NOAA Coastal Ocean Program

FY 1991 Implementation Plan Contracts

Volume 1

Nutrient-Enhanced Productivity
Estuarine Habitat Program
Toxic Chemical Contaminants
Coastal Hazards

These plans represent agreements between the Assistant Administrators and the Coastal Ocean Program Office concerning the management and review processes, scientific and operational procedure, products, and budget for implementing the NOAA Coastal Ocean Program for FY 1991.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Washington, D.C.

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FY 1991 Implementation Plan Contract

This plan represents an agreement between the lead line office Assistant Administrator and the Coastal Ocean Program Office concerning the management and review processes, scientific and operational procedures, products, and budget for implementing this portion of NOAA's Coastal Ocean Program in FY 1991.

02/22/91

Ned A. Ostenso, Assistant Administrator — Date
Office of Oceanic and Atmospheric Research

2/20/91

Donald Scavia, Director — Date
NOAA Coastal Ocean Program

NUTRIENT ENHANCED PRODUCTIVITY

FY 1991 IMPLEMENTATION PLAN

This implementation plan covers three projects:

I. Nutrient Enhanced Coastal Ocean Productivity - Mississippi/Atchafalaya Rivers (NECOP-MAR)

II. Atmospheric Nutrient Input to Coastal Areas (ANICA)

III. Monitoring of Nutrient Overenrichment and Harmful Algal Blooms (MONOHAB)

Details of the first two projects are found in the attached project implementation plans. The third project will operate at a planning level only in FY 1991. A separate request to the NCOPO for planning funds will be submitted later.

The budget allocation for FY 1991 is:

NECOP-MAR	$1,950,000
ANICA	$50,000
TOTAL	$2,000,000

NECOP

Mississippi-
Atchafalaya
River
(MAR)
Implementation
Plan

FY 1991

Contract Version
February 15, 1991

NUTRIENT-ENHANCED COASTAL OCEAN PRODUCTIVITY

MISSISSIPPI-ATCHAFALAYA RIVER OUTFLOW

FY1991
IMPLEMENTATION PLAN

PREFACE

This implementation plan is for one project, the Mississippi-Atchafalya Rivers (MAR) ouflow project, in the Nutrient Enhanced Coastal Productivity (NECOP) Program within the Coastal Ocean Program Nutrient Enhanced Productivitity (NEP) theme. The overall NEP theme strategy is described in a separate document titled "Nutrient Enhanced Productivity: Marine Fertilization and its Consequences. An Action Plan for the 90's".

I. BACKGROUND

The availability of light and the input of 'limiting' nutrients are the two primary factors which regulate the rate of production by plants in the earth's biosphere. In the coastal oceans the rate of organic matter production is primarily controlled by two factors. First, the input of the nutrient in greatest demand, i.e., the 'limiting' nutrient, determines the rate and magnitude of organic matter production by pelagic primary producers, the phytoplankton. The majority of studies in marine coastal waters, that is seaward of riverine freshwater (salinities > 5 °/oo), have shown that nitrogen is usually the nutrient which limits the size (biomass) of phytoplankton populations (Ryther and Dunstan, 1971; D'Elia and Sanders, 1987). Second, the turbidity of the water column determines the depth interval, or the euphotic zone, through which the phytoplankton can fix inorganic carbon. Since light extinction in coastal regions is proportional to the level of suspended matter, the particulate load places an 'upper limit' on primary production in estuaries, river plumes and coastal regions (Cloern, 1988). These factors also influence other marine populations in the coastal ocean, since the phytoplankton form the base of the complex 'food web' supporting higher marine organisms, including the commercially exploited finfish and shellfish resources of the U.S.

Nutrients are supplied to the euphotic zone of the coastal oceans in various ways. Nutrients are derived from the <u>in situ</u> decay of organic material produced in the euphotic zone, predominantly through the recycling of phytoplankton biomass by other organisms. Recycling occurs through such processes as grazing by zooplankton, excretion of dissolved matter, and by the death and decay of grazers and organisms of higher trophic levels. Nutrient input to the coastal ocean also occurs by wind or current-driven upwelling, where nutrients regenerated in the deep ocean by remineralization of sinking organic matter at depth, are returned to the euphotic zone in coastal environments. A third mechanism of nutrient input, which is the concern of this program, is the nutrient supply to coastal environments from the continents. These inputs most commonly occur in river water, or as direct run-off from land. Nutrients supplied via these routes include those derived naturally from decaying terrestrial material, and those contributed from anthropogenic inputs, either as direct discharge or as runoff, including agricultural activities. The impact of nutrients from anthropogenic sources on the coastal oceans is the specific focus of this program.

Evidence is mounting that anthropogenic inputs contribute large quantities of 'limiting' nutrients to the coastal oceans. The increased productivity can result in deleterious effects on the quality of our coastal waters, particularly when phytoplankton production exceeds the capacity of higher trophic organims to assimilate the fixed organic carbon. A worldwide comparison of riverine nitrogen inputs from regions of high population density and development, versus areas of low population density and development, has shown that nitrate-nitrogen is generally 10 to 30-fold greater in rivers flowing through developed regions. Temporal increases also are evident as population increases and industrial development occurs. In the U.S., the concentration of nitrate in the Mississippi River below New Orleans has increased from about 1 mg/l in the late 1950's to 2.2 mg/l in the early 1980's, or ca. 50 to > 150 ug at/l (Fig. 1, from Turner et al., 1987). Within the upper Chesapeake Bay the average annual total nitrogen, phosphorus and chlorophyll a concentrations have doubled during the period 1965-1980 (Price et al., 1985). There is evidence that nutrient inputs to our coastal oceans are steadily increasing even in less-developed U.S. coastal regions. For example, the nitrate - nitrogen concentration within the Altamaha River, Georgia, has tripled from 10 to 30 ug-atm/l since 1960 (Fig. 2, from Walsh et al., 1981).

Our understanding of the effects of increasing nutrient input, and the consequent stimulation of primary biological productivity, is limited, and the full impact of enhanced production can not be predicted at present. In general, sufficient light and nutrients are present in the water column during the summer such that estuarine and coastal phytoplankton are able to fix large amounts of carbon; the majority is ingested by grazers. This particulate matter, mainly as fecal pellets, is oxidized by microbial organisms after it sinks into deeper waters. During these summer months the coastal waters are often stratified into a shallow, warm surface layer and cooler subsurface layer; the surface mixed layer can exceed the depth of the euphotic zone. The density stratification limits the re-aeration of subsurface waters from the oxygen-sufficient surface layer, where oxygen is introduced from the atmosphere and from phytoplankton photosynthesis. Oxygen concentrations in the deeper waters subsequently decline to levels where aerobic respiration cannot be maintained, with decreases in commercially important resources (Price et al., 1985).

While the sequence of events during episodes of hypoxia (low dissolved oxygen) and anoxia (no detectable dissolved oxygen) are fairly well documented in estuarine waters, as for the Chespeake Bay (see Officer et al., 1984), our coastal waters also appear to be developing hypoxic areas. Observation from the Louisiana continental

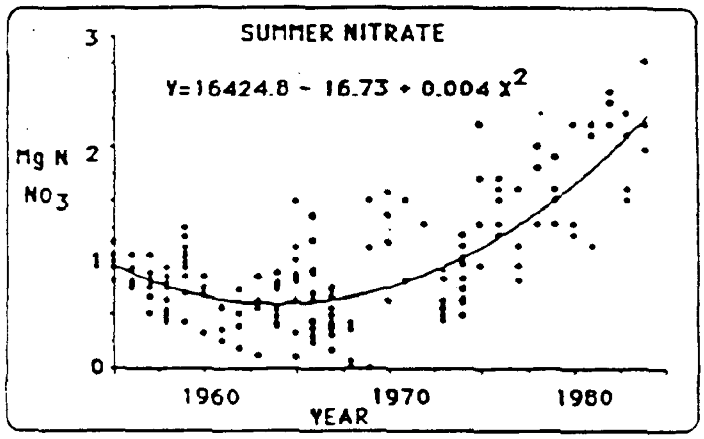
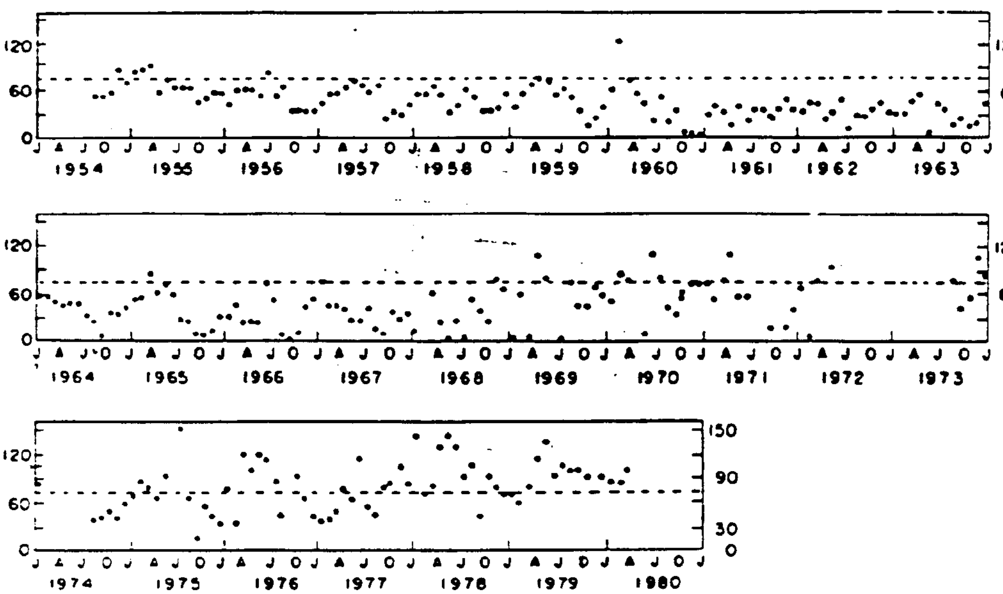


Figure 1. April - July nitrate concentrations (mg/l NO3-N) in the Mississippi River at St. Francisville, Louisiana from 1955 to 1984. From Turner *et al*. (1987).

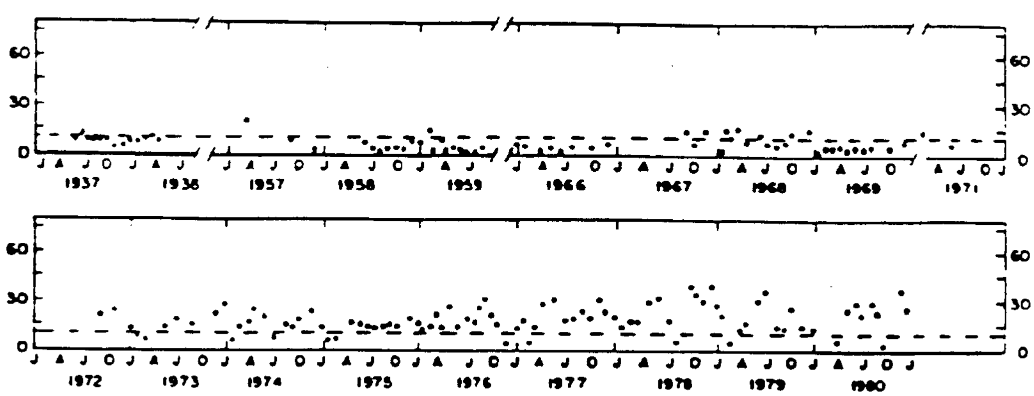
TIME SERIES – NITRATE FLUX

MISSISSIPPI RIVER



A time series of nitrate content (ug-at/l) at 450 km upstream of the mouth of the Mississippi River draining "developed" areas. From Walsh et al. (1981).

ALTAMAHA RIVER (GEORGIA)



A time series of the nitrate content (ug-at/l) at 50 - 100 km upstream of the mouth of the Altamaha River draining undeveloped areas. From Walsh et al. (1981).

Figure 2.

shelf (Turner et al., 1987) and the New York Bight (Swanson and Sinderman, 1979) indicate that the frequency of summer hypoxia events is increasing. The problem is not unique to North American coastal waters, for long-term observations in the Adriatic Sea (Justic 1987) and the outer waters of the Baltic (Andersson and Rydberg, 1988) show similar trends. Hypoxia and anoxia can lead to the death of the benthic marine biota within the impacted area and the displacement of mobile, or migratory, species. Within Louisiana coastal waters several important components of the macrobenthos population, such as shrimp, crabs and demersal fish, are at very low densitites, or absent from hypoxic waters during the summer (Gaston, 1985; Renaud, 1986).

Aside from hypoxia/anoxia events, the stimulation of the biological primary production of our coastal oceans by anthropogenic nutrient inputs may well have other consequences that need to be determined. This enhancement of productivity may impact our coastal ecosystems by altering phytoplankton species occurrence and abundance. Such qualitative, as well as quantitative, changes in primary producers can have serious impacts on the herbivorous species that form the base of our commercial fisheries. As an example, the success of commercially important larval fishes in the first feeding stage has been found to depend upon the existence of specific phytoplankton species that are readily ingested by larvae (Lasker and Sherman, 1981).

Finally, the input of significant amounts of anthropogenic nutrients to the coastal regions has a potentially important role in climate and global change. At present large-scale global models cannot assess the degree to which the oceans remove anthropogenic CO2 from the earth's atmosphere. In addition to the physical absorption of CO2 from the atmosphere at high latitudes, oceanic biota may play a role by photosynthetic fixation of CO2 and subsequent transport as organic carbon to deep ocean waters with an ultimate burial in sediments. The extent of this 'biological pump' in oceanic waters must be quantified if reliable, predictive models of climate change are to be developed (Moore and Bolin, 1987). The role of oceanic biota in the sequestering of carbon dioxide from the atmosphere requires the utilization of 'new' nutrients, rather than those released by the decay and recycling of marine organic material in situ. Otherwise, the rate at which carbon is fixed is limited by the rate at which organic carbon and nitrogen is recycled from that previously fixed by photosynthesis. In summary, a source of 'new' nitrogenous nutrients must be introduced into the oceanic surface waters if carbon dioxide is to be fixed in excess of that already present in the oceans. Man's input of large quantities of nutrients into the coastal oceans may be a major source of the required 'new' nutrients on a global basis. Present estimates of the impact of such nutrient sources are widely disputed (cf. Walsh et al., 1981; Rowe et al., 1986). Research is necessary to clarify the role of coastal oceans in the long-term 'burial' of anthropogenic CO2 in ocean margins, and its subsequent burial in deep water following transport offshore by storms or mass wasting of shelf and slope sediments.

II OBJECTIVES.

The goals of NOAA's environmental quality coastal program are 1.) to better understand the influences of natural and anthropogenic activities on the quality of the coastal environment and its resources, such that, 2.) a better predictive capability is achieved in order to assess the results of society's activities within the context of natural variation. The key objectives of the research program on nutrient-enhanced coastal ocean productivity are to:

* Determine quantitatively the degree to which coastal primary productivity has been enhanced in areas receiving high terrestrial nutrient inputs.

* Determine the impact on water quality (especially dissolved oxygen demand) of this enhanced productivity.

* Determine the fate of the carbon fixed in coastal areas of enhanced productivity and its impact on living resources within the coastal ocean and upon the global marine carbon cycle.

III. APPROACH.

The central hypothesis of this research program is: TERRESTRIAL NUTRIENT INPUTS HAVE ENHANCED COASTAL OCEAN PRODUCTIVITY WITH SUBSEQUENT IMPACTS ON COASTAL OCEAN WATER QUALITY, LIVING RESOURCE YIELDS, AND THE GLOBAL MARINE CARBON CYCLE. Over the long term the intent of this program is to conduct research subprograms in areas receiving differing levels of terrestrial nutrient inputs (including anthropogenic inputs) and under various physical regimes.

The coastal ocean productivity research program will contain the following major technical components:

1) A physical oceanographic program to determine the coastal ocean circulation and buoyancy flux. The objective is to observe the the physical forcings which control nutrient distributions and primary production. Time scales that must be considered include storm event, tidal, diurnal, seasonal and interannual. The horizontal circulation and mixing will be quantified as necessary for understanding processes such as transport and dispersion of nutrients and the various plankton communities. The vertical structure determines the stability of the water column and consequent biological productivity, particle transport, and controls hypoxia/anoxia events. Interannual variability will be reconstructed from historical environmental data records and sediment cores. An understanding of this interannual variability is important to determine the extent to which anthropogenic impacts have affected coastal systems, and whether changes due to these impacts can be documented. At present the historical record is primarily based upon sporadic observations of biota, chemical distributions and hypoxia within the past few decades, with the earliest records from 1935 (Richards, 1957). A more complete sequence of past events may be constructed from available cores (approx. 70 AOML piston, box and

gravity cores, and 36 LUMCON box cores from the Delta area) and perhaps remote SST imagery for the past two decades.

2) A chemical/biological program to measure the distribution of nutrients and organic carbon distributions in the coastal ocean areas as well as the primary and secondary productivity of the study area as a function of space and time. Research will be conducted on the processes which link anthropogenic nutrient fluxes to primary productivity, and on trophic structure within food webs as it is altered in response to increased productivity. Additional studies will relate enhanced productivity to particle transport and export, and the occurrence of subsequent hypoxic events.

3) A remote sensing program utilizing satellite infrared (SST) and ocean color (CAMS) measurements to provide synoptic coverage of coastal ocean productivity over extended space and time periods. Remote sensing is a cost-effective method to provide synoptic estimates of surface temperature and ocean color in oceanic areas. Additional remote sensing capabilities utilizing optical, and acoustic systems will be deployed from ships and drifters to complement the observations from satellite systems and provide reliable ground truth comparisons.

4) A modeling program. Models will be developed, or adapted, with an objective of guiding the research effort and providing predictive capabilities for management. Models are extremely useful to researchers in formulating hypotheses which can be examined or tested in the field during process-oriented studies. Mixed layer and circulation models are required as a basis for understanding and constraining the primary production and food web models. The models should be utilized in order to achieve a predictive capability for assessing the impact of nutrient variability on organic matter production and consumption and, finally, upon particle transport and oxygen demand.

IV. INITIAL STUDY AREA - THE MISSISSIPPI/ATCHAFALAYA RIVER OUTFLOW AND ADJACENT LOUISIANA SHELF REGION

Given the objectives and central hypothesis of the Nutrient Enhanced Coastal Ocean Productivity component of the NOAA Coastal Ocean program, the initial study area should satisfy the following criteria:

Criterion #1 - A clear terrestrial nutrient signal.

Criterion #2 - Resultant nutrient-enhanced productivity of significant magnitude.

Criterion #3 - A demonstrable impact of enhanced production on coastal environmental quality.

Criterion #4 - Renewable resources of significant value.

On this basis we have chosen the initial area of study as the Louisiana Shelf which receives outflow from the Mississippi River Delta and Atchafalaya River (which carries 30% of the total volume of the Mississippi) in the Northern Gulf of Mexico. The impact of this discharge occurs in the adjacent shelf waters. Each of the above criteria is discussed separately in terms of the designated study area.

The Mississippi is the sixth largest river system in the world in terms of water discharge, and the largest in the U.S. It and its tributaries drain more than 40% of the continental U.S. and contribute 65% of the average annual runoff into the Gulf of Mexico (Moody, 1967). The volume of suspended sediment discharge has been estimated to have an annually range of 344 to 544 million tons, in addition to an estimated annual bedload discharge of 136 million tons (Holeman, 1968). These volumes make the Mississippi the seventh largest river in the world in terms of sediment discharge. Most of this water and sediment is discharged through three major passes of the Mississippi Delta (Figure 3), i.e., Southwest Pass, South Pass and Pass a Loutre (Holle, 1967). Much of the river sediment load is deposited in shallow areas around the Delta, contributing to very high sedimentation rates (up to several cms per year). This rapid sedimentation results in rapid burial which has preserved the geologic and geochemical history of the last several centuries. This history can be readily examined in cores, as evident in the study of annual lead deposition within sediments from the Delta (Trefry _et al._, 1985).

Criterion #1 - A clear terrestrial nutrient signal: There is ample evidence that the outflow of the Mississippi River is enhancing the input of nutrients to the adjacent Louisiana shelf. The nutrient loading in the Mississippi river, especially in terms of nitrate, has increased markedly since the mid 1950's (Turner _et al._, 1987; Walsh, 1981; Kempe, 1988). As stated above, and illustrated in Figure 1, during the period from 1955 to 1984 the nitrate concentration of river waters at St. Francisville, LA has more than doubled, increasing from about 50 to > 150 ug at/l. It is reasonable to assume that this increased nitrate-N has an anthropogenic source, given its timing and the extensive agricultural and industrial development that has occured within the Mississippi drainage basin. As early as 1971, Everett (1971) reported that in the 241 km upstream of New Orleans, more than 18 million kilograms of dissolved solids were added to the river daily from industrial discharges. This amounted to 7% (at average high flow) to 20% (at average low flow) of the total dissolved river load.

Criterion 2 - Resultant nutrient-enhanced productivity of significant magnitude: Primary production within the Mississippi Outflow plume has been found to range from 1 to 5 gC/m2/day (Carder et al., 1989). This is a significant level of productivity, as is evident by a comparison with the highly-productive Peru coastal upwelling system. In that ecosystem rates of 1 gC/m2/day are found near shore, where upwelled nitrate first reaches the surface, with rates of 9 to 10 gC/m2/day observed offshore, following sufficient time for the primary producers to attain maximum rates (Walsh, 1983).

Criterion #3 - A demonstrable impact of enhanced production on coastal environmental quality: Possibly the most significant impact of nutrient-enhanced productivity in the Mississippi Outflow/Louisiana Shelf region is bottom water hypoxia during the summer. In the winter the shelf waters are stirred and mixed by wind events on time scales of

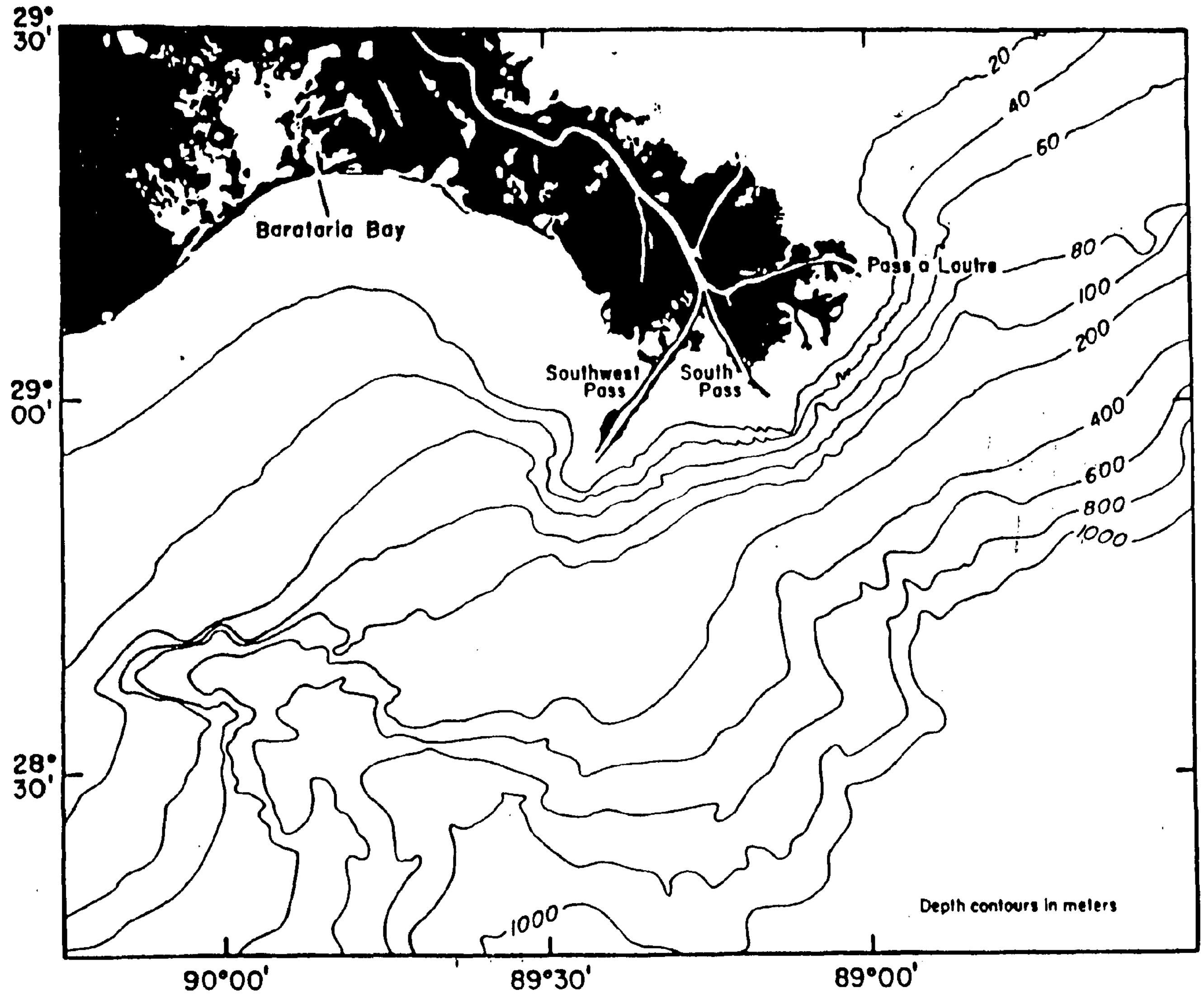


Figure 3. The three major passes in the Mississippi Delta which account for most of the water and sediment discharge.

3 to 8 days (Dagg, 1988). Hence bottom hypoxic regions are typically observed only between April through October. Regions of low dissolved oxygen concentrations begin to develop along the Louisiana Shelf west of the outflow plume in the spring, when the coastal waters begin to stratify, and thereby limit the re-aeration of bottom waters. Hypoxic water masses (oxygen concentrations <2.0 mg/l) form during the summer as stratification intensifies. As oxygen concentrations decrease, the aereal extent of the hypoxic regions expands, finally dissipating in the fall as density stratification weakens in response to increased turbulence. Necessary conditions for the development of bottom hypoxia on the shelf are postulated as: high rates of river discharge trasnporting nutrients to the shelf, phytoplankton blooms (providing oxidizable organic matter to the bottom waters), and water column stratification. The argument for this is developed as follows:

- The Mississippi River is the major source of 'new' nutrients to the shelf waters during the spring and summer. During the winter wind events, which provide energy for reaeration, also result in nearshore upwelling (Dagg, 1988).

- The high levels of primary production in Mississippi plume waters (>300 gC/m2/yr) is supported by the enhanced nutrient input.

- The existence of high levels of phytoplankton degradation products (phaeopigments) in hypoxic regions suggest that hypoxia results from high rates of microbial community respiration (Turner and Allen, 1982), which is supported by the recycling of phytoplankton biomass.

Rabalais (1987; and in press) indicates that the relationship between surface chlorophyll levels and bottom hypoxia is not straightforward, despite initial attempts to correlate the two by remote imagery (Leming and Stuntz, 1984). In fact, in 1985 and 1986 there was no obvious correlation between surface chlorophyll levels and bottom oxygen conditions. Under conditions of severe hypoxia pigment concentrations in bottom waters were generally higher than in overlying surface waters. This suggests that consumption of oxygen in bottom waters by the microbial community respiration was supported by primary production in the Shelf surface waters; however, the source of organic matter may have been the nearshore waters, or the Mississippi plume to the east.

Although it is now clear that the Louisiana shelf ecosystem is adversely affected by development of hypoxic conditions, the situation may intensify. Turner et al. (1987) note that phytoplankton production beyond the light-limited, turbid river plume is primarily nitrogen-limited. They therefore hypothesize that a continued increase in nutrient inputs from the Mississippi (Figures 1 and 2), and consequently any future increase in 'new' productivity on the shelf, will result in higher inputs of phytoplankton carbon to shelf bottom waters, with a potential expansion of hypoxic regions.

