella sp.* are unique to the inshore stations. *Saphirella* is of particular interest because the validity of the genus is still in question. The two pairs of unsegmented swimming legs instead of the usual five pairs, and the unsegmented abdomen, suggest immaturity. Yet these specimens lack the softness of the cuticle characteristic of juveniles. Nicholls (1944) suggests that *Saphirella* represents "the young form of *Hemicyclops*" due to similarity of the mouthparts. However, Gurney (1944) believes that this is unlikely due to the large size of most *Saphirella*. The specimens from Gouldsboro Bay average 1.5mm, and in normal free-swimming copepods the adult is about four times as long as the first copepodid stage. Most *Hemicyclops* do not exceed 1.5mm and it is unlikely that *Saphirella* could molt four times to the adult stage without increasing in size. In the most recent revision of the *Hemicyclops*, Gooding (1960) states that a lack of information on the morphology of the larval stages in the family Clausidiidae prevents an adequate evaluation of Nicholl's suggestion. An investigation of the possible hosts of *Hemicyclops* is now underway in Gouldsboro Bay at stations where *Saphirella* is most abundant.

Examination of plankton samples from August to October showed some seasonal differences in both shelf and inner bay stations. From August to September, the stations near the mouth of the bay are dominated by juvenile copepods and adult cladocerans. The cladocerans are nearly absent in October collections and are replaced by adult copepods. These adults will remain in the plankton until they become reproductively active the following spring. The inshore samples collected in August, in addition to juvenile copepods and cladocerans, contain a wide variety of invertebrate larvae. Larval clams, snails, polychaete worms and decapod crustaceans suggest that Gouldsboro Bay serves as nursery ground during the summer months. Whether this feature is part of the reproductive biology of the species in question (e.g., temperatures 2-4°C higher in summer may accelerate development; the greater abundance of organic detritus may provide more food) or is incidental to hydrographic factors forcing retention is as yet unknown. Samples taken in October are dominated by adult copepods, the breeding season having ended for most invertebrates.

The depletion of phytoplankton by zooplankton grazing during the late spring and summer is a common phenomenon in marine waters (Raymont, 1963) and probably is an important factor contributing to the growth of several species of zooplankton. However, grazing cannot be held completely responsible for the decrease in phytoplankton biomass since the development of copepods follows the peak of phytoplankton production with a time lag of about 2-3 months (Margalef, 1963).

The nutritive values of diatoms and dinoflagellates are generally high and are considered to be the most important food for herbivorous and omnivorous copepods (Ankaru, 1963). However, preliminary observations on the phytoplankton standing crop in Gouldsboro Bay show that these organisms are neither very diverse nor abundant. This has led to the hypothesis that the large herbivorous zooplankton community must be feeding mostly upon nonliving particulate organics in the water column, possibly on the breakdown products of drift macroalgae, the most abundant organic source in bay waters. The concentration of bacteria in sea water column would not be high enough to cover the demand of copepods, and since bacteria are not big enough to be retained by the collecting apparatus, they seem not to be significant as a direct food source. However, they may well be important secondarily in their attachment to organic particulates that are large enough for capture.

It has not yet been determined whether detritus is used effectively by herbivorous copepods as food or not. However, smaller planktonic animals are certainly important for predatory and omnivorous copepods. An attempt to establish a rough "food chain" per station is being carried out by observing the feeding habits of the zooplankton. According to Anraku and Omori (1963) there is a close relationship between the mouth parts and the feeding habits of copepods. In herbivorous species, the maxillipeds, second antennae mandibular palps and first maxillae are well-developed to produce a pair of "feeding swirls". In predatory species, the mouth parts have few setae. The first maxillae, second maxillae and maxillipeds are modified as prehensile appendages. The cutting edges of the mandibles have very sharp teeth. In omnivores, these appendages have a structure intermediate between those of the two previous types.

The inshore stations (Fig.78A) are dominated by typical filter-feeding "herbivorous" copepods rather than the more aggressive predatory animals. Filter-feeders vibrate their mouth parts to set up feeding currents, using setae to strain diatoms, small invertebrate larvae, and perhaps organic particulates from the water. Most filter-feeders found in Gouldsboro Bay are omnivores, but some species, such as Centropages sp., actually prefer an animal diet (Anraku and Omori, 1963). They most likely switch to herbivory only when invertebrate larvae are unavailable. The carnivorous tendency of Centropages allows for the development of a sufficient diatom population to support some of the less efficient herbivorous species.

Acartia spp. use their second maxillae to rake the water rather than setting up feeding currents. Conover (1956) suggests that Acartia is unable to compete with efficient filter-feeders and is basically confined to inner areas of bays and estuaries where phytoplankton and small animals (invertebrate larvae) are more abundant.

The offshore station (Fig.78B) shows a significant reduction in the population of Acartia. The more carnivorous Centropages spp and Pseudocalanus spp are the dominant animals. Tortanus discaudatus is found only here. Tortanus is a large predatory copepod that has abandoned all methods of filter-feeding. The mouth parts of these animals are characterized by a reduced number of setae and the presence of large spines for spearing prey. Tortanus discaudatus is known to eat adult copepods of Temora longicornis and Pseudocalanus spp, as well as members of its own species (Anraku and Omari 1963).

As discussed below, primary productivity markedly decreases from the mouth to the inner reaches of the bay. This feature does not correlate with the corresponding decrease of filter-feeding planktors into the bay and suggests the importance of organic particulate feeding.

Nektonic

Little has been said directly in this report about the nekton, primarily finfish and marine mammals. Herring are critical to the bay. They are fished from three weirs and the landings are discussed under utilization and treated in the preliminary systems analysis. Nevertheless, as near as we can determine at this time, Gouldsboro Bay is and has been traditionally a poor bay for herring. During the summer, a large breeding colony (100-150 animals) of the harbor seal Phoca vitulina occupies the ledges between Gouldsboro and West Bays. Seals are frequently seen in bay waters at all seasons of the year. A relationship between the seal colony and the poor herring fishery, as well as the general lack of other finfish in the bay, as discussed below, is inferred but cannot be established at this time. During the summer of 1982 extensive seal counts will be undertaken. The literature will then be used to assess the impact of these animals on finfish in the bay.

