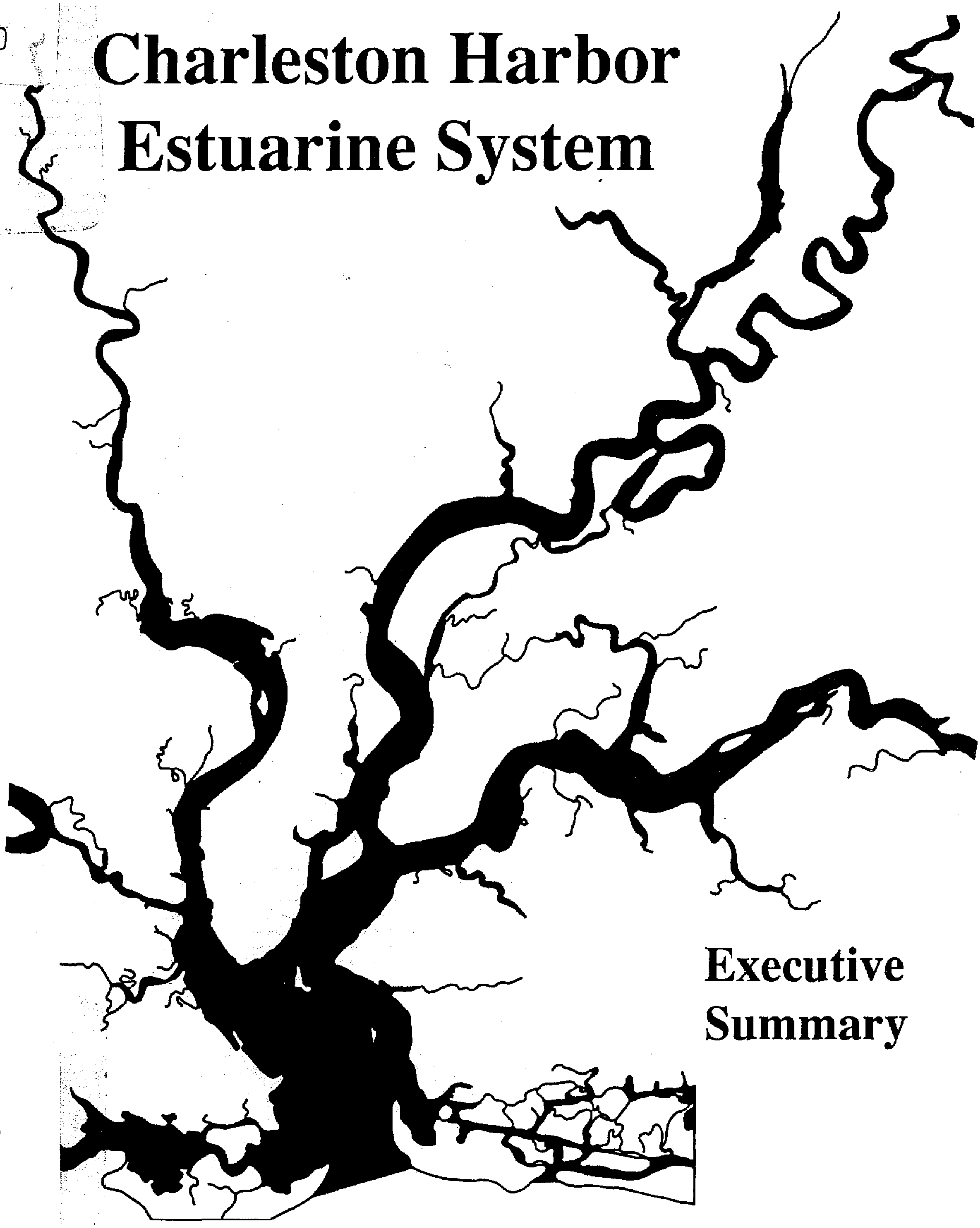
A Physical and Ecological Characterization of the Charleston Harbor Estuarine System



Executive Summary

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Submitted to
the

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Charleston, South Carolina

A PHYSICAL AND ECOLOGICAL CHARACTERIZATION OF THE CHARLESTON HARBOR ESTUARINE SYSTEM

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the

Marine Resources Division
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in cooperation with
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INTRODUCTION

In 1985, the U.S. Army Corps of Engineers completed the "Cooper River Rediversion Project" which significantly altered hydrologic conditions in the lower portions of the Santee-Cooper drainage basin. The Charleston Harbor estuary comprises a major portion of this drainage basin in the coastal zone of South Carolina (Figure 1) and represents the State's third largest estuary encompassing more than 26,000 hectares of valuable marshlands and open water habitat.

