Forging a Partnership Between Federal Monitoring Programs and the Academic Marine Community

marine sciences research center
state university of new york

Forging a Partnership

Between Federal Monitoring Programs

and the

Academic Marine Community

Summary of a Workshop
hosted by the
Marine Sciences Research Center
State University of New York at Stony Brook

April 29 - 30, 1991

J. Kirk Cochran
Associate Director for Research

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J.R. Schubel, Director

Many academic marine science institutions have a research focus on coastal ocean processes and collectively represent a substantial wealth of knowledge on the nation's coastal resources. Yet this knowledge is often overlooked in the planning and execution of federal monitoring programs charged with evaluating the health of the coastal marine environment and long term changes in the states. With this in mind, the Marine Division of the National Association of State Universities and Land Grant Colleges (NASULGC) proposed to the Environmental Protection Agency (EPA) to hold a series of regional workshops with the goal of exploring and fostering the development of an active partnership between the academic marine community and federal monitoring programs. This report summarizes the results of the first of these workshops held at SUNY-Stony Brook's Marine Sciences Research Center. Financial support for the workshop was provided by the Environmental Protection Agency.

Two federal monitoring programs -- the near-coastal component of EPA's Environmental Monitoring and Assessment Program (EMAP-NC) and NOAA's Status and Trends Program -- play major roles in monitoring the coastal zone. EMAP-NC, in particular, has a long term regional focus.

These monitoring programs are designed to document the effects and consequences of society's use of coastal resources, but in order to use this information to manage the resources, it is necessary to understand the causes of the impacts and to explain the observed trends in terms of basic parameters linked to the processes causing them. Monitoring will not satisfy this need; a monitoring program may identify important changes but will not determine why they occur. An active research program, however, will enable a clearer interpretation of monitoring data. Moreover, the National Estuary Program has established a framework and a research community with extensive expertise in major estuarine systems which are important to EMAP-NC and other monitoring programs in five ways:

- Knowledge developed from estuarine research programs can be used to test the validity of the assumptions under which the monitoring programs were designed.

- Intensive measurements made in the course of addressing the research questions will also indicate the representativeness of any particular samples taken in monitoring programs.

- Research results can be used to place the local situation in the context of the regional ecological status as defined by EMAP-NC. This is critically needed for local managers to apply EMAP-NC data.

- The cause of changes in the monitored parameters can be determined through research and can be used to decide how to deal with any problems that are identified.

- The team of local experts provides the regional program with a unique resource for resolving problems and interpreting specific data in terms of locally important conditions and processes.

For these benefits to be realized, the scientists must be attracted to relevant estuarine programs (they are), must have identified specific research themes to follow (they have), and must have the resources to carry on this work (they frequently do not).

Estuarine scientists are attracted to estuaries as natural laboratories for pursuing fundamental research questions. The estuarine environment has three advantageous characteristics relative to the open ocean: (1) intense gradients in critical physical, chemical, and biological properties in a limited area, (2) strong interactions among the physical, chemical and biological agents, and (3) a wide range of variability on both short and long time scales due to periodic changes, episodic events and progressive alterations. The strong gradients accentuate the processes which define and modify the estuarine filter by compressing the temporal and spatial scales to a degree unmatched in other marine realms. Estuarine studies should, therefore, reveal the fundamental nature and the degree of time-dependent coupling among the physics, geology, geochemistry, and biology of the system. The estuaries themselves provide convenient natural laboratories for studies of the basic interrelationships among processes, the results of which will be generally applicable to other parts of the ocean.

The focus of the Stony Brook workshop was Long Island Sound, a large estuary in EMAP-NC's Virginian Province and one sampled during the summer 1990 demonstration project. Recent research activities carried out in Long Island Sound under the auspices of EPA's National Estuary Program, as well as previous work, have led to a broad-based research community with extensive experience in the Sound, and scientists from the Marine Sciences Research Center, University of Connecticut's Marine Sciences Institute and representatives of EPA and NOAA attended the workshop (Appendix A).