Although no formal analysis of finfish has yet been undertaken, it is quite apparent that the numbers and impact of these organisms (other than herring) is minimal in Gouldsboro Bay. An assessment of bay fish populations will be carried out during the summer of 1982.

PRIMARY PRODUCTIVITY

Benthic

The primary productivity of the major photic benthic communities in Gouldsboro Bay was determined by measurements of biomass increase in the dominant plants of those communities. Comparative measurements were also carried out by determining the quantity of chlorophylls and accessory pigments per square meter in each community.

The quantity of chlorophyll and accessory pigments for each community was determined by sampling macroalgae and *Zostera* from a wide variety of locales and analyzing them by calorimetric methods. Using the biomass data discussed above we were then able to calculate a mean photosynthetic pigment content per square meter for each community. These data are presented in table 7, along with a relative photosynthetic quotient based on light energy and pigment.

For macroalgal dominated communities, the percentages of total bay productivity provided by each community based on photosynthetic pigment is likely a reasonable estimate. Per unit quantity of pigment, planktonic cells are probably more efficient than macroalgae, and the primary productivity percentages for the plankton are probably too low.

Intertidally, *Ascophyllum nodosum* is the dominant plant on rocky bottoms. Its productivity was determined by counting the number of growing tips per square meter and measuring mean yearly elongation rates per tip. Branches of *Ascophyllum* produce one bladder per year and by cutting segments out and weighing them, a net yearly increase can be calculated. At each intertidal station, 75 yearly growth segments were weighed. Total rocky intertidal productivity was calculated by multiplying mean tip increase weight by the number of tips per square meter and then by the number of square meters of rocky shore in the bay.

Table 7

Chlorophyll concentrations and estimated primary productivity for Gouldsboro Bay biological communities

Community	($m^2 \times 10^6$) Area	(m) Mean Depth	(g) Pigment/ g/m^2	($uE/m^2/sec$) Light	($g \times 10^6$) Total Community Pigment	Proportional Productivity Light x Pigment	Community (%) Productivity
Intertidal							
Rocky	1.9	2	11.7	1200	22.2	1 (26640)	65.9
Mud Flat	3.5	2	1.5	1200	5.2	0.2	13.2
Subtidal							
Rocky	0.5	5	15.2	900	7.6	0.26	17.1
Zostera	0.7	5	2.3	900	1.6	0.05	3.3
Planktonic	14	4	0.014	850	0.2	0.0064	0.4
							99.9

Mud flat productivity was determined by measuring the standing crop of Zostera late in the season. In both the rocky and muddy intertidal, these are minimum and net values, since they do not account for loss of whole plants during the summer in the Zostera and the loss of branches in Ascophyllum during the spring and early summer.

Subtidally, kelp production was determined by direct measurement of frond elongation, determining mean increase per weight of standing crop and then by multiplying kelp bottom area by this value. Subtidal Zostera beds, being made up dominantly of plants several years old and occurring at shallow depth were assumed to have productivities equivalent to mud flat plants. This needs to be confirmed by direct measurement. These data are given in table 9.

Planktonic

Six stations were established in August and September along the axis of Gouldsboro and West Bays to determine factors relating to the planktonic primary productivity of the Gouldsboro system (Fig. 79). Nutrient, light and standing crop data were collected in addition to C^{14} productivity (Table 8). The relative contribution of plankton to the primary productivity of the Bay complex was estimated based on area and concentration of Chlorophyll A in the water column.

Primary productivity was measured by the method first described by Steeman-Nielson (1952). Depth profiles were tested at five meter intervals at the deeper stations and shorter intervals when water depth was less than eight meters. Two dark bottles were included in each station. Samples were collected from depths with a Niskin sampler, placed in 300ml BOD bottles, innoculated with 2.5 uci/bottle of NA $HC^{14}O_3$, sealed and returned to the depths from which they were collected. Incubations were done between 1200 and 1400 hours on consecutive days. After two hours incubation time bottles were fixed and subsamples of 50 and 150 mls were