The harbor system also supports the state's largest port facilities. These facilities currently make Charleston Harbor the third largest home port nationwide for the U.S. Navy and the second largest commercial port along the Atlantic seaboard in terms of container cargo handled. Prior to rediversion, the cost of maintaining adequate shipping channels for the port had increased to more than five million dollars/year. Much of the sedimentation problem was attributed to an earlier water diversion project completed in 1942 by the South Carolina Public Service Authority. This project involved construction of two dams to form lakes Marion and Moultrie and construction of a diversion canal to connect these lakes (Figure 1). Approximately 88% of the Santee River flow was then diverted into the Cooper River, changing the average freshwater flow into this river from approximately 2 to 442 cubic meters/second.

The Cooper River Rediversion Project, completed in 1985, rediverted approximately 70% of this water flow back into the Santee River system through another canal at St. Stephens (Figure 1). This reduced the freshwater flow into the Cooper River to approximately 122 cubic meters/second which, in turn, should reduce the associated sediment load coming into the estuary.

Several hydrologic changes were anticipated as a result of the Rediversion Project, including an extension of the estuarine boundaries and redistribution of salinity regimes within the estuary, changes in the vertical mixing and current patterns, a reduction in water levels in the upper Cooper River, and a decrease in the dilution and flushing rates of pollutants. These physical changes were also expected to alter the distribution and abundance of floral and faunal communities in this estuary, including recreationally and commercially valuable species of fishes and crustaceans.

Concern over the anticipated changes prompted several studies, including an assessment of selected biological communities which was begun in 1984 by the Marine Resources Division of the South Carolina Wildlife and Marine Resources Department. This study was expanded considerably in 1987 in order to provide a more comprehensive assessment of the Charleston Harbor eatuary. The expanded study involved researchers from several agencies and institutions and included several major objectives. These were to:

1) Describe the hydrographic conditions in the Harbor basin and Cooper, Wando, and Ashley River systems following rediversion, and identify seasonal changes in basic water quality parameters throughout these estuaries.

2) Characterize the nutrient and organic carbon levels and the physical dynamics of the Charleston Harbor estuary following rediversion.

