A Design for a Great South Bay Study

Submitted to

The New York State Department of Environmental Conservation

by

The Sea Grant Institute
of State University of New York and Cornell University

Donald F. Squires
Director

February 10, 1978

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Theodore Hullar, Ph.D.
Deputy Commissioner, Programs and Research
New York State Department of Environmental
Conservation
50 Wolf Road
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Dear Dr. Hullar:

On June 6, 1977 you asked the New York Sea Grant Institute to prepare a plan for a comprehensive, synoptic study of the physical and biological process of Great South Bay. It is now my pleasure to transmit that study plan to you.

You had asked for a plan "to provide the basic data, so as to permit development of a management program for the aquatic resources of the Bay, especially for the shellfish, and to develop a long-term monitoring program to evaluate continuously the water quality of the Bay and the effect of changes in water and land use on that water quality."

This plan conforms to those specificiations, and to the additional requirements that the effort last not more than three years and cost about $300,000 per year.

To develop the study plan, a panel consisting of representatives of the Department of Environmental Conservation, the Nassau-Suffolk Regional Planning Board and the Marine Sciences Research Center was convened, chaired by Dr. J.R. Schubel. This panel met 15 times during the Fall of 1977.

The draft study plan was received in December 1977. It was then discussed with representatives of major research laboratories on Long Island and the New York metropolitan area. Six workshops in January 1978 provided for further discussion of study elements. Represented at these workshops were over 30 agencies, firms, and institutions--a broad spectrum of state, county and town officials, representatives of consulting firms, and the academic community.

At these workshops, participants critiqued the technical aspects of the draft and discussed how the research design should be integrated and coordinated with on-going research. These meetings and workshops have enhanced the technical aspects of the plan. This final study plan has been revised to reflect these contributions.

Given the financial constraints of the study plan, it is clear we cannot address all individual and agency concerns. The plan can only be a starting point--a design for a basic foundation of research most critical for understanding the Bay and its hard clam resource. I think that this plan will become a focal point around which other research and monitoring activities will coalesce to add to our understanding of this valuable State resource.

I believe that this Great South Bay Study Plan reflects the best thinking of a broad spectrum of the scientific community on how to resolve the issues you've placed before us.

Yours truly,

Donald F. Squires
Director

Enclosure

The Sea Grant College
of
State University of New York
&
Cornell University

A Design for a Great South Bay Study

Summary

A thriving commercial hard clam resource has certain basic requirements. These must be satisfied if the resource is to remain economically productive. The major requirements are: 1) adequate food of the right kind; 2) reasonable freedom from predators and competitors; 3) suitable bottom, not too hard, not too soft; 4) good circulation of clean water; 5) periodic assessment of the condition of the resource; and 6) avoidance of overharvesting.

In an important hard clam producing area like Great South Bay these forces are in delicate balance. Disturbance of any one is a threat to the industry and to the economic health of local communities. Management of the fishery and the resource on which it is based has one objective: to be sure that these things remain in balance.

Great South Bay produces more hard clams than the rest of the Atlantic coast combined. It needs no research to conclude from this that conditions there are ideal, and the preservation of this unique environment is essential for continuance of the hard clam industry. At present we have only a very general concept of why the present happy state of affairs exists. Before we can develop plans to preserve it, we must understand how the physical-chemical-geological-biological system works. This research program is designed to provide the minimum information necessary for this purpose.

J.L. McHugh

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A DESIGN FOR A GREAT SOUTH BAY STUDY

Introduction

Management of anything without an understanding of the thing to be managed is "management" in name only. And the foundation of all understanding is knowledge; not, however, complete knowledge. Distinction must be made between necessary knowledge and peripheral knowledge. Necessary knowledge deals with the major forces which govern and their relations: the primary or first order constituents. Knowledge of secondary processes may be interesting and may even prove useful for fine tuning management plans, but until the primary processes, natural and man-made, are all accounted for to a sufficient degree, effective management is impossible. It is unfortunate that no systematic attention, which must be sustained attention, has yet been given to the primary processes which make Great South Bay what it is. In particular, our understanding of what makes Great South Bay the nation's leading source of hard clams is fragmentary and entirely inadequate if that resource is to be managed in any effective way.

In the absence of understanding resort is made, as is too often the case, to management by prohibition. "Standards" whose relevance to the welfare of the clams and the people who eat them can scarcely be proven are imposed on a resentful and uncooperative citizenry; hordes of technicians are sent scurrying about to monitor the "quality" of the environment and its biota; and lawyers become affluent. In the meanwhile the clam harvest is sometimes better and sometimes worse with no discernible connection with the environmental and health standards. If the objective is to manage effectively the Great South Bay and particularly its clam resource, then it is time to abandon "management" by prohibition and to make determined efforts to understand the major forces which make Great South Bay so productive and how they work together to that end.

The first thing that must be realized and, once realized, never forgotten is that Great South Bay is as it is because of a near balance of large forces. In many aspects it changes little from season to season and from year to year. But let one of those forces contributing to the quasi-balance be changed, whether by man or by nature, and Great South Bay will rapidly reach a new balance which may be quite different from the one now so favorable to the clam.

We must identify those primary forces which enter the balance as it relates to the well being of the clam and learn how the mechanism works to maintain the balance. And it must be done for Great South Bay. Information derived from Kamchatka, Chattanooga, and the Chattahoochee may give us leads for speculation. It won't give us the knowledge we need to manage Great South Bay.