The workshop considered two major issues in Long Island Sound: eutrophication and the fate of toxic contaminants. Both areas were highlighted in the recent Long Island Sound Study as issues of concern to managers of Long Island Sound and both have been focal points for research and monitoring activities in the Sound. Although the workshop participants felt that there were strong research connections between the two areas, this report summarizes the working groups' recommendations separately, making links where relevant.

Eutrophication:

H. Bokuniewicz (Chair), R. Cerrato, C. Lee, D. Monteleone, D. Pritchard, M. Scranton, B. Welsh, R. Wilson, P. Woodhead.

The problem of eutrophication in Long Island Sound has some particularly interesting elements. About 8 million people inhabit the drainage basin of the Sound, with most of them living in New York City, Long Island, Westchester and Connecticut. Eutrophication is a critical problem and one that is getting worse. The geometry of the Sound inhibits wind mixing and results in a persistently recurring period of intense summer hypoxia of short duration. In addition, both cold water and warm water fish species occur in the Sound so a wide range of possible biological impacts can be studied.

We have identified three broad areas for research on eutrophication in Long Island Sound that would complement any program of environmental monitoring, EMAP-NC, in particular. These are

1. **The role of physical processes in controlling the seasonal duration and strength of the detrimental consequences of eutrophication.**

   Background: Experience in a number of estuaries, but most particularly in the Chesapeake Bay and Long Island Sound, has demonstrated that the duration, intensity and extent of the annual period of hypoxia in estuaries within the Virginia Province are related to the strength of the vertical stratification. Observations have shown that the intensity, areal extent and duration of actual anoxia in these estuaries varies significantly from year to year. The most extensive and intensive periods of hypoxia correspond to years of strong vertical stratification during spring or summer. There is some evidence that variations within this general pattern are related to the timing of the spring period of high fresh water runoff relative to the onset of strong heating of the surface waters of the Chesapeake Bay. This relationship probably exists in Long Island Sound also, although the data are as yet insufficient to clearly demonstrate this phenomenon.

In spite of the fact that the general trends of the relationship between hypoxia and vertical stratification are known, quantifying these relationships has not yet been accomplished. It is possible that other physical processes, such as variations in the estuarine circulation pattern, and the frequency, duration and intensity of strong wind events during spring and summer, also influence the intensity, areal extent and duration of the annual period of hypoxia in the estuaries.

Recommendation: We propose a research program to use existing data, plus new data developed by other research activities and collected by monitoring programs, to quantify the relationships between the physical processes described above and the intensity, areal extent and duration of the annual period of hypoxia/anoxia in the estuaries of the Virginian Province, but particularly in Long Island Sound. The ultimate goal of this quantification would be the development of a methodology for predicting the probable intensity, areal extent and duration of periods of hypoxia/anoxia. However, actual predictions would require that forecasts of a number of meteorological variables be made. For many purposes, the use of such a predictive methodology to hindcast the probable intensity, areal extent and duration of the period of hypoxia/anoxia would be valuable.

Importance to Monitoring Programs: How would the development of a methodology for the prediction or even for the hindcasting of the intensity, areal extent, and duration of the annual period of hypoxia/anoxia in Long Island Sound (and, by extension, in other estuaries) be of value to the EPA and NOAA monitoring programs, and to local resource and environmental managers?

To answer this question, it is necessary to first recognize that the effects of eutrophication, i.e., the development of hypoxia/anoxia, depend on the decomposition rate of organic carbon which directly acts to reduce dissolved oxygen and on the addition of nutrients (phosphorus and nitrogen) which lead to enhanced organic carbon production. The prediction or hindcasting methodology would be based on an assumed constant loading of these materials. This methodology could be used to identify whether short term (over a few years) trends in hypoxia/anoxia are due to changes in loading of estuary, to a several year period of unusual fresh water inflow or to meteorological processes.