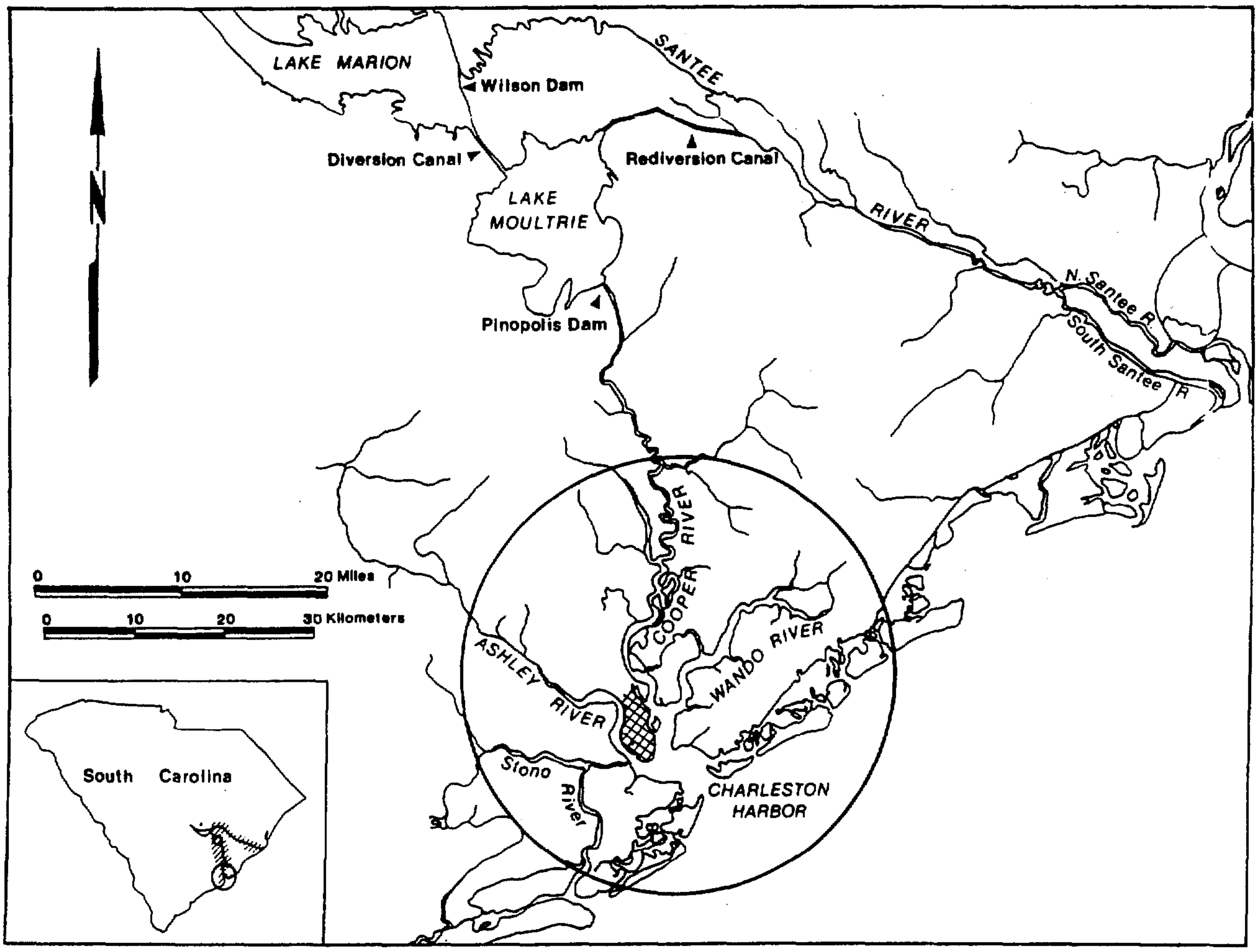

Figure 1. Map of the lower Santee-Cooper drainage system showing aspects of the diversion and rediversion system. The Charleston Harbor estuary is shown within the circle.

3) Describe seasonal and yearly changes in the bottom dwelling invertebrate communities in the harbor basin and associated river systems, and evaluate the distribution of these communities in relation to various natural and anthropogenic environmental parameters. These studies also provided information on the distribution of surficial sediments within the estuary.

4) Describe seasonal and yearly changes in the fish and crustacean communities present in the harbor basin and associated river systems, with particular emphasis on (a) defining the distribution of recreationally and commercially important species of finfish, shrimp and crabs, and (b) identifying patterns of recruitment for some of these species in different portions of the estuary.

5) Describe changes in the macrophyte (plant) communities in the upper Cooper River where changes in water levels were expected.

6) Document organic and inorganic contaminant concentrations

throughout the Charleston Harbor estuary, with particular emphasis on determining the pollutant levels in sediments and in the tissues of important fish, crustacean, and molluscan species.

7) Evaluate the significance of changes resulting from rediversion by comparing the post-rediversion information with data obtained prior to rediversion, where available.

8) Convene a series of research/technical workshops to identify and evaluate extant information/data sources, with particular emphases on (a) identifying major data needs and strategies for acquiring needed research data, and (b) determining the requirements and mechanics for establishing a comprehensive information/data base for the estuary.

This document provides a brief overview of the findings from these major study components.

HYDROGRAPHY

Hydrographic data were collected by the South Carolina Marine Resources Division from surface and bottom depths as part of the regular trawl and bottom grab sampling conducted from November 1984 through 1988. A more intensive sampling program was completed in 1988 that included monthly surface and bottom measurements from 36 sites throughout the estuary during high and low slack tides. Hydrographic parameters recorded included: temperature, specific conductance, salinity and dissolved oxygen at all stations, as well as turbidity, nitrate, nitrite, total ammonia and ortho-phosphate measurements taken at selected stations.

Results indicate that the salinity levels in the Cooper River and harbor basin have been much higher since rediversion. On average, the mean freshwater line (<0.5 ppt) on the surface was approximately 6 km (3.2 mi.) further upriver in the Cooper River after rediversion, and approximately 2.5 km (1.3 mi.) further upriver on the bottom. After rediversion, it appeared that salinity in the harbor basin and Cooper River were primarily controlled by tidal stage rather than by freshwater flow. Turbidity levels at the mouth of the harbor were significantly lower during post-rediversion sampling (approximately 3x lower), although no significant differences were observed in the rest of the estuary. No significant differences were observed for nutrient levels in the estuary between pre- and post-rediversion sampling.

Salinities throughout the estuary exhibited no distinct seasonal trends after rediversion. Salinities in the Ashley and Wando Rivers were less stratified than those in the Cooper River and harbor basin. Percent saturation of dissolved oxygen exhibited distinct seasonal trends throughout the system, with highest levels occurring in the winter. Lower levels of dissolved oxygen occurred in spring and fall, and the lowest levels were recorded in late summer. Dissolved oxygen in the Cooper River generally decreased upriver to the middle portion of the river, and then began to increase further upriver. In addition, the upper Ashley River stations exhibited significantly lower dissolved oxygen saturation levels than those found in the harbor basin. Turbidity levels were highest in the upper Ashley River, somewhat lower in the harbor basin, and lowest in the Cooper and Wando Rivers. No seasonal trends in turbidity were observed at any stations in the estuary.