It is currently fashionable to think of changes in natural balances produced by human intervention. We have a right to be cautious. We have been burned often enough by the results of acting in ignorance. The dredging of a new inlet into Great South Bay could so alter the exchange of sea water and Bay water and the patterns of circulation within Great South Bay as to wipe out the clams as swiftly as the algal blooms attributed by some to effluent from duck farms wiped out the oysters approximately 25 years ago. It could. But we don't know whether it will in Great South Bay. Events as catastrophic have ensued elsewhere from human interventions on the same scale. In our ignorance of Great South Bay who wants to issue the dredging permit?

Nature, as well as man, changes the force-balance. If, as some say, the climate is cooling toward another ice age the environment of Great South

Bay may become less salutary for clams--or maybe more. The point is that balance will change when the forces change and it doesn't matter who does the changing. It may well be that Great South Bay will be an optimal area for clam production for only a limited time--10, 30, or 60 years--due entirely to natural causes beyond our control. The knowledge of Great South Bay needed for effective management of the clam crop can not afford to concentrate on man-made changes to the exclusion of natural changes. All primary forces, whatever their source, must be understood. If clam productivity can be maintained only for 30 years, the wise manager will work to get the most out of those 30 years while planning for an orderly transition to another use for Great South Bay.

Great South Bay is presently a natural clam factory. To call it "natural" means that it has not been rationally designed for the purpose. No rational production facility is planned to accommodate discotheques or yacht races in the middle of the assembly line. But the problems of the hard clam industry are hardly restricted to multiple, and possible conflicting, uses of Great South Bay. There are many and immediate questions, some specific to Great South Bay and others more generally applicable to the industry, which must be answered before management can achieve its intended goals with reasonable assurance of success.

Some of the Questions

There is at present inadequate information on the size of the standing crop, on the recruitment rate, growth rate, on mortalities from harvesting and from natural causes, and little on the variations in the foregoing. In brief, managers need to know the present state of the clams in Great South Bay.

For the clam population and, therefore, the clam industry, spawning is a critical stage in the life cycle of the clam. We need answers specific to Great South Bay to several questions, among them:

1. Do the local stocks spawn only once or do they spawn repeatedly?
2. Do spawning clams imported into Great South Bay contribute significantly to the local stock? Where? And how?
3. Can a way be devised to distinguish between larvae of indigenous clams and larvae from imported spawners?

Clams do not live in a vacuum. They live in Great South Bay. Some of the processes which go on in the Bay have profound effects on them. Following spawning, the larvae float and are swept passively be the water motions. After a few weeks the larvae settle to the bottom.

4. Where will the larvae spawned by a clam bed be when they must set? The bed where they were spawned is most unlikely.
5. Will the bottom they do settle on encourage or discourage their growth? It depends on where the currents have carried them.
6. How many larvae are carried out to sea and lost? Again, it depends on the circulation of the Bay.

Clearly, we must know the circulation patterns of the Bay, and its exchanges with the Sea.

But even before we consider where larvae may settle we need to know whether there will be any larvae at all. Under some combinations of salinity, temperature and other water characteristics, clams will spawn copiously while under others spawning will be inhibited or even precluded. We need to know what areas of the Bay have characteristics favorable to spawning; and when. We must understand the operation of the forces which maintain the balance that produces the water characteristics observed in the Bay so that we may predict how changes in them will effect spawning.

Once we understand where and when spawning in the Bay will be most intense and have followed the larvae to their settling place, we must know to what degree the water qualities surrounding their resting place promotes or inhibits growth to commercial size. Successful spawning at a particular site will contribute nothing to the stock if the larvae settle in a hostile environment.

As everyone knows, clams live in the bottom. Not the least of our worries is the nature and distribution of the bottom sediments in Great South Bay.

7. Is there an inherent difference between "good" areas and barren ones? Where are they?
8. Would it be useful to "mine" a bed down to some preselected optimum density level, let it lie fallow, and then monitor its recovery? This might lead to improved harvesting techniques.
9. Are there areas which could become productive but are not because the larvae never reach them?
10. Could they be made productive by releasing larvae in a strategically chosen location and time in their life cycle so that the circulations bring them to the right place when they settle?

Clearly, we must know the bottoms in considerable detail.

Nature generally arranges it so that conditions favorable for a species are also favorable for its predators--but not always exactly so. The environmental understanding gained for clams can also be applied to their predators so that the conditions for reducing predation losses can be balanced to yield maximum growth.

Finally, clams must eat. But here we confront the entire food web with its complex chains, varying flows and nexes. This is a vast, much studied, and little understood structure. Any effort at a detailed study of food webs and nutrient flows would probably be unrewarding for management; at least within any reasonable period of time. But we can readily get a grip on the macrophytes (seaweeds and seagrasses) in general and on eelgrass in particular. True, clams eat neither but the greater part of the nutrient budget passes through the macrophytes, stored during growth, released slowly again during decay and cycled between water and sediments. Macrophytes appear to play a major role in determining all of the forms of food available to the organisms of the Bay because of their control of the nutrient budget. Experience suggests that when the standing stock of macrophytes, particularly eelgrass, is low, nutrient levels are high and intense blooms of unicellular green algae may occur. Some of these unicellular algae are apparently not suitable food for shellfish, and the shellfish may literally starve to death.

The managers of the clam industry have problems of their own. A besetting problem is how to get reliable information on catch and effort. Fishermen are frequently not very forthcoming. With unreliable initial data subsequent statistics and the actions based on them become a case of "Garbage in, Garbage out."

