ECOLOGY OF SHEEPSCOT RIVER ESTUARY

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EXPLANATORY NOTE

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United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner

ECOLOGY OF THE SHEEPSCOT RIVER ESTUARY

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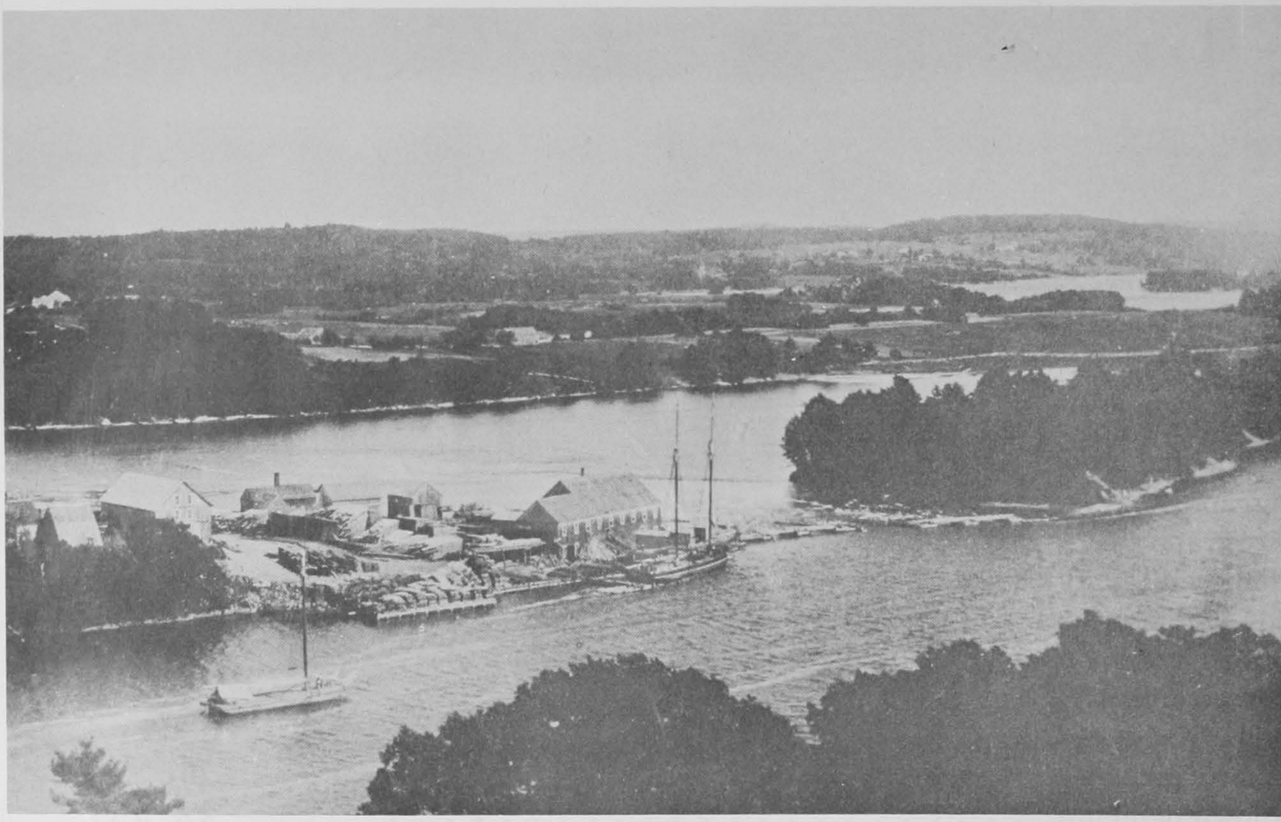
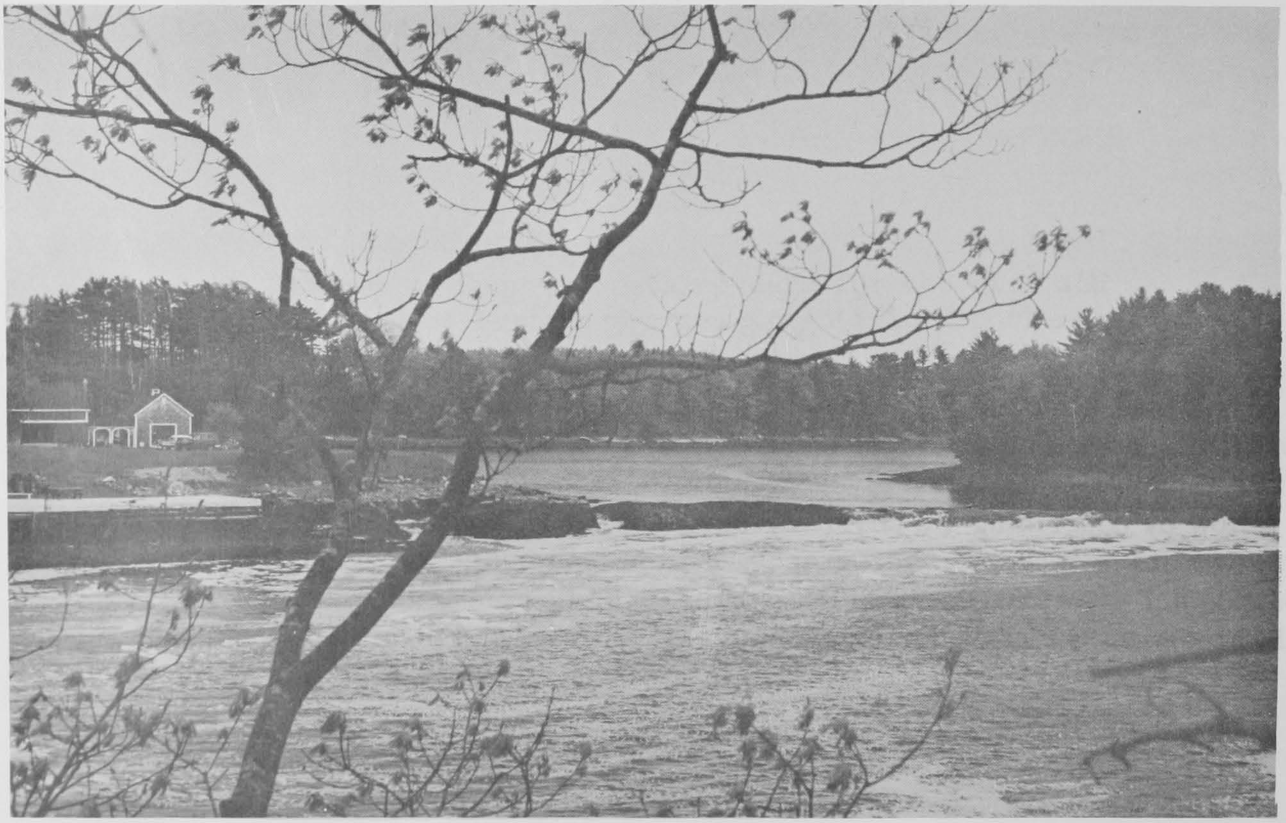
ABSTRACT

Three Fish and Wildlife Service and three State of Maine organizations collaborated on a comprehensive study of the ecology of the Sheepscot River estuary. This paper gives background material to introduce papers to follow by describing the physical, and biological characteristics of the estuary: Its geography, hydrography, bottom sediments, plankton composition and distribution, and higher animals and plants in the several habitat zones. Lists of the common aquatic animals and plants are included.





Tidal falls at Sheepscot Village. Top: From an old photograph (circa 1900) showing one-time dam and tide gates. Tide is flooding. Bottom: Appearance of the falls at the present time. The view is from a lower elevation. Tide is ebbing.

ECOLOGY OF THE SHEEPSCOT RIVER ESTUARY

In 1954 the Atlantic salmon research of the U.S. Fish and Wildlife Service was oriented to include a study of the ecological complex in a salmon river and its estuary. The project has been coordinated with the regular activities of State and Federal agencies concerned with the study of certain estuarine species and has been concentrated in a single river, the Sheepscot, near Boothbay Harbor, Maine.

Cooperating on this project are the Clam Investigations, the Atlantic Herring Investigations, and the Atlantic Salmon Investigations of the U.S. Fish and Wildlife Service; and the Department of Sea and Shore Fisheries, the Department of Inland Fish and Game, and the Atlantic Salmon Commission of the State of Maine.

The Sheepscot River was selected as a suitable study area as it was convenient to a well-equipped fishery laboratory in Boothbay Harbor where personnel of four of the cooperating agencies were stationed; in addition, studies were already in progress on several economically important species in that area, such as herring, alewife, smelt and clams.

The Sheepscot River itself is not an important salmon stream, but it does support small natural runs of these fish and is regularly stocked with hatchery-reared young.

