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An Inventory of Benthic Flora in the Casco Bay Region

by

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I. INTRODUCTION

A. Project Description

This report addresses the intertidal flora of rocky shores and salt marshes. Much of the work conducted over the last two decades has suggested that the intertidal flora are the most heavily impacted by oil which tends to concentrate in intertidal areas. While damage to largely subtidal flora, such as *Zostera marina*, and the laminarians has been occasionally observed, the effects of oil appear to be relatively minor. Because the effects of oil on subtidal flora are considered less harmful, and subtidal populations of flora cannot as easily be assessed, no attempt has been made to assess subtidal flora.

It is widely accepted that short or long term oil damage is often very localized. The understanding and assessment of oil damage, therefore, requires a precise understanding of local baseline data. With most biological groups, the gathering of such detailed baseline data is often time consuming and very costly. Large-format false-color infrared photography represents one of the most powerful tools for the examination of intertidal marine flora. Intertidal plant communities are, in fact, one of the marine communities that allow aerial photography to be used to its full potential. When false-color infrared photography is complemented by ground truth transects at selected sites, we gain an important perspective on intertidal marine communities, where important communities can be distinguished, and their extent of coverage documented. The examination of selected intertidal plant communities by false-color infrared aerial techniques complimented by ground truth transects also represents an effective way to examine seasonal changes in intertidal flora.

There are many ways to approach intertidal population analysis with respect to potential oil damage. We feel that the aforementioned approach has particular merit in that it allows for the examination of the entire coast with documentation of major plant communities at a local level stressing the dominant intertidal plant communities.

We feel that the project would best be served by establishing which elements of plant communities deserve attention. In our view it is most important to consider plants that either have real or potential economic value or function as important elements in coastal systems which may be impacted by oil. While species lists may be developed from ground truth transects, we feel that too much effort should not be given to this exercise as it is more important to describe economically important or dominant flora. While certain, often minor, elements of intertidal plant communities might be described as rare, or unusual, or have been shown to be sensitive to oil, such as various "indicator species", we feel that it is a mistake to structure this program around them. It would be wrong to over-emphasize the protection of minor floral elements at the expense of more dominant plants of economic value or greater environmental function. If one were to structure a program around "indicator species" of oil pollution, and these plants were of minor economic or ecological importance, it would be difficult to translate the disappearance or injury of these plants into a meaningful assessment of oil damage.

B. Value of benthic flora

1. Salt marsh plants

The preservation of salt marsh is important to Maine. These areas perform numerous vital functions that contribute to the well-being of coastal ecosystems.

Among their most important biological functions are those of providing food and habitat for many types of fauna.

The growth of salt marsh flora and its subsequent decay into detrital-bacterial conglomerates provides a food source for fauna that inhabit or frequent salt marshes. The production of organic matter also provides a food source to associated estuaries. The extent to which salt marshes provide a food source to associated estuaries is related to their size, productivity and relative degrees of flushing. The large tidal ranges and fringing nature of many Maine salt marshes promote a large flux of aerial (above ground) salt marsh food products to surrounding waters.

Salt marshes are additionally important as stabilizing and building elements along coastlines. While extensive root systems stabilize and bind sediment, aerial shoots of salt marsh plants decrease water velocities resulting in depositon of suspended matter. Sediment levels are gradually raised, making the area suitable for the invasion of higher level salt marsh vegetation, and finally terrestrial flora. Salt marsh flora also function to protect vulnerable coastline from erosion.

Citizens also directly benefit from the presence of salt marshes which provide aesthetically pleasing recreational areas and the opportunity to enjoy expanded hunting and fishing activities. Salt marshes are an integral part of the scenic attraction of Maine. As such they contribute to the economically important tourist industry.

It has been estimated that the Maine coast supports approximately 17,000 acres of salt marsh. When one considers the long, highly invaginated Maine coastline, it becomes apparent that salt marshes constitute only a small fraction of the total coastal marine and estuarine habitat.

Its ecological and indirect economic value together with its relative scarcity along the Maine coast certainly qualify salt marshes as areas worthy of intense preservation efforts.

With the realization that salt marshes play important roles in the structure of coastlines and the function of coastal ecosystems, salt marshes have received much attention. Excellent background information on salt marshes appears in works by Teal (1962), Redfield (1972), Niering (1973), Reimold *et al.* (1974), Halverson *et al.* (1974), Odum (1974) and Chapman (1977).

The salt marshes of Maine, however, have not received a great deal of attention. Much of what is "known" of Maine salt marshes has arisen from the extrapolation of work done in other regions that often support large salt marsh areas. Maine salt marshes have most recently been reviewed by Thornton (1981). Works dealing with Maine salt marsh areas include those by Taxiarchis (1953), Dow (1962), Sherman (1968), McCall (1972), Reed and Dandrea (1974), Gustafson (1974), Adams and Clough (1976), Hunter (1976, and Anon. (1977). Additional works appear in the 1971 Conference on Maine's salt marshes (Anon, 1971).

Primary productivity investigations of Maine's salt marsh flora include those of Vadas *et al.* (1976), McGovern (1978), Linthurst *et al.* (1978), Topinka (1980b), and Topinka (1981) which suggest that Maine salt marshes are often highly productive areas.

Salt marsh work on the Casco Bay area study region is limited. This work includes the efforts of Rowe (1972a, 1972b, 1973a, and 1973b). Rowe's studies are based on semi-quantitative observations of intertidal biota along transect lines in the vicinity of Cousin's Island, Casco Bay. While some of the common flora are noted, this work only provides general insight for a specific region. The dominant salt marsh plant was *Spartina alterniflora*, and the dominant rocky shore macroalgae were *Fucus* and *Ascophyllum*. The greatest, most comprehensive investigations of the gross size and nature of salt marshes in the Casco Bay region have been undertaken by the Maine Department of Inland Fisheries and Wildlife. This work provides some of the most detailed information on salt marsh size and type for salt marshes greater than 10 acres. This gross data was mentioned by Little (1972), and is referenced in the manual for the Maine Wetlands Inventory (McCall, 1972).

2. Rocky shore macroalgae

The function of marine macroalgae in coastal systems is varied. The primary productivity of seaweed communities is widely acknowledged to be one of the most highly productive systems in the world. On an invaginated rocky coast such as that of Maine, marine macroalgae are no doubt important producers of food matter and in many areas may have an annual productivity in excess to that of phytoplankton. While the energy flows of seaweed systems are poorly understood, substantial amounts of this production ultimately becomes available for various invertebrates, fish and other wildlife. Recent work, for example, has suggested the interdependence of lobster, sea urchin and seaweed populations. Another major function of macroalgal communities is associated with its value as a habitat. Many animals, especially invertebrates are closely associated with and dependent on seaweed communities.

Of all the factors acting to govern the distribution of marine macroalgae, availability of rocky or hard substrata for attachment is perhaps the most important. With few exceptions, this group of plants requires a stable base for attachment. The rocky coastline of Maine therefore provides great areas for potential growth. The diversity and productivity of algal communities are influenced by a large number of physical, chemical and biological factors. Of the physical factors, light is the most important as it drives the photosynthetic process. Light, thus becomes a major factor which prevents algal growth at greater water depths. The degree to which plants endure various physical stress, especially dessication, limits their upward penetration into the intertidal zone. The operation of light and dessication are therefore among the most important factors which result in a zone of macroalgae which extends from just below Mean High Water to approximately 20 m, depending upon light penetration. Other major physical factors of importance include salinity, temperature and wave exposure. While relatively little is known concerning the effects of nutrients on benthic algae there are strong indications that various inorganic nutrients such as nitrogen and organic substances may also be important.

The marine macroalgal populations of Maine are greatly influenced by the grazing activity of various invertebrate animals. Among the most important intertidal grazers are snails. In the subtidal, sea urchins often exert tremendous influence in keeping large areas essentially devoid of most vegetation which would otherwise grow in profusion.

The invaginated rocky coast of Maine provides a large number of habitats, each with its own but usually related flora. There are also pronounced seasonal changes in the presence and abundance of many plants which may result in large scale alteration of community structure. Much of this change is under the control of light and temperature. Rocky intertidal areas are however dominated by *Ascophyllum* and *Fucus* which are long lived. There is, therefore, no major seasonal change in the dominant plant structure on rocky shores.

While scientists believe they understand some of the major environmental factors controlling the growth and distribution of macroalgae, much of what is "known" has resulted from extrapolations from areas outside of Maine. The macroalgal flora of Maine has been reviewed by Topinka (1980b) in the State of Maine Coastal Characterization. Other reviews of macroalgal flora in Maine appear by Halvorson and Dawson (1974), Gustafson (1974), and Topinka (1977). Characteristics and data on macroalgal populations of Maine appear in Taylor (1957), Stone *et al.* (1970), Vadas (1972) and Topinka (1980b).

This report deals with the dominant intertidal macroalgal flora of the Casco Bay Region. In Maine, *Ascophyllum* and *Fucus* commonly dominate macroalgal biomass (Vadas, 1972; Topinka *et al.* 1980). The quantities of these fucoid algae as well as their distribution are considered by Topinka *et al.* (1980, 1981). There is little baseline data for macroalgal populations of the Casco Bay region. In his transect studies, Rowe (1972a, 1972b, 1973a, 1973b) observed that *Fucus* and *Ascophyllum* dominated intertidal macroalgal populations on rocky bottoms, apparently in a similar fashion to other Maine regions.