Important economic questions about the hard clam industry, deserving attention but which cannot be addressed within the scope of this research plan, are:

11. What is the hard clam industry really worth to the fishermen and to the citizenry; of Long Island, of New York, of the United States?
12. Can prices be advanced, particularly on the lower grades of products like chowder, sufficiently to support the development of the tools necessary to manage the industry without driving the customers to MacDonald's? Or must we continue to regard

the fishery falsely as a "free good" requiring payment only for processing and merchandising?

13. Can uses be found for what is now considered waste, e.g., broken clams?

14. Can a scientific rationale be developed for "controlled entry?"

In all truth, the clam industry needs to know a lot more than it does if it is to stop flying blind. And the clam industry of Great South Bay needs to know Great South Bay.

It would be presumptous to suggest that the study programs suggested in the following sections of this report offer solutions to all of the manifold problems of the clam industry. They are, instead, addressed to the knowledge of the environment management needs with due regard to utility, adequacy, and completeness. For convenience and as an aid to comprehension they are separately organized under six headings:

I. Clam distributions and their biological determinants in Great South Bay.

II. Nutrient distributions and their fluxes in Great South Bay.

III. Circulation and diffusion in the water in the Bay and the exchanges of water between Bay and ocean. In a word, the physics of water movement in Great South Bay.

IV. Bottom sediment distributions and characteristics in Great South Bay.

V. Pollution which renders clams unavailable or unfit for use in Great South Bay.

VI. A monitoring program in Great South Bay.

but all are interrelated and form a necessary whole. It will not be enough to do one without doing the others. One may describe an automobile in terms of its component systems but the purchase of spark plugs and a fuel tank does not buy an automobile.

Let us stress it again. Much is known about the clam but little as it applies to clams in Great South Bay. Hydrodynamics and geology are large subjects with as many well established results which have not been applied to a specific understanding of Great South Bay. Our task is not hopeless. Many tools are ready to our hand, but we will never understand Great South Bay and be able to manage it intelligently until we take those tools and use them on Great South Bay.

The Proposed Research and Monitoring Program

The following are statements of the research and monitoring studies identified as having the greatest potential for improving our effectiveness in managing the hard clam industry of Great South Bay.

I. Clam distributions and their biological determinants in Great South Bay

Justification

Hard clams constitute the most important living resource of Great South Bay. Effective management of this resource is required to assure sustained levels of productivity of healthy, marketable products. Additional, basic biological information is required about this animal, and its populations. Professor John L. McHugh, Marine Sciences Research Center, SUNY at Stony Brook is assembling a comprehensive annotated bibliography of the hard clam. All research undertaken should be tested against that knowledge.

Four basic tasks should be considered: (1) A survey of hard clam distribution and abundance; (2) determination of the environmental factors characteristic of "good" and "poor" clam areas; (3) a study of the spawning of hard clams; (4) an evaluation of programs to artificially enhance recruitment.

Suggested Research

Task 1. A survey of hard clam distribution and abundance. Data regarding the patterns of distribution, areas of abundance and scarcity, and standing stock to rational management. Existing information should be compiled. If necessary, a sampling program should be designed to provide a comprehensive data base. Patterns of hard clam distribution should be related to known environmental factors.

Duration of study - 3 years
Initiation date - first year

1st year
Approximate level of funding - $10-15,000
Estimated minimum requirement for scientific leadership - 1 man month by principal investigator
Estimated level of effort - 11 man months

2nd year
Approximate level of funding - $50-55,000
Estimated minimum requirement for scientific leadership - 6 man months by principal investigator
Estimated level of effort - 29 man months

3rd year
Approximate level of funding - $50-55,000
Estimated minimum requirement for scientific leadership - 6 man months by principal investigator
Estimated level of effort - 29 man months

Task 2. Determination of the environmental factors characteristic of "good" and "poor" clam areas. Identification of "good" and "poor" areas should consider clam growth rates, clam abundance and fishing intensity. Theoretically, four types of areas could be defined: (1) abundant-fast growing, (2) scarce-fast growing, (3) abundant-slow growing, (4) scarce-slow growing. The basic objective of this study is to identify why particular clam areas are productive and others not. Where possible critical life stages should be determined for particular areas. For example:

a. Do larvae reach the area?

b. Do larvae set successfully?

c. Does the set survive?

d. Do the clams grow fast enough?

e. Do the adult clams survive long enough to reach harvestable size?

f. What is the role of predators and competitors in determining the standing stock of hard clams?

Environmental conditions most favorable to clam growth and recruitment should be identified. With this information it would be possible to predict how changes in the environment can be deterimental to the clam resources.

Duration of study - 2 years
Initiation date - first year

1st year
Approximate level of funding - $25-30,000
Estimated minimum requirement for scientific leadership -
3 man months by principal investigator
Estimated level of effort - 26 man months

2nd year
Approximate level of funding - $35-40,000
Estimated minimum requirement for scientific leadership -
4 man months by principal investigator
Estimated level of effort - 42 man months

Task 3. Study of reproduction of hard clams. Spawning behavior of hard clams in Great South Bay should be determined. Critical questions are: When do the clams spawn? Do they spawn more than once each season? Do they spawn at the same time throughout the Bay? What environmental factors appear to trigger spawning? Do the older chowder clams contribute to the reproduction of the population? Do clams in heavily polluted areas contribute to the reproduction of the population? Environmental monitoring (Task 2), combined with spawning studies, will show some of the factors involved in stimulating gonadal maturation and spawning. Concurrent studies of clams of various age classes should provide a comparison of the relative contribution from various age clases (age-specific fecundity). For example, is there a critical density of parent stock? Can clam density be reduced to the point at which clams are unable to reproduce?

