LOOP MARINE AND ESTUARINE MONITORING PROGRAM, 1978–95

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VOLUME 5: DEMERSAL NEKTON

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ABBREVIATIONS USED

Abbreviation or Symbol	Meaning
m	meters
km	kilometer
cm	centimeter
mm	millimeters
g	grams
kg	kilograms
%	percentage
‰	parts per thousand
ppm	parts per million
mg/l	milligrams per liter
hr	hour
°C	degrees Centigrade
NTU	nephelometer turbidity units
$\geq$	greater than or equal to
±	plus or minus
SE	standard error
CPUE	catch per unit effort
$\log_e$	natural log
gal.	gallons

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Data Analysis of the LOOP Marine and Estuarine Monitoring Program, 1978-95

Introduction

The Louisiana Offshore Oil Port (LOOP LLC.) is licensed under the federal Deepwater Ports Act (33 U.S.C. 1501, *et seq.*) and the Louisiana Offshore Terminal Act (LA R.S. 34:3101 *et seq.*) to construct and operate facilities in coastal Louisiana for off-loading oil tankers, transporting oil ashore through pipelines, and temporarily storing oil before ultimate shipment to refining centers located nationwide. Both state and federal licenses required environmental monitoring of LOOP construction and operational activities. As part of the Environmental Monitoring Plan, demersal nekton (i.e., bottom oriented fishes and large invertebrates that are active swimmers but susceptible to trawl capture) were sampled at monthly intervals at several stations along the LOOP pipeline and in adjacent areas.

Methods

Between February 1978 and December 1995, a total of 3,193 samples were collected using 4.9 and 15.2 m trawls. Nekton were identified, weighed, and counted to provide information on species abundances and community structure (i.e., the proportional composition of species in the community). A total of 2,528,703 organisms from 288 taxa (i.e., species or higher levels of systematic organization) was collected with a total biomass of 39,396 kilograms. Forty taxa were common and included in some aspects of the analyses. However, several taxa had to be excluded from the species-level analyses because they were a combination of two or more species at the generic level. The remaining 37 species were each analyzed in up to four size classes (generally small juveniles, juveniles, subadults, and adults) because some species use different habitats at different life stages (i.e., ontogenetic changes). Using a size-class approach, we were able to detect six additional impacts that were not apparent for the species as a whole, and we were able to identify the life history stage affected.

Because there was no *a priori* association of control and impact stations, a principal components analysis was used to identify highly correlated environmental variables, to reduce the variables to a lesser number of environmental factors (i.e., three independent axes of correlated variables), and to assist in pairing control and impact stations for the Before-After-Control-Impact (BACI) analyses. The three new statistically independent axes, Factors 1-3, characterized spatial and temporal variation in the environment and explained 75.5% of the variance in the system (i.e., six variables were reduced to three axes while retaining > 75% of the original variation). Depth and turbidity weighed heavily in the first axis (Factor 1) and were inversely related to each other. This large-scale spatial axis reflected the salinity classification of stations into inshore, middle, and offshore zones, and arranged the

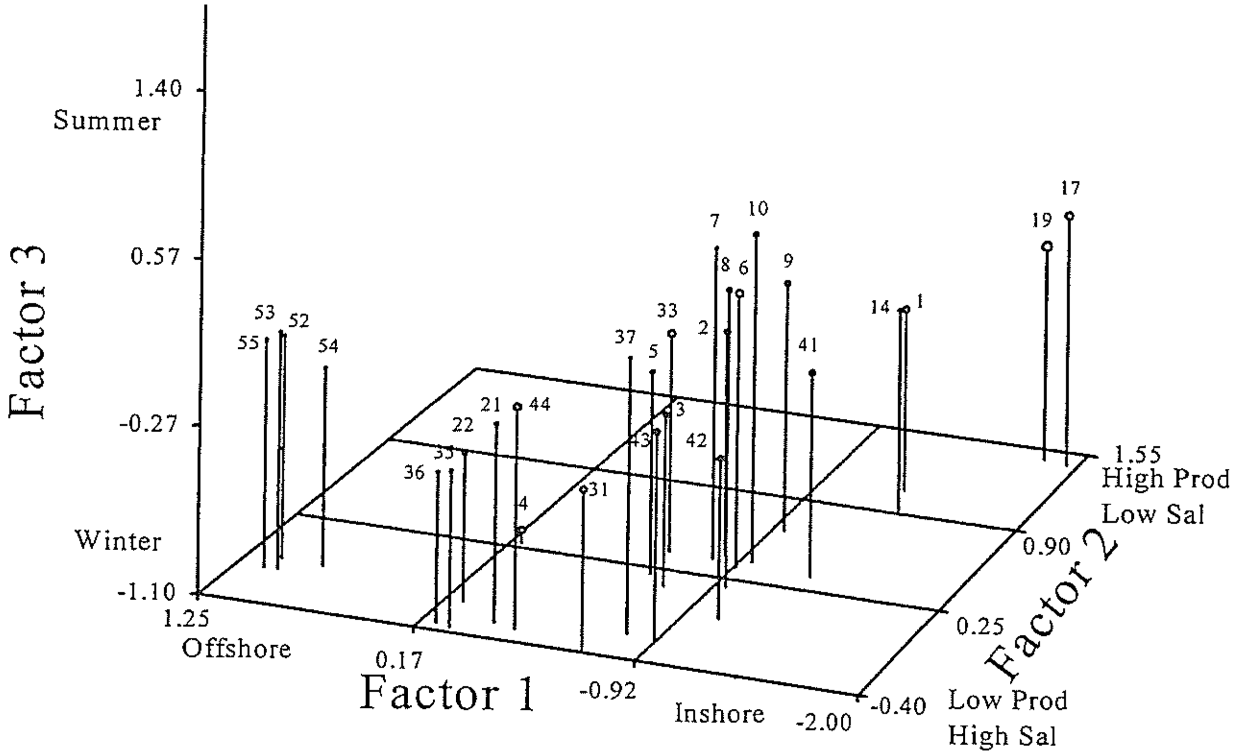

Figure ES1. Three dimensional environmental factor space showing the relationships of stations to the factors. The diameters of the balloons encompass one standard error.

shallow, turbid stations at one end and deeper, clearer stations at the other (Figure 1). The second axis (Factor 2) was weighted heavily for chlorophyll *a* and salinity, which were also inversely related to each other. Since chlorophyll *a* concentrations provide an index to productivity, this axis was interpreted as a productivity-salinity axis. In the third axis (Factor 3), temperature and dissolved oxygen weighed heavily and were inversely related to each other, reflecting the seasonality of environmental variation in the year-round sampling program. The LOOP sampling stations showed strong separation along the first two axes, but not along the third axis (Figure 1). From the plot of stations in factor space (Figure 1), we were able to identify five groups of environmentally similar stations for the BACI analyses:

Groups	Impact Stations *	Control Stations *
1. Furthest Inshore stations	19_I	14_C and 17_C
2. Middle zone stations	7_I	2_C, 6_C, 8_C, 9_C, and 10_C
3. High salinity, coastal stations	33_I	3_C, 5_C, and 43_C
4. Offshore Stations	22_I, 31_I, and 36_I	21_C, 35_C, and 44_C
5. Offshore Terminal Statons	53_I, 54_I, and 55_I	52_C

* Subscripts I and C indicate designation of Impact and Control stations, respectively (e.g. Station 19_I is an impact station and Station 14_C is a control station).