Nutrient levels were generally higher during summer months than during winter months, although each basin exhibited unique seasonal changes. Levels of nutrients were similar in the Cooper and Wando Rivers and harbor basin. Nutrient levels in the Ashley River, however, were significantly higher than nutrient levels recorded from the rest of the estuary. The upper Ashley River stations exhibited extremely high concentrations of nitrate and orthophosphate (often 5-10x higher than the rest of estuary), which decreased in the seaward direction.

NUTRIENTS AND ORGANIC CARBON

An intensive study of nutrients, organic carbon, and general water quality was also conducted along the Charleston Harbor/Cooper River estuarine gradient by researchers at the University of South Carolina. This study involved sampling along a 45-km (24 mi.) transect from the mouth of Charleston Harbor up the Cooper River through industrialized urban areas to relatively undeveloped tidal freshwater reaches. During this study period (Feb. 1988-Feb. 1989), freshwater inflow was highly variable on a daily basis (0-330 cubic meters/second), although seasonal fluctuations were not as great.

With reduced flows in the Cooper River (following rediversion), salinities were less variable and less predictable. However, salinity was still significantly correlated with weekly mean flows. Up to 55% of the variability in salinity in the upper and middle reaches of the estuary could be explained by variability in river flow.

Surface water turbidity typically displayed two peaks related to location in the estuary. A peak in the upper reaches (30-35 km upstream) suggested increased flocculation of particulate matter at the upper zone of fresh/salt water mixing. A second peak in the harbor suggested considerable influence of turbulence, resuspension, and influx of particulates from the coastal ocean and from the Ashley River. Surface turbidity was significantly correlated with concentrations of particulate organic carbon (POC) and phytoplankton (algae) biomass.

Total organic matter in the estuarine waters was dominated by dissolved organic carbon (DOC) which varied largely between 1 and 10 mg/l with a mean of 4.7 mg/l. There were significant spatial differences in DOC concentrations with higher concentrations in the surface water and in mid-estuarine reaches. Mixing diagrams indicated a net source of DOC within the mid-estuarine area, especially in the bottom waters, perhaps related to effluent from the Westvaco paper mill.

Particulate organic carbon (POC) generally constituted approximately 25% of the total organic carbon and varied between 0.1 and 4.7 mg/l, with an overall mean of 1.3 mg/l. POC was composed largely of detrital material, except during phytoplankton peaks when algal carbon accounted for >50% of the total POC. Seasonal variability in POC was dominated by peaks during the winter and summer corresponding to peaks in phytoplankton biomass. Phytoplankton biomass was typically higher in freshwater areas and declined significantly through the estuary, but showed some recovery in the harbor area. This pattern suggests a net loss of freshwater phytoplankton through the estuarine areas and a partial succession to marine and estuarine species in the harbor.

The distribution pattern of total POC was dominated by a higher concentration in the upper portions of the estuary and in the bottom waters. Mixing diagrams suggested a net loss of POC from the surface waters to bottom waters in the harbor region. The sinking and decomposition of POC from the surface waters also probably accounts for some of the observed DOC source in the bottom waters.

Dissolved phosphorus (PO_4) varied between <0.01 and 6.0 μg at./I. There were significant spatial trends in PO_4 distribution. Higher concentrations observed in the harbor at high tide suggested a potential oceanic source. Concentrations varied linearly with salinity, suggesting a net balance in sources and sinks of PO_4 through the estuary. Higher concentrations occurred in bottom waters, with peak levels occurring in March and July.

Dissolved inorganic nitrogen was composed of slightly higher ammonia (NH_4) concentrations than nitrate/nitrite concentrations (NN). Ammonia ranged from <0.01 μg at./I to 126.5 μg at./I, with a mean of 3.78 μg at./I. Higher concentrations were detected during low tide and in surface waters at mid-estuary stations. Mixing diagrams suggest a major source in mid-estuarine areas. Peak NN concentrations were typically located one station below peak NH_4 concentrations at low tide and one station above at high tide, suggesting rapid oxidation of the ammonia entering the estuary in the mid-estuarine reaches. Unlike NH_4, there were no significant differences between high and low tide levels. Highest NN concentrations occurred during late summer (August and September).

PHYSICAL DYNAMICS

Hydrographic sampling was also conducted in the harbor basin and Cooper River to further characterize the physical dynamics of the estuary. Measurements included current velocity records and vertical profiles of conductivity, temperature, density, and transmissivity collected along a longitudinal transect of the Cooper River and a cross-sectional transect of the Harbor entrance. A two-dimensional numerical circulation/dispersion model of the Charleston estuary was developed and extended to include tidal portions of the Ashley, Cooper, and Wando Rivers. The numerical model, together with the hydrographic field data and additional data obtained from United States Geological Survey and National Ocean Survey/National Oceanic and Atmospheric Administration, are being used to assess salinity responses of the Charleston Harbor/Cooper River estuarine system.