Criterion #4 - Renewable resources of significant value: In addition to the extensive, non-renewable mineral resources (e.g., petroleum and sulfur) which must be exploited, the U.S. Gulf Coast has extensive

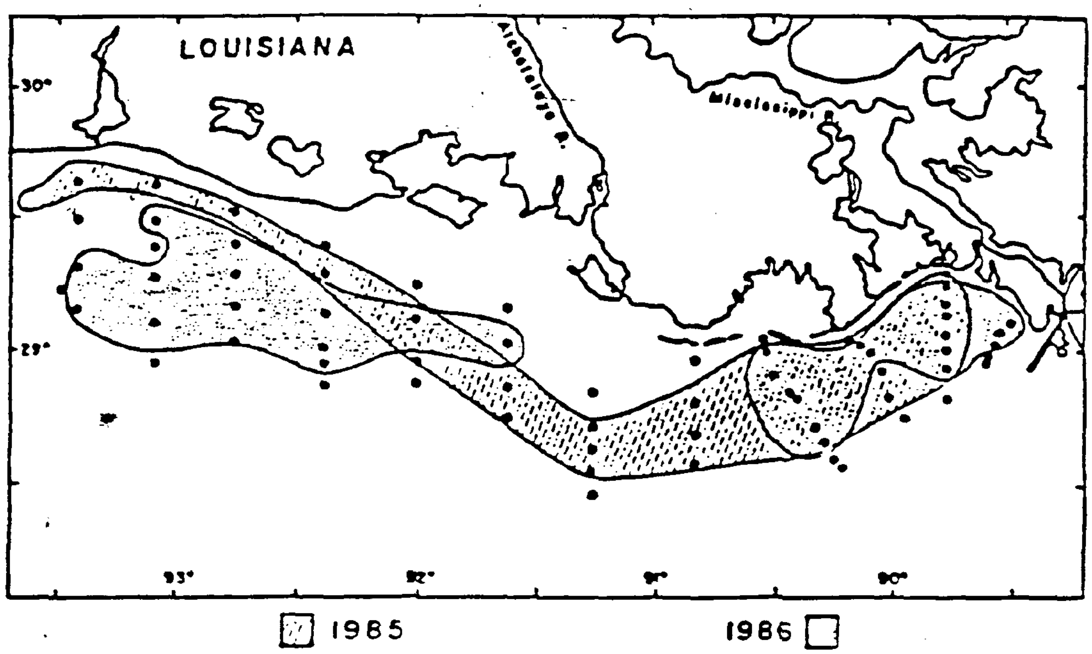


Figure 4. Areas of the Louisiana shelf where hypoxic bottom waters were found in 1985 and 1986. Station locations indicated by closed circles for 1986 stations only. From Rabalais (1987).

renewable resources and environments which have a significant commercial value. Approximately 30% of the U.S. fisheries catch (in both landing tonnage and dollar value) comes from the Gulf of Mexico. The highest dollar value fishery (shrimp) and the highest tonnage fishery (Gulf menhaden) in the U.S. exists in the Gulf. In 1977 there were approximately 30,000 full and part-time commercial fishermen in the U.S. Gulf States, with nearly 5,000 fishing vessels exceeding 5 net tons displacement (French, 1981). Although harder to quantify, the recreational fishery has a similar value. The coastline and coastal waters of the Gulf serve as an important recreational area for a significant portion of the U.S. population; population growth in the five U.S. Gulf Coast states has exceeded all projections and is expected to continue through at least the year 2,000. Much of the lucrative recreational fishery is located within the shelf areas influenced by the Mississippi/Atchafalaya outflow. This region will be directly influenced by any future impact of nutrient-enhanced productivity, whether desirable or not. While hypoxia has a clearly adverse impact on fisheries, enhanced productivity per se could have potentially beneficial effects. Our current understanding of the linkage among the physical regime, productivity and ecosystem response is presently too incomplete to realistically predict these impacts.

V. Key Research Questions.

The following series of questions delineate key research areas to be addressed as research activities under the Nutrient Enhanced Coastal Ocean Productivity program. The questions represent the consensus of approximately thirty NOAA and academic scientists.

Key Question #1: Does a historical record exist within sediments which indicates that the productivity of Shelf waters has increased on time scales commensurtae with the historical record of anthrpogenic nutrient loading?

Key Question #2: What is the temporal and spatial scale of physical and biological variability in riverine outflow regions of the northern Gulf of Mexico?

Key Question #3: What is the production rate, distribution and fate of biogenic carbon in riverine plumes and the shelf on seasonal-to-annual time scales in the northern Gulf of Mexico?

Key Question #4: What physical and biological processes regulate the flux and chemical composition of carbon, and concentrations of nitrogen, phosphorus and silicon, as well as suspended particulate matter, from the riverine outflow in the northern Gulf of Mexico?

Key Question #5: Has increased nutrient loading in the Mississippi / Atchafalaya outflow contributed to the occurrence of hypoxic conditions on the northern Gulf of Mexico shelf?

VI. Program Plan:

A. Retrospective Analysis

1. Sedimentary Record. An underlying hypothesis of the proposed program is that shelf productivity has been enhanced as a result of anthropogenic loading from riverine outflow. However, no direct measure of productivity exists for northern Gulf shelf waters over the past few decades, although a large number of unpublished pigment measurements have been taken. Since shelf sediments are deposited at rates of 10 - 20 cm y-1 in the region immediately impacted by the Delta outflow, the temporal records of sedimentary biogeochemical parameters may provide the sole record of past productivity, or anoxic events, on spatial and temporal scales commensurate with the nutrient records from the Mississippi River.

Following an initial survey of core libraries, individual cores will be selected on the basis of coherent geochronology (by Pb-210, Pu-239/Cs-137 dating) from various depositional sites on the shelf/slope for analysis of biogeochemical constituents. The geochronology will ensure that the selected cores contain a coherent annual record over the past few decades, as previously successfully demonstrated for lead (Trefry et al., 1985). Given that rapid sediment transfer off-shelf can occur by mass wasting and slumping during high energy periods, such as storms, the dating is necessary to permit a temporal and spatial record of biogeochemical constituents to be compiled. The constituents examined would ideally serve as 'biomarkers' of past events. The temporal and spatial records of these indices may potentially reveal the influence of anthropogenic nutrient loading over the shelf. An increase in productivity indices which parallel the documented increase in nutrient concentrations in the Mississippi River, for example, would imply a causal link between between the two parameters. In addition, plankton fossil records may reveal changes in community structure which could reflect alterations in dissolved inorganic N:P:Si ratios as river outflow composition changed due to anthropogenic influences.

B. Productivity of the Shelf/Plume System

1. Process Studies. An understanding of the hierarchy of physical processes which control the distribution of nutrients, particulates, and optical properties in river plumes, shelf, slope and ultimately the open Gulf of Mexico, is a prerequisite in quantifying the influence of anthropogenic nutrient input on primary production. In broad terms the processes which must be examined are those which control 1) the dilution of the river plumes and mixing of plume and shelf waters, 2) regional variability in stratification, plume dimensions and shelf, slope waters, and 3) the advection and diffusion of oxygen and particulate materials from riverine through slope water regimes. These physical processes span a continuum of spatial and temporal scales (see Figure 5), and must be quantified by a field program to observe the variability in physical parameters. The primary objective of these studies is to provide a description of the influence of physical processes on the fate of nutrients, oxygen, carbon and particulates within a fluid parcel as it progresses from a riverine source to the offshore waters of the open Gulf of Mexico. The field program incorporates shipboard drifting, and moored instrumentation.

Observations of the seasonal variability in the density (temperature, salinity structure by CTD casts), optical (beam transmissometry, submarine light spectrum) and flow (u, v by acoustic doppler current profiler) patterns will be made during seasonal cruises. The first of these will occur in July-August 1990 and will involve three ships (NOAA Ship MALCOMB BALDRIGE, R/V GYRE from Texas A&M University, R/V PELICAN from the Louisiana Marine Sciences Consortium, LUMCON) and one aircraft (NASA Lear Jet). The second cruise will occur in winter-spring 1991. During the winter-spring cruise in FY 91 emphasis will be placed on observing the impact of high volume discharge on the shelf.

Synoptic measurements of chemical parameters, dissolved oxygen, particulates and pigments will be conducted on all cruises to determine cause-effect relationships. Surface wind stress and solar irradiance will be recorded at sea, and throughout the year at shore facilities. The field program in FY 91 will consist of a 'spring' cruise to measure physical and optical parameters on transects between 88° and 94° W from the nearshore to the slope regime. The transects will be oriented from plumes to offshore waters parallel to the main flow field, as well as perpendicular to the major axis of river plumes. It is proposed that the specific orientation of the transects for each cruise will rely, in part, on the most recent satellite imagery of the SST field. These transects will provide a more synoptic examination of the area than is possible with the drifting platforms, and provide physical and biological oceanographers with an opportunity to make synoptic observations on the sub-mesoscale. This is necessary to establish causal mechanisms between the physical environment and ecosystem responses.

An important consideration is to quantify the extreme variability in the optical fields across the shelf. Since productivity within plumes is initially light-limited, due to the high SPM content, the spatial and temporal distribtuion of productivity and nutrient utilization is regulated in the near field by light availability. The measurements are planned as an integral part of the field observation program, by both shipboard and drifting platforms, with emphasis on the plume and shelf regimes. A series of Lagrangian drifters, capable of measuring submarine irradiance, temperature and pigment fluorescence profiles at predetermined time intervals will be launched during the cruise to supplement the shipboard observations.

Prior studies have shown that the level of productivity in the nearshore plumes is proportional to algal biomass and light availability, (Lohrenz, et al., submitted). Further offshore the rate of nutrient supply controls the level of production. A suite of observations by academic scientists has shown that over the course of the past few decades a decrease in turbidity (and dissolved silica) in the outflow areas, (attributed to reduced SPM loading of the Mississippi due to damming upriver) has resulted in an improvement in the light regime in nearshore waters. With the increase in light availability and concomitant production, the nutrient which 'limits' production has potentially shifted from nitrogen to silicon during some periods of the year, e.g. siliceous organisms such as diatoms become silica-limited at levels of 1 - 2 uM silica (Q. Dortch, pers. com.).

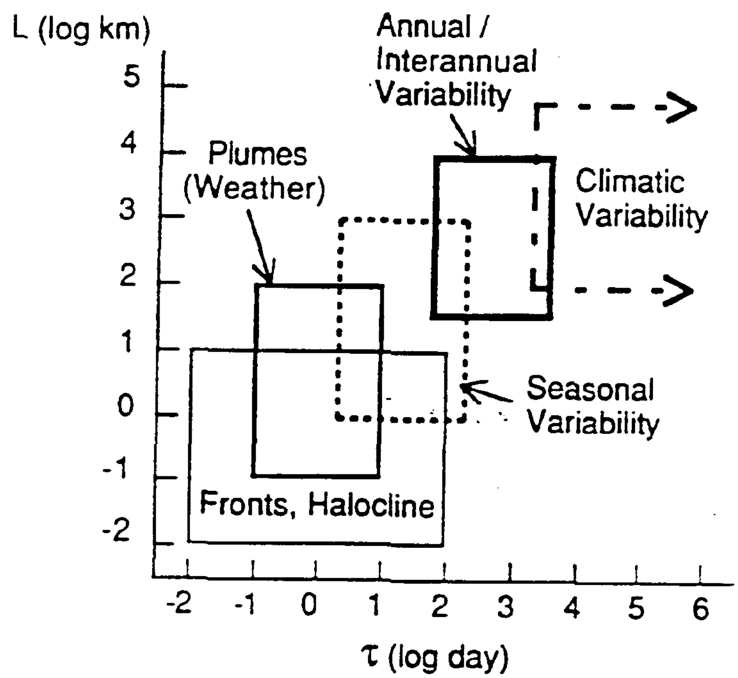


Figure 5. A schematic flow diagram illustrating the temporal evolution of a near-surface fluid parcel and the associated horizontal spatial scales of various processes as it progresses from a riverine source to the 'open Gulf' (i.e., souce to fate). Advection is assumed at ca. 12 cm/s with dimensions in the near field corresponding to less than a 10:1 dilution and dimensions in the far field at greater than 10:1.

These conditions often occur during periods of high productivty. This shift in the nutrient species limiting primary production, and the relaxation of light stress, has important implications for the trophic structure of the shelf ecosystem, and ultimately the fate of biogenic carbon, as discussed in the section on Carbon Flux.

The relationships between nutrients and productivity on the shelf will be addressed by determining how present levels of production are coupled to present rates of seasonal-to-interannual nutrient supply. This is accomplished by productivity and nutrient observations during the field program at different seasons (stages of river flow) to monitor the spatial patterns in primary production, (by 14C uptake), algal biomass and species composition. Routine sampling of nutrient concentrations (dissolved forms of nitrogen, phosphorus, and silicon), are made on the transects from 88° to 94° W. Since 'new' production in this area is supported by nutrients imported from riverine and runoff sources, as well as from deep water by upwelling, 'new' nitrogen includes not only nitrate (as in the open ocean) but also reduced forms of nitrogen. Thus it is necessary to monitor the utilization of several dissolved inorganic nitrogen species across the plume/shelf regime.

2. Models. Two modeling efforts are included within NECOP, with initial box models relying on existing data of physical, optical, and chemical-biological parameters. The results of the first box models are employed to identify which parameters and regions in the shelf should be emphasized in the field program, and guide in the design of sampling protocol. The goal of the modeling effort examining physical processes and hypoxia is to identify the dominant space and time scales of variability for parameters which contribute to processes associated with the development of low oxygen waters. Sufficient data exists from the LASER program to begin modeling efforts examining the linkage between changes in the qualitative nutrient composition and the taxonomic composition of primary producers. A second generation product will be the generation of diagnostic models to be used by individual investigators for their particular research questions. Ultimately it should be possible to predict the dominant space/time scales for the various physical, chemical, and biological fields, as well as the dominant processes regulating the distribution and variability of these fields from simulation models in the latter phase of the program.

C. Hypoxia Research & Modeling

1. Time Series, Processes and Impact Studies. The impact of extensive hypoxic areas on the shelf from Mississippi to Texas is one of the potentially most important consequences of enhanced coastal productivity in the United States (Turner et al., 1988). The research on hypoxia is therefore intimately linked to both the Productivity and Carbon Flux components. Hypoxia contributes to shrimp mortality, and occurs during the spawning season of shrimp. It may alter migration patterns, resulting in a local concentration of commercially important fish populations in the nearshore waters, making them more accessible to fishermen ('jubilees'). The NECOP program includes two components

involved with research on hypoxia; one for monitoing and the second addressing the relationship of hypoxia to biota. The time series field program will provide a more refined view of hypoxia development than has been possible in the past, and is to include observations of vertical dissolved oxygen profiles in conjunction with CTD casts, and ancillary biological parameters (pigments, productivity) from a small ship. Process studies will be conducted in concert with the time series observations in the field. One componrnt is examining measurements of community respiration, both in the water column and benthic environments. The rate of oxygen consumption will be measured over seasonal periods at selected sites to derive oxygen utilization parameters for validating predictive models. An assessment of the impact of hypoxia on living marine resources is an integral part of this research. This research assess the influence of low oxygen concentrations on commercially important demersal fish and shellfish (especially shrimp) populations.

2. Modeling. A primary objective of the modeling components with respect to hypoxia is to achieve a predictive capability allowing successful forecasting of the timing and spatial distribution of events. As in the productivity component, diagnostic models are dveloped to assist individual principal investigators in the analysis of their data. More advanced modeling efforts, probably during the outyears of the program, will incorporate advective fluxes of oxygen, carbon and respiration rates to derive a predictive capability for oxygen distributions on the shelf. This will require the combined input of physical parameters, productivity, and carbon flux (advective and sinking) at various locations on the shelf. When combined with the DO utilization rates, the efforts should be capable of predicting the temporal development and decay of hypoxia at specific sites.

D. Carbon Flux

1. Process Studies. The fate of organic carbon in the plume, shelf and slope waters and the underlying sediments is of utmost importance in determining the linkage between anthropogenic nutrient inputs and the impact of enhanced production. The research program examining the fate of carbon can be focused on two sets of linked processes: the utilization of photosynthetically-fixed carbon by consumers and the fate of organic carbon sinking from the euphotic zone to sediments. These processes are linked by the 'bio-packaging' of phytoplankton carbon sinking to the bottom by grazing herbivores (Nelsen and Trefry, 1986). A complete understanding the cycling of organic carbon by consumers also includes studies of dissolved carbon utilization by microbial organisms as well as quantifying the micro- and macro-zooplankton abundance, biomass, and grazing-fecal pellet production rates. If feasible, the abundance and distribution of zooplankton should be related to the growth and survival of juvenile fish, particularly the commercially important species which are examined in relation to hypoxia (see above). The microbial heterotroph and zooplankton studies are to be made in conjunction with the seasonal productivity studies in the field.

A specific task is to determine the quantity of phytoplankton carbon which is unassimilated (excreted as dissolved carbon and fecal pellets); the particulate fraction represents an important source of carbon input to the sediments. The fate of carbon in the benthos will is quantified by measurements of nutrient regeneration, benthic respiration and carbon deposition to sediments, with particular emphasis on hypoxic areas.

Another NECOP component is examining rates of particulate carbon flux in plume and shelf waters by floating sediment traps for short-term fluxes. The rates of carbon flux to sediments provides an indication of 1) the carbon source supporting oxygen demand in benthic hypoxic regions and 2) the potential for carbon export from the shelf to the slope and 'deep sea' for prolonged burial. The quantitative assessment of this flux serves to assess whether or not enhanced productivity on the shelf is an important carbon sink for long-term burial of anthropogenic carbon in deep sediments (e.g., Walsh et al., 1981).

Sediment resuspension during short-term events, such as winter storms or hurricanes, and mass wasting are transport processes which could rapidly move a significant quantity of biogenic carbon from nearshore regions to the deep sea for long-term burial. A potentially important process for sediment, and organic carbon, transport offshelf is via particle transport down the Mississippi Canyon, as suggested by the fact that sedimentation rates in the Canyon are two-fold greater than on the adjacent shelf to the east. The potential offshore transport of carbon from the shelf to slope 'depocenters' is being evaluated as an important objective in quantifying carbon flux.

2. Modeling. Two modeling approaches are relating the fate of carbon in the plume/shelf system, with both efforts orienting the results to productivity and hypoxia. The first efforts are concentrating on assembling the existing data for box models which, as in the productivity and hypoxia components, are guiding hypotheses development and design of field experiments.

E. FY 1990-91 Field Program:

The field effort for the first year (FY1990) is concentrating on process studies and hypoxic region development. A three ship study is planned for July-August, 1990, including the N/S BALDRIGE, the R/V Gyre and the R/V PELICAN. A series of overflights from a NASA jet with Airborne Ocean Color Imagers (AOCI and CAMS) will supplement the synoptic view of the Mississippi River plume and contiguous hypoxic regions. Prior surveys for monitoring the region during State of Louisiana funded LASER cruises will provide information on the design of the specific field sampling plan. The overall objective is to provide a description of the buoyancy flux and nutrient input to the coastal waters from the Mississippi River. Emphasis will be placed on the input of nutrients and organic carbon from the Mississippi River to the shelf. The specific FY1990 program components within NECOP are listed in Table 1 with a brief description of the research objectives. These basic program elements will be maintained in FY1991 and additional funding will be focussed on developing an effort in nitrogen uptake into lowest trophic levels and a field program in the Atchafalaya outflow and Atchafalaya Bay.

VII. PROGRAM PRODUCTS

FY91 Products.

Program products during FY 91 will be the result of the initial field experiment (summer, 1990) and the FY 91 cruise (February-March, 1991) and are listed below. The scientific value and validity of these products will be judged as high when results are published in peer reviewed journals. The social value will be measured in terms how successfully they add to the synthesis of useful information resulting from the program and recommendations emanating therefrom.

* Documentation of the intensity and areal extent of hypoxia on the Louisiana Shelf during summer, 1990. To be presented at a PI meeting in late 1991 and concomitant report.

* Evaluation historical data sets and core data to provide a historical record of carbon flux, hypoxia and nutrient inputs to the Shelf. Estimates of seasonal and interannual variability will be assessed based on the feasibility of 'biomarkers', and preliminary correlations attempted for relating these patterns to environmental records. To be presented at a PI meeting in late 1991 and concomitant report.

* A preliminary understanding of the physical, chemical, and biological aspects of Plume/Shelf water interactions from monitoring and process-oriented observations during the summer months. To be presented at a PI meeting in late 1991 and concomitant report.

* Initial results from an ecological models utilizing existing data and observations from the summer, 1990 cruise and spring, 1991 cruise to quantitatively examine linkages among nutrient inputs, primary productivity, particle transport and oxygen demand on the Shelf. To be presented at a PI meeting in late 1991 and concomitant report.

B. Long-Term Products

* Quantifying the impact of terrestrial nutrients on the productivity of our coastal oceans.

* A capability to predict the impact that nutrient control strategies are likely to have on productivity.

* A capability to predict the likelihood of hypoxic/anoxic events as a function of physical, chemical, and biological parameters in the coastal oceans.

* Quantitatively determine the role which the coastal oceans play in the marine carbon cycle, and an estimate of the flux of biogenic carbon to the deep sea from these oceans.

* The development of new measurement and modeling capabilities in NOAA, and the oceanographic community as a whole.

VIII. PROGRAM MANAGEMENT AND REVIEW

A. Program Management Goals

1. Meet program objectives as presented in NOAA Coastal Ocean Program Plan and Program Implementation Plan.

2. Support the best science possible.

3. Encourage large, interdisciplinary proposals rather than small, individual principle investigator efforts.

4. Encourage cooperative efforts between OAR laboratory scientists and Sea Grant university researchers.

5. Support a multiyear research effort.

6. Ensure that funded research is completed and useful products produced.

B. Program Management Plan

1. Program Management Committee

The Program Management Committee (PMC) will be the senior coordinating group in the program management structure. The PMC will report to the Assistant Administrator of OAR or his designee who will have ultimate approval authority over program technical and spending plans. The committee shall be comprised of three members:

(a) A Senior Member of OAR Headquarters.

(b) A Senior ERL Scientist.

(c) A Sea Grant Director or his/her designee.

The Program Management Committee will:

(a) Appoint the Technical Advisory Committee.

(b) Issue the annual Call for Proposals.

(c) Appoint proposal evaluation panels.

(d) Develop the annual program plan.

(e) Coordinate interagency cooperation, e.g., with the MMS Gulf of Mexico physical oceanography program.

(f) Coordinate intra-NOAA and intra-COP cooperation, e.g., cooperation with other COP elements such as CoastWatch, Coastal Fisheries Ecosystems Recruitment and EHRP.

(g) Conduct such program reviews as it deems necessary.

2. Technical Advisory Committee

The Technical Advisory Committee (TAC) will serve as the major source of program guidance and planning for the PMC. The TAC will be composed of scientists from the Environmental Research Laboratories, the Gulf Coast Sea Grant program and other NOAA line organizations. The PMC and the Field Coordinator will be members. The PMC may appoint other members of the TAC as needed.

Primary functions of the TAC will be to:

1. Based on the Implementation Plan, identify for the PMC the priority subjects/research areas to be addressed by the annual call for proposals.

2. Given a total budget, recommend a level of effort for each priority research area.

3. Advise the PMC as to adjustments in the Implementation Plan in future years.

4. Address the organization of program-wide functions such as data management.

5. Address other issues as requested by the PMC.

C. <u>NECOP Executive Director</u>

A NOAA Corps Officer will be selected to serve as Executive Director of the program. This Officer will work to implement the decisions of the PMC, as advised by the TAC, and to assist the Field Coordinator (see below).

D. <u>Program Field Coordination</u>

A Program Field Coordinator position will be established at AOML. The Field Coordinator will have full responsibility for the day-to-day conduct of the program. The Field Coordinator will establish P.I. coordinating and technical groups as needed to carry out his/her responsibilities.

E. <u>Ad Hoc Committee</u>

The PMC will establish as needed the following:

1. Proposal Review Panel(s).

One or more proposal review panels will be established by the PMC.

The number and composition of the panels will be determined by the call for proposals. The panel will be comprised of both academic and Federal laboratory scientists; none will be potential investigators or their close associates. The panel will evaluate the scientific merit of proposed research and advise the PMC on the merit of and modifications required of submitted proposals.

2. Program Review Panels.

As necessary, the PMC will appoint a panel to review the organization, operation, and accomplishments of the program and to advise the PMC on any changes that seem desirable.

IX 1991 BUDGET

	($K)
Process Studies	$1041.0
Hypoxia Monitoring	211.0
Hypoxia Modeling	150.0
Remote Sensing	45.0
Retrospective Analysis	
Sedimentary Records	175.0
Nutrients	19.0
Data Management	92.0
Program Management	100.0
Ship Time	117.0
Total	$1950.0

X. NECOP DATA MANAGEMENT PLAN

Per the recommendation of the NECOP Technical Advisory Committee (TAC) the NECOP data servicing function will be located at NOAA/AOML (Miami). It will be established in cooperation with NOAA/NODC and co-located with the Southeastern U.S. NODC Liaison Officer, who is stationed at AOML.

NECOP data servicing staff will consist of the NODC Liaison Officer and a NECOP Data Manager. The NODC Liaison Officer will receive salary support from NODC and NECOP will provide support for specific activities related to NECOP data management, e.g., travel. The NECOP Data Manager will be an AOML employee supported by NECOP funds and supervised by D. K. Atwood with significant work leadership provided by the NODC Liaison Officer. The data manager will be hired as a GS-09 scientist at an M.S. level or equivalent. In addition AOML employees will provide technical hardware and software expertise to the data management operation with minimal cost to NECOP.

The NODC Liaison Officer will use existing contacts and authority to expedite data submissions in a timely manner. The NECOP Data Manager will maintain the data base and provide assistance to project PI's on data submission. Such assistance will include travel to various research sites to assist in establishing communication links and maintaining same.

The system will be "PC based" and operate at a level where remote PI interface will allow listing of data sets available and transfer of same to and from the main the primary computer. Remote access to the primary computer operating system and relational database will not be allowed except to the system manager(s). The primary computer at AOML will be of the Intel 486 type with Write Once Read Many (WORM) optical disk(s) as the primary data storage site. The installation will have three dedicated telephone lines to allow communication through a NECOP Bulletin Board and communication software (e.g., PROCOM) at PI sites. The possibility of providing access through OMNET will also be explored. The NECOP data management function will include purchase of communication software and licenses and installation at PI sites where necessary. Data sets will be appropriately flagged as to the extent of quality control and proprietary nature of the data.

Most of the PC based communication software will probably operate at 1200 or 2400 baud which may be too slow for some transfers of data, therefore, linkage through the existing SPAN network will also be provided and large data sets, e.g., ocean color, acoustic doppler current profiles, etc., will have to be transfered by mailing diskettes.

The NECOP data servicing function will represent a remote data entry station for NODC. Once data is in machine readable formats and quality controlled it will be transferred to NODC in appropriate formats.

The following general data sets are anticipated.

- Primary productivity.
- Pigments
- CTD
- Nutrients
- Ocean color
- Acoustic doppler current profiles (ADCP)
- Current meter records
- Sediment trap data
- Transmissometer data
- In situ plankton camera data and resulting zooplankton counts
- Benthic respiration data
- AVHHR data interpretations
- Benthic biota
- Demersal fish
- Dissolved oxygen
- In situ irradiance
- In situ fluoresence
- Sediment cores
- Numerous other direct observational and derived data sets
- Historical data sets as required by investigators

All data collected by funded PI's must be submitted to the AOML Data Servicing Center within one year of collection. For the first 18 months after collection the PI's proprietary rights to the data are recognized and said PI will has sign off authority on release of said data. During this 18 month period PI's are encouraged to share data on a cooperative basis. After 18 months the data will be transferred to NODC for final archival and will be considered available to the general community.