The purpose of the present report is to give a comprehensive description of the study area to provide a background for other more detailed reports covering specific problems. It will also serve to complement the report of Bryant (1956) which described the fresh-water part of the river.

Methods and materials

A series of stations was first established where regular observations were to be made, (fig. 1). Water samples were collected at these stations with a Kemmerer sampling bottle. Salinities were determined by titration with silver nitrate according to Knudsen's method (Oxner, 1920) and, where less accuracy was permissible, by means of specially calibrated hydrometers. Temperatures were taken with a mercury thermometer directly in the sampling bottle. As the time required to raise the bottle from the deepest water sampled was only a few seconds, change in temperature within the bottle was disregarded.

Plankton was collected by two methods: vertical hauls from bottom to surface with a 1/2-meter #2 silk plankton net and four-minute surface tows with a Clarke-Bumpus plankton sampler equipped with a #10 silk net. Currents were measured according to a method described by Pritchard and Burt (1951), in which a weighted current cross is suspended at various depths and the wire angles resulting from the drag of the current are measured to compute the direction and velocity of current.

Fish were collected by means of gill nets and seines of several sizes, traps, fyke nets, and a small otter trawl. Intertidal invertebrate populations were sampled by removing a 0.1 M^2 quadrat from the sediment to a depth of 10 centimeters. The material was then sieved through a 14 x 16 mesh-per-inch plastic screen. Subtidal populations were sampled with a 0.1 M^2 Petersen-type grab and similarly sieved. These procedures were supplemented by numerous field observations and hand collections. A counting weir was constructed near the head-of-tide in the river to obtain information on the movements of salmon and other anadromous fish. Stomach analyses were made on numerous fish and some birds to aid in the study of certain food relationships.

Geography

The Sheepscot River is a stream of modest size [1/] which originates in the low uplands between the Penobscot and Kennebec valleys and flows generally southward to the Gulf of Maine.

1/ A description of the river proper may be found in Bryant, 1956. See list of literature cited.

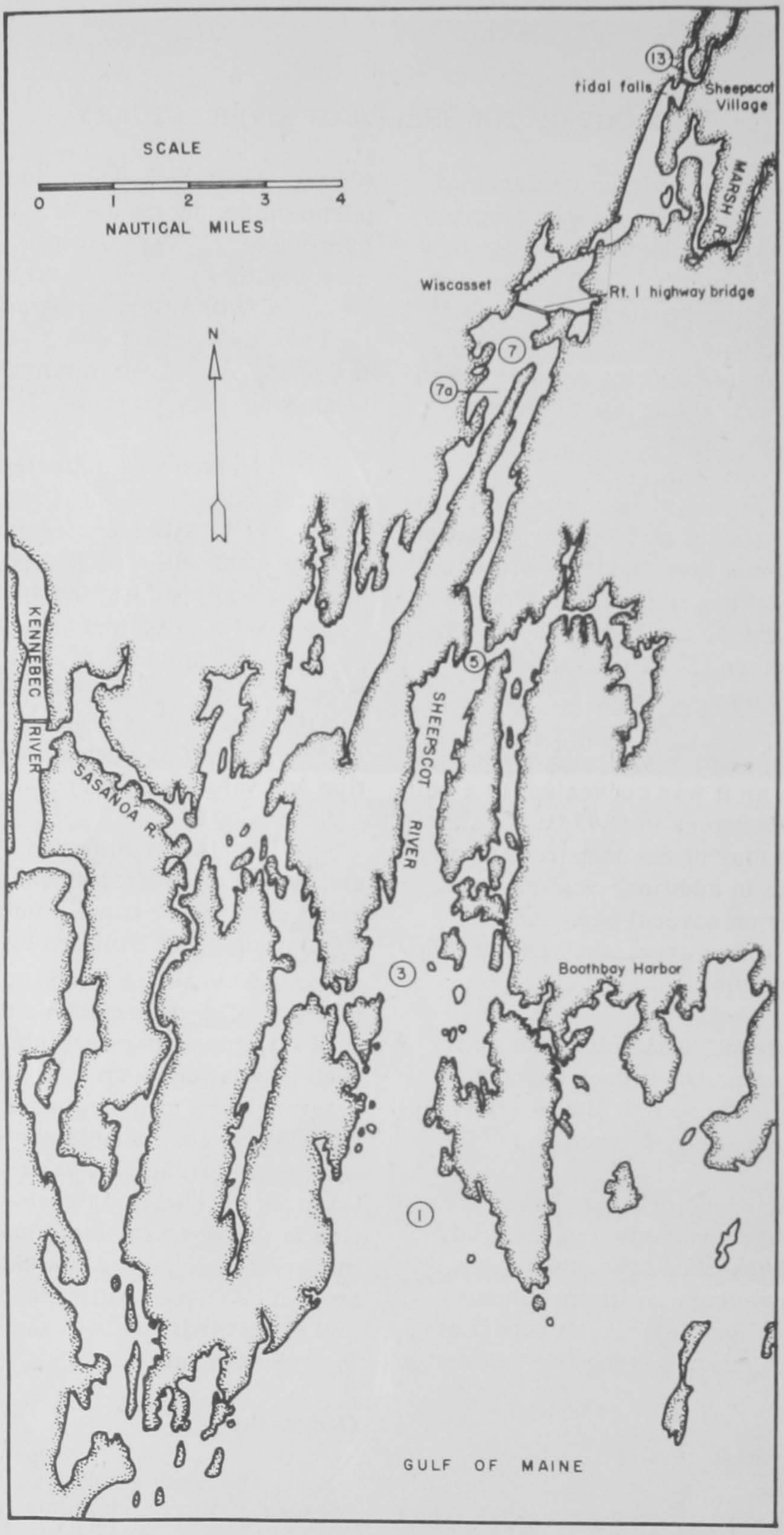


Figure 1.--Outline chart of the Sheepscot area showing the locations of principal geographic features, water masses, and sampling stations (numbers in circles).

Where it intersects the coastline it forms a deep, narrow embayment superficially resembling a fjord. The valley, however, is river cut rather than glacier cut (Johnson, 1925) and has no sill at its seaward end. It is a typical submerged or "drowned" river valley. The size of this portion of the estuary relative to the size of the river itself is so large that it is not, strictly speaking, an estuarine environment. For the purposes of this discussion, therefore, it will be referred to as the lower estuary and distinguished from the upper or true estuary, which occupies a shallow valley about five miles long from the river mouth to the upper end of the lower estuary. The town of Wiscasset, Maine and the U.S. Route 1 highway bridge form a convenient dividing line between the two.

The lower estuary ranges from about 60 meters in depth at its seaward end to about 20 meters at its upper end. For the most part its shores are steep and rocky. The upper estuary is much shallower, with a channel from 1 to 10 meters in depth at mean low water and bordered by extensive mud flats and salt marshes. About midway along this upper estuary at Sheepscot Village is a constriction between two headlands where a transverse ledge of rock tends to hold back the water above it, creating a waterfall on the ebbing tide. At one time a mill dam was erected at this site. There are other constrictions at several places in the estuary where currents are rapid but without falls. There are two major tributary branches to the upper estuary: Marsh River and Dyer River. Both are largely tidal but are fed by streams.

As can be seen in fig. 1, the lower estuary is a complex affair of interconnecting channels including one, the Sasanoa River, which connects it directly with the nearby Kennebec River.

Hydrography

In contrast to the lower estuary of the Sheepscot, the upper estuary has these characteristic features: shallower water, greater tidal exchange ratio, lower and more variable salinity, and a wider range of temperature. The upper estuary shows the effects of the river very noticeably at all times of the year. The river discharge varies from about 20 to over 1000 cubic feet per second during the course of a year, being greatest at the time of the spring thaw in April or after heavy rains, and lowest during August and September. The salinity of the estuary varies accordingly.

Tidal variation in salinity depends on the stage of the river and the particular locality, but fluctuations between high and low tides often exceed 15 o/oo in much of the upper estuary. Seasonally, at a given location and tidal stage, salinity varies by about 15 to 20 o/oo, as can be seen from Station 13 in fig. 3.

In comparison, the lower estuary is characterized by: deeper water, smaller tidal exchange ratio, higher and less variable salinity, and a narrower range of temperatures. Dilution by the Sheepscot River is rapidly attenuated below Wiscasset and is hardly distinguishable five miles south of that town where, due to the narrowness of the basin, swift currents mix the diluted surface water with the highly saline deeper layers. The mixed water extends southward to the region opposite the entrance of the Sasanoa River near Station 3 where the surface water is again diluted by an influx of low salinity water from the Kennebec. The area thus influenced extends southward along the western shore of the lower estuary to the Gulf of Maine.