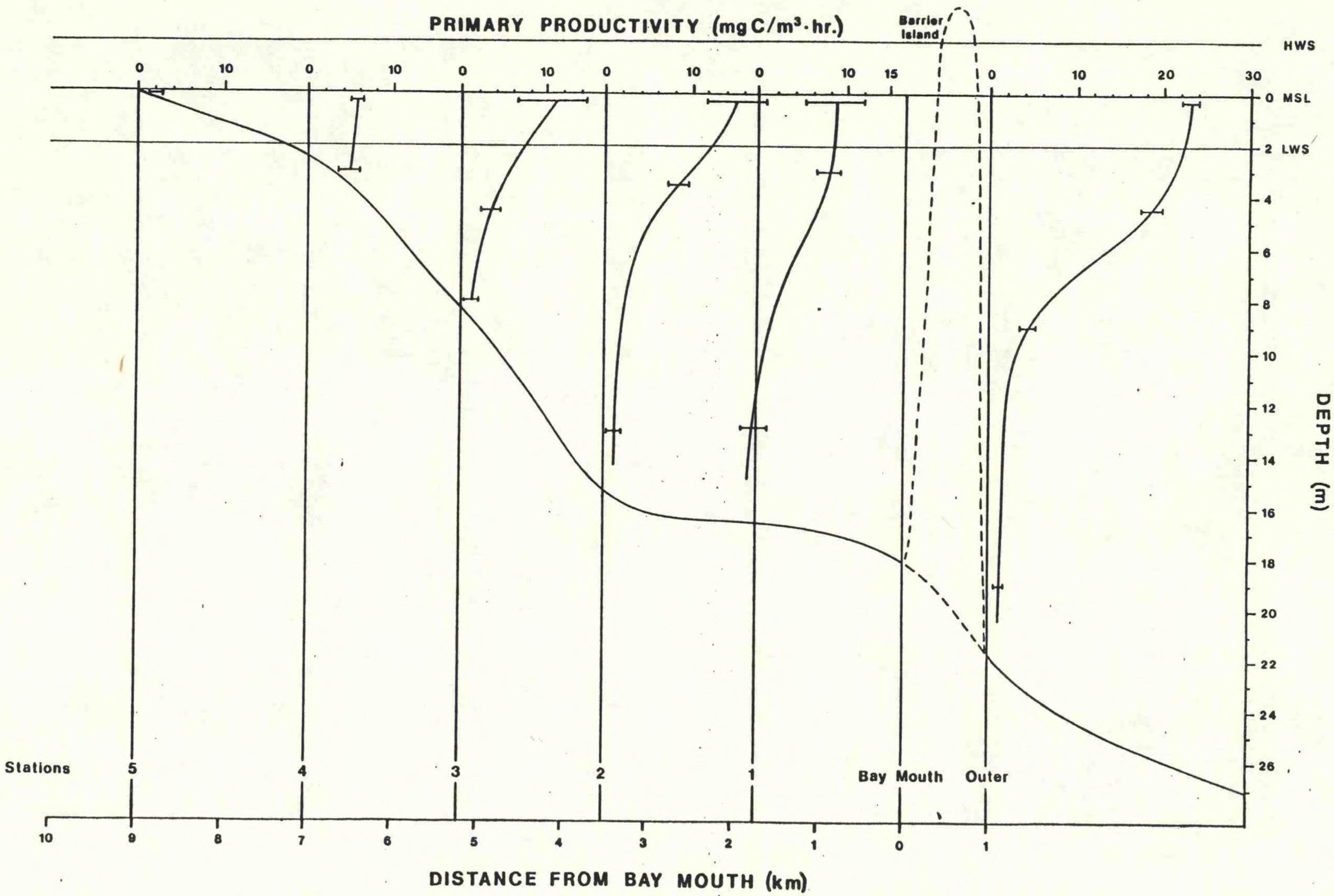


Figure 79. Planktonic primary productivity of Gouldsboro Bay.

Table 8 Physical-chemical characteristics of water column in Gouldsboro Bay. August/September, 1981.

A. Light penetration for six stations in Gouldsboro Bay. ($uE/m^2/sec$)

Station	Surface	3m	6m	10m
1 (offshore)	1300	600	225	80
2	1300	525	130	37
3	1150	375	130	25
4	1300	550	90	--
5	1000	275	---	--
6	195	---	---	--

B. Surface estimates of Chlorophyll A (mg/m^3 ± Standard Deviation

Station	
1	1.88 ± .45
2	1.96 ± .19
3	3.0 ± .48
4	2.33 ± 1.1
5	2.63 ± 1.08
6	2.45 ± .68

C. Ambient Concentration of $NO_3 + NO_2$ (mg /liter) ± Standard Deviation

Station	
1	.707 ± .14
2	.685 ± .10
3	.671 ± .16
4	.700 ± .16
5	.914 ± .20
6	.871 ± .26

filtered, rinsed and stored in scintillation vials. Filter membranes were 2 micron acropore membranes. Samples were counted for C^{14} beta emissions on a Packard 2660 scintillation counter at the Smithsonian Radiation Biology Laboratory. Net productivity is reported as the difference between light and dark uptake.

Primary productivity generally increases from the head to the mouth of the bay system (Fig. 79). Turbidity remains relatively constant inside the bay (Table 8) and its branches. It increases in the mud flats and decreases offshore as expected. Chlorophyll measurements were made on different days from productivity but at the same stations; they do not reflect primary productivity (Table 8). The reasons for this are not clear and will be the object of studies during the next field session. It is possible that prevailing tides or currents concentrate plankton in the upper reaches of the bay where they eventually sink out of the water column due to a lack of mixing. Inner bay stations are probably not significantly different in light penetration, standing crop, or nutrients (Table 8); however, primary productivity undoubtedly increases in the direction of the open sea. This is probably due in part to mixing from waves and currents which are higher toward the mouth of the system and to decreasing turbidity at the mouth of the bay.

Contribution of the phytoplankton to the primary productivity of the bay system may be assessed by combining an estimate for the euphotic area of the bay with estimates of productivity per unit area. The photic zone is estimated to be not more than nine meters for an average day. Mean productivity has been calculated by breaking the bay up into five productivity areas, based on figure 79 and then into unit 3 meter depth zones, depending upon depth, for each area. The mean value for midday at 28.1 mgC/m^2/hour is considerably less than the productivity that is achieved just outside the bay (156mgC/m^2/hour - Fig. 79). Mean bay productivity for the whole day would be about 0.7 for a 10-hour day or approximately 0.20gC/m^2/day. August/September in these moderate nutrient waters should provide about average planktonic productivity for the well-lighted, warm season. Assuming nil production in mid-winter, the average plankton production for the year would be about 36.5gC/m^2/year. This is well below the estimate of 150gC/m^2/year provided by the Fish and Wildlife Service (1980). However, if the productivity values just outside the bay are used, then one finds a yearly rate of 198gC/m^2/year. Thus, depth and turbidity are very critical factors determining bay planktonic productivity. Conversion of gC to wet biomass by a standard-factor of 10 gives approximately 0.36kg (wet)/m^2/year, which is used in table 9 to calculate community productivity.

Total Bay Primary Productivity

Comparing community productivities calculated by photosynthetic pigment analysis (Table 7) against harvest and C^{14} analysis (Table 9) shows that, for macroalgae, the results are more or less in agreement. As mentioned above, chlorophyll probably gives too low a value for phytoplankton and the C^{14} value is probably closer to reality. In any case, it is quite apparent that within the bay system, benthic primary productivity dominates heavily over planktonic productivity. This is a factor of critical concern in any systems or management analysis.