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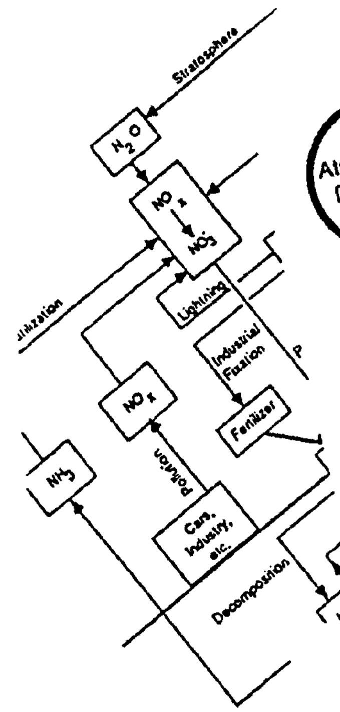
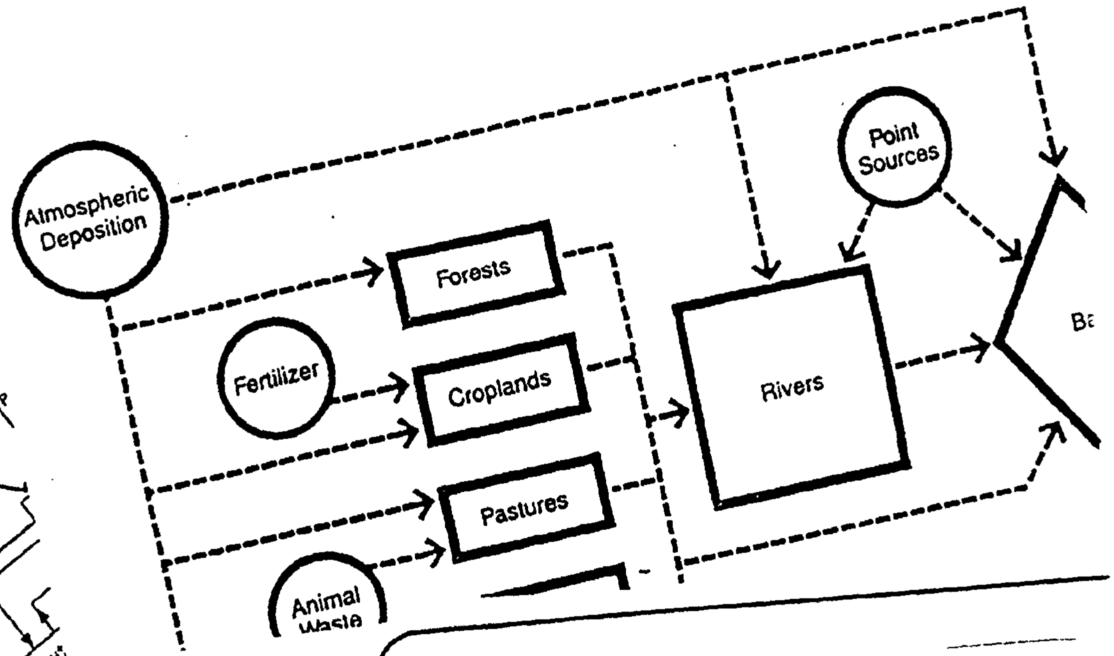
Table 1. Investigators with the NECOP Program. Principal Investigators, institutions, and research component:

Investigators	Institution	Component
A. Bratkovich	GLERL	Buoyancy, nutrient flux of river plume systems
Q. Dortch	LUMCON	Phytoplankton size and species composition
T. Whitledge G. Hitchcock	U. Texas AOML	Spatial-temporal variability in nutrients & pigments
N. Hawley T. Nelsen Trefry	GLERL AOML FIT	Concentration, composition and transport of suspended J. sediments
T. Nelsen B. Eadie B. McKee J. Trefry P. Blackwelder	AOML GLERL LUMCON FIT RSMAS	Retrospective analysis of productivity in sediments from the Louisiana shelf
G. Fahnenstiel S. Lohrenz G. Knauer D. Redalje	GLERL USM/CMS USM/CMS USM/CMS	Primary productivity and the vertical flux of carbon in the Louisiana shelf waters
M. Dagg P. Ortner	LUMCON AOML	Zooplankton grazing and the fate of carbon
H. Mofjeld	PMEL	A time dependent model of productivity-hypoxia
W. Gardner Benner	GLERL U Texas	The fate and effect of R. dissolved organic matter
G. Rowe	TAMU	Benthic metabolism measured with a GOMEX benthic lander
F. Kelly D. Vastano	TAMU TAMU	Satellite estimation of surface flow fields & river plume evolution
N. Rabalais Harper	LUMCON TAMU	Impact of hypoxia on benthic D. organisms
W. Wiseman Bierman	LSU LTI	Modeling of hypoxia on the V. inner Louisiana Shelf
N. Rabalais Turner W. Wiseman	LUMCON LUMCON LSU	Hypoxia modeling and related R. process studies

T. Leming	NMFS/SSC	Large scale synoptic sampling of surface chlorophyll and suspended sediment
R. Miller	NASA/SSC	
M. Dagg	LUMCON	
B. McKee	LUMCON	





ATMOSPHERIC NUTRIENT INPUT TO COASTAL AREAS

(ANICA)

The Fringe of the Ocean Under Siege from Land

The ecology of the ocean margins, crucial to human life, is being disrupted by our activities—and perhaps by global change

Berlin

WHAT WAS THE LARGEST peacetime mari- ...time operation in the history of Norway? An attempt to save salmon from foul-smelling ...hytoplankton. Although U.S. scientists ...night not have known the precise answer to ...at question, in the wake of the Valdez oil ...ill they might well have guessed that hu- ...an activity was the ultimate culprit. And it ...as.

In the spring of 1988, salmon being ...ared off the neighboring Swedish coast ...rted dying from a yellow-brown slick. As ... coastal current swept the slick north- ...rd, it threatened Norway's much larger ...riculture industry. The rescue operation ... a massive naval juggernaut in which ... numbers of salmon cages were towed ...er into the Norwegian fjords to save ...n from the foul slick.

... the end marine biologists found the cause of the slick was a ...oscopic organism called *Chry-... ...molina polylepis*. But this slick ...ust one of a number of remark- ...toxic algal blooms that have ...red around the world in recent ... And those same marine biolo- ...ave a pretty good idea that the ...ying cause of the blooms is ...nutrients being dumped in the ...margins—by man.

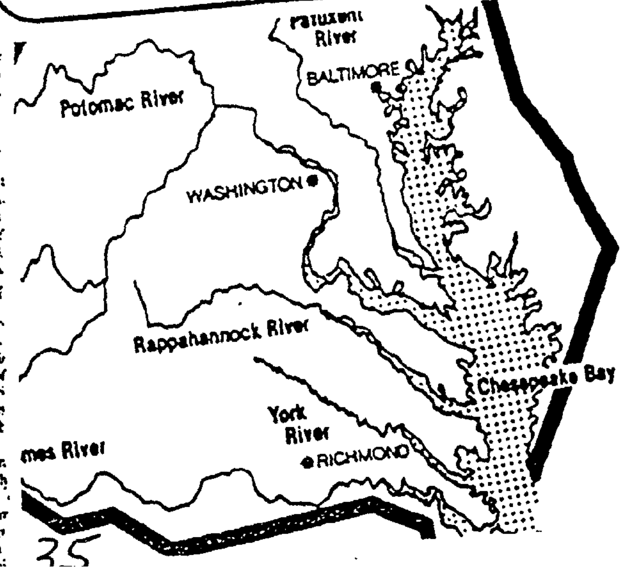
...that's only one threat to the delicate fringe. In addition, ...ming of rivers has decreased ... of fresh water into the sea, ...g life for all the organisms ...ll at the edge of the ocean. ...ects will have serious conse- ...for human beings, because ...n margins are critical for ...r. Although they cover only ...e ocean's surface and contain less ... of its volume, the margins are ...e for 30% of the oceans' produc- ...d they are where the human popu- ...ll: 70% of all human beings make ...s on coastal plains, within reach of the ocean margins.

That's why the organizers of a recent Dahlem conference* in Berlin devoted the meeting to what is going on in the ocean margins now. In particular, they were interested in whether the changes seen there might reflect global climatic changes, such as those stemming from the greenhouse effect. The large question of whether what is happening in the ocean margins is due to a global cause is hard to answer. Indeed, at the Dahlem workshop it was agreed that the extent—and even the existence—of global change remains debatable. But there was a strong consensus that whether they reflect global changes or not, there are things going on in ocean margins around the world that will have critical consequences—and soon.

Perhaps the most dramatic of these changes is eutrophication—the release of excess nutrients into the ocean margins, upsetting the balance of plants and animals. Eutrophication seems to be happening at the mouths of almost all the world's rivers. The extra nutrients are often remnants of fertilizers spread on the land, which find their way through the rivers to the sea. They ...

The bloomin' sea. *Ceratium tripos, a dinoflagellate, is one of the microorganisms that have been implicated in algal blooms.*

...Workshop on "Ocean Margin Processes in ..." was held in Berlin from 13 to 13 March.



35

FY 1991 Coastal Ocean Implementation Plan
for the NOAA/OAR/ARL program on

ATMOSPHERIC NUTRIENT INPUT TO COASTAL AREAS (ANICA)

Revised

February 1991

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EXECUTIVE SUMMARY

The FY 1991 ANICA program will focus on the Chesapeake Bay watershed, where strong evidence already exists that excess nutrient input to the Bay is affecting its biological productivity and is reducing its attractiveness as a recreational resource. There is a large pool of nutrients contained within the water body of the Bay, and especially in its sediments, which is slowly being increased as a results of inflow primarily from streams and rivers. Some of this input is known to be a result of deposition from the air to the catchment area serving the Bay. The long term goal of ANICA is to develop methods for assessing the importance of this atmospheric input, using the Chesapeake Bay as a first target of contemporary importance (as evidenced by its specific mention in the Clean Air Act Amendments of 1990).

There is already a large, multi-organizational research effort addressing the Chesapeake Bay problem. The ANICA program is designed to interface with this effort, so as to bring to bear the unique skills of NOAA that relate to the problem of deposition to landscapes. Without this component, the large-scale effort to investigate the nutrient characteristics of the Chesapeake Bay will fail to show how much of the problem is due to atmospheric inputs, and inappropriate control strategies might then result.

FY 1991 goals of ANICA are modest --

- To initiate collaborative work on the problem of nitrogen transport processes that involve the terrestrial, riverine and atmospheric paths to and within the Chesapeake Bay.
- To form a Consortium of actively involved researchers from among local university, state, and federal research establishments.
- To commence measurement of atmospheric nitrogen fluxes to a single calibrated catchment area within the Chesapeake Bay watershed.
- To assemble all the wet and dry deposition data presently available for the Chesapeake Bay watershed and begin data analysis.
- To initiate a data system combining catchment deposition data with streamflow and water quality information.

The program is proposed to start in earnest in FY 92, with an immediate effort to expand the single-location deposition focus of FY 91 to a watershed-wide assessment. At this time, it would then be possible to relate time records of areal deposition data to similar records of Bay water quality and streamflow information, yielding a first estimate of the spatially averaged consequences of retention of nitrogen in soils and vegetation across the catchment area. In subsequent years, the deposition quantifications would be verified against independent budget estimates using models, derived from aircraft studies, and the methods that are developed in the initial phases of ANICA would be applied to other coastal and/or catchment areas.

Budget details --

	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96
Wet Deposition (ARL Hq)	$15K	90K				
Dry Deposition (ATDD)	25	110				
Aircraft Studies (ARS)		50				
Model Calculations (ASMD)		90				
Synthesis (ARL Hq)		30				
External (university, etc.)	10	50				
Total	$50K	$420K	$800K	$800K	$1.0M	$1.0M

FY 1991 Coastal Ocean Implementation Plan
for the NOAA/OAR/ARL program on

ATMOSPHERIC NUTRIENT INPUT TO COASTAL AREAS (ANICA)

I Background

Man can disturb the natural environment in many ways, particularly when disposing of the wastes resulting from his activities. A prime example of this is the influx of man-made nutrients, mainly in the form of nitrogen and phosphorus compounds to estuary and coastal areas, which may result in the long-term decline of marine life. Though we often think of nutrients as being beneficial to life, an overabundance may cause perceptible water quality deterioration as well as chronic or intermittent health hazards, including toxicity and losses of aesthetic and hence recreational values of affected waters (Paerl, 1988). This potential degradation has been documented in the companion OAR proposals under the Nutrient Enhanced Coastal Ocean Productivity (NECOP) activities, 1989.

The natural ecological state of lakes, estuaries and coastal areas is typically determined by a balance between nutrient inflow and outflow, each being relatively small in comparison to the amount of nutrient recycled within the ecosystem itself. The impact of changes in the nutrient loading to a body of water is consequently not quickly evident; the "insult" accumulates over time, and it is only after many years that adverse effects start to become evident. At first, these effects may be subtle, but eventually they may well lead to eutrophication. The time scale over which effects may become apparent is determined by the magnitude of the imposed loading, relative to the nutrient "pool" contained within the water body itself. The larger the change in net loading, the more rapid the onset of eutrophication. The Chesapeake Bay is of special concern because the loading rate is now relatively high; in some circles, it is feared to be such that the time scale for eutrophication may be reduced to less than twenty years.

Until recently, rivers were considered the only important conduit for nutrients from sources such as commercial fertilizers, animal waste and municipal/industrial discharge. However, preliminary analyses of atmospheric deposition measurements have shown that the atmosphere can be an important path of nitrogen compounds (nitrate, ammonium, and possibly organic nitrogen) to estuarine and coastal waters, particularly in the northeastern U.S. and Canada (Paerl, 1985; Fisher et al., 1988; GESAMP, 1989). On the other hand, only a very small percentage of phosphorus and other nutrients are estimated to come through the atmospheric path (Duce, 1986).

Over the last decade, NOAA has taken an active part in investigations of nitrogen deposition, both as part of the National Acid Precipitation Assessment Program (NAPAP) and as the source of technical guidance to the Environmental Protection Agency. Under NAPAP, research has focused on the effects of acid rain, particularly those of sulfuric (H_2SO_4) and nitric acids (HNO_3) on forests, crops, lakes, freshwater streams and materials. Ammonia and ammonium deposition has also been measured under this program. Investigation of the coastal waters has not been an identified part of the acid rain research, though specific projects such as the Western Atlantic Ocean Experiment (WATOX) were closely related. However, the NAPAP results, summarized in a series of assessment documents which covered a ten year period of research activities, provide us with information and a number of tools that can be used to build a foundation for investigating nitrogen deposition to coastal areas (Irving, 1990).

Based on the NAPAP studies and other considerations, the Congress passed at the end of 1990 the Clean Air Act Amendments (S1630). This act placed into law a number of reporting requirements for NOAA regarding NAPAP and specifically relating to Coastal Ocean studies. For example, the law states

> "The Administrator of EPA, in cooperation with the Administrator of NOAA, shall report every two years on the contribution of atmospheric deposition loadings to the Great Lakes, the Chesapeake Bay, Lake Champlain, and coastal waters. Moreover, the sources of any pollution that cause the deposition from the atmosphere must be identified."

Thus NOAA has a direct charge to investigate atmospheric inputs to lakes, estuaries and coastal waters. Since this proposal deals with atmospheric transport of nutrients to the catchment area of the Chesapeake Bay, it can contribute significantly to requirements spelled out in the Clean Air Act.

We begin to address the problem by focusing on nitrate, where it has been shown that its wet and dry deposition from the atmosphere is dominated by the products of chemical reactions, largely derived from nitrogen oxides (NO and NO_2 = NO_x). The major emissions come from transportation and utility sources (Figure 1). Nitrogen oxides are released in the atmosphere where they are transformed into nitric acid by photochemical processes. During this transformation process, these compounds may be transported over hundreds or even thousands of kilometers. Eventually, the nitrate is deposited, either by incorporation in particulate form in cloud and rain drops (leading to "wet deposition") or by gas (NO_x) transfer and particle settling and impaction ("dry deposition") to the surface (Hicks, 1989). If our hypothesis that the atmosphere is a significant path for nitrate to the coastal/estuarine areas is correct, then anticipated increases in NO_x anthropogenic emissions of up to 50% (Figure 2) will have a direct impact by adding to the atmospheric nitrate loading. Present international negotiations on NO_x emission reductions may effect this emission increase, but it remains clear that if riverine nitrates are cut back by regulatory actions, atmospheric wet and dry deposition would become an even more important factor in potential damage to marine life including eutrophication and nuisance algal blooms in estuarine and coastal areas.

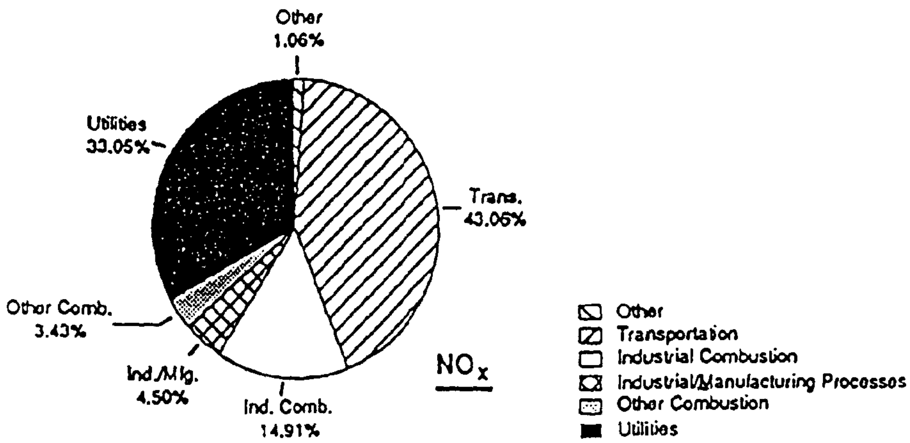

Figure 1. Distribution of NO_x emissions by source in percent. (Source: NAPAP)

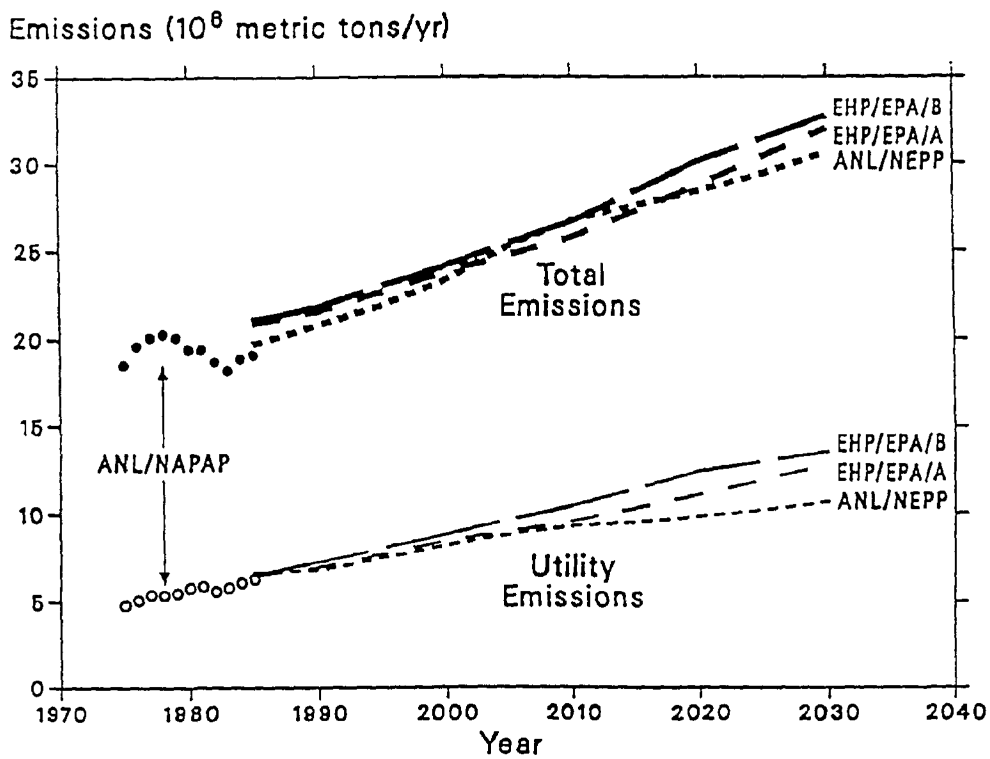

Figure 2. Projections of total NO_x emissions based on calculations of different groups. (Source: NAPAP)

The role of atmospheric transport in providing an important path for nitrogen to estuarine areas was recently underlined in the Environmental Defense Fund (EDF) report (Fisher et al., 1988). Based on one year of measurements (1984), the authors estimated that one third of the nitrogen (nitrate and ammonium) entering the Chesapeake Bay comes via the atmosphere. Though many scientists working in the acid rain field were at first skeptical about the report, a closer reading showed that the assumptions made were reasonable. Specifically, the authors took the wet deposition of nitrate and ammonium to the Chesapeake Bay's watershed from the nearby National Acid Deposition Program monitoring sites. Dry deposition to the Bay and catchment area was taken to be equal to the wet deposition. Using the other known contributions from riverine sources, a rough budget was formulated for nitrogen loadings to the Bay. This is shown in Figure 3. From this preliminary estimate it was clear that the atmospheric path is an important one for the Bay. A more comprehensive study of nitrate deposition, sponsored by the State of Maryland (Tyler, 1988), confirmed the EDF estimate that nitrate from the atmosphere comprised about one quarter of the total man-made nitrate entering the Bay.

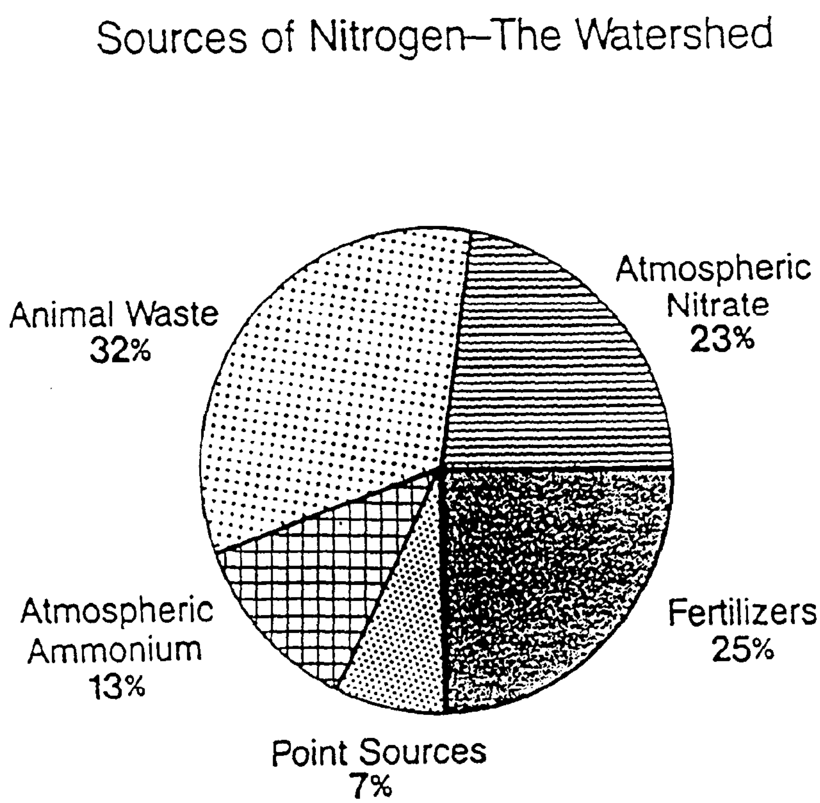

Figure 3. A preliminary estimate of the sources of nitrogen in the Chesapeake watershed. (Source: Fisher et al., 1988)

The Chesapeake Bay is not the only estuary on the East Coast that is affected by nitrogen deposition. Another system, the Narragansett Bay, is a watershed that is much smaller than the Chesapeake. However, a first rough estimate shows that about 18% of the total deposition could come from the wet and dry deposition of nitrate (Huebert, 1990). Farther south in the New York Bight, a rough figure of about 37% is given for nitrogen coming from the atmosphere (URI, 1989). Given the very preliminary evidence from these three major East Coast areas, it is reasonable to speculate that most estuaries in this region experience significant atmospheric contributions to their nitrogen loading.

The problem of nitrogen deposition to coastal waters is not unique to the North American continent. Scientists have evidence that there is significant contribution from atmospheric nitrogen to European marine areas. A recent summary by Hägerhäll (1990) has shown that a large portion comes via the atmosphere even in the polluted Baltic and North Seas (Table 1). Further it has been suggested that transport to the open oceans of nitrogen may have an impact on biological activity in remote regions (Michaels, 1990). It goes without saying that the atmospheric movement of nutrients is not only of regional importance but has global implications.

Table 1. Inputs of nitrogen from various sources to the North Sea and the Baltic Sea areas. (Source: Hägerhäll 1990)

Area	Sources (tonnes per year)				
	Rivers	Direct	Atmospheric	Dumping	Total
North Sea	1,000,000	95,000	400,000	11,700	1,500,000
Baltic Sea	449,000	80,000	413,000	---	940,000

Though the atmosphere was already known to be a major path of transport for many substances in the environment, the EDF report did a great service by pointing out the potential importance of this mechanism in East Coast estuaries. The large uncertainties of the studies to date, however, make it imperative that we develop a better understanding of the processes that transport and deposit nitrogen to the estuaries and coastal zones as well as potential biotic impacts. This proposal - Atmospheric Nutrient Input to Coastal Areas (ANICA) - outlines a plan to address this problem through a measurement and modeling approach. It seeks to quantify the contribution of atmospheric nitrogen to the total loading of nutrient nitrogen to coastal and estuarine waters especially in light of the anticipated increase in NO_x emissions.

In addition, and as a result of collaboration with other research groups focusing on the Chesapeake Bay, the ANICA program will provide quantitative information on the retention of nutrients by soils and biological components of the landscape. The question here is critical -- if the landscape is saturated in nitrate, for example, then all of the atmospheric nitrate falling to the entire watershed will flow into the Chesapeake Bay. However, some of the deposited nitrate will serve as a nutrient to watershed vegetation, and hence only part of the deposited nitrate will flow into the Bay. The simple question is -- "How much?"

II Objectives

As an atmospheric component of the nutrient research program of NOAA's Coastal Ocean initiative, the long term objectives of the research program are:

- To determine the wet and dry deposition of nitrogen to certain East Coast estuarine areas selected for intensive study (the Chesapeake Bay will be the first area of study). This would include determining nitrogen inputs separately to the water surface area itself and to its catchment area,

- To develop a strategy for assessing the dry and wet deposition affecting other coastal watersheds in the Northeastern United States and Maritime Canada, on the basis of the measurements that are made during the initial part of the program,

- To apply the models that are developed in this program to describe and predict present and future atmospheric deposition scenarios for catchment areas impacted by nitrogen deposition,

- To link the findings from ANICA with the ecological and terrestrial components of NOAA's Coastal Ocean Program.

The specific objectives for FY 91 are as follow.

- To initiate collaborative work on the problem of nitrogen transport processes that involve the terrestrial, riverine and atmospheric paths to and within the Chesapeake Bay. This will be accomplished by forming the ANICA Consortium (See Section VI) and supporting pertinent workshops.

- To commence measurement of atmospheric nitrogen fluxes to a calibrate catchment area within the Chesapeake Bay watershed.

- To assemble all the wet and dry deposition data presently available for the Chesapeake Bay watershed and begin data analysis.

- To initiate a data system combining catchment deposition data with streamflow and water quality information.

III Approach

The major question that must be addressed can be expressed as follows:

How much of the nutrients that contribute to environmental disruption in our estuaries and coastal areas comes via the atmosphere?

In this regard, it is important to recognize that the deposition of relevance is not only that to the exposed water surface itself, but also to the surrounding catchment area. It is clearly inappropriate to assume that nitrogen compounds deposited to the watershed as a whole will all enter the Chesapeake Bay itself, since there will be considerable exchange occurring during transport through soils and in streams. There is large uncertainty about the proportion of deposition occurring to land surfaces which affects the water body of the Bay. This question will not be addressed directly in the first phases of the ANICA program. Instead, the initial work will focus on defining deposition rates separately to the land and water areas, and on generating an archive of data on streamflow and water quality as well as on deposition quantities. In later stages of ANICA, these archived data will be used to address the matter of soil retention of nitrates statistically, such as (in concept, and yet to be refined) by relating changes in stream chemistry to changes in deposition rate. To this end, initial steps will be taken to assure that the compatibility of all sampling protocols; a consortium of participating scientific groups will be set up.

Considering the above factors, it is first necessary to evaluate the accuracy of the estimates of other nitrogen inputs from terrestrial and riverine sources affecting the Chesapeake Bay. Thus we propose host a small workshop in the fall of 1991 to assemble a conceptual and organizational framework in which the results of ANICA can be evaluated.

Three major technical components will comprise the initial phases of the present research program:

1. Measurements

- *Wet Deposition to East Coast Areas*

Because of the NAPAP program, the gross picture of nitrate and ammonium deposition over the United States can be described (Figures 4 and 5). However, there may be wide variations of deposition on a regional basis, due to topographical features, seasonal differences from changing meteorological regimes, and year-to-year climatological shifts. To describe the wet deposition in estuarine and coastal areas, a careful study will be made using available monitoring data to establish the range of wet deposition along the Northeast Coast of the North America. Particular effort will be made to develop a complete data base for the Chesapeake Bay water shed to include not only the federal and state monitoring sites but also data from individual research projects that have been conducted in the area. This study will be used to point out areas where additional wet deposition measurements should be made.