Below a depth of ten meters water of rather uniformly high salinity extends the entire length of the lower estuary. Fig. 2 shows the vertical distributions of salinity on a longitudinal section of the estuary from the Gulf of Maine to Wiscasset as it appeared on a typical spring day (showing the effect of the spring runoff) and on a typical summer day. Seasonal salinity trends are shown in fig. 3.

There are pronounced horizontal and vertical temperature gradients in the estuary, particularly in summer. There are also seasonal and tidal variations, which are strongest in the inner estuary or in other places where the water is shallow and protected. The greatest thermal stratification occurs from mid-April to September, although during this period intermittent mixing by waves, wind and current may partially dissipate it. After September the mixing overcomes any surface warming and temperatures are nearly uniform at all depths, although during the coldest part of the winter the surface water may be somewhat cooler than that at the bottom.

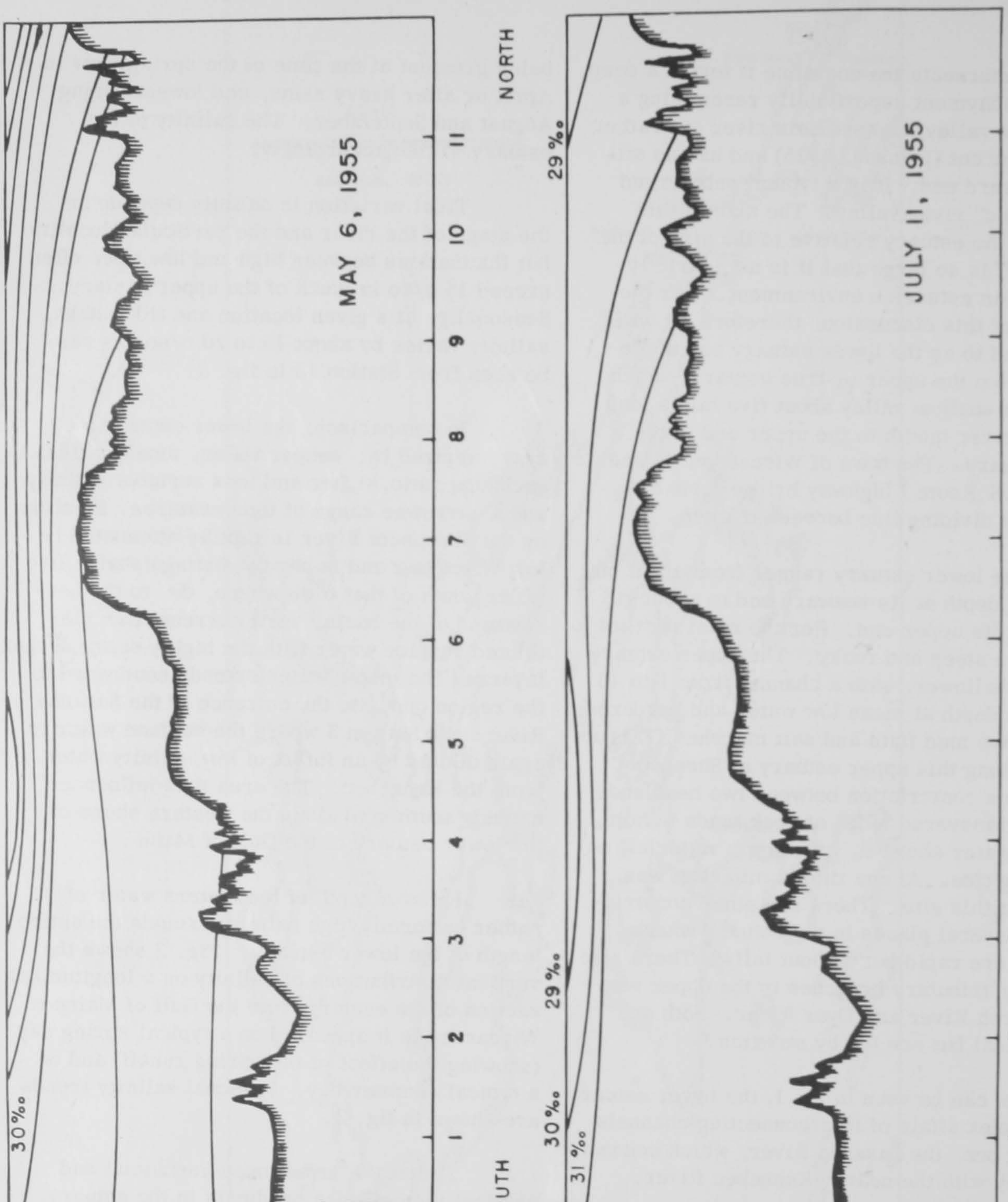


Figure 2.--Longitudinal section of the lower Sheepscot estuary from the Gulf of Maine to Wiscasset showing the distribution of salinity on a typical spring day (maximum river influence) and a typical summer day (minimum river influence).

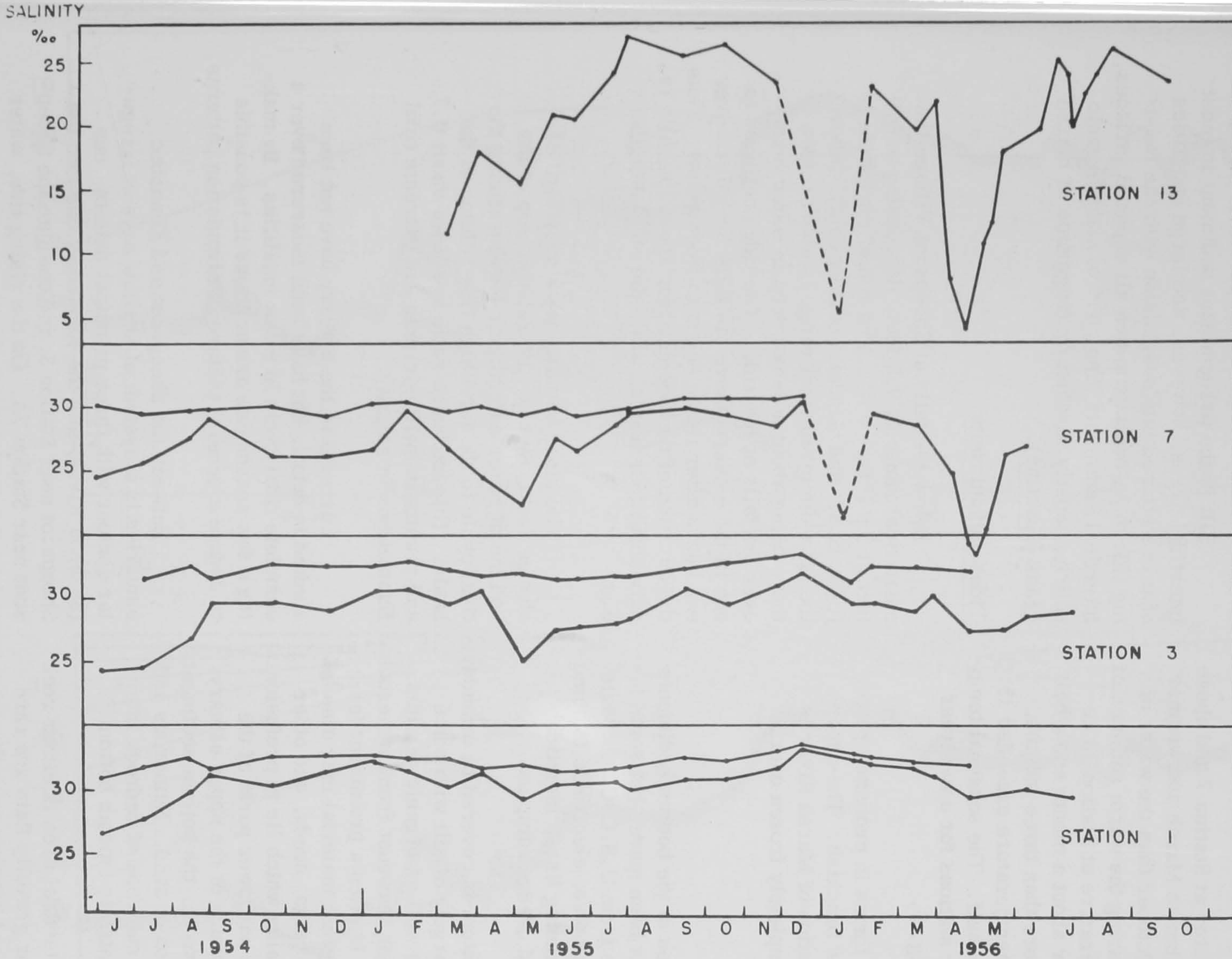


Figure 3.--Seasonal salinity trends at four stations in the Sheepscot estuary. The lower curve in each pair represents surface salinity; the upper curve, bottom salinity. At Station 13 surface salinity only is shown. Dashed portions indicate diversions from the normal trend occasioned by a January thaw and a heavy rain.