Station 19_I was located near a Shell Oil pipeline that was constructed at the same time as the LOOP pipeline to carry crude oil from the Clovelly terminal to Shell's refinery in St. James, Louisiana. Although this station was not constructed by LOOP, Inc., it was treated as a LOOP-related impact station for analytical purposes because the pipeline was built to carry oil from the LOOP pipeline. Stations 1_C, 4_C, 37_C, 41_C, and 42_C were not similar enough to any other impact stations to be grouped, and were excluded from the BACI analysis.

Common species and community characteristics at impact stations along the pipeline were compared to control stations in a modified BACI statistical design to test whether the construction and/or operation of the LOOP pipeline significantly influenced demersal nekton. The BACI design analyzes environmentally related changes in spatial and temporal patterns to examine the null hypothesis of no LOOP-related impact on common species or community characteristics by testing the spatial-temporal interaction term.

The number of analyses was determined by the number of impact stations, the number of impact events, the number of community characteristics, the number of species, and the number of size classes within species. In all, a total of more than 2,200 separate analyses were conducted, and fourteen significant impacts of LOOP construction and operation were detected on species and size classes of demersal nekton. We also tested eight community characteristics (i.e., species diversity, richness, and evenness, total nekton, total fishes, total invertebrates, total decapods, and the contribution of rare species).

Results

LOOP construction and brine discharge significantly influenced size classes of several species, including spotted seatrout and southern flounder. No influences on species abundances or community characteristics were detected from the two largest oil spills that we were able to examine. We were unable to examine several spills at the Clovelly Dome Storage Facility because no nekton samples were collected there.

Specifically, we detected several significant construction-related trends in nekton species and size class abundances in the BACI analysis. Summaries of 11 LOOP impact findings for species and size classes with significant (MIXED procedure, $p < 0.05$, Dunn-Šidák adjustment) interaction terms indicate that LOOP construction influenced the Catch Per Unit Effort (CPUE) of important nekton species. An additional 13 temporal or spatial effects (i.e., main effects) associated with these impacts (i.e., interactions) were also detected. Significant interactions (Least Squares Means Test, $p < 0.05$, Tukey-Kramer adjustment) that imply LOOP impacts, the significant effects (i.e., spatial, temporal, or interaction), the trend direction, if any, and probable causes of the observed effects are indicated:

Station[a]	Species	Size Class (mm)	Significant Effect	Trend	Cause of Difference
Station 31					
	Lesser blue crab	< 15	Temporal	Increase	LOOP construction
			Interaction	Increase	LOOP construction
	Southern kingfish	30 to 100	Temporal	Decrease	LOOP turbidity increase
			Spatial	High at impact	Non-LOOP
			Interaction	Decrease	LOOP turbidity increase
Station 33					
	Lesser blue crab	< 15	Temporal	Increase *	Non-LOOP
			Interaction	Decrease *	LOOP construction
	Bay whiff	≥ 100	Temporal	Decrease *	LOOP construction
			Interaction	Decrease *	LOOP construction
	Mantis shrimp	≥ 100	Temporal	Decrease *	Non-LOOP
			Interaction	No trend *	Non-LOOP
	Spotted seatrout	30 to 100	Temporal	Decrease *	LOOP construction
			Interaction	Decrease *	LOOP construction
	Spotted seatrout	All sizes	Temporal	Decrease *	LOOP construction
			Interaction	Decrease *	LOOP construction
Station 36					
	Southern flounder	≥ 100	Temporal	Decrease *	LOOP turbidity increase
			Interaction	Decrease *	LOOP turbidity increase
	Southern flounder	All sizes	Temporal	Decrease *	LOOP turbidity increase
			Interaction	Decrease *	LOOP turbidity increase
Station 53					
	Atl. brief squid	≥ 100	Temporal	Decrease *	LOOP construction
			Spatial	High at impact	LOOP construction
			Interaction	Decrease *	LOOP construction
Station 54					
	Atl. brief squid	≥ 100	Spatial	High at impact	LOOP construction
			Interaction	Decrease *	LOOP construction

[a] Impact station compared to appropriate control station(s).

* Species estimates were not available for the before-construction phase, so trends refer to the during-construction and after-construction phases.

We also detected significant (MIXED procedure, $p < 0.05$, Dunn-Šidák adjustment) LOOP-related influences of brine discharge at the brine diffuser (Station 36_I) on size classes of two species, Gulf menhaden and southern flounder. Both impacts were also associated with significant downward temporal trends. Significant interactions (Least Squares Means Test, $p < 0.05$, Tukey-Kramer adjustment) that imply LOOP impacts, the significant effects (i.e., spatial, temporal, or interaction), the trend direction, if any, and probable causes of the observed effects are indicated:

Species	Size Class	Significant Effect	Trend	Cause of Difference
Gulf menhaden	30 to 100 mm	Temporal	Decrease	LOOP turbidity increase
		Interaction	Decrease	LOOP turbidity increase
Southern flounder	≥ 100 mm *	Temporal	Decrease	LOOP turbidity increase
		Interaction	Decrease	LOOP turbidity increase

* The only individuals collected were in the size class ≥ 100 mm; therefore, the species-level comparisons for southern flounder were identical.

We detected significant temporal trends in the analyses of LOOP construction and operation for 31 size classes of 16 species that did not have significant interaction terms (i.e., these were not LOOP-related impacts). In the analysis of the construction phase, significant temporal effects were detected for 11 size classes of seven species with non-significant interaction terms. In the analysis of the brine discharge at the brine diffuser station (Station 36_I), significant temporal effects were detected for nine size classes of five species with non-significant interaction terms. In the analyses of three oil spill events at the offshore oil port, we did not detect any significant interactions for any of the size classes of the 37 species analyzed. Nevertheless, we did detect significant temporal trends for 11 size classes of six species. Although these temporal trends could not be attributed directly to LOOP activities, they indicate the dynamic nature of marine and estuarine nekton populations.

Discussion and Conclusions

No significant LOOP-related spatial, temporal, or interaction effects on community descriptors (i.e., species diversity, richness, and evenness, total individuals, total fishes, total invertebrates, total decapods, and contribution of rare species) were detected for the construction or operation phases, and we did not detect significant effects for the majority of the size classes or species. Nevertheless, this does not necessarily lead to the conclusion that LOOP-related construction, brine discharges, and/or oil spills were benign. While the impact events may not have been biologically or statistically significant for most nekton, a variety of factors could reduce the sensitivity of BACI analyses to detect significant events, including the absence of samples or the small number of before-construction samples at some stations, the absence of appropriate impact and control stations, the use of less than optimal control stations for some impact stations, discontinuity in the monthly sampling at some stations, and the possibility of a LOOP-related influence on a scale large enough to include the designated control stations. Thus failures to reject the null hypothesis in most instances tested on most species and size classes do not mean that the null hypothesis was correct.