SEDIMENTS

Sediment samples were collected throughout the harbor system as part of the sampling effort to assess benthic macrofaunal communities. These samples provided information on the spatial and seasonal distribution of sediments in the harbor system both before and after rediversion.

The four-year seasonal study revealed several non-seasonal fluctuations in the distribution of surficial sediments in the estuary. Changes in bed material at harbor basin stations were attributed to spatial variability rather than temporal (seasonal) fluctuations. All three tributaries reflected a trend towards sandier sediments proceeding upriver. This corresponded to a decrease in the percentage of silt and clay with increasing distance from the river mouth. Possible effects of rediversion were noted at the lowest station in the Cooper River, where the occurrence of fine-grained sediments increased during the three-year period following rediversion.

Results from intensive sampling at 178 stations in the harbor basin and lower portions of each river system were compared with historical data. The northern half of the harbor basin and portions of the mouths of the three tributaries were considerably sandier than before rediversion. Sand was less dominant upriver, possibly due to the decreased tidal sorting of the sediments which allowed more fine-grained materials to settle out. Organic matter was closely associated with the occurrence of silt- and clay-size material (fines) both before and after rediversion, but those materials became more widely distributed in all reaches of the estuary after rediversion, based on comparisons with data obtained from an earlier study.

BENTHIC MACROFAUNAL COMMUNITIES

Benthic macrofaunal communities were sampled at several locations within the harbor basin, Cooper River, and Wando River from 1984 through 1988 to evaluate seasonal and yearly changes in these assemblages. Additional sampling was also conducted in 1988 to assess the seasonal abundance of benthic organisms in the Ashley River and to more thoroughly evaluate the distribution of benthic communities throughout the lower portion of the estuary in relation to natural and anthropogenic factors.

Results from the four-year study indicate that the spatial distribution of benthic macrofauna is similar in many respects to that of other gradient estuaries along the mid-Atlantic, southeast, and Gulf coasts of the United States. Cluster and nodal analyses showed clear distinctions among tidal freshwater, low salinity (oligo-mesohaline) and high salinity (meso-polyhaline) brackish water faunal groups. Within each salinity zone, benthic assemblages were further distinguished by their affinities for different sediment types. Temporal patterns of distribution and abundance were not as readily apparent as spatial trends. Although total numbers of individuals and species varied greatly throughout the four-year study, no consistent seasonal or annual periodicity in these fluctuations was evident. These findings are consistent with observations made by other researchers that estuaries are typically inconstant environments, with benthic fauna dominated by opportunistic species which characteristically have widely fluctuating abundances. Although effects of rediversion on the benthos are difficult to infer from this study in the absence of a long-term pre-rediversion database, comparison of pre- and post-rediversion data collected in this study and other studies suggests that the qualitative composition of the macrobenthos has not changed markedly since rediversion. Despite the lack of evidence for drastic alterations of the benthos, a few of the dominant species appeared to exhibit a trend toward decreasing abundance in certain reaches of the estuary.

Results from the more intensive short-term assessment of the bottom organisms at 178 stations in the harbor basin and lower reaches of the three river systems showed species distribution patterns which were generally similar to those noted in the four-year study. Environmental factors which showed some correlation to the benthic community variables measured included location in the estuary, salinity, and sediment characteristics (percent sand, percent calcium carbonate, percent organic content, and sand grain size). None of these parameters was strongly correlated with the community variables measured due, in part, to the high degree of variance in the data obtained, combined with a lack of well-defined gradients in the salinity and sediment regimes within the sampled portion of the estuary. Many of the numerically dominant taxa collected, such as mollusks, polychaetes, oligochates, nematodes, and amphipods, were abundant throughout the study area, although their distribution was often very patchy.

The short-term study did not reveal any clear relationships between the abundance and distribution of benthic organisms and various anthropogenic activities in the estuary. Within the harbor basin, a few sites showed evidence of reduced benthic diversity, low faunal abundance, or small scale differences in community composition that may have reflected perturbations from dredging operations and the sewage outfall at Plum Island. Among the three river systems, average diversity estimates were lower in the Cooper River than in the Ashley and Wando Rivers. The Cooper River also had the highest percentage of stations with relatively low estimates of diversity ($H' < 2.0$). While this may reflect some effects from the higher concentration of industrial and port facilities in this river compared to the other two river systems, comparison of the other community parameters among the sites sampled in all three rivers did not show major differences that could be clearly related to anthropogenic activities. This may be due, in part, to the large variability observed in both the benthic and environmental variables, which tends to obscure evidence of biological stress.