II. RESOURCE INVENTORY

A. Goals

The purpose of this resource inventory was basically twofold. The first goal was to provide the most useful type of data base that could describe and quantify dominant intertidal benthic floral resources. The second goal was to have that data provide the most effective mechanism for analyzing the potential effects of oil. The heart of this work is an atlas of false-color infrared aerial photographs which documents the distribution of intertidal salt marsh and rocky shore macroalgae. This atlas is accompanied by a key. From these tools the salt marsh and macroalgal resources in the Casco Bay region were quantified in terms of the area that they occupy. These methods were complimented by seasonal ground truth transects to observe major vertical zonation patterns and describe the dominant plants. As the major salt marshes are among the most important areas for benthic flora and are among the most vulnerable areas to long-term oil damage, the gross outlines of major salt marshes were presented as overlays on 1:24,000 topographical maps.

B. Methods

The area of salt marsh and intertidal beds of fucoid seaweeds was derived from aerial photographs taken specifically to examine intertidal flora. False-color infrared aerial photographs were taken vertically by a 70 mm format Hasselblad 500-CM camera equipped with an 80 mm lens. Kodak type 2443 false-color infrared film was used in conjunction with a Wratten #12 filter. Exposure was set at 1/500 sec., at f5.6. Photography was done at an altitude which gave a scale of 1:24,000 on 70 mm color transparencies. These photographs were taken along a predetermined grid to include all the coastline between Scarborough salt marsh and Cape Small during September 3-4, 1980 (Fig. 1). All photographs were taken ±1.25 h of low water during midday.

The outlines of individual photographs were traced onto 1:24,000 topographical maps to enable the user to more easily identify the position of photographs. An atlas was then constructed of the 468 aerial photographs which were keyed to the labeled topographical maps. The large salt marshes, having areas of at least 10 acres (0.040Km^2) and having mean widths between high and lower water of at least 50m were classified as the major, more mature salt marshes. The perimeter of these marshes were traced on plastic and their area determined by planimetry.

The area of fringing salt marsh and beds of fucoid seaweeds was computed from the shoreline length and the width of systematically observed plant beds. The product of the length of shoreline and the mean band width of vegetation yields plant cover of fringing salt marshes and seaweed beds. A milage wheel was used to measure shoreline length in the Casco Bay Region. Shoreline at MHW was found to be 769 Km. Aerial photographs were examined at 4 Km shoreline intervals at 222 sites. The width of plant zones was determined with the aid of a calibrated grid in a map reader. When sites were not clearly visable or plant identification was in question, nearest unobscured sites were examined. Sites were not examined for fringing salt marshes or macroalgae when they fell within shoreline boundaries designated as major marshes.

The intertidal zonation of dominant plants was examined seasonally at 6 sites. Representative salt marsh was examined at four locations including sites at Presumpcot River, Scarborough River, Cousins River and Whartons Point. Rocky shore sites were located at Fort Point and Crescent Beach. These sites are depicted in Fig. 1. Plant zonation was determined by transect analysis. Each transect line was identified by proximity to a numbered stake or landmark near extreme high water marks. Transect lines were extended at right angles to high water marks which directed transects down to lower intertidal levels. The flora along this transect line was photographed and vertical zonation of dominant flora determined.

C. Results

The atlas of false-color infrared photographs documents gross plant cover of dominant intertidal macrophytes. In the event of major oiling a loss of these plants may be estimated by examining the change that has arisen since these photographs were taken. Due to mechanical difficulties with the aerial camera and shading by clouds, photographic coverage is available over approximately 90% of the intertidal shoreline. Depending upon light intensity, color variation exists between various photographs. The color key to identifaction in Table 1 serves as a useful guide but careful judgement must be used to adequately define plant boundaries.

The plant cover of some of the major intertidal resources is given in Table 2. Dominant plant cover in the larger salt marshes totals 16.2 Km^2 (4001. acres). The cover of narrow bands of fringing salt marsh found outside the boundaries of larger marshes totaled 2.0 Km^2 (494. acres). Plant cover of intertidal rocky shore macroalgae, primarily fucoids, totated 7.7 Km^2 (1902. acres).

These values represent the gross magnitude of some of the dominant intertidal resources in the Casco Bay region between Scarborough and Cape Small. It seems apparent that the fringing salt marsh and intertidal macroalgal populations occur along extensive areas of shoreline and could not easily be protected from oiling. Effort, however, should be made to protect the major salt marshes.

The location of major salt marshes greater than 10 acres is given as a series of overlays in the appendix B. These overlays were taken from composite photographs to show gross outlines and magnitudes of salt marshes. Some distortion is apparent when an exact match to underlying topographical maps is attempted. A total of 15 salt marshes have been identified. A summary of the area of these salt marshes is given in Table 3. Major salt marsh within the study region totaled 16.2 Km^2 (4001. acres). The Scarborough River marsh accounted for 66% of this marsh and therefore dominates salt marsh area within the study region. Other larger salt marshes included the Spurwink River marsh and Cousins River marsh which accounted for 15% and 6% respectively of major marsh area. The remaining 12 marshes account for only 13% of major salt marsh area.

Estimates of salt marsh abundance agreed well with data based on the Maine Wetlands Inventory. Within the study region, a total of 15 salt marshes greater than 10 acres were identified and had a total area of 4001 acres. Mr. A. Hutchinson from the Department of Inland Fisheries and Wildlife provided data on the same region which suggested that 18 salt marshes greater than 10 acres were identified for a total plant cover of 4,330 acres. Considering that the criteria used to delineate salt marshes and/or salt meadows may differ and that the boundries of salt marshes are sometimes somewhat subjective, both inventories appear in general agreement.

The flora of salt marshes and intertidal macroalgal populations within the Casco Bay region are similar to those found elsewhere in Maine (Tables 5-10). A brief review of the Casco Bay flora examined is presented in the following section.

The salt marshes of the Casco Bay region are found in some protected areas where soft sediment has accumulated. The vertical zonation of flora corresponds to intertidal position. The lower marsh is dominated almost exclusively by *Spartina alterniflora*. At the base of these plants large amounts of salt marsh fucoids may also be found. The upper marsh is dominated by *Spartina patens*, *Juncus gerardi* and *Distichlis spicata*. Other plants are also common in the upper marsh, particularly near the upland border (Table 4).

A pronounced seasonal abundance of plants occurs in salt marshes. Growth of most of the dominant plants is initiated in the beginning of May. By mid-June, many dominant plants have reached 5-10 cm in height. Growth proceeds rapidly during summer. During July and August, many plants have beome mature. Maximum biomass is apparently reached by August and September. After this period, almost all remaining plants go into a senescent phase followed by the death of above-ground plant parts. Winter storms and scouring by ice finally removes much of the dead plant material, especially in well flushed marshes. Active growth is therefore principally restricted to the period between May and August. During this period they are apparently most vulnerable to oiling.

In contrast to salt marshes, a cover of intertidal macroalgae persists all year. Although pronounced changes occur in the abundance of small plants, *Ascophyllum nodosum* and *Fucus* dominate biomass all year. Major losses of these plants occur in spring, after *Ascophyllum* becomes reproductive and during winter due to the severity of storms and ice scouring. The vertical zonation of dominant plants does not change seasonably nor does the near-infrared reflectance. Spring and summer are apparently the periods of most active growth for fucoids, and they would presumably be more vulnerable to oil damage. *Chondrus crispus* populations occur at lower intertidal levels and in the upper subtidal regions. More luxurient growths of *Chondus* also occur in more wave exposed areas. As such, *Chondrus* populations are not very vulnerable to oil damage.

III. PROTECTION PRIORITIES

A. Literature Review

1. Rocky shore macroalgae

The effects of oil pollution on benthic marine algae has been reviewed by Nelson-Smith (1973), and most recently by O'Brien and Dixon (1976). While many of the possible effects of oil on benthic marine flora have not been investigated, some useful observations can be made. Based on surveys (Nelson-Smith, 1973; O'Brien and Dixon, 1976), much of the more deeply submerged flora apparently escape serious oil damage. As oil approaches the shore, much of it is deposited in the intertidal zone where it is often concentrated and can do the most damage to benthic flora. The most severe toxic effects of oil appear to be associated with direct contact. The extent of damage is a function of many factors. These include: the amount and type of oil, its degree of weathering, the duration of exposure, environmental conditions including temperature, the physiological state of the plants, the degree to which these plants are subjected to other forms of stress, and indirect effects such as those on grazers.

There are numerous ways in which intertidal macroalgal communities may be affected. Physically, plants may be smothered or substrate surfaces may be made unsuitable for colonization. The exchange of gases and uptake of nutrients may be impaired, increased wave drag of oiled plants will tend to dislodge large plants and greater heating effects during emersion may be observed. Plants may also be sensitive to various toxic fractions, such as the aromatics, which may cause death, or result in some form of physiological impairment. Reproductive activity, or other essential functions may additionally be damaged. Plants would also be expected to vary in their susceptibility to damage during different stages in their development or life cycle. More subtle effects could include long-term exposure to low levels of hydrocarbon pollution which could result in plant damage, but this is more unlikely on a rocky shore. Unfortunately, relatively little is known of these possible effects.

The physiological effects of oil and oil components on algae have been examined elsewhere (O'Brien and Dixon, 1976; and Vandermeulen and Ahern, 1976). Some physiological studies have indicated that oiling may result in decreased rates of photosynthesis (Clendenning and North, 1960; North, Neushul, and Clendenning, 1965), and of RNA and DNA synthesis (Davarin, Mironov, and Tsimbal, 1975). Growth rates may be similarly affected by exposure to petroleum hydrocarbons (Boney, 1974).

