1977-78 Annual Sea Grant Report
Woods Hole Oceanographic Institution

Annual Report
Woods Hole Oceanographic Institution Sea Grant Program
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1977-78

Marine Resources Development and Management

Table of Contents

Introduction

The Woods Hole Oceanographic Institution is a private, non-profit research institution dedicated to broad research and educational programs in all aspects of marine science and technology. We have five departments: Biology, Chemistry, Geology and Geophysics, Physical Oceanography, Ocean Engineering and a Marine Policy and Ocean Management Program. Our ships and scientists work in all parts of the world's oceans, often in cooperation with colleagues from other institutions and countries.

In recent years we have increased our efforts in the coastal region and the scientific and policy aspects of that area. Sea Grant has played a very important role in this endeavor. Our increased focus in the coastal zone has benefitted from interactions with citizens and local, state and federal agencies, seminars and individual research programs. The support from the Office of Sea Grant has helped to initiate many of these interactions and resulting programs, both through its support of our research projects as well as allowing us to initiate new studies and, rapid response to needs. The increased growth and broadening of our Sea Grant program has had extremely positive effects on other research and policy efforts through the Institution.

During the past year we have had programs in Aquaculture, Living Resources, Socio-Political Studies, Ocean Engineering and Marine Environmental Research. For the coming year our efforts will be primarily in Coastal Zone - Biological, Geological and Physical Aspects; Chemical Processes and Pollution; Aquaculture; and Marine Policy.

David A. Ross
Sea Grant Coordinator
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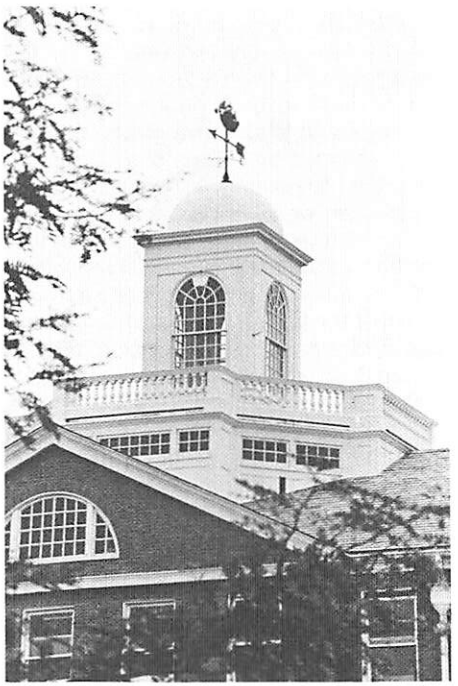
Woods Hole, Massachusetts 02543
December 1978



Environmental Research

The Marsh Biostimulation Project

John Teal and Ivan Valiela (M.B.L.)

Last year's efforts on the biostimulation project were involved with background studies for the stimulation experiment itself which will be conducted in succeeding years. We made an initial survey of the productivity and nutrient exchange characteristics of four marshes along Buzzards Bay. These were Great Sippewisset Marsh and Herring Brook Marsh in Falmouth, Pocasset Marsh and Back River Marsh in Bourne. We measured production of *Spartina alterniflora* by means of non-destructive samples taken every two weeks. The ten tallest plants on tenth square meter quadrants placed randomly on the marsh were measured and total above ground productivity calculated by means of a regression technique developed in previous years during our work in Great Sippewisset Marsh. Similar marsh types in all four marshes exhibited the same productivity which in turn was similar to that we measured over the last seven years from control plots at Great Sippewisset Marsh. (Fig. 1) Herring Brook marsh receives considerably more fresh water runoff, principally via a fresh water stream that enters close to our plots, than did the other marshes. Thus, on the average, it is more brackish. It does, however, revert to full bay salinity on every spring tide. The equivalence of grass productivity at Herring Brook with the other marshes supports our hypothesis that there will not be a detrimental effect due to the fresh water in sewage effluent that might offset the effects of nutrients. The question, of course, still needs direct experimental investigation. We have compared the growth rate of clams in the same four marshes. We placed marked clams, *Mercenaria mercenaria*, in sand boxes in creeks supported above the bottom and protected from predation by wire screens. Although mortality varied between marshes to a small extent, there was no significant difference in growth rates of the clams between marshes (see figure 2).

The foregoing measurements indicate that the marshes we have investigated for our experiment are comparable and may be used for either experimental or control purposes. Although our present plan is to concentrate our experiments on Great Sippewisset Marsh, we will continue to visit the other marshes occasionally for comparative purposes.

We have investigated the ecological behavior and occurrence of fish within the various marshes. The occurrence of over twenty-five species of fish has been noted, including such important commercial or recreational species as bluefish, eels, striped bass and menhaden. However, most of the work has been concentrated on the small species of minnow-like fishes that regularly come up into the smallest marsh creeks at high tide. These fishes, *Menidia menidia, Fundulus heteroclitus* and *Fundulus majalis*, are in that order by far the most abundant regular fish inhabitants of the marsh. (Fig. 3) *Menidia,* the silversides, spends nearly all of its time in the marsh creeks up off the bottom feeding on plankton and detritus suspended in the water itself. The two species of *Fundulus* stay close to the bottom moving up the tidal creeks as the tide rises, then into the grass itself to feed at the highest levels of the tide. This behavior pattern divides the resources between the species. Further division based on food habitats will be elucidated when stomachs collected during the summer have been examined.

We have also begun analyzing the distribution and abundance of insects, crustacea, arachnids, annelids and molluscs living in the soils. These samples were principally taken from the small scale experiments that have been conducted over the past eight years, sorted and identified but not previously analyzed. They will be extremely valuable in interpreting the results of the larger experimental stimulation of productivity. We have also continued to look at the distribution of heavy metal pollutants in the small scale experiments where stimulation was achieved by applying sterilized sewage sludge. We have examined the distribution in the marsh sediment of lead, copper, manganese, chromium, cadmium, zinc, iron, mercury and nickel. The effects of these metals on germination and growth of *Spartina alterniflora* are also being investigated experimentally to compare with the field results which exhibit no measurable effects on heavy metal contaminants on overall marsh productivity.

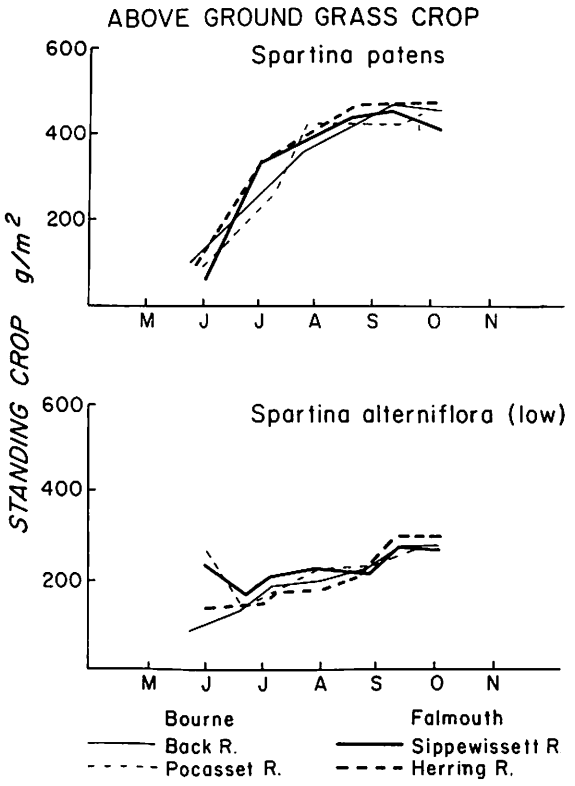


Figure 1

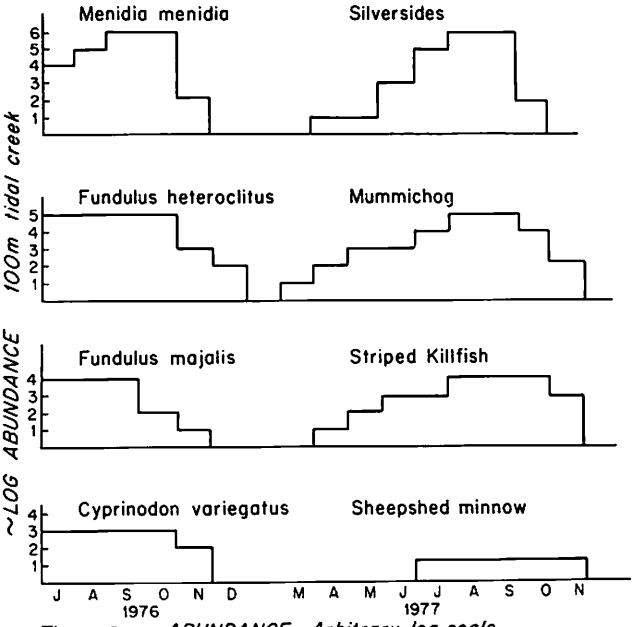


Figure 3 *ABUNDANCE - Arbitrary log scale*

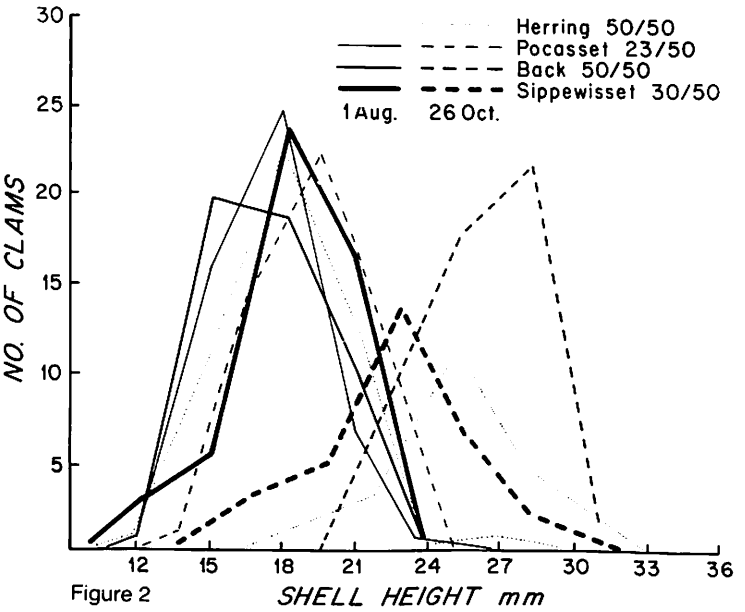


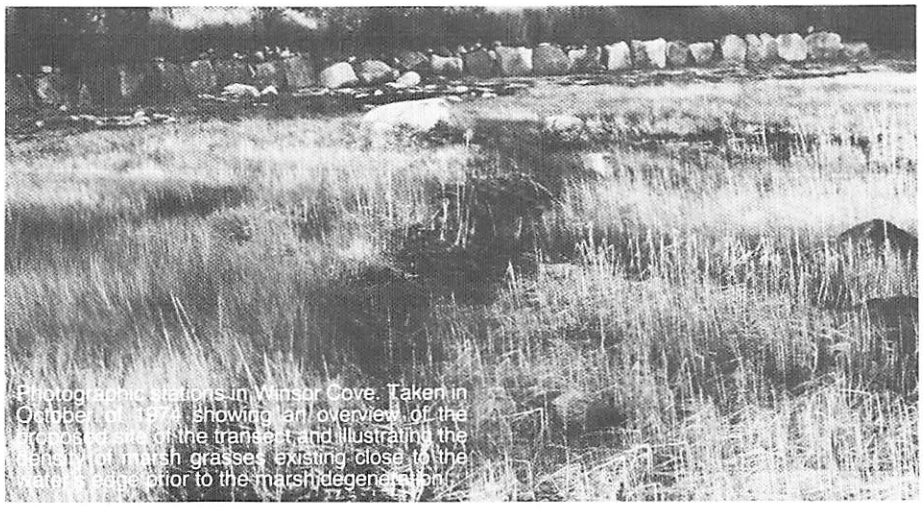
Figure 2

No. 2 Fuel Oil Spill in Bourne, Massachusetts: Immediate Assessment of the Effects on Marine Invertebrates and a 3-Year Study of Growth and Recovery of a Salt Marsh.