Factors influencing the dispersal of larvae include: the nature of water movement in the Bay; the relationship between the movement of water and the dispersal of clam larvae; and, patterns of larval dispersal and life span.

The study of water circulation (Task 10) of the Bay, should be integrated into the study of larval dispersal. This task should also be closely related to Task 12.

Duration of study - 2 years
Initiation date - first year

1st year
Approximate level of funding - $20-25,000
Estimated minimum requirement for scientific leadership -
3 man months by principal investigator
Estimated level of effort - 26 man months

2nd year
Approximate level of funding - $35-40,000
Estimated minimum requirement for scientific leadership -
4 man months by principal investigator
Estimated level of effort - 42 man months

Task 4. Evaluation of programs to artificially enhance recruitment. Do clams transplanted as spawners contribute to recruitment? How many clams must be transplanted to make a significant contribution to the population? Do hatchery produced seed clams contribute to recruitment?

Duration of study - 2 years
Initiation date - second year

1st year
Approximate level of funding - $20-25,000
Estimated minimum requirement for scientific leadership -
3 man months by principal investigator
Estimated level of funding - 24 man months

2nd year
Approximate level of funding - $30-35,000
Estimated minimum requirement for scientific leadership -
4 man months by principal investigator
Estimated level of funding - 39 man months

II. Nutrients and their fluxes in Great South Bay

II. A. Phytoplankton/Nutrient relationships

Justification

The concentrations, distributions and cycling rates of various nitrogen and phosphorus compounds, in combination with light availability, temperature, selective grazing and ocean exchange, regulate the productivity and species composition of the phytoplankton community in shallow estuaries such as Great South Bay. To the managers of the hard clam resource of Great South Bay, knowledge of the phytoplankton species composition, and the concentrations and productivity of individual species, is essential. Our knowledge of which phytoplankton are suitable as food for the clam is quite limited. This, however, will be investigated in laboratory studies in other components of this program. What needs to be assessed in the field, where the clams live, is the availability and growth potential of the major individual plant species during various times of the year. The manager needs to know what the relationship between nutrient availability and the phytoplankton productivity and composition is to predict (or assess) the consequences of natural or artificial increases of nutrient inputs or losses.

It is thought that some of the abundant phytoplankton in Great South Bay, especially the "small forms" such as Nannochloris, predominate because of the availability of certain nitrogenous nutrients and N/P ratios. Ryther's studies during the 1950's noted that the small forms, which appear to be unpalatable to oysters and clams, are abundant mainly as a result of the organic nitrogen added by the numerous duck farms on the south shore. It is of major importance to determine what nutrients are utilized in the field by small farms. If urea or uric acid is utilized preferentailly over nitrate or ammonia, then the source of organic nitrogen should be controlled.

The individual effects of nitrate, nitrite, ammonia, and organic nitrogen availability on the phytoplankton and their productivity in the Bay are not known. Factors regulating the availability of nitrogen species include 1) input rates of "new nitrogen"(primarily nitrite) from land run-off and streams, 2) flux between the water column and sediments and 3) uptake and release by plant species and their consumers. Inputs from land and streams have recently been investigated in Great South Bay under the 208 study. However, the source (or sink) capacity of nitrogen forms from the sediments and rates of uptake by plants or regeneration have not been studied in the Bay. The required investigations on fluxes between sediments and the water column, and through the plant community, must include seagrass colonized areas, but it is anticipated that Task 9 of this program would provide part of that information. A close cooperation between studies on uptake and cycling rates in phytoplankton and seagrass communities is essential. Investigators of phytoplankton species and nutrient concentrations in Bay water should be made aware of several limited studies being conducted by a number of local agencies and should explore the coordination of sampling times and/or stations.

Other factors and processes which are important to the nutrient budget in Great South Bay must be considered for future research, but cannot be included here. Among these are: 1) rates of nitrogen fixation in the sediments, algal mat, *Spartina*, and epiphytes of *Spartina* and *Zostera*; 2) rates of denitrification; 3) flux of particulate nitrogen to the sediments; 4) rates of nutrient recycling within the zooplankton and nekton; 5) role of trace elements, auxiliary growth factors, and competition in phytoplankton production

Suggested Research

Task 5. Approximately a year of nutrient and phytoplankton species distribution data should be collected at a number of stations representative of various portions of the Great South Bay. Frequency of sampling for water column nutrients, phytoplankton and sediment exchange rates should be keyed to important physical and biological event-time scales. The effects of clam raking and dredging on sediment nutrient exchange rates should be studied. Size selection studies of uptake rates and regeneration rates of nitrogen in plankton and sediments should be conducted on approximately a 6-week interval. A surface irradiance monitor should be established on the Bay and estimates of light attenuation by the water column should be made. Temperatures should also be recorded.

Duration of study - 2 years
Initiation date - first year
Approximate level of funding - $85-90,000 (total costs)
Estimated minimum requirement for scientific leadership -
10 man months by principal investigator
Estimated level of effort - 58 man months

Task 6. Analysis and reduction of data should be carried out and coordinated with similar determinations in eelgrass beds (Task 8 and 9) and with output from circulation studies (Task 10). Ideally, the output of reduced data should be graphical or tabular, with due consideration to modelling concepts. The most suitable information for the future managers of Great South Bay would be that which lends itself easily to predictive modelling of nutrient and/or plant population perturbations.