In his experimental work, Schramm (1972a, 1972b) found some decrease in photosynthetic activity in macroalgae by crude oils, but the effects were sometimes not immediate. Although the possible mechanisms involved were not identified, Schramm felt it was not interference of metabolic processes, but reduced CO_2 diffusion that caused this photosynthetic response. Such compounds as phenolics, however, can be metabolically toxic (O'Brien and Dixon, 1976) and can reduce photosynthesis (Clendenning, 1960; Clendenning and North, 1970). In oiling incidents, pigment degradation of affected species is often readily apparent. Respiratory activity may also be depressed by exposure to toxic hydrocarbons (Hopkins and Kain, 1971).

There are apparently few baseline data on the accumulation of hydrocarbons by marine seaweeds. The Massachusetts coast has been provided with some baseline information on the natural hydrocarbon content of benthic marine algae (Clark and Blumer, 1967; Youngblood and Blumer, 1973). Butler and Morris (1976) also have hydrocarbon data for *Sargassum* from the Atlantic. Clark, Finley, and Patten (1973) found significant amounts of pollutant hydrocarbons in *Fucus gardneri* three months after a large oil spill off the Washington coast which remained measurable for twelve months (Clark *et al.*, 1975). Significant differences in hydrocarbon content in *Ulva* so. and *Enteromorpha* sp. also were found between relatively polluted San Francisco Bay, and a clean water coastal inlet (DiSalvo, Guard, and Try, 1975).

Fourteen months after the AMOCO CADIZ oil spill off the coast of Brittany, France, (Topinka and Tucker, 1980) found that oil associated with *Fucus vesiculosus* tissue was correlated with gross levels of initial exposure. In heavily oiled estuaries *F. vesiculosus* continued to be contaminated with oil two years after the spill (Topinka, unpublished data). Transplant experiments between oiled and clean sites suggested that this long term oil contamination arose from oil leaching from contaminated nearby sediments.

The rocky shores, such as those found along the coast of France, support rich benthic communities which are susceptible to oil damage. Oil deposited in the intertidal zone can extensively damage benthic macroalgae. This is especially true at higher levels in the intertidal zone. Within a vertical distribution range, organisms of a single species occupying higher intertidal levels generally sustain greater damage than those from lower levels (Smith, 1968). This stress may result in the depression of the upper boundaries of susceptible plants. Recovering plant communities may not merely begin to raise vertical zonation levels, but upper population boundaries may be elevated to levels higher than previously occupied before oil spills (Southward and Southward, 1978). This is in apparent response to decreased grazing pressure at higher intertidal levels.

The action of browsing animals, the abrasion of waves, ice and sand, combined with evaporation of light fractions, and the incorporation of particulate matter by oil, all tend to remove oil from the rocky shores. Oil may also be removed through the action of marine microorganisms. Almost complete removal of oil by natural agencies, following a moderate oiling, may take only three to four months (Smith, 1970). Approximately one year after the rocky shores of Nova Scotia were heavily oiled, only small amounts of oil remained (Thomas, 1973). Since much of this oil is deposited in upper intertidal areas, oil may remain here for longer periods, where it may delay recolonization. Small amounts of oil may persist for some time in areas such as rock crevices, or amongst seaweed, barnacles, or mussels (Nelson-Smith, 1973).

The extent of oil damage to benthic macroalgae has been found to vary considerably with the factors associated with the spill. In the TORREY CANYON oil spill, *Fucus spiralis* suffered more damage than the other fucoid algae, but part of the damage may have been due to detergent spraying (Smith, 1968). The oil spill at Bantry Bay (Ireland) also resulted in macroalgal damage (Culliane, McCarthy, and Fletchar, 1975). Although high level fucoids were not as severely affected as in the TORRY CANYON spill, *Fucus serratus* was, as were a number of other algae, especially red algae. Here again, however, the use of detergents makes it difficult to distinguish between the effects of oil and those of detergents. The oil spill off Kent, in 1971, combined effects of oil and detergent, yet apparently resulted in little damage to luxurient *Fucus* and *Ascophyllum* populations, but some of the red algae did suffer (Tittley, 1972). Notini (1978) similarly observed little or no macroalgal damage when the tanker IRINI spilled medium and heavy fuel oil off the coast of Sweden. In his initial study of the oil spill in Chedabucto Bay, Thomas (1973) found *Ascophyllum nodosum* and *Fucus vesiculosus* fairly resistant to oil damage; only *F. spiralis* apparently suffered extensive mortality. Subsequent observation suggested that the intertidal range of *F. vesiculosus* was depressed down the shore and returned to a normal distribution after approximately 5 years. *Fucus spiralis* had not yet returned after 6 years (Thomas, 1978).

In general, moderate oiling apparently does not result in major damage to much of the benthic vegetation (Smith, 1970). Approximately 4 months after exposure to crude oil, following the Santa Barbara oil spill, significant damage to the intertidal zone was not evident (Holmes, 1969). The lower intertidal fucoid algae are more tolerant of both oil and detergents than other intertidal forms (Boney, 1974). Some plants, such as the delicate reds, may, however, be severely affected (Boney, 1974; O'Brien and Dixon, 1976). In local areas where heavy oil cover is complete and persists, complete plant communities could be destroyed, and no recolonization may be expected while surfaces remain oil-covered (Holmes, 1969).

Cross, Davis, Hoss, and Wolfe (1978) observed that considerable oil remained on *Ascophyllum, Pelvetiopsis,* and *Fucus* following the AMOCO CADIZ spill. The estimate of a 10 year recovery time for an oiled marine environment suggested by Morris and Clark (1978) appears reasonable as a maximum time for intertidal rocky shores. In areas that have been cleaned, or receive considerable tidal flushing or wave exposure, much of the recolonization would be expected to occur within a couple of years. Perhaps the term "complete recovery" should be abandoned for this implies that we understand the intertidal marine system well enough to make this judgement. Although the recovery following the TORREY CANYON spill of Kuwait crude oil off Cornwall in 1967 has been described as rapid and complete, recovery has not been extremely rapid and it is the opinion of some distinguished shore ecologists that the biota has not yet returned to normal (Southward and Southward, 1978).

An interesting pattern of gradually occuring oil damage appears to occur after oil exposure. Immediately after the AMOCO CADIZ oil spill much of fucoid vegetation appeared to persist in an apparently healthy state (Chasse, 1978). Upon closer examination however, a gradual loss of heavily oiled plants was noted over a period of several months (Floch and Diouris, 1979). This argues with the observation that *Ascophyllum*, oiled after the NEW CONCORD oil spill gradually lost its mechanical strength and was easily dislodged (Topinka, unpublished data). Tagged specimens of *Fucus vesiculosus* suggested that plants oiled by the NEW CONCORD oil spill grew at half the rate of unoiled plants during the winter of the first year. Observations, one to two years after the AMOCO CADIZ oil spill, however, suggested that no growth inhibition occured in *F. vesiculosus* from weathered oil leached from sediments (Topinka and Tucker, 1980).

Subtidally, the adverse effect of an oil spill on benthic plants would be comparatively minor, although subtidal plants whose frondage reached the water surface may be injured. Based on surveys (Nelson-Smith, 1973; O'Brien and Dixon, 1976), much of the more deeply submerged flora apparently escape serious oil damage. The TAMPICO MARU spill of toxic diesel oil into a small cove resulted in a very heavy shore damage to nearly all of the intertidal benthic algae, only a few specimens remaining (North *et al.*, 1964). Most of the plants, however, became re-established within a few months. Subtidally, the kelp *Macrocystis* was damaged somewhat, but subsequently returned and grew prolifically under decreased grazing pressure. Less toxic crude oil, however, from the Santa Barbara spill, did not appear to result in an appreciable damage to *Macrocystis* even though oil was trapped in large quantities by this plant (Holmes, 1969). Following the release of Navy fuel oil from the GENERAL M.C. MEIGS off Washington in 1972, damage to *Laminaria andersonii* was severe and still apparent after 2 years (Clark *et al.*, 1975). In intertidal areas, 2½ years after the spill, many plants began to appear in normal distribution patterns (Clark, Patten, and DeNike, 1978).

2. Salt marsh

Thomas (1973) reported oil damage to *Spartina alterniflora*. Other flora, however, were not visually seriously affected by oiling, but damage to various marsh plants has been documented (Ranwell, 1968). After a crude oil spill, Crowell and Baker (1969) found less damage to *Spartina*, while other plants varied in recovery. Moderate damage to lesser floral components by oil, however, would probably have a lesser effect on salt marsh ecology than damage to the principal floral components.

The rate of recovery or recolonization of *Spartina* after oiling will depend upon some of the factors already mentioned for macroalgae, in addition to the specific toxicity of the type of oil reaching the salt marsh, as well as the degree and frequency of oiling. Where sedimentation is greater, repopulation may occur sooner. Stebbings (1970) found repopulation of *Spartina* was almost complete 16 months after the TORREY CANYON spill. In this instance, *Spartina* grew in newly deposited sediment on top of the oiled marsh surface.

Many plants other than *Spartina* are susceptable to oil damage. Generally speaking they face the same types of problems as mentioned for *Spartina*. Individual salt marsh species have been found to vary considerably in their tolerance to oil pollution. In her extensive studies of the effects of oiling on salt marshes, Baker (1971a) has provided a useful classification of salt marsh plants on the basis of their resistance to oiling. As in other intertidal situations, considerable oil may be deposited in salt marshes after an oil spill. As a dominant plant in many marshes, *Spartina* has received considerable attention.

While *Spartina* can be eliminated in very heavily oiled areas as found by Thomas (1973), *Spartina* has an intermediate resistance to oil damage. Baker (1971a) found that a single oiling of *Spartina* did not result in severe damage, but repeated oiling could. She also indicated that *Spartina* has the capacity for fairly rapid recovery where rhizomes survive oiling, but very slow recovery when rhizomes are killed.