George R. Hampson and Edwin T. Moul

On October 9, 1974, the oil barge BOUCHARD spilled an undetermined amount of no. 2 fuel oil off the west entrance of the Cape Cod Canal in Buzzards Bay, Massachusetts. Within the following 2 week period, oil from the barge was found contained along the west side of Bassett's Island and inner Red Brook Harbor. Qualitative samples of dead and moribund marine invertebrates were collected in tidal pools and identified. Noticeable effects of the oil on the salt marsh plant community were also observed for a three-year period. Sea Grant New Initiative Funding provided us with the means to have our data properly illustrated and eventually published in the *Journal of the Fisheries Research Board of Canada*.

We conducted a detailed quantitative examination to determine the effects of the oil on various components of the affected salt marsh community in the effected area compared to a selected control site. From data collected 3 years after the mishap, some part of the marsh grass in the lower intertidal zone in the affected area has shown an inability to reestablish itself by either reseeding or rhizome growth (see Figures 1 and 2). The associated sediments showed a correspondingly high concentration of petroleum hydrocarbons impregnated in the peat substrate. Erosion rates measured in the affected area, as a result of the 3-year period of marsh degeneration, were 24 times greater than the control site.



Photographic station in Winsor Cove. Taken in October of 1974, showing an overview of the proposed site of the transect, and illustrating the healthy stand of marsh grasses existing close to the water's edge prior to the marsh degeneration.

Figure 1.

Photograph of the identical site taken in September 1977, three years later. Note the total absence of the *Spartina* in the lower marsh zone.

Figure 2.

Environmental Survey Design and Statistical Consulting to Sea Grant Programs

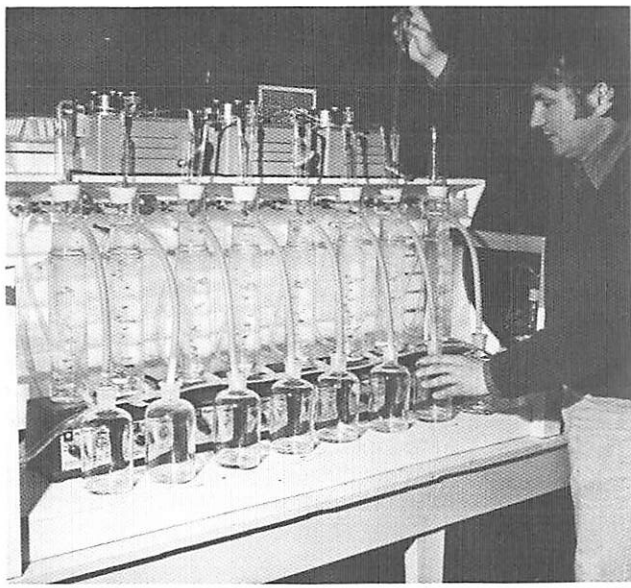
Woollcott Smith

This year's work emphasized a time series approach to environmental survey design, and a statistical consulting service was begun. The statistical consulting service was set up to aid individual Sea Grant investigators within the Woods Hole program, and also to advise state and local organizations on environmental sampling and data analysis problems.

Scientists working in the coastal and estuarine waters are faced with difficult sampling and data analysis problems. Important processes in this environment cannot be observed directly and in detail, as one might observe a field or forest. Observations are limited to samples taken with equipment such as plankton nets and bottom corers at fixed points in space and time. Collecting and analyzing these samples is both expensive and time consuming. The goal of both the survey design project and the statistical consulting program is to increase the information gained from these coastal and estuarine field studies.

The statistical consulting activities included, at various levels, most of the projects within the Woods Hole Sea Grant program. Fish populations in oiled and uncontamined marshes were analyzed statistically to determine differences in enzyme activity and histopathology. Liver size and body weight were used as control for some of the natural variability in enzyme activity within populations. Other activities included assistance in the analysis of tag-recapture data for a study of eel populations on Cape Cod, and aid in the design and analysis of the economic and social survey of New England fisheries conducted in the Marine Policy Program. We also worked with several groups outside of the Woods Hole Oceanographic Institution, including the Town of Falmouth on flood level estimation and the Massachusetts Division of Fisheries on the interpretation of environmental survey data.

The goal of the environmental survey design study is to provide both quantitative and qualitative tools for evaluating the effectiveness of existing and proposed survey programs in the marine environment. Major results of this work were published in *Estuarine and Coastal Marine Science* this year. In addition, using weighted regression techniques, we have developed a set of qualitative rules for judging the effectiveness of baseline surveys.



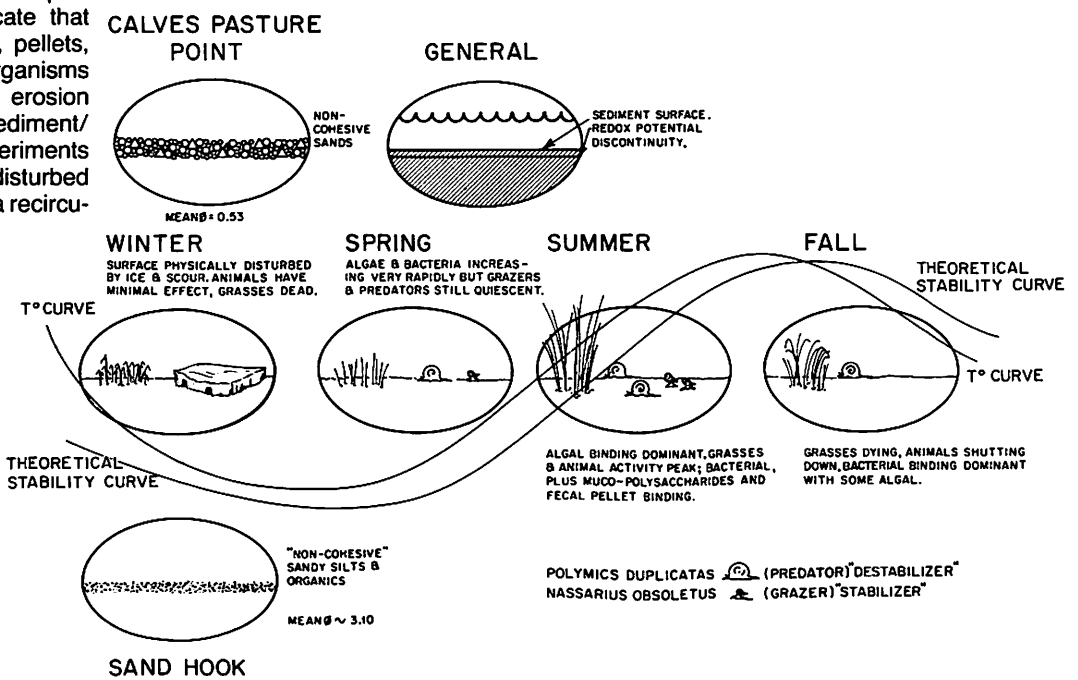
Biological and Physical Control of Erosion at the Sediment-Water Interface in Estuaries

Larry F. Boyer

The objective of this project is to create a predictive model for the seasonal erosion or preservation potential of features at the estuarine sediment/water interface.

Studies of the erosion and transport of sediments, both natural and artificial, have been conducted for years. They have historically indicated that the dominant sediment parameter associated with erosion is the sediment grain diameter, and the cohesive or noncohesive nature of the particles. Recent observations indicate that biological components — mucus, pellets, etc. — and the activities of the organisms themselves — can control the erosion resistance of the immediate sediment/water interface. Therefore, experiments were conducted with natural, undisturbed cores of the estuarine interface in a recirculating saltwater flume to determine the seasonal effects of organisms and their products on sediment erosion (initiation of sediment motion). These studies were conducted on samples from Barnstable Harbor, Massachusetts; run at Yale University in a flume provided by Dr. D.C. Rhoads. The flume was maintained at 20°C and 35% salinity. Particles were observed with a wide binocular scope trained on the interface.

The preliminary results indicate there is a seasonal trend in the erosion of the sediment/water interface and an asymmetry in erosion potential (giving high potential at ebb tide) due to meiofaunal reworking of the sediments. A conceptual model of the results is shown in the figure below.



Grain Size in Laminae of Beach Sand

K.O. Emery

Beach sands have long been known to contain many laminae that differ in grain size and mineral content. General observations and laboratory analyses show that the fine-grained laminae contain most of the dark heavy minerals (magnetite, ilmenite, garnet, etc.), and the coarse-grained laminae contain most of the light minerals (quartz, feldspar, and calcite). The differences in mineral composition and grain size appear to be due to differences in competence of the fast landward rush of wave swash followed by the slower oceanward return of the water. An additional important control of erosion-deposition (and thus of laminae) is the position where the water table intersects the beach surface. Landward of the water table outcrop the backwash is lessened by the amount of water that escapes into the sand, whereas oceanward of it the backwash is augmented by escaped groundwater. In effect, this means that erosion by swash is concentrated seaward of the water table at the time of the swash, and deposition is concentrated landward of it. Laminae are to be expected only above the water table on the foreshore.

Simple hand lens or binocular observations of grain size are sufficient to describe vertical grading and general structure of laminae but collection of individual thin laminae for precise laboratory analysis is difficult. Use of a small corer having a piston controlled by a screw-in drive shaft permits the collection of a series of thin (1.67 mm) slices of sand deposits. (See figure). Several slices are required to penetrate a single coarse or fine-grained laminae on foreshores of beaches. Grain-size analysis of the sand in each slice by settling tube is followed by computation of statistical parameters. The results show that the slices have a much broader range of median diameter, are better sorted, and are more positively skewed than are those for a composite core of the same sands. This means that investigations of beach-sand sources and of hydraulic conditions of erosion and deposition based upon sand texture may be better served by analysis of laminae than of total sample.

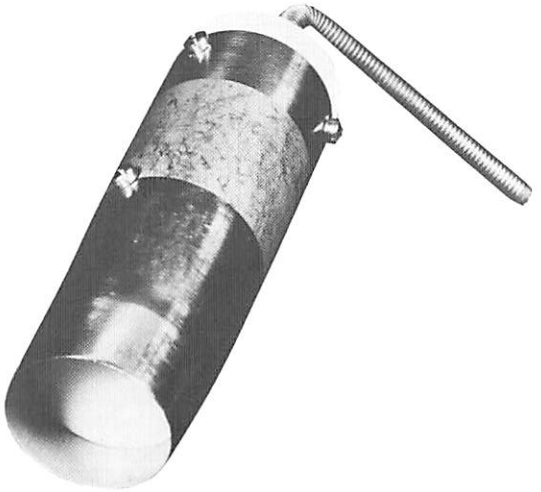
The results of this study yielded several conclusions concerning laminated beach sands:

1. Lamination due to swash appears to be restricted to the foreshores, absent in the offshore, and generally absent on berms.

2. Differences in textural parameters between coarse laminae and fine laminae are great enough to (a) require better sampling of foreshores than is permitted by previous methods, particularly when the intent is to investigate sources of the sands or hydraulic conditions of deposition, (b) influence patterns of textural parameters in grids or along lines of beach sand samples, (c) cause anisotrophy in permeability of the sand, and (d) permit depth variation of total heavy minerals (and microfossils) and the ratios between minerals or microfossils of different specific gravity or shape.

3. Phi shewness measures for most laminae are positive, and for composite foreshore samples slightly less positive. Earlier findings of typical negative skewness for beach sands may have been based upon samples from beaches containing dominantly fine-grained laminae as well as upon analysis by sieving.

