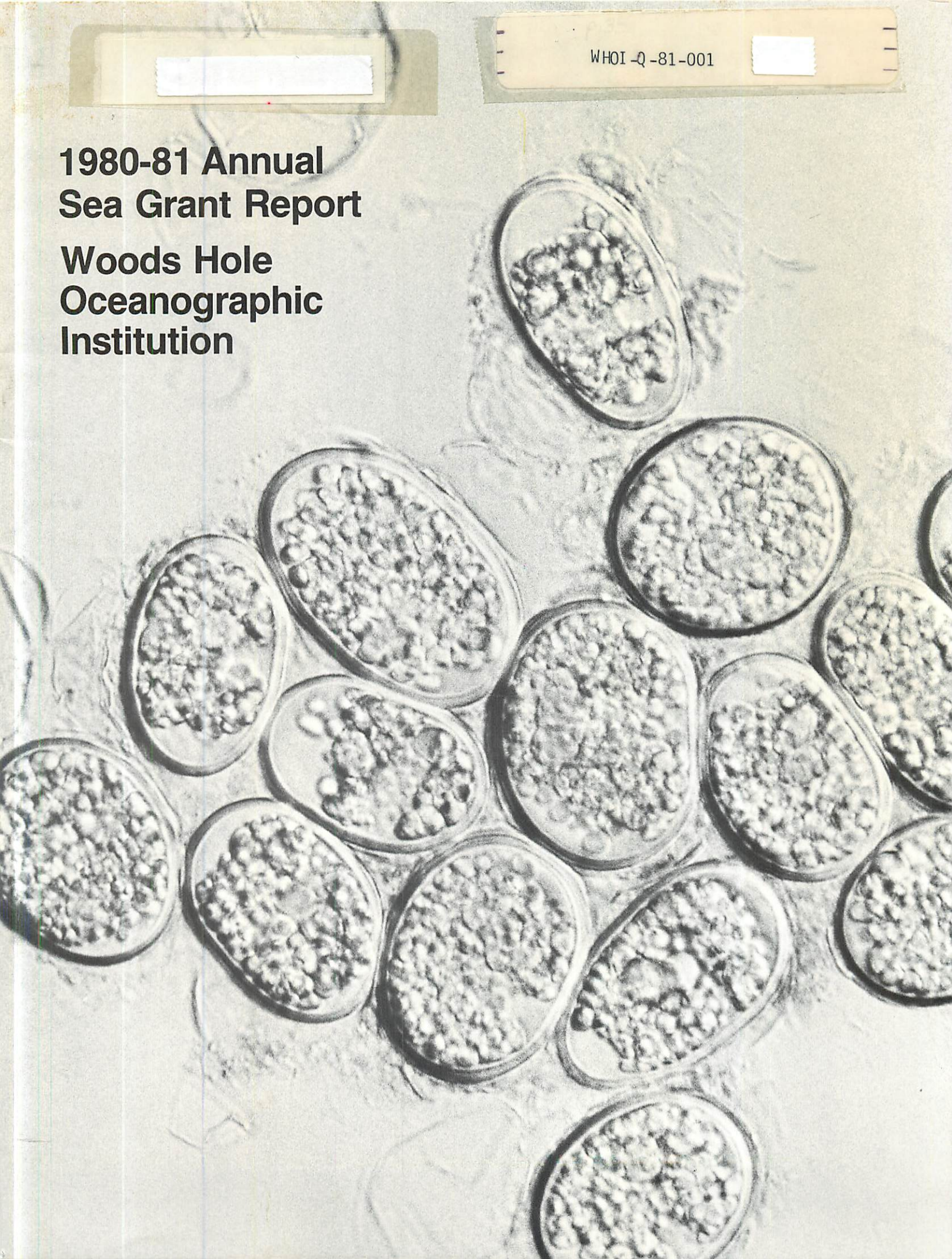
1980-81 Annual Sea Grant Report

Woods Hole Oceanographic Institution



1980-81 Annual Sea Grant Report Woods Hole Oceanographic Institution

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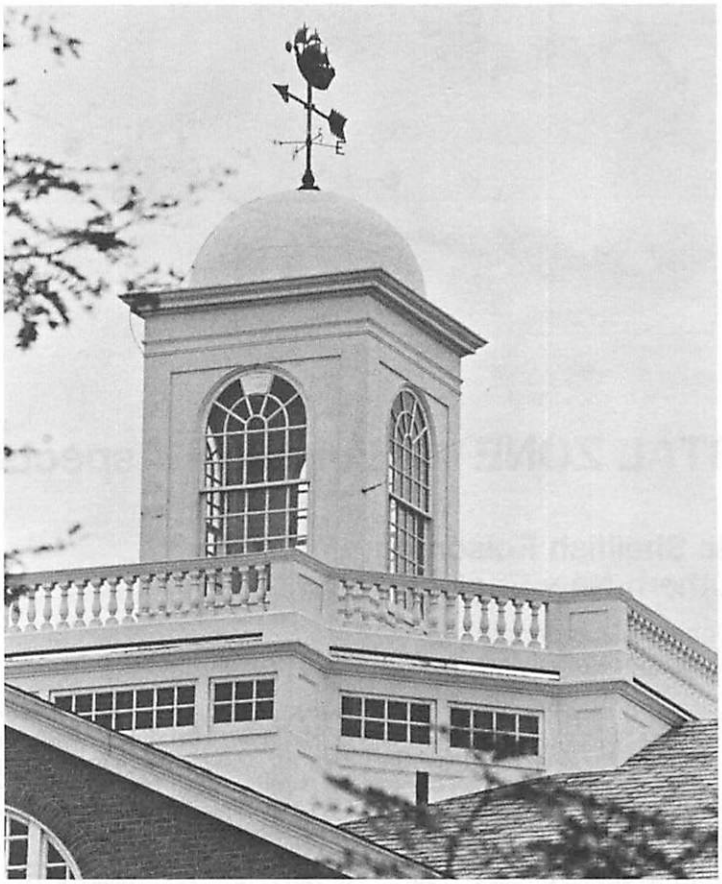
Cover: Resting cysts of Gonyaulax tamarensis (red tide). The presence of these dormant cells in sediment is a useful indicator of the occurrence of motile cells of this species during the year in nearby waters.

INTRODUCTION



The National Sea Grant Program plays a major role in the development of a responsive marine research effort for the United States by its encouragement of the understanding, assessment, development, utilization, and conservation of our Nation's ocean and coastal resources. The Program is a partnership between the Federal Government and academic and research institutions. Our Sea Grant Program draws strongly on the strengths of the Woods Hole Oceanographic Institution, which is a private, non-profit institution dedicated to broad research and educational programs in many aspects of marine science, policy, and technology.

Over the years the Woods Hole Sea Grant Program has focussed on the use and conservation of our marine resources and related marine policy aspects. Examples are the study of paralytic shellfish poisoning and the havoc it continues to play in coastal waters and measuring moveable bed roughness and sediment transport, information necessary in studying tidal inlets and coastal zone circulation. Within our aquaculture efforts we have continued our research into the suitability of hydrogen sulfide as a source of energy for the production of chemosynthetic bacterial biomass for direct use as food for shellfish. Hydrogen sulfide, at present, is a harmful waste material and any process that could turn it into a useful resource should be beneficial to all.

The importance of coastal and ocean resources has long been a research theme at the Institution. The recent establishment of a Coastal Research Center has sharpened our interest in the scientific and policy aspects of the nearshore regions. Sea Grant has been especially valuable to us at Woods Hole and has helped us to develop and expand many new areas of research relative to our use and conservation of the marine environment.

We hope you find this report informative; please contact us if you have any questions on the enclosed material or other aspects of our work and we will do our best to answer them.

David A. Ross
Sea Grant Coordinator

December 1981

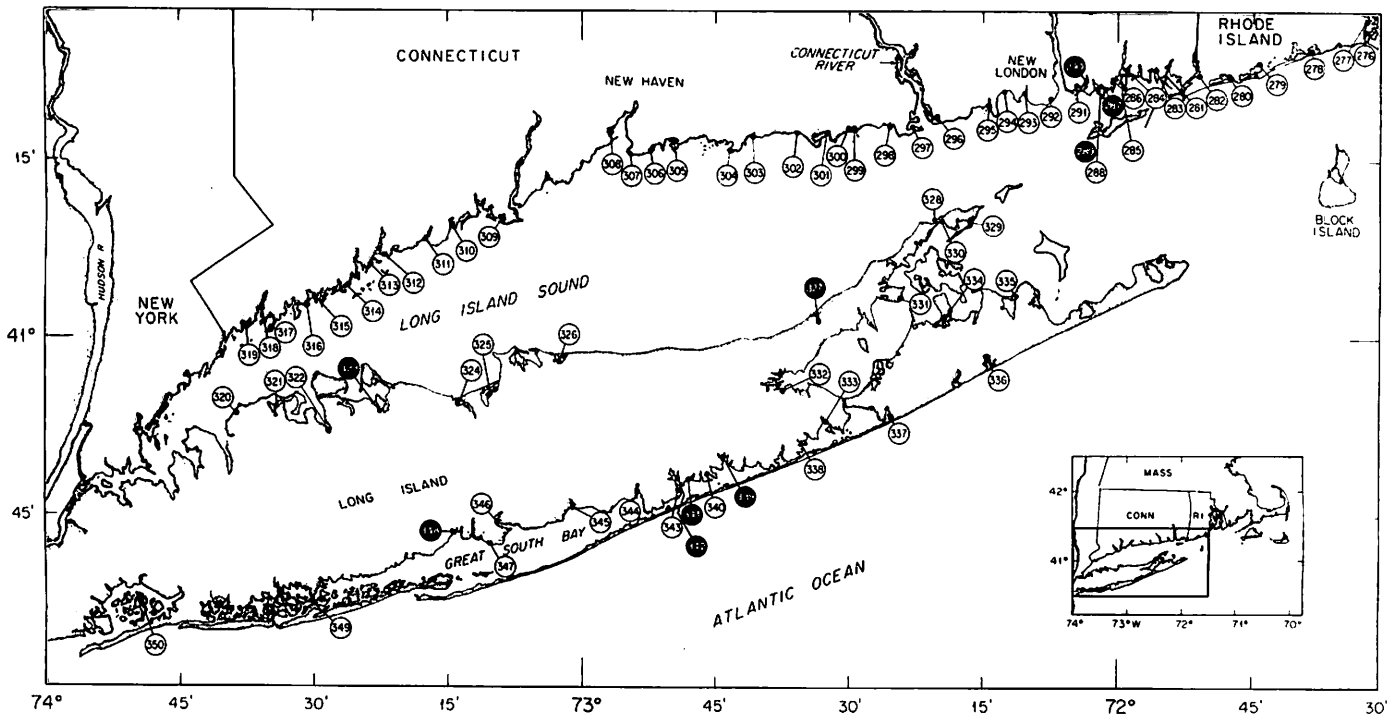


Fig. 1. Distribution of Gonyaulax tamarensis cysts (blackened circles) in the Connecticut and Long Island region.

COASTAL ZONE — Biological Aspects

Paralytic Shellfish Poisoning in Southern New England

Donald M. Anderson
Department of Biology

1981 marks the final year of this project. The overall objective was to determine the factors affecting the geographic distribution of the toxic red tide dinoflagellate Gonyaulax tamarensis in the southern New England region. The trend of paralytic shellfish poisoning (PSP) outbreaks reported for this region suggests a gradual southward spreading of the causative organism - 1958 in Maine, 1972 in Massachusetts and New Hampshire, and 1979 in Rhode Island. A major component of this project was thus to delineate the geographic distribution of this species using a survey of sediments in the region, looking for dormant cysts as an indication of the presence of the motile, vegetative cells in the overlying waters during the year. That effort is now complete, with 350 samples examined from a variety of estuarine and nearshore areas. Most of those results were discussed in last year's report, but we can now add a number of important observations from a continuation of the survey into Connecticut and Long Island, both areas with no previous history of PSP. The southern limit of documented G. tamarensis motile cells is in Massachusetts on Cape Cod, which is also a region where the cysts of this organism were numerous. Proceeding to the west and south, the dinoflagellate could not be found in numerous samples from Buzzards Bay and Narragansett Bay, but suddenly reappeared in one isolated region in Connecticut and six around Long Island (Fig. 1). Cultures established from two of these stations have proven to be toxic, with further tests planned for the remainder. We thus are aware of the potential for toxic outbreaks in two regions with no previous history of PSP (and with extensive shellfish resources).

Given the number of locations where the cysts were found in these two states (9), it seems highly unlikely that each represents a recent introduction of the species. It is more probable that these localized populations existed for years without being noticed (due to the absence of optimal bloom conditions, an infrequent harvesting, or low toxicity strains of G. tamarensis). If a PSP outbreak does occur in these areas in the future, it will not mean that the red tide has spread further south (as would be widely concluded), but would be more indicative of a change in local conditions. It is fortunate indeed that we have detected potential problems well before they appear in the form of a dangerous PSP outbreak. It is now possible to work with appropriate state agencies to design shellfish monitoring programs suitable for each specific region.

Another major project focused on G. tamarensis bloom dynamics in three Cape Cod embayments. Since blooms of this species occur at widely differing times in these three salt ponds, we have an excellent opportunity to detect underlying mechanisms common to bloom initiation, development, and decline. Data are not yet fully analyzed, but it is evident that we have a valuable data base with synoptic measurements before, during, and after three separate blooms in 1980, and over the same interval in 1981 when no blooms occurred.

A final aspect of this project examined the possible role of trace metals in the G. tamarensis distribution, with optimal growth only at those locations and times where a suitable combination of metals and organic chelators occurs. Methodology involved a bioassay technique which, after considerable refinement, now gives us reliable, reproducible estimates of the copper-complexing capacity of seawater and an estimate of the natural ion activity. As we had hypothesized, there is solid evidence that a significant difference in metal speciation can be detected as one moves from an estuary that supports G. tamarensis growth to nearby coastal waters where the organism is not found. Further, we also see a systematic change in these parameters through time, with conditions gradually becoming less inhibitory through the spring. The final step is to relate these findings directly to the metal requirements and sensitivities of G. tamarensis. This work is in progress but is not yet complete.

Tintinnid Predation on Toxic Dinoflagellates (Red Tides)

Diane Stoecker
Department of Biology

Recurrent episodes of paralytic shellfish poisoning (PSP) result in economic losses in the shellfish industry in New England not to mention the direct adverse public health effects. PSP is caused by consumption of shellfish during blooms of the toxic dinoflagellate Gonyaulax tamarensis (red tides). Although there has been considerable research on toxic dinoflagellate blooms, little attention has been given to the influence of predation by zooplankton on G. tamarensis blooms. Predation may be a biological control that naturally limits red tides.

The predator I investigated is Favella, a tintinnid (planktonic ciliated protozoa). In collaboration with D. M. Anderson I have sampled salt ponds that have a history of red tide outbreaks. Favella is only abundant during dinoflagellate blooms. In spring this tintinnid first appears when the water warms to 12-13° but fails to bloom unless high dinoflagellate densities co-occur with its appearance. Favella population peaks coincide with peak dinoflagellate densities; then both Favella and dinoflagellate populations rapidly decline.