Duration of study - 1 year
Initiation date - third year
Approximate level of funding - $15-20,000
Estimated minimum requirement for scientific leadership -
2 man months by principal investigator
Estimated level of effort - 12 man months (total)

Task 7. All available data on nutrient input from tidal marsh areas and other boundary areas should be assembled. Some estimates of nutrient and particulate carbon losses to neighboring waters should be made, either from the literature or through limited sampling. A record should be compiled of such major Bay activities as channel dredging and of recent historical changes in salinity and tidal action which are likely to have affected phyoplankton distribution.

Duration of study - 1 year
Initiation date - first year
Approximate level of funding - $10-15,000
Estimated minimum requirement for scientific leadership -
2 man months by principal investigator
Estimated level of effort - 14 man months

II. B. Distribution, Abundance and Productivity Patterns of Eelgrass

Justification

Previous limited studies in Great South Bay have established that eelgrass (*Zostera marina*) is generally abundant and productive in this estuarine lagoon. However, there is no quantitative knowledge on its distribution and abundance patterns in large portions of Great South Bay. The fact that eelgrass is the major primary producer in the Bay has certain important implications. It is the major user of nutrients in the Bay because of its large biomass in relation to that of phytoplankton and seaweeds. Its roots and leaves are in contact with both the sediment and water environments and can regulate and, possibly, buffer nutrient concentrations in the water column. Therefore, any changes in eelgrass density can significantly effect changes in water quality. Phytoplankton abundance is dependent on nutrient availability and shellfish are, in turn, dependent on the availability of phytoplankton food.

Eelgrass has in the past, undergone large fluctuations in abundance that were apparently caused by fungal infections and/or lengthy periods of unusually cold or warm temperatures. There is a need to know the dynamics of eelgrass abundance and distribution to establish a background data bank for the present time and a further need to develop long-term monitoring capability of eelgrass density. If the dynamics of eelgrass abundance, and prediction of consequences of changes therein, are not understood, an overall management program for water quality and shellfishery will not be very successful. It will be difficult to predict the yield and growth potential of shellfish under a variety of eelgrass density, i.e., nutrient availability, conditions.

Suggested Research

Task 8. Determine the density of eelgrass throughout Great South Bay. This task should be closely correlated with Task 5. This study will permit the determination of seasonal eelgrass abundance patterns and, if conducted in subsequent years, the dynamics of eelgrass distribution in Great South Bay.

Duration of study - 3 years
Initiation date - first year

1st year
Approximate level of funding - $40-45,000
Estimated minimum requirement for scientific leadership - 6 man months by principal investigator
Estimated level of effort - 38 man months

2nd year
Approximate level of funding - $40-45,000
Estimated minimum requirement for scientific leadership - 6 man months by principal investogator
Estimated level of effort - 39 man months

3rd year
Approximate level of funding - $20-25,000
Estimated minimum requirement for scientific leadership - 1 man month by principal investigator
Estimated level of effort - 14 man months

II. C. Nutrient Distribution Patterns and Dynamics in Eelgrass Beds

Eelgrass appears to be the dominant primary producer in Great South Bay. The functional roles of eelgrass in estuarine ecosystems have only recently come to light. Among its roles is its ability to regulate cycling of nutrients between the sediments and water column. It can do this because it has functioning roots embedded in the sediment and leaves protruding into the water column.

Recent experimental evidence, obtained in eelgrass beds in Alaska, indicates that eelgrass can pump phosphorus from sediments into the water. It may also be able to pump nitrogen in a similar fashion but the quantity of available nitrogen in eelgrass bed sediments is largely unknown. It has, however, been demonstrated that eelgrass can absorb nitrogen from water through its leaves.

Experimental evidence, therefore indicates that eelgrass can have a significant influence on nutrient concentrations because of its high density in many shallow estuaries. It may not only provide an increased source of nutrients from sediments but may also buffer nitrogen inputs into the water column. Those effects are of great importance to phytoplankton. It is known that nitrogen and phosphorus availability, and the ratio between them, dictate the nature of the phytoplankton community, namely abundance (productivity) and species composition.

Only certain species of phytoplankton are suitable as food for shellfish. In order to successfully manage water quality and shellfisheries, it is necessary to determine to what extent nutrient availability to these phytoplankton depends on eelgrass. The pool-sizes of nitrogen and phosphorus in eelgrass sediments and waters will need to be evaluated in relation to eelgrass distribution and abundance patterns and uptake kinetics of these nutrients from water and sediment. The first work element in this group will determine the pool-size of nutrients in the water while the second element will ascertain patterns of eelgrass density. This study will then enable the modelling of nutrient flux rates in eelgrass beds so that one will be able to predict the consequences of variations in eelgrass density/on nutrient availability and phytoplankton productivity. This model will be most useful to managers of water quality and shellfisheries.

Suggested Research

Task 9. Nitrogen, phosphorus and carbon exchanges between the water column, eelgrass tissues (when the grass is present) and the sediment milieu should be determined.