To evaluate changes in sensitivity with increased sampling frequency in a response plan, we used Atlantic brief squid ($\geq$ 100 mm), a common species at the offshore port stations, which had a marginally significant interaction term ($p > 0.067$) for a moderate oil spill (October 21, 1985). The current data set with 220 samples was sufficient to detect a CPUE difference of about 85% between stations before and after the spill. To detect a 50% change in the CPUE of Atlantic brief squid CPUE the sample size would have to be about 430 for the six year period surrounding the spill (three years before and three years after). The current sampling intensity would only generate 144 samples for the six year peroid. Because of the transient nature of most impacts, a three year time frame for impact assessment should be used for planning. By sampling three times per month at four stations for three years, 432 samples can be collected. Alternatively, with only one sample per station per month, either nine years of data would be needed, which would be insensitive to short-term effects, or three times the number of impact and control stations would be required.

The construction and operation of the LOOP pipeline did significantly influence some nekton species abundances, but the analyses were not as robust as possible because of factors related to the monitoring program design. The most notable impacts included a significantly negative influence on southern flounder resulting from brine discharge, and a positive short-term influence of construction on spotted seatrout at Station 33_I. Some of the apparently positive influences, however, may translate to negative or neutral impacts away from the particular impact station. This is because the locally increased relative abundance of a size class or species may influence densities elsewhere. Individuals responding to locally favorable conditions may be drawn from nearby locations where densities diminish and the overall density of the population remains unchanged. Therefore, we cannot conclude that apparent positive LOOP-related effects are enhancements to the nekton populations or to the whole nekton community.

From of a total of over 2,200 comparisons, only 14 significant interactions were detected. There are several possibilities as to why we did not detect more significant differences. It is possible that LOOP did not impact any more demersal nekton. Nevertheless, the variability of the CPUE estimates was high, due to the natural variability inherent in nekton populations, low trawl replication, and discontinuous monthly sampling. Significant temporal effects for size classes and species without significant interaction terms may still be related to the LOOP pipeline if the sphere of influence of the LOOP construction and operation extended to the chosen control stations. If control stations were even slightly influenced by LOOP activities, then the sensitivity of the BACI comparisons would be reduced. Another possibility is that short term impact events, such as oil spills, may not have occurred at a sensitive stage in the life cycle of the observed species. The absence of an impact from an oil spill does not necessarily indicate that the system is insensitive to the spill, but may only be less sensitive to the spill at certain times of the year, when sensitive life history stages of nekton species are not present. Additionally, the tested oil spills were relatively small. Larger spills would probably have a greater influence on demersal nekton.

Given that the original objectives of the LOOP Environmental Monitoring Plan are still relevant, it is vital to continue to monitor for LOOP-related impacts on the nekton community, species, and size classes. The existence of significant temporal and spatial trends and 13 impacts provides further justification for continuing to monitor LOOP activities because the baseline for future comparisons must be current for reliable analyses. Continued sampling will also reduce the variability in the data, resulting in a more robust assessment of future potential impact events and possibly a better understanding of the observed changes that were not attributable to LOOP activities.

Technical Information for the LOOP Marine and Estuarine Monitoring Program Revision

Based on the results presented above, several recommendations to alter the monitoring program are proposed:

- **The monitoring of nekton associated with the LOOP pipeline should be continued on a monthly basis each year, with increased replication in the event of a potential impact.**
- **If additional major construction is proposed, sampling at appropriate impact stations and control stations should be conducted for at least two years, twice monthly, to ensure adequate before-construction data for impact analysis (higher sampling rates over one year would be a less powerful alternative).**
- **Control stations without appropriate impact station pairings should be discontinued, unless these stations are necessary for the evaluation of impacts related to variables in other datasets (e.g., Plankton, Water Chemistry, etc.).**
- **Additional impact and control stations are necessary inshore of Station 7_I.**
- **An additional control station is required in conjunction with the Offshore Oil Port, and one of the impact stations could probably be dropped.**
- **Assignment of control stations to impact stations for comparisons should be made *a priori*, if possible.**
- **Monitoring of the current environmental variables, species, and sizes, used in the nekton data analyses should continue.**

DATA ANALYSIS OF THE LOOP MARINE AND ESTUARINE MONITORING PROGRAM, 1978-95

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INTRODUCTION

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Both state and federal licenses required environmental monitoring of LOOP construction and operational activities. The Environmental Monitoring Plan was developed under the mandate of the Superport Environmental Protection Plan (revised 1977), a regulation of the State of Louisiana implementing the Offshore Terminal Act. The Board of Commissioners of the Offshore Terminal Authority selected the Louisiana Department of Wildlife and Fisheries (LDWF) as the agency to conduct the monitoring program. The objectives of the program, as stated in the Environmental Monitoring Plan, are:

(1) to obtain seasonal environmental and ecological data so that conditions existing during operation can be related to historical baseline conditions;

(2) to detect any adverse alterations or damages to the environment during the operation of the project so that corrective action can be taken as soon as possible;

(3) to obtain sufficient data to determine the cause or causes of environmental damages or alterations so that responsibility can properly be placed; and

(4) to provide information in order to evaluate long- and short-term impacts of the project.

Literature Review

Coastal fisheries are an integral part of life in Louisiana, and Louisiana has some of the most productive fishery resources in the United States (NMFS 1997). Fishery resources of the Gulf of Mexico constitute a significant portion of commercial and recreational landings within the United States. Commercial landings from the northern Gulf of Mexico made up about 15.6% of total U.S. domestic landings and 19.5% of dollar value in 1996 (NMFS 1997). Recreational fishing trips within the northern Gulf of Mexico were correspondingly successful, accounting for 42% of the total catch within the Atlantic and Gulf sub-regions in just 29% of total trips (NMFS 1997), so recreationalists were nearly twice as successful in the northern Gulf of Mexico than in the Atlantic sub-region. Louisiana leads fishery production within the northern Gulf of Mexico, contributing about 66% of the total commercial catch and 39% of the dollar value within the Gulf of Mexico, and ranks second only to Alaska among all states. Total seafood landings at Louisiana ports have exceeded one billion pounds annually since 1969 and have totaled 47 billion pounds over the last 36 years (NMFS 1997).