Vertical temperature distributions on a longitudinal section of the lower estuary on a typical summer and a typical winter day are shown in fig. 4.

The interior water at Station 7 and above is cooler from November to March and warmer from March through October than the water of the lower estuary. During the warm summer of 1955, the water temperature at Station 13 remained above 20°C for about a month and a half and above 15°C for more than three months, while at Station 1 the temperature exceeded 15°C for only a month and a half. The seasonal temperature trends at four stations for a two-year period are shown in fig. 5.

In winter, ice forms in protected places and where the water is brackish. The upper estuary above the junction of Marsh River is sometimes nearly completely frozen over.

Bottom Sediments

Detailed studies of the bottom sediments of the estuary have not been made, but some information is available from U.S.C.G.S. charts, Petersen-type grab samples, electronic fathometer records, hand sounding lines, intertidal samples and trawl and dredge samples.

Most of the bottom is covered by a muddy sediment composed largely of silt with some fine sand and clay, as well as organic detritus. Of the latter component, sawdust from numerous now defunct sawmills is often a prominent feature. Much of the organic material may also be derived from leaves, twigs, seeds, and other terrestrial plant remains which lie in profusion on the bottom. In the narrower parts of the lower estuary and in much of the upper estuary, where currents are strong, the bottom sediments contain a large fraction of sand. Numerous and sometimes extensive outcrops of bedrock interrupt an otherwise relatively smooth bottom.

Most of the intertidal area is either rock or mud-flat. Sandy or gravelly flats are rare except for a few exposed beaches near the seaward end of the lower estuary and some small sandbars in the upper estuary. Intertidal flats usually show a zonation of sediments ranging from coarse to fine from the high water level to the low. The reverse is true under certain conditions, as in the case of the marginal flats between grass marshes and tidal creeks with fast currents.

Silt is the predominant sediment in most intertidal areas, however, and large quantities of it are stirred into suspension with the flooding tide to be redeposited on all exposed surfaces. Intertidal sediments also contain much organic debris, mostly sawdust or fragments of marsh grass (Spartina).

Tides and currents

Below the falls at Sheepscot Village the mean tidal range is 9.5 feet, decreasing to 8.9 feet at the extreme seaward end of the estuary (U.S. Coast and Geodetic Survey data). Above the falls the mean tidal range is about 6 feet, there being about a 3-foot drop in water level over the falls at low tide. The tide continues to ebb in the estuary above the falls for a little over two hours after it has begun to flood below. Thus the duration of the flooding tide above the falls is only about four hours, while the ebb lasts about eight.

The inner estuary has a very high exchange ratio, that is, the relationship of the volume of water entering or leaving during the tidal cycle to the total high tide volume of the basin. This exchange ratio averages about 0.7, and results in swift currents and extreme tidal fluctuations in salinity.

Currents in the estuary have not been studied in detail, but have been measured over a complete tidal cycle in a few localities. By making a few reasonable assumptions it is possible to deduce a general picture of circulation patterns.

Between the Sheepscot and Kennebec estuaries is a system of shallow bays of irregular contour with three principal outlets: one (Sasanoa River) into the Kennebec; one into the Sheepscot near Station 3; and one into the Sheepscot near Station 7A. On the rising tide, water enters the system from the Sheepscot through the two latter channels and leaves on the ebb. Water from the Kennebec enters through the Sasanoa on the ebbing tide and, mixed with the other water present, passes into the Sheepscot.

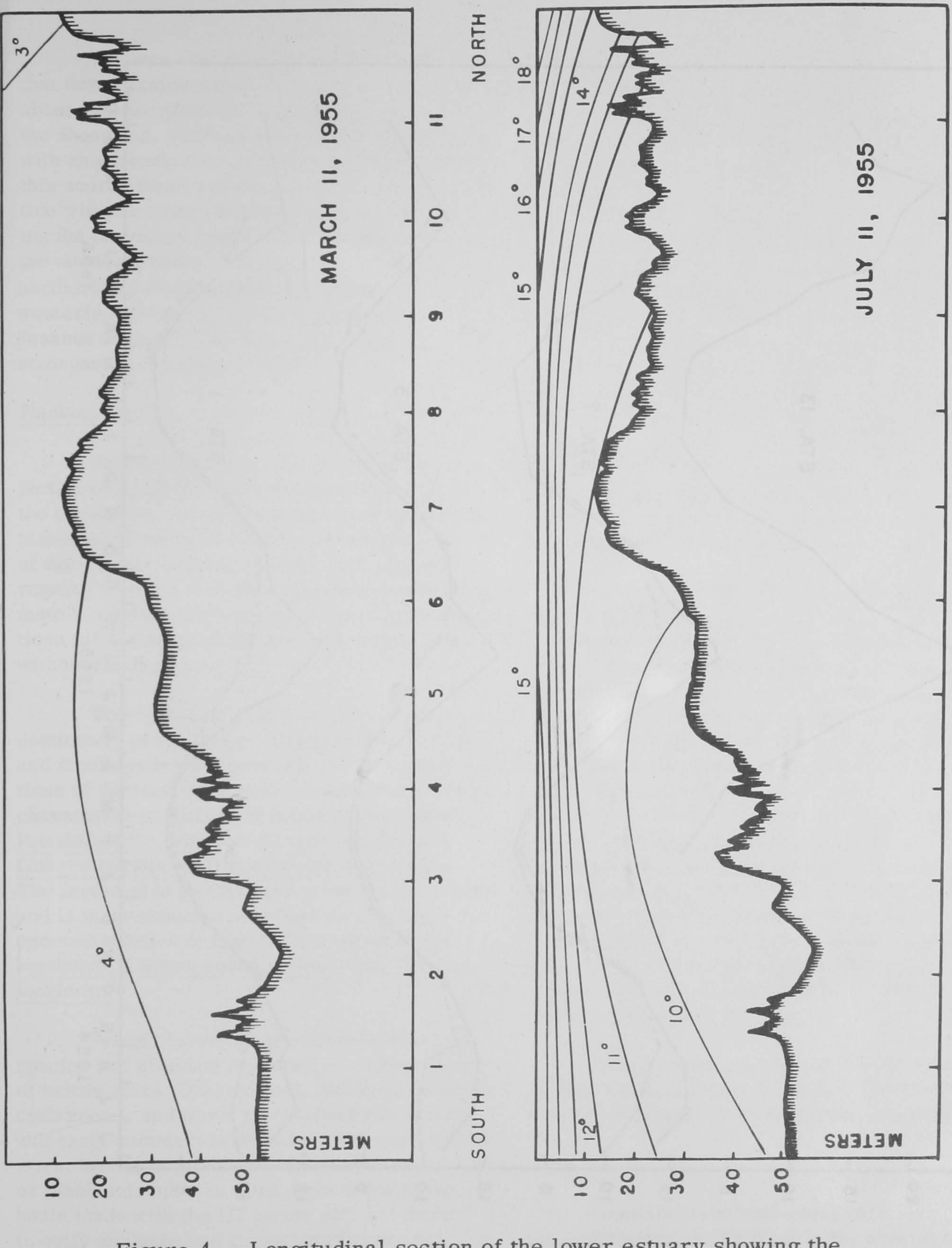


Figure 4.--Longitudinal section of the lower estuary showing the distribution of temperature on a typical winter day and a typical summer day.