Table 9

Area, plant biomass and primary productivity of the major biological communities of Gouldsboro Bay

Community	($X10^6$ m^2) Area	(kg/m^2) Mean Standing Crop	(10^6 kg) Total Standing Crop	(kg/m^2 yr.) Mean Primary Productivity	($kg/yr.10^6$) Total Community Primary Prod.	% of Total Bay
Intertidal						
Rocky	1.94	18.9	35.3	10.6	20.1	62.8
Mud Flat (m/w)	3.50	1.2 (on about one-half of surface)	2.1	1.2	2.1	6.6
Subtidal						
Rocky	0.56	5.8	3.2	7.2	4.0	12.5
Zostera soft bottom	0.68	1.56	1.1	(1.2?)	0.8	2.5
Planktonic	14.0	0.12	1.7	0.36	5.0	15.6
	20.68			X = 1.5 kg/m^2. yr	32.0	100

BAY UTILIZATION - FISHERIES

It is difficult to estimate the fisheries harvest from Gouldsboro Bay from the Maine Department of Marine Resources and National Marine Fisheries Service data. These data are by county or sometimes township. Unfortunately, the bay forms the boundary between Hancock and Washington Counties, and the towns of Gouldsboro and Steuben also split the bay. Nevertheless, the field biologists of both of those Services were extremely helpful, and the data provided served to give us a larger scale framework into which our local analysis could be placed and judged.

The primary data presented here were derived from interviews with individual fishermen, processors and dealers and from formal reports being developed by local wardens and regional biologists. The study is incomplete at this time, as we are still waiting on an extensive report on clamming from the Steuben warden and a variety of lesser information for the other fisheries.

Table 10 establishes the basic fisheries pattern for the Maine Coast. Lobsters, scallops, clams and herring, in that order, form the dominant fisheries in dollar value. However, in pounds landed, superficially the critical factor in a systems analysis, herring exceed all others by five times. In an individual bay environment, however, the situation is much more complex. As discussed below, an estimate of 650,000 pounds of herring were landed from Gouldsboro Bay in 1980 and 1981 as opposed to approximately 100,000 pounds (for two years) of lobster. Herring spend only a small part of their life cycle in the bay environment, and their occurrence in Gouldsboro Bay is sporadic. They feed on zooplankton and invertebrate larvae and are thus relatively low in the food chain. The herring fishery probably has little effect on the bay ecosystem. Lobsters, on the other hand, are higher

Table 10

1980 Maine Landings* of Species Valued at More Than $50,000 Ordered by Descending Value with Poundage and Price per Pound Ranking.

Species	Rank	Thousands of Dollars	Percent of Total	Rank	Thousands of Pounds	Percent of Total	Rank	Dollars per Pound
Lobsters	1	41,705	45	2	21,981	9	5	1.90
Scallop, Meats	2	10,752	12	12	3,233	1	2	3.33
Clams, Soft, Meats	3	8,554	9	10	5,676	2	8	1.51
Herring, Sea	4	5,977	6	1	107,823	44	30	.05
Dab	5	4,914	5	4	14,553	6	14	.34
Ocean Perch	6	3,032	3	5	13,805	6	19	.22
Haddock	7	2,902	3	8	7,107	3	13	.41
Cod	8	2,623	3	7	11,359	5	18	.23
Pollock	9	2,094	2	6	12,855	5	22	.16
Gray Sole	10	1,900	2	11	3,601	1	12	.53
Bloodworms	11	1,404	2	28	118[a]	-[b]	1	11.90
Swordfish	12	1,190	1	22	584	-	4	2.04
Sandworms	13	1,095	1	26	354[a]	-	3	3.09
White Hake	14	844	1	9	5,997	3	25	.14
Mussels	15	546	1	14	2,332	1	17	.23
Menhaden	16	450	1	3	18,806	8	31	.024
Anglerfish	17	424	↑	20	754	-	11	.56
Winter Flounder	18	387		16	1,251	-	16	.31
Cusk	19	290		15	1,594	1	21	.18
Yellowtail	20	220		21	643	-	15	.34
Crabs, Rock	21	213		17	1,253	1	20	.17
Alewives	22	149	3	13	2,561	1	29	.058
Shrimp	23	126		27	153	-	10	.82
Halibut	24	109		30	69	-	7	1.58
Eels, Common	25	108		29	102	-	9	1.06
Tuna, Bluefin	26	108		31	62	-	6	1.74
Grayfish	27	96		18	1,172	-	27	.082
Mackerel	28	78		23	538	-	24	.14
Skates	29	61		25	390	-	23	.16
Sea Moss	30	61		19	1,010	-	28	.06
Silver Hake	31	60	↓	24	535	-	26	.11
Total	(1-31)	92,472	99.8		242,986	99.5		.381
Total for all Maine Landings		92,674	100.0		244,216	100.0		.379

[a]Calculated from DMR estimates of 172 bloodworms and 82 sandworms per pound (Maine Landings use estimates of 44 bloodworms and 40 sandworms per pound).

[b]All species contributing less than 0.5% to the total landings were left blank.

*Statistics compiled by NMFS and DMR.

predators, and, at least as adults, are probably top carnivores in their own environment. Also, they spend a major part of their life cycle in bay waters. The effect of lobster fishing on the bay system is probably very marked. On the other hand, several times the weight of lobster removed from Gouldsboro Bay is returned to the bay in the form of lobster bait (herring and redfish), and the effect of this input needs to be carefully studied.

Clams

Documentation for the number of clams harvested in Gouldsboro Bay including West and Joy Bays is being calculated by the Gouldsboro town clamming warden and will be presented later.

Gouldsboro Bay has historically been clear of red-tide, although shellfish beds are closed by the state when the neighboring bays show signs of contamination. Local people historically have claimed that Gouldsboro clams have never been directly affected by red-tide.