Potential threats to the health of commercial and recreational fisheries from the construction and operation of LOOP facilities need to be monitored and periodically evaluated. A LOOP-related oil spill is one of the environmental concerns. Concerns also involve the potential safety hazard of eating seafood harvested from an oil contaminated area after a spill and additionally adress environmental changes that adversely influence nekton species or their community. Nekton populations are most likely to be exposed to and affected by the water-soluble fraction of crude and refined oils (RPI International 1987). Various crude oils generally have a solubility ranging from about 20 to 28 ppm, while refined oils such as gasoline, No. 2 fuel oil, and kerosene typically have solubilities of 7,000 (kerosene) to 120,000 (gasoline) ppm. The actual concentration of water-soluble hydrocarbons under an open-water oil slick (from experimental and accidental oil spill data) is generally much lower, and is likely to be 100-10,000 times lower than the acute toxicity values for most fishes (RPI International 1987). A spill or leak, therefore, is not likely to have an immediate appreciable effect on adult fish mortalities, especially since adult nekton are able to escape or avoid the contaminated area. Avoidance by actively swimming members of the nekton community, however, may alter the distribution patterns of one or more species, the overall community structure, or disturb spawning aggregations, which would indicate a degradation of habitat quality. Other, less obvious, environmental changes related to the construction and operation of the LOOP facility (e.g., brine discharges and turbidity changes) may also influence demersal nekton (Cyrus and Blaber 1992). Entrainment of oil into sediments may affect the distribution, abundance, or behavior of benthic and epibenthic organisms, altering predator/prey relationships and nekton community structure. Sublethal exposure to water-soluble oil fractions may affect viability, survival, and development of eggs, larvae, and juvenile nektonic organisms and may result in a long-term change in communities and populations.

Analytical Objectives

In line with the overall objectives of the Superport Environmental Protection Plan, the specific objectives of these analyses of the nekton data base were: 1) to determine if the initial construction and subsequent operation of the Louisiana Offshore Oil Port had a positive or negative influence on the demersal nekton abundances, 2) to assess any influences of the construction and operation of LOOP on nekton community structure, and 3) to determine if the contribution of rare species to the overall nekton community structure differed over time between the control and impact sites.

METHODS

Field Methods

Demersal nekton communities were sampled at 28 stations (Figure 1) ranging across the monitoring area from Lake Salvador to the LOOP marine terminal 29.7 km offshore (Anon 1996). The LOOP, INC. port, its associated pipeline rights-of-way, and the biological and geophysical composition of the area have been summarized by Hanifen (1987) and Anon (1996). Since 1978, sixteen inland sampling stations were sampled with a 4.9 m flat otter trawl. Eight additional stations located offshore were sampled using the 4.9 m trawl. Seven stations were sampled with a 15.2 m balloon trawl; one station was located in Bayou Lafourche and six stations were located offshore. Towing durations for the 4.9 and 15.2 m trawls were 10 and 15 minutes of bottom time, respectively.

Although the trawls were standardized, there was some intended variation in the gear types used at the various sampling stations to enhance sampling effectiveness. The 4.9 m trawl consisted of 1.91 cm bar mesh wings and a 0.64 cm bar mesh codend. The net was coated with green plastic and had a 1.1-1.2 m footrope with a 3.2 mm diameter loop chain for inshore use or a 4.8 mm chain for offshore use. The boards were 40.6 x 76.2 cm with 9.5 mm iron for inshore sampling and 12.7 mm iron for offshore sampling. The 15.2 m trawl was made of green plastic coated 1.91 cm bar mesh wings and tail, with a 6.4 mm diameter loop chain and a 6.4 mm diameter tickler chain attached to 86.4 x 259 cm boards with 15.9 mm iron. Trawls were towed off the stern of the boat except for the 4.9 m trawls taken from aboard the LOOP M/V Vigilance, which were towed off the starboard side of the vessel.

Laboratory Methods

After trawls were retrieved, the demersal nekton catch was placed on ice until it could be processed at the LDWF laboratory. Particularly large trawl catches were subsampled onboard the vessel. The weight of the discard was recorded and the proportion of catch to discard was used to estimate total catch. If a scale was not available, an ocular estimate of a portion of the catch was recorded as a percentage of the total catch. Each sample was sorted to species using standard Louisiana and Gulf of Mexico references (Felder 1973, Douglas 1974,

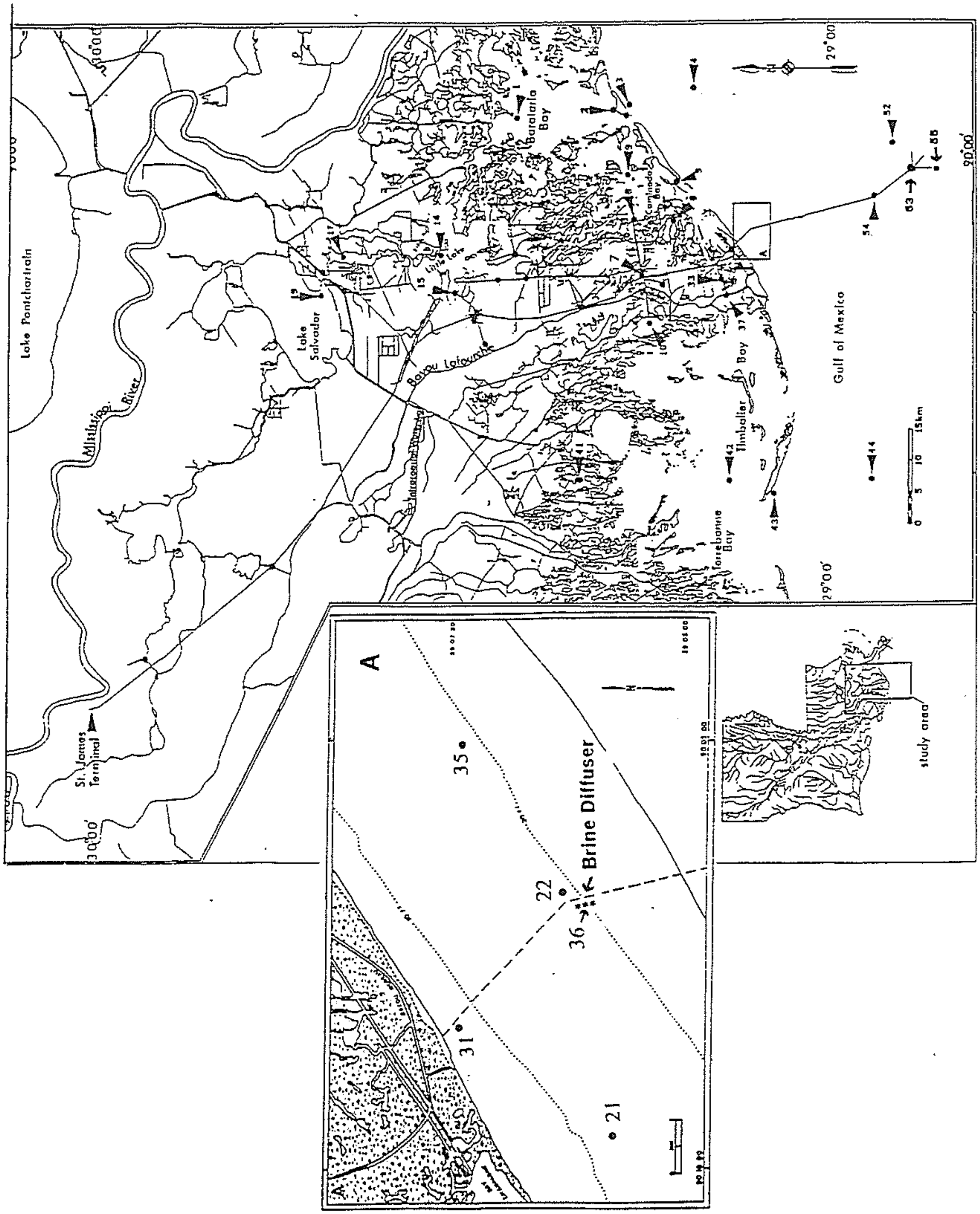

Figure 1. The LOOP monitoring area showing the nekton stations sampled.