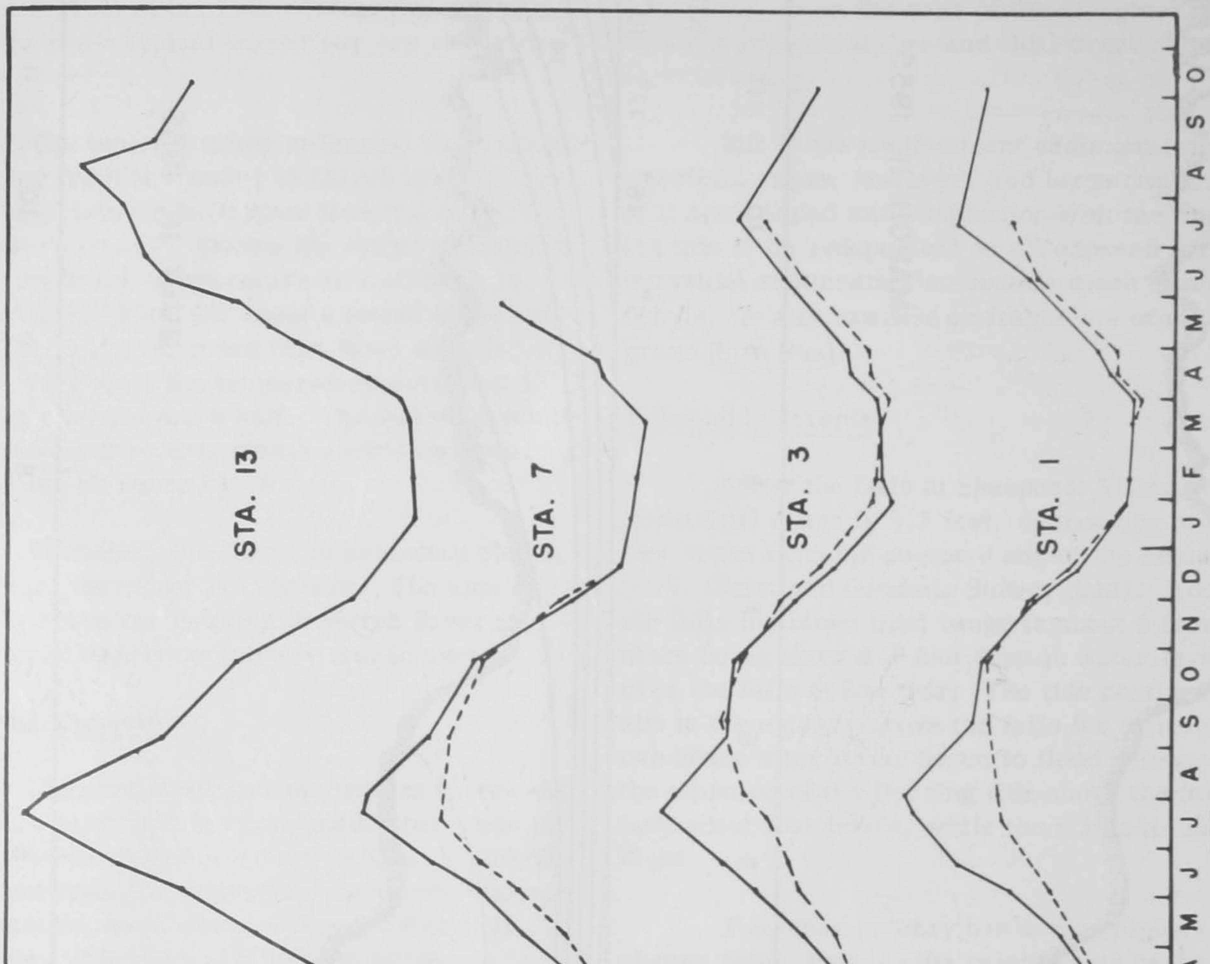


Figure 5.--Seasonal temperature trends at four stations in the Sheepscot estuary. Solid lines indicate surface temperatures; dashed lines, bottom temperatures.

Current observations at Station 3 indicate that water drains out of the Sasanoa system for about an hour after the tide has begun to flood in the Sheepscot, producing a swift surface current with an easterly set. The peak current from this source occurs about three hours after high tide with the same direction at all depths. During the last three hours of the flooding cycle, the dominant component of the current flows northerly up the Sheepscot while a lesser westerly moving current flows into the Sasanoa system. The latter component is strongest in the deeper layers.

Plankton

Plankton sampling was done with the objective of providing general information about the abundance, composition and distribution of plankton stocks in the estuary at different times of the year. Although plankton was sampled regularly over a two-year period at approximately monthly intervals only, some generalizations for the purpose of this report can be made without much risk.

Volumetrically the plankton consists predominantly of copepods. Cladocerans, diatoms and dinoflagellates also make up substantial portions of the total volume at certain times. Four characteristic species of copepod predominate: Pseudocalanus minutus, Acartia longiremis, Oithona similis, and Microsetella norvegica. The last occurs chiefly during the winter months and is most abundant near Station 3. Other common species of copepod are Eurytemora herdmani, Centropages hamatus, and Temora longicornis.

Pelagic larval stages of non-planktonic species are abundant seasonally: pluteus larvae of brittle stars (Ophiuroidea), barnacle nauplii, crab zoeae, and worm trochophores in spring and early summer; bivalve veligers and various worm larvae in middle and late summer. Larger planktonic species were often taken in the hauls made with the 1/2 meter net, but these (mostly medusae and ctenophores) were not specifically identified. The jellyfish Aurelia aurita and Cyanea arctica are abundant in the early part of the summer, the former often appearing in dense concentrations.

Phytoplankton blooms occur from time to time, some extend in from the Gulf of Maine and others are local populations inside the estuary. Diatoms of several species, chiefly of the genera Thalassiosira, Thalassiothrix, and Chaetoceras appear in the spring, mostly in the most seaward parts of the estuary and outside it. Skeletonema, Asterionella and Rhizosolenia appear during the summer, often in local concentrations within the estuary. Coscinodiscus (several species) is nearly always present.

Ceratium tripos, C. longipes, C. fusus, and one unidentified species are the most abundant of the dinoflagellates but several species of Peridinium are common. Bigelow (1924) has described the phytoplankton populations of the Gulf of Maine and the times of seasonal maxima, and the observations made in the Sheepscot agree in general with his account.

The abundance of all plankton decreases during the winter and early spring from November to May. With the exception of a substantial increase in the local population of Acartia late in the summer and occasional local diatom blooms the plankton abundance diminishes as one proceeds up the estuary. The plankton of the upper estuary contains scattered elements from the more seaward regions and several species that are indigenous to the area, e.g. Acartia longiremis, Eurytemora herdmani, the nauplii of the brackish water barnacle Balanus improvisus, and numerous mollusc and worm larvae. Marine and estuarine plankton can be found as far into the estuary as any salt is detectable. Harpacticoid copepods (except for Microsetella) are more common in the plankton of the upper estuary than that of the lower.

Plankton abundance may vary from year to year as can be seen in fig. 6. There also may be variations in its taxonomic composition.

Other populations

Important environmental variables exerting an influence on the biota in the Sheepscot estuary are temperature, salinity, tides, depth of water and the nature of the substrate. Combinations of these variables create a variety of environments or habitats, differing enough in