Weather system typing and trajectory analysis will be applied as an additional method to evaluate different deposition scenarios. The above data collection and analysis will be completed at ARL/Silver Spring under the direction of J. Miller.

Also, while the wet deposition of inorganic nitrogen to coastal ecosystems has been measured, there are no data on the wet deposition of organic nitrogen. Because a few short-term measurements indicate that organ may be large (Pedulla, 1988), estimates will be made of this deposition based initially on the limited data available. Measurement of organic nitrate will be considered during a later phase of the program.

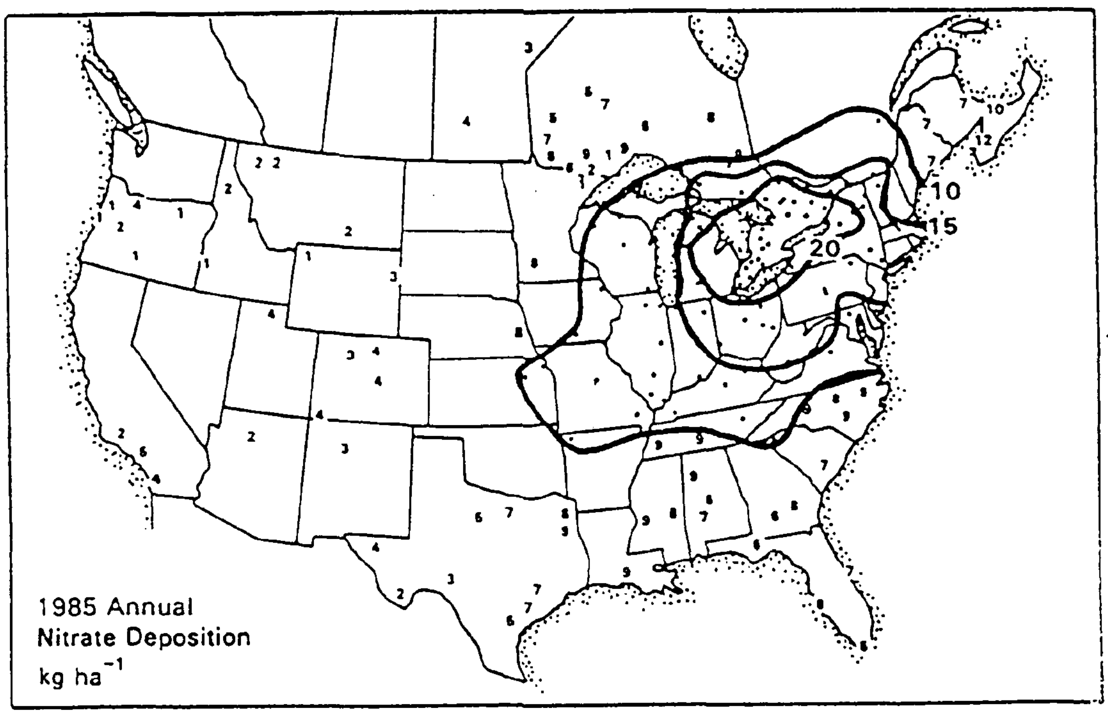

Figure 4. The 1985 annual distribution of NO_3 deposition.
(Source: NAPAP)

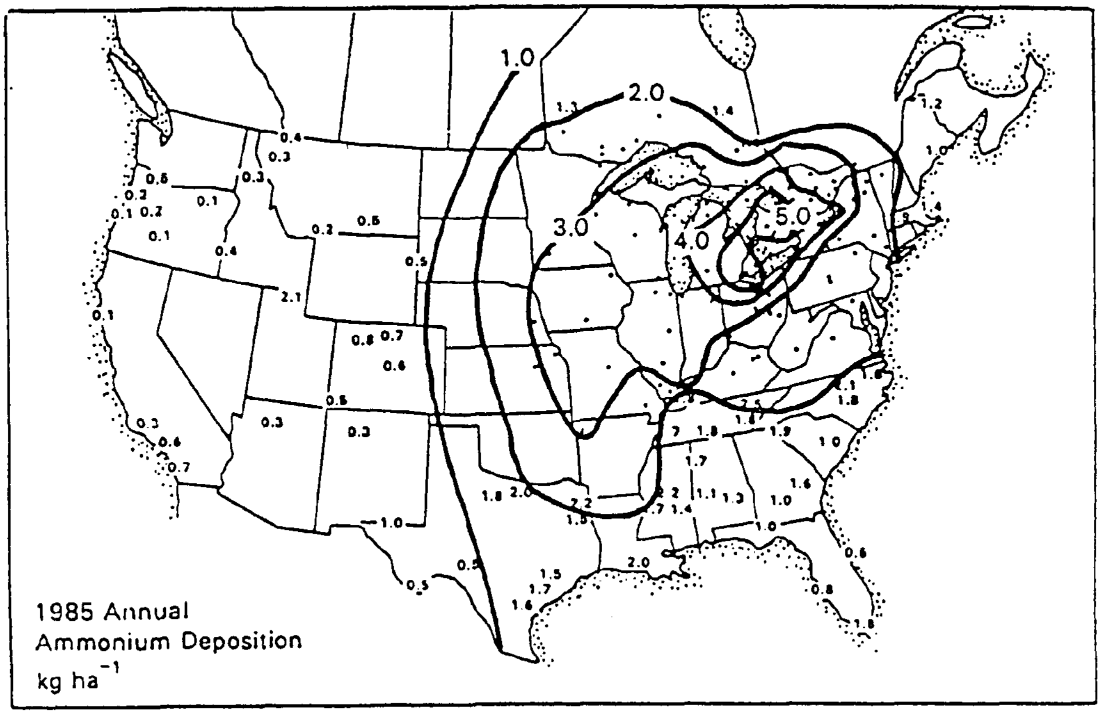

Figure 5. The 1985 annual distribution of NH_4 deposition.
(Source: NAPAP)

- *Dry Deposition to East Coast Areas*

In the estimates made by Fisher et al. (1988) and Tyler (1988), dry deposition of nitrogen was calculated only as a percentage of the wet deposition; no measurements were used. There is little doubt that dry deposition to water bodies and their watershed is a very complicated process. In order to obtain a more realistic estimate for dry deposition, we propose to apply the measurement protocols developed and tested under NAPAP. These methods would quantify dry deposition to experimental catchment areas when only air concentrations and not actual fluxes are measured directly. In practice, sufficient accompanying data must be obtained to permit improved dry deposition rates to be computed from air concentration measurement; these additional data include meteorological data (site specific), biological species distributions, soil characteristics, water status, etc. Key components of this study will be:

a. operation of NOAA's Dry Deposition Inferential Method (DDIM) systems within selected target catchment areas beginning with a Chesapeake Bay location,

b. implementation of "benchmarking" field studies to calibrate the DDIM systems,

c. development of deterministic models to estimate dry deposition rates from routinely collected field data, and

d. extension of the DDIM approach to other areas of interest in the NOAA Coastal Oceans Program.

The Atmospheric Turbulence and Diffusion Division of ARL will take the lead under the direction of T. Meyers.

- *Three Dimensional Studies*

We will begin to quantify the rate of depletion of nitrogen compounds from air crossing the watershed zone of the Chesapeake Bay region. The scientific problem is simply stated but difficult to address -- coastal and estuarine areas are often subjected to regular and organized wind circulations (i.e., sea breeze) which can cause locally emitted pollutants to be trapped in close contact with the ground, while tending to isolate the surface from pollutants from more distant sources. At other times, pollution from distant sources carried above the surface layers of the atmosphere can be "fumigated" to the surface and confined within such organized circulations as the land-sea breeze. All such behavior patterns inject a new level of complexity into the treatment of problem involving transport, diffusion, and deposition. Initial steps will be largely exploratory, to be conducted in a range of atmospheric situations so as to "scope" the problem and to provide a basis for refining experimental approaches for later years.

The Global Change Expedition - Coordinated Air-Ship Experiment - Western Atlantic Ocean Experiment (GCE/CASE/WATOX) studied the biogeochemical cycles of carbon, nitrogen, sulfur and trace metals in the North Atlantic Ocean during the summer of 1988. Its primary purpose was not to determine the atmospheric nutrient input to coastal areas. However, some results from the project can be applied to ANICA. For example, Ray et al. (1990), using data collected with the NOAA King Air, found that NO_y ratios decreased from less than 3 ppbv above the U.S. East Coast to about 1.7 ppbv at 160 km offshore. (NO_y or the total reactive nitrogen is defined as the sum of nitric oxide (NO), nitrogen dioxide (NO_2), peroxyacetyl nitrate (PAN), nitric acid (HNO_3) and nitrate (NO_3).) They attributed this decrease to conversion of NO_y to HNO_3 and NO_3 with the subsequent deposition to the ocean. Nitrate removal rate was estimated at 3-6% per hour. Assuming a removal rate of 4% per hour and a 5 m/s offshore air flow, removal will be virtually complete with 450 km. If local, coastal recirculation affects the offshore flow, complete removal could occur in a much shorter distance. Other studies show similar results (Luke and Dickerson, 1987).

In the Chesapeake Bay case, initial aircraft studies will be conducted at the same time as intensive studies of wet and dry deposition to the surface are made, and will be designed to reveal the linkages between the large-scale flow of pollutants aloft with their watersheds. The methods to be used rely on accurate definition of concentration profiles across the area of interest.

The NOAA King Air will be used to monitor the three dimensional distribution of reactive nitrate over the Chesapeake Bay area. This part of the project would be lead by J. Boatman of the Aerosol Research Section of ARL. It is expected that a number of university investigators would be involved.

2. Modeling of Deposition to Estuarine Watersheds

The first project involves measurements and their interpretation in detailing relevant processes. Another approach to atmospheric deposition estimation, which will begin in the first year, is to use comprehensive atmospheric models, which are constructed using basic physical and chemical principles. The model of choice would be the Regional Acid Deposition Model (RADM), which was developed under the NAPAP program. The use of other mesoscale models will also be investigated.

Initially RADM can provide horizontal fluxes across specific boundaries, budgets and indications of spatial patterns of wet and dry deposition on its 80 km grids. However a number of refinements are planned for RADM, which include better nitrogen partitioning, constructing a nested grid version of the model, and tagging emission sources so that the origins of the modeled nitrogen can be identified. Eventually the data from the measurements from project 1 will be fed back into the model for verification and adjustments of parameters. Because of their extensive experience with RADM, the Atmospheric Sciences Modeling Division/ARL under F. Schiermeier will take the lead in reconfiguring and applying RADM to the Chesapeake Bay study.

3. Synthesis of ANICA Results with other the Coastal Ocean Program Products

The initial workshop (as mentioned earlier) will be the first step in the process of synthesis. There the framework will be developed to hang the different pieces together. In particular, there is need to draw on data obtained in other programs, relating to the chemical composition of surface and ground waters. The question of the effect of subsurface chemistry and biology as deposited nitrogen compounds are transported through the catchment area towards the Chesapeake Bay will be addressed in later phases of this program and will require close collaboration between ANICA and other projects of the Coastal Program.

The requisite links with other Coastal Program activities will be forged early in the process, although the requirement for data from them is not until later stages of the ANICA program. Early attention will be given to the needs of other programs for data from ANICA, which may be more immediate. The facilitator of all such interactions will be ARL/Silver Spring (J. Miller).

IV Program Products

A. FY 91 Products -

The following products will be available at the end of the first year of the ANICA program.

- Workshop reports which will be used in establishing the framework of ANICA.

- A collection and a preliminary analysis of existing deposition data will be made in order to establish a gross estimate of nutrient deposition to the Chesapeake Bay.

- Preliminary results from field studies aimed at testing methods for measuring dry deposition over catchment areas will be available.

FY 92 Products -

Products that will be available if the funding request at the end of this proposal is granted.

- A first assessment of wet and dry deposition into the Chesapeake Bay will be completed.

- The initial atmospheric modeling results will become available.

- Combining the above two activities with other information provided by members of the ANICA Consortium, nutrient inflow and retention to the Chesapeake Bay will be computed.

- Planning will begin for measuring horizontal fluxes of nitrogen compounds into the Chesapeake Bay area and out of it, so as to provide an independent test of the deposition quantifications made above. This will involve use of the NOAA King Air aircraft.

B. Long Term Products

In subsequent years, the following products will be provided.

- Results from more intensive field studies that includes aircraft, ship and other platforms will be published. As a cooperative program that would involve the participation of several U.S. and Canadian organizations, programs would produce profiles of atmospheric deposition not only to the Chesapeake Bay but also other watersheds and coastal areas in the Northeast.

- The model results will be available so that a more detailed and concise calculation of wet and dry deposition can be made to the Chesapeake Bay and other watersheds. The results will be compared with the accumulated measurements from routine networks and field projects. At that point, a more sophisticated picture can be drawn by combining the measurements with the model. Considerations would be made if the predictive capacity of the model could be employed in order to aid in future control strategies both in the air and water.

- ANICA results will be integrated with other Coastal Ocean research to achieve a comprehensive overview of the impact of nutrients on the marine environment. This would be documented in a series of peer-reviewed publications.

V Data Management

The Air Resources Laboratory/NOAA will be responsible for all data archiving in ANICA. This function has been considered as being supported through the requested funds.

The following data sets will be available from the ANICA project in FY 91:

- Wet deposition data for the Northeast U.S. and Canada.

A specialized subset of wet deposition data will be prepared for the Chesapeake Bay watershed in which both monitoring and research data will be combined and archived. These data will be drawn from all available sources, examined and quality assured, and archived by ARL/Silver Spring.

- Dry deposition data for selected areas of Northeast U.S.

The Atmospheric Turbulence and Diffusion Division/ARL will collect and archive these data. A small set of data will be available by the end of the first year.

The long term data management program would remain in ARL and would include the four separate parts, wet deposition, dry deposition, aircraft measurements and model calculations. Hard copy summaries of the data will be available to the user community the first year.

The full set of data on disk will be prepared for distribution by the end of the second year. This will be updated every two years, in accord with the spirit of the language of the Clean Air Act Amendments.

VI Program Management and Review

A. Program Management Goals

1. Fulfill the scientific goals of ANICA

2. Promote interdisciplinary proposals which involve not only NOAA investigators, but also scientists from the academic community. It is expected that a large portion of the resources will go to outside groups primarily in the university community.

3. Encourage cooperation with other agencies, such as EPA.

4. Support a five-year research effort.

B. Program Management Plan

1. Program Coordination Committee-ANICA

The Program Coordination Committee (PCC-ANICA) will be the senior coordinating group for ANICA and be composed of scientists from the Air Resources Laboratory (ARL)/NOAA. This group will report to the coordinator of the nutrient research program of NOAA's Coastal Ocean initiative. The committee will include five members:

B. Hicks, chairperson, ARL Director, Silver Spring, MD
J. Boatman, Aerosol Research Section/ARL, Boulder, CO
T. Meyers, Atmospheric Turbulence and Diffusion and Divn./ARL, Oak Ridge, TN.
J. Miller, ARL Headquarters, Silver Spring, MD
F. Schiermeier, Atmospheric Sciences Modeling Divn./ARL, Research Triangle Park, NC

The PCC-ANICA will:

- Form the ANICA Consortium
- Issue a call for proposals
- Arrange for evaluation of proposals and manage the contracting to outside groups
- Develop the annual program plan
- Ensure proper review procedures.

2. ANICA Consortium

The ANICA Consortium (ANICA-CON) will serve as the chief source of scientific guidance and planning for PCC-ANICA. ANICA-CON will be composed of scientists from ERL, other federal agencies, and the university community. This will be the mechanism to entrain outside researchers. Functions of this group will be to

- Identify, on the basis of the implementation plan, the priority areas to be addressed by internal and external proposals.

- Establish priorities based on the funding allotted.

- Help in the annual revision of the implementation plan.

- Address program-wide concerns such as data management and quantity assurance

- Advise on other issues as they arise.

An informal group/consortium has been established that includes the Smithsonian Environmental Research Center; Departments of Meteorology and Chemistry, the University of Maryland; the Atmospheric Sciences Research Center, SUNY and ARL representatives.

C. Field Coordination

A Field Coordinator position will be established at ARL in order to conduct the program on a day-to-day basis. J. Miller, Deputy Director, ARL, will fill this position.

D. Ad Hoc Committees

The PCC-ANICA will establish ad hoc committees that will help evaluate submitted proposals for their inclusion in the project. Members of these committees will be chosen to give independent scientific advice.

VII Budget

	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96
Wet Deposition (ARL Hq)	$15K	90K				
Dry Deposition (ATDD)	25	110				
Aircraft Studies (ARS)		50				
Model Calculations (ASMD)		90				
Synthesis (ARL Hq)		30				
External (university, etc.)	10	50				
Total	$50K	$420K	$800K	$800K	$1.0M	$1.0M

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NOAA Coastal Ocean Program

Estuarine
Habitat Program

EHP

FY 1991 Implementation Plan Contract

This plan represents an agreement between the lead line office Assistant Administrator and the Coastal Ocean Program Office concerning the management and review processes, scientific and operational procedures, products, and budget for implementing this portion of NOAA's Coastal Ocean Program in FY 1991.

Ned A. Ostenso, Assistant Administrator, OAR — 31 Jan '91
Date

William W. Fox, Jr., Assistant Administrator, NMFS — 2-22-91
Date

Donald Scavia, Director, NOAA Coastal Ocean Program — 2/28/91
Date

NOAA COASTAL OCEAN PROGRAM
ESTUARINE HABITAT PROGRAM
FY 1991 Implementation Plan Contract

I. BACKGROUND

Estuaries and their associated coastal systems are extremely valuable components of the marine environment. Two-thirds of the Nation's commercial and recreational marine fisheries harvest is estuarine dependent. In fact, estuaries provide food, shelter, migratory pathways, and spawning grounds for over 70% of the commercial fisheries landed in the United States. These were worth $5.5 billion to the Gross National Product in 1986. In addition, recreational fishing generates annual expenditures of over $13.5 billion, while contributing significantly to the quality of life for 17 million anglers (Mager and Thayer 1986, NMFS Operational Guidance 1990).

As human populations increase in the coastal region estuaries are placed under increasing pressure. They are fringed with cities and attendant industries, they serve as transportation corridors, recreational sites, and dumping grounds for society's waste products. Excess nutrients may alter estuarine food webs or lead to conditions that reduce oxygen levels in the water column. Toxic compounds, including halogenated- and petroleum-hydrocarbons, occur in fishes and sediments in concentrations warranting concern. Various pathologies in fishes and crustaceans have been linked with waters receiving agricultural drainage or effluent from heavily industrialized areas. Less dramatic but equally insidious are changes in the clarity and volume of water reaching estuarine habitats (Kenworthy et al. 1988, 1989 and references cited therein). Silt and particulates from dredging, upstream erosion, or eutrophication reduce the intensity of light reaching estuarine vegetation. The upstream withdrawal or addition of large quantities of water in association with domestic, industrial, and/or agricultural uses also may disrupt estuarine habitats and the organisms they support.

The House Committee on Merchant Marine and Fisheries recently issued a report entitled *Coastal Waters in Jeopardy: Reversing the Decline and Protecting America's Coastal Resources*. The report states:

> The evidence of the decline in the environmental quality of our estuaries and coastal waters is accumulating steadily. The toll of nearly four centuries of human activity becomes more and more clear as our coastal productivity declines, as habitats disappear, and as our monitoring systems reveal other problems... The continuing damage to coastal resources from pollution, development, and natural forces raises serious doubts about the ability of our estuaries, bays, and near coastal waters to survive these stresses. If we fail to act and if current trends continue unabated, what is now a serious, widespread collection of problems may coalesce into a national crisis by early in the next century.

It is the vegetated wetlands in estuaries (seagrasses, salt marshes and mangroves) that provide the refuge, food resources and nursery areas for a majority of commercially important, estuarine species (e.g., Peters et al. 1979, Boesch and Turner 1984, Ferguson et al. 1980, Kenworthy et al. 1988, Short et al. 1989). However, more than half of the nation's original acreage of coastal wetlands has been lost, and the rate of loss appears to be increasing (Tiner 1984, Kean et al. 1988). Thus, California has lost 87% of its original 3.5 million acres of coastal wetlands. Dramatic declines have also been observed in Florida and in the submerged seagrass beds of Chesapeake Bay. In the southeastern United States, where estuarine–dependence of fisheries is greatest, the loss of coastal wetlands is most pronounced. Louisiana alone is losing 50–60 square miles of wetlands annually. Loss of coastal wetlands results in decreased yields of those species dependent on these habitats. Thus, the President has declared a "no–net–loss" policy for the Nation's wetlands.

NOAA has resource management responsibilities for the nation's living marine resources throughout their range. Accordingly, NOAA is charged with ensuring the continued productivity of the habitats that support these commercially important species. This chapter of the Coastal Ocean Program FY91 Implementation Plan describes the Estuarine Habitat Program (EHP), an integrated effort to develop and disseminate the information necessary for effective management of these critical estuarine and coastal habitats.

II. PROGRAM OBJECTIVES

The EHP, initiated in FY90, focuses special attention on wetlands (seagrasses and salt marshes), and linkages among these and other habitats, because of their importance to the production of living marine resources. Federal and state habitat managers need more quantitative information on the functional mechanisms by which wetlands support living marine resources. Managers need to know the location, extent, and rate of loss or modification of existing wetlands. Finally, managers need to know how to restore and/or create these habitats more effectively. Information on which to base management decisions must be easily available in the form of "...accurate maps depicting where wetlands exist, [and]... information banks containing the results of research on the functioning of wetlands, and on restoration and creation efforts (Kean et al. 1988)." Accordingly, the three basic and interrelated objectives of the EHP are:

1. To determine how coastal and estuarine habitats function to support living marine resources. This includes research on factors causing habitat degradation and loss, as well as on methods for habitat restoration.

2. To determine the location and extent of critical habitats and the rate at which these habitats are being changed or lost. This includes satellite, aerial photographic, and surface level surveys to map habitat location and extent, and to determine change through time.

3. To synthesize the new and existing information in the form of mechanistic models of habitat function of use to managers in protecting, conserving, and restoring critical habitats.

No other national effort within or outside of NOAA addresses these fundamental questions in a comprehensive and integrated program as described below. Recent advances in technology have been made in data acquisition, analysis, display, storage and retrieval. This is an opportune time to integrate broad scale mapping and change analysis with mechanistic studies of cause and effect, essential for effective management.

III. APPROACH

The Estuarine Habitat Program (EHP) is designed to achieve its objectives through three interrelated avenues of investigation: A) research on estuarine habitat function and restoration; B) a program of coastal habitat change analysis; and C) a program of synthesis and model building to make this information available to managers.

A. Estuarine Habitat Function and Restoration

The EHP is documenting the role of habitats in supporting living marine resources and provide information to improve restoration procedures. Research teams are drawn from NOAA laboratories and academia. These teams are focussing expertise on trophic interactions, habitat dynamics and effects of habitat alteration. The program builds upon ongoing, successful research efforts, many of which have been supported under the National Sea Grant Program. It will take advantage of existing data bases or historical studies and capitalize on serendipitous environmental "experiments" that result from natural events or human actions, including those detected remotely.

Research initiated in FY90 and continued in FY91 focuses on three research efforts identified in FY89 workshops which included managers and research scientists:

1. How do stresses impact the viability of seagrass habitats and what are the consequences of loss of seagrass habitat for estuarine productivity?

2. What are the effects of hydraulic manipulation on salt marsh viability and their functional role in marine ecosystems?
3. How can seagrass and salt marsh habitats be restored to assure they are functionally equivalent to natural habitats and how can the process be accelerated and improved?

In addition, in FY91 the EHP will hold at least one workshop including EHP PIs and experts on modeling. The workshop objectives are: 1) to evaluate present knowledge of habitat function and change analysis, including advances made as part of the EHP; 2) to identify the most promising approaches for synthesizing and modeling this information; and 3) to determine the direction of future research.

A.l. Seagrass Habitat

Seagrass systems are at the interface between man's development on the coast and the open ocean environment and are becoming increasingly stressed by man's activities in the coastal region (Ferguson et al. 1980, Zieman 1982, Thayer et al. 1984, Zieman and Zieman 1989). Some of the fluctuations appear to be a recurring feature of seagrass meadows and are a consequence of the extreme environmental conditions the plants experience in shallow water. Others, however, have been identified as long-term, large-scale declines in response to deteriorating water quality. Recently, disease symptoms, similar to the historic wasting disease episode of the 1930's, have appeared in association with dramatic fluctuations in eelgrass populations located in northeastern estuaries (Short et al. 1987, 1988). Likewise, in Florida Bay, seagrass habitats have undergone an unprecedented decline (Everglades National Park Staff, Pers. Comm.). Utilizing these major declines as experimental sites will improve our ability to predict the consequences of seagrass habitat loss.

A.1.a. Continuing projects

The EHP is developing the capability to conserve and protect seagrass habitats through an understanding of the primary factors which control their distribution, abundance and productivity, e.g., water clarity (turbidity), nutrients, and the combined effects of both factors. Three-year projects initiated in FY 1990 to address functioning and restoration of seagrass habitats are:

Accelerating and Evaluating the Development of Restored and Created Sea Grass Beds. Susan Bell - University of South Florida, Mark Fonseca - NMFS Beaufort, Charles Peterson - University of North Carolina at Chapel Hill

This project will develop a model of spatial heterogeneity of seagrass beds as a function of wave energy regime. It will evaluate settlement, survival, feeding, and predation of macroepifauna, suspension feeders, and meiofauna as indicators of habitat function in relation to energy regime and patch size. It will also determine the effect of energy regime on the functional development of transplants. Transplants using plugs placed in manufactured peat pots will be tested for improving transplanting. Fertilizer amendments will be tested on a split-plot basis. Effects of large bioturbators on transplants will be examined by using exclosures around the new transplants. Abundance and composition of fish will be compared between transplanted and natural meadows. Habitat creation research results should provide specific guidance in the use of planting technology to accelerate and obtain equivalent levels of secondary productivity in restored beds.

Factors and Processes Controlling Eelgrass Habitat Persistence and Loss. Fred Short - University of New Hampshire, David Porter - University of Georgia

The objective is to understand the factors that lead to the alteration, degradation and loss of eelgrass habitat, including decreased water clarity, nutrient loading, and wasting disease (slime mold-like protozoan, *Labyrinthula*). The program will utilize field studies to determine mechanisms leading to disease-caused mortality, chemical analysis of plant resistance to disease, identification of resistant eelgrass populations, and a series of mesocosm experiments to look at the effect of eutrophication on seagrass survival. The goal is to acquire sufficient knowledge to predict how eelgrass habitat responds to adverse environmental conditions and to recommend management strategies to insure the survival and recovery of these habitats.

Effect of Eutrophication on Seagrass Habitats of Coastal Lagoons. Scott Nixon – University of Rhode Island, Sybil Seitzinger – Philadelphia Academy of Science

This project is part of a larger investigation of the effects of various types and levels of nutrient enrichment (nitrate, ammonium, and/or phosphate) on the structure and functioning of eelgrass-based lagoon ecosystems. This particular project is concerned with determining the relation, if any, between level of nutrient enrichment and growth or dieback of eelgrass, *Zostera*, and the role of the interactions of fish, amphipod/isopod and seaweed assemblages in regulating the responses of eelgrass systems to nutrient enrichment. Long-term, replicated and controlled nutrient addition experiments will be conducted using ten lagoon eelgrass mesocosms at the University of Rhode Island. Densities and growth of eelgrass plants will be monitored at weekly intervals in mesocosms receiving different levels of nutrient enrichment. Grazer exclusion experiments will be used to investigate the effects of amphipod/isopod grazing on the biomass and production of the filamentous seaweed, *Cladophora*, mats which develop in the mesocosms in summer. Laboratory predation experiments will be used to estimate the rates of consumption of the dominant amphipods and isopods in the mesocosms by the three fish species in the mesocosms (mummichogs, *Fundulus majalis*; silversides, *Menidia beryllina*; and 3-spine sticklebacks, *Gasterosteus aculeatus*). Eutrophication has been identified as a threat to the extensive seagrass beds of shallow lagoon ecosystems along the eastern seaboard of the US. The present project will provide some of the most basic information necessary to empirically define these relations.