The rapid decrease of dinoflagellates may be due to Favella predation. Laboratory data support this hypothesis. This tintinnid is a selective predator on dinoflagellates (Stoecker et al., 1981) and each Favella can consume 6-8 toxic Gonyaulax cells h^{-1} (Stoecker and Guillard, submitted). Favella densities in integrated surface-to-bottom water column samples can be as high as 400 l^{-1}. If we assume a density of 100 organisms per liter and a predation rate of 7 Gonyaulax h^{-1} $Favella^{-1}$; then 16,800 Gonyaulax cells would be consumed l^{-1} day^{-1}. This would have a considerable impact on toxic blooms because during PSP outbreaks Gonyaulax densities may be only 10,000 to 100,000 cells l^{-1}.

Predation rates may be enhanced by aggregation of Favella at depths where dinoflagellates are most abundant. In laboratory experiments, we found that this tintinnid aggregates in areas of high prey density and that light, which causes the dinoflagellates to swarm, can increase predation rates (Stoecker and Guillard, submitted). Diurnal vertical sampling of both dinoflagellate and Favella populations supports this hypothesis. During certain times of the day, this organism can aggregate and reach high densities (up to 5000 l^{-1}) at depths where dinoflagellates are also concentrated.

In the laboratory, Favella's generation time is as short as 12-13 hours. Microzooplankton cages were used in situ to determine its growth rate under close to natural conditions. Field generation times are comparable to laboratory generation times and indicate that Favella can grow as fast or possibly faster than the dinoflagellates on which it preys and therefore could limit the duration and intensity of their blooms.

An understanding of biological controls, such as Favella predation, is necessary so that we can predict under what circumstances these natural controls could be disrupted. Potential effects on natural controls should be considered before decisions are made to employ physical or chemical control measures.

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Stoecker, D., R.R.L. Guillard, and R.M. Kavee, 1981. Selective predation by Favella ehrenbergii (Tintinnia) on and among dinoflagellates. Biol. Bull. 160: 136-145.

Stoecker, D. and R.R.L. Guillard, submitted. Effects of temperature and light on the feeding rates of Favella sp. (Ciliated protozoa, suborder Tintinnia).

The Biology of the Ocean Quahog, *Arctica islandica*

Roger Mann
Department of Biology

The objective of this research is to document the reproductive biology of the ocean quahog Arctica islandica in the Middle Atlantic region, to relate the reproductive biology to seasonal changes in the physical and biological characteristics of the overlaying water column, and to subsequently present the data in a manner that will aid in the development of a fishery management plan for this valuable species. Our 1980-81 research effort was on laboratory culture and description of the larval and juvenile forms of A. islandica. The research effort was a co-operative venture among Dr. Richard A. Lutz working at Rutgers University with the support of Sea Grant funds, Mr. Michael Castagna working at the Wachapreague Eastern Shore Laboratory of the Virginia Institute of Marine Science, and myself.

The larvae of A. islandica have only been reared once before, by Mr. Warren Landers working at the National Marine Fisheries Service Laboratory at Milford, Connecticut. Larvae were reared at both the Wachapreague and Woods Hole laboratories from adults collected off the coasts of New Jersey and Rhode Island respectively. In no instance were we successful in our attempts to stimulate ripe adult A. islandica to spawn viable gametes of both sexes in the laboratory. Therefore gametes were "stripped" from ripe adults by making surface incisions into the gonad and irrigating the gonad with filtered sea water. Active spermatozoa were routinely obtained by this method; however, the ripe eggs were unusual in that, unlike those of most marine bivalve molluscs, they were enclosed in a membranous capsule, and fertilization of stripped encapsulated eggs was poor. Removal of the egg capsule was possible, however, by immersion of the stripped eggs in a weak solution of ammonium hydroxide (3 mls of 0.1 N NH_4OH per 100 mls of egg suspension) prior to addition of spermatozoa.

The egg capsules frequently confined the developing embryo up to at least the 16 cell stage. The capsule conferred some asymmetry on the fertilized egg, the diameter of which ranged from 75-90 µm. The mean length of the smallest shelled stage (prodissoconch I) was 107.1 µm (n = 50 s.d. = 5.3 µm). As shell length reached 150 to 165 µm the hinge line was obscured by the appearance of a low, rounded umbo. With subsequent growth the larvae assumed a distinctly

Table 1. Culture conditions for rearing of larval Arctica islandica.

Group	1*	2	3	4	5
Culture volume (L)	40	4	50	12	12
Larval density (/ml)	1-2	2	6		6
Temperature (°C)	12.7-13.0	12.0-14.5	11.0-13.5	13	8.5-10°C
Salinity (°/oo)	32-34	32	32	32	32
Food concentration	100 cells/ l mixed sp.	[50 cells/ l Isochrysis galbana + 50 cells/ l Pavlova lutheri]			
Frequency of (days) Water change	2	3	3	3	3

*reared at Wachapreague, VA.

(Continued)

circular appearance when viewed laterally being slightly more pointed at the anterior than posterior end. The pediveliger foot became functional at a length of 230 μm and metamorphosis occurred at a mean length of 259.3 μm (n = 100 s.d. = 13.1 μm). A combination of all length versus height measurements gave the regression line:

shell height (μ) = [1.02 x shell length (μ)] - 30.0 (n = 821 r = 0.99)

Larval growth rate appeared to be relatively independent of feeding regime, size of culture vessel, frequency of water change, and site and date of origin of parent stock; however, a strong influence of temperature was evident. Cultures No. 1-4 (see Table 1), reared at mean temperatures of approximately 13°C, reached metamorphosis in 32-35 days; however culture No. 5, reared at a mean temperature of 9°C, required a minimum of 53 days to reach metamorphosis (Figure 1).

Shortly after metamorphosis the valves became an opaque white and a large exhalant siphon began to form. At 1 mm length the exhalant siphon was partially surrounded by the developing tentacles of the tentacular ring that completely surrounds both inhalant and exhalant siphons of the adult form. The inhalant region was marked by a juxtaposition of the mantle edges ventral to the exhalant siphon. The foot was extendable to a length equal to at least that of the shell length. At 2-3 mm the inhalant siphon had formed but, unlike the exhalant siphon, it was not extensable. The number of tentacles in the ring surrounding the siphons continued to increase. At 6 mm length the periostracum had assumed the characteristic dark yellow coloration common in smaller adults collected from the field. The active foot was still present. Some reduction in the size of the exhalant siphon had occurred and the surrounding tentacular ring was fully formed. The characteristic lunule of the adult was present, and both valves exhibited regular external ridges.

Future work will emphasize laboratory studies on larval response (both behavioural and growth responses) to pressure and temperature, and field plankton studies to document seasonal occurrence and depth specific distribution of A. islandica larvae. These studies will subsequently expand to include physical data on depth specific current direction and velocity in the development of a three dimensional, time-specific model of larval dispersion of A. islandica in the Middle Atlantic Bight.

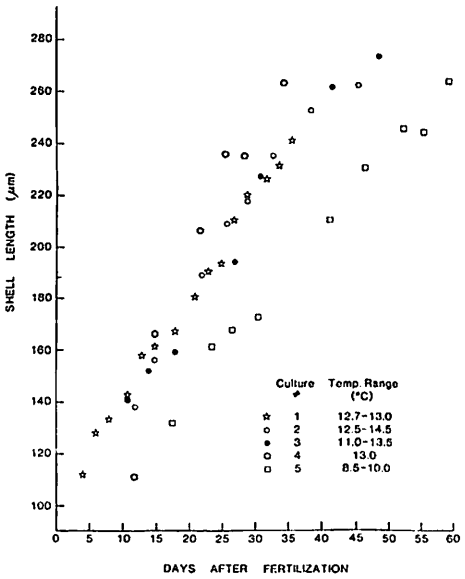


Figure 1. Growth of five groups of A. islandica larvae under various culture conditions (see Table 1). All values are mean of 10-30 individual measurements.

COASTAL ZONE — Physical/Geological Aspects

Moveable Bed Roughness in the Coastal Zone: Field Study and Model Design

William D. Grant
Albert J. Williams, III
Department of Ocean Engineering

Accurate models of bottom friction are required to make predictions of sediment transport rates, coastal currents, near-bottom velocity profiles, mixing processes, and the dissipation of shallow-water surface wave energy. In the recent past, the inability to model bottom friction has led to the necessity of using numerical models for these processes which must be tuned using field data before reasonable predictions can be made. This is an expensive procedure and results in large uncertainty in predictions extrapolated beyond the data base. Over the past three years we have been studying the bottom friction developed over moveable beds under oscillatory flows with the goal of developing a predictive, field tested model for the bottom friction.

A simple model for the bottom roughness was developed for oscillatory flows over sand beds. The roughness is partitioned into two distinct contributions. The first contribution is associated with the form drag over the wave-formed ripples. The second contribution is associated with intense near-bottom sediment transport. Ripples account for most of the roughness when they are present; however, at large values of the boundary shear stress typical of storms, the ripples are washed away and the roughness is controlled by the near-bed sediment transport. The total roughness is a function of shear stess, since both the ripple geometry and sediment transport vary with local skin friction. Predictions of friction factors in oscillatory flow based on the roughness model agree well with laboratory data.

Field testing of the model is more complex than the laboratory testing. Measurements of wave energy are made at two points separated by approximately 10km on the open shelf in a region of simple topography and under swell conditions only (Figure 1 shows a schematic of an experiment). The change in wave energy between the two points after correcting for refraction and shoaling is used to determine the average friction between the stations. Ripple geometry, bathymetry, sediment type, and currents are accurately monitored during the experiment. Special instrumentation has been developed during the research program to assist in these tasks.

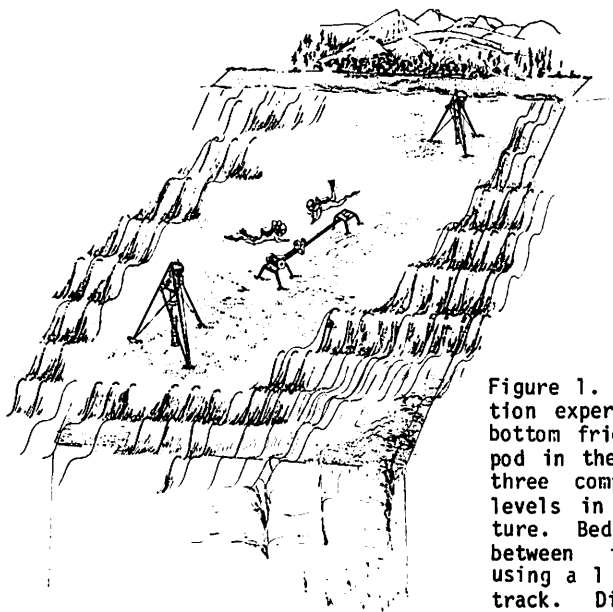


Figure 1. Schematic of wave dissipation experiment to make estimates of bottom friction for waves. Each tripod in the picture measures pressure, three components of velocity at 4 levels in the vertical, and temperature. Bedforms are measured at points between the stations acoustically using a 1 Mhz transducer mounted on a track. Divers also monitor bedforms and take sediment samples.

Laser Velocimeter for Boundary Layer Studies Under Combined Waves and Currents

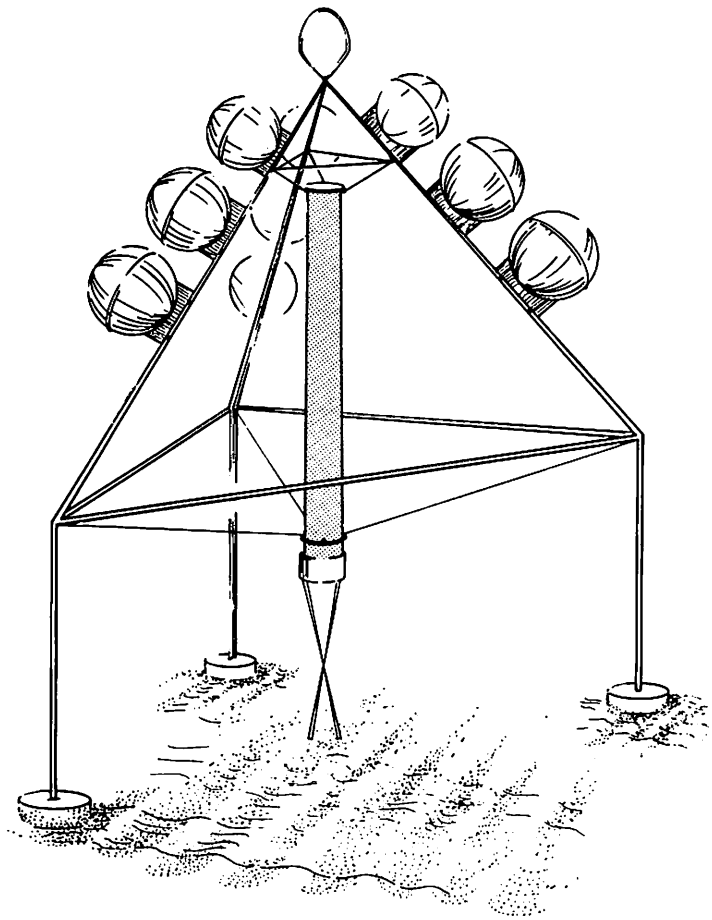
Yogesh C. Agrawal
William D. Grant
Department of Ocean Engineering

Numerous processes in the coastal bottom boundary layer are affected or even driven by the fluid dynamics of water and the generally moveable seabed. For example, turbulence generated at the bottom is the dominant mechanism responsible for diffusion and mixing, both of nutrients as well as pollutants. The transport of sediment depends on the fluid stresses exerted by the combined action of waves and currents. Forces on bottom structures such as pipelines depend on the vertical profile of horizontal velocity above the seabed. Finally, to the extent the assimilative capacity of the oceans depend on the strength of the diffusive processes, it too, is ultimately determined by characteristics of the bottom boundary layer (BBL). Clearly, the ability to model the dynamics of the bottom boundary layer is central to the problem of correctly managing our coastal resources. An effort to make detailed flow measurements in the BBL has been initiated at Woods Hole originally by Drs. William Grant and Albert J. Williams III. Their studies, using an acoustic current meter array, were able to probe the current boundary layer, but were too large to measure the velocity field in the wave boundary layer, which is only of order 5-10 cm in thickness. The laser Doppler velocimeter (LDV) being developed under the present program will undertake high spatial and temporal resolution measurements in the bottom 0.5 m of the BBL, thus generating data in the wave boundary layer against which theoretical models may be tested.

The LDV under development is of the backscatter design, which by sensing the Doppler shift in light scattered by a particle carried by the water, measures its velocity. By illuminating the scattering particle, simultaneously, by three frequency offset beams derived from the same laser, two horizontal components of velocity are to be obtained. The backscatter design allows the LDV to be mounted vertically and optical focussing under microprocessor control will allow sequential profiling of the velocity field at several heights above the seafloor. A separate algorithm in the microprocessor identifies the position of the seabed for reference purposes. Velocity time series are recorded on tape and subsequently analyzed on a shore based computer.

LDV measurements are being made at two site types: 1) over a muddy flat bottom under moderate wave activity, and 2) over a sandy rippled bottom exposed to large swell in Buzzards Bay and on the south coast of Martha's Vineyard. A bedform profiler developed by Williams and Grant at Woods Hole for an earlier Sea Grant project will be employed to record detailed bedforms.