2. **The effect of eutrophication on shifts in water column trophic structure in western Long Island Sound.**

Background: Eutrophication in western Long Island Sound is shifting water column trophic structure toward increased microbial metabolism. This shift is compatible with basic ecosystem theory in that the microbial community is best adapted to rapid conversion of particulate and dissolved organic carbon loadings (allochthonous and andochthomous) to CO_2 and constituent nutrient elements. The question arises as to whether the high levels of microbial metabolism measured by Welsh & Drapeun (University of Connecticut) occur in addition to or at the expense of classical microfaunal trophic pathways leading to fish and shellfish. Bypassing the microfaunal pathways could occur because (1) the microbial components are too small to be effectively utilized by macrofauna, and/or (2) increased metabolism resulting from the microbial processors depletes ambient oxygen supplies to levels which inhibit or exclude macrofaunal organisms.

It is possible that during periods of summertime stratification, there is a cumulative shift in water column communities which augments microbial pathways at the expense of macrofaunal pathways leading to fish and shellfish. This fundamental shift in water column biotic structure leads to depletion of macrofaunal communities in the water column and benthos.

Recommendation: We suggest that research be undertaken which permits

(1) measurement of production and consumption in the water column along with microbial and zooplanktonic components (a) through the

stratification period (temporal gradient), (b) over the vertical gradient, and across the horizontal gradient.

(2) determination of the relative and absolute magnitude of the secondary production involving microbial and macrofaunal components.

(3) relation of changes in allocation between these major components, to the cumulative effects of hypoxia on living marine resources.

Importance to Monitoring Programs: This system-level approach to fundamental processes and changes in community structure links eutrophication with the health and abundance of living marine resources.

The measurements will provide seasonal information on the intensity, variability and extent of changes related to hypoxia which will not be available through the single-point-in-time approach of most monitoring programs.

This information will be applicable to cross-system comparisons of eutrophication in Chesapeake Bay and Delaware Bay where microbial studies have been conducted, or any other bays where microbial abundances relative to metabolic structure have been measured.

3. **The impact of low dissolved oxygen on key species and life stages, including synergistic effects.**

Background: Dissolved oxygen (D.O.) is an especially important EMAP-NC exposure indicator. It is linked to the eutrophication process and is a critical component of the EMAP-NC conceptual model. Low D.O. is one of the most important factors contributing to shellfish mortalities in estuaries. Although the ecological impacts of chronic hypoxia are not fully understood, sublethal biological effects are more widespread and include reduced activity, vulnerability to predation, decreased feeding and growth and increased susceptibility to toxicants and disease. The literature on effects of low D.O. on organisms is very diverse, with most studies being in freshwater environments. Fewer studies have concerned estuarine and coastal organisms, and only a small subset of measurements have been made at temperatures typical of estuaries in summer. There is not sufficient information to relate low D.O. measurements to the biological responses/effects in estuaries and coastal waters with much confidence. The data are inadequate to support the development of D.O. criteria for estuarine and marine waters and related management assessment decisions.

The 1989 sampling of Long Island Sound indicated that western Long Island Sound is a region of extremely high chlorophyll concentrations. These concentrations do not exhibit the more typical seasonal patterns found in the central and eastern portions of the Sound due to the high degree of eutrophication in the western area. EMAP-NC sampling is a snapshot of the community in late summer when hypoxia is most intense. EMAP does measure chlorophyll concentrations but does not address the question of whether or not the species structure of the phytoplankton community is changing. Species in the next trophic level, i.e. copepods, require phytoplankton of a particular size and quality. Is the phytoplankton community in western Long Island Sound different from other regions, and, in turn, changing the players in the food web? Possibilities include supporting a different species of copepod, a different group of zooplankton or bypassing this level altogether and changing the system completly. Larval fishes require an abundance of copepods to sustain them, and if the copepod community changes and favors a different species of copepod with different habitat tendencies (e.g. *Temora* tends to be most abundant in deeper waters while *Acartia* may be more uniform throughout the water column), it is not clear that there will be available food for the larval fish community.

Other questions which can be addressed in a field program are:

- Do fish avoid hypoxia in western Long Island Sound? If not, will they spawn under stressed conditions?

- If they spawn, do they spawn in the upper water column and avoid the lower hypoxic regions?

- If they spawn, do the larvae tend not to migrate to the lower depths? If they don't migrate are they more susceptible to predators by being retained in the upper layer?

- If larval migration is restricted, do the larvae encounter the same quantity of food? Is this food even of the same type as found in the other depth regions.