Sedimentologists who may believe that the above results are different from those obtainable by sieving or by other statistical treatments are encouraged to test their preferred methods on new samples. In the process they will broaden and extend geographically the inquiry into laminae within beaches and other sedimentary deposits.



Volatile Organic Compounds in Coastal Seawater

P.M. Gschwend, M. Hulburt and O.C. Zafiriou

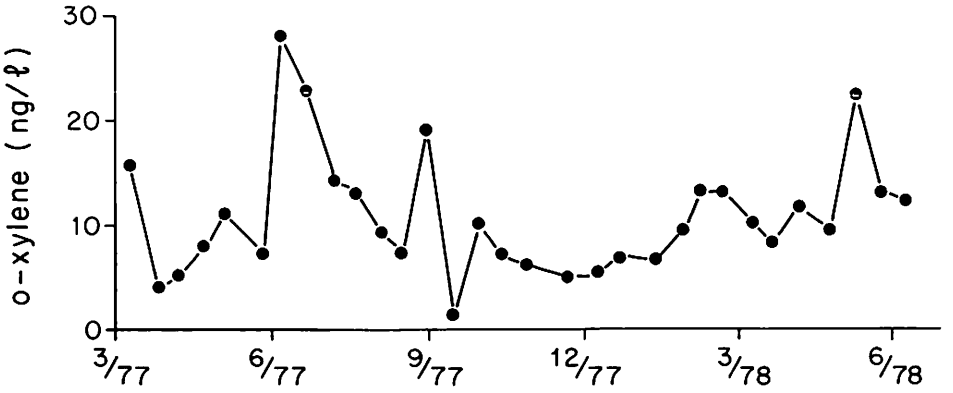


Figure 1

Under Sea Grant new initiation funding we have continued to analyze surface waters from the vicinity of Chemotaxis Dock near Woods Hole on a bi-weekly or more frequent schedule. Using newly developed methods (Schwarzenbach et al, 1978), we are able to quantify and identify a wide variety of trace organic compounds, including about fifty different substances of varying chemical structure. Some of these substances appear to have natural sources while others are anthropogenic. It is often not easy to resolve the anthropogenic vs. natural origin question.

Figure 1 shows 15 months of data on the abundance of 1, 2-dimethyl-benzene (ortho-xylene); this compound is abundant in many oil-derived products and has no known natural sources. For two years running a pronounced spike above the "background" level was found after Memorial Day weekend, a period of intense traffic on Cape Cod. We thus strongly suspect that automobile and/or small boat traffic are the major source for this pollutant material.

Evidence for a "weekend effect" was sought by plotting the level found against day of the week (sampling varied during the 15 months). There is a clearly discernible trend towards high Monday values and a rapid decline to the 10 ng/1 level during the week. A part of the orthoxylene input in our area is thus indisputably anthropogenic and must derive from the tourist industry. Whether the "background" derives from everyday traffic levels or from some other source is harder to determine, but further studies of this kind should be most revealing.

We have assigned to a natural source one of the major compounds seen at this site, aldehyde tridecanal. During February-March, 1978 there was a strong peak in tridecanal concentration in the water, which rose to over 100 ng/1. Concentration of chlorophyll a in the water simultaneously peaked, suggesting that the source might be a marine phytoplankter. Cell counts showed algae present to be 85% *Thalassiosia nordenskioldii,* a diatom which may well be the source of this compound. The cell count, chlorophyll level, and aldehyde (do-decanal and tridecanal) levels are shown in Figure 2. We do not understand why any marine organism would make and excrete these substances, nor are we sure that the predominant organism must be the source. The same species or a related one may be producing much smaller amounts of the closely related compound dodecanal.

These two instances reveal how trace chemical observations can be combined with other information about the coastal zone to understand some of the processes chemically affecting the water there. Continued observation is required in order to test our hypothesis further. For example, future sampling schedules will be intensified near holiday weekends, and we shall see whether next year's *Thalassiosia nordenskioldii* blooms are directly accompanied by large aldehyde increases.

It is also noteworthy that the peak levels reached in the waters by a compound with a strong biological source are similar in magnitude to levels reached on busy weekends by the anthropogenic input ortho-xylene.

Reference:

Schwarzenbach, R.P., R.H. Bromund, P.M. Gschwend and O.C. Zafiriou, in press. Volatile organic compounds in coastal seawater: preliminary results. *Organic Geochemistry.*

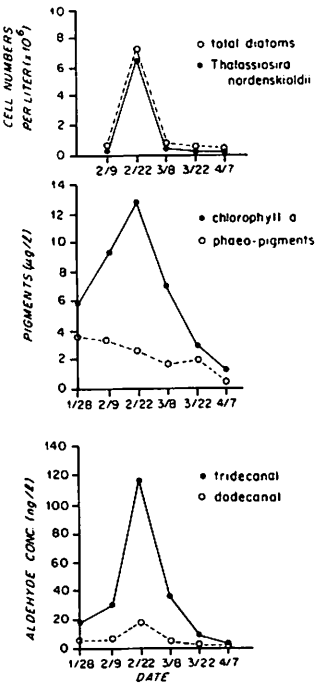


Figure 2

Source and Fate of Urban Estuarine Sediments - Boston Harbor

John D. Milliman, Marshall Orr, Michael Fitzgerald and Jeffrey P. Ellis

By their nature, urban estuaries are subjected to a variety of human pressures. Boston Harbor is perhaps unique in New England in that its major source of both "fresh" water and sediment is from sewage treatment outfall. To examine the movement of anthropogenics, organics, and contaminants through this urban estuary, we initiated a two-year field program, the first year of which emphasized the study of suspended particulates, seismic surveying, and sampling of the sedimentary record.

Suspended matter sampling and water column measurements — temperature, salinity, dissolved 0_2, and nutrients — at eight stations delineate tidal and seasonal variations within the system. Particulate concentrations vary from 0.5 mg/L to 10.0 mg/L, with tidal variations often equalling seasonal changes. Laboratory and scanning electron microscope analyses of the particulates suggest the importance of organics in the transport of heavy metals.

A 200 kHz profiling system enables delineation of the spatial distribution of particulates and tracing the development and dispersal of the outfall plume. Over 100 nautical miles of seismic (3.5 kHz) lines define the bottom morphology and subbottom characteristics. These data aid in identifying the erosional and depositional provinces, and help in interpreting the late Holocene history of the harbor. Several areas display turbidity - coincident with bottom sediments containing high organic and trace metal concentrations.

To examine the pollution history of the harbor, 5 harbor sites were cored using a hydrostatically damped corer. The sediments recovered were primarily dark, anerobic muds with traces of H_2S. Sedimentation rates from Pb^{210} "dating" were as high as 0.5 - 1.0 cm/yr. - very high, considering the relatively low suspended matter concentrations. Heavy metal concentrations show gradual increases since about 1900, a further indication of increased pollution within the harbor.

An interesting sidelight has developed from the suspended matter observations in this and related projects. Carbonate laths (both calcitic and aragonitic) occur in suspension in nearshore and shelf waters during winter months. These laths appear to come from the degradation of mollusc shells by winter storms. Coincidence of these suspended carbonate laths with bottom molluscan debris suggests relatively little lateral transport. Laths either settle out of suspension or are dissolved.

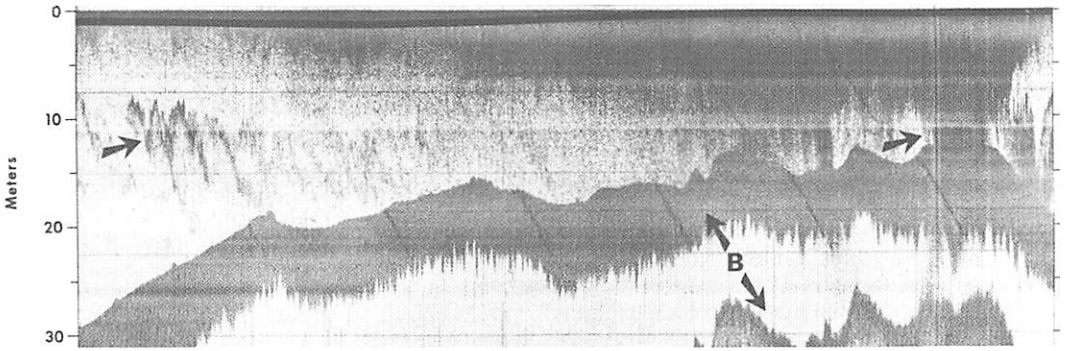
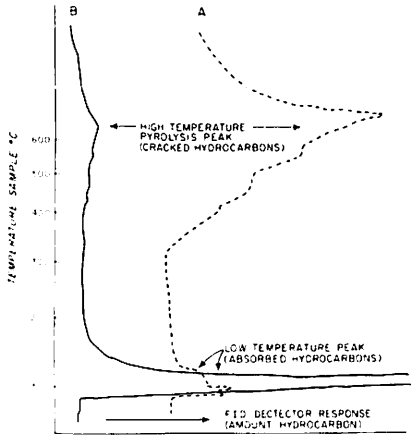


Figure 1 — 200 kHz profile showing the distribution of particulates within the water column off the Deer Island outfall in Boston Harbor. The bottom (and a secondary echo) are delineated by the letter B. Note both the heavy concentration of suspended particulates in the surface of the water, seemingly emanating from the bottom (arrow at the right). Note also the concentration of particulates at approximately 10 meters water depth (arrow on the left) suggesting either settling from the surface or introduction of new material from another source.

Figure 2



A New Method for Characterization of Marine Organic Material in the Water Column and in Sediments

By Jean Whelan

The objective of this work is to develop a method for characterizing small samples (0.1 - 300 mg) of marine organic matter utilizing the techniques of gas chromatography, (GC) - thermal distillation and GC-pyrolysis. The former is designed to recover volatile, organic molecules absorbed onto the particles without significant alteration. The latter cracks the molecules and uses the molecular patterns of cracked products for identification. Such techniques are potentially faster, less expensive, less subject to contamination, and of wider applicability than conventional extraction procedures.

Technique development is nearly complete. A flow diagram of the instrument as currently set up is shown in Figure 1. We can currently analyze compounds with volatilities in the range of C_1 to C_{20} hydrocarbons via capillary GC. The compounds can also be trapped on a solid absorbant (TENAX) for later further analysis by GC-mass spectrometry, if desired.

Examples of the type of data available from the analysis is shown in Figure 2. Figure 2 shows a plot of hydrocarbons evolved as the sample is heated for a fuel oil spiked sediment versus a non-polluted marine sediment containing a very high (11%) organic carbon content. The relative areas of the low temperature peaks represent the relative amounts of absorbed hydrocarbons in the two samples — low for the non-polluted sediment and high for the fuel oil spiked sediment.

Work has started on testing some of the possible uses of the method. These include:

1) Seeing if a specific area is polluted with anthropogenic organic compounds. A shipboard version of the analysis would be very useful, in environmental studies—for example, in determining where samples should be collected for further analyses.

2) Delineating types of particles, such as marine organisms or fecal pellets, on which organic pollutants are carried.

3) Characterizing small organic-rich particles by pyrolysis. The method has been applied to several marine sediments, as mentioned above. In addition, it was applied to some fossilized fecal pellets isolated from a deep ocean sediment. No other chemical analytical methods were applicable since only a few mg of each sample were available. The cracking patterns of the pellets were identical. In addition, another mysterious particle in the sediment was also tentatively identified as a fecal pellet because of a similar pyrolysis pattern. The pattern did not resemble that of the bulk of sediment or of diatoms isolated from the sediment.