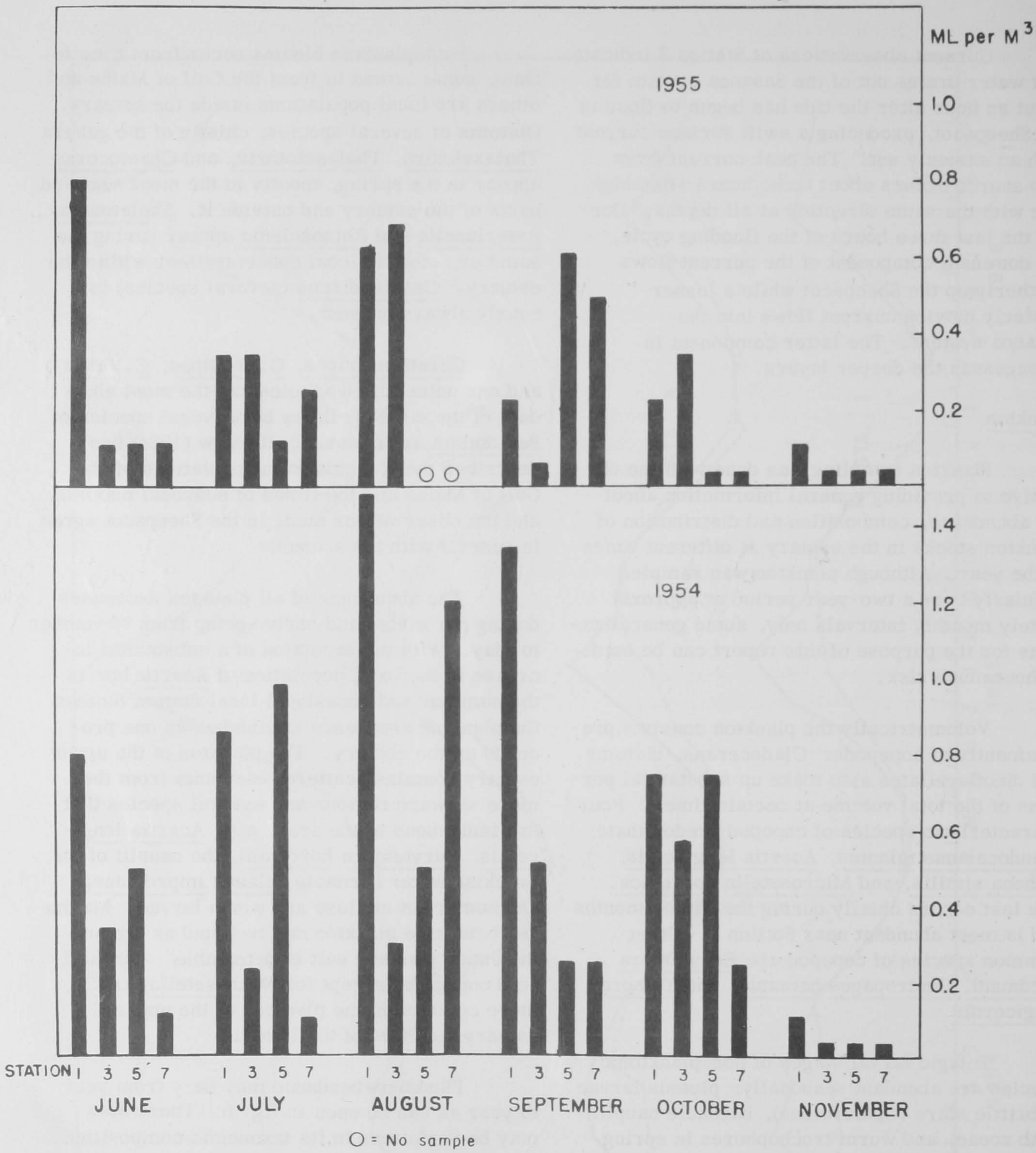


Figure 6.--Comparison of plankton volumes (displacement) in milliliters per cubic meter taken at four stations in the lower estuary during the summer and fall of 1954 and 1955. Volumes are computed on the basis of vertical hauls from bottom to surface made with a 1/2-meter #2 silk net.

some cases to be distinguished from one another as separate faunistic regions. For example, between the deep, cool, saline water of the lower estuary and shallow, warmer (in summer), fresher water of the upper, the physical differences are very noticeably reflected in the faunas. The number of species is far greater in the lower estuary, even when an area of a size comparable to that of the upper estuary is considered. The lower estuary contains populations of such stenohaline creatures as lobsters, rock crabs, sea scallops, sponges and starfish which are absent in the upper. Besides a few euryhaline species (e.g. soft-shell clams or mud shrimp) the upper estuary contains numerous organisms which are limited to it by their requirements of higher temperatures or less saline water. The temperature differential, which may be 5°C or more in the summer, particularly through limitations on larval survival, spawning activity or gametogenesis, is an effective barrier to the spread of certain species. These species may be called "relict", that is, they appear to be remnants of a more universal distribution at some past time when the coastal waters were warmer than at present. Such relict populations are common on the strongly dissected coast of Maine. Those of Casco Bay, for instance, have been discussed by Verrill (1873).

Marine populations along the coast of Maine belong to a zoogeographical sub-unit to which the term "Acadian" is sometimes applied. Those farther south are sometimes called "Virginian". Three species in the Sheepscot estuary which are more typically Virginian than Acadian are the American oyster (*Crassostrea virginica*) and the two mud crabs *Neopanope texana* and *Rhithropanopeus harrisi*. These are limited to the upper estuary. Another species which is typically more southern in its distribution is the horseshoe crab (*Limulus polyphemus*), and this species is most common in the upper estuary. Its ecological requirements, however, seem to be less restrictive than those of the other three species mentioned, and its distribution along the coast of Maine in general is more widespread.

Oysters are less abundant now than formerly in the Sheepscot. During the early part of this century, a dam was maintained across the narrows at Sheepscot Falls. This partially impounded the tidal water above it, and excellent sets of oysters are said to have occurred there each year. The maintenance of the oyster population is dependent, among other things, on favorable temperatures for spawning and larval survival. With the high tidal exchange ratio in the upper estuary, more than half of the oyster larvae in the water of the upper estuary during the period of a tidal cycle would be flushed out, their surrounding water mixed with the colder water of the lower estuary, and a consequent loss of large numbers of them would take place with each tide, either by simple dilution or through mortality due to unfavorable temperature. This procedure, taking place day after day would tax the reproductive potential of the oyster population even though conditions around the beds were suitable for gametogenesis and spawning. When the dam was in place, the tidal exchange was considerably reduced and more larvae were able to remain in favorable water long enough to reach setting size.

At present, small populations of mostly older oysters are all that remain. The largest beds are located in the inner extremity of Marsh River. Setting of young occurs but seldom (Taxiarchis, Dow, and Baird, 1954) although in unusually warm years a small number of larvae apparently survive in numbers sufficient to produce a small set. Such an event took place in 1955, for example.

The foregoing discussion refers primarily to temperature barriers. A few species are quite definitely limited to the upper estuary by a salinity barrier. One of the most interesting of these is the hydroid *Cordylophora lacustris*, the salinity tolerance of which is a very narrow range near the fresh water end of the scale. This hydroid is known from coastal estuaries and also from inland rivers. The amphipod *Gammarus tigrinus* occupies only the portion of the Sheepscot estuary from the lower limit of continuous fresh water to the level of Station 13.

Other species are more characteristic of the upper estuary than the lower, although by no means confined to it. The blood worm, *Glycera dibranchiata*, is an example.

The distribution of organisms is divided on another plane by the depth of water and the range of tides, producing the characteristic zonation that parallels the shore line. The most obvious environmental factors which may determine this zonation are the exposure to air which the organism must tolerate, exposure to wave action and winter ice, and salinity and thermal stratification.

Intertidally, the predominant species living in sediments are the soft-shell clam, Mya arenaria; a smaller clam, Macoma balthica; the sand worm, Nereis virens; and an amphipod, Corophium volutator. Another worm, Nephtys caeca, is also abundant along the lowest edge of the intertidal zone. In the corresponding zone on hard substrate are the barnacle, Balanus balanoides; the snails Littorina littorea and obtusata; and the purple whelk, Thais lapillus. In the upper estuary, Nereis diversicolor replaces N. virens and saxatilis replaces L. obtusata.

No attempt has been made to analyze further the tidal zonation, a subject which has been treated thoroughly by the Stephensons (1949, 1954), and the principles of which are generally applicable throughout this area, although there are variations in particular species. Many species that ecologically are not intertidal are found in the intertidal zone since they occupy only its lowest margin, scarcely above the spring low tide level, and then are usually hidden in sheltered spots or in tide pools. These species are usually members of subtidal or infralittoral communities, and include lobsters, rock crabs, starfish, sea urchins, anemones, and a host of other interesting creatures.

On the most seaward shores of the estuary are a few sandy coves, fringed by ledges and boulders, but protected from severe wave action. In such places the number and variety of intertidal and infralittoral organisms are relatively great. In the more sheltered places the abundance of silt appears to discourage all but the hardiest species or those which normally live in silty sediments.

Subtidal fauna has not been studied in detail, but studies currently being made by the biologists of the Clam Investigation of the U.S. Fish and Wildlife Service will provide much information relative to the distribution of these subtidal populations.

Fish populations in the estuary include both migratory and indigenous species. Of the former, there are such seasonal migrants as the Atlantic herring and Atlantic mackerel; anadromous species, such as the American smelt, the alewife, and the Atlantic salmon; and the catadromous American eel. Mackerel and small herring appear in the waters of the lower estuary during the summer months. There appears to be some relationship between their local abundance and the quantity of plankton in the water, but this has not been conclusively demonstrated. Inshore herring and mackerel catches [2] were smaller in 1955 than in 1954, and the summer plankton volumes were also smaller during 1955 than the year before as is shown in fig. 6. The appearance of a large school of mackerel in a cove near the laboratory in August 1954 coincided with an extremely dense concentration of zooplankton in that cove on which the mackerel were feeding.

The alewife (Pomolobus pseudoharengus) ascends into fresh water in May, followed by the glut herring (aestivalis) in June. Sea lampreys (Petromyzon marinus) ascend the river in great numbers in May, but observations made at the counting weir indicate they reach the head-of-tide earlier than this, probably some time in April. During May and June elvers of the American eel ascend the river, while adults move downstream in both spring and fall. Atlantic salmon are not abundant but a few ascend each year, mostly in the fall. Smelt (Osmerus mordax) enter the estuary in the fall, remain in the tidal creeks and the upper estuary during the winter, and ascend the river and tributary brooks to spawn in April. Striped bass (Roccus saxatilis) appear in the upper estuary during the summer and are said to have been abundant there all year round when the dam was present at Sheepscot Falls.

No definitive check list of fish indigenous to the estuary has been compiled, but certainly many of the species listed by Bigelow and Schroeder (1953) are regular inhabitants, at least in the more seaward parts of the estuary.

2/ The information regarding the size of these catches has been obtained from the herring catch statistics on file at the Boothbay Harbor Laboratory and from interviews with local fishermen and distributors.