Duration of study - 3 years
Initiation date - first year

1st year
Approximate level of funding - $15-20,000
Estimated minimum requirement for scientific leadership -
1 man month by principal investigator
Estimated level of effort - 18 man months

2nd year
Approximate level of funding - $30-35,000
Estimated minimum requirement for scientific leadership -
5 man months by principal investigator
Estimated level of effort - 18 man months

3rd year
Approximate level of funding - $35-40,000
Estimated minimum requirement for scientific leadership -
5 man months by principal investigator
Estimated level of effort - 40 man months

III. Circulation and diffusion in the water of Great South Bay and the exchanges of water between Bay and ocean

Justification

In Great South Bay, *Mercenaria* larvae spend about 7 to 24 days in a planktonic larval stage before settling to the bottom. Early on, the larvae are lighter than sea water and therefore remain suspended. Later, after acquiring valves, the larvae tend to sink. By means of a ciliated velum, however, they are able to maintain a position off the bottom and away from bottom-dwelling predators. Although the velum is effective in keeping the larvae off the bottom and within the water column, they are at the mercy of the horizontal currents and natural mixing processes, both of which tend to disperse the animals horizontally within the system.

At the end of its 7 to 24 day planktonic existence, the animal becomes benthic or bottom-dwelling. Early bottom-dwelling larvae undergo two successive stages, however, which provide considerable freedom in selecting a habitat. During the first such stage, a larva moves with the water mass over large areas of bottom within a tidal excursion by alternation of crawling and swimming. The second or byssal stage is characterized by the animal alternating byssal fixation with crawling for short distances from an unfavorable site on a motile foot.

From this brief description of the behavior of Mercenaria larvae it is clear they are at the mercy of currents and tide during a considerable portion of their early existence. The oscillatory motion of the tide, together with the wind, will supply a major portión of the energy that leads to advection and turbulent diffusion, the physical processes that will disperse larvae.

Great South Bay, however, is not a single environment with respect to circulation and diffusion. For this study, these differences are critical. The eastern, and largest portion of the Bay, is largely open water which reacts to wind as much as tide. The western portion is dominated by regions of tidal flats and Spartina marshes divided by tortuous channels. Here circulation is more dependent upon tidal flows. The study of circulation in these two different environments requires very different tools. Channel flow is governed by hydraulic considerations in which friction between water, sediment and rooted aquatic vegetation is very important. In areas such as the western Bay, circulation must be examined in great detail, and is therefore more costly and time consuming.

We have limited our consideration of circulation and diffusion to the open waters of the Bay. This is justified because the open portion of the Bay is most susceptible to alteration should a new inlet form by erosion of the outer bar. Further, distribution of hard clams in Great South Bay is largely a function of area under water, which suggests that the open water region is the largest producer. Although it is desirable to have a full understanding of the physical processes affecting all portions of the the complexities of the tidal channels must await the attention of other researchers.

Finally, since Great South Bay is connected to the ocean, an intertidal volume plus any runoff accumulated during the previous flood tide will be discharged from the Bay to ocean on the ebb tide. On the succeeding flood tide, an intertidal volume will be returned to the Bay, however it will contain some of the same parcels of water that were discharged on the previous ebb. As a result, a gradual exchange of the water in the Bay with the ocean will take place which will, of course, flush significant quantities of plankton out to sea.

In our view, therefore, the fate of *Mercenaria* larvae in Great South Bay will depend primarily on the physical processes of advection and diffusion, and their mortality due to predation and other causes.

Suggested Research

Task 10. At present, there is very little archival information regarding long period ($\geq$ 1 day) circulation patterns in Great South Bay. For the first year, therefore, we propose a simply but fundamental study of the relation between the non-tidal current and the local wind. For this purpose, current meters and tide gauges will be required in addition to a centrally located weather station.

Duration of study - 1 year
Initiation date - 1st year
Approximate level of funding - $45-50,000
Estimated minimum requirement for scientific leadership - 2 man months by principal investigator
Estimated level of effort - 38 man months

Task 11. A second study would involve analysis of the wind, current, and elevation data together with a study of Fire Island Inlet designed to measure the fraction of water that leaves Great South Bay on the ebb tide and the fraction of the discharged fraction that subsequently returns on the next flood.

Duration of study - 1 year
Initiation date - second year
Approximate level of funding - $40-45,000
Estimated minimum requirement for scientific leadership - 3 man months by principal investigator
Estimated level of effort - 42 man months

Task 12. A third-year study would involve site specific studies to determine the probable location of the brood stock which produced the sets on those beds that have been designated as productive. The design of these studies is, of course, critically dependent upon the collection and analysis of the first year's data.

Duration of study - 1 year
Initiation date - third year
Approximate level of funding - $50-55,000
Estimated minimum requirement for scientific leadership - 5 man months by principal investigator
Estimated level of effort - 48 man months

Task 13. The groundwater influx is probably a significant source of freshwater into the Bay. The groundwater influx is a necessary parameter in the description of the circulation and salinity distribution, in the estimates of the rates at which dissolved chemicals are transported and in the water quality models. For the first year, observations of the groundwater flow into the Bay should be undertaken to define the magnitude of the inflow and its variability.

Duration of study - 1 year
Initiation date - first year
Approximate level of funding - $10-15,000
Estimated minimum requirement for scientific leadership - 1 man month
Estimated level of effort - 12 man months

Task 14. Funding permitting, it would be desirable to characterize the salinity distribution of Great South Bay on at least a seasonal basis. Daily information would also be highly desirable during the months of July and August during all three years. Important inferences can be drawn from these data concerning the overall exchange of Great South Bay with the ocean.