The Role of Light Attenuation Processes and Plant Sediment Interaction in Determining Seagrass Survival. Robert Orth –VIMS, 5 Co-P.I.'s from VIMS, University of Maryland

The objective is to investigate aspects of light attenuation in a shallow lagoonal seagrass system and assess the role of plant-sediment interactions in determining the minimum light requirements for seagrass growth and survival. The hypothesis is that light attenuation in the water column and epiphytic cover affect oxygenation of the seagrass rhizosphere through regulation of photosynthetically produced lacunal oxygen. Oxygenation of the rhizosphere is necessary for maintaining aerobic root respiration and for the oxidation of potential toxic metabolites (e.g., sulfides). Hence the minimum light requirement for seagrass growth and survival is controlled by seagrass-sediment interactions. This hypothesis will be tested by measuring seasonal patterns of light attenuation, factors affecting light attenuation processes, and seagrass production dynamics. Study sites are located in Chincoteague Bay, and Delaware and Virginia coastal lagoons. Data from these sites will be coupled with field and laboratory experiments testing the effects of light and sediment characteristics on growth, distribution, and abundance of seagrasses. A simulation model will of these interactions will be developed and validated by simulation using parameter values and data sets from other east coast estuarine and lagoon systems. The model is intended to facilitate development of proper management policies to insure survival of these important systems.

Response of Fish and Shellfish to Changes in Composition and Heterogeneity of Habitats in Western Florida Bay. Don Hoss –NMFS Beaufort, Pete Sheridan – NMFS Galveston

The seagrass communities of Florida Bay are undergoing a period of rapid change due to a die-off of turtle grass (*Thalassia* and invasion/colonization of some denuded areas by shoal grass (*Halodule*). This research will clarify ecological relationships between the different types of seagrass habitats and their associated faunas. A variety of sampling gears (light traps, pop-nets, push-nets, trawls, drop samplers, gillnets) will be used to provide comprehensive measures of the structure of faunal communities associated with the different habitats. Field enclosures will be used in short term (3–6 hr) experiments to measure prey availability and predator selectivity. Enclosures will also be used in long-term (3–4 weeks) experiments to compare growth of selected organisms in the different habitats. Tethering experiments will be conducted to estimate relative value of different seagrasses in providing prey refuge from predation. Plant parameters (shoot density, coverage, average leaf length, and above-ground dry-weight biomass) will be measured concomitantly with each field effort to provide quantitative characterization of the plant community at sampling and experimental sites. The research will provide a basis for predicting the consequences of altered seagrass dynamics for fisheries production in subtropical seagrass systems.

A.1.b. New projects

The EHP received several proposals during FY90 that were approved by the outside review panel in April 1990, but were not funded due to insufficient funds. Two of these proposals that deal with seagrasses will be funded in FY91.

Modeling Spectral Light Available to Submerged Aquatic Vegetation in Relation to Water Quality and Epiphytic Growth. Charles Gallegos – Johns Hopkins University
The objective is to quantify the relative contributions of suspended solids, phytoplankton, dissolved light-absorbing substances and epiphytic growth to shading of submerged aquatic vegetation beds. A recently developed model will be refined and extended to relate spectral light penetration to the concentrations of light absorbing and scattering materials, using data from study sites in the Patuxent and Chester rivers. In addition, the absorption spectrum of epiphytes and settled sediments on leaf surfaces will be measured. This information will facilitate efficient management actions to improve habitat for submerged aquatic vegetation (e.g., reduction of nutrients, control of sediment runoff or erosion) by identifying specific problem areas.

Micropropagation and Aquaculture of *Zostera marina* and *Spartina alterniflora*. Kimon Bird – University of North Carolina at Wilmington
The objective is to apply plant genetics, selections, and biotechnology applications to developing superior strains of marine angiosperms for habitat restorations. The project will also develop micropropagation protocols and aquaculture technologies for several species of marine angiosperms. Healthy, living plants will be obtained and grown as candidates (*Zostera* and *Spartina*). Meristematic sources in different media supplemented with various combinations of plant growth regulators will be tested. Plants or shoots will be multiplied on a multiplication medium and transferred to a rooting medium. This will be followed by potting and nursery establishment. This research will provide the technology necessary for successful propagation and nursery production of two plants necessary for restoring marshes and seagrass meadows.

A.2. Salt Marsh Habitat

Hydrology is the dominant factor controlling the ecological structure, function, and productivity of salt marsh systems (Waltby 1986). Much of the human impact on salt marsh systems has been through some type of alteration to hydrology, e.g., dams, levees, dikes, dredge and fill, drainage, culverts, roadways, increased or decreased water flow. Salt marsh functional research focusses on the mechanisms of hydrologic control of estuarine salt marsh productivity. Research is also being conducted to improve our ability to restore and construct salt marshes that are functionally equivalent to natural marshes.

A.2.a. Continuing projects

Three-year projects initiated in FY90 are:

Accelerating the Development of Ecosystem Functions in Restored and Constructed Wetlands. Steve Broome - North Carolina State University, Gordon Thayer - NMFS Beaufort

This project will evaluate the potential for accelerating functional development of constructed salt marsh by incorporating organic matter in the substrate prior to establishing vegetation. Functional development will be determined by comparing experimental plots with nearby natural marsh (above and below ground biomass, chemical and physical substrate properties, nitrogen fixation, denitrification, and infauna characteristics). Organic enrichment will be tested as an amendment to aid in salt marsh construction. A better understanding of functional equivalency and how to use the proper techniques will enable the attainment of the national policy of "no net loss" in wetland acreage and function.

An Ecosystem Comparison of Transplanted and Native Salt Marshes: The Chronological Development of Habitat for Fishery Species. Tom Minello - NMFS Galveston, James Webb - Texas A&M

The overall objective of this study is to evaluate functional development and equivalency of created salt marsh habitats compared with natural salt marshes in the Galveston Bay system. The approach will be to make univariate and multivariate comparisons of five natural and ten transplanted salt marshes (5, 5–7 years old; 5, 13–15 years old). Specific objectives will be to characterize each marsh by its overall morphology, hydroperiod, slope, elevation, amount of marsh/water edge, percent of open water, sediment organic content, sediment grain size, growth of *Spartina alterniflora* (plant height, density, and above and below ground biomass), benthic and epiphytic algae (chlorophyll *a*, taxonomic composition) and densities of meiofauna, macroinfauna, and natant macrofauna. Caging techniques will also be used to compare the marshes on the basis of benthic infaunal productivity, predation pressure on infauna, and growth of penaeid shrimp. These experiments will determine whether differences exist in the ability of the marshes to support secondary productivity.

Accelerating Salt Marsh Functional Development Through Plant Genotype Selection: Intraspecific Diversity from Natural Populations and the Tissue Culture Laboratory. Dennise Seliskar - University of Delaware

The objectives are to produce and select varieties from dissimilar genotypes of three salt marsh plant species, *Spartina alterniflora, Spartina patens*, and *Distichlis spicata*, which will drive the substrate, aerial detritus production, and decomposition in created wetlands toward functional equivalency with the natural marsh. Studies will take place in a one-half acre marsh which was created during the fall of 1989 at Lewes, Delaware and planted with five different genotypes of *S. alterniflora* and four of *S. patens*. Five genotypes of *D. spicata* will be planted this spring (1990). The rates at which various salt marsh plant genotypes are able to accelerate the functional development of a created salt marsh will be ascertained by measuring soil development, detrital production potential, and the microbial community associated with the detritus. These processes in the created marsh will be compared with those in the adjacent natural marsh. Plant genotypes of a particular species differ in many respects which pertain to salt marsh functional development. Identifying these differences and selecting those genotypes which accelerate salt marsh development will lead to successful marsh creation and restoration.

Influence of Inundation Regime on the Use of Gulf Coast Marshes by Fishes and Macrocrustaceans. Lawrence Rozas - Louisiana State University
The objective is to understand the factors causing alteration, degradation, and loss of salt marsh habitat through modification of hydroperiod, especially how hydroperiod alteration affects faunal utilization and secondary production of salt marshes. Specific objectives are: 1) to assess how depth of flooding and frequency and duration of flooding affect the use of salt marshes by nekton species; 2) to compare growth of fisheries species among marshes having different hydroperiods; and 3) to compare predator encounter rates and mortality rates of dominant species of nekton among marshes having various hydroperiods. Densities of nekton will be compared among three marshes having different inundation regimes by using flume nets to collect twice-monthly marsh-surface samples on each marsh for one year. Rates of growth for several species of nekton within enclosures will be compared among the three study marshes. Predator encounter rates will be estimated from tethering experiments conducted in each study marsh. Mortality rates of dominant species will be estimated for each marsh by comparing densities of cohorts over the two-week sampling intervals. An understanding of these relationships will be used to predict the effect of changes in hydroperiod on marsh utilization and production.

Use of Sediment Fences for Marsh Restoration and Creation. John Day - Louisiana State University
The object is to investigate the factors influencing sediment deposition and erosion in shallow ponds and mudflats. Sediments are important to maintain marsh elevation and as a source of nutrients to support growth of wetland vegetation. Specific objectives are: 1) to monitor the effects of sediment fences on sediment deposition and erosion patterns in shallow coastal ponds and to determine the effect of sediment fences on vertical sediment accretion, elevation, and vegetation establishment; 2) to quantify the relationship between sediment deposition, sediment erosion, and the following factors: fetch, wind speed, soil strength, submerged vegetation, sediment exposure, and wave characteristics; and 3) to develop a mathematical model to describe sedimentation and erosion patterns in shallow coastal ponds and mudflats including the effects of wind speed, fetch, water depth, and wave parameters on sedimentation patterns. There is a high rate of wetland loss in coastal Louisiana. Inadequate sediment delivery and accumulation in coastal wetlands is a major factor leading to this loss. Sediment fences represent a way to enhance sediment deposition and to reduce resuspension, thus leading to greater sediment accumulation.

A.2.b. New projects

The Bird proposal (described earlier with research on seagrasses) will also augment our knowledge of micropropagation of salt marsh grasses. One new proposal will be funded that deals with salt marsh ecology in California. It is a companion project to the Broome/Thayer project in North Carolina and will provide the EHP with a geographic comparison. It was approved for funding by the outside review panel in April 1990, but was not funded at that time because of insufficient funds.

Accelerating the Development of Ecosystem Functions in Restored and Constructed Wetlands. Joy Zedler - San Diego State University

In order to predict rates of ecosystem development and organic matter accumulation in constructed marshes, we will compare sites of different age and in individual sites through time. A two-year study (1987-89) has followed the development of a 5-ha wetland constructed in fall 1984 and transplanted in Jan.-Mar. 1985. We propose to continue the comparison of the Connector Marsh (CM) with its adjacent natural wetland (Paradise Creek = PC) to examine rates of increase in organic matter, nutrient pools and vegetative canopy. Our second objective is to accelerate the development of salt marsh nutrient functions using experimental organic matter augmentation in the new 7 ha experimental Marisma de Nacion (MN). Different types of organic matter will be tested in order to develop the best methods of enhancing nutrient-supply and food-chain-support functions.

B. Habitat Mapping and Change Analysis

Quantifying changes in land use and vegetation cover (wetlands and adjacent uplands) in the coastal zone is critical in linking land-based human activities to the productivity of the coastal ocean. Habitat change in the coastal zone occurs faster and more pervasively than we previously have been able to monitor. The Wetlands Policy Forum notes that "...current survey efforts are too infrequent; only one national survey has been completed, and this is being updated only once a decade. Particularly in regions where wetlands are being lost rapidly, where they are under substantial threat, or where they are of unusual value, more frequent assessments...preferably every one or two years...are essential to an effective protection and management program...(Kean et al. 1988)."

NOAA is undertaking a program (using satellites and aerial photography) to develop the protocol and techniques to monitor vegetation cover and habitat change in the coastal region of the United States. This information, when coupled with other components of the Coastal Ocean Program (i.e., Habitat Function and Restoration, and Coastwatch) and fisheries data, will allow us to relate coastal habitat change to changes in fisheries production. For example, this mapping project is being coordinated with Coastwatch to develop the capability to monitor water turbidity via satellite sensors to identify areas of potential loss or re-establishment of seagrasses.

Habitat maps are being produced from satellite imagery and aerial photography both for recent and past time periods (e.g., 1984 and 1989). These maps are classified by habitat type and compared for habitat changes between time periods, producing a habitat change analysis. Current efforts include the submerged aquatic vegetation (SAV) in North Carolina and the emergent coastal wetlands and adjacent uplands of Chesapeake Bay. This approach is intended to build upon and complement ongoing research and mapping programs carried out by other Federal and state agencies including the USFWS National Wetland Inventory. The EHP will provide timely and synoptic habitat maps, including SAV, and maps of habitat change in the coastal region of the U.S. The monitoring cycle for change analysis will range from 1 to 5 years depending on region and availability of funds. Areas of most rapid change will be monitored annually while areas of less rapid change will be monitored on a less frequent basis (2-5 years).

The current program has three specific objectives:

1. To demonstrate the feasibility of using satellite imagery and aerial photography to map coastal habitats and to determine habitat change through time.

2. To develop standard, nationally accepted protocols for mapping SAV, emergent coastal wetlands and adjacent uplands. National acceptance of these protocols will allow comparable data to be obtained regardless of which Federal or state agency or university conducts the effort.

3. To perform a literature search and review, and summarize the status of remote sensing of biomass, productivity and functional health of coastal wetland habitats.

The Chesapeake Bay prototype that was conducted in FY90 will be completed and an independent verification of the change analyses between 1984 and 1988/89 will be conducted in FY91. This verification will be jointly funded between the Coastal Ocean Program and the NOAA portion of the Chesapeake Bay Program. A meeting with several statistical experts, including a nationally recognized statistician, was held in Beaufort, NC, in September 1990, to scope out the experimental design of the verification.

In FY91, regional projects concerning change analysis of emergent coastal wetlands and adjacent uplands will be conducted in selected areas along the Atlantic and Gulf coasts of the U.S. These projects will add to our geographical coverage and assist in the resolution of technical issues necessary for protocol development. They will include representative habitat types and will be distributed along the coastal region of the U.S. such that latitudinal, longitudinal and tidal differences (i.e., vegetation type, height, biomass, and degree of inundation) will be considered. At the present time cooperative efforts for regional projects are being discussed with the University of South Carolina, the University of Rhode Island, the states of Texas, North Carolina, and Florida, and the EPA's E-MAP Program. The number and scope of individual projects are now being finalized.

The seagrass mapping and change analysis project will continue. Current emphasis is in North Carolina, but plans to expand the mapping effort to other regions are underway. This task uses aerial photography at scales of 1:12,000 to 1:24,000 and will produce photographic scale tracings and 1:36,000 scale hard copy maps to document location, area, and change of SAV habitat. The digital data base is obtained from 1:24,000 scale compilations of SAV habitat.

All initial aerial photography of SAV for the area from Bogue Inlet, NC, to the Virginia border will be completed. The completion of photography of western Pamlico Sound, however, is contingent upon funding (proposal submitted) from EPA's National Estuary Program, Albemarle-Pamlico Project. This year a change analysis map will be completed for southern Core Sound (1985 to 1988). This map is the third in a series. The first, of southern Core Sound (1985) was printed in 1989. The second, northern Core Sound and southeastern Pamlico Sound (Drum Inlet to Ocracoke Inlet, 1988) is currently being produced.

This project is being conducted cooperatively with the EPA Albemarle-Pamlico National Estuary Program and all maps are being digitized and placed in the state of North Carolina GIS system. This effort is cooperative with the Photogrammetry Branch of NOS which is doing the aerial photography, providing accurate shoreline delineations and producing the hard copy maps. In addition, a cooperative effort with the EPA's E-MAP Program, USFWS and states to map SAV in the northern Gulf of Mexico is currently being negotiated. Ongoing mapping of SAV habitat in Chesapeake Bay (not funded by COP) will be merged in FY91 with the Chesapeake Bay Prototype (emergent coastal wetlands and adjacent uplands) begun in FY90. The combination of submerged and emergent wetlands and adjacent uplands is a unique feature of this program's data base.

During calendar year 1991, the development of an operational protocol for mapping and change analysis will be completed for SAV, emergent wetlands and adjacent uplands. The first of four emergent wetland and adjacent upland protocol workshops was completed in May 1990 at the University of South Carolina and the second took place during the first week of January 1991 at the University of Rhode Island. The third emergent wetland protocol workshop is scheduled for the west coast (Seattle) in April 1991. The final emergent wetland workshop will be on the Great Lakes in July 1991. The SAV protocol development workshop took place in Tampa in July 1990. Additionally, special meetings on statistical evaluation (September 1990), data management and dissemination (October 1990), use of NWI data base (December 1990 and February 1991) and habitat classification (February 1991) are being held to assist in the resolution of particular protocol issues. The integrated protocol for SAV, emergent wetlands and adjacent uplands will be available for operational use by December 1991.

A literature search, review and summarization of the status of using remote sensing to determine biomass, productivity and functional health of coastal wetlands will occur during FY91. The review will include all remote sensing techniques which can provide answers to the following questions:

* What proportion of mapped wetlands are in good condition? How many are in relatively poor condition?

* Are conditions improving or degrading over time? In what proportion of the wetland resource are conditions continuing to decline and at what rate?

* What are the most likely causes of poor or degrading condition? Which stresses seem to be most important, affecting the greatest numbers (or area) of wetlands?

C. Synthesis and Model Development

The eventual goal of habitat research is to produce mechanistic models of habitat function. These models will enable managers:

1. To evaluate the functional health of existing wetlands.

2. To estimate the consequences for living marine resources of habitat change, such as measured in the coastal habitat change analysis program.

3. To predict the consequences of planned and unplanned environmental modifications. These include changes in hydrology brought about by dredging and filling, or decreased water quality brought about by eutrophication (as described in the section on Habitat Function and Restoration).

4. To determine the success of restoration projects, i.e, whether they are functionally equivalent to existing wetlands, and to predict rates of habitat development under different construction approaches.

Conceptual and mathematical ecosystem models will be developed for each habitat by the EHP. This is likely to involve separate formulations for each ecologically distinct region in the coastal zone of the U.S. For example, Fonseca (1989) has suggested 6 such regions for seagrass: 1) northeast coast, north of Chesapeake Bay; southeast temperate coast, Chesapeake Bay through Georgia; 3) Florida and Gulf Coast, north of 28°N latitude; 4) Florida and Caribbean, south of 28°N latitude; 5) west coast, including Alaska; and 6) Hawaiian Islands and Pacific jurisdiction.

The modeling effort will focus on the way habitats respond to environmental change and the effect of change on their ability to support living marine resources. Models will synthesize past information as well as that produced by the EHP. The modeling approach will be inclusive; functional health will be evaluated by the presence or absence of physical and biological characteristics typical of undisturbed habitats, rather than on the basis of a few commercially important species. A number syntheses are already available (e.g., Kusler and Kentula 1989) and several modeling efforts are being supported in FY90 and FY91. However, it is too early to predict the form and content of the mechanistic habitat models envisioned here.

At least one workshop will be held during FY91, including EHP PIs and experts on modeling. The workshop objectives are: 1) to evaluate present knowledge of habitat function and change analysis, including advances made as part of the EHP; 2) to identify the most promising approaches for synthesizing and modeling this information; and 3) to determine the direction of future research.

Ultimately, a comprehensive Geographic Information System (GIS) will be developed for each ecologically distinct region of the U.S. combining: 1) the models of habitat function; 2) information derived from the habitat classification and change analysis; and 3) other spatial data (e.g., demographic, land use, pollution, distribution of commercially important species, fisheries yields, and economic activity). Thus, demographic patterns can be linked to wetland stability or loss on an area specific basis. Spatial and temporal patterns of habitat change (loss) can be related to changes in (loss of) fisheries productivity. Economic assessments can be made of alternative management strategies. Achievement of this task will require program planning, included in the proposed FY91 modeling workshop, and cooperative efforts of a multidisciplinary team within and outside of NOAA. Regional habitat and fisheries managers require this type of information synthesis and will be encouraged to participate in the planning for its generation.

IV. PRODUCTS

The EHP includes provisions for interpreting findings as they become available. Technical output from these research efforts includes presentations at meetings (e.g., the American Fisheries Society and the Estuarine Research Federation), symposia, workshops, reports to management agencies, guidance documents, synthesis documents (e.g., maps and models), and peer reviewed publications. The Sea Grant network will work with pertinent elements of NOAA (including NOAA libraries and state Coastal Zone Management Programs) to develop and distribute interpretive products for non–technical audiences.

The EHP has already developed a wide and diverse complement of potential users and cooperators. These include both public and private sector individuals and organizations such as coastal and state Fishery Management Councils, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, National Park Service, Minerals Management Service, NMFS Habitat Conservation Division, NOAA Sea Grant Advisory Services, and State Departments of Natural Resources, Departments of Environmental Regulation, and Departments of Transportation. Two generic products that will be or have been provided directly to these users are:

* Information to assist NMFS Regional Offices in formulating their recommendations to regulatory agencies on actions that may adversely affect habitats of living marine resources.

* Guideline documents (brochures) for Federal and state managers for the restoration and construction of marsh and seagrass that are functionally equivalent to their naturally occurring counterparts.

More specific products from research on habitat function and restoration are:

* Participation in the September 1990 NOAA Habitat Restoration Symposium and contribution to the FY 1991 Symposium publication.

* Publication of proceedings from a turbidity standards workshop, including an evaluation of how well these standards protect seagrasses.

* Conceptual and mathematical models relating seagrass growth and functional value to eutrophication, growth of phytoplankton and epiphytic algae, turbidity, and sediment type.

* Conceptual and mathematical models relating salt marsh growth and functional value to hydroperiod and sediment accretion.

* Improved wetland restoration methodologies through selection of specific genotypes and micropropagation technology, and augmentation of sediment with organic matter.

More specific products from research on habitat mapping and change analysis are:

* Completion of an operational protocol in December 1991, for determining habitat classification and change in the coastal region of the U.S.

* Habitat classification and change analysis maps for the Chesapeake Bay estuarine drainage area (emergent wetlands and uplands, 1984 to 1988/1989) were completed in FY90. Statistically verified maps will be produced in late FY91 or early FY92.

* A change analysis map of SAV in North Carolina will be completed for southern Core Sound (1985 to 1988).

* A map of SAV in northern Core Sound and southeastern Pamlico Sound (Drum Inlet to Ocracoke Inlet, 1988) is currently under production.

* Completion of interagency agreements with EPA and states of Texas and Florida for cooperative mapping and change analysis projects.

* Report on assessing the health of emergent wetland habitats using remotely sensed data, describing previous research, status of technology and knowledge, and future research directions.

More specific products from research on synthesis and model development are:

* Reports from workshop(s) on program synthesis and modeling.

V. DATA MANAGEMENT PLAN

A. Habitat Function and Restoration

Currently, research studies are being funded on the Atlantic, Gulf and Pacific coasts. The principal investigator for each funded study is ultimately responsible for data management and development of the products required by the EHP. As noted under PROGRAM MANAGEMENT AND REVIEW, component projects will be reviewed for organization, operation and accomplishment. In addition, since proposals generally are funded for more than one year, funding for out-years will be dependent upon demonstrated progress and peer-review.

B. Habitat Mapping and Change Analysis

The digital data base will be archived and disseminated in standard exchange formats as either an optical disc or data tape. NOAA/NESDIS/NODC will distribute the data base on a cost-recoverable basis to outside users. We are investigating the feasibility of hardcopy map production by the NOAA/NOS on a cost-recoverable basis. For those participating in the program, both the digital data and preliminary habitat classified maps will be provided through the Manager by the group responsible for the processing of the imagery. Such copies will meet programmatic needs: quality control, integration and archiving of data, guidance, oversight, and planning.

VI. PROGRAM MANAGEMENT AND REVIEW

A. Program Management Committee

Overall responsibility for the estuarine habitat studies component of the Coastal Ocean Program will rest in the hands of the Program Management Committee (PMC). The PMC will be charged with: 1) long-range planning of research, analytical, and outreach activities; 2) developing future implementation plans; 3) soliciting and selecting projects for funding; 4) broad oversight of funded efforts to assure appropriate progress; 4) periodic reviews of program performance; and 5) effecting program revisions in response to changing factors such as available support, the success or failure of funded efforts, and the needs of NOAA and the larger Federal community. The PMC will report to the AA's and will be the interface between the estuarine habitat studies component of the Coastal Ocean Program and the Coastal Council.

The PMC is composed of six individuals as follows: 1) a senior OAR headquarters scientist; 2) a senior NESDIS headquarters scientist; 3) an OAR Sea Grant director; 3) a NMFS laboratory director; 4) a senior NMFS scientist; and 5) a representative from NMFS headquarters. Representatives will possess both strong technical and organizational backgrounds and will be expected to contribute actively to the formulation and conduct of the habitat studies program.

The PMC will not oversee field or day-to-day operational activities. However, the PMC has selected a senior OAR headquarters scientist in the SAC as a Research Program Coordinator and a senior NMFS scientist as the mapping progrom coordinator. These two individuals are coordinating the various research, mapping, and synthesis activities of the EHP.

B. Scientific Advisory Committee

Technical assistance and advice will be provided to the PMC by a Scientific Advisory Committee (SAC). In FY 1990, the SAC consisted of eight members: four each representing OAR and NMFS. A NMFS and an OAR senior scientist co-chaired the Committee. During FY 1991 this committee will be expanded to include representation for habitat mapping and change analysis. Like the members of the PMC, Advisory Committee appointees will possess both technical and organizational skills germane to the development of a high-quality, national program of study on estuarine habitats. The SAC will provide detailed information and technical assistance, as needed, to enable the PMC to carry out its duties with regard to program planning, implementation, and evaluation. This includes assembling short-term committees or *ad hoc* groups of experts to evaluate potential approaches to new areas of study and to assist in the review of research progress in funded EHP research areas.

As noted earlier, two interrelated areas of investigation will be emphasized in FY 1991: research on the functioning and restoration of seagrasses and salt marshes, and assessment of the distribution, abundance, type and change in vegetated wetlands. Topical committees reflecting each of these areas and sub-elements, as necessary, will be established as proposals are selected and funded. A representative of each investigative team will be invited to participate in the appropriate topical committee. The topical committees are intended to promote interchange of information regarding findings, opportunities for collaboration, and common problems.

The PMC will select a chairman for each topical committee. He or she will be added to the membership of the SAC. As the estuarine program matures, the number and type of topical committees will change, as will the size of the SAC. The link between topical committees and the SAC should facilitate feedback to the PMC on the progress, problems, and needs of on-going estuarine efforts.

C. Ad Hoc Committees

C.1. Proposal Review Panel

Two review panels were convened in FY90 to rank research proposals on seagrasses and salt marshes. The panels were comprised of academic and Federal laboratory scientists external to the program as well as representatives from the user community. No proposal review panels are contemplated for FY91; the EHP has 8 projects awaiting funding which were approved by the review panels in FY90, but which remain unsupported due to insufficient funds.

C.2. Program Review Panel

As necessary, the PMC will appoint a panel to review the organization, operation, and accomplishments of the program and advise the PMC of any changes that seem desireable. Representatives of the user community will be invited to participate on this Panel.

During FY 1991 PI's for the seagrass and salt marsh research projects will meet with the SAC and PMC to review progress and recommend areas of research direction and emphasis for FY 1992 and beyond. This will include recommendations for phasing out as well as phasing in research activities. This meeting will probably coincide with the modeling workshop described in the section on Synthesis and Model Development.

For Habitat Mapping and Change Analysis, an external review panel will be established during FY91 to review this program. The review panel will consist of representatives from appropriate Federal and state agencies and from academia. The user community will be represented on this panel. Additionally, reviews of both mapping components (SAV and emergent wetlands) took place in FY90 and FY91 through site visits and Federal/state/academia protocol workshops.

D. Coordination and Interactions

Research on habitat function and restoration in the EHP builds on a broad base of previous work, both inside and outside NOAA. Much of the existing data base on the amounts and types of critical habitats in estuarine systems and the fishery species they support, is a result of previous and ongoing research in the National Sea Grant Program and the National Marine Fisheries Service.

NOAA's Habitat Mapping and Change Analysis effort under the EHP involves 4 of NOAA's Line Organizations: the National Marine Fisheries Service (NMFS), the Office of Oceanic and Atmospheric Research (OAR), the National Ocean Service (NOS), and the National Environmental Satellite, Data, and Information Service (NESDIS). Extant land use and habitat mapping data bases in other federal and state agencies will be used where feasible to minimize data acquisition cost, supplement ground truth, and assist in verification. Current federal land use/habitat mapping programs within the U.S. Departments of Interior, Agriculture, Defense, and Commerce, as well as the U.S. Environmental Protection Agency and the National Aeronautics and Space Administration can provide valuable historical/collateral data for this program. Portions of habitat mapping programs, ongoing in many states, will be incorporated into the overall program where appropriate.