Some of the more common species collected in the lower estuary have been cod, pollack, silver hake, mud hake, cunner, winter flounder and spiny dogfish. The mummichog, or killifish, is ubiquitous but favors tidal creeks and the shallow water of the upper estuary. Winter and smooth flounders, fourspined sticklebacks, eels and tomcod are also common in the upper estuary.

Table 1 provides a partial list of both fish and invertebrates that have been found in the Sheepscot estuary.

The bottom organisms which constitute a dietary staple of many kinds of fish are abundant everywhere. Some of the chief food organisms of this sort - shrimps (Crago septemspinosus particularly), cumaceans, amphipods, small bivalves and polychaete worms - are extremely numerous and widely distributed. Small forage fish are also abundant: herring brit, young alewives, silversides and mummichogs, especially during the warmer months.

There are a few predators which are important because they attack species of commercial value. The spiny dogfish and the harbor seal are very common and range far into the estuary. Their depredations are at least troublesome to the fishermen if perhaps less serious to the populations preyed upon. The double crested cormorant is a fish eater and probably like the two predators cited above, may be more a pest than a menace. On the other hand, the green crab (Carcinides maenas) has been demonstrated to be a serious predator on the soft-shell clam and one of the chief factors involved in the recent decline in the populations of this shellfish (Glude, 1955; Dow and Wallace, 1952). The relative scarcity of this crab in the upper estuary where the water reaches very low salinity levels may partly account for the successful sets of clams that frequently occur in that area. These ubiquitous and hardy creatures do, however, manage to stray in small numbers so far into the estuary as to mingle with similarly vagrant fresh water species, such as dragon fly larvae. It should not be assumed from this that they normally penetrate fresh water. Due to the seasonal and tidal fluctuations in the location of the transition zone between fresh and brackish water, mixed populations of euryhaline marine and fresh water organisms are common in the innermost part of the estuary.

Great blue herons and kingfishers are numerous among the salt marshes and along the banks of the estuary and the river. Red breasted mergansers, American mergansers, ospreys and other fish-eating birds have been observed from time to time, also. The American merganser appears to be a serious predator on young salmon (White, 1939; Huntsman, 1941).

Some mention should be made here of the characteristic aquatic vegetation in the estuary. No attempt has been made to list all of even the common species, but there are a few which cannot escape notice. The common rockweeds Ascophyllum nodosum and Fucus vesiculosus are abundant on rocks and other solid substrata from the open coast to slightly above the falls at Sheepscot Village, between the tide marks. Below the low tide level, sometimes exposed at spring low water are Irish moss (Chondrus crispus) and kelp (Laminaria spp.) but they do not penetrate as far into the estuary as the other species mentioned. Enteromorpha intestinalis, a green alga, is common in the upper estuary, extending almost to fresh water in the summertime. This plant was found, along with the diatom Melosira spp., to constitute an important item in the diet of the mummichog (Fundulus).

Eel grass (Zostera marina) is present in shallow protected places from the seaward end of the estuary to somewhat above the falls at Sheepscot Village, and it appears to be increasing in abundance. Marsh grasses (Spartina alterniflora and S. patens) border the upper estuary and many tidal inlets elsewhere, often forming broad expanses of salt marsh. S. alterniflora was found to extend up the estuary somewhat beyond the average penetration of saline water, where it was associated with various species of sedge (Scirpus).

SUMMARY

During the years 1954 - 1956, a general ecological and hydrographic survey was made of the estuary of the Sheepscot River, Maine. This was done to provide background information for further more detailed studies of Atlantic salmon, clams, alewives, smelt, oysters and other

economically important species by cooperating Federal and State agencies.

The estuary is large relative to the size of the river, but its greatest area was found to be not estuarine ecologically or hydrographically. It can be conveniently divided into two parts: an upper, or interior part, and a lower. The upper section, within about six nautical miles of the river mouth, is characteristically estuarine, with marked dilution by the river and subject to strong seasonal and tidal variations in salinity. The lower section, extending about 14 nautical miles further to the Gulf of Maine, is actually a ria or long, narrow bay with typical neritic marine conditions. It is a complex system with many islands and interconnecting channels, one of which connects it with the estuary of the Kennebec River. This has the effect of producing a local lowering of salinity in the surface water toward the seaward end.

Temperature and salinity characteristics vary throughout the year and with locality and tidal stage so that a simple summary statement cannot be made with respect to these variables. However graphs are presented that summarize this information reasonably well.

Animal and plant life in the lower estuary are characteristically neritic or coastal marine. There is a much greater number of phyla and species represented there than in the upper estuary. The populations of the upper estuary are either isolated oligohaline species or mesohaline species with some extension of euryhaline populations from the lower estuary. A few species appear to be isolated in the upper estuary by a temperature barrier as well.

Table 1. *List of the more common aquatic animals collected or recorded from the Sheepscot estuary arranged according to habitat.

I. High salinity (28-30 o/oo) intertidal sediments	
Polychaete worms:	
Nereis virens Sars	sand worm
Nephtys caeca Fabricius	
Polydora ligni Webster	
Streblospio benedicti Webster	
Heteromastus filiformis Claparede	
Arenicola marina Linnaeus	lug worm
Clymenella torquata Leidy	bamboo worm
Pectinaria hyperborea Malmgren	trumpet worm
Amphitrite sp.	
Molluscs:	
Mya arenaria Linnaeus	soft-shell clam
Macoma balthica Linnaeus	
Ensis directus Conrad	razor clam
Gemma gemma Totten	

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*/ This list contains but a small fraction of the aquatic organisms in the estuary. The most interesting, conspicuous, or abundant species of fish and invertebrates are listed according to the habitat in which they are most likely to be found. It does not follow, however, that every situation where these various conditions prevail will be inhabited by every species listed for that habitat, nor that many species so listed will not be found elsewhere.

Most of these animals have no common names, but where such a name is in general usage it is included in the righthand column of the table as an aid to those not familiar with the Latin names. As a further aid, the species are arranged in groups of more or less related members.

Nassarius obsoletus Say | mud snail
Paludestrina minuta Totten

Crustaceans:

Corophium volutator Pallas
Phoxocephalus holbolli Kröyer

Protochordates:

Dolichoglossus kowalewskii Spengel | acorn worm

II. High salinity, infauna of subtidal sediments

Coelenterates:

Cereantheopsis americana Verrill | sea anemone
Edwardsia elegans Verrill | sea anemone
Acaulis primarius Stimpson

Polychaete worms:

Pholoe minuta Fabricius
Phyllodoce groenlandica Oersted
Nereis virens Sars
Nephtys incisa Malmgren
Nephtys caeca Fabricius
Lumbrinereis tenuis Verrill
Ninoë nigripes Verrill
Aricidea spp.
Diplocirrus hirsutus Hansen
Flabelligera affinis Sars
Pherusa plumosa Müller
Scalibregma. inflatum Rathke
Ammotrypane aulogaster Rathke
Maldane sarsi Malmgren
Praxillela spp.
Rhodine loveni Malmgren
Ampharete acutifrons Grube
Sternaspis scutata Ranzani
Hartmania moorei Pettibone

Molluscs:

Yoldia limatula Say
Yoldia sapotilla Gould
Nucula spp.
Thyasira gouldii Phillipi
Cerastoderma pinnatulum Conrad | cockle
Clinocardium ciliatum Fabricius | cockle
Crenella decussata Montagu
Thracia myopsis Müller
Tellina agilis Stimpson
Astarte undata Gould

Crustaceans:

Phoxocephalus holbolli Kröyer
Orchomenella pinguis Boeck
Leptocheirus pinguis Stimpson
Corophium spp.
Casco bigelowi Blake
Ampelisca spinipes Boeck
Dulichia sp.
Diastylis quadrispinosa Sars
Eudorella sp.

Echinoderms:

Caudina arenata Gould	sea cucumber
Ophiura robusta Ayres	brittle star

III. High salinity, subtidal epifauna, solid substrate

Sponges:

Halichondria sp.	
Chalina oculata Pallas	dead man's fingers

Coelenterates:

Metridium dianthus Ellis	sea anemone
Urticina crassicornis Müller	sea anemone
Obelia spp.	
Sertularia spp.	