Damage to *Spartina* may not be immediately apparent. The extent of damage appears to vary with the physiological condition of the plants, as well as the time of oiling. Actively growing vegetation appears susceptible to damage when fresh oil adheres to plants (Ranwell, 1968). Outside of the growing season, Ranwell (1968) found that a moderate amount of fresh oil does not result in severe killing of *Spartina*. The presence of oil may, however, produce reducing anaerobic conditions in the sediment, which can result in the indirect death of *Spartina* (Baker, 1970). This oiling of sediment may be more critical during winter, when aerial shoots are absent (Thomas, 1973). Sporadic re-oiling of salt marshes can also occur during summer, when elevated temperatures remobilize oil.

After the NEW CONCORD oil spill *Spartina alterniflora* grew back relatively well in many oiled areas (Topinka, 1980a). Only in some heavily oiled areas was there some suggestion of oil damage. Long term effects of oiling could however be more severe. After the ARROW oil spill of Bunker C oil in Chedabucto Bay, a gradual attrition of *S. alterniflora* occured over three years, where plants that initially appeared healthy gradually died off in the next two years (Thomas and Harley, 1978).

The incorporation of oil into salt marsh sediments makes it practically impossible to remove. Natural degradation of oil takes place slowly and oil may persist for years (Nelson-Smith, 1973). Data from the oiled spilled into Buzzards Bay, Massachusetts also suggested that petroleum hydrocarbons persist in marsh and sediments (Blumer and Sass, 1972). The introduction of detergents in an attempt to reduce oil in salt marsh would greatly increase the potential damage to the marsh. It must be concluded that while a light oiling would probably result in only minor damage to a salt marsh, heavy or repeated oilings could destroy large areas with the possibility of slow recovery.

B. Oil sensitivity

Table 11 gives the relative sensitivity of common Casco Bay flora to crude oil. As the preceding reviews of oil damage to macroalgae and salt marsh have suggested, predicting the effects of oil is complex. If, however, one uses laboratory or field observations, some plants quite often suffer more oil damage than others. Part of this vulnerablility is due to the endogenous resistance to oil. Another factor would include the likelihood of a plant to become oiled. The relative sensitivity of plants to crude oil given in Table 10 is taken primarily from the work of

Baker (1971) and the author's knowledge based on his own observations. The usefulness of such a system is that it acts as a general guide to oil vulnerability. No precise rating of oil vulnerability is possible.

C. Protection priority system

In the event of an oil spill, what can be done to protect intertidal plant populations? Certainly oil spillage should be minimized. Once oil has escaped, quite often very little can be done to protect intertidal plant resources. In more wave exposed areas booms will not work well. Wave action in these more exposed regions will, however, tend to dissipate oil more quickly. More sheltered areas are more vulnerable to long-term oil contamination, but in regions where current velocities are high, protection by booms is also difficult if not impossible.

At this point it should be stressed that only the most wave and current sheltered regions are serious candidates for protection. Protection may include booms, deflection booms, skimmers and various pumping devices. It is in these sheltered areas that oil may do major damage and it is also in these regions that the aforementioned devices and others will be of the greatest use.

In a very broad sense, the open water intertidal macroalgal populations would be the least susceptible to oil damage as oil is often held away from these populations due to wave reflection. Wave and current action will also tend to remove deposited oil more quickly in these areas. In wave sheltered regions, rocky shore macroalgal populations tend to be more vulnerable to the damaging effects of long-term oiling. Salt marshes, however, with their shelter, poor flushing characteristics, and ability to retain oil are by far the most vulnerable populations of flora.

A reasonable protection plan would give salt marsh the highest priority relative to other populations. The best protection plan would be one where preventative measures were emphized. It would, therefore, be advisable in future planning to stress safe oil handling techniques and if possible avoid oil handling or tanker routing in the vicinity of salt marsh.

An adequate protection plan should also include the use of an oil spill response group which could be called upon by DEP and/or DMR to offer advice during major or potentially threatening oil spills. Such a group could also make recommendations on cleanup techniques. With the marine flora, oil cleanup often involves the cutting of intertidal marine plants. While this can remove significant amounts of oil from oiled shorelines, such cleanup techniques can result in more damage to plant populations than would have resulted if the oil were allowed to remain. Under some conditions harvesting would be advisable and under other conditions it would not. The ultimate decision to harvest should be made with a better understanding of the multitude of factors involved. If the harvesting of plants is decided upon, there are ways that it may be done to minimize damage to plant populations.

In the author's opinion, a convenient set of circumstances exists which allows some generalization with regard to protection priorities for marine resources. It has already been stressed that the major salt marshes should receive the highest protection priority. Salt marshes quite often support mudflats at their base which are among the most vulnerable marine invertebrate habitats. Also, both salt marshes and mudflats are important areas to many water birds. All of this represents a convenient set of circumstances for establishing gross protection priorities. It is therefore recommended that the highest protection priority be given to mudflat - salt marsh areas that are more extensive and/or productive in terms of marine invertebrates or waterbirds. Protecting these regions would, in fact, protect areas containing the most vulnerable and important marine resources. Such a gross protection plan could and should be complemented by plans to protect other regions that have been identified as vulnerable and are capable of being protected.

IV. DAMAGE ASSESSMENT

A. Ecological Damage

Before any estimates of damage are considered, it is important to make the distinction between monetary damage or loss and ecological damage. It would clearly be a mistake to place emphasis solely on those elemetnts that had a cash value. There are certainly those persons who would claim that no ecological disturbance should be accepted. While we certainly do not understand many of the systems we work with to the extent that we could predict all the important effects of oil, it is possible to define those major functions that are among the most important. Efforts should be directed toward preserving those activities, especially when they are important for functioning of coastal ecosystems.

For the intertidal flora considered in this report, the major functions include those of food production and providing habitat for fauna. Any damage resulting from oil spills that impairs to any significant extent these functions is clearly not acceptable. Such damage must not be allowed under any circumstances, even if such damage is not easily quantifiable in a monetary sense.

It is indeed unfortunate that damage claims require that the injured part of a marine system have an established monetary value. If a population has no commercial value, it is valueless. As absurd as that statement appears, it does in fact represent the present state of affairs. As biologists, we know that many parts of the marine system have a great worth to the system, but have no recognized market value. To declare valueless such things as many invertebrate larvae, and the primary producers that supply the biological energy is wrong. All this is said to emphasize the need for examining and protecting a great many facets of the marine system which do not have commercial value.

B. Monetary Damage

Monetary damage to marine resources can be claimed if it can be shown that damage has taken place to a commercial resource or resource which has some recognized monetary value.

A number of criteria must often be met if oil damage is to be established. Firstly, it is necessary that contamination by oil has taken place. Photographs and notes of contamination should be accompanied by the sampling of the original oil cargo and oiled samples of the marine resource in question. Here, it must be emphasized that the sampling for oil contamination should be started as soon as possible. In some instances, waiting a few days or two weeks may not be adequate if oil quickly disburses or weathers chemically. Ideally, a time course of sampling would allow a weathering, chemically changing oil to be identified for a longer period of time as its weathering characteristics could then be established. If heavy oiling is anticipated, sampling before oiling occurs will provide valuable baseline information on oil contamination before the spill arrives.

An important point to consider is that sampling of initial oiling should be adequate. Oversampling is highly recommended. Not all the samples need ever be analyzed, but may later be necessary if oiling is to be demonstrated over large areas. It is necessary that the magnitude of the oiled area be determined. This can be accomplished by aerial photography, and accompanied by observations made from a boat. It is, however, significant that oil may be remobilized during the first weeks or months and spread to other areas. This movement may be subtle and not involve large masses of oil at any one time. Where oil persists, its spread should be examined at some period after the initial spill.

Experience following the NEW CONCORD oil spill suggested that oiling cannot easily be visibly observed on many intertidal surfaces. Fortunately, fringing salt marsh along the Piscataqua River provided an excellent background for observing oil contamination from a small boat (Topinka, 1980). It is suggested that this is one of the best methods for determining the eventual spread of oil, even if salt marsh is not the major item of concern.

Ultimately, one needs to determine the area affected, the density of organisms, and the degree (%) of loss. Plant loss may be assessed by biomass transects with respect to control areas, growth studies documenting loss, or estimates of biomass harvested during cleanup. This product, multiplied by a dollar value will yield a damage estimate. Reasonable allowances should also be made for long-term damage if it is believed that oil may persist for extended periods. For salt marshes and intertidal macroalgae the contaminated area may be multiplied by the plant density and the degree of loss. With salt marshes, this loss may be expressed in calories of salt marsh food lost to the system multiplied by $1/10,000 Kal. For fucoid seaweeds on rocky shores, the loss may be multiplied by the value to seaweed harvesters or product value as determined by the Atlantic Laboratories in Waldoboro, Maine.

In addition to the previously mentioned methods for estimating monetary damage, other assessments are possible. Where appropriate, the cost of habitat restoration may be claimed. If advisable, funds from such claims might be used to physically and/or biologically restore regions such as salt marshes. Alternatively, such funds could be used to purchase similar habitat by the State which could be set aside as a preserve. The loss of water bird habitat could also be claimed. Estimates might be made of lost bird production or survival and the replacement value of birds claimed. If oiled birds were found, direct claims could be made for replacement costs.

The success of claims ultimately depends upon the support given to appropriate scientific investigations and the cooperation of the Attorney General's Office. Both must work together. While some claims for commercial loss may be straight forward, it is important that damage to traditionally non-commercial marine resources also be evaluated. Such evaluations should include attempts to place monetary values on ecologically important marine resources. In the final analysis, all important marine resources must be valued if they are to be adequately protected. Some will argue that the valuation of some non-commercial resources is too arbitrary and some of the methods used are not well substantiated. We must admit that to a large extent this is true. While "absolute" estimates of oil damage to non-commercial resources may not be possible, reasonable damage estimates must, however, be sought to deter oil damage to these resources.