The measurements carried out will test two principal hypotheses in modeling the BBL under the combined action of waves and currents. The first one states that due to nonlinear interaction, the joint action of waves and currents increases the "mean" frictional stress over the seabed (compared with the value for currents alone), and increases the apparent roughness of the seabed. Second, it is hypothesized that the effect of the moveable bed manifests itself through the development of ripples initially, and under greater stress the net transport of sediment results.



The laser Doppler velocimeter, shown here mounted vertically on a tripod, will record velocities at several heights (up to 0.5 m) above the seafloor. Two horizontal components of the velocity vector are measured.

Sediment Transport in a Tidal Inlet

David G. Aubrey
Department of Geology & Geophysics

The modeling and prediction of sand transport in a tidal inlet/ocean/bay system present considerable theoretical complexities as well as experimental hardships for verification attempts. Formulation of a realistic model of tidal inlet sediment transport entails proper consideration of the individual and combined effects of nonlinear shoaling gravity waves, high flow velocities through constricted inlets, water depths approximately equal to the tidal range, bedform heights which cover an appreciable fraction of water depth, and convoluted intricate channel systems.

Over the past two years, we have made a detailed study of the flow kinematics and resultant sediment transport in a natural, unstructured tidal inlet -- Nauset Inlet, Cape Cod, Massachusetts. A detailed historical survey of inlet changes, using aerial photography and charts (extending to Champlain's seventeenth century map) has revealed the dominant patterns of inlet migration and sedimentation, while suggesting hypotheses for this activity (Aubrey et al., 1981). In addition, a high resolution, detailed geophysical and sedimentological study was performed just offshore from Nauset Inlet, to depths of 30 meters, clarifying the recent geological history of the region as well as active modes of shallow shelf sediment transport (Figure 1; Aubrey et al., in prep.). These preliminary studies have guided our experimental design for monitoring water and sand flux through the inlet/ocean/bay system.

In August 1980, a field experiment at Nauset Inlet resulted in time series of sea surface elevation and velocity, as well as a detailed map of inlet conditions during the study (Figure 2). Velocity measurements (u, v, w) at four locations in the inlet and at four elevations (30, 500, 100 and 200 cm above the bed) were made over a full tidal cycle using the Benthic Acoustic Stress Sensor (BASS), an instrument developed in part through a Sea Grant project by W.D. Grant and A.J. Williams, III. These measurements are being used primarily for mean flow estimates at different parts of the inlet.

Sea surface elevation was monitored at various inlet locations (Figure 2) using tide gages and pressure sensors. Pressure sensors deployed across the inlet show elevation differences of up to 30 cm between the bay and ocean, in response to the intense energy losses due to bottom friction during maximum tidal flows. This graphically demonstrates the importance of adequately modeling frictional effects in these channelized flows.

Asymmetries in the tide within the inlet/bay system play a major role in controlling net sediment transport rates and directions. Records of sea surface elevation at an open ocean station and an inlet station (Figure 4) distinctly document tidal asymmetries in the Nauset Inlet/bay system, and demonstrate the need for correctly modeling non-linear processes of tidal propagation in a shallow, complex bay.

Current tasks for this project include adapting a numerical model of tidal inlet hydraulics to reflect the physics of inlet/bay systems of this scale; processing current meter and pressure sensor information from inlet experiments for model evaluation; and planning a future experiment on bedform migration to look at the link between flow kinematics/dynamics and resultant sand motion.

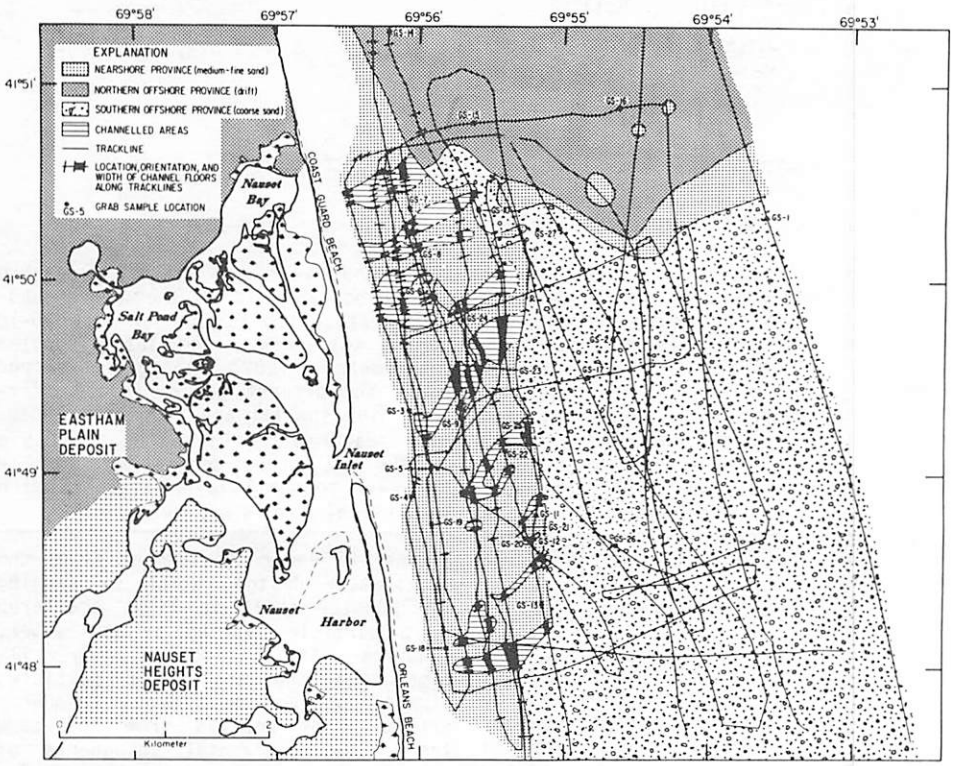


Figure 1: A textural chart of the shallow nearshore sediments off Nauset Inlet illustrates three distinct provinces. The northern offshore province is an erosional surface on the Eastham Plains Deposits exposed on land; the southern offshore province is composed of coarse sand, probably reworked Pleistocene or early Holocene material, and the nearshore province composed of more recent Holocene material overlying coarser, older sands.

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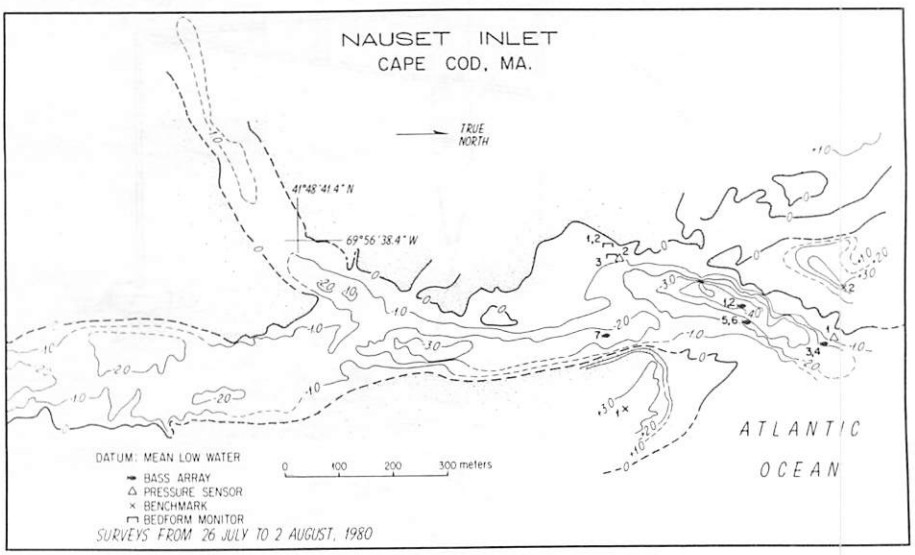


Figure 2: Bathymetric chart (in meters) of Nauset Inlet during the August, 1980, field experiment. Instrument locations are superimposed on the bathymetry. Land areas (above mean low water) are stippled.

Development of Loran-C Buoy System For Coastal Circulation Studies

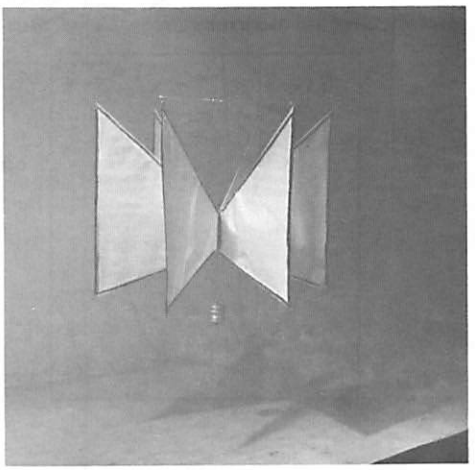
Fritz Hess[1], Robert D. Beardsley[2]
Richard Limeburner[2]
[1]Department of Ocean Engineering
[2]Dept. of Physical Oceanography

Our colleagues Robert Walden and Clay Collins have demonstrated, with past Sea Grant support, the feasibility of using a commercially available, automatic Loran-C receiver as a position location system for an unattended drifting buoy. Based on their work, we have continued the research and development of a practical Loran-C drifting buoy system for coastal circulation studies. Our prototype system has been designed and satisfactorily bench-tested this past year and works as follows. An Internav Model LC-403 automatic Loran-C receiver is turned on for a short period (five minutes) at whatever sampling interval is required for the buoy motions expected in the test area, typically once per hour. Rather than directly rebroadcasting the two Loran-C delays determined by the receiver, the indicated series of time delays (TD) together with a time code and buoy identification code are stored in a random access memory (RAM). These data blocks can also be expanded to include auxiliary sensor data. Using narrow shift frequency shift keying (FSK) at 150 bits per second, the data is then transmitted to a shore monitoring station. Sending the complete data block twice takes about three minutes, once per day, minimizing transmitter power consumption. The burst transmission technique simplifies the radio link requirements where short to moderate range is expected, i.e., 50 to 200 miles. There is no single frequency in the HF spectrum which will give 24-hour circuit reliability. The burst technique allows one to set the buoy clocks such that the best time of day (or night) for the frequency in use is utilized. The prototype system has two modes of operation:

Normal Mode: In this mode, a Loran-C fix is obtained each sample interval, nominally each hour on the hour. This fix, consisting of two TDs along with a clock and up to sixteen bits of auxiliary data (wind, temperature, etc.) is stored in random access memory (RAM). Once per day at a pre-set time optimized for radio transmission, the data is transmitted by high frequency radio to a shore station. Each transmission repeats some previous data to provide redundant data to fill in gaps in transmission.

Locate Mode: For purposes of buoy recovery, a coded high frequency receiver is incorporated. This receiver is enabled during the first five minutes of each hour during which time it can receive, decode and lock on a command to change mode. If a proper coded signal is received, the buoy transmitter comes on immediately and transmits the Loran-C fix just obtained. It comes on at 15, 30, and 45 minutes past the hour sending new fixes. This cycle runs for one hour and if the buoy has not been sighted, the command receiver must be again interrogated during the XX00-XX05 minute time period so that the rapid fix transmission will continue for another hour.

Figure 1. 45 cm scale model of drogue.



W. Burke, a Woods Hole Oceanographic Institution-Massachusetts Institute of Technology Joint Program student, has made an analysis of conventional drogue designs and finds that drogue kiting can be responsible for much drogue slippage. Kiting occurs when the drogue assumes an inclined position to the horizontal flow and results in the drogue not towing true with the current. This is a serious problem for both the crossed-vane type drogue and the window-shade drogue. Burke designed a new drogue based on the three-crossed vane type. As shown in Figure 1, the vane geometry has been modified to balance the drag moments about the tether point. This should allow the drogue to remain vertical, independent of the amplitude of the drag force. Scale model tests of this design in the WHOI towing tank were performed using full scale slippage speeds of 0.2 to 10 cm/sec. These tests indicate that the new drogue does not kite, tows true with the current, and has a drag coefficient of 1.65 $\pm$ .06.

Burke has also designed a buoy hull for the Loran-C drifting buoy (Figure 2) consisting of a metal frame enclosing a body of closed-cell polyurethane foam, covered by fiberglass. The principle design objectives were to minimize wind and current drag forces and provide ample storage space for the batteries. Fabrication of the buoy hull is presently underway, and we anticipate initial field testing of the complete prototype Loran-C system in the winter/spring of 1982.

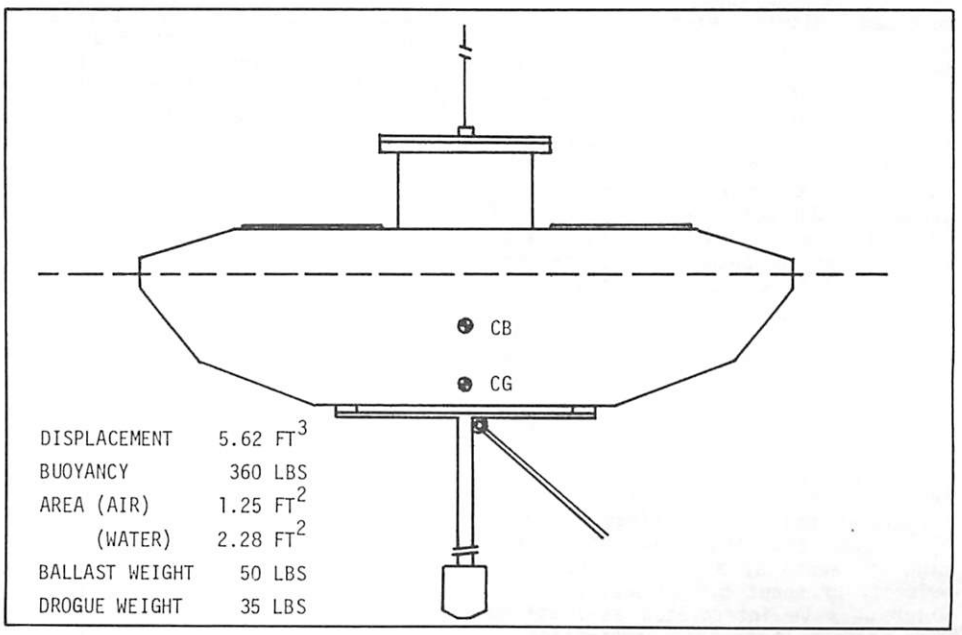


Figure 2. Loran-C driftng buoy.

Potential Deep-Water Gas and Oil Resources in the Northwest Gulf of Mexico

Elazar Uchupi
Department of Geology & Geophysics

The tectonic fabric of the Gulf of Mexico consisting of extensive diapiric fields, massive carbonate platforms, and thick clastic wedges is the result of the break-up of Pangaea in the Mesozoic and the drift of the fragments to their present positions. Distension, which began in Late Triassic, resulted in the formation of an intra-continental rift system. During the Middle Jurassic this system was flooded by seawater from the western Pacific by way of Mexico resulting in the deposition of evaporites. When the continents de-coupled in latest Jurassic the evaporite basin was broken in two with one segment in the northern and another in the southern Gulf. As continental drift continued open water circulation was established and massive carbonate structures were developed around the periphery of the oceanic basin. From the Cretaceous to the Holocene massive clastics prograded seaward burying the carbonate structures in the western Gulf of Mexico. At the same time sediment loading forced the underlying evaporites basinward to form the present diapiric field and salt fronts in the western Gulf of Mexico. At present oil and gas production from this tectonic complex of carbonate platforms, clastic wedges, salt ispirs, and massive gravitational slides is restricted to the shelf from Louisiana (Mississippi Delta) to the Gulf of Campeche (Yucatan Platform).