Duration of study - 3 years
Initiation date - first year
Approximate level of funding - Included in costing of Tasks 10-13

IV. Bottom sediment distributions and characteristics in Great South Bay

Justification

The character of the surficial sediments strongly influences the diversity and productivity of marine benthic communities. The most important properties of a sedimentary deposit include: (a) texture, (b) organic carbon content, and (c) contaminant levels, including metals, chlorinated hydrocarbons, oils and greases. Sediment particle size and organic carbon content are known to have a major effect on hard clam distribution, growth and survival. An accurate sediment map of Great South Bay would be useful for locating particular benthic environments and for identifying areas that are optimal for clam growth. Such information would be useful for further biological studies and for clam management programs. The nature of sediments, particularly in relation to contaminant levels, must be considered in resolving questions of dredging and spoil disposal. Data provided by a sediment study would also be useful for detecting long term changes in Bay sediment quality due to increased pollution loads and other environmental changes.

Despite its potential usefulness to future biological and resource studies, a detailed and comprehensive study of the surficial sediments in Great South Bay has never been done. Knowledge of the sources of sediments, the routes and rates of sediment transport are also important and are excluded from this study only because of monetary constraints.

Suggested Research

Task 15. Design and implement a sampling and analysis program to provide coverage of the unstudied surficial sediments of Great South Bay. The project should have four basic objectives: 1) determine and map sediment texture; 2) determine and map organic carbon content; 3) determine the levels of selected contaminents in the sediments; 4) determine the permeability and shear strength of different kinds of sediment.

Duration of study - 2 years
Initiation date - first year

1st year
Approximate level of funding - $15-20,000
Estimated minimum requirement for scientific leadership - 2 man months by principal investigator
Estimated level of effort - 26 man months

2nd year
Approximate level of funding - $15-20,000
Estimated minimum requirement for scientific leadership - 1 man month by principal investigator
Estimated level of effort - 19 man months

Task 16. Assess the role of man in determining the flux of selected materials to the recent sedimentary record (over approximately the past 150 years) in selected areas of Great South Bay.

Duration of study - 1 year
Initiation date - Third year
Approximate level of funding - $20-30,000
Estimated minimum requirement for scientific leadership - 1 man month by principal investigator
Estimated level of effort - 19 man months

V. Pollution which renders Clams unavailable or unfit for human consumption: A Coliform Model for Great South Bay

Justification

Extensive data on the concentration of coliform and fecal coliform bacteria have been obtained by the Shellfish Sanitation Program, NYS Department of Environmental Conservation and the Nassau County Department of Health. Great South Bay comprises the shellfish growing areas 1 through 7. These data need to be analyzed to reduce the statistical uncertainties introduced by the multiple fermentation tube method of coliform counting. The improved data can then be used to determine the rate of spatial decay of the bacterial contamination from coastal source areas under clear weather and storm runoff conditions. These decay rates are needed to predict the impact of pollution control measures on the closure of shellfish areas and to explore management options under the federal regulations.

Suggested Research

Task 17. Coliform data for Great South Bay for the last five years should be assembled. Assembled, analyzed and displayed data should be, where possible, related to known events, for example: the closing of duck farms, enlargement of sewage treatment plants, the influx of seasonal residents, etc.

Task 18. All significant data for current coliform distributions under various conditions should be prepared. The statistical data mapped should be verified against the coliform data routinely obtained by various agencies during the first nine months of the project. Identification of locations where additional data would be most diagnostic should be identified.

Task 19. Appropriate statistical methods should be applied to assess the relative impact of steady discharges and storm events on coliform contamination levels. The effects on the areas closed to shellfishing of proposed waste treatment and land use alternatives should be determined utilizing the modified coliform inputs and the spatial decay model.

Cost figures are for Task 17-19 together
Duration of study - 2 years
Initiation date - second year

1st year
Approximate level of funding - $30-35,000
Estimated minimum requirement for scientific leadership -
4 man months by principal investigator
Estimated level of effort - 34 man months

2nd year
Approximate level of funding - $30-35,000
Estimated minimum requirement for scientific leadership -
4 man months by principal investigator
Estimated level of effort - 34 man months

VI. A Long-Term Monitoring Program

Justification

Establishing a baseline of data and continuing its collection would assist decision-making by helping to evaluate the significance of natural or man-made major alterations in the Bay system.

Suggested Research

Task 20. One permanent tide gauge should be maintained in the central part of the Bay in a reasonably secure location on the mainland. The gauge must be leveled in. Reduced data from this gauge should be available within one week after a major man-made or natural alteration of the inlets to aid in decision-making.

Task 21. Average salinity and nutrient concentration (nitrogen and phosphorus) in the Bay should be monitored on a weekly basis. Other parameters such as the average turbidity of the water may also be useful and should be considered.