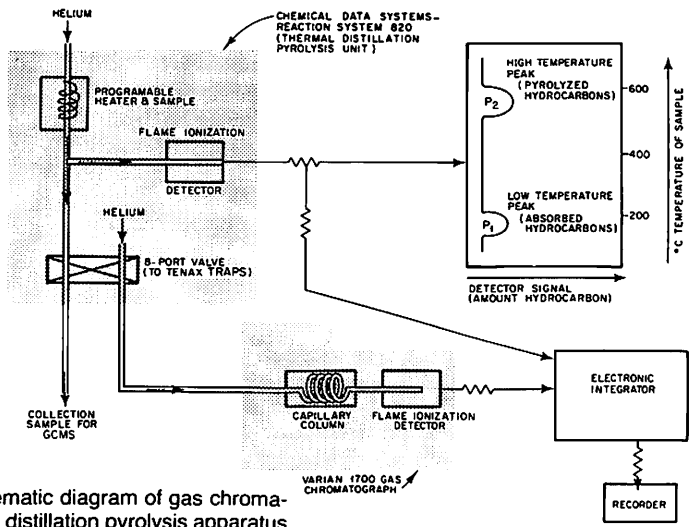


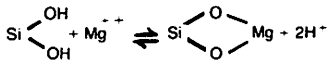
Figure 1 — Schematic diagram of gas chromatography-thermal distillation pyrolysis apparatus (4-port valve in C_1 - C_6 analysis mode).

The Interactions between Chemical Species and Phytoplankton Growth in Natural Water Systems.

Joel C. Goldman and Peter G. Brewer

Our work carried out with new initiation funds, is a continuation of our previous study (Brewer and Goldman, *Limnol. Oceanogr.* 21: 108, 1976) in which we showed that alkalinity changes in seawater could be mediated by phytoplankton assimilation of cationic and anionic nitrogeneous nutrients. We showed that a virtual one to one stoichiometry existed between ammonia (NH^+_4) uptake and alkalinity reduction and between nitrate (NO^-_3) uptake and alkalinity increase. One unexpected feature of our results was that there was a constant acidic offset, suggesting that the phytoplankton were excreting organic acids, quite possibly glycollic acid, a known excretory product of marine phytoplankton.

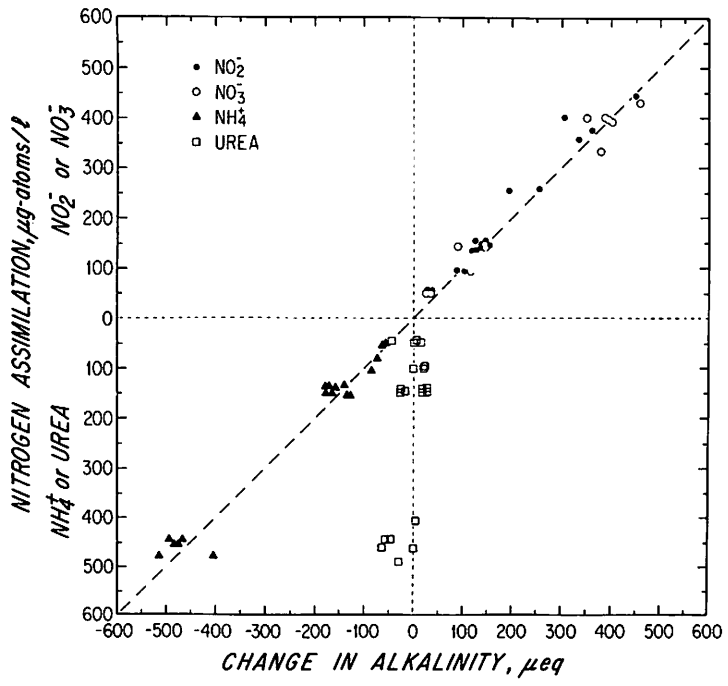
In our new work we were able to demonstrate that the apparent acidic offset we observed in the earlier study was really an artifact of our filtration process during the preparation of culture samples for the alkalinity titrations. Culture samples were first filtered through glass-fiber filters that had been pre-rinsed with distilled water. On passing sea water through the filter an ion-exchange reaction occurs, schematically given by:



and resulting in reduction of the filtrate alkalinity.

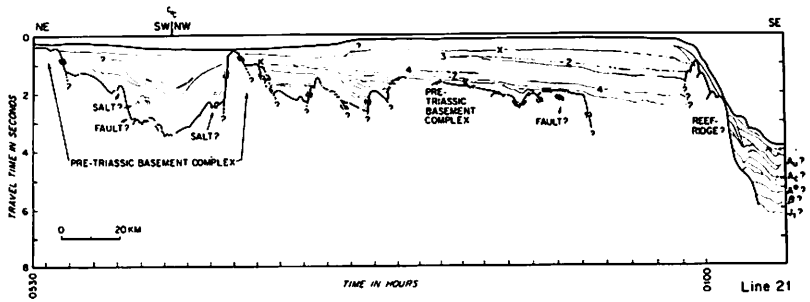
With corrections made for the acidic offset, we observed that there was a distinct one to one relationship between both nitrate and nitrite (NO^-_2) uptake and alkalinity increase and ammonia uptake and alkalinity decrease for the marine green alga *Dunaliella tertiolecta* grown in continuous culture (see results in Figure below). In addtion, with the uncharged nutrient urea as the nitrogen source, there was no change in alkalinity regardless of quantity of urea assimilated. Similarly, there was no effect of phytoplankton growth rate on the stoichiometry between alkalinity change and nitrogen assimilation.

With these careful observations we are able to set limits on acid production by phytoplankton. One widely held belief is that growing phytoplankton excrete glycollic acid, and this would certainly be seen in our studies. Our work shows that this acid excretion does not occur, though excretion of a salt, such as sodium glycollate, cannot be ruled out.



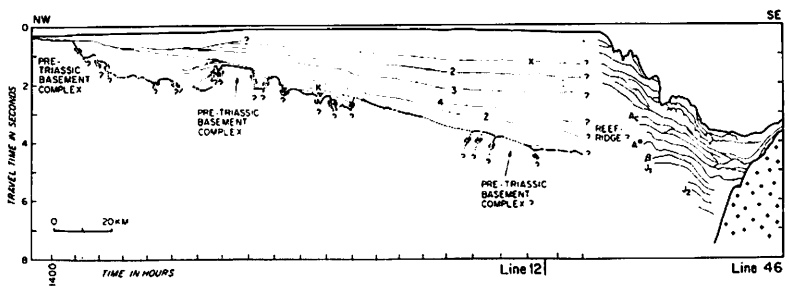
Sedimentary Framework of Georges Bank

E. Uchupi and J. Austin



The sedimentary framework of Georges Bank has been reconstructed using all available geological and geophysical information in order to determine its economic potential. Two major sedimentary sequences can be distinguished. The lower "rift" sequence occurs within grabens and half-grabens entrained into a Precambrian/ Paleozoic basement terrain. The rift structures are oriented northeast-southwest, roughly parallelling the Paleozoic structural trend. On land the graben-fill consists primarily of coarse-grained fanglomerates and fine-grained flood-plain deposits of Late Triassic-Early Jurassic age. In the rifts offshore, evaporites may form part of the fill, as is suggested by the occurrence of a possible diapir in one of the Triassic basins immediately north of Georges Bank. Detailed work in the Gulf of Maine indicates that the rift structures are a product of regional uplift and tensional fracturing associated with the initial stages of decoupling of the North American and African continents in the Late Triassic. At the time of actual continental separation in the Early Jurassic, the rifted arch was eroded and large quantities of sediments were deposited within lows on the shelf seaward of a basement "hinge zone" which probably represents the decoupling plane (see profile 21. Reflector "K" is the unconformity created by this erosional episode.

Above "K" is the "drift" sequence, which consists of all sediments deposited after the completion of continental separation in the Early Jurassic. This sequence is associated with gradual margin subsidence as a result of lithospheric cooling and sediment loading. It exhibits its greatest thickness in the area of the outer shelf and upper slope. Deformation of the drift sequence is restricted to salt intrusion, compaction over basement blocks, and the reactivation of basement faults. The oldest sediments of this sequence consist of red-bed conglomerates and shales, the products of rapid deposition associated with the massive erosional cycle which produced "K". Overlying these nonmarine sediments are Early Jurassic evaporties, reefal limestones (along the present shelf-edge), and lagoonal limestones and dolomites. The lagoonal carbonates grade northward to marls, shales, and sandstones. Seaward of the reef complex, fore-reef deposits interfinger with pelagic limestones and shales. Middle Jurassic clastics are succeeded by widespread shelf carbonate and marine shale units of Middle and Late Jurassic age. A long period of diastrophism beginning at the end of the Jurassic and culminating with the separation of Europe and North America at 110 my BP caused large portions of the New England margin to be uplifted. A consequent rejuvenation of sediment source areas led to widespread regression and progradation of Early Cretaceous clastic wedges. The influx of terrigenous material inundated and killed the reef which had flourished on the continental slope south of Georges Bank. At the same time, submarine canyons were cut into the reef front by turbidity currents. The Early Cretaceous regressive phase was succeeded by



Single (slope and rise) and 6-channel (shelf) seismic reflection profiles on Georges Bank and the Scotian Margin. Profile 21 and 46 are from the eastern end and western ends of Georges Bank, respectively. Reflector "K" separates the underlying "rift" sequence from the "drift" sequence. Line 21 demonstrates the Mesozoic reef complex that forms the foundation of the continental slope and the "hinge zone" along which continental separation took place.

Paleotemperatures and Paleosubsidence of Continental Shelf Sediments

R. Von Herzen, L. Royden

a Late Cretaceous transgression during which limestones and chalks were deposited. Another major regression occurred in the latest Eocene-earliest Oligocene, apparently the result of eustatic lowering of sea-level in response to the onset of Antarctic glaciation. As in the late Early Cretaceous, turbidity currents excavated canyons on the continental slope from the Grand Banks to as far south as the Blake Plateau. Some of these canyons have deep-sea extensions hundreds of kilometers offshore. The Oligocene regression is represented in the western North Atlantic basin by the regionally recognizable seismic event known as the Horizon A complex, and specifically by the A^u unconformity as described by Tucholke (in press). Atop A^u, terrigenous wedges produced by both downslope and contour current depositional mechanisms compose the continental rise and the outer ridge systems. The uppermost part of the margin's drift sequence is complicated by eustatic sea-level fluctuations associated with latest Miocene-Holocene continental glaciation.

Now that the reconstruction of the Georges Bank stratigraphy is complete, the second phase of the investigation is underway. Facies maps of the units composing the "rift" and "drift" sequences are being compiled. Particular emphasis will be placed on the Late Jurassic-Early Cretaceous clastic wedges, because it is felt that these sediments have the greatest source and reservoir potential.

Passive continental margins have been shown to subside with a 50 million year exponential decay which cannot be explained by isostatic compensation for sediment loading. The similarity between this curve and the depth-age curve for older ocean floor strongly suggests that the subsidence of passive continental margins results from thermal contraction of the lithosphere. Two simple geologic models for continental break-up (1) attenuation (thinning) of continental lithosphere by stretching and (2) injection of mantle material via thin, vertical dikes, produce thermal subsidence compatible with observational data for the eastern seaboard of North America. At present it is not clear which of these mechanisms dominates margin formation; both produce essentially the same subsidence history, but differ radically in estimates of initial heat flow.

If marginal evolution can be explained by a combination of these mechanisms, the paleo-heat flow must lie somewhere in the range bounded by the two extreme models. In particular, heat flux vs. time can be estimated directly from thermal subsidence, i.e., subsidence not due to sediment loading. If sedimentation history is well known and estimates of thermal conductivity can be made throughout the section, temperature vs. time can be calculated as a function of depth. In most instances, time/temperature reconstructions are not strongly dependent on the exact mechanism of continental break-up, providing that the thermal regime is dominated by simple thermal expansion/contraction of the lithosphere.