In 1981 Abou-Bakr K. Ibrahim (formerly of the University of Texas and now at the U.S. Nuclear Regulatory Commission) and I used geophysical data previously collected from tne Gulf of Mexico supplemented by four reversed seismic refraction measurements on the east Texas Shelf to determine the crustal structure of the outer part of the Gulf Coast geosyncline (Ibrahim and Uchupi, in press). From the compiled section we were able to demonstrate that the rifted terrain formed by the break-up of Panagea extended to the outer edge of the shelf and that the oceanic basement/continental basement boundary was located near the shelf's edge. Our investigation also suggested that beneath the diapiric field on the upper continental slope there was an oceanic crustal high whose top was at a depth of about 15 km below sea level. The crest of the high is probably even shallower, possibly as shallow as 10 km below sea level, as our measurements came from the northern and southern edges of the structural high. The refraction data also indicated that the structural high is capped by a material having a velocity of about 5.5 km/sec, material which we have interpreted as platform carbonates. It is this combination of a crustal high, massive carbonates, thick sediment accumulations along the periphery of the conplex which makes the structure such a promising future drilling target for gas and oil. Water depths over the target range from slightly deeper than 100 meters on the landward edge to 3200 meters at its seaward edge and covers an area of over 38,000 sq. km.

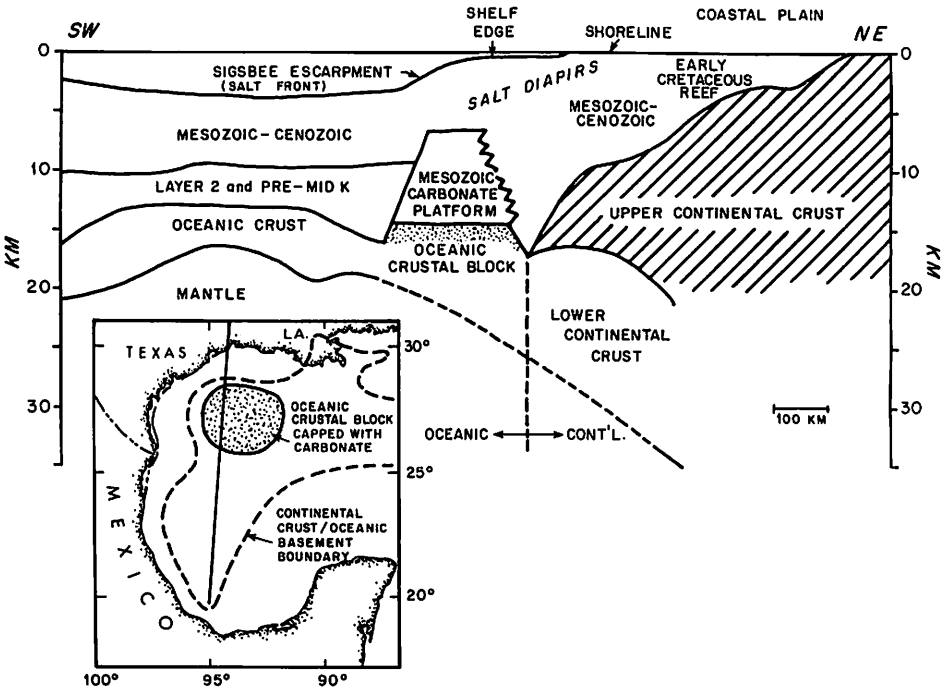


Figure 1. Crustal structure of the western end of the Gulf Coast geosyncline (modified from Ibrahim and Uchupi, in press). The crustal high with its carbonate cap on the upper continental slope south of Texas represents a potential drilling site for gas and oil.

Reference:

Ibrahim, Abou-Bakr K. and Elazar Uchupi, in press. Continental/oceanic crustal transition in the Gulf Coast Geosyncline. Am. Assoc. Petroleum Geologists Hedberg Memoir.

AQUACULTURE

Bacterial Chemosynthesis for Aquaculture

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[1]Department of Biology
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By analogy with mechanisms shown to support the dense biological communities in submarine thermal vents we have proposed that hydrogen sulfide (H_2S) may serve as an effective energy base for commercial mariculture. Illustrated in Figure 2, H_2S with its chemically and biologically mediated partial oxidation products (e.g. elemental sulfur, S_o; thiosulfate, $S_2O_3^{-2}$; tetrathionate, $S_4O_6^{-2}$) would provide energy for the incorporation of nutrients, and dissolved forms of carbon into cell material by chemolithotrophic, colorless sulfur bacteria. The produced cellular biomass would then function as food for a secondary stage of filter feeding animals of commercial utility. This mode of mariculture is an untried concept, requiring verification of its feasibility at all trophic levels. Our recent work has therefore emphasized a dual approach: a) an investigation of the microbiology of H_2S driven mass culture, and b) the initiation of studies exploring the utility of colorless sulfur bacteria as food for filter feeding bivalves.

Our early studies, employing a mass culture reactor for direction H_2S-enriched seawater along the surfaces of a lamellar array of baffles, demonstrated rapid colonization and growth of surface-attached, colorless sulfur bacteria from an inoculum naturally present in estuarine seawater. Continuous operation of the reactor this past year has revealed a remarkably stable mode of biomass production. Experiments with filtered seawater have shown that once colonized the reactor biomass is self perpetuating, precluding the need for a continuous external inoculum and freeing the system of influences from seasonal variations in the indigenous estuarine microflora.

The physical character of the produced biomass is imparted by an undescribed filamentous sulfur bacterium of dimensions 0.3 x 5-50 m that grows not as biofilm but as an entangled matrix extending deeply into the flowing stream of H_2S containing seawater. This organism and additional sulfur bacteria entrained within the matrix serve in effect as a H_2S and O_2 consuming filter of tremendous surface area. Within the aerobic zone of the reactor the immobile flocculent biomass ultimately fills the channels between the baffles. By its loose association with the baffles, however, the biomass can be easily dislodged and flushed from the reactor by abruptly increasing the flow rate of the seawater at appropriate timed intervals. Routine harvest of material from the reactor in this manner permits the immobile microflora to be maintained in an active state of growth for semicontinuous biomass production.

By the appropriate supply of nutrients (nitrogen and phosphorous) via the natural levels present in the incoming seawater, and when necessary by exogenous enrichment, it is possible to produce biomass with a C:N ratio between 6 and 7 (by weight). Approximately 45 percent of the organic matter is protein. These data suggest a significant potential for the production of biomass of high nutritional quality.

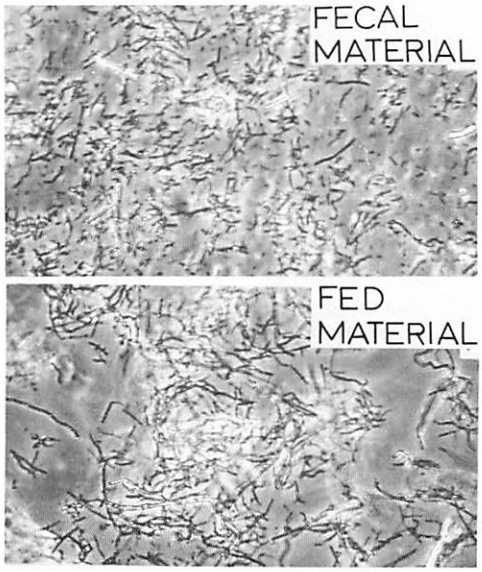

Figure 2. H_2S generated biomass ingested by Mytilus edulis.

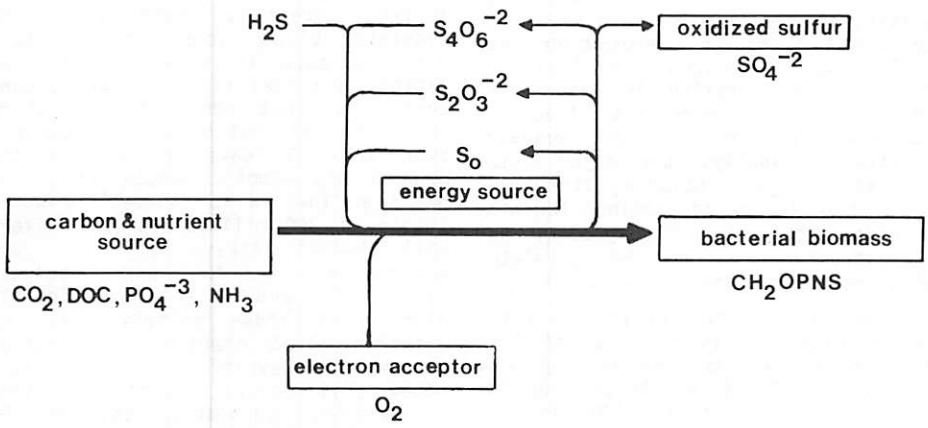

Figure 1. Utilization of reduced sulfur compounds for growth of colorless sulfur bacteria.

As indicated in Figure 1, elemental sulfur is often an intermediate product during oxidation of H_2S to sulfate by colorless sulfur bacteria. If the kinetics of sulfur formation exceeds its subsequent oxidation to sulfate, an accumulation of this element can occur. Analysis of the material from the reactor has revealed that elemental sulfur is indeed present, particularly in the leading baffles where the biomass was greatest and H_2S and O_2 coexist. Utilization of the energy available in elemental sulfur will therefore be an important component of our continuing microbiological studies. One approach will be to include an aerated tank between the H_2S containing biomass generator and the output to the secondary stage of filter feeders. The necessary size of this flow-through tank, i.e., the retention time required, will depend upon the bacterial sulfur oxidation rates which must yet be determined.

Qualitative feeding studies have clearly shown that the biomass is actively filtered from seawater and passed through the intestinal tract of the blue mussel Mytilus edulis (Figure 2). Analysis of the data indicate

(Continued)

(Figure 3) that the fecal material consists of bacterial cells of a size distribution similar to that which was fed to the animal. There appears to be some bias for cells of smaller dimensions, and filaments greater than 5 m were not observed in the feces. Separate experiments have indicated that bacterial filaments longer than approximately 15 m tend to be consolidated into pseudofeces and not taken into the intestinal tract, particularly under feeding conditions employing high bacterial cell densities. Observations thus far suggest that a means for reducing the filamentous nature of the biomass may be called for. Preliminary studies indicate that this function can be effected by aeration, whereby conditions for the continued oxidation of elemental sulfur also result in a reduction of filament length to an average 5 μm.

Our studies for establishing H_2S-generated biomass as food for the growth of Mytilus edulis are currently underway.

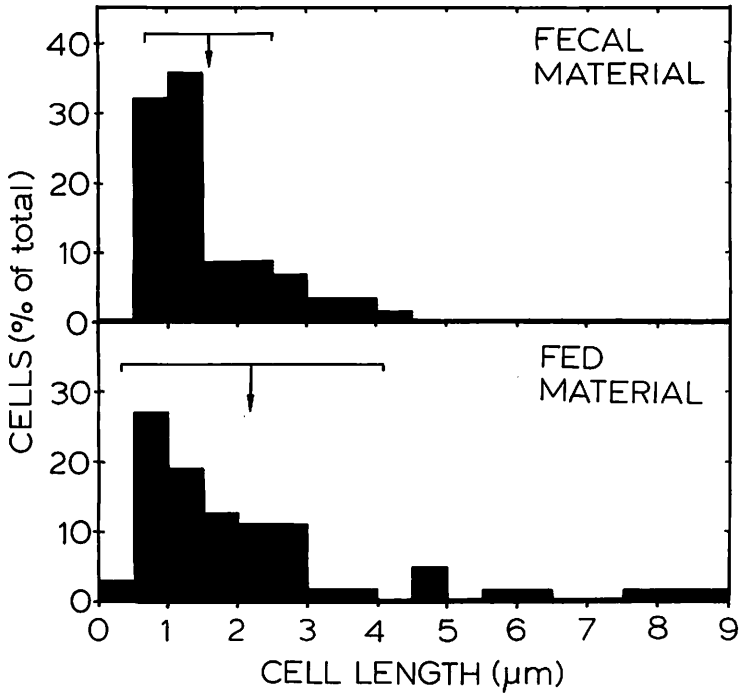

Figure 3. Size distribution of colorless sulfur bacteria ingested by Mytilus edulis. Representative areas of the photographs in Figure 2 were analyzed for cell length and categorized in increments of 0.5 μm. The average cell size of the populations and the standard deviations (N=60) are indicated by the arrows.

Osmoregulation in Sea Trout *(Salvelinus fontinalis)*

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Brook trout (Salvelinus fontinalis) often migrate from freshwater to seawater when given free access to the ocean. Movement into comparatively rich marine systems can result in growth rates that are four to five times that of cohorts remaining in freshwater. This fact, in combination with high return rates of brook trout to their parent stream, makes this a potentially valuable species for sea ranching, fish farming and enhancement programs. However, several questions concerning the migratory tendency of brook trout remain unanswered. One important question is the osmoregulatory ability of brook trout, specifically the roles of size, age and photoperiod in determining their ability to osmoregulate in seawater. Current work in our laboratory is designed to answer this and other questions related to salmonid osmoregulation and smoltification.

In order to determine whether size, age and/or photoperiod are important in the osmoregulatory ability of brook trout, we separated several thousand fry of a controlled genetic stock into fast and slow growing groups using feeding rate to control growth. We further divided the fish into two photoperiods; one is "normal" daylength, decreasing in fall and increasing in the spring, while the second is 3 months out of phase with the normal photoperiod. Every 6 weeks fish from each group are acclimated to seawater using a gradual procedure of one week in 10‰, another week in 20‰ and then exposure to 30-31‰ seawater. Growth and survival of brook trout in seawater is monitored for at least 20 days. To determine the osmoregulatory ability of these fish, plasma levels of Na^+, Cl^-, K^+, Mg^{++} and total osmotic concentration are measured at discrete intervals. Gill Na^+-K^+ ATPase, an enzyme responsible for blood ion homeostasis, is measured in animals exposed to seawater and in a freshwater control group. The circulating levels of the hormone thyroxine is also being measured to determine its effect on osmoregulatory ability and seawater survival. Finally, the major osmoregulatory organs including gills, gut and kidney are being examined for histological changes in morphology and ultrastructure that may be correlated with increased salinity tolerance.

The use of different feeding rates has resulted in an increase of 1.6% body weight per day for fast growing fish and 0.9% body weight per day for slow growers. As of July 1981 fish in each group were 12 cm and 8 cm, respectively. Brook trout of this size are not normally found in full strength seawater. Work at the Woods Hole Oceanographic Institution's Matamek Research Station indicates that brook trout do not enter 30‰ seawater until they have reached a length of at least 15 cm. Other studies indicate that brook trout under 150 g (20 cm) could not survive direct transfer to seawater. However, by using a gradual acclimation process we have shown limited survival of our larger, 12 cm fish after 34 days in seawater. Brook trout of 12.2 cm had a survival rate of six percent while no fish in the slower growing group (7.8 cm) were able to tolerate 30‰ seawater. This relatively low survivorship indicates that brook trout of these sizes and age have a limited ability to osmoregulate in seawater.