FINFISH AND INVERTEBRATE COMMUNITIES

Fish and invertebrate populations were sampled by trawl at nine locations in the Cooper River, Wando River and harbor basin over the four-year study period. Three stations were also sampled seasonally in the Ashley River during 1988.

Comparison of catches obtained after rediversion with those collected prior to rediversion in this study and other studies indicated that there has been a significant increase in the number of taxa and number of individuals since rediversion occurred, although the dominant species were essentially the same. A significant decrease in the biomass of fishes was also noted following rediversion. Invertebrate biomass, on the other hand, increased after rediversion.

Analyses of specific changes in the abundance of twenty-three species, which were evaluated because of their numerical dominance or economic importance in the estuary, revealed several different patterns. No significant differences were found in the abundance or biomass of five species: the brief squid (*Lolligunucula brevis*), brown shrimp (*Penaeus aztecus*), blue catfish (*Ictalurus furcatus*), summer flounder (*Paralichthys dentatus*), and blackcheek tonguefish (*Symphurus plagiusa*). Yearly fluctuations independent of rediversion were noted for eleven taxa: the pink shrimp (*Penaeus duorarum*), roughneck shrimp (*Trachypenaeus constrictus*), lesser blue crab (*Callinectes similis*), Atlantic menhaden (*Brevoortia tyrannus*), white catfish (*Ictalurus catus*), sea catfish (*Ariopsis felis*), spotted hake (*Urophycis regia*), silver perch (*Bairdiella chrysoura*), weakfish (*Cynoscion regalis*), star drum (*Stellifer lanceolatus*), and hogchoker (*Trinectes maculatus*). Significant increases were observed in the abundance and biomass of four species after rediversion: white shrimp (*Penaeus setiferus*), grass shrimp (*Palaemonetes vulgaris*), bay anchovy (*Anchoa mitchilli*), and southern flounder (*Paralichthys lethostigma*). The increases in white shrimp may have resulted from a combination of recovery from poor recruitment caused by a cold winter in the first year of this study and increased exploitation of a more stable environment after rediversion. One species, blue crab (*Callinectes sapidus*), exhibited a decrease in abundance and biomass. The hydrographic changes resulting from rediversion should not have produced the observed decreases since blue crabs are tolerant of salinity changes much greater than those resulting from rediversion. Two species, spot (*Leiostomus xanthurus*) and Atlantic croaker (*Micropogonias undulatus*), showed significant increases in abundance, decreases in biomass, and increases in the frequency of smaller individuals. Eight taxa also showed an increase in the frequency of smaller individuals. These were the white shrimp, bay anchovy, white catfish, blue catfish, weakfish, star drum, summer flounder, and southern flounder. The increased use of the Charleston Harbor estuarine system by a greater number of smaller individuals may have resulted from increased utilization of the estuary as a nursery area. Finally, nine taxa exhibited an upriver shift in their peak abundances of 11-22 km (6-12 mi). This corresponded to the upriver shift in salinity resulting from rediversion. These species were pink shrimp, white shrimp, blue crab, bay anchovy, white catfish, blue catfish, spot, Atlantic croaker, and hogchoker.

The increased utilization of the estuary by more taxa, more individuals, and younger individuals has not been reported for other estuaries which have undergone similar reductions in freshwater flow. However, more time may be required before the full effects of rediversion are apparent. Alternatively, long-term negative impacts on these faunal elements may be minimal.

RECRUITMENT STUDIES

Artificial settlement substrates were sampled over a 15-month period to collect crab postlarvae at a single site in the harbor basin to examine the relationships among light phase, lunar phase, vertical distribution, and settlement. Among the 19 brachyuran crab taxa collected, the most prevalent species in both number and frequency of occurrence was the blue crab (*Callinectes sapidus*). Other numerically important species included the common mud crab (*Panopeus herbstii*), and the fiddler crabs (*Uca* spp). Settlement patterns were highly episodic, with approximately 42% of the total number of megalopae (postlarvae) collected on a single sampling date. Diel differences in abundance were apparent, with a significantly greater number of megalopae collected at night. Although light phase was found to have a significant effect on overall abundance, it had little influence on the vertical distribution of brachyuran megalopae. Temperature was the only physical factor that was significantly correlated with megalopal abundance. In Charleston Harbor, the period of major ingress of blue crab postlarvae occurred from August through October in both 1987 and 1988. Blue crab megalopae exhibited a semilunar pattern of settlement. Peak settlement occurred around the quarter moons, with greatest settlement on waning lunar phases.