Approximately 165 commercial licenses are issued in Gouldsboro township and 125 issued in Steuben. Of the total 290 licenses issued between Gouldsboro and Steuben approximately 130 people will harvest clams on an average of 100 days per season, each producing an average of 1½ bushels a tide. Most diggers will only work one tide, and therefore 1½ bushels per person/per day is probably a reasonable assessment. 130 diggers producing 1½ bushels amounts to 195 bushels harvested/per day at 100 days/per season for 19,500 bushels harvested from Gouldsboro Bay each season. At $24.00 per bushel the value of 19,500 bushels is $468,000.00. One bushel will shell approximately 2 gallons of clam meat, therefore 19,500 bushels = 39,000 gallons of shucked meat. 39,000 gallons of shucked meat is approximately 312,000 lbs/shucked clam meat harvested from Gouldsboro Bay.

Scallops

Scallop beds are sporadically discovered in the Gouldsboro Bay area. Once a bed is discovered it is quickly harvested.

According to the Corea co-op, 8 boats were rigged for scalloping in the 1980-1981 November-April season. This season was unusual in that 7,000 pounds of scallops were landed from beds a few miles south of Corea. In an average year, i.e., 1981-1982, 2,000-3,000 pounds would be considered a high estimate. Corea co-ops records indicate in November-December 1981, 100-200 lbs were landed each day. This figure is very low.

One lobsterman reported that in the winter of 1981 a boat from Stonington discovered a scallop bed in Gouldsboro Bay. On the first day, 256 pounds were harvested, 2nd day 227 lbs, 3rd day 80 lbs, 4th day 0 lbs. This indicates how quickly the resource is harvested once it is discovered. Very little scalloping apparently occurs in Gouldsboro Bay on a long-term basis.

Maine law states draggers are limited to four foot widths in Gouldsboro Bay. The season is November 1st-April 1st so as not to interfere with lobster traps set during the summer months. According to the state scallop specialist, Dan Shick, 30% of the scallop catch in Maine does not go through the dealers; therefore, it is difficult to assess the amount of scallops actually harvested.

Mussels

Although abundant, mussels are rarely harvested in Gouldsboro Bay. Most sizeable mussels exposed during low tides are many years old and contain pearls. They are thus not very desirable for the market.

Herring

The Maine Department of Marine Resources (DMR) has studied the Maine herring fisheries in great detail, including the biology of the species, catch and landing statistics and the industry's impact on Maine's economy. To clarify terms: catch refers to actual amounts of herring caught in Maine waters; landings are catches plus additional herring caught in Canadian waters or another state that are brought into Maine by boat and landed at Maine ports. DMR records indicate 51,976 metric tons of herring were landed at Maine ports in 1981. Of this total amount, 24,795 metric tons were landed in Maine's eastern section including Gouldsboro Bay.

Three methods of gear types are used to catch herring: purse seines, stop seines and weirs. Gouldsboro Bay has three weirs, Dyers Bay six weirs and Millbridge has three weirs in Sands Cove. Stop seining is often used in Dyers Bay and Millbridge, but rarely in Gouldsboro Bay. Past records have indicated smaller quantities of herring have been caught in Gouldsboro Bay in comparison to neighboring areas.

Mr. Calvin Stinson of the Stinson Canncove in Prospect Harbor provided data on the quantity of herring his company purchased from Gouldsboro weirs. Stinson's key suppliers are not local; they purchase herring from Canada to ship to Gloucester, Mass. Only a very small portion of their business is local. Local competition lies between the L. Ray Packing Company and the Jasper Wyman Company, both located in Millbridge. Interviewing Gary Ray of L. Ray Canning made it very clear they were not willing to discuss specific landing data. Due to a reduction in the resource and recent federal labor laws affecting overhead costs and operations, many other canneries established for many years were forced to close.

A computer search by the National Maine Fisheries Service in Woods Hole, Mass., to retrieve information concerning catch data specific to Gouldsboro Bay has been requested. Hopefully this information will be available soon.

Herring season is usually from May through October with the best fishing during the summer months. The herring purchased by Stinson from Gouldsboro Bay weirs were caught from mid-June through mid-July during the 1981 season.

At this time, the following calculations are based on the information obtained from the Stinson Canning Company. In 1981, Gouldsboro Bay yielded 332 hogshead or 651,700 lbs or 295.55 metric tons of herring. This amount is 0.6% of the total 51,976 metric tons landed in Maine and 1% of the 24,795 metric tons landed in Maine's eastern section.

Bloodworms and Sandworms

With the assistance of Mr. Bruce Joule, worm specialist from Maine's Department of Marine Resources, we were able to collect available statistical data on this industry, which is an important contribution to Maine's fishing industry (see Table 10).

Worms are harvested for the recreational sport fishery industry for use as bait. Key markets are on Long Island, New Jersey and California, during the summer months when the demand is high.

The State of Maine requires a Maine worm diggers license. There are no restrictions where worms may be harvested; therefore, citizens travel from Wiscasset to Jonesboro to collect worms depending on the market demand. The dealers provide daily limits and prices per worm, and the availability, accessibility and location of the resource.

Bloodworms are rarely found in Gouldsboro Bay. Occasionally several have been collected from Noyes Cove in the early spring. Sandworms are more prominent and are usually found in mussel beds rather than in clam flats.

Depending on the market and dealers limit, an average count allows 1500 worms collected per person/per day. There are two large dealers located in Jonesboro and Hancock. Since travel costs to these dealers would be deducted from the value of one's daily catch, one often sees families or large groups working together to make the trip worthwhile.

Value of sandworms averages 3-5¢ per worm, bloodworms 8-10¢ per worm. There are 43 dealers presently listed in the State of Maine. Diggers distribute worms into lots of 125 or 250 before selling them to the dealer.