Examination of physiological data further suggests a limited ability to regulate blood ions in seawater. After 4 days in seawater the fish exhibit a normal rise in osmotic concentration that accompanies a sharp change in external salinity. However, even after 34 days in seawater the mean plasma osmotic concentration has not been lowered to "normal" seawater levels of 350 milliosmoles per liter. Gill Na^+-K^+ ATPase activity does not change after the initial adaptation period and is not significantly higher for those animals that can maintain blood osmotic concentration at normal levels. This indicates other physiological mechanisms, such as membrane permeabilities, may be responsible for the poor osmoregulatory performance.

We are current examining 15 cm brook trout that are close in size to natural "sea-run trout" that migrate into seawater. Increased survival rates of larger fish will allow us to examine physiological changes in greater depth.

Seeding Program For the Bay Scallop: Comparison of Local Bays, Falmouth, MA

Judith M. Capuzzo
Rodman E. Taylor
Department of Biology

The bay scallop, Argopecten irradians (Lamarck), comprises an important part of the fishery activities on the east coast of the United States. As of 1969 it ranked fourth in importance among bivalve molluscs caught in the U.S. fishery. In 1978 U.S. bay scallop landings were valued at $4.2 million with Massachusetts being the leading producing state. It continues to be an important economic resource for the coastal towns of Cape Cod and the islands of Martha's Vineyard and Nantucket.

Although many facets of the natural history and life cycle of the bay scallop are well understood, the fishery is hindered by the unpredictable abundance of natural set and the apparent instability of local populations. Factors that may cause the instability of bay scallop populations include the loss of eel grass and other epibenthic supports for setting juveniles; loss of larvae from local bays by tidal flushing; biological interactions, such as overcrowding, disease, parasites and predation; and harvesting of juveniles prior to maturation.

Attempts to enhance natural production and/or restock local bay scallop populations have included transplanting bay scallop seed cultured in commercial hatcheries or collected from productive beds. Transplanting of bay scallop seed to marginally productive bay scallop beds will presumably increase the base population for both reproduction and harvesting. In order to efficiently manage such seeding programs, an understanding of the physical, chemical and biological characteristics of potential seeding areas is essential. The best transplanting locations are areas with stable physical and chemical conditions, high rates of productivity and low predator interaction.

In our on-going research program we have investigated three local bays in Falmouth, MA -- Waquoit Bay, West Falmouth Harbor and Green Pond -- as potential areas for seeding of the bay scallop. Physical and chemical parameters related to shellfish growth and settlement have been monitored bi-weekly at each of the three locations since July 1980 and will continue being monitored through June 1982. In addition, detailed surveys at each location of sediment types, vegetation cover, predator type and abundance, and density of bay scallop populations are in progress. Further analysis of the growth, maturation and survival of newly set bay scallops are also being conducted with marked caged and uncaged seed scallops to ascertain periods of rapid growth, spawning and high mortality.

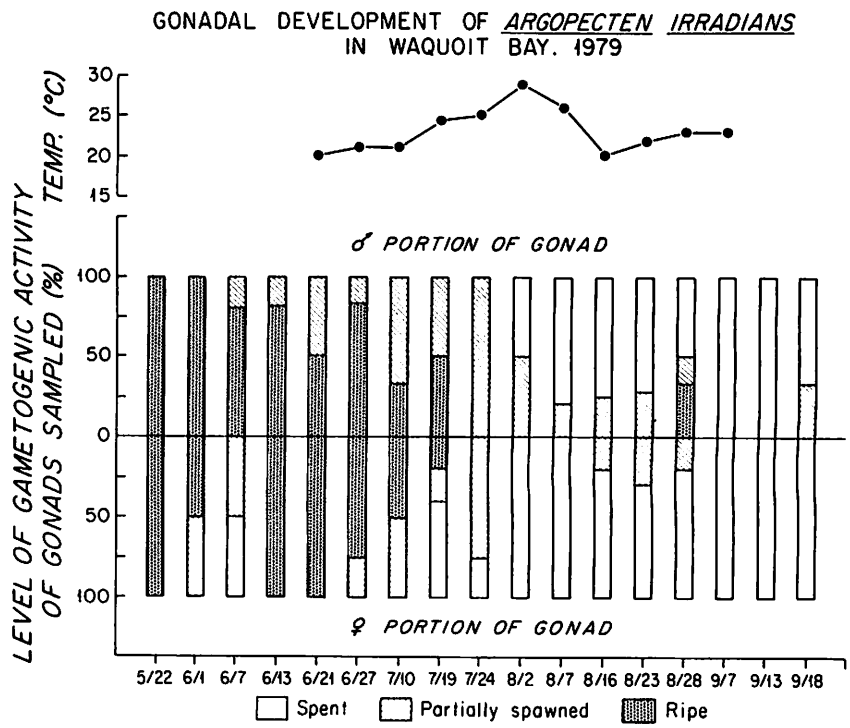
Mortality of both adult and juvenile stages have been attributed to predation by the blue crab Callinectes sapidus, the green crab Carcinus maenas, and the oyster drill Urosalpinx cinerea in addition to infestations by Polydora ciliata and an unidentified colonial ascidian; in the latter instance, infestation on the outside valve of affected bay scallops was so extensive as to restrict valve movement considerably. No signficant mortality attributable to the green alga Codium fragile tomentosoides was observed.

Additional mortality of adult scallops during post-spawning periods was attributable to the synergistic effect of a weakened physiological condition and high summer temperatures (28°-29°C) at some stations. At stations where thermal maxima were less severe (26°-27°C), post-spawning mortality was minimal. A summary of the relationship of spawning activity of bay scallops and temperature in Waquoit Bay is presented in Figure 1. Spawning activity was evident from late May through late July resulting in a wide size range of juveniles in the fall set. Early setting and periods of rapid growth during the summer and early fall have resulted in an abundance of juveniles within a harvestable size range (50mm).

Waquoit Bay appears to have a more stable nutrient input and productivity rate than Green Pond and is a more favorable area for seeding, particularly in the lower half of the bay where eel grass beds dominate the benthos; the latter is especially important for juvenile seed as a refuge from predators and as a site of attachment. Larval loss due to tidal flushing is minimal because of the long residence time of water within the bay. Mortality due to predation, however, has significantly reduced bay scallop abundance in some sections of the bay.

West Falmouth harbor has historically been an area of high bay scallop production and the fall set for 1980 was the highest among the three areas studied (15). Physical and chemical conditions are more stable than in Green Pond, but tidal flushing is more rapid than in the other two embayments; this could explain the high density of bay scallop seed observed offshore. Although predator density and flushing rate are high, there are a number of protected coves in the harbor where successful seeding may occur.

The interactions of physical, chemical and biological parameters are important in determining the success of a bay scallop seeding program. Selection of sites with stable physical-chemical conditions and predator control of bay scallop beds appear to be the more major problems facing the establishment of a successful program.



Microencapsulated Foods For Larval Fishes

Roger Mann and Glenn Sasaki
Department of Biology

The inherent difficulties of obtaining sufficient live food organisms for research and mariculture have provided the impetus for developing artificial feeds. Marine larval fish, however, require food particles at sizes where degradative loss due to leaching and bacterial attack can be quite severe. Microencapsulation, a process coating particles with a protective and retentive material, is a possible solution to this problem.

Our previous Sea Grant work compared techniques of microencapsulation. By the use of a modification of the nylon polymerization method of Chang (1972) we solved problems with feed aggregation and longterm storage, and eliminated the use of potentially toxic material during preparation. The resulting microencapsulated feed was then ready for feasibility testing (Figure 1).

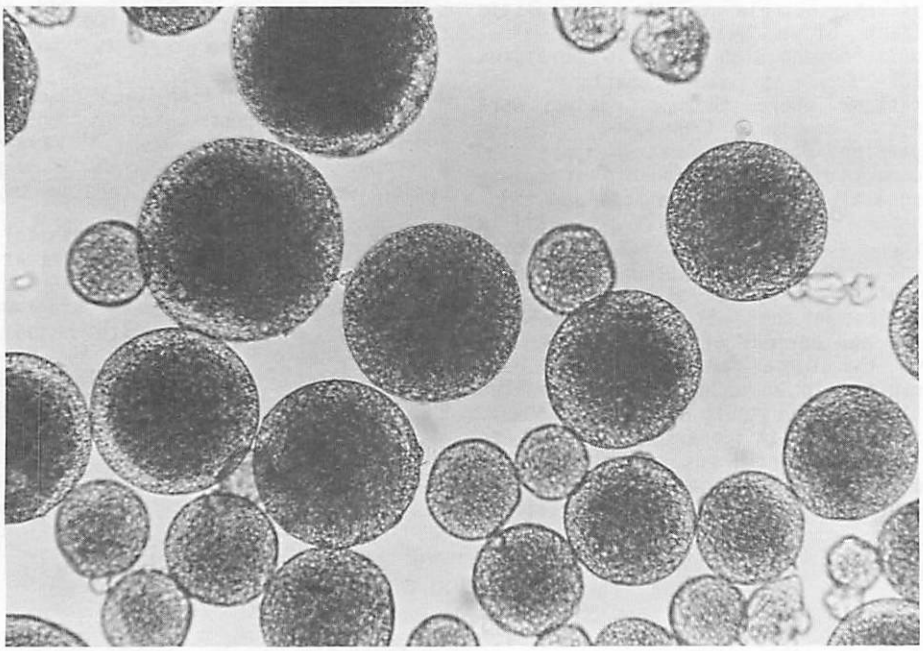


Figure 1. Microencapsulated Artemia homogenate, rehydrated after 16 months of dry storage.

During the next year our work focused upon quantitative and qualitative analyses of the leaching process for the microencapsulated feed as compared to a conventionally bound (carboxymethylcellulose [CMC]) feed; both contained a filtered homogenate of adult Artemia. The microencapsulated feed containing the Artemia homogenate was fed to larvae of the mummichog, Fundulus heteroclitus, to compare assimilation and resultant growth on this diet with that of control animals fed live Artemia nauplii and the CMC bound Artemia homogenate.

In the leaching tests all feeds were subjected to either a brief (5 min.) or prolonged (90 min.) water rinse and filtration. The brief rinse in both the bound and microencapsulated feeds resulted in large loss of material, (60% and 61%, respectively), but for the prolonged rinse only the conventionally bound diet continued to lose material (to a total of 74%); the microencapsulated feed did not experience any further loss past brief rinse levels. Thus, while CMC bound feed caused visible fouling of feeding tank water, briefly-rinsed microcapsules caused no fouling problems.

Qualitatively, the prolonged leaching tests for the microencapsulated Artemia homogenate resulted in a 52%, 87% and 26% loss of the original protein, carbohydrate and lipid respectively, less extreme than the losses experienced by the bound diet (83%, 99% and 38% respectively). These high losses suggest the potential utility of formulated feeds, rather than natural homogenates, as such formulations will permit the use of high molecular weight compounds. In microcapsules, for example, the use of starches (to replace the free sugars in the homogenate) would eliminate the loss of carbohydrate due to leaching.

Feeding trials with Fundulus demonstrated that the apparent assimilation efficiencies were highest (90%) with Artemia nauplii, followed by the CMC bound feed at 83%, and the microencapsulated feed at 46%. Although microcapsules were assimilated with a comparatively lower efficiency, this level is more than sufficient to support growth, and these experiments further successfully answer a crucial question by demonstrating that fish are able to break through the nylon-protein microcapsule membrane.

Figure 2 shows the superiority of live Artemia nauplii as a feed in this study. The microencapsulated feed, however, did support initial growth, indicating that the fish were receiving the required macronutrients. The lack of continued growth in these fish may indicate a nutritional deficiency, possibly the water soluble vitamins. The bound feed did not support growth, even though it was efficiently assimilated. This may be due to poor water quality resulting from degradation of the feed. Further feeding studies such as these using enhanced natural homogenates and formulated feeds should be conducted.

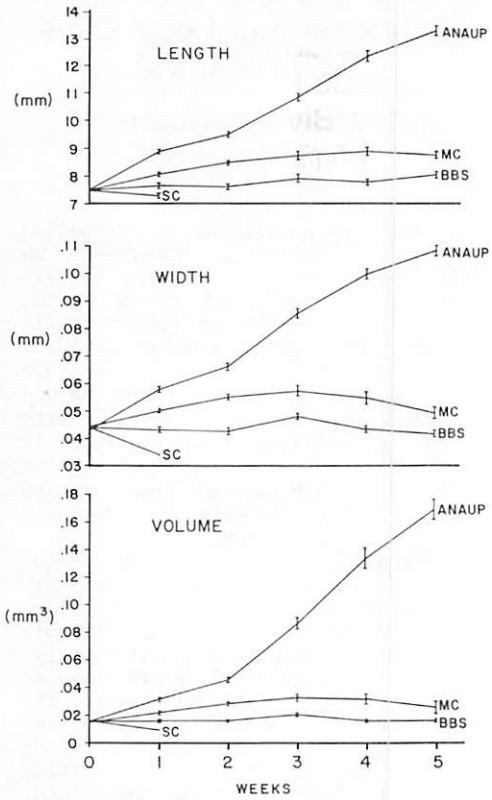


Figure 2. Graphs showing comparative growth of F. heteroclitus larvae on the three feeds: ANAUP - Artemia nauplii, BBS - bound feed, MC - microencapsulated feed, SC - starved control.

Because leaching from the microcapsules is significant, future research should explore the simultaneous use of binders in the microcapsule contents, use of formulated feeds versus natural homogenates, and use of specialized microcapsules to contain the more soluble components which can then be incorporated into larger capsules. Other uses for microcapsules should also be explored, such as a means for precise drug delivery, as nutritional supplements, or for toxicological studies.

Reference:

Chang, T.M.S. 1972. Artificial Cells. Charles C. Thomas, Publisher; Springfield, Illinois, 207 pp

CHEMICAL PROCESSES AND POLLUTION

Metabolism of Aromatic Hydrocarbons by the Bivalve Mollusc *Mytilus edulis*

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Department of Biology

The work of this and the previous year provided a clear indication that the bivalve mollusc Mytilus edulis possessed a capacity to carry out oxidative metabolism of aromatic hydrocarbons. There were several lines of evidence to suggest that this activity was carried out by membrane-bound, especially microsomal, enzymes like those in vertebrates. First, the flavoprotein NADPH-cytochrome c reductase was localized in the microsomal (endoplasmic reticulum) fractions prepared from several tissues, while NADH-cytochrome c reductase activity sedimented with mitochondrial fractions. In vertebrates, the former activity is associated with microsomal electron transfer systems that initiate metabolism of foreign compounds such as aromatic hydrocarbons. Second, in vitro metabolism of the aromatic hydrocarbon benzo[a]pyrene could be measured, and this activity too was localized in microsomal fractions of selected tissues. However, the rates of hydrocarbon metabolism that could be measured were very low. The activity was also quite variable, and at times this activity could not be detected at all. There was a seasonal pattern in the variability of benzo-[a]pyrene metabolism, but this did not account for all of the variation. Sex-linked variation was not observed.