Recommendation: These questions should be addressed in a more intensive sampling of plankton in areas suggested by EMAP-NC as hot spots of eutrophication and, in turn, hypoxia. Plankton sampling should be done at discreet depths to determine vertical distributions of the organisms in the water column and how these distributions relate to zones of low dissolved oxygen. Sampling would have to be on the order of twice a week through the summer. This would enable the investigator to determine the population dynamics, i.e. growth and survival of zooplankters and early life stages of fish. Bottle casts to collect water and identify the species of phytoplankton which are abundant during this time would be necessary.

Once the field component is completed, this information can be taken into the laboratory to determine the impact hypoxia has directly on organisms and indirectly on the food chain. Direct impacts include alteration of the spatial distribution of species. Limiting lethal concentrations of D.O. should be measured under chronic exposures for representative organisms chosen from EMAP-NC target species if possible. Measured physiological parameters can be used to assess hypoxia effects on organisms and respiratory and blood parameters of representative organisms can be measured to determine physiologically limiting concentrations of D.O. It is important to relate existing data on physiological limitations of hypoxia to the temperatures typical of estuaries in summer time, because at present these relationships are uncertain. Thus, effects of temperature on such limiting physiological parameters should be investigated for selected organisms.

Importance to Monitoring Programs: The proposed study will contribute data needed for the development of criteria for dissolved oxygen in estuaries and coastal waters. Groups of sensitive (at risk) and tolerant species will be identified. Life-stages will be considered for critical sensitivity to hypoxia.

Toxic Contaminants:

N. Fisher (Chair), J. Aller, R. Aller, F. Bohlen, V. Breslin M. Bricelj, B. Brownawell.

The fate of toxic contaminants in estuaries is important in understanding their effects on living marine resources. This working group identified four areas in which research efforts would complement monitoring programs.

1. **The relationship between contaminant levels in organisms and biological response.**

   Background: It is well known that many marine organisms inhabiting moderately or even severely contaminated waters exhibit body burdens of a variety of toxic contaminants. Using sentinel bivalves, the NOAA National Status and Trends Program has already demonstrated that many contaminants are in bioavailable form. There is every reason to expect that EMAP's indicator organisms will be contaminated with moderately high toxicant levels. One of EMAP's goals is to assess the health of select populations exposed to these contaminants. The impacts, if any, of these body burdens on the health of populations are generally poorly understood.

   Recommendation: Long-term sublethal toxicity tests should be conducted to examine the relationship between body burden and health of the population. These long-term exposure studies should adjust the contaminant concentration (either in sediments or water) so that the resulting body burdens of the contaminants in the test organism approximate those in organisms in natural waters. The reproductive capability and growth of the organisms should be compared with those of "control" organisms of the same genetic stock. It is also recommended that a few environmental factors (including the presence of another environmentally relevant contaminant) be varied in controlled conditions to elucidate any obvious synergistic interactions which may affect contaminant toxicity. These experiments should employ one or more representatives of surface deposit feeders, suspension feeders, and head-down deposit feeders. The specific organisms should be important components of the ecosystem being studied and, ideally, would be indicator organisms used throughout EMAP-NC.

Importance to Monitoring Programs: The value of monitoring data, particularly of chemical contaminant concentrations in sentinel organisms, would be greatly enhanced if there were ancillary research on the toxic potential of such contaminant concentrations. By having long-term sublethal toxicity data available from a research program, it would be possible to assess the likely impact of contaminants on marine populations without extrapolating from acute toxicity tests employing extremely unrealistic contaminant levels.

2. **The validity of organisms and clones used in bioassays for contaminant toxicity.**

Background: The use of organism survivorship in sediment toxicity bioassays is complicated by genetic variability among test organism clones. Resistant or hyper-tolerant strains of indicator species can arise in cultured populations as well as in organisms collected from impacted areas. Large scale studies that include bioassays in which "wild" and genetically altered subspecies are used may include a non-systematic bias that could complicate the interpretation of results.