Polychaete worms:

Harmathoë imbricata Linnaeus	scaled worm
Lepidonotus squamatus Linnaeus	scaled worm
Spirorbis borealis Daudin	

Molluscs:

Hiatella arctica Linnaeus	
Anomia simplex Orbigny	jingle shell
Anomia aculeata Gmelin	
Ischnochiton ruber Linnaeus	
Aeolidia papillosa Linnaeus	
Odostomia bisuturalis Say	

Crustaceans:

Balanus crenatus Bruguiere	barnacle
Idothea baltica Pallas	
Idothea phosphorea Harger	
Aeginella longicornis Kröyer	
Gammarus marinus Leach	beach flea
Gammarus annulatus Smith	

Echinoderms:

Asterias vulgaris Verrill	common starfish
Asterias forbesi Desor	purple starfish
Henricia sanguinolenta O.F. Müller	blood starfish
Ophiopholis aculeata Linnaeus	brittle star
Gorganocephalus arcticus Leach	basket star
Cucumaria frondosa Gunnerus	sea cucumber
Strongylocentrotus droehbachiensis O. F. Müller	sea urchin

Protochordates:

Boltenia echinata Linnaeus	sea squirt
Amaroucium sp.	
Didemnum albidum Verrill	
Dendrodoa carnea Agassiz	

IV. High salinity, intertidal, solid substrate

Molluscs:

Littorina littorea Linnaeus	periwinkle
Littorina obtusata Linnaeus	periwinkle
Thais lapillus Linnaeus	dog whelk
Acmaea testudinalis Müller	limpet
Mytilus edulis Linnaeus	common mussel

Crustaceans:

Balanus balanoides Linnaeus	barnacle
Gammarus locusta Linnaeus	beach flea

V. High salinity, subtidal, soft bottom epifauna

Molluscs:

Placopecten magellanicus Gmelin	sea scallop
Retusa obtusa Montagu	
Lacuna vincta Turton	
Nassarius trivittatus Say	mud snail
Cingula aculeus Gould	
Cylichna alba Brown	
Colus sp.	distaff shell

Crustaceans:

Pandalus borealis Kröyer	shrimp
Crago septemspinosus Say	mud shrimp

Echinoderms:

Echinarachnius parma Lamarck	sand dollar

VI. High salinity, miscellaneous bottom types, wanderers

Crustaceans:

Homarus americanus Milne-Edwards	lobster
Cancer borealis Stimpson	Jonah crab
Cancer irroratus Say	rock crab
Carcinides moenas Linnaeus	green crab
Hyas araneus Linnaeus	toad crab
Pagurus bernhardus Linnaeus	hermit crab

VII. Low salinity (0-27 o/oo), intertidal sediments

Polychaete worms:

Nereis diversicolor O. F. Müller	
Glycera dibranchiata Ehlers	blood worm
Polydora ligni Webster	
Scolilepides viridis Verrill	
Heteromastus filiformis Claparède	
Hypaniola grayi Pettibone	

Molluscs:

Mya arenaria Linnaeus	soft-shell clam
Macoma balthica Linnaeus	
Ensis directus Conrad	razor clam
Nassarius obsoletus Say	mud snail
Paludestrina minuta Totten	
Hydrobia salsa Pilsbry	

Crustaceans:

Cyathura carinata Kröyer	
Corophium volutator Pallas	

VIII. Low salinity, intertidal solid substrate

Molluscs:

Littorina littorea Linnaeus	periwinkle
Mytilus edulis Linnaeus	mussel
Volsella demissa Dillwyn	ribbed mussel

Crustaceans:

Balanus balanoides Linnaeus — barnacle
Gammarus locusta Linnaeus — beach flea

IX. Low salinity, subtidal solid substrate

Coelenterates:

Obelia longissima Pallas
Cordylophora lacustris Allman

Molluscs:

Crassostrea virginica Gmelin — oyster
Mytilus edulis Linnaeus — mussel
Odostomia bisuturalis Say

Crustaceans:

Balanus improvisus Darwin — barnacle
Rhithropanopeus harrisi Gould — mud crab
Neopanope texana Smith — mud crab
Jaera marina Fabricius
Leptochelia rapax Harger
Aeginella longicornis Kröyer
Gammarus annulatus Smith — beach flea
Gammarus tigrinus Sexton — beach flea
Carinogammarus mucronatus Say — beach flea
Corophium lacustre Vanhoffen
Melita nitida Smith

X. Low salinity, subtidal sediments

Polychaete worms:

Nereis diversicolor O. F. Müller
Scolilepides viridis Verrill
Hypaniola grayi Pettibone

Molluscs:

Mya arenaria Linnaeus — soft-shell clam
Paludestrina minuta Totten

Crustaceans:

Crago septemspinosus Say — mud shrimp
Cyathura carinata Kröyer

Arachnids:

Limulus polyphemus Linnaeus — horseshoe crab

XI. Nekton (fish) of deep, salty, or cold coastal waters

Squalus acanthias Linnaeus — Atlantic spiny dogfish
Raja erinacea Mitchill — little skate
Clupea harengus Linnaeus — Atlantic herring
Brevoortia tyrannus Latrobe — menhaden
Pollachius virens Linnaeus — pollack
Gadus callarias Linnaeus — Atlantic cod
Melanogrammus aeglefinus Linnaeus — haddock
Urophycis tenuis Mitchill — mud hake
Merluccius bilinearis Mitchill — silver hake
Pseudopleuronectes americanus americanus Walbaum — winter flounder
Scomber scombrus Linnaeus — Atlantic mackerel
Poronotus triacanthus Peck — butterfish
Myoxocephalus aeneus Mitchill — sculpin

Hemitripterus americanus Gmelin	sea raven
Cyclopterus lumpus Linnaeus	lumpfish
Liparis liparis Linnaeus	striped sea snail
Pholis gunnellus Linnaeus	gunnel
Ammodytes americanus DeKay	sand lance
Tautogolabrus adspersus Walbaum	cunner
Lophius americanus Cuvier & Valenciennes	goosefish

XII. Nekton of shallow, brackish, or protected waters

Fundulus heteroclitus Linnaeus	mummichog
Microgadus tomcod Walbaum	tomcod
Liopsetta putnami Gill	smooth flounder
Pungitius pungitius Linnaeus	ninespined stickleback
Apeltes quadracus Mitchill	fourspined stickleback
Syngnathus fuscus Storer	pipefish
Menidia sp.	Atlantic silversides
Morone americana Gmelin	white perch

XIII. Nekton, anadromous and catadromous, migratory

Pomolobus pseudoharengus Wilson	alewife
Pomolobus aestivalis Mitchill	glut herring
Alosa sapidissima Wilson	American shad
Salmo salar salar Linnaeus	Atlantic salmon
Osmerus mordax Mitchill	American smelt
Roccus saxatilis Walbaum	striped bass

XIV. Plankton, high salinity coastal waters

Coelenterates:	
Cyanea arctica Peron & Leseuer	red jellyfish
Aurelia aurita Linnaeus	white jellyfish
Ctenophores:	
Pleurobrachia pileus Fabricius	sea walnut
Chaetognaths:	
Sagitta spp.	arrow worms
Copepods:	
Calanus finmarchicus Gunner	
Pseudocalanus minutus Kroyer	
Centropages typicus Kroyer	
Centropages hamatus Lilljeborg	
Temora longicornis Muller	
Eurytemora herdmani Thompson & Scott	
Acartia longiremis Lilljeborg	
Tortanus discaudatus Thompson and Scott	
Microsetella norvegica Boeck	
Oithona similis Claus	
Cladocerans:	
Evadne nordmanni Loven	
Podon leukarti Sars	
Tintinnids:	
Tintinnopsis sp.	

XV. Plankton, shallow, brackish, and protected waters

Copepods:

Acartia longiremis Lilljeborg

Eurytemora herdmani Thompson and Scott

Table 2. List of the more common aquatic plants collected or recorded from the Sheepscot estuary.

I. High salinity coastal waters	
Algae:	
Laminaria longicruoris De la Pylaie	kelp
Laminaria digitata Linnaeus	kelp
Fucus vesiculosus Linnaeus	rockweed
Fucus spiralis Linnaeus	rockweed
Fucus evanescens C. Agardh	rockweed
Ascophyllum nodosum Linnaeus	rockweed
Chorda filum Linnaeus	
Desmarestia aculeata Linnaeus	
Chordaria flagelliformis Muller	
Chondrus crispus Linnaeus	irish moss
Polysiphonia lanosa Linnaeus	
Polysiphonia flexicaulis Harvey	
Corallina officinalis Linnaeus	
Ulva latuca Linnaeus	sea lettuce
Enteromorpha compressa Linnaeus	
Seed Plants:	
Spartina alterniflora var. glabra Fernald	marsh grass
Spartina patens Ait.	marsh grass
Zostera marina Linnaeus	eel grass
II. Low salinity, protected waters	
Algae:	
Enteromorpha intestinalis Linnaeus	
Enteromorpha clathrata Roth	
Lyngbya sp.	
Melosira sp.	
Polysiphonia subtilissima Montagne	
Dasya pedicellata C. Agardh	
Ectocarpus sp.	
Ceramium sp.	
Seed Plants:	
Spartina alterniflora var. glabra Fernald	marsh grass
Spartina patens Ait.	marsh grass
Zostera marina Linnaeus	eel grass
Ruppia maritima Linnaeus	

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