VII. PROGRAM BUDGET[1] (K)

		90	91
A.	Habitat Investigations		
	FY90 Starts	1,030	1,180
	FY91 Starts		120
	Total	1,030	1,300
B.	Habitat Mapping and Change Analysis		
	1. Chesapeake Bay prototype change analysis	207	275
	2. SAV mapping & change analysis	142	165
	3. Development of operational protocol	61	95
	4. Site specific projects to test and refine protocol		235
	5. Program management and interagency coordination		75
	Total	410[a]	845[b]
	GRAND TOTAL	1,440	2,145

[a]Includes $80 K of Chesapeake Bay funds.

[b]Includes $45K of Chesapeake Bay funds.

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NOAA COASTAL OCEAN PROGRAM

Toxic Chemical Contaminants

FY91 Implementation Plan Contract

This plan represents an agreement between the NOAA Assistant Administrator for Ocean Services and Coastal Zone Management, the NOAA Assistant Administrator for Fisheries, and the Coastal Ocean Program Office Director concerning the management and review processes, scientific and operational procedures, products, and budget for implementing the Toxic Chemical Contaminant component of NOAA's Coastal Ocean Program in FY91.

Virginia K. Tippie, Assistant Administrator, NOS	3/5/91 Date
William W. Fox, Assistant Administrator, NMFS	3/29/91 Date
Don Scavia, Director, NOAA Coastal Ocean Program	Date

COASTAL OCEAN PROGRAM

IMPLEMENTATION PLAN FOR THE TOXIC CHEMICAL CONTAMINANTS THEME AREA FY91

SUBMITTED TO THE
NOAA COASTAL OCEAN PROGRAM OFFICE
March 19, 1991

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COASTAL OCEAN PROGRAM

FY91 IMPLEMENTATION PLAN FOR THE TOXIC CHEMICAL CONTAMINANTS THEME AREA

BACKGROUND

The functioning of the advanced technological society of this country results in the release of major quantities of many different potentially toxic substances to the environment. The waste waters and solid wastes from our industrial and municipal treatment facilities often contain appreciable quantities of toxic trace metals and/or organic chemicals such as polychlorinated biphenyls (PCBs). Our intensive agriculture spreads pesticides and herbicides across many millions of acres each year. The exhausts from our millions of automobiles discharge polycyclic aromatic hydrocarbons (PAHs) and other substances resulting from the incomplete combustion of gasoline engines. Our power plants release large amounts of sulfur and nitrogen gases and other pollutants to the atmosphere while burning coal and other fossil fuels for energy production. Our domestic use of a wide variety of chemicals leads to their disposal in garbage, sewage, and other means and their ultimate escape to the environment. All in all the usage, with concomitant environmental dispersal, of potentially toxic chemicals provides one of the major underpinnings for the development of our society.

These toxic substances sometimes accumulate and become immobilized for long periods in specific areas on the land. This is the intent with well-designed land fills and can also occur due to natural processes such as adsorption of certain chemicals on soil particles. Much of the toxic material, however, rather quickly finds its way into our coastal and estuarine waters (including the Great Lakes), either by direct discharge or by way of additions as part of surface and ground water inputs or with atmospheric deposition. There is a great deal of evidence showing the presence of appreciable quantities of anthropogenic contaminants in certain U.S. estuarine and coastal areas, especially in the vicinity of major urban areas (e.g. McCain et al., 1989; National Oceanic and Atmospheric Administration, 1988, 1989; O'Connor et al., 1989; Robertson, 1989; Robertson and O'Connor, 1989; Varanasi et al., 1988, 1989a; .

Much less is known concerning the ultimate fates of these contaminants and especially concerning the effects they are having on living resources and other organisms in the contaminated areas. Very low trace concentrations of toxics in coastal environments seem to cause no demonstrable harm. However, when the exposure of the organisms in the environment exceeds a certain level, undesirable biological effects start to occur. These can take many forms ranging from directly obvious consequences such as fish kills to more subtle and difficult to detect, but nevertheless often serious, effects such as changes in feeding or predator avoidance behavior or in vital life processes such as respiration and reproduction. Toxic contaminants can also accumulate in living marine resources at levels that pose a threat to human consumers of these resources.

There are now a number of documented cases where toxic contaminants have been found to have caused deleterious effects in coastal environments. For example, there is a rapidly expanding body of evidence linking exposure to the myriad of chemical contaminants found in certain coastal urban bays and in rivers connected to the Great Lakes to high prevalences of hepatic lesions, including neoplasms, in bottom-dwelling fish. Hepatic neoplasms have been reported in English sole (Parophrys vetulus) residing in urban bays of Puget Sound, Atlantic tomcod (Microgadus tomcod) from the Hudson River Estuary, brown bullhead (Ictalurus nebulosus) in waterways associated with the Great Lakes, winter flounder (Pseudopleuronectes americanus) from Boston Harbor, and white croaker (Genyonemus lineatus) in coastal waters adjacent to Los Angeles. Other studies have identified pollution-associated reproductive impairment in marine fish species, including English sole and white croaker. These well-documented cases of effects of toxics are in general, however, relatively few. There are many more situations where toxics are known or suspected of being at appreciably elevated levels, but where adequate information is not available to determine what if any degradation has resulted in the exposed biological community. The magnitude and extent of the threats to our coastal environments from toxic substances and the specific causes of these are not well understood.

Yet the resource managers and others who make the vital decisions on regulation and protection of our coastal environments need accurate and reliable information on toxics, their sources, their accumulation and fate in the environment, and their effects on populations and communities of exposed organisms. Such information is crucial to provide the basis for making well informed decisions on how to proceed with the development needed for our economic growth, while still protecting our coastal environments and the resources they provide so these are available for the benefit of future generations.

The National Oceanic and Atmospheric Administration (NOAA) initiated a program in 1984, the National Status and Trends Program (NS&T), to help provide such information on a national scale. The purpose of this program is to determine the current status of, and to detect changes that are occurring in, the environmental quality of our nation's estuarine and coastal waters. The initial focus of the program is on toxic contaminants.

The NS&T Program is composed of three primary components. The first, Nationwide Monitoring, measures the levels of toxic chemicals and certain associated effects in biota and sediments. It provides data for making spatial and temporal comparisons of contaminant levels to determine which regions around our coasts are of greatest concern regarding existing or developing potential for environmental degradation. It includes measurements of concentrations of 24 polycyclic aromatic hydrocarbons (PAHs); 20 congeners of polychlorinated biphenyls (PCBs); DDT, its breakdown products (DDD and DDE), and 9 other chlorinated pesticides; butyltins; and 13 trace elements in sediments, mussels, and oysters at about 250 regionally representative sites through the Mussel Watch Project. Additionally, determinations of the levels of the same chemicals in bottom-dwelling fish and associated sediments are made through the Benthic Surveillance Project at about 75 sites. The frequency of external and internal disease conditions is documented in the fish studied. Data from all monitored sites are stored in NOAA national data bases and analyzed. These are made available to coastal and marine resource managers and the public in a variety of formats and reports.

The second component, Historical Trends Assessment, combines new NS&T data with pertinent historical data to provide assessments about priority environmental quality concerns. It primarily involves a closer examination of the environmental conditions in the regions that were indicated by the Nationwide Monitoring component as having the highest levels of specific contaminants and so the greatest potential for environmental quality problems. Available NS&T data are synthesized with literature information on the status and trends of toxic contaminants and their effects in these regions to assess the magnitude and extent of degradation to living resources and their habitats. Detailed nationwide assessments are also conducted to evaluate the present understanding of the distribution and possible threat from these contaminants to U.S. coastal waters.

The third component, Biological Effects Surveys, consists of a series of intensive two- to three-year studies primarily conducted in those regions where the first and second components have indicated a potential exists for substantial environmental degradation. These studies are designed to provide detailed assessments of the magnitude and extent of ecosystem degradation. Most of these studies focus on living marine resources, especially bottom-dwelling fish. Studies are carried on such aspects as reproductive impairment, genetic damage, sediment toxicity, and evaluation of new indicators of contamination, as well as on contaminant concentration gradients in the biota.

The NS&T Program is very closely coordinated with the Near Coastal component of EPA's Environmental Monitoring and Assessment Program (EMAP-NC). A joint NOAA-EPA agreement to determine the status, trends, and ecological effects of anthropogenic stress in coastal and estuarine areas of the United States has been signed. This agreement provides a mechanism for coördination of NS&T and EMAP-NC planning activities leading to the establishment of an unified NOAA-EPA program for monitoring the status and trends of near coastal environmental quality and ecological conditions. A joint committee to coordinate the two programs meets approximately monthly. A merged quality assurance/quality control project has been developed and future peer reviews of the two programs will be conducted jointly. Where the two programs are making the closely related measurements, i.e. contaminant concentrations in fish and sediments, care has been taken to assure the results can be merged by assuring that same contaminants are measured. The data from the two programs will be exchanged quickly and joint reports are being planned.

NOAA has also recently initiated a program, the Coastal Ocean Program, that includes a theme area dealing with toxic chemical contaminants and directed at developing the information needed by decision makers concerning these contaminants. This paper presents the FY91 implementation plan for the Toxic Chemical Contaminants Theme Area and for the integration of the activities in this theme area with those of the ongoing National Status and Trends Program.

OBJECTIVES

To develop improved information for resource management decisions involving toxic contamination of our coastal environments, the Toxic Chemical Contaminants theme area of the Coastal Ocean Program has established the following long-term goals:

- Assess the status and trends of environmental quality in relation to levels and effects of toxic contamination in U.S. marine, estuarine, and Great Lakes environments.

- Develop a predictive capability for effects of toxic contamination on marine resources and human uses of these resources.

The following more specific objectives have been established for the program to guide the development of a monitoring, research, and assessment program that will make a major contribution toward achievement of these goals:

Objective 1. Assess the magnitude and extent of environmental degradation in U.S. coastal waters related to toxics contamination.

Objective 2. Develop new, or improve existing, methodologies for quantifying biological effects associated with exposures to environmental contaminants, resulting in the enlargement of the suite of bioindicators (e.g., measures of biochemical, immunological, physiological, and histopathological changes) that best assess contaminant-induced adverse biological effects in marine species.

Objective 3. Establish the links between contaminant exposure and significant biological effects in individual organisms, with focus on effects with potential implications at the population and community levels.

APPROACH

The work conducted in Toxic Chemical Contaminants theme area in FY91 will involve studies directed at these three objectives. The Coastal Ocean Program initiated studies directed at the first two objectives in FY90, and the activities in FY91 will be based on the continuation and expansion of these ongoing efforts with the addition of a series of studies directed toward the third objective. Three programmatic elements presented below describe the studies to implemented under these three objectives in FY91.

<u>Element A: Assess Environmental Degradation in U.S. Coastal Waters</u>

The NS&T Program presently provides broad national and regional assessments of the levels of toxic contaminants and their effects around the shores of the United States. However, because of the spatial resolution and types of measurements that can be included in this large-scale national monitoring, the results can not be used to provide quantitative estimates of the magnitude and extent of our coastal areas that are experiencing appreciable ecological degradation from exposure to anthropogenic toxic materials. A series of systematic multi-year field surveys was initiated in FY90 as part of the Coastal Ocean Program to provide such estimates by measuring selected biological indicator properties in all coastal areas where substantially elevated levels of toxics have been found by the NS&T Program. The results will be used to provide estimates concerning magnitude and extent of degradation in each of the areas studied and will also be cumulated, when all areas have been surveyed, to provide an overall national estimate.

These surveys have a secondary but important purpose related to objective #2 above; that is to provide a means to test promising new bioeffects indicators under operational field conditions. As the bioeffects surveys in each area involve several independent measures of contaminants effects, the surveys provide an excellent and relatively inexpensive opportunity to compare the performance of promising new indicators with the results from well-established measures to aid in establishing the value and interpretation of the results from the developmental tests.

The bioeffects surveys include tests to determine such properties as sediment toxicity to sensitive organisms, reproductive impairment and genetic damage in important fish species, indicators of contaminant-induced stress in sessile indigenous invertebrates, and evaluations of changes in bottom fauna and community structure related to levels of contamination. Teams of experts from both inside and outside of NOAA participate in these surveys with funding being provided to NMFS, academic, and private enterprise scientists to carry out the work. In the preliminary stages of each survey extensive discussions through phone calls and visits are conducted with the organizations that are conducting and/or coordinating monitoring and assessment programs related to marine and estuarine toxic contamination in the area. Cooperative projects are developed and carried out wherever practicable. The primary criterion for selection of the survey areas is the level of contamination, with all areas with substantial indications of contamination by toxics ultimately included. The secondary criterion is the potential to carry out cooperative activities.

In FY91 surveys already initiated for the moderately contaminated Tampa Bay and the highly contaminated Hudson-Raritan Estuary and Boston Harbor will be continued. In addition a new survey will be initiated for contaminated coastal waters near Los Angeles in the California Bight. The bioeffects studies in these areas will include:

Tampa Bay--An initial study in this bay in FY90 provided preliminary evidence of contaminant effects in the hardhead catfish. This study will be continued in FY91 and will provide expanded information on the distribution in Tampa Bay of target fishes (both the open-water hardhead catfish and a shallow-water species) and blue crabs exhibiting evidence of contaminant exposure, histopathological alterations, and early biochemical effects. Two further studies will be added in FY91. One will follow up on initial indications from other investigators of contaminant effects in oysters by measuring a number of indicators of oyster relative health at a series of sites along a gradient of contamination in Tampa Bay. The second will carry out a survey of sediment biotoxicity at a number of sites in Tampa Bay. It will particularly investigate sediment toxicity in those part of Tampa Bay in which previously measured concentrations of certain contaminants have been found to exceed postulated effects thresholds for animals exposed to sediments (Long and Morgan, 1990). This survey will use bioassays tests employing an echinoderm (sea urchin), a crustacean (Ampelisca abdita), and a mollusc (oyster larvae).

Hudson-Raritan Estuary--Work funded in FY90 in the Hudson-Raritan Estuary is measuring a number of bioindicators of reproductive impairment in winter flounder, acute sediment toxicity to several indicator organisms, contaminant trends in sediment cores, and ambient water toxicity of copper and zinc at various sites in this estuary. These studies are still in progress and will be continued during FY91 with no further funding. One additional study will be added in this estuary for FY91 to investigate the occurrence of sublethal indications of sediment toxicity. This study will employ sediment bioassays of growth in a polychaete (Armandia) and an echinoderm (sanddollar). It is believed that these tests can provide indications of the long-term cumulative toxicity effects of sediments to supplement and augment the information on acute toxicity already being acquired.

Boston Harbor--Bioeffects studies concerning sediment toxicity and reproductive impairment of fish (winter flounder) and molluscs (mussels) in Boston Harbor have already been carried out using NOS/OMA base funds. A study expanding the work commenced in FY90 concerning reproductive impairment in mussels will be conducted in FY91. This study will examine the relationship between bioconcentration levels of lipophilic organic contaminants and measures of effects on reproductive processes in mussels from sites in Boston Harbor and Buzzards Bay

Southern California--A new bioeffects survey will be initiated in Southern California coastal bays and estuaries in the vicinity of Los Angeles during FY91. This work will be coordinated with a new State of California program to develop and test assessment tools for marine and estuarine sediment quality. The California program will include surveys of sediment toxicity and contaminant distributions in sediments and measures of biological response to contaminants in bivalve molluscs (both indigenous and caged). Through participation in the planning for, and subsequent cooperation with, the California program, NOAA can greatly increase the expected value from our projected level of effort in this region.

Past work in the Southern California Bight has indicated a variety of biological responses to contaminants, especially in the vicinity of Palos Verdes and San Pedro Bay. Hepatic multi-function oxydase (MFO) activities have been found to be elevated in white croaker from these regions compared with fish from Dana Point (Cross and Hose, 1987); also elevated hepatic glutathione levels in sculpins and other species relative to those found in Santa Monica Bay have been detected (Brown et al.,1987). Female white croaker and kelp bass from San Pedro Bay both have shown reduced rates of spawning in response to gonadotropin injection, decreased fecundity, and reduced fertilization success, compared to reference fish from Dana Point (Cross and Hose, 1988, 1989; Hose et al., 1989).

It is proposed to further evaluate the spatial extent of contaminant bioeffects in fish and to confirm the relationship of any reproductive detriment to contaminants. One of more species of territorial inshore species of fish will be collected from selected coastal lagoons and bays at several locations along the coast between San Diego and Los Angeles. Spawning success will be correlated with other direct measures of contaminant exposure and response, including fluorescent aromatic compounds in bile, hepatic MFO activities and glutathione levels, DNA adducts, and liver histopathologies. Levels of organic contaminants will also be measured in the livers and gonads of these fish.

The State of California is presently designing an extensive survey of sediment toxicity and contaminants in coastal areas statewide. The NOAA project on bioeffects in fish will select sampling locations in the Southern California Bight to coincide with some of those in the broader state survey, in order to take advantage of that extensive source of data.

Element B: Develop New and Improve Existing Methods for Quantifying Bioeffects of Toxics

At present, the NS&T monitoring program measures the concentrations of a relatively large number of contaminants in biota and sediments, but includes only a few routine measurements of indicators of biological effects. Further, the biological effects measured in the NS&T Program include some relatively severe effects, such as liver lesions in benthic fishes and mortality of organisms (e.g., amphipods) exposed to sediments in acute bioassays. While these measurements have considerably enhanced our understanding of the potential impact of pollutants on aquatic ecosystems by linking the presence of certain contaminants to observed biological effects, these biological effects generally occur only in highly contaminated environments and hence cannot be used either to distinguish among organisms exposed to moderate, low and no contamination or to predict deterioration of environmental quality.

This lack of sensitive biological indices to assess environmental quality has led to considerable interest in gaining a better understanding of the underlying mechanisms that govern contaminant-induced alterations in marine organisms and evaluating a suite of indices that measure contaminant-induced alterations in marine organisms. These indices are defined as bioindicators and they include measurements of contaminant exposure and responses at the biochemical, physiological, and organismal level. Measurements of contaminants and their metabolites in tissues and fluids of organisms are also defined as bioindicators of exposure because biochemical and physiological processes within an organism influence both the level and distribution of these compounds.

Important factors supporting the use of bioindicators as an effective means of improving aquatic environmental monitoring strategies are that (a) measurements can be made on indigenous organisms; (b) the concurrent use of several relatively inexpensive tests should provide a better assessment of stress from exposure to complex mixtures of xenobiotic compounds present in contaminated environments than measurement of a single indicator; and (c) with further knowledge, biochemical and physiological indices may serve as early-warning signals of population or community effects. However, prior to inclusion of any bioindicator in a large-scale monitoring program, it should be (a) shown to be linked to contaminant exposure; (b) tested in the laboratory to establish the range of sensitivity by conducting dose- and time-response studies; and (c) validated in small-scale field studies with one or two well-understood species.

Studies will be conducted under this element in FY91 in two major categories: 1. To test the applicability of recently developed

bioindicators in target fish species of NOAA's National Status and Trends Program. These bioindicators are: hepatic aryl hydrocarbon hydroxylase (AHH) activity, levels of DNA-xenobiotic adducts in liver, and levels of fluorescent aromatic compounds (FACs) in bile.
2. To develop and evaluate new bioindicators of contaminant exposure and effects in fish species for incorporation in the assessment of environmental quality. The bioindicators to be investigated include indices of oxidative damage, altered immunocompetence, and altered heme metabolism. These studies are designed to expand the suite of bioindicators in fish available for use in biomonitoring programs such as the NS&T Program or EPA's Environmental Monitoring and Prediction Program (EMAP), with emphasis on identifying bioindicators that may be directly linked to serious biological effects. A research proposal describing the experimental design during the first three years of this project has been prepared and peer-reviewed by two outside academic reviewers and by reviewers from inside NOAA. All reviewers gave the proposal high marks and several helpful suggestions were received and are being incorporated.

Briefly, three bioindicators have been recently developed for use in the Benthic Surveillance Project of the NS&T Program to assess contaminant exposure and effects in bottomfish. Levels of FACs in bile have been measured in every Cycle of the Benthic Surveillance Project thus far, and hepatic activities of AHH have been measured beginning in Cycle V (1988). The measurement of FACs is useful because it provides an estimation of exposure to aromatic compounds, such as aromatic hydrocarbons, which usually cannot be measured directly in tissues because of extensive and rapid metabolism of these compounds by fish (Krahn et al., 1986; Varanasi et al., 1989b). Hepatic AHH activity is a sensitive indicator of exposure to a variety of chemical contaminants, including aromatic hydrocarbons, chlorinated hydrocarbons, dioxins, and petroleum compounds, and represents a very early physiological response to such exposure (Payne et al., 1987). Additionally, during the metabolism of xenobiotic chemicals, such as polycyclic aromatic hydrocarbons (PAHs), reactive metabolites are formed that can covalently bind to the genetic material, DNA, to form DNA-xenobiotic adducts. Recently, a very sensitive technique (^{32}P-postlabeling) has been developed (Gupta and Randerath, 1988) and shown to be able to detect DNA-xenobiotic adducts in feral fish (Dunn et al., 1987; Varanasi et al., 1989c; Stein et al., 1989). The measurement of these adducts provides an assessment of exposure to genotoxic compounds, and because this type of DNA damage can be linked to more severe biological effects, such measurements may be very important in establishing causal relationships between contaminant exposure and damage to living marine resources (Stein et al., 1989; Schiewe et al., 1990).

To date, results from the use of bioindicators in the Benthic Surveillance Project (FACs and AHH) have shown that these two indicators are generally responsive to contaminant exposure of target fish species, but there appear to be substantial species differences in the magnitude of the responses (Varanasi et al., 1988 and 1989a; Collier et al., 1989). Each of these measures has been shown to be increased in one target species (English sole) after exposure to organic solvent extracts of a contaminated sediment, in a time- and dose-responsive manner (Collier and Varanasi, 1987), but the responses of other target species used in the NS&T Program have not been similarly tested. Similarly, levels of DNA-xenobiotic adducts in English sole have been shown to increase after exposure to extracts of contaminated sediments (Varanasi et al., 1989c). However, time course and dose-response data are still needed for this species, and hepatic DNA adducts have not yet been examined in the other Benthic Surveillance target species. Only through the use of data obtained from detailed studies relating time- and dose-response to chemical contaminants can results from different species be usefully compared in the Benthic Surveillance Project. Accordingly, a major initial effort under this element will involve the systematic validation and comparison of these recently developed bioindicators in fish species.

It is also desirable to increase our suite of available bioindicators for use in biomonitoring programs by developing bioindicators that are more specific for certain types of biological effects than those currently in use, or which provide information about differing mechanisms through which biological damage may occur. Such effects include alterations in immunocompetence, early indications of cellular injury; changes in heme metabolism, which may lead to porphyria; or measures of oxidative damage from metabolic formation of reactive oxygen species.

The reason so few bioeffects measurements have been included to date in the Monitoring Program to assess environmental quality is largely that only a few measures have been clearly shown to be reliable indicators of the level of exposure or response of organisms to toxic contaminants. The work proposed in this element is aimed at identifying improved bioindicators of toxic contamination for implementation in large-scale biomonitoring programs. The emphasis will be placed on developing additional indicators of subtle, adverse biological effects that result directly from contaminant exposure. Moreover, the determination of multiple bioindicators of exposure and effects should provide better cause and effect linkages which will be invaluable in understanding the susceptibility or resistance of different species to contaminant-induced effects (Varanasi et al. 1991). Making exposure and effect measurements in the same organisms will enhance our ability to develop statistical models to assess if a certain level of contaminant exposure is predictive of a certain biological response or perturbation in the exposed population.

Element C: Establish Links Between Contaminant Exposure and Significant Biological Effects

NOAA's ongoing national environmental monitoring programs have found that urbanized and industrialized estuarine and coastal areas have high concentrations of contaminants in their sediments and in the tissues of the organisms which inhabit these affected regions. In some of the highly contaminated areas, resident species are showing signs of impaired health which appear to be caused by chronic exposure to contaminants. Studies have equated chemical contaminant exposure to growth inhibition, organ dysfunction, and reproductive impairment. And in some locations, contaminant levels are sufficiently high to cause mortality to primary prey organisms (copepods) (Sunda et al., 1990). Significant declines in estuarine populations are believed to be related to the combined effects of chemical pollution, habitat loss and degradation, harvesting practices, and other factors. The bioeffects research described here is aimed at understanding the role chemical pollution plays in this overall problem.

Bioeffects Research under Element C seeks to relate concentrations of toxic chemicals in the near coastal ocean environment to effects on marine organisms. A primary need is to gain a sufficient understanding of how contaminants affect key species at critical points in their development and their reproduction. Studies will be undertaken to develop an understanding of the processes that link chemical contaminants to biological effects at the individual organism level. Results from such studies should eventually enhance our ability to assess and predict the effects of a broad spectrum of chemical contaminants on populations of key marine species and their associated communities. It will provide environmental managers with scientifically valid information for decision making.

Funding of research under this element will be initiated in FY91 and will aimed at establishing linkages between contaminant exposure and significant biological effects in individuals. Even though the ultimate goal of contaminant research is to demonstrate effects at the population or ecosystem level, it is first necessary to establish the mechanisms and sequences of events required to produce demonstrable effects in individuals. Therefore, the primary effort within this element will be to establish relationships between the environment, contaminant exposure, and biological processes in marine biota. Research should be concentrated on measuring effects in individuals that appear most likely to have implications at the population level, namely, studying parameters that affect survival, growth, and reproduction.

For FY1991, funding will be limited to species and locales for which there is already ample documented evidence of biological effects occurring (i.e., lesions, disease, DNA damage, reproductive impairment, abnormal behavior) and for which there is a reasonable suspicion (but not necessarily a firm link) that the observed effects are related to contaminant exposure. For these species, some field and/or laboratory studies should have already been done which correlate pollutants to specific biological effects.

Three parameters that are measurable at the individual level which seem most likely to cause widespread, deleterious population effects are decreases in: **growth, fecundity,** and **survival.** Accordingly, the program element will be structured as a series of research studies that are designed to flesh out the conceptual model given below.

CONTAMINANT EXPOSURE

- Bioindicators of exposure

EARLY WARNING RESPONSES

- Bioindicators of stress

BIOLOGICAL EFFECTS

- impaired growth
- impaired fecundity
- decreased survival

Successful measurement of processes and and parameters that establish links between contaminant exposure and the above three biological endpoints, either directly or indirectly by studying for effects such as diseases, reproductive dysfunction,disease resistance etc, will drive the design of research projects. This element will strive to embrace studies on a variety of vertebrate and invertebrate species at different stages of their development and from a variety of geographic locations. It is critical to understand the processes that control these endpoints at the level of the individual before we can even begin to evaluate the impacts of altered survival, fecundity, or growth in the context of populations or ecosystems.

As discussed below, a variety of studies could be conducted under the overall structure of this element. However,limited funding in FY1991 for this element will allow initiation of only a few of these studies:

-- perform environmentally relevant dose/response experiments to establish the cause-and-effect relationship between contaminants and biological effects.

-- determine the long term effects, if any, of a brief pulse of contaminant exposure on migratory species(e.g., salmon) during an early life stage.

-- determine the varying sensitivities to exposure of an organism at different stages in its life cycle, with an emphasis on early life stages.

-- determine which parts of the reproductive process may be impaired due to contaminant exposure (i.e., gonadal maturation, hormonal regulation, fecundity, spawning, and egg/larvae survival) to develop an understanding of the physiological or molecular mechanisms by which it occurs.

-- determine cause and effect relationships between reproductive impairment and the uptake (bioaccumulation) and fate (bioconversion) of toxic contaminants.

-- determine how the timing, duration, and sequencing of reproductive events are impaired by contaminant exposure for selected commercially and recreationally important estuarine fish.

-- determine the hatchability, viability, and survivability of offspring from contaminated sites as related to the body burden of contaminants in the tissues of spawners.

-- assess effects on subsequent generations (filial effects)

-- _in situ_ environmental chamber studies to determine factors affecting growth and survival of the early life stages of key species (to link laboratory and field research).

The research conducted under this element will produce an information base that could be used to identify and predict significant toxic chemical contamination problems in coastal environments. While there are at present no established cases where fish population variations can be clearly attributed to contaminant inputs, it is believed that such declines could be occurring. One way to test for population-level effects is through checking within a single species for large alterations in individual members' growth, fecundity, and survival. These endpoints may serve as measurable indices of that species' overall well-being within the affected habitat. It is hoped that eventually these studies will begin to address this important issue of populations effects in at least a few resource species. By understanding these linkages one can begin to identify and restore areas showing substantial degradation by contaminants. One may also be able to identify high risk areas showing early warning signs of effects which therefore should receive rapid attention to mitigate further damage.