Recommendation: We recommend research in which strains of organisms that exhibit varying degrees of resistance to environmental stressors are subjected to standard sediment bioassays. The hypothesis of such a project is that the bioassay-measured toxicity of sediments is not a function of the genetic make-up of the test animals. Genetic differences should be assessed phenotypically by comparing the tolerance of organisms to typical toxicants at a range of environmentally relevant concentrations over at least three generations of each organism where possible. For organisms not easily maintained in the laboratory, nuclear DNA mapping of different strains will be used to define genetically disparate populations.

Importance to Monitoring Programs: This research will:(1) assess the reliability of bioassays as they are currently performed in monitoring efforts, (2) suggest possible improvements to such assays in terms of what animals give the least variability in sediment toxicity bioassays when genetically varied sub-species are likely to occur.

3. **Long-term sublethal exposure studies to couple biomarkers response to biological effects.**

Background: A variety of biomarkers have been developed which provide sensitive indicators of sublethal contaminants present in the field. The links between effects of individual biomarkers and stress at the level of an organism or ecosystem have not been established. Lack of progress in this regard is due to the logistical difficulty of conducting long-term laboratory exposure studies. (Experimental and funding constraints are both important limitations.) Field effects at higher levels than those measured at the sublethal level are inherently difficult to make, due to poorly understood natural variability in populations and environmental conditions and the open nature of coastal environments. Recruitment, for example, can potentially mask the effect of reproductive impairment on species abundances. Sublethal but important long-term effects on ecosystem health due to toxicants are presently impossible to detect in the field.

Recommendation: Long-term exposure studies should be conducted with the purpose of effectively linking sublethal biomarkers to effects at higher levels of biological organization (for example, determining the relationship between AHH activity, DNA adducts and changes in reproductive success, tumor genesis or larval survival). The relationships between contaminant stressors (e.g. pathogens, dissolved oxygen or multiple contaminants) and resultant biological effects should be the long-term goal of such studies, although these are difficult, labor-intensive studies.

In order to conduct such experiments, there is a need for a funding base to establish long-term exposure facilities for sensitive bioindicator species. (In the case of sole or flounder multi-year exposures might be necessary.)

Moreover, we recommend continuing research to identify new toxicant-specific biomarkers which can provide indications of the responsible classes of contaminants that lead to disruption of organism or ecosystem health.

Importance to Monitoring Programs: The presence of biomarkers of contamination in organisms is being sought in some monitoring programs, but the relevance of these biomarkers for the health of populations has yet to be established. An active research program relating biomarkers to population health and toxic impacts would enable a more realistic interpretation of monitoring data and may provide one or a few particular biomarkers which could be demonstratively related to toxic impacts.

4. Evaluating spatial variability in contaminant distributions in sediments.

Background: Sediments provide a major repository in nearshore waters for many metal and organic contaminants. Measurements of concentrations and inventories of such contaminants in sediments are an important component of any monitoring program because sediments represent a potential long-term source to the ecosystem. Ideally, sediments should be representative of local or regional conditions such that the data can be used to determine inventories, sources and historical trends of contaminants.

However, sediments and associated contaminated distributions can exhibit extreme spatial variability in many nearshore and estuarine environments. The question of local representativeness is a difficult and often unconstrained problem for monitoring programs. In many coastal environments the deposition and redistribution of fine-grained sediment is believed to govern contaminant distributions in sediments. The primary factors which control contaminant concentrations are: (1) proximity to source; (2) sediment properties which affect interactions between contaminants and particle surfaces (e.g. grain size and organic carbon); and (3) properties of the depositional environment (i.e., sediment accumulation, rate and depth of particle mixing). There is evidence that suggests that there are easily measured sediment properties that can be used to determine the representativeness of a sediment sample or to normalize for differences in sediment properties. For example, local variability of contaminant concentrations in sediments often can be largely eliminated by normalizing to sediment characteristics (% silt and clay, % organic carbon) and tracers of deposition (e.g. ^{210}Pb in some environments).