The thermal history of continental shelves, sedimentary basins and the deep sea has particular relevance to the formation of petroleum hydrocarbons. Although many factors contribute to organic metamorphism, the process is primarily dependent on the integrated time/temperature history of the buried organic material. By theoretically reconstructing temperature vs. depth from the two geologic models mentioned previously, we were able to calculate the state of thermal alteration in two regions; the eastern end of the Falkland Plateau and a section across the Eastern Atlantic margin near Cape Hatteras. In general, there appears to be significant thermal potential for generation of oil and gas on the continental rise, seaward of the rise and in some deep sea sedimentary basins.

Living Resources

Histopathology of Marine Fish Exposed to Organic Contaminants

John S. Stegeman and Richard E. Wolke (URI)

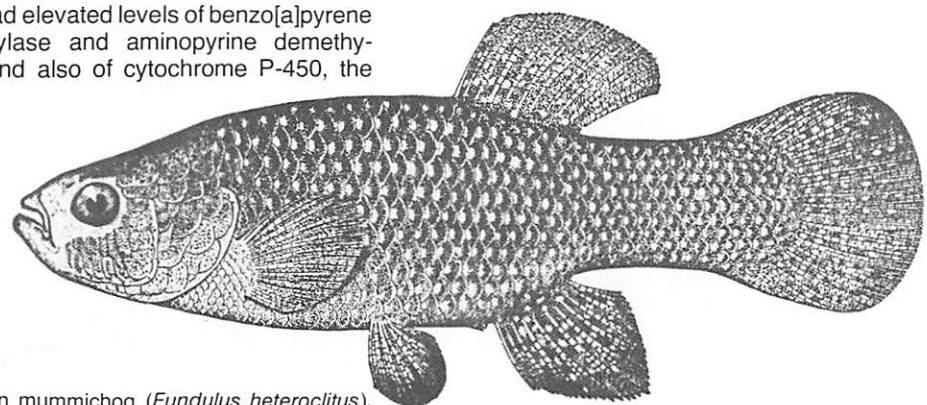
Establishing cause and effect relationships between environmental contamination and subtle sublethal responses in marine organisms is very difficult. Identifying specific pathological lesions or biochemical alterations associated with environmental contamination is of fundamental importance to the eventual understanding of the significance of such contamination and the discovery of cause and effect relationships.

Our study of fish histopathology was undertaken in conjunction with a study of mixed-function oxygenases in fish from clean and contaminated environments. The aim of the research was to identify associations between the presence of organic pollutants, specific pathological lesions, disease prevalence, and alterations in mixed-function oxygenases, enzymes which initiate metabolism or biotransformation of many foreign organic compounds. A further objective was to estimate the validity of using any identified alterations or lesions as indicators of environmental contamination, and to provide an assessment of the health of fish in contaminated environments.

A common marsh minnow (*Fundulus heteroclitus*) was sampled from eight sites in Massachusetts and Rhode Island. Five of these sites were known to be contaminated by organic compounds and three were believed uncontaminated. Twenty tissues were examined in each of the several hundred fish sampled from these sites. Several differences were found between the various groups of fish. There was consistently a much higher incidence of infectious and parasitic disease in fish from the contaminated sites. Particularly striking were differences in hepatic coccidiosis which was virtually absent in fish from the cleanest site and very high in fish from contaminated sites. There were also differences in incidence of lesions which may have been caused directly by the chemicals. Only the fish from contaminated sites showed a degeneration of cells along the lining of the foregut.

Differences in the rate of metabolism of foreign compounds, like the aromatic hydrocarbon benzo[a]pyrene, were also noted between fish from clean and contaminated marshes. Those from the latter sites had elevated levels of benzo[a]pyrene hydroxylase and aminopyrine demethylase, and also of cytochrome P-450, the protein responsible for catalyzing these activities.

We are further studying the associations between environmental contamination and the observed biochemical and morphological changes. While certain histopathological lesions may be used to access the health status of fish, the origin of such lesions may often be obscure, particularly when identified in natural populations. Fluctuations in the incidence or severity of such lesions can occur with season, sex, and age, as well as with environmental contamination. Before suspected lesions or the levels of certain enzyme activities can be used as indicators or diagnostic tools, the influence of such factors must be determined.



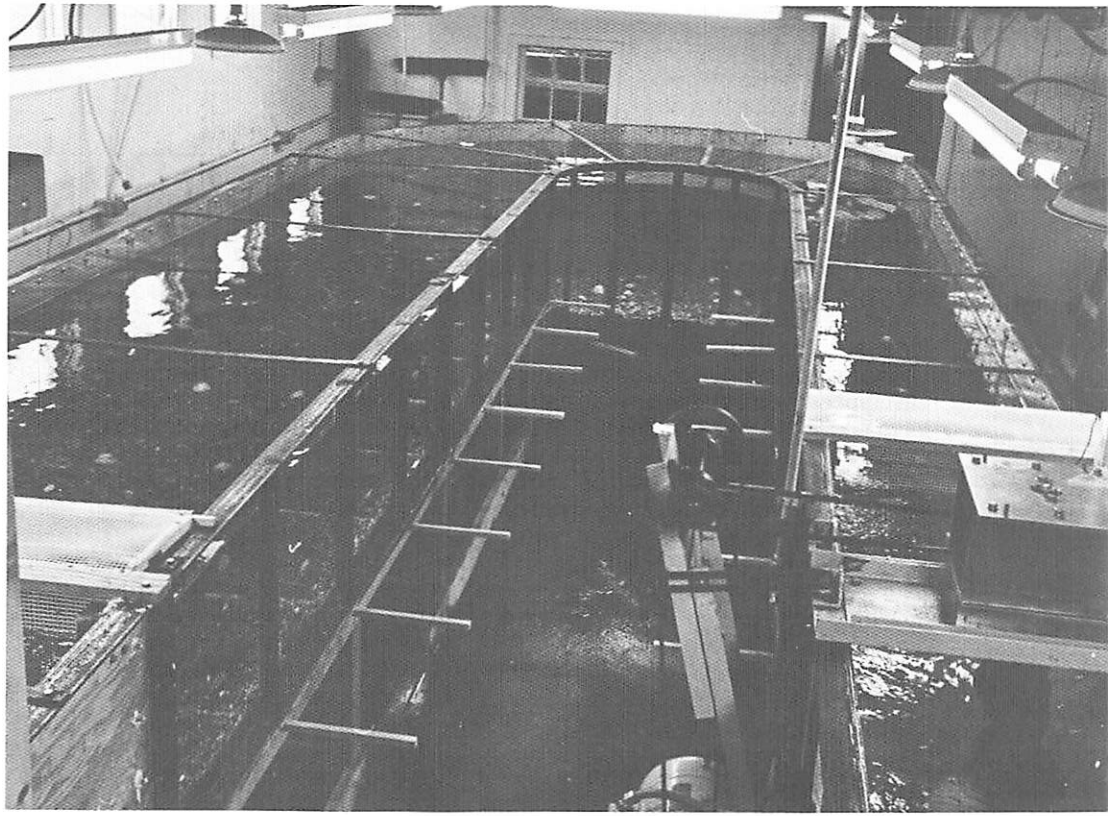
Common mummichog (*Fundulus heteroclitus*), Maryland. From Jordan and Evermann. Drawing by A. H. Baldwin.

Interactions of Fluviatile Salmonid Species

R. J. Gibson

Studies in a stream tank have now been completed on the behavioral interactions of juvenile Atlantic salmon (*Salmo salar*), coho salmon (*Oncorhynchus kisutch*), brook trout (*Salvelinus fontinalis*) and steelhead trout (*Salmo gairdneri*). Final analyses have not yet been made, but preliminary analyses and general observations suggest the following results.

With all species, the channel with the medium flow (10-20 cm/s) was the preferred area, and the dominant fish chose the upstream station. Generally, larger fish displaced smaller fish regardless of species. However, Atlantic salmon were more aggressive than coho and were able to displace coho of the same size, or slightly larger. When these two species were tested together, Atlantic salmon displaced coho from the medium and fast channels into the pool. Atlantic salmon were more aggressive than brook trout, but steelhead trout were more aggressive than Atlantic salmon. The ecological equivalent of Atlantic salmon on the West coast appears to be juvenile steelhead, and of brook trout the coho, so that severest competition might be expected between these pairs. Atlantic salmon parr were the least buoyant and were the only species that normally kept contact with the substrate in fast water. This species would be expected to be most efficient at using resources in fast water and would probably displace the other species from this habitat by exploitation. Experiments were carried out at 7°C, 15°C, and 20°C. Aggressive activity was positively related to the temperature.



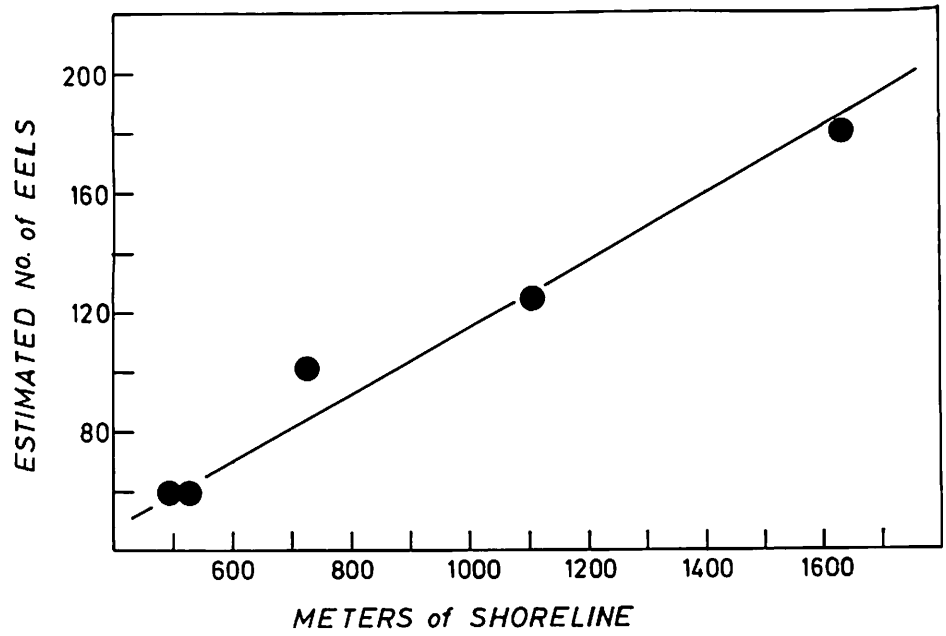
Oblique view of experimental stream tank, with 4 ft. wide channel on left, 2 ft. wide channel on right and 5 ft. wide pool at top.

Eels in Cape Cod Waters

Richard L. Haedrich and
Pamela T. Polloni

The fishery for eels (*Anguilla spp.*) is an extremely important one, worth over $200 million annually on a worldwide basis. In the United States, the fishery has been marginal, practiced by only a relatively few people with the catch going almost entirely to exporters. but, because the U.S. eel populations represent the last unexploited stocks, there is here an economic resource of unknown but certainly considerable dimension. The purpose of our Sea Grant research has been to gather, in one typical coastal environment, data on the abundance, growth rate, and population structure of eels. These data are vital in planning for a rational use of the resource.

An important goal is to be able to predict the number of eels that occur in an area. We have chosen to investigate whether some simply measured physical parameter might correlate well with eel abundance, and thus serve as an order-of-magnitude predictor. During our first year working in two salt marshes, we have concentrated much effort in determining absolute abundances by the time-consuming and laborious techniques of mark-and-recapture and by fishing out restricted areas. We find, and these findings repeat themselves in the work continuing now in the second year, that the amount of linear shoreline has an excellent correlation (r = .99) with the number of eels present (see figure). Since we know that eels are both active in the night and to an extent territorial, such a finding represents a reasonable expectation. Thus, for coastal environments in New England, we can tentatively offer the relationship shown in the figure as a simple way to estimate local eel abundance.



It is also important to know the size and, particularly, the growth rate of the eels. To determine these parameters is another of our goals. The data comes from our catch statistics, the growth of marked individuals over time, and from size versus age as determined from otoliths. The trapable eels in our areas, which are not entirely free from exploitation, average 52 cm in length and 270 gm in weight. Growth rates are very slow. Our average eel is about 10 years old and is gaining about 2 cm (5%) in length per year.