According to statistics supplied by DMR, an average of 3,000 worms were harvested per person and an average of 2,000 bloodworms were harvested per person in 1980. According to estimates by local wardens, approximately 100 local residents and visitors traveling between Wiscasset and Jonesboro harvest from the Gouldsboro Bay area during the summer months. If we assume an average of 3,000 sandworms were harvested per person during the peak season, then approximately 300,000 sandworms were harvested from the bay area. If their values varied between 3¢ and 5¢ per worm, then using 4¢ as a common figure, the value in dollars of sandworms harvested from Gouldsboro Bay would contribute $12,000.00 to Maine's worming industry or 1.2% to the total value of the industry.

According to DMR estimates there are 82 sandworms per pound. Therefore, 300,000 sandworms is equal to approximately 3,658.53 pounds of sandworms landed in 1980 in Gouldsboro Bay.

Lobsters

Jim Thomas of the DMR in Boothbay Harbor provided state statistical landings of lobster. Gouldsboro Bay was included in data collected from Corea to Eastport where 2,100,000 million pounds were landed. There is no breakdown specific for Gouldsboro Bay, although 182 lobster licenses were issued by the state to lobstermen in Corea and Gouldsboro.

The Corea co-op has 47 members, 20 full-time fishermen, 2 offshore in the winter months. Newman Young, manager of the Corea co-op, stated that in FY 81' July 1, 1980 - June 30, 1981 an average of 250,000 lbs of lobsters were landed at the co-op. Each fisherman has 200-600 traps. These men do not fish in Gouldsboro Bay; their traps are set south of Corea in inshore waters. Bait used are herring cuts supplied by local herring processors, alewife available in the spring, and redfish trucked in from Frank O'Hara's, Inc. in Rockland, Me. Several men also used experimental bait prepared by University of Maine Sea Grant.

Approximately 25 Gouldsboro residents own boats and lobster fish in the bay from July-November. Another 25 Steuben residents moor their boats in Dyers Bay. Local fishermen varied in the number of traps each owned, varying from 80 traps to 300 traps. The majority of these fishermen fish part-time and supplement their incomes from clamming, worming or tree-cutting and "wreathing" during the Christmas season.

Interviewing three dealers and lobster pound owners indicated that approximately 100,000 pounds of lobsters were harvested from the Bay ten years ago. There has been a steady decline in pounds landed due to 1) fewer men fishing full-time and 2) a reduction in the resource.

These same lobstermen fishing actively and full-time ten years ago are now fishing part-time as they approach retirement. Most young fishermen now fish out of Corea or in Dyers Bay. Each dealer interviewed now estimates a range of 25,000 to 50,000 lbs are now harvested from Gouldsboro Bay. These dealers were reluctant to state the quantities landed at their docks. Local Gouldsboro fishermen were reluctant to discuss their individual landings. The assessment of landing data for Gouldsboro Bay for lobsters is somewhat speculative.

Two approaches were used to collect the data:

1) Visual - a daily count of the number of men, boats, days fished and traps set.

This was carried out in an informal way during the summer of 1981.

2) Economic analysis - estimate the annual average income of the fishermen, market value of the product and number of men fishing and estimate the number of pounds landed.

The Department of Marine Resources has stated that 21,981,000 pounds of lobsters were landed at Maine ports in 1981, a value of $41,705,000 to Maine's economy. This figure indicates that the value of the lobster fisheries comprises 45% of the entire fishing industry in Maine.

DMR estimates the number of hauls per trap for all traps set in 1981 totals 33,959,356 hauls. This information provides the calculation that approximately 0.6 lbs of lobster per haul/per trap were taken. This figure is close to our estimates made in Gouldsboro Bay during the 1981 summer. Calculations indicated that 0.5 lbs per trap/per day was an average yield based on 25 fishermen fishing 5,000 pots annually. The following example demonstrates particular economic input from Gouldsboro Bay lobstermen according to information based on interviews and DMR reports.

Using 50,000 pounds of lobsters harvested per season from Gouldsboro Bay, 25 fishermen, 3 hauls per week on 5,000 traps and a 16-week season, the following can be calculated: a harvest rate of 0.21 lbs/trap haul and a yearly income of $3,840 for 50 days labor. These figures appear to agree roughly with individual lobstermen analysis of their harvest/income rate in Gouldsboro Bay today.

These data, as discussed above, are summarized in table 11.

Table 11

Fisheries Landings, per year, from Gouldsboro Bay

Lobsters:	50,000 pounds
Herring:	651,700
Scallops: (approximately)	600
Sandworms:	3,658
Clams:	312,000
Mussels	0
Groundfish	0
Sea Moss	0
Total:	1,017,958 pounds

Lobster bait input (Herring, Redfish)	300,000 pounds

PRELIMINARY SYSTEMS ANALYSIS

At this point an ecological systems analysis of Gouldsboro Bay can only be tentative, as the study is one-third to one-half complete. Nevertheless, a first attempt is made graphically in figure 84. An effort has been made in the diagram to differentiate between hard numbers (5.8), educated guesses (est. 8) and guesses based on little information (block or arrow-sized without a number). No attempt is made at this preliminary stage to explain in detail the background of the information.

Most striking about this analysis, as compared to previous generalized treatments for the Maine Coast (e.g. Fish and Wildlife Service, 1980), is the prominent role accorded to primary production by benthic algae (as compared to phytoplankton) and the extensive replacement role of fine macroalgal detritus for phytoplankton. A beach drift stage is central to the functioning of this detritus system, and a large part of the primary production is cycled through drift (Figs. 85-87). Also quite apparent in this analysis is the very heavy utilization of the bay's biological resources by humans. The equivalent of over 60% of the bay's total primary productivity, as estimated by level in the food chain and the x 10 rule of thumb, is removed by fisheries.