Walls 1975, Hoese and Moore 1977, Williams 1984, Shipp 1986). Initially in 1978, all species were measured on a scale of 5 mm intervals. Beginning in April 1986, penaeid shrimp (i.e., brown, white, and pink shrimp) were measured in 1 mm increments, and all other species were measured in 1 mm increments starting in January of 1992.

The lengths, weights, and counts of all specimens were recorded in each sample. Total length of finfish was measured (i.e., tip of snout to tip of caudal fin). Shrimp were measured from tip of rostrum to tip of telson. Crab carapace width (distance between the tips of the two lateral spines), ray disk width, and squid beak to tip of mantle length measurements were used instead of total length. Each species was weighed in aggregate to the nearest gram. Penaeid shrimp were further sorted, measured, and weighed by sex and reproductive stage (Brown and Patlan 1974). Species in a given collection that were too numerous to measure were subsampled, then the lengths and weights of 50 individuals were recorded as well as the aggregate species weight. The subsampled catch was extrapolated to obtain an estimate of the number of individuals of each species caught in the trawl. All scientific and common names of fishes, decapod crustaceans, and molluscs follow Robins *et al.* (1991), Williams *et al.* (1988), and Turgeon *et al.* (1988), respectively. All information was recorded on data forms and then entered into the LDWF VAX/VMS SAS® data management system. Because of questions related to their identification in the early years of the study, several species were treated at the generic level for these analyses: bay anchovy (*Anchoa mitchilli*) was grouped with striped anchovy (*A. hepsetus*) as anchovy spp.; all *Trachypeneus* species were grouped as roughneck shrimp spp.; and blackcheek (*Symphurus plagiusa*) and offshore tonguefish (*S. civitatum)* were grouped as tonguefish spp.

Statistical Methods

Treatment of Data

Several additional modifications to the data set were necessary following data screening to detect and correct entry errors and identify outliers for examination before statistical analysis. Since collections before February 1981 were weighed in ounces, weights were converted to grams for consistency and comparisons to published literature. All lengths were converted into 5 mm classes to provide greater consistency and to increase the number of comparable observations. Catch per trawl was standardized by duration (i.e., number collected was divided by the duration of the trawl in hours) to give a measure of catch per unit effort (CPUE), which was expressed as individuals collected per hour. Since no conversion factors could be determined to compare the two gear types, and since only one gear type was used at each station (except for Stations 35 and 36), the analyses were typically conducted within gear types. Where appropriate, gear type was included as a block variable to increase the number of observations available for the analyses.

Statistical analyses were conducted on the relative abundances of species, size classes, and community descriptors (i.e., species diversity, richness, evenness, total organisms, total fishes, total invertebrates, and total decapods). We examined the responses of 37 species and tested distribution and abundance patterns for LOOP-related impacts. Because different life history stages of a species may behave ecologically as separate species (Livingston 1988), common fishes and invertebrates were divided into size classes determined from 1) the literature (see Brown and Patlan 1974) and 2) an examination of size-frequency plots. The four size classes used, generally corresponding with small juveniles, juveniles, subadults, and adults, were defined as lengths of < 15 mm, $15 \leq x < 30$ mm, $30 \leq x < 100$ mm, and ≥ 100 mm, respectively. We analyzed patterns for up to four size classes for each of the 37 common species and tested for LOOP-related impacts. Species diversity (Shannon-Weiner Index), richness, and evenness were calculated for each trawl (Pielou 1966). Species diversity is a community metric that can take many forms, but basically it is a numerical index of how the community (i.e., the assemblage of species' populations and number of individuals) is constructed and considers how many species are present (richness) and how individuals in the community are distributed among the species (evenness). We also analyzed changes in the relative abundance of rare species. "Rare" species were defined as taxa comprising less than 0.01% of the total number of organisms collected. Species with greater than 0.01% contribution, but not included in the 40 common taxa selected for analysis, were defined as "uncommon." The proportions of rare species were transformed ($\log_e$(proportion + 0.01)) to more closely approximate the normal distribution for analytical purposes (Sokal and Rohlf 1981).

Nekton sampling stations were assigned to inshore, middle, and offshore zones based on mean salinity (< 10, 10 to 22, and > 22 ‰, respectively). Stations were also designated as either control or impact stations, based on their location and proximity to the pipeline and the results of a rotated principal components analysis (see below). Our analysis required temporal comparisons of events in the construction and operation phases. Pipeline construction lasted from 1979 through 1980, and samples collected prior to January 1979 were designated as "before" observations, samples collected from January 1979 to December 1980 were designated as "during" observations, and samples collected after December 1980 were designated as "after" observations for analyses of temporal patterns and interactions with control and impact (i.e., spatial) stations. Temporal designations during the operational phase were defined similarly around the impact events being examined. Since the pattern of brine discharge was a period of high discharge followed by a protracted period of moderate discharge, the temporal designation categories were the same three used in the construction (i.e., before, during, and after discharge events); however, it should be clarified that the during category included only the high discharge phase and the after category included the moderate, maintenance phase. Oil spill events were temporally more confined and did not include a "during" category (i.e., only before and after).

General Statistics

We developed descriptive statistics for the species and environmental variables associated with each trawl sample. Statistical means were calculated to estimate average conditions and standard errors (SE) were calculated to estimate variation around the averages. The mean number, mean biomass, and mean CPUE were calculated for each species or higher taxa. Means (± SE) of environmental variables were also calculated by station and salinity zone. Environmental means, including station depth, surface temperature, salinity, dissolved oxygen concentration, turbidity, and chlorophyll *a* concentration were also calculated for each taxa, as well as for each size class within taxa. Environmental means among nekton size classes were compared using an analysis of variance (ANOVA) approach (SAS Institute 1989). The significance level for the initial analyses was adjusted with the Dunn-Šidák correction to compensate for the large number of statistical tests and avoid bias in testing for significant effects (Sokal and Rohlf 1981). When a significant effect of an environmental variable was indicated, an *a posteriori* test, the Least Squares Means (LSMeans) test, was used to compare environmental means among size classes (SAS Institute 1989). The LSMeans test provides a more detailed analysis by statistically comparing pairs of environmental means after an overall effect is detected to determine more precisely which means, if any, are different. Because unequal numbers of samples were collected in each salinity zone, sampling bias was avoided by adjusting means for relative sampling effort (weight = total number samples / number samples by zone). To yield a conservative Type I error rate of 0.05 for *a posteriori* testing (Johnson and Wichern 1988), the alpha level was adjusted using the Tukey-Kramer correction (SAS Institute 1989).