V. BIBLIOGRAPHY

Adamus, M.S. and Clough. 1976. A preliminary listing of noteworthy natural features in Maine. Report prepared by Center for Natural Areas, S. Gardiner, Maine.

Anon. 1976. Maine Coastal Inventory. Report to the Coastal Planning Program of the Maine State Planning Office.

Anon. 1971. Proceedings of the Maine Salt Marsh Conference, Bowdoin College, November, 1971. 45 pp.

Baker, J.M. 1970. Oil pollution salt marsh communities. Mar. Poll. Bull. 1: 27-38.

Baker, J.M. 1971a. Seasonal effects of oil pollution on salt marsh vegetation. Oikos 22: 106-110.

Blumer, M. and J. Sass. 1972. Oil Pollution: Persistance and Degradation of spilled fuel oil. Science 176: 1120-1122.

Boney, A.D. 1974. Toxicity studies with an oil spill emulsifier and the green algae, *Prasinocladus marinus*. Mar. Biol. Assn. U.K. 50: 461-473.

Chapman, V.J. 1977. (ed.) Wet Coastal Ecosystems. Elsevier Scientific Pub. Co., Great Britain.

Clark, R.C. and W. Blumer. 1967. Distribution of N-paraffins in marine organisms and sediments. Limnol. Oceanogr. 12: 79-87.

Clark, R.C., Jr. and J.S. Finley. 1973. Techniques for analysis of paraffin hydrocarbons and for interpretation of data to assess oil spill effects in aquatic organisms. In: Proc. Joint Conf. Prevention and control of Oil Spills, 161-172. American Petroleum Institute, Washington, D.C.

Clark, R.C. Jr., J.S. Finley, B.G. Patten and E.E. DeNike. 1975. Long-term chemical and biological effects of a persistent oil spill following the grounding of the General M.C. Meigs, p. 479-487. In: Proc. Conf. Prevention and Control of Oil Pollution, San Francisco, Calif. Am. Pet. Inst., Washington, D.C.

Clark, R.C., Jr., B.G. Patten, and E.E. DeNike. 1978. Observations of a Cold-Water Intertidal Community After 5 Years of a Low-Level, Persistent Oil Spill from the General M.C. Meigs. J. Fish. Res. Bd. Can. 35: 754-765.

Clendenning, K.A. and W.J. North. 1960. Effects of wastes on the giant kelp *Macrocystis pyrifera*. Proc. Intern. Conf. Waste Dispos. Mar. Environ. 1: 82-91.

Cowell, E.B. and J.M. Baker. 1969. The recovery of a salt marsh in Pembrokeshire, South Wales, from pollution by crude oil. J. Biol. Conserv. 1: 291-295.

Cross, F.A., W.P. Davis, D.E. Hoss, and D.A. Wolfe. 1978. Biological Observations. *In* (W.N. Hess, ed.) The Amoco Cadiz Oil Spill - A Preliminary Scientific Report. NOAA/EPA Special Report, 283 pp.

Culliane, J.P., P. McCarthy and A. Fletchar. 1975. The effect of oil pollution in Bantry Bay. Mar. Poll. Bull. 6: 173-177.

Devarin, I.A., Q.G. Mironov, and I.M. Tsimbal. 1975. Influence of oil in nucleic acid of algae. Mar. Poll. Bull. 6: 13-15.

DiSalvo, L.H., H.E. Guard and K. Try. 1975. Comparative hydrocarbon content of algae from a San Francisco Bay wharf and a California coastal inlet. Phycologia 15: 245-247.

Dow, R.L. 1962. Maine's coastal marshlands - their values, present and future. Me. Dept. Sea and Shore Fisheries, Augusta, mimeo rpt.

Dubois, A. 1964. Les possibiltes de la photographic et de l'observation aeriennes pour l'etude des peuplements vegetaux marius. *In* Conf. Principes Methodes Integrat. Etudes Explor., Aerienne Resources Nat. en Vue Possibilites Mise en Valeur. Toulouse, S.I. 3 p.

Gilfillan, E.S., J.A. Topinka and C.S. Yentsch. 1974. Evaluation of potential impact on the marine resources of the northern coast of Massachusetts of an oil terminal at the Isles of Shoals. Submitted to the F.R. Harris Co.

Grundlach, E., S. Berne, L. D'Ozouville and J. Topinka. 1981. Shoreline oil two years after AMOCO CADIZ: New complications from TANIO. In: Proceedings 1981 Oil Spill Conference, EPA, API and USCG publ. 13 pp.

Guftafson, A. 1974. Macrophytes. In: A socio-economic and environmental inventory of the North Atlantic Region. Vol. I. Report to the Bureau of Land Management, Marine Minerals Division. 1-11: 1-14.

Halvorson, W.L. and Dawson, C.G. 1974. Coastal Vegetation. Coastal and offshore environmental inventory Cape Hatteras to Nantucket Shoals. Complement Volume. Marine Experimental Station. Graduate School of Oceanography, University of Rhode Island Marine Pub. Series 3.

Hunter, M.L. 1976. Maine Ecosystems. Report prepared by Center for Natural Areas, S. Gardiner, Maine.

Kelly, M.G. and A. Conrad. 1969. Aerial photographic studies of shallow water benthic ecology. *In* (P. Johnson, ed.) Remote Sensing in Ecology. University of Georgia Press, Athens, pp. 173-184.

Linthurst, R.A. and R.J. Reimold. 1978. Estimated net aerial primary productivity for selected estuarine angiosperms in Maine, Delaware, and Georgia. Ecol. 59(5): 945-955.

Little, A.D. 1976. A systems study of oil pollution abatement and control for Portland inner and outer harbor, Casco Bay, Maine. Report to the State of Maine Dept. of Environmental Protection, State House, Augusta, Maine.

Mann, K.H. and R.B. Clark. 1978. Long-term effects of oil spills on marine intertidal communities. J. Fish. Res Bd. Can. 35: 791-795.

McCall. 1972. Manual for Maine Wetlands Inventory. Maine Dept. of Inland Fisheries and Game publications. 37 pp.

McGovern, T.A. 1978. Changes in biomass and elemental composition in a northern population of *Spartina alterniflora* Laisel. Thesis submitted to Dept. of Botany and Plant Pathology, Univ. of Maine, Orono. 46 pp.

Nelson-Smith, M. 1973. Oil Pollution and Marine Ecology. Plenum Press, New York. 260 pp.

Niering, W.A. 1973. Ecology of a New England salt marsh. Ecol. Monogr. 43(2): 463-498.

North, W.J., M. Neushul and K.A. Clendenning. 1965. Successive biological changes observed in a marine cove exposed to a large spillage of mineral oil, pp. 335-354. *In* Symp. Poll. Mar. Micro-org. Prod. Petrol. Monaco.

North, W.J., G.C. Stephens and B.B. North. 1970. Marine algae and their relations to pollution problems. FAO Conf. of Mar. Poll., Rome, Italy.

Notini, W. 1978. Long-term effects of an oil spill on *Fucus* macrofauna in a small Baltic Bay. J. Fish Res. Bd. Can. 35: 745 -753.

O'Brien, P. and P.S. Dixon. 1976. The effects of oil and oil components on algae: A review. Br. Phycol. J. 11: 115-142.

Odum, H.T., B.J. Copeland and E.A. McMahan. (eds.), 1974. Coastal Ecological Systems of the United States, Vol. 4. The Conservation Foundation, Washington, D.C. 470 pp.

Ranwell, D.S. 1968. Extent of damage to coastal habitats due to the Torrey Canyon incident. Fld. Stud. Vol. 2, supplement, the biological effects of oil pollution in littoral communities. pp. 39-47.

Redfield, A.C. 1972. Development of a New England salt marsh. Ecol. Monogr. 42: 201-237.

Reed and D'andrea. 1974. Salt marsh relocation restoration in Maine. Report to the Maine Dept. of Transportation. 48 pp.

Reinmold, R.J. and W.H. Queen (eds.). 1974. Ecology of Halophytes. Academic Press, N.Y., N.Y.

Rowe, G. 1972a. Environmental study in the vicinity of Cousins Island, Casco Bay, Maine, August 1972. Report submitted to Central Maine Power Co., Augusta.

Rowe, G. 1972b. Environmental study in the vicinity of Cousins Island, Casco Bay, Maine, November 1972. Report submitted to Central Maine power Co., Augusta.

Rowe, G. 1973a. Environmental study in the vicinity of Cousins Island, Casco Bay, Maine, March 1973. Report submitted to Central Maine Power Co., Augusta.

Rowe, G. 1973b. Environmental study in the vicinity of Cousins Island, Casco Bay, Maine, June 1973. Report submitted to Central Maine Power Co., Augusta.

Schramm, W. 1972a. The effects of oil pollution on exchange in *Porphyra umbilicalis* when exposed to air. Proc. Int. Seaweed Symp. 7: 309-315.

Schramm, W. 1972b. Unter suchungen uber den Einfluss von olverschmutzunger auf Merrasalgen. I. Die Wirking von Rohofilmen auf den CO_2 - Geswechsel ausserhalb des Wassers. Mar. Biol. 14: 189-198.

Sherman, E.A. 1968. Toward saving Maine's salt marshes. Maine Fish and Game, Winter 1968.

Smith, J.E. (ed.). 1968. Torrey Canyon Pollution and Marine Life. Cambridge University Press, Cambridge.

Southward, A.J. and E.C. Southward. 1978. Recolonization of Rocky Shores in Cornwall after use of toxic dispensants to clean up the *Torrey Canyon* spill. J. Fish. Res. Bd. Can. 35: 682-706.