Well conceived and executed research under this element C, combined with data generated from elements A & B should assist in the development of alternative management schemes to reduce pollution and to make recommendations for restoration efforts.

PRODUCTS

Element A--The bioeffects surveys are composed of a number of separate studies documenting various aspects of the magnitude and extent of contaminant bioeffects in each of the areas of concern. A number of reports and articles describing the results of these individual studies will be published, primarily in peer-review journals. At the completion of the survey in an area of concern, a NOAA Technical Memorandum report will be published focusing on that area and summarizing the results and conclusions from the studies conducted there and assessing our knowledge concerning magnitude and extend of the biological effects due to toxic contaminants. These summary reports will undergo thorough peer review by reviewers from both inside and external to NOAA. Synthesis reports assessing the national extent of environmental degradation due to toxics will be published when all or almost of the primary regions of concern have been surveyed.

Element B--The bioindicator research will result in the development and evaluation of new and improved bioindicators for assessing contaminant exposure and associated effects on individual organisms and on populations of living marine resources in U.S. waters. Peer-reviewed NOAA reports and scientific articles in peer-review journals documenting the development of these indicators, specifying how they should be measured, and evaluating their utility will be produced.

Element C--The research on the links between exposure and effects will be conducted as a number of separate research projects, and these will lead to the publication of peer-reviewed scientific articles and reports. Periodically the participants in the activities of the Toxics Chemical Contaminants Theme will cooperate to develop summary reports on the status of the research and assessment being conducted in this theme area and to recommend priorities for the future directions of work.

DATA MANAGEMENT

Element A--The intensive bioeffects surveys will collect data on fish and invertebrate reproductive properties, prevalence of DNA adducts, acute and sublethal sediment toxicity, biochemical indicators of stress, and other biological properties as well as on bioaccumulation and sediment levels of chemical contaminants. The principal investigator for each one of the studies conducted as part of these surveys will be the primary contact for these data. The data will be available within two years of the completion of the field work and will be maintained by the principal investigator. The data will also be included in the final reports from the studies. After submission of these final reports, NOS/OAD will maintain copies and will make copies available on request.

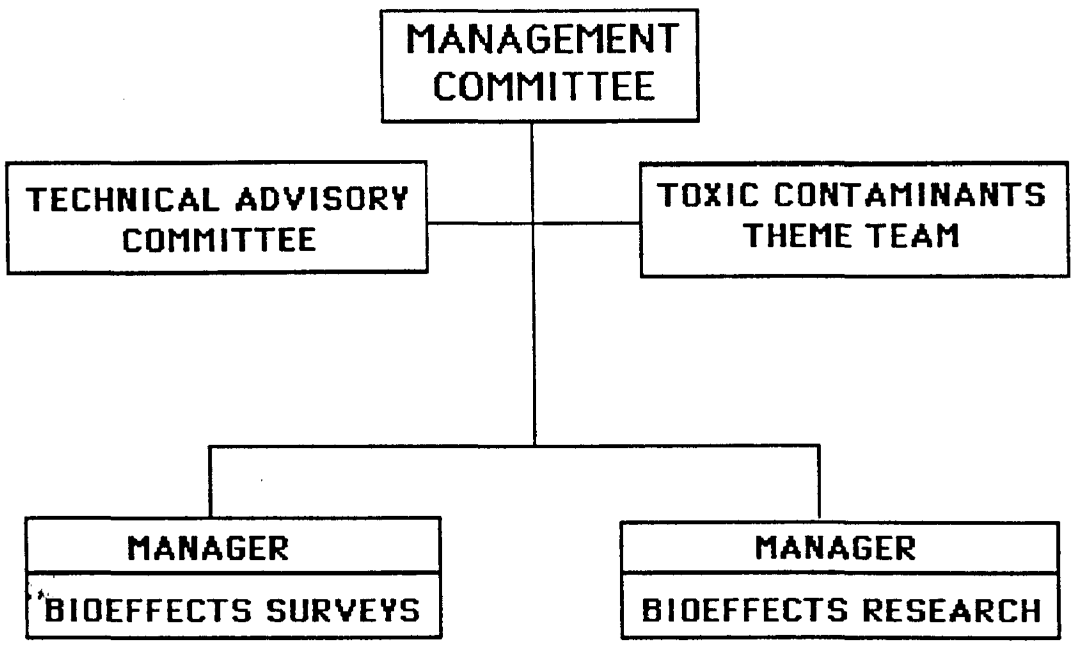
Element B--The data collected from the studies to develop new and improve existing bioindicators will be primarily laboratory results measuring such properties as the levels of hepatic aryl hydrocarbon hydroxylase activity, DNA-xenobiotic adducts in livers, and fluorescent aromatic compounds in bile from winter flounder, Atlantic croaker, and white croaker. The principal investigator (Environmental Conservation Division, NWFC) for this study will be the primary contact for these data. These data will be available within one year of the completion of the dose-effect laboratory studies and will be maintained by the principal investigator. The data will be included in the reports from this work and copies of these reports will be available on request from the principal investigator.

Element C--The data collected in the research to establish links between exposure and effects will be defined in the proposals for work in this area. Funded principal investigators will be required to submit their data in a final report within one years of completion of their studies and copies of these final reports will be available from the Program Office in NOS/OAD.

Data management in all the studies outlined in this plan will be handled as an integral part of the studies and will not be funded separately. The number of data points gathered by any one study will be relatively few and will measure a number of properties; further the properties measured will be differ among the studies. Thus, it is more efficient to integrate data management into the individual studies rather than to have it handled as a separate component across the theme area.

PROGRAM MANAGEMENT

The final management responsibility for planning and carrying out the Toxic Chemical Contaminants Theme program is with both the Assistant Administrator for Ocean Services and Coastal Zone Management and the Assistant Administrator for Fisheries. To carry out these responsibilities, the management structure in the following diagram has been established.



The composition and responsibilities of the components in this structure are:

Management Committee--This three-person committee is composed of the cochairs of the Theme Team, one from NMFS and one from NOS, plus a representative from the scientific community external to NOAA who is an expert in the area of contamination of the marine environment by toxic chemicals. This non-NOAA member is selected by the Theme Cochairs in consultation with the Director of the Coastal Ocean Program Office. The Management Committee is responsible for overall management of the Toxic Chemical Contaminants Program including: (1) setting and revising guidelines for the general direction of the Program, (2) developing and submitting to the Coastal Ocean Program Office the long-term and the annual implementation plans for the work in this Program, (3) obtaining scientific review of studies proposed in the Program, (4) making decisions concerning funding for the studies conducted by the Program, (5) providing broad oversight of the funded studies to assure satisfactory progress, and (6) carrying out periodic reviews of overall program progress. The Management Committee reports to the Assistant Administrator for Ocean Services and Coastal Zone Management, the Assistant Administrator for Fisheries, and to NOAA's Coastal Council, and is the interface between the Toxic Chemical Contaminants Theme of the Coastal Ocean Program and the Council.

<u>Toxic Chemical Contaminants Theme Team</u>--This team is composed of NOAA scientists and scientific managers who are actively involved in programs related to toxic chemical contaminants. They are selected by and represent their NOAA line offices on the team. The primary function of the team is to provide advice and guidance to the Management Committee. It assists in the long-term planning for the program and in providing recommendations on the specific types of studies that should be conducted. The team members provide input to the Program regarding the interests of their Line Office and its scientists in participating in the Toxics Program and also provide information about the Program to interested persons within their offices.

<u>Technical Advisory Committee</u>--This committee is composed of five scientists/scientific managers from <u>outside of NOAA</u> who are experts in the area of contamination by toxic chemicals in the marine environment. It is chaired by the non-NOAA member of the Management Committee, and its members are selected by this committee in consultation with the Director of the Coastal Ocean Program Office. This Technical Advisory Committee reviews, and provides advice on how to improve, the overall scientific quality of the Program. More specifically it also reviews and evaluates all in-house NOAA studies both as these are being proposed for inclusion in the Program and as they are being conducted. It provides its evaluations and recommendations on these studies to the Management Team, and the Team will not approve funding for studies judged to be of poor scientific quality by the Technical Advisory Committee.

3rd!

Bioeffects Surveys and Bioeffects Research Projects--The Toxic Chemical Contaminants Program is subdivided into two major projects that are managed separately. One project is responsible for the Bioeffects Survey component of the Program (Element A), while the second is responsible for the Bioeffects Research component, which includes the studies concerned with developing new and improved indicators of biological effects (Element B) and those directed at obtaining the linkage between exposure and these effects (Element C). Both projects are directed by a project manager selected by the Management Committee. Projects may be redefined, added, or subtracted in future years as deemed appropriate by the Management Committee in consultation with the Theme Team and the Coastal Ocean Program Office. Funds allocated for each of the projects are to be distributed to appropriate Project Manager's Line Office for disbursement. The Project Managers for the Bioeffects Survey and Bioeffects Research Projects are presently the NOS and NMFS cochairs of the Management Committee, respectively. The project managers have responsibility for the detailed management of their projects. They develop guidelines and specifications for the studies to be conducted in their project, obtain proposal for carrying out these studies, and provide recommendations to the Management Team as to which proposals to fund and the levels of funding required. They assure peer-review of all proposed research studies, including at least two reviews from outside of NOAA for each proposal. They provide support to the Technical Advisory Committee in its assessment of the scientific quality of all studies conducted in-house by NOAA. They oversee evaluation and review of the studies in their project and provide assessment to the Management Team and Coastal Council on these matters as appropriate.

The procedures used to plan and implement the studies in the each of the three elements are as follows: Element A (Bioeffects Surveys): The first step in planning a survey is to develop a report summarizing and synthesizing the existing information on occurrence and distribution of toxic contaminants and associated biological effects in the specific survey area. A survey proposed to be conducted in that area is then planned based on this summary and in close consultation with scientists and resource managers who have experience in the specific geographical area. The plan for each area is sent to scientific and resource management experts in the geographical area under consideration for their review and is revised based on this review. At least once a year, the Technical Review Committee reviews the overall scientific competence and relevancy of the studies carried out in this element. Element B (Bioeffects Indicator Development): To take advantage of NOAA's extensive experience and interest in development of bioindicators, the studies in this element are carried out by scientists from within NOAA, although subcontracting to other organizations is encouraged as appropriate. All proposed studies are reviewed both through peer-review (at least two outside NOAA reviewers) and by the Technical Review Committee. Element C (Bioeffects Research): The research studies concerning the linkage between contaminant exposure and bioeffects (Element C) is carried out through a competitive proposal procedure. An RFP detailing the scientific area of interest and the criteria by which proposals will be judged is developed and distributed. The proposals received are peer-reviewed (at least two outside NOAA reviewers) and the Management Team makes the final selections based on the peer-review and the recommendations of the Project Manager.

REVIEW

Proposals for research studies to be conducted in this theme area are peer-reviewed, including at least two reviews from outside NOAA. The peer reviewers are asked to evaluate the proposals for intrinsic technical merit relative to the following concerns: (1) applicability of the proposed study toward meeting the theme and project objectives, (2) use of the best available data and information for planning and conducting the study, (3) appropriateness and scientific validity of proposed research design and testing methodologies, and (4) background, experience, and scientific competence of the proposed investigators to carry out the proposed study. For the parts of the Program where substantial numbers of proposals are expected a Proposal Review Panel is established comprised of distinguished scientists external to the Program. These panels evaluate the scientific merit of the proposed research and advise the Project Manager and the Management Committee on the merits of and modifications recommended for the submitted proposals. In FY91 it is the intent to establish such a panel for the proposals received to carry out studies under Element C. The Project Managers will make recommendations on funding decisions in their respective projects to the Management Committee based on the results of these reviews and on the cost effectiveness of the proposed studies. Proposals with cost sharing, matching funds, or other mechanisms to increase cost effectiveness in the use of the Coastal Ocean Program funds will be especially encouraged.

In addition to the peer review of proposals, the program in this theme area will be reviewed periodically by a panel of outside experts to evaluate the scientific competence and relevance of the work being conducted. These reviews will be held approximately biennially and will be organized by the Management Team in conjunction with the Technical Advisory Committee.

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PROGRAM BUDGET (Dollars in thousands)

	FY91	FY92	FY93	FY94	FY95
Element A--Bioeffects Surveys	750	900	1200	1500	1500
Element B--Bioindicator Develop.	400	600	1100	1400	1500
Element C--Effects Research	350	700	1400	2400	4000
Element D--Intake/Bioaccumulation Research	0	300	800	1400	2000
TOTAL	1500	2500	4500	6500	9000

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Fisheries Science Center
Environmental Conservation Division
2725 Montlake Boulevard East
Seattle, Washington 98112

April 11, 1991

MEMORANDUM FOR: Coastal Ocean Program Toxics Theme Team

FROM: Usha Varanasi, Project Manager, Bioeffects Research

SUBJECT: Final Implementation Plan/ Announcement of Availability of Funds

Enclosed you will find copies of:

- The final FY91 Implementation Plan Contract for the Toxic Chemical Contaminant component of NOAA's Coastal Ocean Program as it was signed by Don Scavia.

- Our "Announcement of Availability of Funds" for Bioeffects Research (Element C) as it was sent off today to NMFS Center Directors and to Bill Graham at Sea Grant headquarters for broad academic distribution.

As outlined in the announcement, 2-3 page "planning letters" are being requested of all interested applicants by no later than May 10th. It will be interesting to see what kind of response we get. Please feel free to make extra copies of the announcement for additional distribution.

Enclosures

cc: Andrew Robertson
Peter Landrum
Anders Andren
Margrita Conkright
Thomas O'Connor
David Engel
Tom Siewicki
Stanley Rice
Fred Thurnberg
James Chambers

ANNOUNCEMENT OF AVAILABILITY OF FUNDS
Coastal Ocean Program
Toxic Chemical Contaminants Theme Area
Bioeffects Research

I. Introduction/Background

NOAA's ongoing national environmental monitoring programs have found that urbanized and industrialized estuarine and coastal areas have high concentrations of chemical contaminants in their sediments and in the tissues of the organisms which inhabit these affected regions. In some of the highly contaminated areas, resident species are showing signs of impaired health which appears to be caused by their chronic exposure to contaminants. A number of studies have equated chemical contaminant exposure to growth inhibition, organ dysfunction, and reproductive impairment. And in some locations, contaminant levels are sufficiently high to cause mortality to primary prey organisms. Significant declines in estuarine populations are believed to be related to the combined effects of chemical pollution, habitat loss and degradation, harvesting practices, and other factors. The bioeffects research described in this Announcement of Availability of Funds is aimed at gaining a better understanding of the specific role chemical pollution may play in this overall problem.

Research solicited under this announcement seeks to establish linkages between exposure to toxic chemicals in the near coastal ocean environment and significant biological effects on marine organisms. A primary need is to gain a sufficient understanding of how contaminants affect key species at critical points in their development and their reproduction. There is a need for research studies to be undertaken that will develop an understanding of the processes that link chemical contaminants to biological effects at the individual organism level. Results from such studies should eventually enhance the ability to assess and predict the effects of a broad spectrum of chemical contaminants on populations of key marine species and their associated communities. This in turn will provide environmental managers with scientifically valid information for decision making.

II. Guidance

Funding for Bioeffects Research under this announcement will be $350,000 in FY1991 and is anticipated to grow in FY1992. This announcement requests proposals for research to begin on or about October 1, 1991. Funding will thereafter be determined annually. However, projects of up to 3-years duration will be considered. Funding after the initial year will depend on satisfactory progress and Congressional appropriations. Cooperative proposals between NOAA scientists and academic investigators are encouraged. However, proposals solely involving investigators from academia or from NOAA laboratories are not precluded.

It is anticipated that the typical proposal award for FY91 will be about $75,000.

III. Areas of Interest: 1991-1992 Program Years

For FY1991, research funding will be limited to species and locales for which there is already ample documented evidence of biological effects occurring (e.g., lesions, disease, DNA damage, reproductive impairment, abnormal behavior) and for which there is a reasonable suspicion (but not necessarily a firm link) that the observed effects are related to contaminant exposure. For these species, some field and/or laboratory studies should have already been done which correlate pollutants to specific biological effects.

Research will be aimed at establishing linkages between contaminant exposure and significant biological effects in individuals. While the ultimate goal of this program is to demonstrate effects at the population or ecosystem level, it is first necessary to establish the mechanisms and sequences of events required to produce demonstrable effects in individuals. Therefore, the primary effort within the scope of this theme area will be to establish relationships between environmental contaminant exposure and biological processes in marine biota. Research should be concentrated on measuring effects in individuals that might have implications at the population level. Three parameters or endpoints measurable at the individual level which appear most likely to cause widespread, deleterious effects among populations are: **impaired growth, impaired fecundity,** and **decreased survival.**

<u>Proposed research projects that seek to measure processes and parameters that establish links between contaminant exposure and one or more of the above three biological endpoints, either directly or indirectly, are especially encouraged.</u>

Examples of the types of studies sought for this announcement are listed below. This is not a complete list, and proposals suggesting alternative projects are welcome.

(1) Environmentally relevant dose/response experiments to establish cause-and-effect relationships between contaminants and biological effects.

(2) Studies to determine the long term effects, if any, of a brief pulse of contaminant exposure on migratory species (e.g., salmon) during an early life stage.

(3) Studies to determine the varying sensitivities to exposure of an organism at different stages in its life cycle, with an emphasis on early life stages.

(4) Studies to determine which part(s) of the reproductive process may be impaired due to contaminant exposure (e.g., gonadal maturation, hormonal regulation, fecundity, spawning, and egg/larvae survival), and to elucidate the physiological or molecular mechanisms by which such impairments occur.

(5) Studies to identify possible cause-and-effect relationships between reproductive impairment in fish and invertebrates and the uptake (bioaccumulation) and fate (bioconversion) of toxic contaminants.

(6) Studies to determine how the timing, duration, and sequencing of reproductive events may be impaired by contaminant exposure in selected commercially and recreationally important estuarine fish.

(7) Studies to assess possible effects on subsequent generations (filial effects).

(8) In situ environmental chamber studies to determine factors affecting growth and survival of the early life stages of key species (to link laboratory and field research).

III. Results of Studies/Products

Research on the links between exposure and effects will be conducted as a number of separate projects which will lead to the publication of peer-reviewed scientific articles and reports. On a regular basis, participants in COP's Toxics Chemical Contaminants Theme Area will cooperate to develop summary reports on the status of their research and to recommend priorities for future studies.

Funded Principal Investigators (P.I.s) of multiyear projects will be required to submit annual progress reports, and all funded P.I.s will be required to submit a final report including their data within one year of completion of their studies. The research conducted under this announcement will produce an information base that may be used to identify and predict significant toxic chemical contamination problems in coastal environments, including those requiring rapid attention to mitigate further damage.

IV. Planning Letter Submission

The proposal submission process will take place in two stages:
(1) Applicants must submit a 2-3 page **planning letter** to the **Bioeffects Research Project Manager** (see Section IX for address). Planning letters should be single-spaced and typewritten on 8 1/2 x 11 inch paper. They should include intended research plans and justify their significance with respect to the interest areas described herein. A budget sheet and curriculum vitae of the P.I.(s) should be attached. All planning letters will be reviewed and the applicants will be notified of their status within several weeks of submission.

(2) Applicants whose planning letters are selected will then be asked to submit more detailed **research proposals.** These proposals will be directed at describing specific research plans and exact technical approaches. Sets of proposal guidelines will be sent to successful planning letter applicants upon notification of their acceptance at the planning letter stage.

V. Proposal Submission and Evaluation

In stage two of the evaluation process, research proposals (subsequent to planning letter acceptance) will be submitted to a **Toxics Proposal Review Panel** and rated for their intrinsic technical merit relative to the following concerns: (1) applicability of the proposed study toward meeting the project's objectives, (2) use of the best available data and information for planning and conducting the study, (3) appropriateness and scientific validity of proposed research design and testing methodologies, and (4) background, experience, and scientific competence of the proposed investigators to carry out the proposed study. Proposals with cost sharing, matching funds, or other mechanisms to increase the cost effectiveness in the use of the Coastal Ocean Program funds will be especially encouraged. The Toxics Proposal Review Panel will evaluate all submitted proposals and advise the **Toxics Program Management Committee (PMC)** on the merits of and modifications recommended for such proposals. In addition, the **Toxics Technical Advisory Committee (TAC)** (composed of five scientists/scientific managers from outside of NOAA) will review the overall scientific quality of all research proposed under the Toxics program area and will evaluate all in-house NOAA proposals.

VI. Selection Criteria: FY1991

(1) For FY1991, funding will be limited to species and locales for which there is already ample documented evidence of biological effects occurring (e.g., lesions, disease, DNA damage, reproductive impairment, abnormal behavior). Consideration will be only given to proposals for species and locations with previously observed problems.

(2) In addition, there must be a reasonable suspicion (but not necessarily a firm link) that the observed effects are related to contaminant exposure. For these species, some field and laboratory studies should have already been done which correlate pollutants to specific biological effects (i.e., cause-and-effect studies).

(3) The proposal should show promise of establishing linkage between contaminant exposure and at least one of the three major endpoints: **growth, fecundity,** or **survival.** (see Section III.)

(4) The proposal should build on existing knowledge and embrace a "holistic approach;" i.e., there is a preference for multidisciplinary teams working together.

(5) NOAA/University cooperative projects are encouraged.

(6) Encouragement is given to formulate proposals that show matching funds or cost-sharing.

VII. Obligations of Principal Investigators

Investigators funded under the Toxic Chemical Contaminants Theme Area must agree to undertake the following:

(1) Participate in annual meetings of P.I.s for planning and coordination of program activities, and in developing summary reports on the status of the research and assessment being conducted in this theme area, including the recommendation of priorities for the future directions of work.

(2) Perform quality control checks on data and make them available through the program data management system to other investigators in the program to further common program objectives.

(3) Participate in the synthesis and interpretation of research results and the development of products of value to environmental managers.

(4) Publish research results in the peer-reviewed literature for the benefit of the marine toxicology scientific community.

(5) Produce annual progress reports.

(6) Submit their data in a final report within one year of completion of their studies and copies of these final reports will be available from the Program Office in NOS/OAD.

VIII. Funding Schedule

- **May 10, 1991** — Deadline for planning letter submission to the Bioeffects Research Project Manager (address below).
- **May 27, 1991** — Completion of planning letter review by Toxics PMC/Toxics TAC. Notification of results to applicants, and requests made for detailed research proposals to successful applicants. (Proposal guidelines sent.)
- **June 18, 1991** — Deadline for research proposal submission to appropriate sponsoring organization and to Toxics PMC.
- **June 22-23, 1991** — Completion of proposal review by Toxics Proposal Review Panel and Technical Advisory Committee. Notification of results.
- **July 1, 1991** — Submission of approved grant proposals to the National Sea Grant Office for processing.
- **July 15, 1991** — Submission to NOAA Grants Office for processing and awarding of grants.

IX. Submission of Planning Letters by May 10, 1991 to:

Dr. Usha Varanasi
Project Manager, Bioeffects Research
Environmental Conservation Division
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, WA 98112
(206) 553-7737/FTS 399-7737

X. Toxics Program Management Committee

Dr. Andrew Robertson
Chief, Ocean Assessments Division
Office of Oceanography & Marine Assessment
National Ocean Service, NOAA
6001 Executive Blvd., Rm.323
Rockville, MD 20852
(301) 443-8933

NOAA COASTAL OCEAN PROGRAM

COASTAL HAZARDS

FY91 IMPLEMENTATION PLAN

March 1991

This Plan represents an agreement between the Coastal Ocean Program Office and the Coastal Hazards Theme line office Assistant Administrators concerning the management and review processes, scientific and operational procedures, products, and budget for implementing this portion of NOAA's Coastal Ocean Program in FY91.

Ned A. Ostenso, Assistant Administrator 3/29/91 **Date**
Office of Oceanic and Atmospheric Research

E.W. Friday, Assistant Administrator 3/29/91 **Date**
National Weather Service

Virginia K. Tippie, Assistant Administrator 3/27/91 **Date**
National Ocean Service

Donald Scavia, Director 3/30/91 **Date**
NOAA Coastal Ocean Program

U.S. Department of Commerce
National Oceanic and Atmospheric Administration

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COASTAL HAZARDS

IMPLEMENTATION PLAN FOR FY91

1.0. Introduction

1.1. Background. In one way or another, U.S. coastal populations, resources, and environments are periodically impacted by extreme natural phenomena, often with resultant loss of life and extensive property damage. Whether they are east coast northeasters, Gulf of Mexico hurricanes, Great Lakes frontal systems, or Pacific coast tsunamis, mitigation of and recovery from the effects of flooding, shoreline erosion, channel and harbor sedimentation, and wave action cost U.S. interests billions of dollars each year.

NOAA's mission to protect life and property has been hindered by the incorporation of improved numerical simulations developed by the research community into operational models for marine warnings and forecasts. In addition, effective management decisions and engineering solutions require a firm understanding of the physical processes affecting coastal evolution, as well as accurate models for predicting the impacts of natural and man-made changes. These inadequacies were identified at a 1989 inter-agency/academia workshop on Coastal Ocean Prediction Systems and recommendations were made to develop and validate a predictive system for the U.S. coastal ocean, including the capability of forecasting the EEZ for several days and of simulating it for several years (Mooers, 1990).

Adequate predictions of coastal winds, waves, and storm surges are indispensable for predicting physical hazards in coastal waters and managing coastal resources. Coastal winds and waves present navigational hazards to ships, cause flood and erosion damage to coastal properties, and destroy living marine resources. Consequently, improved operational models are urgently needed for predicting coastal marine winds and waves and real-time forecasts. These forecasts will help NWS marine forecasters provide more accurate and timely warnings of hazardous conditions to the public, commercial maritime transportation interests, recreational boaters, and other shoreline users. These improvements also will benefit the private atmospheric and oceanographic sectors which furnish specialized products and services to marine interests. In addition, improved knowledge about over-water meteorology and coastal wave conditions will benefit circulation and thermal structure modeling efforts, ecological and environmental modeling and assessment, Coast Guard search and rescue operations, and hazardous spill response efforts.

As noted by an NSF/ONR panel on natural coastal hazards: "**winter storms, hurricanes, tsunamis, ... and other marine hazards have caused heavy loss of life and property on the coasts of the U.S. and at sea.**" (Nath and Dean, 1984). The panel also noted that "**losses can be greatly reduced through better design, construction, and planning**" and "**advances in knowledge were effected by the complexity of the problem and the lack of measurements.**" The panel recommended that "**research is encouraged to reduce the risk to the nation from marine hazards.**"

The impacts of long-term changes in sea level must also be considered. For example, as sea level has risen over the past few thousand years, erosion of the continental margins has increased. Today, extensive media coverage of the problems of our nation's eroding beaches and retreating shorelines, as well as growing expenditures for shore protection, show an increasing public concern about coastal erosion. The level of this concern has been increasing recently for two reasons.

First, coastal areas have become much more highly urbanized. About half the U.S. population presently resides in coastal areas, and by 2010 the coastal population will have grown from 80 million people to over 127 million (Culliton, et al, 1990). Consequently, the actual and potential economic impacts of inundation and erosion on coastal life and property are enormous. Difficult management decisions are made at local, state, and national levels whether or how to stabilize shorelines, implement flood protection works, or plan economic development.

Secondly, sea level changes and storm frequency and intensity are markedly dependent upon changes in large scale weather patterns. Considerable emphasis also has been placed upon the possibility of man-induced changes to climate and weather. Some attempts are being made to protect beaches and beachfront property, but they are very expensive. In 1987, federal funds for beach erosion projects on the East Coast totaled $500 million, and California recently spent $70 million for seawalls and beach nourishment projects. Yet these projects and other coastal structures are designed today much as they were 50 years ago: with primitive models and intuition. Consider the findings of a recent National Research Council study, "Managing Coastal Erosion," (NRC,1990): **"In order to improve the methodology for assessing beach erosion and the risk of collapse of structures, much more research needs to be undertaken by FEMA and other appropriate agencies, e.g., NOAA and the Corps of Engineers on the following:**

- **o determination of the long-term wave climatology through field data collection programs**
- **o monitoring of beach response to wave climate variations and episodic events**
- **o predictive mathematical and statistical models of probability distribution of shoreline locations"**

Our understanding of coastal winds and waves and their impacts is hindered by insufficient data sets necessary for determining their spatial and temporal variability. Considering the length of the U. S coastline, very few wave data are available to describe spatial and temporal variations in coastal wave climate. The Coastal Data Information System monitors wave conditions at about 20 locations on the west coast (Seymour and Sessions, 1976). NOAA and the Corps of Engineers obtain wave data from very few offshore buoys. Detailed measurements of infragravity waves are almost nonexistent, as are comprehensive long-term mean flow data in the shoreface region.