A principal components analysis was used to identify highly correlated environmental variables and reduce them to a lesser number of environmental factors (i.e., three independent axes of correlated variables), to assist in pairing control and impact stations for the BACI analysis, and to identify species' responses to environmental factors (Grossman *et al.* 1991). The analysis defined three new statistically independent axes, that characterized spatial and temporal variation in the environment, based on the six original environmental variables and their relationships to each other. An optional step in the process, called rotation, allowed for easier interpretation of the axes. The varimax rotation option (Johnson and Wichern 1988) was used in the principal components analysis (i.e., generating a factor analysis) of environmental data from 3,193 samples and yielded three interpretable axes (SAS Institute 1989). Thus each of three independent axes (with eigenvalues greater than one (range 1.39 to 1.74)) explained more than one of the original six variables. Weighted means of three factor scores were calculated for each station and plotted on the three axes to assist in identifying major associations to pair impact stations along the pipeline with appropriate control stations. The assignment of stations to the impact or control grouping is indicated by subscripted I and C, respectively (e.g., Station 36_I is an impact station and 52_C is a control station). The centroids, or three-dimensional means (Baltz and Moyle 1993), of the species were also plotted along these axes to visualize the relationships of species' distribution and abundance patterns to environmental gradients and the stations. Assemblages of fishes, shrimp, and other invertebrates were plotted separately, using the same graph dimensions, for ease of visual interpretation.

The contributions of the six environmental variables to the prediction of species abundance patterns were also analyzed using a Multivariate Analysis of Variance (MANOVA) approach (SAS Institute 1989). Species abundances (expressed as CPUE) were transformed ($\log_e (x + 1)$) to more closely approximate the normal distribution. The significance level of the overall tests for each species was adjusted for the 37 comparisons of species using the Dunn-Šidák correction (Sokal and Rohlf 1981). The significance level of the Type III sums of squares was adjusted similarly for the six environmental variables. The MANOVA also tested each environmental variable for overall significance in predicting species' CPUE.

Impact Analyses

We used a modification of the BACI (Before-After-Control-Impact) statistical model (Green 1979) to detect and evaluate potential influences on demersal nekton for all aspects of the LOOP monitoring program (Anon 1996). We modified the approach by including a "during" temporal phase in the analysis in addition to the "before" and "after" phases. Specific to the nekton community, the model states:

H_O: Differences in nekton species abundances, lengths, or community descriptors among the control and impact stations were not significantly different before, during, and/or after a LOOP-related event.

H_A: Differences in nekton species abundances, lengths, or community descriptors among the control and impact stations were significantly different before, during, and/or after a LOOP-related event.

This BACI approach was used to test for specific LOOP-related events that may have influenced nekton abundance and community structure. The BACI design tests for temporal and spatial effects, but most importantly tests for the interaction of temporal and spatial variables. A significant interaction indicates that a change in a species' abundance or community structure was not uniform over time or space, and may be a response to the LOOP-related event being tested. The MIXED procedure in SAS, which adjusts for unbalanced designs, was used to test BACI main effects and interactions (SAS Institute 1989). Significant effects and interactions were further analyzed *a posteriori* using LSMeans with the Tukey-Kramer correction for multiple comparisons. Analyses were conducted for each impact station along the pipeline and tested the influence of pipeline construction on species abundances and community indicators. The indicators tested included species diversity, evenness, richness, total organisms, total fishes, total invertebrates, total decapods, and the contribution of rare species. To gain information on the possible mechanisms of influence on species abundances, we also analyzed selected environmental variables at the nekton stations. The analysis of the potential influence of brine discharge was limited to Station 36_I and appropriate control stations, which were generally located in the general area and depth range of the brine diffuser. The monthly total brine discharge volume was used as a covariable in the analysis. Specific oil spills were tested where appropriate control/impact stations could be identified. The oil spill analyses were conducted on the entire data set at the appropriate impact and control stations in the vicinity of the spill, and on data restricted to observations within three years before or after the oil spill events.

RESULTS

Treatment of Stations and Zones

A total of 3,193 trawl samples were collected between February 1978 and December 1995 from 28 stations in southeast coastal Louisiana. Stations, ranging from southern Lake Salvador southward to about 43 km south of Grand Isle in the Gulf of Mexico (Figure 1), were classified into three zones based on mean salinity. The inshore zone (low salinity) included Stations 14_C, 17_C, and 19_I where the annual mean (± SE) salinity was 3.2 ± 0.22 ‰ and ranged from 0 to 18.4 ‰. The middle zone (intermediate salinity) included Stations 1_C, 2_C, 3_C, 6_C, 7_I, 8_C, 9_C, 10_C, and 41_C where the annual mean salinity was 18.2 ± 0.22 ‰ and ranged from 0.7 to 37.6 ‰. The offshore zone (high salinity) included Stations 4_C, 5_C, 21_C, 22_I, 31_I, 33_I, 35_C, 36_I, 37_C, 42_C, 43_C, 44_C, 52_C, 53_I, 54_I, and 55_I where the annual mean salinity was 25.7 ± 0.12 ‰ and ranged from 8.3 to 37.6 ‰.

The factor analysis reduced the six environmental variables to three axes (Table 1) of correlated gradients that explained 75.5% of the variance (i.e., six variables were reduced to three axes while retaining > 75% of the original variation). The primary objective of this analysis was to associate sampling stations into control and impact groupings for further analyses. Depth and turbidity weighed heavily in the first axis and were inversely related to each other. This large-scale spatial axis reflected the salinity classification of stations into inshore, middle, and offshore zones, and arranged the shallow, turbid stations at one end and deeper, clearer stations at the other (Figure 2a). The second axis was weighted heavily for chlorophyll *a* and salinity, which were also inversely related to each other (Table 1). Since chlorophyll *a* concentrations provide an index to productivity, this axis was interpreted as a productivity-salinity axis. In the third axis, temperature and dissolved oxygen were inversely related to each other (Table 1), reflecting the seasonality of environmental variation in the year-round sampling program. The stations showed strong separation along the first two axes, but not along the third axis (Figure 2a).

Table 1. Rotated factor loadings for the environmental variables measured in the LOOP monitoring program from February 1978 to December 1995. Major loadings (≥ 0.50) in each factor are underlined.

Variable	Factor 1	Factor 2	Factor 3
Depth	0.85	-0.14	-0.03
Turbidity	-0.82	0.21	-0.03
Chlorophyll *a*	-0.16	0.81	-0.01
Salinity	0.45	-0.63	-0.06
Water temperature	0.17	0.25	0.90
Dissolved oxygen	0.27	0.46	-0.76
Variance explained	1.74	1.40	1.39
% Cumulative variance exp.	29.00	52.33	75.50
Factor characterization	Spatial	Productivity/Salinity	Seasonality

Environmental Variables

Environmental variables ranged widely during the monitoring program and reflected the spatial and seasonal variation inherent in the project area that had to be accounted for in the sampling design (Table 2). These included surface salinity (range 0 to 37.6 ‰), temperature (2.1 to 36.5 °C), dissolved oxygen concentration (0.3 to 20.0 mg/l), turbidity (0 to 200 NTU), and chlorophyll *a* concentration (0 to 139.4 mg/l). Nominal station depths also varied from shallow to deep (0.1 to 35 m) across the depth gradient from inshore to offshore zones. Except for water temperature, all environmental variables differed between control and impact stations in at least one zone (Table 3).