Stebbings, R.E. 1970. Recovery of a salt marsh in Brittany sixteen months after heavy pollution by oil. Environ. Pollut. 1: 163-167.

Steele, R.L. 1977. Effects of certain petroleum products on the reproduction and growth of zygotes and juvenile stages of the alga *Fucus edentatus* de la Phy (Phaeophyceae: Fucales). *In* (D.A. Wolfe, ed.) Fate and effects of petroleum hydrocarbons in marine organisms and ecosystems, Pergamon Press, New York.

Stone, R., E. Hehre, J. Conway and A. Mathieson. 1970. A preliminary checklist of the marine algae of Campobello Island, New Brunswick, Canada. Rhodora 72: 313-338.

Taylor, W.R. 1957. Marine algae of the northeastern coast of North America. Univ. Michigan Press, Ann Arbor. 509 pp.

Taxiarchis, L.N. 1953. Survey of the littoral zone of York County, Maine, with respect to commercial productivity. General Bulletin No. 2, Department of Sea and Shore Fisheries, Augusta, Maine. 14 pp.

Teal, J.M. 1962. Energy flow in the salt marsh ecosystem of Georgia. Ecol. 43: 614-624.

Thomas, M.L. 1973. Effects of bunker C oil on intertidal and lagoonal biota in Chedabucto Bay, N.S.J. Fish. Res. Bd. Can. 30: 83-90.

Thomas. M.L.H. 1978. Comparison of Oiled and Unoiled intertidal communities in Chedabucto Bay, Nova Scotia. J. Fish. Res. Bd. Can. 35: 707-716.

Thornton, L. 1980. Emergent Wetland. In: An ecological characterization of coastal Maine. U.S. Fish and Wildlife Service publication.

Topinka, J.A. 1977. Benthic Flora. In: A summary and analysis of environmental information on the continental shelf - Bay of Fundy to Cape Hatteras. Center for Natural Areas Rept. to B.L.M.

Topinka, J.A. 1980b. Benthic macroalgae. In: An Ecological characterization of coastal Maine. U.S. Fish and Wildlife publication.

Topinka, J.A. 1980a. Effects of the NEW CONCORD oil spill on the salt marsh resources of the State of Maine. Report to the Maine Department of Marine Resources. 23 pp.

Topinka, J.A. 1980. Long-term oil contamination of fucoid macroalgae following the AMOCO CADIZ oil spill. AMOCO CADIZ: Consequences d'une pollution accidentelle par les hydrocarbores. Pub. Sc. Tech. CNEXO.

Topinka, J.A., L. Tucker and W. Korjeff. 1980. The distribution of fucoid macroalgal biomass along central coastal Maine. In press, Botanica Marina.

Topinka, J.A., L. Tucker and W. Korjeff. 1981. A comparison of the geographical distribution of fucoid algae interpreted from false-color infrared aerial photography and ground truth measurements. Submitted to Aquatic Botany.

Turner, R.E. 1976. Geographic variations in salt marsh macrophyte production: A review. Contr. Mar. Sci. 20: 47-68.

Vadas, R.L. 1972. Survey of the hydrography sediments, plankton, benthos and commercially important plants and animals, including finfish, in the Montsweag Bay - Back River Area. VI. Marine Algae. Third Ann. Rept. to Maine Yankee Atomic Power Co., Augusta. 250-310.

Vadas, R.L., M. Keser and B. Larson. 1976. Marine Algae. Semi-annual report No. 8 submitted to the Maine Yankee Atomic Power Co. 242-280.

Vadas, R.L., M. Keser and C.P. Rusanowski. 1976. Influence of Thermal Loading on the Ecology of Intertidal Algae. Symp. on Thermal Ecology (G.W. Esch and R.W. MacFarlane, eds.) Augusta, Ga. pp. 202-212.

Vadas, R.L. and F.E. Manzer. 1971. The use of aerial photography for studies of rocky intertidal benthic marine algae. *In* Proc. Third Biennial Workshop on Aerial Photography in the Plant Science and Related Plant Sciences and Related Fields, American Society of Photogrammetry, pp. 225-266.

Vandermeulen, J.H. and J.P. Ahern. 1976. Effects of petroleum hydrocarbons on algal physiology: review and progress report, p. 107-125. *In* (A.M.P. Lockwood, ed.) Effects of pollutants on aquatic organisms. Cambridge University Press, London.

Walker, F.J. 1960. Sublittoral seaweed survey of the Orkney Islands. J. ecol. 38: 139-165.

Walker, F.J. 1954. Distribution of *Laminaria* around Scotland. J. Cons. 20: 160-166.

Wolfe, D.A. 1977. Fate and effect of petroleum hydrocarbons in marine organisms and ecosystems. Pergamon Press, New York.

Youngblood, W.W. and W. Blumer. 1973. Alkanes and alkenes in marine benthic algae. Mar. Biol. 21: 163-172.

Youngblood, W.W., M. Blumer, R.L. Guillard and J. Fiore. 1971. Saturated and unsaturated hydrocarbons in marine benthic algae. Mar. Biol. 18: 190-201.

Table 1. Identification of Dominant Marine Flora by false-color infrared aerial photography. An index to the aerial survey.

Plant group or substrate	Location	Color
Intertidal macroalgae *Ascophyllum*, *Fucus* and *Chondrus*	rocky shore	bright red-orange
Spartina alterniflora	lower salt marsh along creek or river margins	light purple, pink, blue, darker when under exposed
Juncus gerardi, *Distichlis spicata* and *Spartina patens*	upper salt marsh near border of bright red upland broad leaf plants	greenish-gray, pink-purple
Broadleaf upland vegetation	upper fringe of salt marsh	bright red
Mudflat	upper salt marsh	green-brown
Mudflat	lower shore clam-flats	gray, blue gray
Water	ponds, streams, rivers, open water	blue to black
Rock	upper intertidal on rocky shores	white to gray
Sand	sand beach	white

Table 2. Plant cover of dominant intertidal plants

Plant Group	Area of plant cover (Km^2)
Rocky shore macroalgae	7.7
Larger salt marshes	16.15
Fringing salt marsh	2.0

Table 3. Major salt marsh areas.

Location	#	Chart overlay	Area (Km^2)
Small Point	1	I	0.40
Doughty Cove	2	II	0.09
Mare Brook	3	II	0.28
Long Island	4	IV	0.40
Wharton Point	5	III	0.26
Little River	6	IV	0.07
Mill Brook	7	IV	0.28
Cousins River	8	V	1.04
Royal River	9	V	0.18
Presumpscot River	10	IX	0.46
Spurwink River	11	VII	2.37
Cod Rocks	12	VII	0.07
Scarborough River	13	VIII & IX	10.68
Fore River	14	X	0.23
Long Creek	15	X	0.05

Table 4. Common Marine Flora in the vicinity of Casco Bay

Plant	Habitat	Importance of marine resource based on value and extent of populations[1]. commercial importance	ecological importance
Ascophyllum nodosum	rocky shore	+++	+++
Fucus vesiculosus	rocky shore	+++	+++
Fucus spiralis	upper rocky shore	+	+
Fucus spp.	rocky shore	++	++
Chondrus crispus	lower rocky shore	+++	++
Gigartina stellata	lower rocky shore	+++	+
Laminqria spp.	subtidal rocky shore	+	+++
Enteromorpha spp.	mudflat, rocky shore	-	++
Zostera marina	mud-sand flat	-	++
Spartina alterniflora	lower salt marsh	-	+++
Spartina patens	upper salt marsh	-	+++
Juncus gerardi	upper saly marsh	-	+++
Distichlis spicata	upper salt marsh	-	++
Salicornia spp.	upper salt marsh	-	-
Scirpus spp.	upper salt marsh	-	+
Suaeda maritima	upper salt marsh	-	-
Triglochin maritima	extreme upper salt marsh	-	+
Solidago sempervirens	upper salt marsh border	-	-
Panicum vigatum	upper salt marsh	-	-
Atriplex patula	upper salt marsh	-	-
Typha spp.	upper salt marsh border	-	+

Table 4. (Con't.)

Plant	Habitat	Importance of marine resource based on value and extent of populations[1].	
		commercial importance	ecological importance
Rosa rugosa	terrestrial salt marsh fringe	–	–
Ruppia	salt marsh ponds	–	+
Salt marsh fucoids	lower salt marsh	+	++