The fact of this slow growth, coupled with the particular vulnerability of eel populations to exploitation by simple methods, means that the resource can be readily diminished, and, even more importantly, once diminished will not restore itself quickly. The situation is quite similar to that in lobsters. Clearly, frameworks for management should be thought about before over-exploitation occurs, and in this regard we are glad to see that Massachusetts has recently passed certain legislation pertaining to the taking of eels. We played a modest part in the development of these new laws, which are designed to regulate the fishery for adults, prohibit the taking of elvers for export, and encourage eel aquaculture.

During the first year, we relied heavily on small plastic dart tags for marking eels. These were not without their problems. Many eels developed large festering sores around the tags, with the result that the tags fell out within a month or so. This was especially so for eels tagged during the warm summer months, and we cannot recommend such tags for warm-water work. Eels marked in the late fall, when the water is cool and the eels are about to go into winter hibernation, show much better tag retention.

Socio-Economic and Legal Studies

Marine Policy and Ocean Management Program

Robert W. Morse

This Program has two purposes:

- To stimulate links between the scientific efforts of the Institution and the social, economic and political problems of the oceans, and
- To offer postdoctoral research opportunities for professionals in policy-related fields in which they are involved with marine problems emphasizing the relation of science, technology and policy.

The Program in 1977-78 included two Research Associates and eleven postdoctoral Fellows. These individuals pursued independent projects and, in addition, participated in cooperative projects with members of the Scientific Staff. In 1977-78 these projects included:

- environmental impacts of large-scale algal biomass systems,
- biomass energy from the oceans as an alternative energy source,
- a study of changing public attitudes toward cetaceans,
- systems model application to experimental design in aquaculture,
- input-output analysis of a salt marsh,
- a review of laws relating to the introduction of exotic species,
- a review of marine policies in Latin America,
- regulations regarding the use of drilling muds in OCS development and their scientific bases,
- a sociocultural analysis of a New England fishery cooperative,
- definitions of boundaries in state C.Z.M. plans,
- identification of environmental parameters for Buzzards Bay,
- New England fishing, processing and distribution
- applicability of predator-prey models to fisheries management,
- case studies of the economic effects of limiting entry to fisheries,
- ocean science planning in the USSR: case study of the Polymode program.

Some of these studies were in support of other projects within the Woods Hole Sea Grant Program, such as the project on the enhancement of salt marsh productivity.

Plans have been made for the second phase of an international aquaculture project aimed at understanding the social, economic and cultural factors controlling the success or failure of projects in developing countries. The second phase consists of a week-long, working-group meeting at Woods Hole in September 1978. This meeting, under the chairmanship of Dr. Courtland Smith of Oregon State and staffed by members of the Marine Policy Program, was attended by a group of experts from the U.S., South America and Africa. The purpose of this meeting and subsequent efforts by the participants was to create a critical analysis of the present state of knowledge of this subject. This project is conducted under the sponsorship of The International Federation of Institutes for Advanced Study, of which the Institution is a member.

The Program this year has sponsored two continuing, "working seminars" of an interdisciplinary nature which bring together scientists and members of the Marine Policy Program. The two subjects were the *benthic boundary layer* and *coastal processes*. The purposes of these seminars is to review the existing state of scientific knowledge and attempt to stimulate new research activities within the Institution of an interdisciplinary nature.

The benthic boundary layer seminar, which started last year, continued under the direction of Dr. Derek Spencer and was most successful in stimulating new proposals for research. There is an obvious policy interest in such research since the assessment of many future activities such as dumping and mining will depend upon scientific understanding of the processes at the ocean floor.

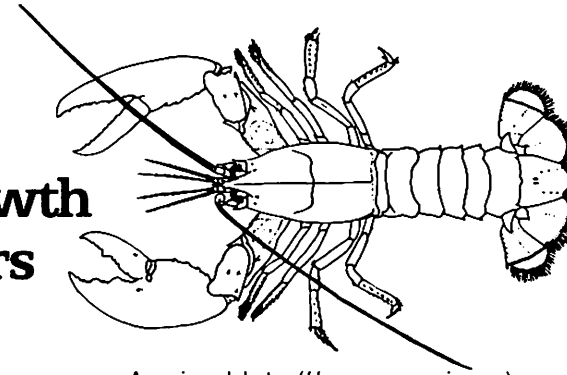
A weekly seminar conducted by scientific staff was provided during the fall semester for members of the program. During the spring semester a public seminar was sponsored by the Program on marine policy subjects. A course on Science Policy was taught in the spring semester by Dr. Morse in the joint Woods Hole M.I.T. graduate program. This was attended by Marine Policy Fellows, graduate students and staff members from the Woods Hole institutions.

Aquaculture

The Effects of Diet on the Growth Energetics of Postlarval Lobsters

(Homarus americanus)

Judith M. Capuzzo



American lobster (*Homarus americanus*).

Mass culture of commercially important carnivorous species, such as the American lobster, will be facilitated by the use of artificial diets. The basic features of such diets would be:

1) that the animal's nutritional requirements are met, resulting in high growth rates and no significant difference in biochemical composition from that of wild populations;

2) that the diets are readily consumed and assimilated by the animal; and

3) that the diets are formulated from commercially available feedstuffs, thus reducing the costs of producing the diets and minimizing the cost of feeding in aquaculture systems.

For an adequate formulation of compounded diets, however, an understanding of assimilation and utilization of various dietary components by an animal is needed.

During this year research has focused on the effects of nutritionally-defined compounded diets on growth energetics and metabolic utilization by postlarval lobsters. The growth energetics of lobsters fed a brine shrimp diet were compared with the energetics of lobsters fed three artificial diets. The artificial diets were pelletized shrimp meal diets, varying in both protein (16-23%) and carbohydrate (23-32%) content and in protein:carbohydrate ration (0.5-1.0); the brine shrimp diet had a protein content of 51% and a protein:carbohydrate ratio of 5.1. The best growth was measured among lobsters fed the brine shrimp diet and the 25% protein diet, with no significant difference in growth rate being detected between the two groups. Lobsters fed 16% and 20% protein diets had slightly lower growth rates. The protein efficiency ratios (Δg/g protein consumed), however, were inversely related to the protein level of the four diets.

All diets were assimilated at the same level (~90%) but there were significant differences in consumption rates, respiration rates and ammonia excretion rates among lobsters from the four experimental groups. Although all lobsters were given equal rations in grams, the artificial diets were slightly lower in caloric content than the brine shrimp and the pellets were fragmented by the lobsters during the feeding process, resulting in significantly lower ($P < 0.01$) consumption rates of the artificial diets.

Respiration rates measured immediately after feeding were highest among the brine shrimp-fed lobsters and were ~35% higher than the standard respiration rate measured 24 h later. The increased rate of oxygen consumption associated with feeding is termed the specific dynamic action (SDA) and reflects the calorigenic effect of protein catabolism. The values for SDA from lobsters fed the three artificial diets were not significantly different from one another and were ~16% higher than the standard respiration rate. There was no significant difference in standard respiration rates of lobsters from the four test groups.

Ammonia excretion rates of lobsters fed the three artificial diets and the brine shrimp diet were significantly different from one another and were directly correlated with the protein level of each diet. The O:N ratios (atomic ratio of oxyen oxygen consumed to ammonia-N excreted) measured in the four experimental groups were inversely related to the protein level of the four diets, indicating an increased dependence on carbohydrate catabolism for energy production with low dietary protein levels.

The reduced growth rates of lobsters fed the 16% and 20% protein diets are apparently a result of differences in the amounts of food consumed and not increased energy expenditures or reduced assimilation efficiencies. No significant difference in biochemical composition (protein, lipid, carbohydrate) could be detected among the four groups of lobsters.

The results of this study provide a strong indication that dietary carbohydrate is important as an alternative energy source in postlarval lobsters. Its role in nutrition and metabolism and its relationship to other dietary components should be further explored.

The Genetic Component of Growth and Survival in Raft-Cultured and Natural Populations of Quahogs,

(Mercenaria mercenaria)

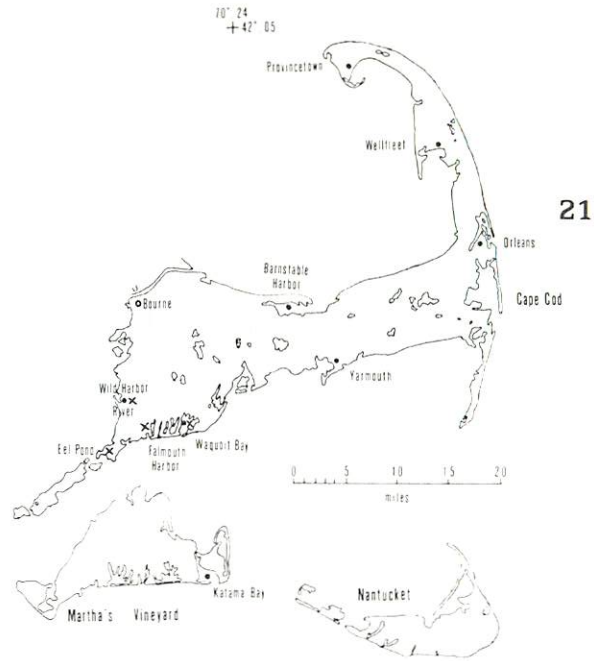
Judy Grassle (MBL)

This is an ongoing project with several objectives: first, to correlate the frequency of single gene and multigene markers with growth rate and survival in hatchery-reared stocks of *M. mercenaria* at different localities on Cape Cod by the frequencies of these same genetic markers.

The single gene markers used in this and many other population genetic studies are polymorphic enzymes which are visualized by specific histochemical staining of starch gels after electrophoretic separation of proteins in individual samples. The figure (below) shows a typical gel stained for the enzyme phosphohexoseisomerase (PHI). The individual samples with a single-banded pattern are homozygous at the PHI locus, the 3-banded patterns represent heterozygotes.

Early in our study the allele frequencies at the polymorphic loci being examined were determined in samples from 3 stations in the vicinity of Woods Hole (marked by x on map). These samples included animals from all the year classes represented in these relatively unexploited populations, in an attempt to examine the effects of selection on allele frequencies. It has commonly been found that marine bivalve populations, often show marked excesses of homozygous individuals, and it is thought that this may be due to mixing of individuals from several populations with different gene frequencies, this mixing occurring during transport of the planktonic larval stage. In order to sort out the relative effects of changing allele frequencies in the cohorts of larvae settling in a given area, from the effects of selection, we began in the Fall of 1977 to examine recently-settled juveniles at 9 localities around Cape Cod (marked by • on map). This Fall, collections of the 1978 cohort have been made at the same localities. Genetic characterization of all these animals will provide a preliminary picture of the spatial and temporal variation in the genetic input to these populations.

It is expected that genetic characterization of natural populations of *M. mercenaria* will be intercalibrated with those of two other population geneticists who are examining populations from other areas of the east coast, thus providing a broad-scale estimate of the genetic variability of this important commercial species over a large part of its geographic range.