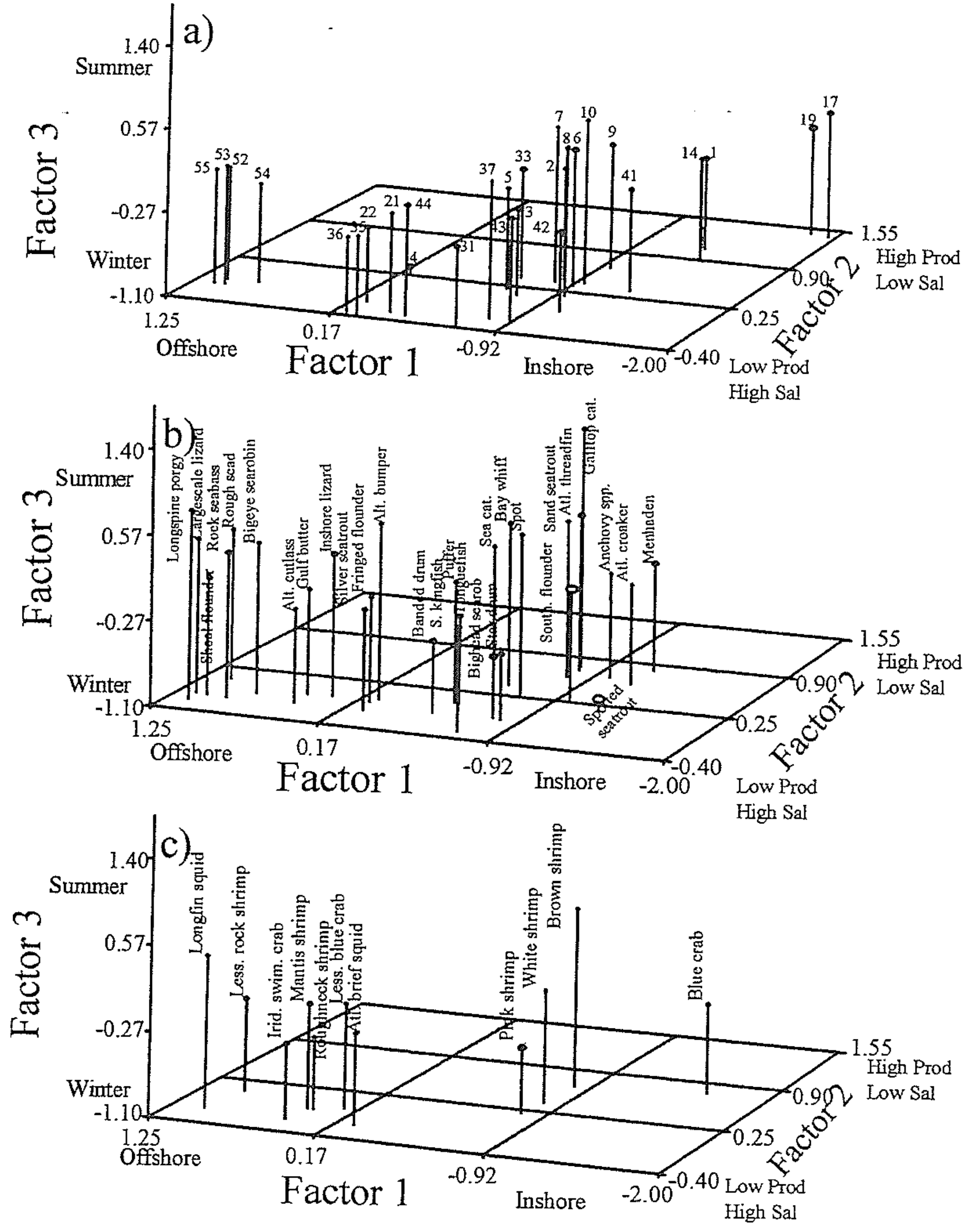

Figure 2. Three dimensional environmental factor space showing the relationships of a) stations, b) fish taxa, and c) macroinvertebrate taxa. The diameters of the balloons encompass one standard error.

Table 2. Environmental means (± SE) at the nekton stations sampled for the LOOP monitoring program between February 1978 and December 1995. Stations are arranged by salinity zones (see text).

Salinity Zone and Station	Depth	Salinity	Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Inshore zone						
Station 14	1.92 ± 0.03	3.67 ± 0.28	21.90 ± 0.50	39.57 ± 2.81	8.18 ± 0.11	9.78 ± 0.55
Station 17	1.57 ± 0.05	1.96 ± 0.28	21.95 ± 1.17	78.73 ± 5.71	8.30 ± 0.26	18.54 ± 2.40
Station 19	1.91 ± 0.05	1.95 ± 0.27	21.95 ± 1.23	71.37 ± 5.25	8.63 ± 0.40	15.96 ± 2.15
Middle zone						
Station 1	1.91 ± 0.03	13.06 ± 0.79	22.27 ± 0.85	46.28 ± 4.34	8.43 ± 0.22	18.05 ± 2.27
Station 2	2.08 ± 0.04	19.90 ± 0.81	22.55 ± 0.82	28.24 ± 2.33	8.28 ± 0.20	13.56 ± 1.75
Station 3	2.54 ± 0.07	20.71 ± 0.84	22.69 ± 0.80	27.55 ± 2.56	8.29 ± 0.22	11.51 ± 1.34
Station 6	2.19 ± 0.07	21.88 ± 0.71	22.48 ± 1.08	35.57 ± 3.10	7.61 ± 0.23	14.01 ± 1.95
Station 7	1.66 ± 0.03	17.68 ± 0.32	22.60 ± 0.48	21.17 ± 1.21	7.14 ± 0.13	13.63 ± 0.61
Station 8	1.67 ± 0.06	18.79 ± 0.59	23.02 ± 0.96	35.74 ± 2.96	7.58 ± 0.23	12.94 ± 1.18
Station 9	2.00 ± 0.07	18.15 ± 0.81	23.25 ± 1.09	42.16 ± 4.81	8.44 ± 0.22	15.50 ± 1.41
Station 10	2.10 ± 0.09	18.21 ± 0.64	22.78 ± 0.96	35.21 ± 2.50	7.36 ± 0.24	15.77 ± 1.46
Station 41	1.95 ± 0.04	17.72 ± 0.60	21.93 ± 0.92	41.90 ± 3.49	8.04 ± 0.28	12.13 ± 1.12
Offshore zone						
Station 4	11.83 ± 0.14	23.20 ± 0.86	23.36 ± 0.80	16.20 ± 2.41	9.34 ± 0.34	9.79 ± 1.44
Station 5	4.10 ± 0.08	22.15 ± 0.41	22.91 ± 0.44	19.03 ± 1.22	8.12 ± 0.12	12.36 ± 0.75
Station 21	7.87 ± 0.06	26.01 ± 0.38	23.02 ± 0.40	8.82 ± 0.72	7.99 ± 0.14	8.15 ± 0.87
Station 22	10.53 ± 0.07	26.05 ± 0.38	23.21 ± 0.40	7.32 ± 0.69	8.29 ± 0.15	8.44 ± 0.92
Station 31	3.29 ± 0.11	25.58 ± 0.99	22.50 ± 0.97	25.12 ± 3.02	8.44 ± 0.44	11.19 ± 2.42
Station 33	2.76 ± 0.11	23.60 ± 0.79	24.48 ± 1.12	32.26 ± 2.85	7.70 ± 0.30	13.62 ± 1.70
Station 35	10.56 ± 0.03	26.34 ± 0.33	22.77 ± 0.34	6.87 ±0.53	8.27 ± 0.12	7.67 ± 0.73
Station 36	10.88 ± 0.03	26.16 ± 0.38	23.46 ± 0.40	5.78 ± 0.56	8.42 ± 0.15	7.58 ± 0.91
Station 37	3.22 ± 0.14	24.60 ± 0.31	23.46 ± 0.47	26.90 ± 1.45	7.09 ± 0.13	11.38 ± 0.56
Station 42	2.35 ± 0.03	22.67 ± 0.51	22.04 ± 0.91	32.54 ± 3.13	8.11 ± 0.27	9.89 ± 0.88
Station 43	2.85 ± 0.08	25.26 ± 0.60	22.24 ± 0.85	30.34 ± 3.52	8.10 ± 0.26	8.23 ± 0.96
Station 44	8.92 ± 0.26	27.02 ± 0.64	23.52 ± 0.82	20.13 ± 2.50	7.89 ± 0.31	6.12 ± 0.74
Station 52	33.05 ± 0.15	26.55 ± 0.45	23.45 ± 0.44	3.01 ± 0.34	8.40 ± 0.18	5.32 ± 0.55
Station 53	33.06 ± 0.11	26.67 ± 0.42	23.55 ± 0.43	3.05 ± 0.40	8.17 ± 0.17	4.68 ± 0.49
Station 54	27.09 ± 0.08	26.29 ± 0.43	23.80 ± 0.44	2.68 ± 0.32	8.44 ± 0.18	5.14 ± 0.54
Station 55	33.95 ± 0.15	27.08 ± 0.44	23.53 ± 0.43	2.68 ± 0.33	8.23 ± 0.17	4.48 ± 0.52