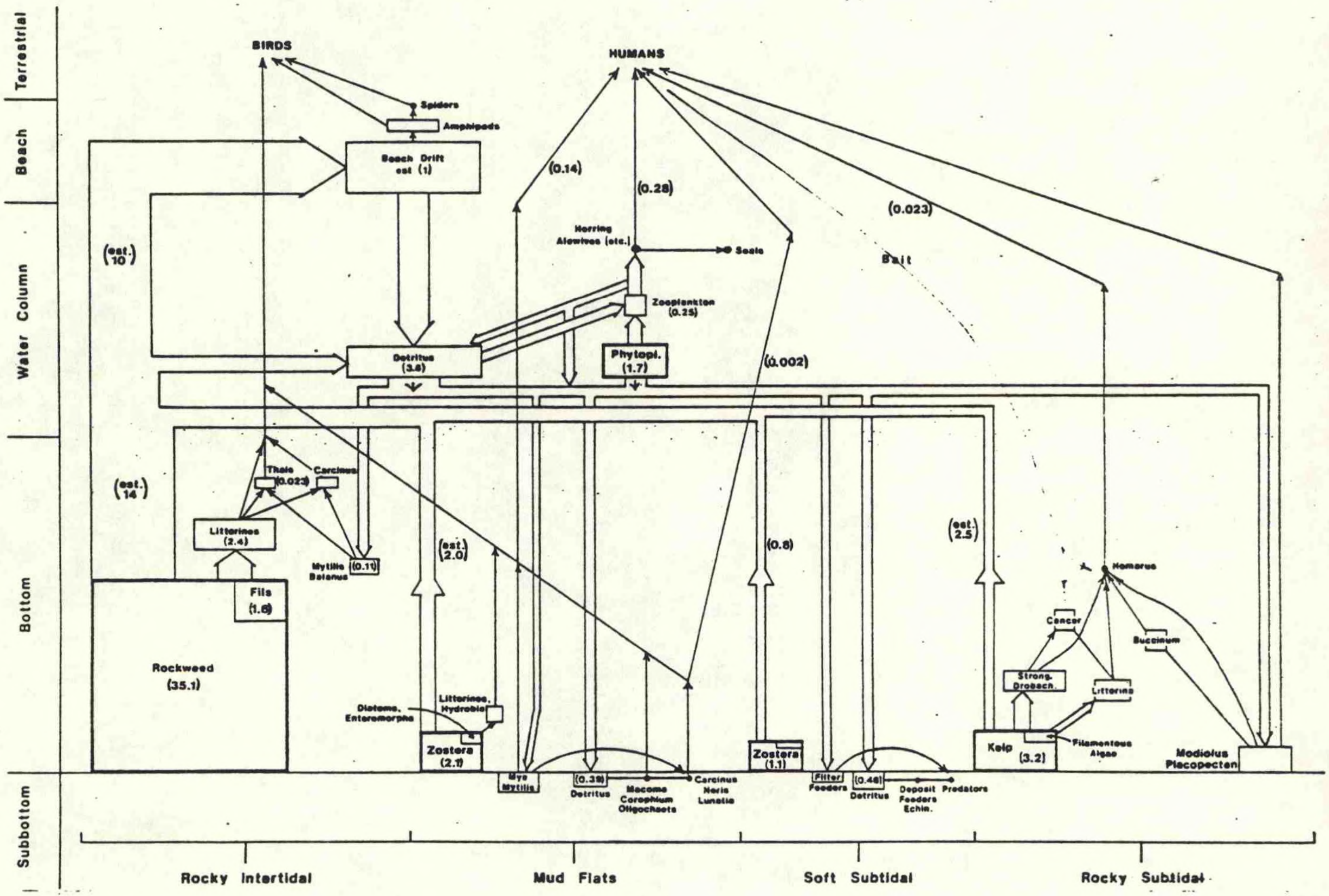


Figure 84. Preliminary systems diagram for Gouldsboro Bay. (see text). Block sizes are proportional to total standing crop (35.1)

Block sizes are proportional to total standing crop (35.1) = $35.1 \cdot 10^6$ kg (wet).
Arrow widths are proportional to biomass transfer (14) = $14 \cdot 10^6$ kg/yr.

PRELIMINARY NOTES

SANCTUARY ESTABLISHMENT PROCESS

Boundary of a Potential Sanctuary

The function of a marine sanctuary is primarily to provide for conservation of biological, ecological and environmental resources and to develop a system for understanding and management of the conservation within a framework of human utilization. Since sanctuary designation is a slow process and efficiency of management will undoubtedly always minimize the numbers of sanctuaries, the inclusion of the widest range of genetic and ecological characters within a single designation is always desirable.

Within the American North Atlantic subarctic biogeographic region, the submerged and generally rocky coast of Maine is unquestionably a marine type needing conservation and intensive study. Beyond the estuarine situation, protected waters with significantly lower salinity levels, which has a separate conservation program, it is quite apparent that the coast complex consists of three interacting major zones, all of which should be considered within a single logical sanctuary unit. These include: (1) the bay environment (as described above), (2) the inshore environment and (3) the offshore environment. These are shown in figure 88, and their basic characteristics briefly tallied for the Gouldsboro Bay area. A species list and ecosystem structure for the three would be quite different, even though all three interact and have many components in common. The tentative sanctuary lines for the Gouldsboro Bay area drawn in the proposal for this project were placed without a full understanding of the nature of the inshore/offshore relationship, as described above. It is more appropriate that new boundaries be drawn to include not only Gouldsboro Bay waters, but also all of the offlying inshore waters and a portion of offshore waters.