In spite of the results that suggest the presence of a microsomal system capable of aromatic hydrocarbons in Mytilus, the nature of this system could not be confirmed. Repeated attempts to demonstrate ether dependence of the activity on molecular oxygen or inhibition of the activity by carbon monoxide produced only inconclusive results. The former would be an indication of mono-oxygenase activity and the latter an indication that cytochrome P-450 was involved. Thus, the nature of the system responsible for the observed metabolism in Mytilus has yet to be defined. In any case, the rates of aromatic hydrocarbon metabolism are very low, certainly less than 10 pmoles/min/g tissue in vitro. Moreover, the rates in animals from areas contaminated with PCBs did not appear to have been induced. The significance of such low rates of metabolism, either to the physiology of the animals or to the composition of hydrocarbon residues in tissue, would appear to be small.

The Comparative Toxicity of Crude Oil and Oil Dispersants To Marine Larval Organisms

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Interest in oil and gas exploration in the coastal regions of the northwestern Atlantic has increased in recent years in efforts to find new sources of petroleum resources. Increased exploitation, however, poses many unanswered questions concerning the toxic effects of drilling and transport operations on commercially important species and the resulting economic impact on established fisheries. With the risk of offshore oil spills, new strategies of oil spill clean up and control have been developed and it has been recommended that the use of oil dispersants may effectively control the movement of an offshore oil slick and prevent its transport into nearshore areas. Effective dispersants will increase the formation of oil droplets, thus reducing the size of the slick and leading to rapid dilution in the water column. Our understanding of the impact of dispersants, however, in the control of offshore oil spills is limited to the physical characteristics of oil-dispersant mixtures under various environmental conditions. The ecological impact of dispersant application needs to be more fully evaluated. The specific questions that need to be addressed include:

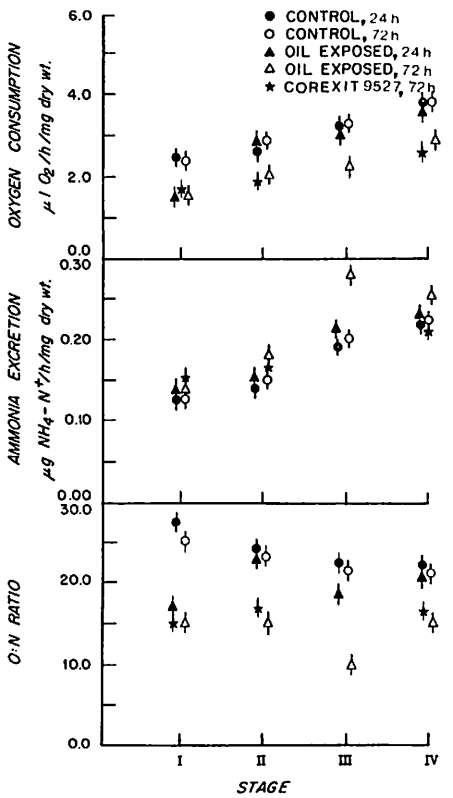
a. How is the dispersed oil phase diluted and transported in field conditions?
b. What is the nature of the dispersed oil, including bioavailability and oil droplet size?
c. What are the resulting biological effects of chemically dispersed oil?

In recent laboratory and field studies the physical characteristics of oil-dispersant mixtures have been documented but the effects of such dispersal on marine biota are not clearly understood.

The planktonic larval stages of many commercially important species are particularly susceptible to environmental stress and exposure to oil dispersed in surface waters could result in reduced survival, increased susceptibility to other stresses such as disease and predation and changes in the rates of growth and development. To approximate field conditions, continuous flow bioassays of naturally dispersed and chemically dispersed oil were conducted on larval stages of the American lobster (Homarus americanus) and the winter flounder (Pseudopleuronectes americanus) with a consideration of both lethal and sublethal effects.

Larval lobsters are acutely sensitive to naturally dispersed concentrations of crude oil as low as 1.0 ppm and significant changes in respiration rates and energy utilization have been reported with exposure to sublethal concentrations. Larval winter flounder are susceptible to concentrations of naturally dispersed crude oil as low as 0.5 ppm and significant delays in metamorphosis are observed among older larvae exposed to sublethal concentrations.

Bioassays have been conducted comparing the effects of naturally dispersed South Louisiana crude oil and chemically dispersed South Louisiana crude oil with Corexit 9527. Corexit 9527, a widely used dispersent manufactured by Exxon Oil Co., has a glycol ether solvent and is effective in dispersing oil at a dosage of 1:10 to 1:50, dispersant: oil ratio. Thus, an oil concentration of 250 ppb can be effectively dispersed by as little as 5-25 ppb Corexit 9527. Survival of larval lobsters was not altered with exposure to chemically dispersed oil in comparison with naturally dispersed oil. At a sublethal concentration of



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25 ppb oil dispersant: 250 ppb crude oil for chemically dispersed oil and 250 ppb for naturally dispersed oils survival of each larval stage in the two oil exposures were similar to control larvae. The effects of naturally dispersed and chemically dispersed oil on the energetics of larval lobsters are presented in Figure 1. Respiration rates, ammonia excretion rates and O:N ratios of each larval stage were monitored during a 96 h exposure to crude oil and oil-dispersant mixtures.

Reduction in respiration rates and O:N ratios were similar among larval lobsters exposed to naturally dispersed and chemically dispersed oil, suggesting a similar toxic effect of the two dispersions on metabolic processes. The O:N ratios measured for control lobsters are indicative of a high dependency on protein catabolism as the principal source of energy for the larval stages but lipid and/or carbohydrate sources are utilized to some extent. The reductions in O:N ratios of oil exposed lobsters are indicative of increased dependence on protein reserves and decreased utilization of lipid reserves. Alterations in lipid class and component fatty acids of control and oil exposed larvae are currently being evaluated.

Addition of Corexit 9527 to an oil dispersion did not result in enhanced toxicity for larval lobsters. This suggests that the increased availability of microdroplets of oil (10-20 m in size) does not correlate with increased toxicity for these larval stages; this may be related to the feeding activity of larval lobsters, as they tend to seize only larger planktonic prey items. Planktonic species that prey on smaller forms, such as winter flounder and oyster larvae, may accumulate droplets in chemically dispersed oil suspensions.

The more rapid dilution of chemically dipersed oil would minimize the duration of exposure for pelagic organisms thus the overall impact on the plankton community may be far less than that of naturally dispersed oil in offshore environments. Research is continuing on comparative aspects of bioaccumulation and metabolic changes associated with exposure of larval organisms to naturally dispersed and chemically dispersed oil.

The Interactions Between Chemical Species and Phytoplankton Growth in Natural Water Systems

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Department of Biology

One of the many biologically-mediated chemical reactions occuring in natural waters, those involving inorganic carbon are the most interesting, complex and important. The reduction of CO_2 to organic carbon by photosynthesis is the basis for all life on earth, and in the oceans this process is a prime step in the cycling of carbon. Moreover, it is well-recognized that uptake and regeneration of CO_2 in the oceans provides a major control of the chemistry of seawater and that the ultimate fate of the current atmospheric excess of anthropogenic CO_2 may lie in the oceans. Thus, possible biological controls of the rate of attaining this equilibrium are not only of immense academic interest, but also are essential to our understanding of the potential impact of one of man's most far-reaching activities on the earth. In addition, the adequate supply of inorganic carbon to intensely grown phytoplankton cultures is, to some degree, dependent on gas-liquid exchange mechanisms similar to those governing the transport of CO_2 into the natural marine environment.

A major and well-studied process of transporting inorganic carbon into the marine environment is diffusion of CO_2 across the air-liquid interface. In a simple case the rate of mass transport of a gas into solution is controlled by the gradient between the partial pressures of the gas in the two phases and the thickness of this diffusive gradient. For iorganic carbon the problem is compounded by the fact that CO_2 not only reacts chemically with HCO_3^- and CO_3^{-2} ions (the major forms of inorganic carbon is seawater), but also is consumed biologically through the process of photosynthesis. Hence, there are potential enhancement mechanisms for transporting atmospheric CO_2 into the marine environment that depend on a complex interaction between biological and chemical factors.

The major objective of this Sea Grant-sponsored research was thus to measure the extent and significance of biological influence on the mass transport of atmospheric CO_2 into the aqueous environment in controlled laboratory experiments involving both natural seawater and cultured marine phytoplankton. The potential enhancement of CO_2 transport into the aqueous phase can occur by three types of processes: 1) photosynthetic assimilation of transported CO_2; 2) possible rate catalysis by extracellular enzymes (e.g., carbonic anhydrase) and other chemicals; and 3) alteration of the chemical environment (e.g., pH and alkalinity changes) caused by photosynthetic activity. To compare the relative influence of each of the 3 processes on CO_2 transport into solution, we developed a unique gas-liquid exchange system (Figure 1). This system consists of both a circulating and closed gas environment coupled through a non-dispersing infra-red CO_2 analyzer and an aqueous phase which is temperature-controlled and mixed to allow moderate turbulent diffusion. Once a steady-state CO_2 partial pressure is established, the gas phase is opened to the aqueous phase and the rate of CO_2 transport between the 2 phases is measured over a fixed period. Chemical enhancement of the mass transfer process is then judged to occur when the rate constant for the above process is greater than would have occurred had the difference between the partial pressures of CO_2 in the 2 phases been the only controlling factor.

Currently, we are carrying out a series of experiments dealing with the effect of pH and temperature on the potential enhancement of CO_2 transport into solution by natural and cultured phytoplankton populations. Part of these efforts is to determine if the enzyme carbonic anhydrase, which

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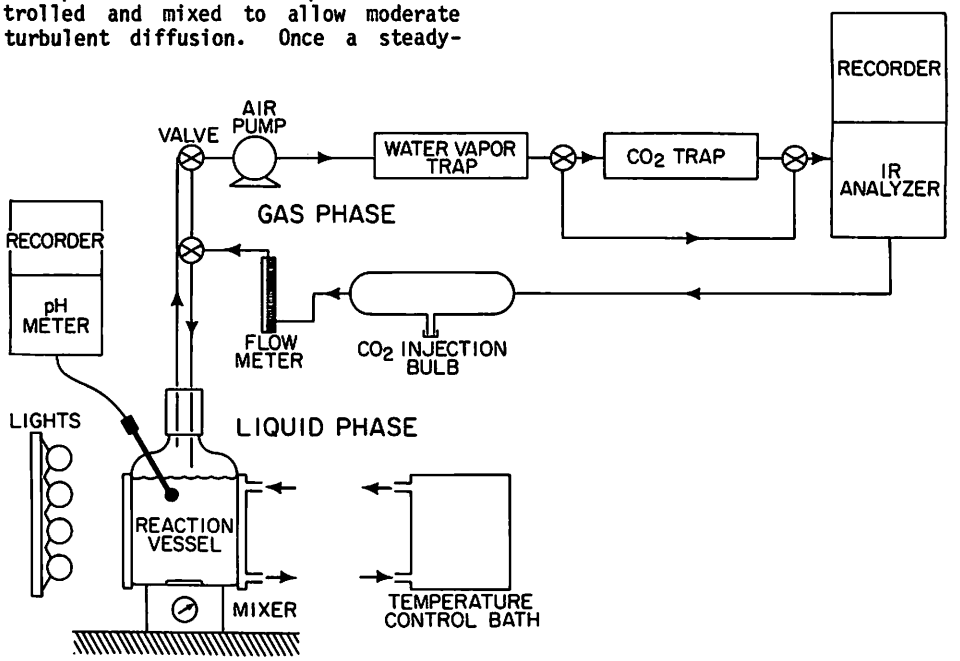
Figure 1. Schematic view of gas-liquid CO_2 exchange system used to study the role of biological activity in the mass transport of atmospheric CO_2 into seawater.



catalyzes the conversion of CO_2 to HCO_3^- is produced by phytoplankton in sufficient quantities to serve in enhancing the mass transport of atmospheric CO_2 into solution. As seen in Figure 2, chemical enhancement (i.e., addition of commercially prepared bovine carbonic anhydrase) of CO_2 transport into solution is heavily dependent on the degree of induced turbulence. Only at intermediate levels of turbulence (ca. 500 RPM) is a compromise achieved between molecular diffusion limits imposed by very low turbulence (0 RPM) and the complete destruction of diffusion barriers created at very high turbulence (700 RPM) so that chemical enhancement is possible. To date, one interesting finding of our results is that chemical enhancement, which occurs only at moderate turbulence, is not nearly as effective in increasing the rate of CO_2 mass transport into solution as is increased turbulence (Figure 2). In addition, some of our preliminary data on CO_2 mass transport in natural seawater indicates that little, if any, chemical enhancement of the process occurs at the prevailing pH of seawater, which is about 8.2.

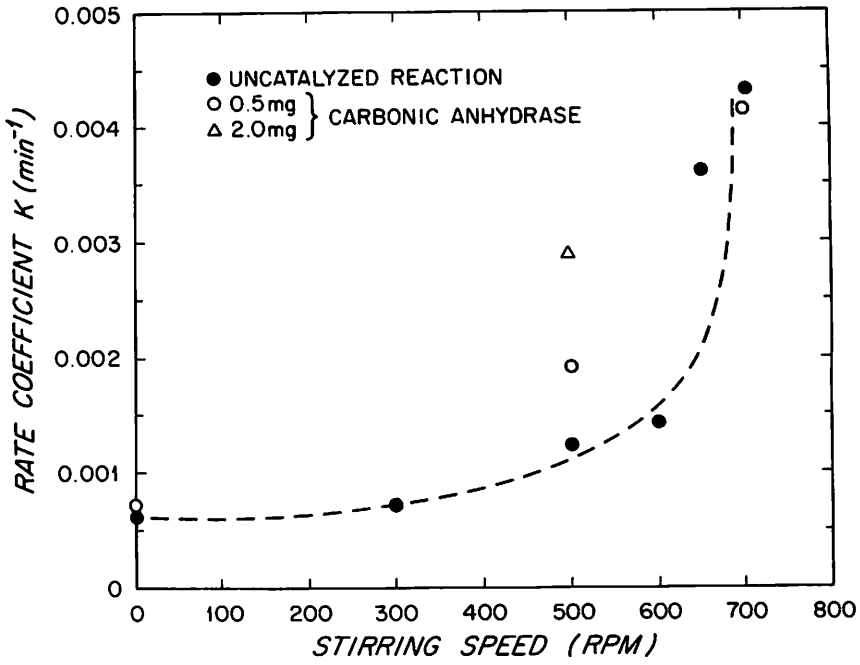


Figure 2. The effect of turbulence, measured as the speed of mixing of the liquid phase, on the rate of CO_2 transport into seawater with and without the addition of commercially prepared carbonic anhydrase.