Cost figures are for Tasks 20-21 together
Duration of study - 3 years
Initiation date - first year

1st year
Approximate level of funding - $30-35,000
Estimated minimum requirement for scientific leadership - 2 man months by principal investigator
Estimated level of effort - 24 man months

2nd year
Approximate level of funding - $20-25,000
Estimated minimum requirement for scientific leadership - 1 man month by principal investigator
Estimated level of effort - 10 man months

3rd year
Approximate level of funding - $20-25,000
Estimated minimum requirement for scientific leadership - 1 man month by principal investigator
Estimated level of effort - 10 man months

Matrix 1 - Costs of Research (in 000's of dollars)

Tasks	Year I	Year II	Year III
1	15	55	55
2	30	40	-
3	25	40	-
4	25	35	-
5	90		-
6	-	-	20
7	15	-	-
8	45	45	25
9	20	35	40
10	50	-	-
11	-	-	45
12	-	-	55
13	15	-	-
14	(included in 11-13)		
15	20	20	-
16	-	-	30
17, 18, 19	-	35	35
20, 21	35	25	25
TOTALS (maximum)	340	375	330

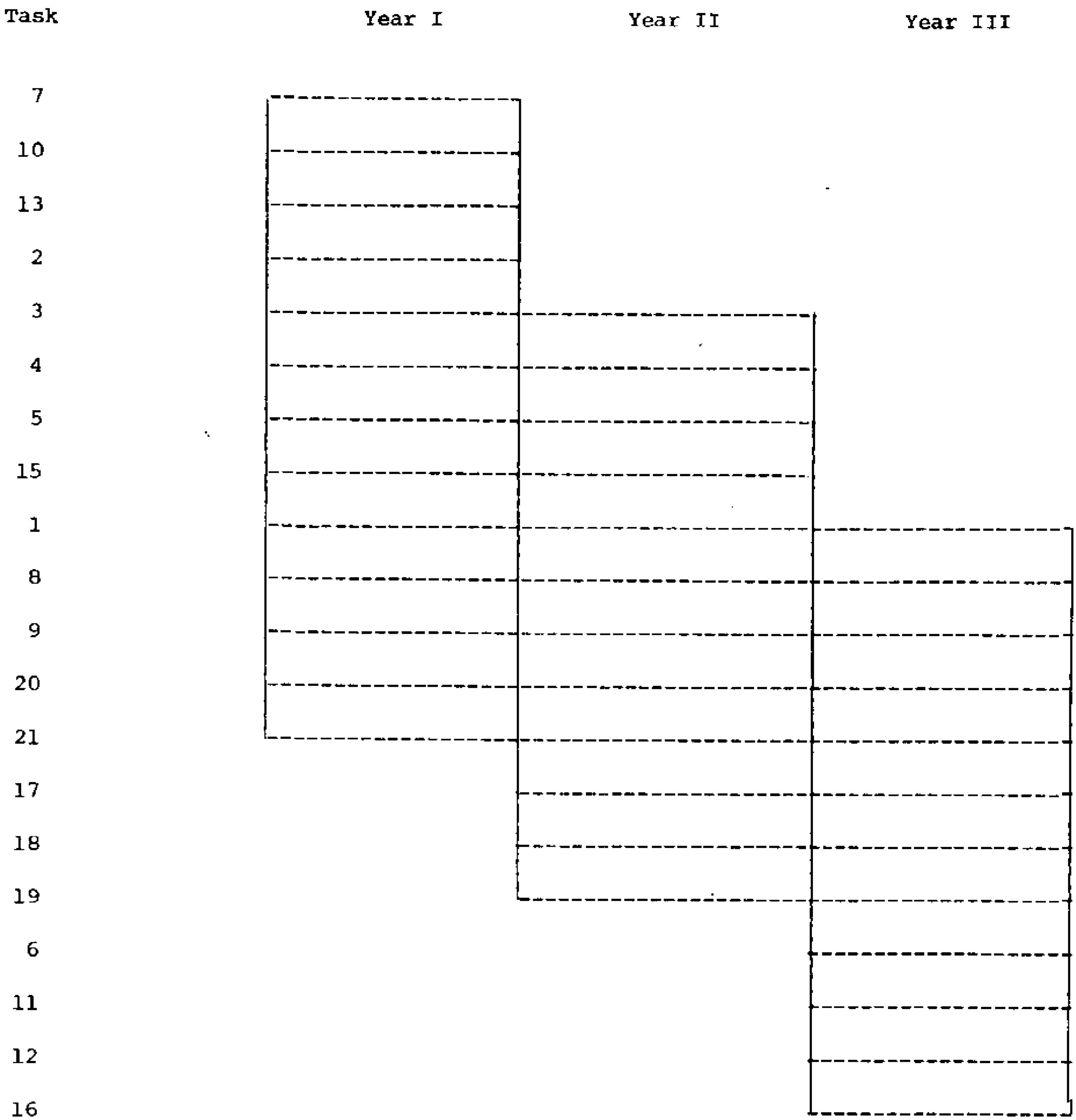
Matrix 2 - Requirements for Scientific Leadership
(In man months of effort)

Task	Year I	Year II	Year III
1	1	6	6
2	3	4	-
3	3	4	-
4	3	4	-
5	10		
6	-	-	2
7	2	-	-
8	6	6	1
9	1	5	5
10	2	-	-
11	-	-	3
12	-	-	5
13	1	-	-
14	(Included in 11-13)		
15	2	1	-
16	-	-	1
17, 18, 19	-	4	4
20, 21	2	1	1
TOTALS	31	40	28

Matrix 3 - Estimated Level of Effort
(In man months)

Task	Year I	Year II	Year III
1	11	29	29
2	26	42	-
3	26	42	-
4	24	39	-
5	58		
6	-	-	12
7	14	-	-
8	38	39	14
9	18	18	40
10	38	-	-
11	-	-	42
12	-	-	48
13	12	-	-
14	(Included in 11-13)		
15	26	19	-
16	-	-	19
17, 18, 19	-	34	34
20, 21	24	10	10
TOTAL	286	301	248

Matrix 4 - Scheduling of Tasks



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