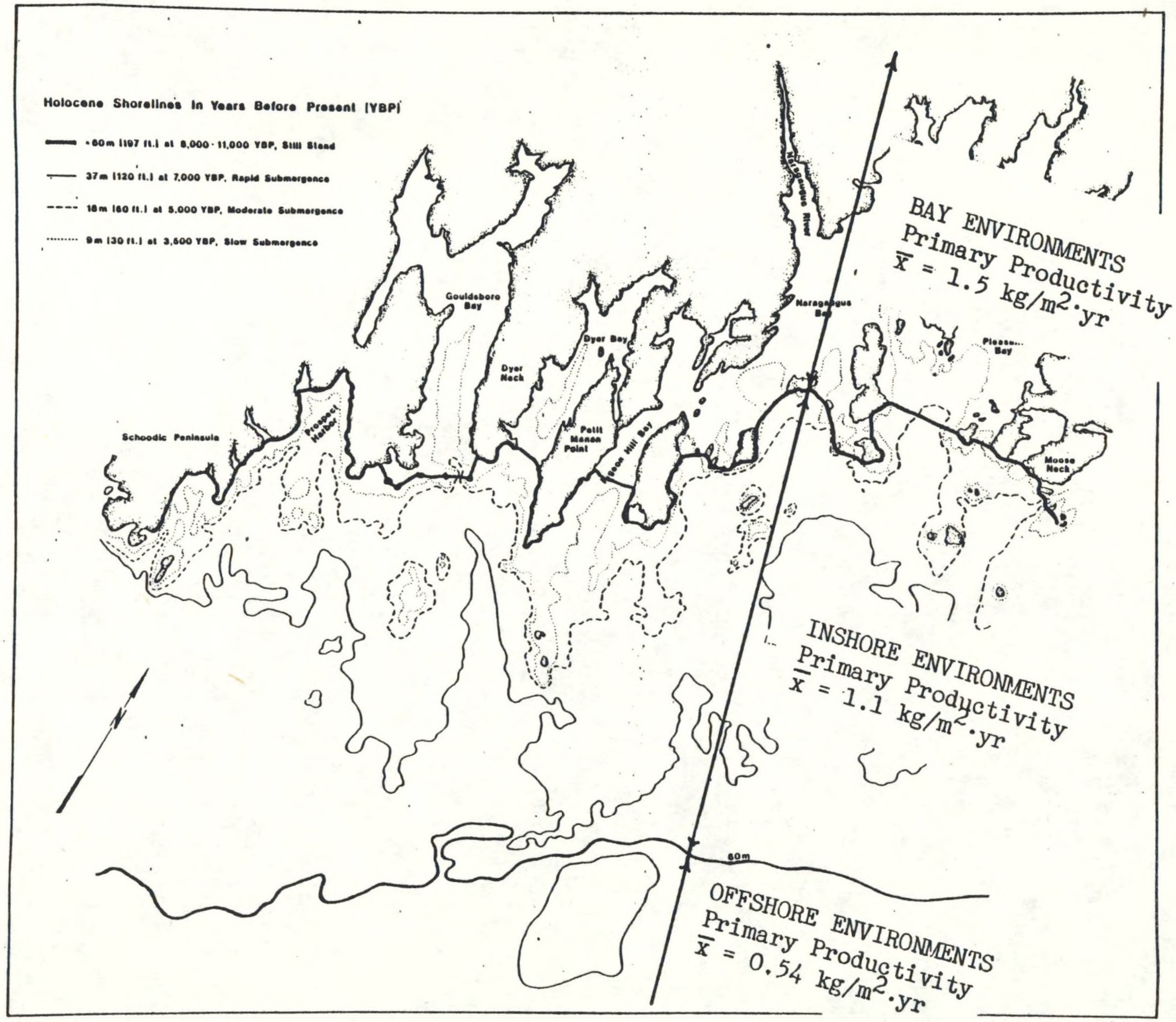


Figure 88. Bay, inshore and offshore environments of Gouldsboro Bay area.

Process of Sanctuary Establishment

Human interaction, primarily that of fisheries, is obviously a critical part of the ecosystem being discussed here. It would appear that increased fishing effort has consistently led to reduced output and that most of the major traditional fisheries are producing above sustainable yield. Wise sanctuary management would almost surely lead to a reduction of current fishery utilization. Maine fishermen are generally conservation-minded. However, they also feel that their incomes relative to the rest of society are flagging, and the mere thought of reducing fishing effort in a sanctuary management process will likely send shock waves through the local political structure that will prevent the establishment of much-needed sanctuaries. It is probably essential that the way to alternate fisheries/income potential be demonstrated before the sanctuary process is initiated on the local level.

It is also clear that a significant additional fishery of reasonable sustainable yield must be placed lower in the food chain. There are a number of possibilities, but here I would tentatively like to suggest a very real and potentially eminent possibility that could provide the basis for increased local income, reduced fishery load, increased species diversity, a more natural coastal ecosystem as a whole and a marine sanctuary that will have the support of all parties.

Mussel aquaculture has been initiated in Maine. Cultured mussels are a high quality, low cost food, and I am firmly convinced (for reasons that will be discussed in a later report) that a mass and growing market can be developed.

Kelp is a potential human and animal food, and biomedical chemical and energy source. The market, although small, can be cultivated into a major fishery. However, natural stocks in Maine would be expensive to harvest on a mass basis and will not stand up to extensive harvest. Kelp can be grown in culture, a process extensively practiced in Japan.

I propose developing a raft polyculture of mussels and kelp for the Maine coast. The kelp will provide cover for the mussels to reduce Eider duck predation. The mussels will provide ammonia for increased kelp production. This system will increase primary productivity of the ecosystem and will generally provide an additional resource at lower levels in the food chain. The culture is best practiced in bays, and the primary base for the lobster food chain, the kelp community, is best developed outside the bays, in the inshore region. Polyculture harvest would also be more economical. This is not the place to discuss the details of mussel/kelp polyculture. However, the process is supportable in detail.

It is essential for the process of sanctuary establishment that the viability of this procedure be established and turned over to local operation. Tentatively, I would recommend that kelp/mussel aquaculture be established in the bays and that, as part of management in a sanctuary, lobster fishing in the bays be phased out. The level of kelp/mussel culture can be established later. Lobster fishing inshore should be continued at the same level. Without the pressure of the bay fishery, harvest and stocks should generally increase. It may also be desirable to slightly reduce the clamming and worming pressure on some mud flats. However, some of the flats are little utilized for clamming, apparently because of the shallowness of the recent marine silt layer over the Presumpscot clay, and the poor harvest in those areas may well provide for "natural" conservation sites. However, it is better not to attempt even preliminary recommendations until the intensive efforts planned for the flats this summer are at least underway.

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