Biogeochemistry of PCBs in New Bedford Harbor and Buzzards Bay, MA

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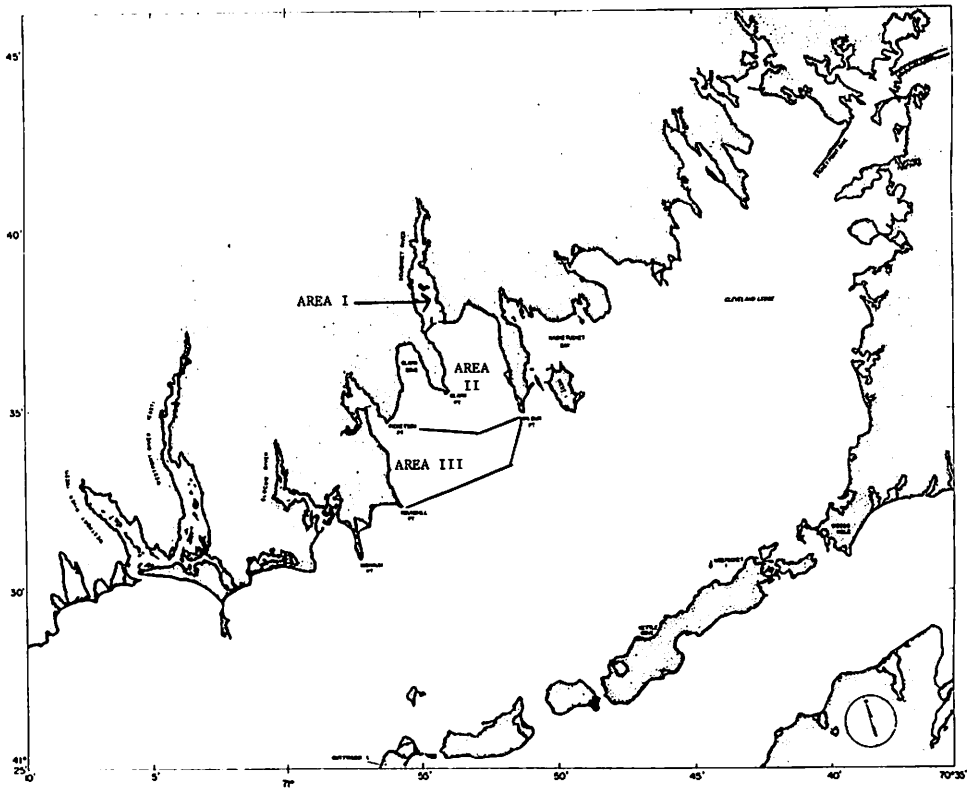
Polychlorinated biphenyls (PCBs) have been recognized as ubiquitous environmental pollutants and PCB manufacturing ceased in the United States in 1977. Nevertheless a large amount of the PCBs produced are still in use and are subject to release to the environment or have already been released to the environment. Several coastal and estuarine areas have received PCB inputs -- sediments of these ecosystems can act as both short term (years) or long term reservoirs.

The Acushnet River Estuary (also known as New Bedford Harbor) at the western end of Buzzards Bay, Massachusetts received PCB inputs as a result of chronic releases from two electronic component manufacturing factories. Measurement of PCBs in lobsters and bottom fish by our laboratory and by Massachusetts state agency laboratories established this harbor area as a severely polluted area. The Massachusetts Department of Public Health closed parts of the area in question to lobstering (Areas I, II, III, Figure 1).

Our research of the past two years with combined funding from Sea Grant, our Coastal Research Center, and the U.S. Environmental Protection Agency Mussel Watch Program has focused on the following:



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1. Assess present knowledge of PCB biogeochemistry in Buzzards Bay.

2. Conduct high resolution gas chromatographic and gas chromatographic-mass spectrometric analyses for PCBs and reaction products.

3. Design and implement a prototype monitoring program using analyses of indigenous and transplated mussels (Mytilus edulis).

We have estimated from our measurements of PCBs in two cores taken in the harbor, and grab sample analyses by state laboratories, that the upper 50 cm of the inner harbor sediments (Area I, Figure 1) contains about 100 tons of PCBs. This is, of course, a rough estimate and needs to be verified by further sampling and analyses. However, this estimate has provided engineers considering various dredging and disposal alternatives with an estimate of the magnitude of PCB contaminated sediment with which they will have to work.

Analyses of indigenous mussel populations in the area have established a basis for estimating the geographical extent of the PCB contamination in Buzzards Bay (Figure 1 and Table 1). Elevated levels of PCBs in East End Beach mussels raise the possibility that along shore transport of suspended sediment from the harbor area has contaminated some shoreline areas with PCBs. The mussel analyses have also provided a sample set to measure changes from year to year. Thus far we see no significant decline in PCB concentrations at locations sampled in 1978 to 1981.

Our high resolution glass capillary gas chromatography mass spectrometry measurements have clearly demonstrated that the mixture of PCBs in lobsters markedly changed from the commercial formulations of either Arochlor 1016, 1242, or 1254. This is consistent with differential metabolism of selected PCB cogeners (specific chemical structures). This raises the question of whether or not current guidelines for closure or opening of areas to lobstering are based on the best available data linking specific PCBs with known or suspected mammalian health problems.

This past summer and fall we successfully initiated deployments, recoveries and analyses of moored, caged mussels as an extension of the shoreline mussel monitoring network into the deeper waters of the bay.

We are now preparing a combined research and monitoring program for the Buzzards Bay - New Bedford Harbor area in conjunction with state agencies to be submitted for funding as part of an overall dredging and clean-up assessment effort.

Table 1

PCB Concentrations in Mussels and Oysters from Buzzards Bay and Nearby Massachusetts Sites.*

10^{-6} g/g dry wt.

Location	Date	Aroclor 1242	Aroclor 1254
New Bedford Harbor Hurricane Barrier	781002	16	15
	800327	39	10
	810504	11	12
East End Beach	800327	1.1	0.9
	810504	0.4	0.9
Slocum River (oysters)	810504	--	0.5
Lloyd Center (oysters)	810504	--	1.0
Cuttyhunk Harbor	791205	0.2	0.6
West End Pond	791205	0.02	0.07
	800626	--	0.03
	800826	--	0.03
	810519	--	0.1
Cape Cod Canal	760925	--	0.2
	770819	--	0.2
	800114	--	0.2
	800214	--	0.3
	800310	--	0.2
	800424	--	0.2
	800522	--	0.2
Vineyard Sound (near Gay Head)	781011	--	0.095
	781026	--	0.096
	790828	--	0.098
	790926	--	0.14
Nantucket Harbor (West Jetty)	800717	--	0.080
	800924	--	0.022
Esther Island	800717	--	0.072
	810519	0.02	0.05
TRANSPLANT EXPERIMENTS (from Nantucket 810519)			
Outer New Bedford Harbor	810605 (Day 17)	0.98	1.3
	810616 (Day 28)	1.4	1.6
	810715 (Day 57)	1.8	2.8
Cleveland Ledge	810715 (Day 57)	0.12	0.36

*All samples Mytilus edulis except two Crassostrea virginica samples as indicated.

MARINE POLICY

Marine Policy and Ocean Management

David A. Ross

Marine Policy and Ocean Management Program participants address ocean-related issues through seminars, workshops, symposia, individual research projects, and research coordinated with social and natural scientists from the Woods Hole Oceanographic Institution and from other academic institutions in the U.S. and abroad. Issues studied have included law of the sea, ocean mining, fisheries management, aquaculture development, coastal zone management, freedom of marine scientific research, energy from the oceans, ocean disposal of industrial wastes, and marine science education. The information and results obtained are conveyed to the public, government personnel, and politicans through publications, lectures, discussions, and individual participation as advisors to regional, national and international policy-making bodies and entities.

The Marine Policy and Ocean Management Program operates in several related ways:

- A research fellowship program for professionals interested in marine policy careers;

- Support of a marine policy staff;

- Sponsorship of marine policy research;

- Cooperative research efforts, between physical and social scientists;

- Advice to individuals, administrators, groups and organizations of important marine policy issues in the public and private sectors;

- Development of workshops or meetings on issues of national or internatonal importance that focus on critical policy problems.

The Program in 1980-81 included three Policy Associates, two Senior Fellows, ten Post-doctoral Fellows, and three Guest Investigators. Program activities during 1981 were many and varied, including the annual meeting of the International Federation of Institutes for Advanced Study (IFIAS). WHOI is a member of this prestigious group and members of the Policy Program have participated in several of its past activities. The meeting focused on the subject of technological advances and third world countries.

In October the Marine Technical Assistance Group (MTAG) of the U.S. National Academy of Sciences' Ocean Policy Committee met at Woods Hole. The objective of the meeting was to finalize a report for the Academy on what the U.S. has done and should do in the area of marine technical assistance to developing countries. A one-day seminar was held during their visit at which time some of the recommendations were presented and the Program's new project for an international cooperative marine policy effort was discussed.

The Program sponsors a lecture series established in honor of Mr. J. Seward Johnson's support of WHOI and the Program. The series brings distinguished scholars to Woods Hole to lecture on current policy issues and the talks are published as a formal series. Dr. John Byrne, Administrator of the National Oceanic and Atmospheric Administration, was the 14th speaker in the series, he spoke in September of 1981 on NOAA's role in national ocean policy. In addition to the Johnson lecture series, the Program sponsored presentations by over 30 visiting scholars in 1981.

As part of the WHOI/MIT joint education program, the Program offered a course in marine affairs. The course presents basic information on the management and regulation of man's use of the ocean and coastal area, living and mineral resources, and the international, federal, state and local agencies designed to protect, conserve, allocate or administer an area or material.

Ecological Theory Applied to Fisheries

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Department of Biology

The management of fish stocks involves trying to catch a lot of fish while still leaving behind an adequate breeding population. A host of problems lies behind this simple statement - problems concerning the ecology of marine systems, fishing technology, and the behavior of fishermen. One approach to these problems is to isolate one or two aspects and study them in detail: if the aspects are well (luckily) chosen, one may gain insights into the workings of a simple system, which are then useful in considering the larger problem from which it was abstracted.

We have investigated simple surplus production fishery models in the context of a developing fishery, in which a manager may be trying to set catch limits at an optimal level and at the same time trying to determine what that level is. In this situation, we have shown that a policy of steadily increasing the fishing quota and carefully watching the stock size is likely to lead to over-exploitation, because at the critical time there is nothing to watch for. For schooling fish, where low densities need not greatly decrease catch-per-unit-effort, a policy of steadily increasing effort has the same dangers. The reason there is nothing to watch for is that the response of the fish population to over-exploitation lags enough that the damage is done before restrictions can be put on further fishing.

Within our models, over-exploitation is signalled by vanishing of fish stock. In reality, there are other species around, and the commonly observed response is a sudden flip in the relative abundance of species. Current extensions of our work suggest why these flips occur, and may offer ways to prevent them if desired.

Small-Scale Commercial Fishing in Southern New England

Susan Peterson
Leah J. Smith
Marine Policy & Ocean Management

Research on the small boat sector of the Southern New England (Massachusetts, Rhode Island and Connecticut) fishing fleet provides a range of data about fishermen whose fishing efforts are poorly recorded and often not considered in fishery management planning (Peterson and Smith, 1981). Most regulations promulgated since the passage of the U.S. 200-mile fishing legislation in 1976 have been based on a style of fishing operation typical of larger, offshore boats. For example, the regulation which limits the pounds of each species which can be landed per trip is intended to spread the opportunity for catching a limited amount of a single species over as many boats as possible. This regulation tends to keep incomes relatively uniform for boats specializing in that species. But in the case of small boat fishermen, many of whom seek a species for only a small portion of the year, such a reglation has the effect of inducing them to remain in the fishery secure in the knowledge that the rate of catch will be maintained and will not be exceeded by other fishermen. This decision replaces a strategy of seeking larger amounts of alternative species and it increases fishermen's dependence upon popular species.

Even though many of the regulations do not directly affect small boat fishermen, often they feel affected by both state and regional fisheries management efforts. Even when not personally bound by quotas, closed seasons, or closed areas, they have sometimes seen an invasion of "their" inshore grounds (see Table 1) by large trawlers attempting to circumvent federal rules by fishing in state-controlled waters.

The general pattern of economic relationships for the small boat segment of the fleet is complex and diversified. Individual fishermen appear to have adjusted their fishing strategies to a combination of factors including relative abundance of species, relative prices of species, weather and ocean conditions, catching efficiency of various gear types, personal experience and the part of the coast from which they come. Their investments in boat and gear are modest in comparison to the requirements of larger boats, and consequently they are not so bound to a known method of fishing and to a traditional species by the requirements of large monthly mortgage payments. Most small boat fishermen can afford the time and effort required to try new gear or a new species, whereas most large boat fishermen find such experimentation too expensive a risk. The flexibility in fishing styles is not the only distinguishing characteristic of the economics of small boat fishermen's operations. Their marketing patterns are also variable and individualized. They often rely on sales directly to restaurants, retailers or consumers rather than the standard channels of selling to wholesalers or processors.

Table 1
Small Boat Fishing Patterns
In Southern New England

Area Fished	Percent of Fishermen											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Ponds	2	2	1	1	1	1	1	2	2	3	3	3
Inshore	12	10	16	17	17	17	16	17	15	19	18	16
1-3 mi.	6	6	8	11	13	18	16	16	17	13	10	7
3-5 mi.	8	8	15	22	25	22	20	18	20	18	13	9
5-20 mi.	23	22	23	25	27	28	30	29	28	29	27	21
20+ mi.	3	4	6	10	11	12	12	14	12	7	6	6
NOT Fishing	46%	47%	37%	16%	6%	3%	6%	6%	6%	12%	22%	39%

Total = 236

Most of the small boat fishermen rely on fishing for the greater proportion of their income although they are attracted to fishing by non-monetary rewards: the style of life available to a man who is his own boss and must face the vagaries of wind, weather and market on a daily basis. Situated in small harbors along the coast, some small boat fishermen are from fishing families while others, attracted to fishing as recreation, have adopted commercial fishing as a lifestyle and occupation. Our findings reflect the diversity of roles fulfilled by fishing in the lives of these fishermen. For some, it is a way of supplementing income and food during the slow winter season; for others it is a release from tensions built up during periods spent on other jobs; for many it is a full-time way of living which combines personal satisfaction and independence with an adequate income and time spent with family.

Reference:

Peterson, S.B. and L. Smith, 1981. Small-scale Commercial Fishing in Southern New England. W.H.O.I. Technical Report 81-72, 44 pp.

PROGRAM ADMINISTRATION

Marine Assistance

Arthur G. Gaines, Jr.
WHOI Marine Assistance Service

Sea Grant Outreach

A major distinction between the National Sea Grant College Program and other federal research-funding programs is Sea Grant's stated commitment toward dissemination of research results to non-academic audiences. The objective is not only to disseminate results but also to involve business, industry, coastal managers, private individuals, etc., in the process of defining marine research needs and to provide those groups with the results on a timely basis and in an appropriate manner. The Marine Assistance Service at the Woods Hole Oceanographic Institution Sea Grant Program formalizes the advisory element of our program. Our main purpose is to provide a means for individuals and groups with marine interests to interact with and benefit from the staff and resources of the Woods Hole Oceanographic Institution.

Specific efforts of the Marine Assistance Service are designed to complement or supplement ongoing public information activities and opportunities provided by other offices at the Institution (see Table 1). The remainder of this report will describe three projects developed during the past year.

Hydraulic Harvesting of Soft Clams

Hydraulic harvesting is a method of separating buried shellfish from sediments by directing jets of water into the bottom. The result is that shellfish "float" to the surface of the sediment where they can be collected by net or other means. Several aspects of this approach to shellfishing in estuaries and bays have caused alarm among natural resource managers and the public: the resuspension of sediments; the effect of the water jets on sub-legal size clams; the impact of the practice on other bottom dwelling species; and possible depletion of clam populations, just to name a few. A host of aesthetic and political objections have also been raised.