1. none –, little +, substantial ++, great +++

TABLE 5
ROCKY SHORE - SITE I
FORT POINT, CAPE ELIZABETH

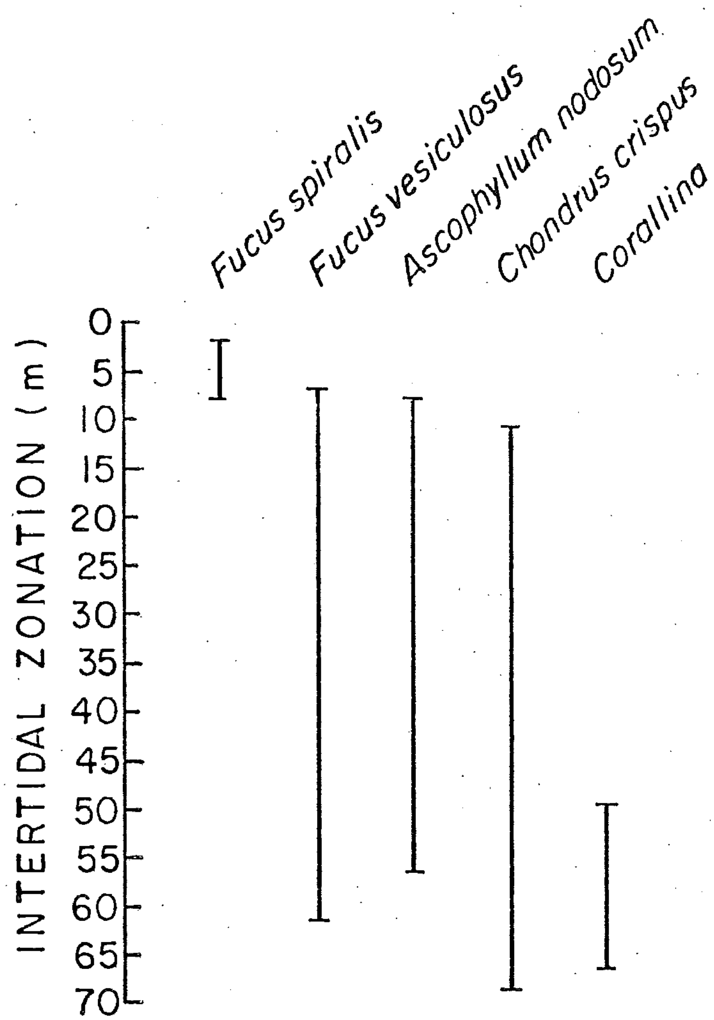

TABLE 6

ROCKY SHORE-SITE 2

CRESCENT BEACH, CAPE ELIZABETH

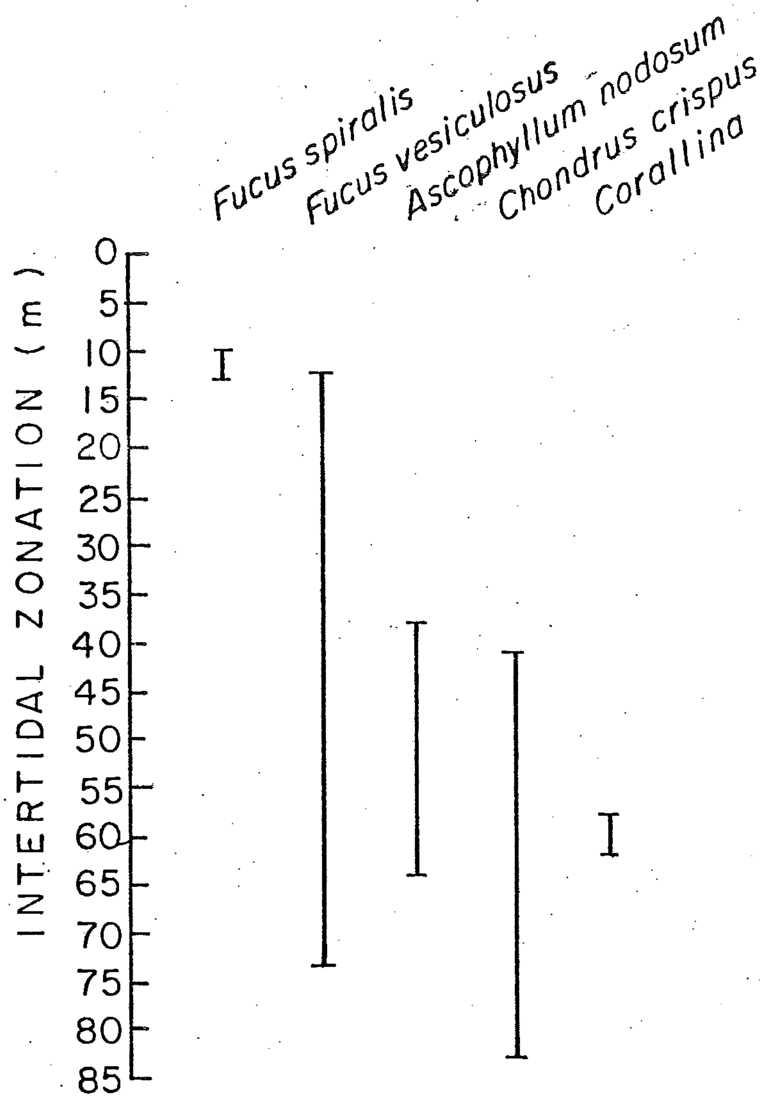

TABLE 7
SALT MARSH SITE 3
PRESUMPSCOT RIVER

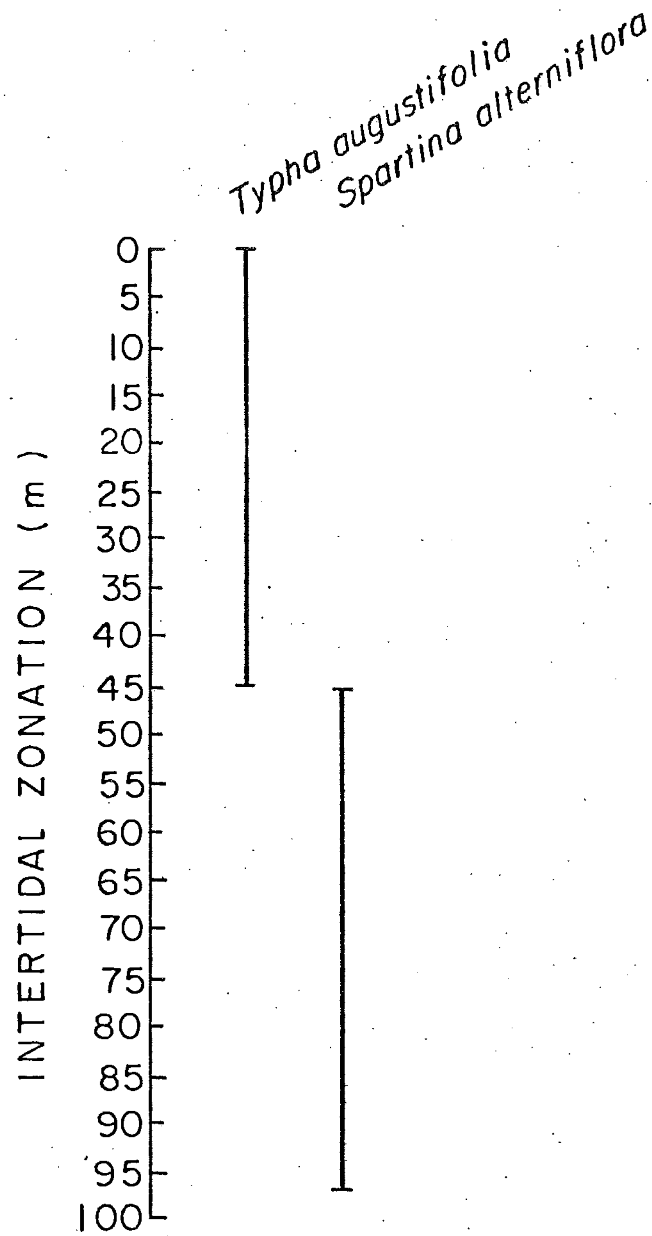

TABLE 8
SALT MARSH - SITE 4
SCARBOROUGH RIVER

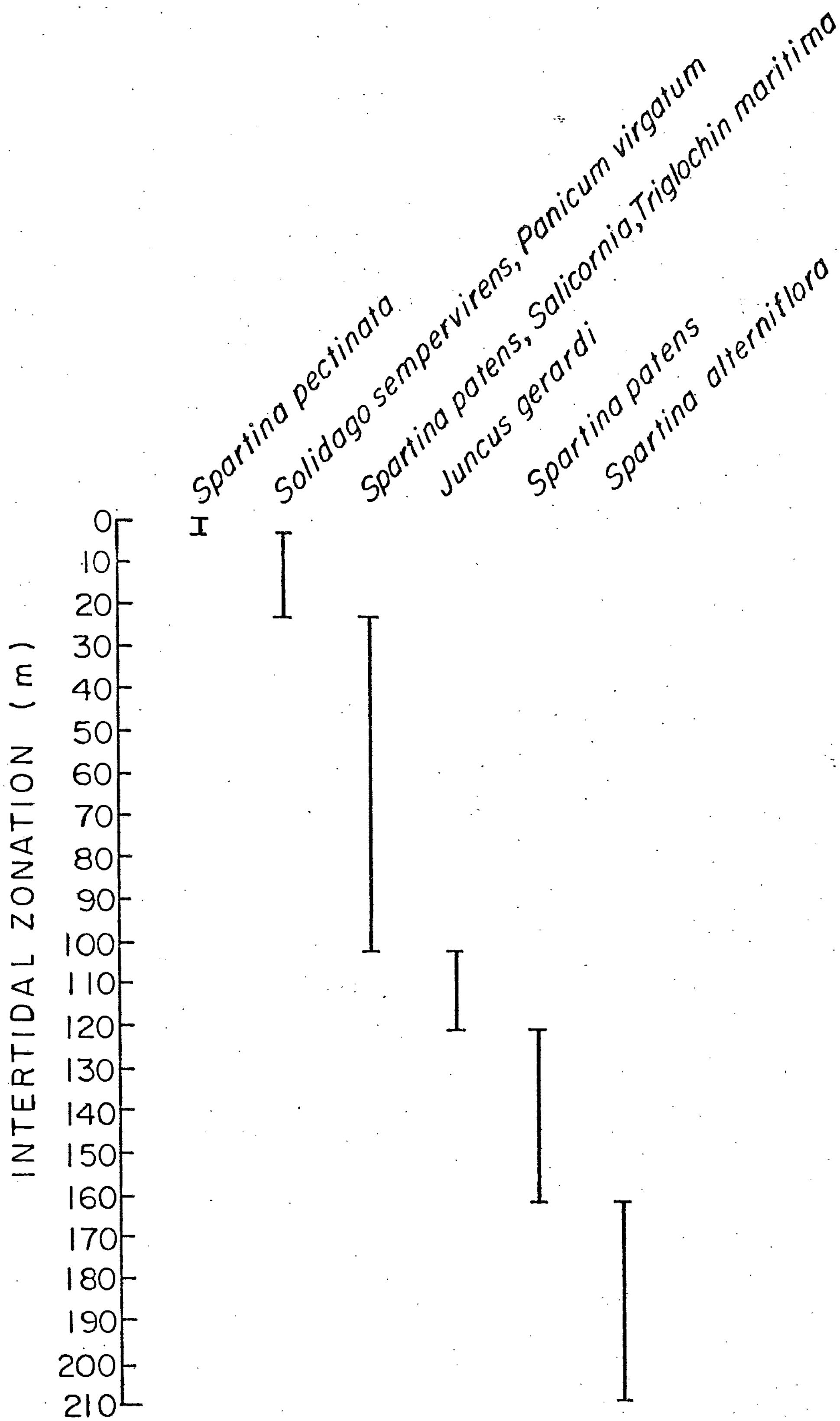

TABLE 9
SALT MARSH - SITE 6
WHARTONS POINT

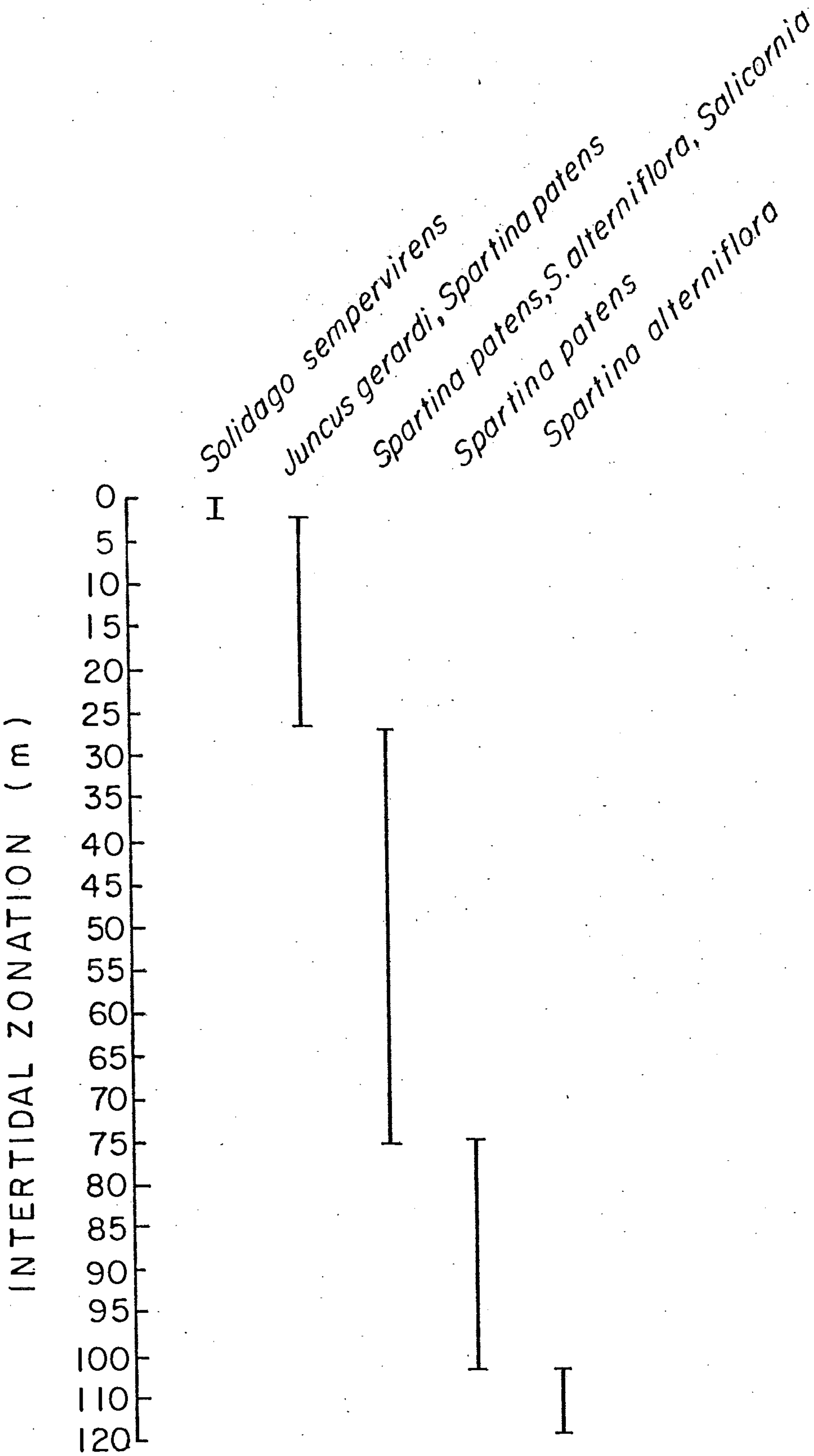

TABLE 10
SALT MARSH-SITE 5
COUSINS RIVER

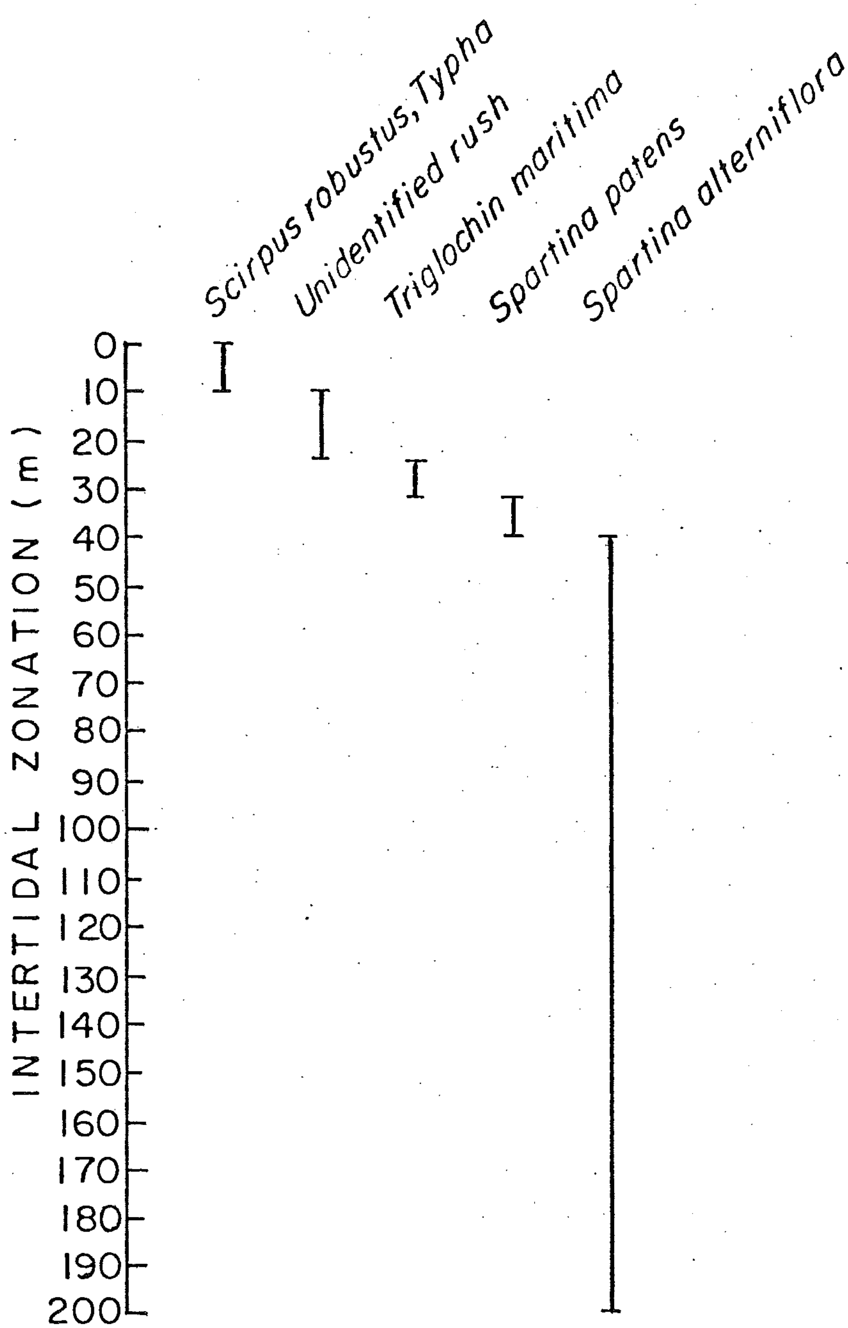

Table 11. Relative sensitivity to crude oil.

	Oil sensitivity
Ascophyllum nodosum	+
Fucus vesiculosus	+
Fucus spiralis	+++
Fucus spp.	+
Chondrus crispus	+
Girartina stellata	+
Laminaria spp.	0
Enteromorpha spp.	+
Zostera marina	+
Spartina alterniflora	+++
Spartina patens	++
Juncus gerardi	++
Distichlis spicata	++
Salicornia spp.	+++
Scirpus spp.	+
Suaeda maritima	+++
Triglochin maritima	0
Solidago sempervirens	0
Panicum virgatum	+
Atriplex patula	+
Typha spp.	0
Rosa rugosa	0
Ruppia	+
Salt marsh fucoids	+

[1]. based on endogenous sensitivity and anticipated exposure.
Insensitive 0, lightly sensitive +, sensitive ++, very sensitive +++