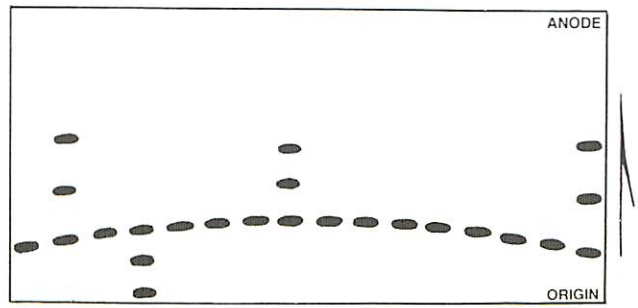
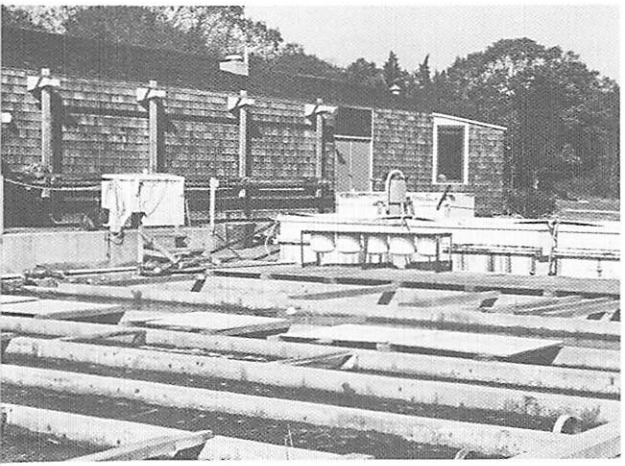


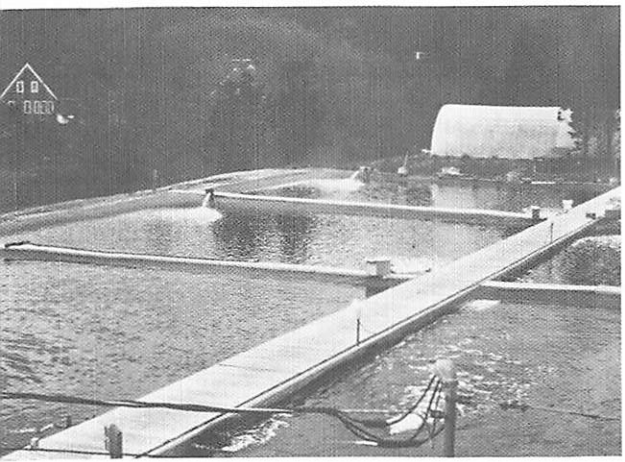
Diagram of phosphohexose isomerase gel. For the PHI locus in *M. mercenaria* we have found 10 alleles at the PHI locus although each stock or population has fewer than 10 alleles.

Public Health Aspects of the Culture of Bivalve Molluscs in Waste Recycling Aquaculture Systems

Roger Mann, J. Vaughn (Brookhaven)



Woods Hole Aquaculture Facility.



Since 1972 Sea Grant has supported work on the development of a waste recycling aquaculture system at the Woods Hole Oceanographic Institution. In this system mixtures of seawater and secondary treated sewage effluent are used to culture marine phytoplankton. The phytoplankton are subsequently diluted and fed to edible molluscs such as clams, oysters, mussels and scallops. During the period 1972-1977 considerable progress was made in the culture of phytoplankton using 120,000 liter or 30,000 gallon outdoor ponds. Nutrient transformation and species predominance in phytoplankton cultures was extensively documented and bivalve growth was optimized through the selection of fast growing species and control of environmental parameters.

During the period 1977-78 research was directed towards the important area of uptake and depuration of harmful trace contaminants — metals, organic pollutants and viruses — by the Japanese oyster. This species was chosen for intensive study because it had consistently exhibited good growth in previous studies. Two series of experiments were carried out. These were as follows:

1) *Long-term uptake and depuration of selected trace metals and organic pollutants.*

Previous experience with the Woods Hole facility had indicated that suspended solid levels in the effluent used in experimental studies were both highly variable and unpredictable. In order to minimize such variation, simple, inexpensive methodology was investigated for removing suspended material and associated contaminants. A combination of sand filtration and activated charcoal treatment was employed. This produced consistent, crystal clear effluent with low contaminant content (Table 1) despite the fact that effluent was obtained from a heavily industrialized location at Cranston, Rhode Island. Filtered effluent was subsequently diluted in the ratio 1 volume effluent:3 volumes seawater and utilized as a culture media for the marine diatom, *Phaeodactylum tricornutum.* In turn, the diatom cultures were diluted in the ratio 1 volume culture:15 volumes seawater to reduce cell concentrations to levels that were optimum for feeding in the subsequent trophic level; in this case the Japanese oyster, *Crassostrea gigas.*

An experimental regime was chosen in which oysters were cultured in a sewage enriched food chain for a period of 12 weeks and subsequently transferred to a sewage free regime for a second twelve week period. At intervals of two weeks throughout the study, samples of 20 oysters were removed and assayed for contaminant content. The results were compared to those obtained for oysters maintained in a sewage-free regime for 24 consecutive weeks. No significant accumulation of either trace metal or organic contaminants (P.C.B.s) was evident in the oysters exposed to the sewage-enriched regime. All

TABLE 1

Trace contaminant levels in Cranston sewage following sand and charcoal filtration.

(For comparison, E.P.A. drinking water and maximum discharge for effluent standards, and ambient seawater concentrations are included).

	Trace Metals							P.C.B.
	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Arochlor 1254 ppb.
	ppb.							
Treated effluent	0.26	2.56	23.9	0.1	196.8	1.76	46.0	046
E.P.A. 1976 drinking water standards	10	50	1000	2	*	50	5000	1.0
Seawater discharge limit	5	*	*	0.1	*	*	*	1.0
Sea water ambient	**	0.3	2.0	**	3.3	1.5	3.3	**

* re standard set
** below detection

TABLE 2

Trace contaminant levels in oysters cultured in a waste recycling aquaculture system compared with control specimens from a sewage free culture regime, and present F.D.A. maximum permissable contaminant levels.

		Trace Metals							P.C.B.
		Cd	Cr	Cu	Hg	Ni	Pb	Zn	Arochlor 1254
min-max range: ppb wet wt									ppb. wet wt.
Experimental oysters	min.	0.3	0.1	12.6	.01	.03	**	134	1.1
	max.	0.7	0.3	59.5	.05	1.3	0.3	236	7.8
Control oysters	min.	0.4	0.1	16.5	.02	.06	**	89	1.1
	max.	0.8	0.3	56.8	.04	0.8	0.1	226	7.8
F.D.A. limits		3.5	2.0	175	0.5	*	2.0	2000	2000

* no limit set
** below detection

values obtained for trace metal content were consistently below maximum permissible or advisable levels as delineated by the U.S. Food and Drug Administration. P.C.B. levels were also well below the 2 ppm maximum permissible level. However, it should be noted that the 2 ppm level is presently under review by F.D.A. (Table 2).

2) *Virus accumulation and depuration by oysters.*

(i) Methods Development. The standard method for virus assay in shellfish was developed in 1977 by Carrick and Sobsey. This involves a multi-step extraction followed by ultrafiltration. This latter step may take from 1-3 days to complete. To date, all studies reported by Sobsey and co-workers have involved the seeding of oyster homogenates with known concentrations of virus. No data has been developed for this method with regard to viruses which have been naturally accumulated by shellfish from the surrounding seawater.

A recent paper by Carrick and Sobsey (1977) and his co-workers indicated that replacement of the time consuming ultrafiltration step with a rapid acid precipitation resulted in no loss of virus concentration efficiency (once again, these experiments were conducted with seeded oyster homogenates). By using the new method, it would be possible to process oysters in a single day.

A comparison was made of the virus extraction efficiency of the acid precipitation method versus the ultrafiltration method using our own modification of the technique of Sobsey and co-workers. In order to avoid any artifact which may have arisen as a result of seeding shellfish homogenates with virus, oysters were allowed to take up viruses naturally from seeded seawater. Results indicated the acid precipitation to be vastly superior. Extractions could be performed within a few hours as opposed to a minimum requirement of two days for the ultrafiltration method. The recovery efficiency of the acid precipitation method was 78% (*i.e.*, 78% of the initial virus seed was recovered) versus 31% for the ultrafiltration method. Additional studies are currently being conducted in order to confirm and provide statistical significance for the above.

(ii) Oyster Depuration Studies. Studies to determine the depuration of poliovirus (LSc) by naturally seeded, activity growing oysters residing in virus-free waters were carried out on three separate occasions. Results indicated that, depending on the season, oysters required from 4-17 days to completely remove viruses. It is recommended that a 20-day depuration period would provide a high margin of safety. These data can only be correlated with rates of poliovirus removal, and cannot be assumed to be representative of all other enteric viruses.

(iii) Survival In Seawater. The ability of viruses to survive in seawater is obviously related to the likelihood of their being taken up by shellfish. By using membrane diffusion chambers suspended in the ambient seawater, the survival rates of a non-vaccine strain of Poliovirus type 1 were determined (NOTE: many authors have criticized the exclusive use of vaccine strains of polio [LSc] for survival experiments, as they may not behave in a manner similar to pathogenic strains). Experiments were conducted during the month of June. The wild-type strain was able to survive for a period of 8-10 days in raw seawater, and for a period of 14 days in 0.45 um filtered seawater. The difference in survival rates suggested a viricidal role for ambient seawater biota (0.45 um). The data also indicated that pathogenic human viruses would be able to sustain infectivity during passage throughout the aquaculture system. These data support the conclusions of previous work conducted with bacteriophage.

Data strongly suggests that while a period of 20 days may be necessary for virus depuration, the goal of producing "clean," edible, bivalve molluscs in waste recycling aquaculture systems is feasible.

Carrick, R.J. and M.D. Sobsey, 1977. The Development of an Improved Method for the Detection of Enteric Viruses in Oysters. Univ. of North Carolina Sea Grant Report 77-13, July 1977.

Marine Technology

Development of an Improved Zooplankton Sampling Pump Station

L.R. Haury and J.R. Brooks

The objective of this research is to study the flow characteristics of pumping system intakes of various configurations under different hydrodynamic conditions. An understanding of pump intake performance is necessary in order to design optimal systems for sampling organisms which can sense the intake flow field and attempt to escape capture, as well as to define exactly where the pumped water originates. In general, avoidance has been thought to be a bigger problem for pumps than for nets, particularly for the larger zooplankton. This is due to the combination of the pumps' much smaller sampling rates and intake designs which cause an early forewarning of their presence. The use of pumps to sample inert particles has proceeded without a clear understanding of the interaction of the intake with the source field.

Pumping stations have many advantages as plankton samplers when properly designed. They are more versatile than nets. The same system may be fished horizontally, vertically or obliquely, or may be used to obtain time series samples at a fixed position. The can sample macro- and microzooplankton, phytoplankton and chemical constituents simultaneously. Pump catches can be monitored 'on-line'. The relatively small sampling rate of a pump and the ability to control the intake's position allows improved fine-scale distribution resolution. This is particularly useful in confined areas such as estuaries.

The experimental portion of this study was conducted with a moderately-sized pump (200 liters/min) in the WHOI flume. Twelve nozzles were built, simulating the nose of a tow fish 12 in. in diameter with 4 in. and 7 in. throats. A hoist system secured the nozzles with their axes oriented into the flume flow of 5 cm/s. The flow into and around the nozzles was observed by means of a pulsed hydrogen bubble generator and photographed, permitting quantification of the velocity field. The results can be scaled up for larger pumps and faster towing speeds. Minimum disturbance occurred with a sharp-edged form, but it is not favored in other modes of operation.

A mathematical computer model is also being constructed to obtain a theoretical prediction of the problem. The flume tests will serve to validate the model, a finite-difference solution of a potential flow field. Its flexibility allows more conditions to be investigated than was possible in the flume.

A separate research program has been carried out to supplement the studies described above. The common marine copepod *Calanus finmarchicus* was subjected to a simple fluid deformation field (a fixed obstruction in a rotating tank) and its avoidance behavior was observed. Characteristic values of the stimulus which produces the escape reaction as well as the direction, rate and persistence of the flight have been determined.

Mr. Brooks is incorporating this behavioral data with that of the intake flow fields in evaluating pump sampling strategies and intake designs in his thesis for the WHOI-MIT Joint Program Ocean Engineer degree.