Although a few of these issues are addressed in published literature, very few scientific studies have been conducted on the impacts of the hydraulic rake -- one kind of hydraulic harvester. Perhaps more important, the popular belief that use of this equipment actually improves the habitat for clam production has not been evaluated. In cooperation with the Town of Bourne Department of Natural Resources and the Bourne-Sandwich Shellfish Association, we began a project to monitor an experimental hydraulic harvesting plot to document major changes in the benthic fauna, with special attention to soft clams (Mya arenaria), and textural properties of the sediment. Samples have been taken over a period of half a year and the results of this study are anticipated in the near future.

Marine Studies Lecture Series

During 1980-81 a lecture series was conducted for math/science high school teachers from the Town of Falmouth school system. The objective was to transfer to the teachers, and indirectly to their students, some of the technical detail and intellectual excitement of recent marine discoveries. These lectures, by members of our scientific staff, covered a variety of topics ranging from "Beach Processes" to "The Shape of the Earth and its Gravity". The series, conducted in cooperation with our Education Office and the Library, was recorded on color video tape for dissemination to similar audiences elsewhere.

Popponesset Beach: A Scientific Basis for Management

One of the major areas of concern on Cape Cod and coastal Massachusetts is beach erosion and storm damage. Several generalizations that have emerged from coastal studies over the years can assist coastal managers, but there is a danger in their indiscriminate application to all portions of the coast. For example, the concept of littoral drift of river-fed sediments, which applies along much of the U.S. west coast is of little value to managers in parts of New England characterized by pocket beaches. The use of inapplicable generalizations at Popponesset Beach (Cape Cod) has left those responsible for its management in a quandary.

During the past year the Marine Assistance Service has sought to provide the Town of Mashpee Board of Selectmen with scientific advice on historical and present beach processes acting on the Town's coast, particularly at Popponesset Beach. The Marine Assistance Service has acted as liaison between the Town of Mashpee, Massachusetts Coastal Zone Management, the Massachusetts Disaster Recovery Team and the WHOI Sea Grant Program. The outcome is a jointly approved and sponsored project by Dr. David Aubrey of our Department of Geology and Geophysics, addressing the sources, pathways and fate of sediment at Popponesset Beach. This project, which began this year with new initiatives support from Sea Grant, will include a complete analysis of historical maps and photographs as well as a field program.

Table 1. Marine information, education and advisory activities of the Woods Hole Oceanographic Institution.

1. Public Information Office.

   Operates public information service; issues news releases on Institution activities; publishes and distributes newsletters, e.g., Woods Hole Notes; operates a public display center; prepares special public displays; assists with documentary films and video coverage.

2. Education Office

   Administers a graduate education program; operates summer fellowship and work programs for undergraduate students; participates in marine education activities with local schools and marine education groups.

3. Ocean Industries Program

   Maintains dialog and information transfer program with ocean-related industries.

4. Marine Policy Program

   Provides fellowships and other opportunities for social scientists, economists, lawyers and others outside the marine sciences to examine and develop policy aspects of ocean activities and resource use.

5. Library

   Operates a major marine science library facility (available to the public); conducts bibliographic searches.

6. Oceanus magazine

   Publishes four issues annually containing articles written by experts for a lay audience.

7. Lecture and seminar policy

   Frequent lectures on marine topics, including some for the general audience, are open to the public. These talks are advertised in local newspapers and a weekly institution calendar.

Development

The Diurnal Tides On the Northeast Continental Shelf Off North America

Peter Daifuku
Dept. of Physical Oceanography

The diurnal tide in the region between Nova Scotia and Cape Hatteras is second in importance to the semi-diurnal tide. Nevertheless, it still contributes significantly to the daily currents observed. Existing current meters and pressure gauge records were analysed for the tides, the results tabulated and plotted for five major constituents. Figure 1 shows the K_1 cotidal map based on the pressure data, figure 2 shows the associated K current ellipses. Offshore, there is a sweep of the tide from North to South, in general agreement with what is known of the global K_1 tide. On the shelf, there is a trapping of the phase lines to the coast, creating virtual amphidromes. Maximum amplitudes of around fifteen centimeters are found in the Gulf of Maine, lowest around seven centimeters south of Cape Cod. Maximum currents of about ten centimeters per second are found south of Cape Cod. In general, current ellipses are aligned with the topography. By and large, currents are barotropic.

The observed tide was modelled by calculating the allowed free and forced waves for the shelf, using the linear inviscid shallow water equations. A least-squares fit to the pressure data shows that most of the variance can be accounted for by the combination of a Kelvin wave and a shelf wave, along with a wave forced by the equilibrium tide. The Kelvin wave dominates the pressure field, while the shelf wave dominates the velocity field. General features, if not the details, are reproduced by the model. Possible improvements include the use of bottom friction, and a better description of the Gulf of Maine, New England shelf interaction.

Effects of Cadmium on Osmoregulation and Gut Transport of the Blue Crab (*Callinectes sapidus* Rathbun)

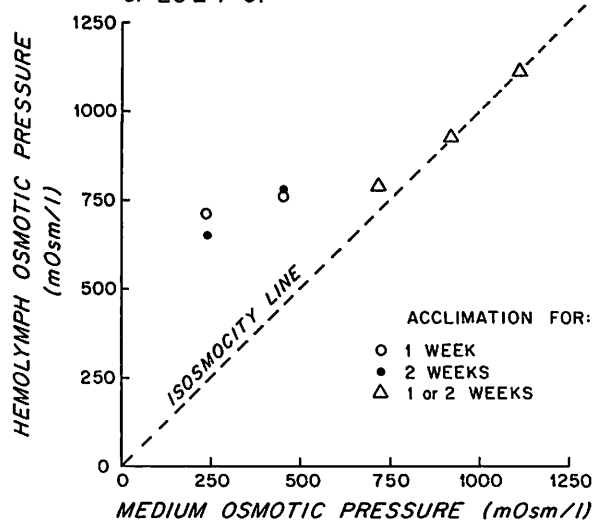
Ka Hou Chu
Judith M. Capuzzo
Department of Biology

The common blue crab, Callinectes sapidus Rathbun supports an important fishery along the east coast of the United States. From 1975-79, hard blue crab landings averaged 132.8 million pounds per year. In 1980, landings of 163.2 million pounds valued at $35.2 million ranked the fourth most important in value among crustaceans caught in the U.S. fishery. The life history of this commercially important species is well documented. The crabs mate in areas of low salinity; the females then migrate to spawn near the mouth of estuaries where the salinity is higher. The resulting young crabs move back to bays and rivers to feed and therefore growth and development take place in areas of low salinity. These two major migrations in the life cycle of the blue crab depend upon its osmoregulatory ability, which therefore is critical to the reproductive and developmental success of adults and recruitment of juveniles of this species. Thus, understanding the effects of pollutants on osmoregulation of this species is essential to evaluate the ecological impact on this fishery resource.

Cadmium is one of the most toxic and relatively accessible pollutants in the estuarine environment. A review of the literature indicates that this trace metal affects osmoregulation of many estuarine organisms. Little attention has been paid, however, to identifying the mechanisms responsible for its action. The gut, one site of cadmium uptake in crustaceans, is a route of ion and water exchange, contributing to osmoregulatory functions. The objectives of our study are to investigate the effects of cadmium on (1) osmotic and ionic concentration of the hemolymph, and (2) ion and water transport across the gut in blue crabs acclimated in water of different salinities.

The remarkable osmoregulatory ability of the blue crab has been demonstrated by many authors. Like many euryhaline crustaceans, it is isomotic in seawater and regulates hyperosmotically in dilute salinities. Using vapor pressure osmometry, automated chloride titration and atomic absorption spectrophotometry, we have confirmed these results in our laboratory (Figure 1). The next step is to determine whether cadmium interrupts this regulatory pattern. Further, gut transport will be studied using an in vitro perfusion technique where an isolated gut segment is perfused with physiological saline through two cannulae and radioactive tracers are used to determine ion and water transport. The gut transport properties of cadmium-exposed and control crabs will be compared. These results will reveal whether cadmium affects membrane transport processes that may account for cadmium toxicity in marine organisms.

Changes in Hemolymph Osmotic Pressure during Acclimation of *Callinectes sapidus* to Media of Different Salinity at 20 ± 1° C.



Development/Testing of Advanced Methods of Sampling for Volatile Compounds in Natural Waters

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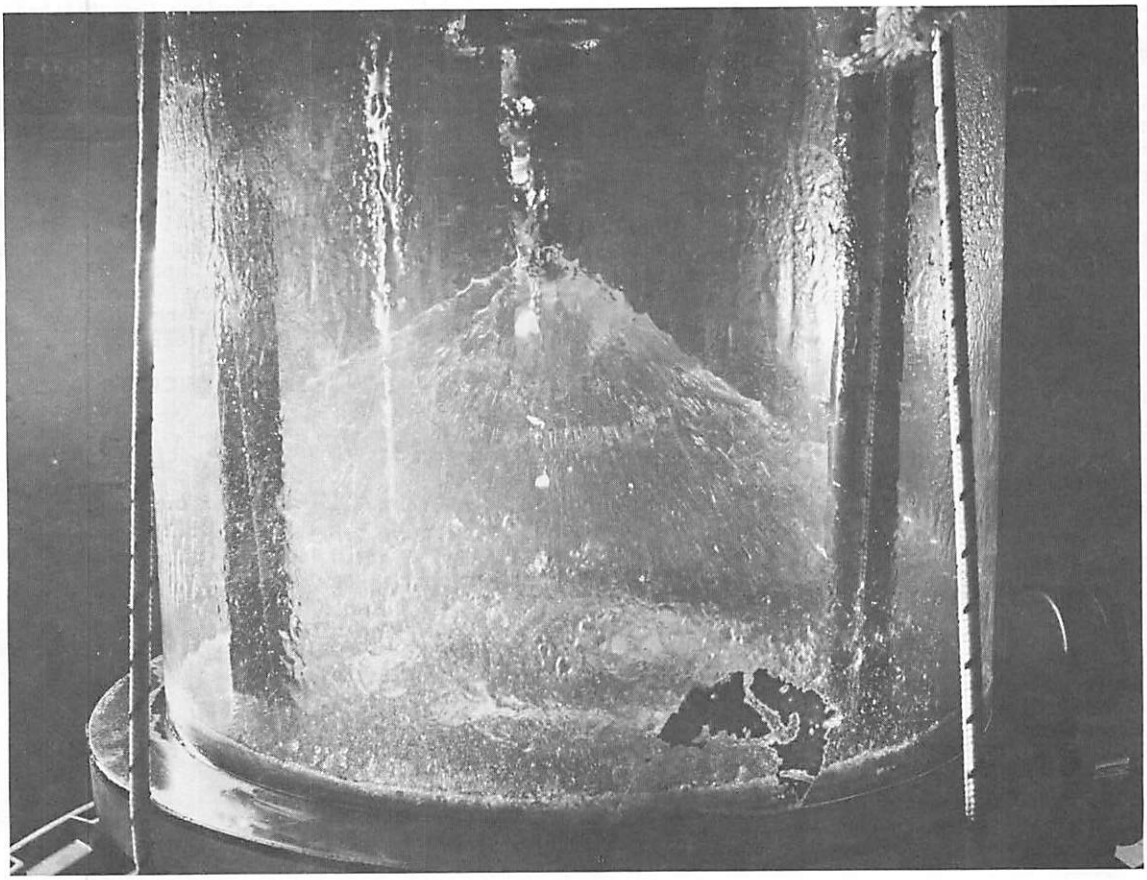
Department of Chemistry

During the past year we have been developing a new and more satisfactory way to sample for a wide variety of volatile organic compounds in surface waters, of environmental and scientific interest. Previous methods required that individual water samples be brought back to the laboratory. Because of contamination problems, delays in analysis, and the small number of samples that could be handled in this manner, it was not feasible to make routine surveys in coastal waters. We have attempted to alleviate this problem by extending the capabilities of a device which has proved very satisfactory for very low molecular weight gases, namely a small sampler towed in the wake of a ship to avoid contamination. Within the sampler, water is sprayed into a vacuum; the extracted gases are piped aboard for analysis or are frozen out for later examination.

A picture of a bench-scale mock-up of such a device is shown in Figure 1. Our work to date indicates that while this device removes some of the larger organic molecules that we are interested in the techniques of freeze-concentration that we had hoped to use to extract and preserve the material from the gas phase have had low and highly variable recoveries. It should be possible to remove the compounds of interest from the gas stream in other ways, however, these will be the focus of future efforts since this sampling device does have the capability of contamination-free sampling and immediate removal of the components of interest.

Figure 1. Bench-scale mock-up of sampler.



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BUDGET SUMMARY: 1980-81

	NOAA	Matching Funds	Total
Development of a Loran-C Drifting Buoy for Coastal Circulation Studies	$ 44,500	$ 000	$ 44,500
Moveable Bed Roughness in the Coastal Zone: A Field Study and Model Design	$ 49,400	$ 18,242	$ 67,642
Sediment Transport in a Tidal Inlet	$ 42,100	$ 56,119	$ 98,219
The Economic Potential of the East Coast Continental Margin: Blake Plateau to Georges Bank: Continental Rise Off Southern New England	$ 19,400	$ 000	$ 19,400
Laser Doppler Velocimeter for Wave Boundary Layer Studies	$ 20,800	$ 5,750	$ 26,550
Stimulated Marine Bioproduction	$ 58,000	$ 17,163	$ 75,163
The Biology of the Ocean Quahog, Arctica islandica	$ 44,800	$ 5,479	$ 50,279
Key Factors in the Initiation, Development and Geographic Spreading of Toxic Dinoflagellate Blooms (Red Tides)	$ 11,500	$ 9,975	$ 21,475
Tintinnid Predation on Toxic and Non-toxic Dinoflagellates	$ 29,300	$ 3,434	$ 32,734
Biogeochemistry of PCBs in New Bedford Harbor and Buzzards Bay, MA	$ 39,000	$ 8,982	$ 47,982
Metabolism of Aromatic Hydrocarbons by the Bivalve Mollusc Mytilus edulis	$ 20,700	$ 000	$ 20,700
The Comparative Toxicity of Crude Oil and Oil Dispersants to Marine Larval Organisms	$ 36,700	$ 20,000	$ 56,700
The Interactions Between Chemical Species and Phytoplankton Growth in Natural Water Systems	$ 30,000	$ 000	$ 30,000
Bacterial Chemosynthesis for Aquaculture	$ 31,700	$ 10,000	$ 41,700
Seeding Program for the Bay Scallop: Comparison of Local Bays, Falmouth, MA	$ 18,800	$ 000	$ 18,800
The Role of Size and Age in Determining Osmoregulatory Ability by Sea-Run Brook Trout (Salvelinus fontinalis)	$ 13,800	$ 24,898	$ 38,698
Microencapsulated Foods for Larval Fishes	$ 7,500	$ 7,238	$ 14,738
Small-Scale Commercial Fisheries in New England	$ 37,700	$ 20,807	$ 58,507
Ecological Theory Applied to Marine Populations	$ 29,400	$ 9,510	$ 38,910
Marine Policy and Ocean Management	$ 25,000	$354,716	$ 379,716
Program Management and Development	$102,100	$ 27,857	$ 129,957
Marine Assistance Service	$ 45,300	$ 000	$ 45,300
TOTALS	$757,500	$600,170	1,357,670

From: Woods Hole Oceanographic Institution, Sea Grant Program, Woods Hole, Mass. 02543