These data deficiencies have several causes. First, the nearshore environment is extremely inhospitable to instrumentation. Storm waves, biological fouling, sediment movement, and human interference inhibit sampling opportunities. Second, only recently have reliable, accurate sensors been developed for long-term measurements of fluid flow and waves. Third, costs for instrument installation and maintenance are often prohibitive.

A report by the NSF-sponsored Coastal Ocean Processes workshop (NSF, 1989) states, **"less is known about the inner shelf than any other portion of the coastal region, yet it is important for a variety of reasons. At present we are limited by a lack of good observations with which to develop and evaluate models of inner shelf processes."**

1.2. Program Goal. The primary goal of the Coastal Hazards component of the Coastal Ocean Program is to reduce the threat to lives, property and coastal resources through more accurate and timely warnings and forecasts of coastal flooding, extreme winds, and hazardous ocean conditions. This will be accomplished through unified experiments and model development. Quantitative understanding of natural processes will be complemented by improved, time-dependent dynamical models. The improved models will be used to meet NOAA mission requirements for early warning of marine hazards: storm surge and tsunami inundation, potential shoreline erosion, and extreme winds and waves. Existing and newly collected data and model results will provide the information necessary to develop design guidance and formulate management plans for hazard identification and emergency response to reduce the threat of extreme events to coastal populations and property. Specific objectives of each component of the program are given in the appropriate sections below.

1.3. Program Strategy. The Coastal Hazards program is founded upon strong theoretical precepts and models that will be tested and improved through an ordered sequence of process-oriented field experiments. Comprehensive sets of long-term field measurements of the important variables must be developed concurrently to provide statistically valid data to define the forcing/response mechanisms over a wide range of time and space scales. The process is iterative. Theoretical models suggest initial experimental design. The resulting data, in turn, allow more advanced model development, which drives the design of more complex experiments. Thus, it is imperative that linkages between numerical modelers and field and laboratory investigators be extremely close. An important outcome of this process will be the ability to establish requirements for a permanent baseline observing network to initialize and quality control the operational prediction models.

The first priority will be improvements to existing NOAA products (warnings and forecasts) through analysis of existing data, carefully planned observational experiments, and development of numerical algorithms based on our improved understanding of the physics. During FY91, emphasis will be placed on improvements in the quality and timeliness of existing products known to be of great utility to ongoing NOAA missions. Academic input will be solicited to assist in enhancing scientific quality of the work. Once existing products have been improved, the program will shift to the development of new NOAA products which contribute to reduced threats and losses from coastal hazards.

2.0. Program Elements.

During FY91, the initial efforts of the Coastal Hazards component of NOAA's Coastal Ocean Program will address the inundation of low-lying coastal areas from hurricane and extra-tropical storm surges and tsunamis and longer-term variability in sea level and shoreline response to episodic erosional forces. The following sections describe the specific rationale, objectives, approaches, products for each program component.

2.1. Tsunami Hazard Mitigation

2.11. Background. NOAA's tsunami warning system presently provides only one product: time of arrival. Existing estimates of coastal flooding, the primary basis for hazard mitigation planning, are derived from models with uncertain accuracy, leading to confusion and a lack of confidence on the part of decision-makers. If tsunami inundation models are to produce useful flooding estimates, then both the proper model physics and a realistic specification of offshore forcing conditions are essential.

In practice, the offshore conditions are provided by a combined generation/propagation model which first simulates the generation of a tsunami through a specific seismic mechanism at a particular geographical location, then propagates the resulting wave energy to the outer boundary of the site-specific inundation model. The questionable accuracy of this two-step modeling process is directly related to a severe lack of high quality field measurements in the open ocean and at exposed coastal locations. The importance of these data is apparent if one considers NOAA's hurricane storm surge program. In sharp contrast to tsunami inundation products, storm surge flooding predictions are made demonstrably more reliable through comparison with reliable field observations.

In 1986, an observational effort was begun to meet this need, when NOAA implemented a deep ocean tsunami monitoring network of five stations in the northeast Pacific. In 1987, the U.S. Corps of Engineers also agreed to develop tsunami measurement capabilities at six exposed coastal locations along the U.S. west coast and Hawaii, through modifications to their existing Coastal Data Information Program (CDIP) observational network. The annual cost of this combined network is approximately one million dollars.

In 1989, a complementary modeling component was initiated when the NOAA/University of Hawaii Joint Institute for Marine and Atmospheric Research created the JIMAR Tsunami Research Effort (JTRE). The State of Hawaii provided $100,000 to study the tsunami flooding problem and specifically to examine the accuracy of existing inundation estimates for the Hawaiian Islands.

Recently, these combined efforts produced the first comparison of appropriate tsunami measurements and model computations. Exceptionally high quality observations of two very small tsunamis were acquired in the open ocean, providing critically important data for comparison with an existing generation/propagation model. Preliminary results indicated that serious shortcomings exist in our present ability to model tsunami generation by a particular seismic event and then to propagate that energy to a region offshore of a specific coastal site. Since accurate specification of the offshore tsunami wave field is crucial to accurate modeling of coastal inundation, two parallel and complementary activities are essential: a continuous tsunami field observation program and a tightly coupled modeling effort.

2.12. FY91 Objectives. The specific objectives for FY91 are to:

- o collect additional deep ocean and coastal tsunami measurements
- o develop improved tsunami inundation modeling capabilities

2.13. Approach. An integrated approach consisting of complementary observational and model development efforts is planned.

Observations. Siting strategy for deep ocean stations will continue to focus on the Shumagin Seismic Gap, a 400-km wide region in the seismically active Aleutian Trench with high potential for generation of tsunamis threatening Hawaii, Alaska and the U.S. west coast. During FY91, reliability of this observational network will be enhanced through the addition of two deep ocean units to the instrument pool. More instruments are needed to replace aging and unreliable units and eliminate the risky process of rapid refurbishment and re-deployment of carefully calibrated sensors under hectic field season conditions.

The existing near-coast observation sites operated by the Corps of Engineers are primarily the result of ad-hoc hardware modifications and data collection procedures designed to obtain shallow water tsunami measurement capabilities on-line when possible. FY91 efforts will involve development of a technical plan by the contractor (Scripps Institute of Oceanography) for an upgraded system incorporating NOAA requirements for instrument accuracy and collection procedures. Implementation of the plan will also begin in FY91 by upgrading one or more of the coastal measurement stations determined by NOAA to have high priority for accurate tsunami observations.

Modeling. Development of a capability to produce standardized, site-specific inundation estimates requires that fundamental scientific questions regarding model physics and numerical schemes be addressed. In addition, practical concerns must be dealt with, such as the availability and quality of bathymetric data, and criteria for estimating the accuracy of inundation estimates. Development of inundation modeling capabilities will focus on Hilo, Hawaii, the U.S. coastal community judged most vulnerable to the tsunami threat, through a competitive peer-review of academic proposals. A letter solicitation (Appendix A) will be sent to the principal U.S. tsunami modelers, proposals will be reviewed by a NOAA/academic review panel, and the top-rated proposal will be funded.

2.14. FY91 Products. Highest priority will be given to improving the reliability and accuracy of the existing tsunami observational network, and to the development of standardized procedures for the production of site-specific tsunami inundation maps. Specifically:

- o Two tsunami measurement systems will be constructed to supplement the existing instrument pool
- o Three oceanographic cruises will be carried out to recover and re-deploy the deep ocean network stations
- o Numerical predictions of tsunami inundation elevations for Hilo, Hawaii will be developed to help in producing maps useful to management and planning agencies.

2.2. Coastal Storm Surges

2.21. Background. For FY91, this component considers the inundation of low-lying coastal areas resulting from storm surges, the rapid and often extreme flooding of coastal areas. Ninety per cent of hurricane related deaths and damage are due to storm surge flooding.

In response to this need, NWS developed the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model in the late 1970's. In FY81, Congress funded a 5-year program to adapt the generalized SLOSH model to vulnerable coastal areas and basins based on their particular physical characteristics. Since that program began, the model has been run with simulations for many hypothetical hurricanes to profile the possible surge flooding in a given basin. Since completion of the 5 year congressional initiative in FY85, a small effort has continued within NWS to improve the SLOSH model and apply it to additional basins.

The Federal Emergency Management Administration relies on SLOSH model results to determine the siting of evacuation shelters and the segment of a basin's population that is at risk from hurricane surge flooding. To date, basic models have been developed for 33 of 39 basins and hurricane simulations have been completed for 17 of the basins.

Extra-tropical storms also generate significant storm surges, especially along the U.S. East Coast, off the Pacific Northwest, and in the Gulf of Alaska. Most damage occurs during the winter when storms often intensify rapidly over near-coastal waters from a combination of terrain effects, air/sea energy exchange, and converging maritime and continental air masses. Such may last for several tidal cycles, producing high waves and water levels.

2.22. Goals and FY91 Objectives. The long-term goals of this component are 1) to develop, calibrate, and verify regional meteorological analysis and prediction models for marine boundary layer winds; 2) to develop, calibrate, and verify models for prediction of wave conditions and hurricane and extra-tropical storm surge; and 3) to implement these models operationally for coastal and Great Lakes regions.

During FY91, the storm surge component will 1) apply the existing SLOSH model to areas urgently requiring inundation predictions for planning evacuation and emergency preparedness plans; 2) improve the model results by continued adaptation to critical segments of the coastline and by incorporating new algorithms for significant physical processes affecting hurricane surge levels; 3) develop new models for predicting surges due to extra-tropical storms. The objectives are to:

- o Develop complete set of hurricane surge scenarios for two additional basins
- o Begin development of a forecast capability for extra-tropical storm surge

2.23. Approach: SLOSH will be adapted to the remaining new basins and updated for past basins to assure that no SLOSH database is over five years old. Early SLOSH models will be enhanced to take advantage of model physics developed after the basin simulation was completed. One additional hurricane simulation study will be completed each year. This work will allow comprehensive evacuation studies to be started in other critical areas. A major consideration is that the model run fast enough on NOAA's computers to allow several SLOSH/SLOSH+wave runs to be made in real-time as a hurricane threatens. The model will, in all likelihood, require a detailed, fine-scale description of the nearshore bathymetry that will be provided by NOS.

During FY91, the systematic update of SLOSH models to keep them current will begin with the updating of two additional basins. The basins selected for updating will be determined based on requirements from the National Weather Service, the Federal Emergency Management Agency, and the U. S. Army Corps of Engineers. All three agencies are closely involved in hurricane evacuation planning for coastal areas.

Extra-tropical storm surge forecasting is also a major thrust for FY91. NWS currently uses a statistical approach for forecasting storm surges along the East Coast. This work was done approximately 20 years ago and is in dire need of updating.
A "perfect prognosis" approach was taken in which statistical relationships were formed by correlating observed water levels with coincident (in time) meteorological analyses. The major drawback of this approach is its applicability only to sites where data has been collected.

The numerical modeling approach to extra-tropical storm surge prediction will begin with the SLOSH model as a basis. An expansion of existing grids along the East Coast will allow coverage of a larger area than is currently used by SLOSH. Existing data from several extra-tropical flooding events and nearshore process experiments will be compiled and analyzed. Analyzed wind and pressure data will be used to drive the numerical model, generating computed values for water levels. Assuming that this test provides acceptable accuracy for the storm surge forecast, the storm surge model will be tested using forecast winds extracted directly from the NWS's numerical models of the atmosphere.

2.24. FY91 Products. FY91 products include updated hurricane surge models for two basins. These models will be available to NHC for real-time hurricane surge forecasting and for use in hurricane evacuation planning through simulation studies.

2.3. Coastal Water Level Variability

2.31. Background. Although longer-term variations in sea and lake levels often exacerbate short-term flooding produced by storms and tsunamis, there has been little documentation of the temporal and spatial variability in coastal water levels. Such information is required to address a host of coastal safety, policy, planning, and operational issues which require an accurate knowledge of past, present and projected variations of water level elevations and coastline positions, e.g. marine boundaries and baselines determinations, coastal protection/erosion policies and programs, statistics of water level variations for planning studies and engineering design, more timely and accurate warnings of inundation hazards, and development of coastal wetland and urban management policies.

2.32. Objectives. The FY91 objectives are

- o to digitize historical data sets of coastal long-term water levels beginning with selected west coast locations
- o to initiate development of U.S. west coast sea level climatology based on existing and newly digitized water level data sets

2.33. Approach. Water Level Climatology and Prediction. For major U.S. coastal regions, a water level climatology will be developed for the coast and offshore waters. It will be based on available observations of water level, weather and offshore oceanic conditions and will characterize the response of water levels to atmospheric and oceanic forcing. Much of the data have been measured over many years, but the older records are hard to use because they have not all been digitized.

The work will determine water level response as a function of frequency and establish the effects of inter-annual variations of forcing functions. It will also look at improving forecast skill for water level by including the oceanic signal. This will help to define the frequency and intensity of extreme events that have occurred as well as the general statistics of water level fluctuations which together are the basis for the water level climatology. The statistics depend on how water levels respond to each time scale (frequency) of forcing. Partitioning of the statistics into "normal" and "anomalous" oceanic conditions is part of the methodology. Models will be used to extend the water level statistics alongshore between observations sites and seaward to the shelf break. The following steps are envisioned.

1. Establishing Geographical Regimes with Different Climatologies. Long-term tide gage records (the primary source of information about water level climatology) that are sparsely spaced along the coast will be combined with more closely spaced but shorter-term coastal secondary tide gage and other records to obtain regional distributions of tidal and non-tidal water level variations. These distributions will then be used to divide coastal regions into geographical regimes, each with its own climatology for the tides, weather-induced and oceanic signals in water level. The climatology will contain the probability of extreme events, the amplitude and duration of synoptic weather, seasonal fluctuations and the effects on sea level of inter-annual variations in atmospheric and oceanic forcing.

2. Development of Predictive Capability. Models are also needed to predict the distribution of sea level variations in a given region. The appropriate statistical methods and partitioning of observations (i.e., into seasons, inter-annual periods) will be applied to produce robust estimates of temporal sea level variability, the probabilities of occurrence of extreme events and a measure of the reliability of these estimates. The duration of non-tidal water level events will be characterized since the

length of time the water level is at an extreme value is often just as important as the maximum elevation of the event. Finally, the extreme sea level events will be interpreted in terms of contributions from tides, weather and oceanic signals to provide the user with an understanding of the events and their likelihood of occurrence, i.e. to define which aspects of the events are predictable. NOS, ERL and NWS will work closely on this effort.

During FY91, PMEL will begin to develop methods for determining the climatology of coastal sea level variations along a portion of the U.S. West Coast using analyses of water level, weather and oceanic time series as follows:

INITIAL REGION OF INTEREST: This region will be from Monterey CA (an exposed coastal site south of the long-term San Francisco station located within the mid-California sea level regime) to Newport OR (near-coastal site where extensive sea level, bottom pressure, weather and oceanic observations have been made; it is located to the north of the transition from the California to Northwest sea level regimes.) This region contains the highly populated and growing San Francisco Bay Area where coastal flooding is a major issue.

The oceanography of the adjacent continental shelf has been studied extensively in the CODE and Super-CODE experiments; classic studies of seasonal and inter-annual sea level variations (e.g., El Nino) have used sea level observations in the region and linked these to the behavior of sea level elsewhere along the West Coast. The shelf in this region is narrow and has a relatively simple tidal regime caused by oceanic Kelvin waves propagating northward along the coast.

The past sea level work in this region includes research on adjusted sea level (ASL, the sum of water levels and atmospheric pressure), shelf currents and the effects on ASL of weather and offshore oceanic conditions. However the behavior of sea level itself (unadjusted for atmospheric pressure) over the full range of important time scales has not been reported in the scientific literature.

INITIAL ANALYSES AND DATA ACQUISITION. The initial analyses will be done on the hourly San Francisco record which is already available at PMEL and extended to other water level records as they become available from NOS and other sources (e.g., Oregon State University which has an extensive database for the region). Many of the analyses are semi-automated on the new EPIC database management, analysis and display system at PMEL. Some effort will be needed to obtain time series and install them in the database and to find the best storage medium for ready computer access to the large data set.

Some weather and surface ocean databases are available at PMEL. They include the Bauken weather distributions (6- and/or 12-hr distributions) for offshore winds and atmospheric pressure) and the COADS distributions of monthly-averaged surface water properties. Some effort is needed to acquire offshore stearic height time series and distributions; the CALCOFI data set is one example. These may be available at universities where substantial research has been done on the region (e.g., Oregon State University and Scripps Institute of Oceanography); it may be necessary to let a small contract to obtain this data. When funding allows, it will be useful to start cooperative studies with academic scientists from these institutions.

Detrending: Following a procedure developed in a pilot study on long-term water level records in the Puget Sound region, the long-term records will be detrended using a spline-fit method which allows for variations in the long-term trends. The results will be checked through the stationarity (temporal constancy of statistics) of annual maximum water events as seen in the hourly data. The programs for detrending and finding the extreme events in hourly data were developed as part of the pilot study and need to be interfaced with the EPIC package.

Tidal Analyses: Sequential tidal analyses will be performed for quality assurance and to check on the 18.6 year nodal variations and stationarity of harmonic constants. This will lead in subsequent work to detailed cotidal charts for the coastal region. The detided time series (observed minus predicted) will be useful in studying high-frequency events.

Low-passed Time Series: Time series plots of 35-hr low-passed water levels (resampled at 6-hr intervals for efficiency) will be analyzed for seasonal behavior and inter-annual variations in the subtidal (frequencies less than tidal) signals as seen in the variance. These will be used to determine the lengths of winter and summer periods for spectral analyses that avoid transitional periods between seasons and to identify anomalous years. The El Nino signal should be most evident in the low-passed time series as well as the 50-70 day waves propagating northward along the coast from the equatorial region.

Auto-spectra and Coherence Analyses: Winter and summer auto-spectra at individual stations (starting with San Francisco) and coherences between tide stations will be compared with published distributions of adjusted sea level to assess how well these represent the spectral behavior of the actual sea level fluctuations (the published ASL spectral and variances undoubtedly underestimate the amplitudes of actual coastal sea level.) The spectral analyses will include subtidal and supertidal (high-frequency) frequency bands. The coherence analyses will provide the transfer functions which relate non-tidal sea level signals at the primary station (San Francisco) to the signals at the other tide stations along the coast.

The scientific payoff is a better understanding of how weather and the ocean force coastal water level over a broad range of time scales and whether there is a relationship between the high-frequency variations (central to forecasting storm surges) and background, low-frequency signals (the focus of climate studies). For example, an ENSO event (El Nino) can affect water levels in many ways. Local water levels can be raised directly by long-distance forcing, water density changes, local or offshore current changes, atmospheric pressure changes, and atmospheric conditions can be altered enough to produce more frequent and more intense coastal storm systems.

Historical Water Levels Digitization. To support the climatology and prediction effort, NOS will begin to digitize historical water level data which are still only in manuscript form and merge them into the modern relational data base presently under development within NOS. The term "digitize" is used for simplicity, a more correct term might be "make computer compatible." Included within this effort are activities in selecting data to be digitized, quality control, adjustments to common datum, and statistical summarization. Future work using this data will include scientific studies and a suite of practical products.

DATA AVAILABILITY AND SELECTION: NOS presently operates 189 long term primary tide (140) and Great Lake water level (49) stations and a varying number of shorter term secondary stations. Over 5000 secondary stations have been occupied at various times in the past. Since the late 1960's most of the data from primary stations has been recorded digitally and are generally available to the entire scientific and engineering communities. However, older historical data (some dating into the last century) and secondary stations are not available in a computer compatible format. These data are needed to extend the statistical reliability, expand the data base to cover coastal regions for which there are no primary stations, and to maintain datums for use by local communities, industries, surveyors, and boundary determinations.

Of these 189 primary stations, about 40 of the longest operating tide stations are expected to be digitized using resources from the Climate and Global Change Program. Some primary stations only have 20 or so years of data, all digital. Records from many of the secondary stations are too short to be useful or no longer have adequate benchmarks remaining. Thus, about 130 primary stations along with about 2000 secondary stations are estimated to need some digitizing under this program, much more than can be afforded immediately. Priorities will, therefore, be established using criteria which are geographical, record length, and record quality.

DIGITIZATION AND QUALITY CONTROL: Digitization will generally be limited to hourly heights and highs and lows along with datum information. This will allow effective reconstruction of the tide/water level time series. Should a few series be needed at faster sampling rates, original analog records can be digitized. However, experience indicates that such would be required infrequently.

Because of the wide range of handwriting types in the original manuscripts, including the flowery styles of yesteryear, it does not appear to be feasible to use automated scanner equipment to perform the digitization. The digitizing will have to be done by hand.

For quality control purposes, all data will be digitized twice and compared. Besides the comparisons, quality control will include several check sums which are available from earlier manual summaries. Further checks will be made using the specialized software which is used to control the quality in modern digital water level data.

The analyses being performed by PMEL will provide a further check on quality. As data become available for the South Atlantic Bight, simple analyses will be performed both to assure that quality.

2.34. FY91 Products. This component of the FY91 Coastal Hazards program will provide improved data to support wave, storm surge, and tsunami forecasting by the NWS; and improved vertical datums for marine boundary determination, nautical charting, and local surveying. The FY91 products include:

- o Expanded water level data set in the NOS relational data base.
- o Statistical analyses, including an evaluation of robust exploratory data analysis methods, for selected coastal tide gage records.
- o A data report summarizing the characteristics and distributions of sea level variations for the Northern California-Southern Oregon Coast. This is an important step toward producing a sea level climatology at individual stations and a necessary foundation for producing a sea level climatology for the region.
- o Detailed plans for future work.

3.0 Data Management

3.1. Tsunami Inundation. PMEL will process and manage tsunami bottom pressure data collected by the observational network. Tsunami instrumentation continues to be refined and improved, so that three generations of tsunami gauges currently exist in the network instrument pool. As a consequence of this evolution, data processing procedures are not completely standardized or automated, and some special processing is generally required to take account of differences specific to each individual record.

In the event of a tsunami, data will be made available to collaborating COP investigators on an individual basis. The appropriate sub-series of records will then be specially processed to extract an accurate tsunami signature, including the application of algorithms to correct for errors such as changes in sensor calibration constants, reference clock drift during deployment, and spurious signals induced by temperature sensitivity of the pressure sensor. Additional processing will be required for removal of tides, appropriate filtering to isolate energy in the tsunami frequency band, and conversion of pressure to sea level values through depth- and frequency-dependent compensation for hydrodynamic filtering. Not all procedures have been fully developed and implemented at this time.

3.2. Coastal Water Level Variability. NOS will assemble and add historical data sets to water level and tidal datum data bases being developed on base funds. All digitized tide and water level data will be available to the entire external community of users at nominal cost. Beginning in late FY92, the data will be available on-line through the new data base management system being developed on base funds and presently under contract.

4.0 Program Management and Evaluation

4.1. Internal. Our approach stresses the integration and application of existing line office capabilities to coastal hazards research, modeling, and information products. Identified gaps in capabilities will be filled through an open, competitive solicitation and review from academic or other non-NOAA sources.

Since this element draws heavily upon the capabilities of several line organizations, an interim project manager in the Coastal Ocean Program Office will coordinate initial program development efforts. NOAA'S Pacific Marine Environmental Laboratory (PMEL) will be primarily responsible for management and implementation of the tsunami observations and modeling effort; NWS's Techniques Development Laboratory will be responsible for the storm surge modeling and development; and NOS and PMEL will work closely on the water level variability research.

The PI's will maintain close and continuous cooperation since results and products derived from one element of the program will frequently be used to upgrade other elements.

4.2. External. External input to the program has been obtained by including academicians in the program development phase and by review of program plans by the NAS Panel on the Coastal Ocean (PoCO). Assistance from the academic community in implementing portions of the program will be obtained largely through a competitive, peer-reviewed process. A technical advisory panel will be selected in FY91 to review and evaluate the technical quality and utility of existing products and to identify the needs for additional products. The panel will eventually provide the working group and the project manager with recommendations for new programmatic thrusts based on both science and management perspectives. The panel will consist of scientists experienced in understanding and modeling coastal inundation phenomena as well as coastal construction and emergency management specialists concerned with developing improved design criteria and management plans impacted by episodic coastal flooding.

4.3. Relationships to and Contributions from NOAA Base and other agency programs.

4.31. Tsunami Inundation. NOAA has historically worked closely with other agencies and the academic community in developing tsunami observational and modeling capabilities, including:

- o PMEL base funding has supported initial development of the deep water tsunami measurement system
- o The JIMAR Tsunami Research Effort (JTRE) is a joint NOAA/University of Hawaii activity partially funded by the State of Hawaii
- o Development of a nearshore tsunami measuring capability using the U.S. Army Corps of Engineers wave gage network and Scripps Institute of Oceanography collection system.
- o NOAA's Pacific Tsunami Warning Center (PTWC) will be a recipient of inundation estimate products,
- o State of Hawaii agencies will also receive inundation products.
- o The National Science Foundation is developing a proposal for enhanced research in tsunami modeling. The NOAA Coastal Ocean Program will work closely with the NSF program manager to insure coordinated and cost-effective approaches.

4.32. Storm Surge. The extra-tropical storm surge development will be done with contractors assistance working inhouse with NWS TDL scientists. Through a competitive process, NWS has in effect a task order contract. The contractor will provide modeling capability based on review and analysis of recognized expertise in storm surge modeling, and subject to TDL approval. Previous experience has shown that this approach effectively satisfies TDL's need for external assistance in research and development activities.

4.33. Coastal Water Level Variability. The water level variability component of this program complements and extends an ongoing $8M NOS effort to measure and predict tidal and lake elevations, circulation patterns, and currents in estuaries and nearshore waters. Through enhanced use and analysis of data collected by base-funded activities improved understanding and predictions of natural variability in water level variability will be obtained. Further, the addition of this historical data to the relational data base being developed with base funding will provide ready access to a much larger water level data set for more timely verification of model predictions and several other purposes. The work may also benefit from a proposed Climate and Global Change Program effort to digitize historical data from a number of U.S. coastal water level gages.

PMEL base funds will be used to support the preparation and publication of research papers on a pilot study of sea level variability in the Puget Sound Region and as matching funds for the analysis of sea level along the Northern California/ Southern Oregon Coast. The pilot study was done as part of the NOAA Marine Environmental Quality Assessment Program. The development of the EPIC computer package to be used in the PMEL analyses of sea level was supported by the NOAA Climate and Global Change Program, FOCI and other NOAA-funded programs at PMEL.

5.0 Resource Requirements

5.1 Program Budgets. Table 5-1 provides shows the distribution of FY91 funds and Table 5-2 is a proposed budget for FY92-FY95. Note that FY92 plans call for a substantial increase in funds to bring this element to parity with other components of the Coastal Ocean Program.

5.2 Aircraft and Ship Requirements. PMEL Deep water tsunami system will be serviced in FY91 according to existing PMEL agreements.

6.0 References

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Table 5-1. FY91 COASTAL HAZARDS BUDGET

TSUNAMI INUNDATION (OAR/PMEL)		
observations		$50,000
modeling		$50,000
	SUBTOTAL:	$100,000
STORM SURGE (NWS/TDL)		
apply and update slosh:		$30,000
extra-tropical model :		$70,000
	SUBTOTAL:	$100,000
COASTAL WATER LEVEL AND COASTLINE VARIABILITY		
PMEL: Develop climatology methodology for West Coast:		$30,000
NOS: Digitize West Coast Historical Water Level Data:		$70,000
	SUBTOTAL:	$100,000
	TOTAL:	$300,000

Table 5-2. PROPOSED FY92-95 COASTAL HAZARDS BUDGET

Funding by Fiscal Year In $ Millions

PROGRAM ELEMENT	FY92	FY93	FY94	FY95
Tsunami	0.50	0.75	0.8	0.9
Storm Surges	0.33	0.85	1.2	1.5
Water Level and Coastline Variability	0.17	1.0	2.0	2.5
Coastal Winds and Waves	0.30	1.5	2.0	2.1
Total	**1.3M**	**4.1**	**6.0**	**7.0**