Experimental Evaluation on Loran-C Telemetry from a Drifting Buoy

R.G. Walden and C.W. Collins

A modest Sea Grant new initiative program allowed the purchase of a Teledyne TDL-701 Loran-C Receiver to begin developing a position-fixing and telemetering drifting buoy system.

Our beginning work was devoted to the evaluation of the Loran-C receiver to see if: (1) it could automatically synchronize itself to Loran-C radio signals and thereby operate unattended; (2) the receiver sensitivity was sufficient to produce a high degree of reliable operation; (3) data accuracy and repeatability were in fact great enough to hold data scatter to a minimum; (4) operation was reliable using a short antenna suitable for buoy installation; (5) the equipment was provided with useable digital output circuitry; and (6) the power requirement was modest enough to allow two months or more mission endurance without servicing.

The evaluation began in February, 1978 when the receiver was first readied for operation and concluded in May, having been turned on and off about 50 times. Operation was both fixed (top floor of buildings in downtown Woods Hole and Quissett campus) and mobile (installed in an automobile), using the 8-foot antenna provided by the manufacturer as part of the system. A control unit was built and used to actuate a signal-status display in the receiver and to trigger the digital output message which was observed on an oscilloscope.

The receiver was operated along the shore in good over-water signal conditions and in various locations where one or more signals were marginally received over land paths, and from a standstill to speeds up to 40 miles per hour. Accumulation of time difference readings (fixes) logged during this part of the evaluation showed the accuracy to be well within the scale of available charts. Further, the repeatability agreed with the theoretical value of 0.1 to 0.2u sec. or a radius of 30 meters or less, this being confirmed in the mobile mode of returning to the same physical spot several times and logging the displayed time difference readings. Observations of the tracking ability of the receiver in a moving vehicle showed that it would not lose synchronization when subjected to various magnitudes of speed and acceleration. The receiver always operated properly along the shore, but some locations inland caused it to show a weak-signal status reading, a situation that was expected.

At all times, except in a poor signal area, the receiver, from an initial turn-on of power, automatically acquired and tracked the signals, a test of its ability to operate unattended.

Power consumption is 33 watts with the display turned off and 40 watts with the display on. Examination of the circuitry indicates that this can be reduced to 20 watts in a buoy system by removing the display entirely.

Our conclusion is that the existence on the market of fully automatic Loran-C receivers having on-board microprocessors makes them a good candidate for use with a radio-telemetry link on moored or drifting buoys. Our evaluation of one such receiver confirms this.

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Program Summary

Project/Principal Investigator	FY 75	FY 76	FY 77	FY 78
ENVIRONMENTAL RESEARCH				
Stimulated Marine Bioproduction/Teal				N
Effects on No. 2 Fuel Oil on a Salt Marsh: A Quantitative Three Year Study of Recruitment and Growth/Hampson			N	F
The Design of Environmental Surveys over Time/W. Smith		N	C	C
Biological and Physical Control of Erosion at the Sediment-Water Interface in Estuaries/Rowe-Boyer				NF
Grain-Size in Laminae of Beach Sand/Emery				NF
Volatile Organic Compounds in Coastal Waters: Levels, Sources and Sinks/Zafiriou				N
Source and Fate of Estuarine Sediments-Boston Harbor/ Milliman				N
A New Method for Characterization of Marine Organic Material in the Water Column and Sediments/Whelan				N
The Interactions Between Chemical Species and Phytoplankton Growth in Natural Water Systems/Goldman-Brewer			N	C
A Study of the Physical Characteristics of Bourne's Pond, Falmouth/Summerhayes-Ellis			NF	
Sediment Dispersal in New Bedford Harbor and Western Buzzards Bay/Summerhayes		N	F	
Stability of a Small Coastal Inlet/Moody		N	F	
The Economic Potential of the East Coast Continental Margin: Blake Plateau to Georges Bank - Part I Georges Bank/Uchupi				N
Paleotemperatures and paleosubsidence of continental shelf sediments/von Herzen				N
LIVING RESOURCES				
Populations and Migrations of Certain Large Pelagic Fish/Mather	*	*	*	*
Behavior of Lobsters in a Semi-Natural Environment at Ambient Temperatures and under Thermal Stress/Atema	T			
The Sources of Important Bio-Chemicals in Marine Crustaceans/Gagosian	F			
Effects of Petroleum Hydrocarbons in Marine Fishes/ Stegeman, Sabo	N	C	F	
Histopathology of Marine Fish Exposed to Hydrocarbon Contaminants/Stegeman				N

Population Density and Distribution of *Limulus polyphemas* in Cape Cod Waters/Smith		NF		
Interactions of Fluviatile Salmonid Species/Gibson		N	C	F
Distribution of Potential Food Resources for Shellfish in Bourne's Pond/Brand		N	F	
Populations of Eels in Cape Cod Waters/Haedrich				N
Initial Investigations of Red Tide Problems on Cape Cod/Wall		NT		
SOCIO-ECONOMIC AND LEGAL STUDIES				
Limited Effort Programs in the New England Fishery/ Smith, Peterson	N	C	F	
Draft Legislation for the Massachusetts Lobster Fisher/ Peterson, Friedman		N	F	
Regulation of Harbors and Ponds of Martha's Vineyard/ Friedman		NF		
Marine Policy and Ocean Management/Morse	C	C	C	C
Marine Technology Transfer as Foreign Aid to Less Developed Countries/Sarr		N	F	
MARINE RESEARCH & TECHNOLOGY				
High Resolution Sub-bottom Profiling/Vine	N	T		
An Acoustic Probe for Ocean Bottom Surveys/Dow	NF			
Solar Energy Conversion/von Arx	NT			
An Optical Trap for the Use of Diffuse Solar Radiation in Hyperthermal Aquaculture/von Arx			N	F
Handbook of Oceanographic Engineering Materials/Dexter		N	F	
Dynamics of the Inclining Spar Current Sensor/Mavor			NT	
Studies for the Development of An Improved Zooplankton Sampling Pump System/Haury			N	F
Experimental Evaluation of Loran-C Telemetry from a Drifting Buoy/Walden				N
AQUACULTURE				
Bivalve Mollusc Culture in a Waste Recycling Aquaculture System/Ryther	C	C	C	T
Finfish Research at Matamek, Quebec/Gibson	*	*	*	*
Culture of Midges/McLarney	F			

Project/Principal Investigator	FY 75	FY 76	FY 77	FY 78
The Genetic Component of Growth and Survival in Raft-Cultured and Natural Populations of Quahogs *(Mercenaria mercenaria)* on Cape Cod		N	C	C
The Effects of Diet on the Growth Energetics of Postlarval Lobsters (*Homarus americanus*)				NF
Uptake of Heavy Metals, Organic trace Contaminants and human enteric Viruses by the Japanese oyster, *Crassostrea gigas*, Grown in a Waste Recycling-Aquaculture System/Mann				NF
MARINE EDUCATION & TRAINING				
Coastal Zone Management/Black		N	F	
Marine Science Libraries Cooperative Network/Winn			NF	
PROGRAM MANAGEMENT				
Program Management and Development/Ross	C	C	C	C

N - New Project; C - Continued Project; F - Completed Project; T - Terminated Project; * - Continued with funds from sources other than Sea Grant.

During FY 78 the Woods Hole Oceanographic Institution Sea Grant Program consisted of:

11 Research Projects (plus 9 new initiatives)
1 Program Management

Personnel associated with the Sea Grant Program were:

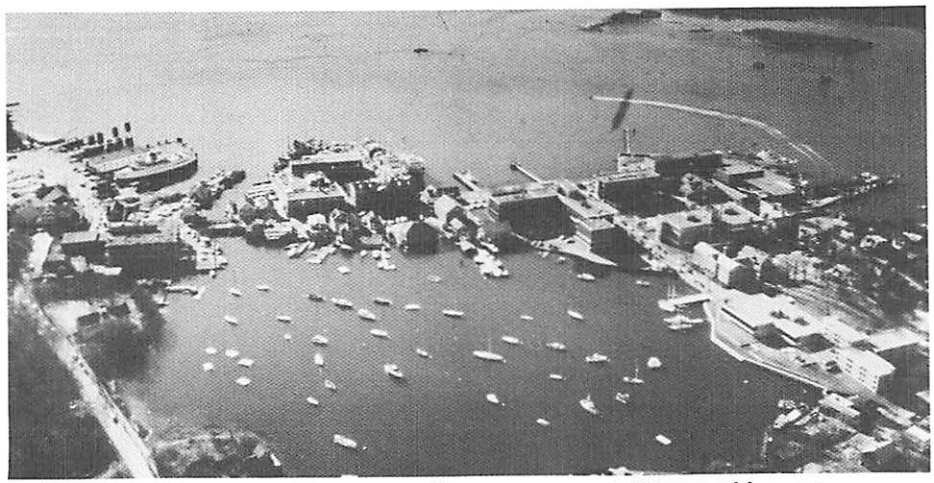
Scientific Staff - 27
Technical Staff - 14
Departmental Assistants - 9
Post-Doctoral Investigators - 10
Graduate Students - 4
Undergraduate Students - 2

Budget Summary 1977-78

	NOAA	Matching Funds	TOTAL
The effects of diet on the growth energetics of postlarval lobsters (*Homarus americanus*)	$ 26,400	$ 000	$ 26,400
Uptake of heavy metals, organic trace contaminants and human enteric viruses by the Japanese oyster *Crassostrea gigas*, grown in a waste recycling aquaculture system	73,000	28,045	101,045
The genetic component of growth and survival in raft-cultured and natural populations of quahogs (*Mercenaria mercenaria*)	42,400	7,225	49.625
Populations of eels in Cape Cod waters	22,100	3,436	25,536
Histopathology of marine fish exposed to organic contaminants	24,000	000	24,000
Marine Policy and Ocean Management	9,900	309,235	319,135
An optical trap for the use of diffuse solar radiation in hyperthermal aquaculture	35,000	33,121	68,121
Environmental survey design and statistical consulting to Sea Grant projects	12,000	3,487	15,487
Source and fate of estuarine sediments - Boston Harbor	40,100	000	40,100
Interactions of fluviatile salmonid species	13,800	14,940	28,740
Stimulated marine bioproduction	40,000	102,493	142,493
Program management and development	86,300	23,100	109,400
	$425,000	$525,082	$950,082

Postscript

The preceding pages have presented the essence of our coherent Sea Grant program for 1977-78. In the coming years our focus on the coastal zone will be increased. Our 1978-79 program has projects in the areas of Coastal Zone - Biological, Geological and Physican Aspects; Chemical Processes and Pollution; Aquaculture; and Marine Policy. During the period from the end of this report we have started five projects with new initiative funds. These include: "Reproductive Biology of Wood Boring Molluscs (*Xylophagainae*) on the Continental Shelf of the Eastern United States" (Carl J. Berg, Principal Investigator); "Stimulation of Fish Growth by Detritus Feeders" (John Teal and Michael S. Connor, Principal Investigators); "Dormant Cysts and Trace Metal Sensitivity: Two Key Factors Affecting the Initiation, Development, and Geographic Spreading of Toxic Dinoflagellate Blooms" (R. Guillard and Don M. Anderson, Principal Investigators); "Systems Models and Experiment Design with Application to Marsh Fertilization and Lobster Feeding Experiments" (Tom Leschine, Principal Investigator); and "Quantitative Assessment of Microbial Transformations in Estuarine Waters" (Craig Taylor, Principal Investigator).



Illustrations:
Teal/Valiela: p. 4, 5
Boyer: p. 8
Gschwend, et al: p. 10
Milliman: p. 11
Whelan: p. 12
Goldman/Brewer: p. 12
Uchupi/Austin: p. 14
Baldwin: p. 16
Haedrick/Polloni: p. 18
Capuzzo: p. 20
Grassle: p. 21
Mann: p. 23

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Hampson: p. 6
Emery: p. 9
Gibson: p. 17
Gately: p. 22
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