Juvenile blue crabs constituted less than 0.3% of the total catch of early stage crabs and megalopae of *Callinectes sapidus*, which suggests that ingress into estuarine habitats occurs at the megalopal stage. However, this study revealed that the juvenile is the primary stage of recruitment of other portunid crabs.

The recruitment of decapod crustaceans and fishes into tidal marsh creeks was also assessed through biweekly sampling with a bottom plankton sled and juvenile trawl from October 1987 through April 1989. All sampling was conducted at two creeks (Orange Grove and Bull) in the Ashley River and Schooner Creek near the entrance of Charleston Harbor. Trawl sampling revealed that the greatest number of decapod crustacean and fish species occurred at Schooner Creek. Species composition differed among the three creeks and seasonally. The most striking differences in species composition were between Schooner Creek, which was characterized by stenohaline marine species in summer and fall, and Bull Creek, which was characterized by estuarine transient and resident species.

Ingress of penaeid shrimp and blue crab to study sites was seasonal, occurring in March-April for brown shrimp (*P. aztecus*), June for pink shrimp (*P. duorarum*) and white shrimp (*P. setiferus*), and August-October for blue crab (*C. sapidus*). Density of penaeid shrimp and blue crab megalopae appeared to be related to lunar day but trends were not consistent among species. Distribution of the other numerically dominant decapod species, *Palaemonetes pugio* and *P. vulgaris*, revealed a general pattern of winter recruitment with juveniles present in spring and summer. Peak recruitment of the numerically dominant finfish (spot, *L. xanthurus*; Atlantic menhaden, *B. tyrannus*; Atlantic croaker, *M. undulatus*; and summer flounder, *P. lethostigma*) occurred in the creeks during winter and early spring, while bay anchovy, *A. mitchilli*, was present throughout the year.

From October, 1987 through April 1989, the adult stocks of blue crab were sampled using crab pots set biweekly at creeks sampled by sled and trawl. The crab pots were fished for six hours during each of 1162 sets, resulting in the capture of 3,916 male and 1,013 female crabs. Catch rates responded to temperature variation, with greatest catches recorded during warm weather and fewest crabs captured during coldest weather. Mean total carapace width (TCW) also varied seasonally. The smallest crabs were captured during late winter and early spring. Mean TCW increased each summer to a peak in late fall. On average, larger crabs were captured at Schooner Creek, the most seaward site, while the most crabs were captured at Bull Creek, the uppermost site in the Ashley River. Molt activity was also greatest at Bull Creek, where many pubertal pre-molt females were captured. Mark-recapture studies and tag/releases were carried out with internal-anchor "spaghetti" tags. Tagging mortality was high, with summer taggings resulting in the lowest tag return rate. Apparently, tagging mortality varied directly with temperature. The few recaptures obtained indicated that blue crab movements were not far from the location of release.

MACROPHYTE VEGETATION

The characteristics of macrophyte vegetation in a tidal freshwater marsh on the Cooper River were studied in 1988 for comparison with pre-rediversion data collected at the same site in 1982. Comparisons included species composition, net above ground primary productivity, patterns of seasonal succession, trends in species standing crop, and changes in species cover. The number of species present increased slightly from 44 in 1982 to 47 in 1988. Net primary production decreased from 1571 grains dry weight/meter squared in 1982 to 1432 grains dry weight/meter squared in 1988. Several dominant species; e.g., *Zizaniopsis, Peltrandra* and *Lycopus*, showed decreased mean standing crops in 1988. On the other hand, approximately one third of the species common to both years had increased frequencies in 1988 with only one species, *Lycopus*, showing a decreased frequency. Species abundance also increased in 1988. Seasonal succession occurred in both years, although no two corresponding months had the same dominant species. Two periods of maximum biomass occurred in 1982 but there was only one peak period in 1988. All events noted were successional in nature and appeared to be related to lowered water levels.

CONTAMINANTS

Trace metals and organic contaminants were studied in sediment and animal tissue samples collected from the estuary over a two-year period. Chromium and copper were widespread constituents in the sediments. Copper was also common in tissue but chromium was not detected in any tissue samples. Concentrations for both metals were typical of other industrialized southeastern locations, with higher levels generally associated with fine-grained sediments and areas of industrialization. Chromium concentrations in the sediments were as high as 81.18 ppm at a lower Cooper River station. The maximum concentration for copper (208.2 ppm) was detected in oysters from the lower Ashley River, whereas copper in sediments did not exceed 39.95 ppm. Cadmium was not detected in any sediments, but it was found in oysters at concentrations up to 3.11 ppm as well as in one blue crab sample (1.79 ppm) and one shrimp sample (1.35 ppm). Probably because of a lack of analytical sensitivity, lead was not detected in any tissue samples, and it was detected in sediment samples at only five stations. Lead concentrations were moderately high, however, with the maximum being 88.1 ppm. Mercury was present in 41% of the tissue samples and 44% of the sediment samples with maxima of 21.0 ppb and 25.7 ppb respectively.