Recommendation: A field study should be conducted which could evaluate the potential and limitations of such an approach throughout a broad range of environments. There are two complementary ways of testing such an approach to contaminant distributions: (1) determine sediment tracer and contaminant profiles, sediment properties, and ^{210}Pb inventories across a range of sediment types far from local contaminant impact (i.e., where one can assume that water column concentrations have been regionally similar); and (2) conduct the same studies in an estuary which has a known point source of contaminants.

Importance to Monitoring Programs: These proposed studies have the potential for providing criteria for representatively sampling sediments for monitoring purposes and for interpreting spatial and temporal trends in observed sediment concentration data.

Other Recommendations

In addition to the specific recommendations which each working group formulated, the workshop participants concluded that the links between eutrophication and contaminant cycling should be stressed. Research scientists are uniquely well suited to conduct the spatial and temporal sampling necessary in an estuary such as Long Island Sound to evaluate these links and to complement the one-time-per-year snapshot provided by EMAP-NC. Such a research program would evaluate the intra- and interannual variability in the physical, chemical, and biological factors being measured by EMAP-NC and their interrelationship within particular estuaries. This program should be designed to help differentiate long-term trends from periodic and extreme or aperiodic (such as hurricanes, floods) variations.

Specific research areas which should be addressed in evaluating patterns of temporal change include:

(1) The coupling between seasonal variations in physical, chemical and biological factors and the rates and routes of contaminant uptake (bioaccumulation)/depuration in common species and indicator organisms.

(2) The relationship between cycles in primary productivity and anoxia on the one hand and contaminant cycling between sediments and water on the other.

(3) The determination of environmental factors which regulate bioaccumulation and result in sublethal effects (i.e. low D.O. which in turn affects growth, reproduction, and bioturbation activities of benthic species and indicator organisms.

(4) The impact of sublethal stresses to individual benthos and benthic communities on nutrient and contaminant cycling.

The integrated research program should be multidisciplinary and include field as well as laboratory components. The field component would extend over a minimum of a 12-month period (to examine seasonal variability) and be repeated every 3 to 5 years (to evaluate the long-term trends). Specific details of the temporal and spatial aspects of sampling design should be tailored to a particular estuary.

The intervening time periods should be used for laboratory experiments to examine mechanisms (in particular, questions related to rates and routes of contaminant uptake/depuration and impact of environmental stress (i.e. low D.O.) on activities of organisms.

These field and laboratory data will be used to develop better or more appropriate field measurements to improve interpretation of the monitoring data, form a basis for evaluation of established monitoring protocol, and enable modification of existing field programs.

Finally, the workshop participants recommended that federal agencies conducting monitoring programs consider providing support in the form of fellowships to graduate students. These students represent the next generation of research scientists, and agency fellowships will provide a means of fostering a strong link between academic research and monitoring programs. Such fellowships will also enhance the number of individuals with expertise on specific geographical areas.

Appendix A

Workshop Participants

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APPENDIX B

Agenda

Workshop to Identify Research Priorities for Federal Monitoring Programs in Long Island Sound

Hosted by the Marine Sciences Research Center

April 29, 1991 Challenger Hall 165

0830	Continental Breakfast	
0900	Welcome and Introduction	J. R. Schubel
	Overview of the Workshop: Statement of Expected Outcome	
0930	Overview of Federal Monitoring Programs: Progress and Results	J. Paul T. O'Connor
1100-1115	Coffee Break	
1115	Charge to groups Break up into working groups: - Toxic Contaminants - meets in Endeavour Hall - 113 - Eutrophication - meets in Challenger Hall - 165	J. K. Cochran
1230	Catered Lunch in Challenger Hall 165	
1400	Continue in Working Groups	
1600	Coffee Break	
1615	Reassemble in Challenger Hall 165 Discussion of Progress (Reports from Group Chairs) (Consider Additional Groups) Response from Agency viewpoint Response from NASULGC viewpoint	 J. K. Cochran J. Paul/T.O'Connor J. Schubel/W. Queen
1730	Dinner on your own	

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0800	Continental Breakfast	
0830	Recap and break up into working groups	J. K. Cochran
1200	Catered lunch	
1300	Reassemble in Challenger Hall 165 Discussion of Recommendations	
1400	Tie-up loose ends, in groups or in plenary session	
1530	Adjourn	