Synthetic organic chemicals were generally not detected in the sediment samples analyzed except at one station in the lower Ashley River. This station had a relatively high concentration of polynuclear aromatic hydrocarbons (PAH's) compared to other estuarine areas within the state. The PAH's ranged up to 4.4 ppm fluoranthane, 4.1 ppm pyrene, and 1.18 ppm chrysene.

Tissue samples examined in this study contained several different synthetic chemicals. Polychlorinated biphenyls (PCB's) were the most common organic form detected in the tissue samples, although no levels exceeded 538 ppb. Other organics in tissue included chloroform, benzoic acid, hexachlorobutadiene, isophorone, 1,2,4 - trichlorobenzene, some PAH's, and some organochlorine pesticides. Though these compounds were generally less than 500 ppb, some did exceed 1000 ppb, e.g., 1430 ppb benzoic acid in oysters in the lower Wando River.

Anthropogenic sources probably accounted for the majority of the organic compounds and metals found. Even though the chemicals detected did not exceed any published Environmental Protection Agency and US Food and Drug Administration limits, they may pose some threat with respect to sublethal effects on estuarine organisms.

TECHNICAL WORKSHOPS

Four workshops were conducted on major areas of concern to the research and technical communities involved with the Charleston Harbor estuary: (1) hydrography, circulation and modelling; (2) water quality, nutrient fluxes, and contaminants; (3) phytoplankton and macrophyte productivity; and (4) estuarine fauna. Major objectives identified for research to support management needs of the estuary included developing hydrologic models; identifying the effects of anthropogenic sources on selected organisms; defining the oxygen requirements of selected organisms; modelling dissolved oxygen and sediment dynamics within the estuary; identifying sources and sinks of phytoplankton production; evaluating the roles of phytoplankton production, organic carbon flux, submerged macrophytes and benthic macro- and microalgae; and establishing the adequacy of existing criteria used in management and planning decisions. The magnitude of this research program will require considerable augmentation of existing institutional capabilities.

All workshops concluded that a comprehensive management plan for Charleston Harbor was desirable. The most frequently identified concern related to such a plan was political support for its success. Factors key to achieving such support are: (1) widespread involvement of all those potentially affected by the management plan, and (2) public commitment for protection of resources in the future. Workshop participants also agreed that improved capabilities to archive and retrieve relevant data are important, but that a single integrated database is probably impractical. The technical workshops initiated a process of defining specific objectives, data needs, and existing sources of these data through which a workable data management system for the Charleston Harbor estuary can be developed. Further steps toward developing such a system include: (1) design of an information translation process that will produce the particular syntheses needed by decision-makers, (2) specification of archiving procedures for new data sets collected as part of research undertaken in support of estuarine management, and (3) identification of information contained in existing data sets whose relevance warrants re-formatting to achieve consistency with other data sets.

OVERALL CONCLUSION

The Charleston Harbor estuary appears to be in relatively good shape from a biological/ecological perspective, and has not been drastically altered as a result of the Cooper River Rediversion Project during the period covered by this study. Some changes have occurred, however. Among the most obvious are the following:

(1) Waters in the harbor basin and the three associated river systems are more saline than before and the salinity regimes throughout the estuary are more stable. Other water quality factors, such as dissolved oxygen and nutrient levels, have not changed much as a result of rediversion.

(2) There may be less sedimentation of fine materials (muds) than before in the lower harbor, and there appears to be some reduction in turbidity, at least at the mouth of the harbor.

(3) Some changes in the floral and faunal assemblages have occurred, but no major differences in the overall community structure or declines in species diversity were detected that could be clearly related to rediversion effects. Some negative trends may be associated with areas of heavy impact by man. On the other hand, the harbor may well be a more productive nursery area than before for a variety of marine fish and motile invertebrates (including shrimp). Additional time will be required before the full effects of rediversion on the biota in the estuary are known.

(4) Another notable finding of the study is that, while a variety of contaminants were detected in sediments and in animal tissues from the harbor system, none were especially high. Nevertheless, because of the reduced river flow into Charleston Harbor now, the residence time for pollutants is probably greater, increasing opportunities for food-chain bioaccumulation and impacts on the aquatic fauna.

The challenge now is for those involved and interested in Charleston Harbor to come together and develop harbor-wide monitoring, management, and research programs to insure that this national ecological resource is not further degraded by man's activities.