Table 3. Environmental means (± SE) for the three salinity zones (Zone 1 = inshore, Zone 2 = middle, and Zone 3 = offshore), as well as for the control and impact stations within zones. Significant differences (GLM, $p < 0.05$, Tukey-Kramer adjustment) among zones, and between control and impact station groupings within zones are indicated by different letters, reading vertically.

Salinity Zone	Depth	Salinity	Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Zone Means:						
Zone 1	1.9 ± 0.02 A	3.2 ± 0.22 A	21.9 ± 0.44 A	50.2 ± 2.51 A	8.3 ± 0.11 A	11.9 ± 0.63 A
Zone 2	1.9 ± 0.02 A	18.2 ± 0.22 B	22.6 ± 0.27 B	31.7 ± 0.9 B	7.8 ± 0.07 B	14.0 ± 0.46 B
Zone 3	14.8 ± 0.27 B	25.7 ± 0.12 C	22.8 ± 0.13 B	11.8 ± 0.38 C	8.2 ± 0.05 C	8.1 ± 0.24 C
Control/Impact						
Zone 1						
Control	1.6+0.05 A	2.0+0.28	22.0+1.17	78.7+5.71 A	8.3+0.26	18.5+2.40 A
Impact	1.9+0.02 B	3.4+0.25	21.9+0.47	45.0+2.64 B	8.3+0.12	10.8+0.60 B
Zone 2						
Control	2.1+0.02 A	18.4+0.29	22.6+0.32	35.9+1.19 A	8.0+0.08 A	14.1+0.60
Impact	1.7+0.03 B	17.7+0.32	22.7+0.48	21.2+1.23 B	7.13+0.13 B	13.7+0.63
Zone 3						
Control	9.9+0.28 A	25.1+0.16 A	22.7+0.18	15.9+0.56 A	8.1+0.06	9.1+0.31 A
Impact	21.5+0.39 B	26.7+0.18 B	23.0+0.19	5.9+0.36 B	8.4+0.08	6.6+0.37 B

In the GLM comparison of environmental means across the three major zones, several significant differences ($p < 0.05$, adjusted) were detected. Salinity was used to define zones and differed significantly among all zones (Table 3). Mean temperature and dissolved oxygen showed significant differences, but the magnitudes of the differences among zones were probably not biologically important (less than 1 °C and 0.5 mg/l, respectively). Although mean dissolved oxygen levels at the stations were not biologically limiting, hypoxic conditions did exist at some stations for some of the trawls. Eight samples were collected with surface dissolved oxygen concentrations less than 2 mg/l, and 142 samples recorded bottom dissolved oxygen concentrations less than 2 mg/l. Offshore stations had lower mean turbidities and chlorophyll *a* levels.

When the environmental variables were compared between nekton control and impact stations within the major zones, several statistically significant differences were detected

(Table 3). Significant differences between control and impact stations in all three zones were detected for depth, but these differences were probably due to the *a posteriori* selection of stations as control or impact for this analysis. Within the inshore and offshore zones, turbidity and chlorophyll *a* were higher at the control stations than at the impact stations. Within the middle zone, turbidity and dissolved oxygen were significantly higher at the control stations, but the absolute difference in dissolved oxygen concentration (0.9 mg/l) was probably not biologically meaningful. Within the offshore zone, salinity also differed significantly, but this difference (1.6 ‰) was not considered to be biologically meaningful. Where differences were statistically and biologically meaningful, we included the environmental variables in subsequent analysis as covariates to help evaluate impacts in nekton analyses.

Construction Impacts on Environmental Variables

The BACI analysis (i.e., MIXED model on temporal and spatial effects and their interactions) of the potential influence of the construction phases (i.e., before, during, and after) of the LOOP pipeline revealed several significant effects for environmental variables (Table 4). A total of 48 comparisons were made for the six environmental variables at the eight impact stations and associated controls. Four significant temporal effects and two significant interactions effects on turbidity levels were detected at five impact stations. No significant effects on environmental variables were detected for the LOOP platform stations (Stations 52_C, 53_I, 54_I, and 55_I). No significant effects were detected for water temperature, salinity, dissolved oxygen, station depth or chlorophyll *a* at any impact station grouping.

For Stations 14_C, 17_C, and 19_I, a significant decrease in turbidity was observed after construction ended (Table 4). Turbidity at Stations 2_C, 6_C, 7_I, 8_C, 9_C, and 10_C also decreased significantly after construction ended (Table 4). Nevertheless, no influences of LOOP construction on turbidity were detected (by significant interaction terms) for Stations 19_I and 7_I.

Table 4 Construction-related trends in environmental variables in the BACI analysis with significant effects (MIXED, $p < 0.05$). Effects with a slash (e.g., Before/Control) signify a significant interaction between temporal and spatial effects. Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically within station and variable.

Station & Variable	Effect	Mean ± SE
Station 19		
Turbidity	Before	87.8 ± 14.11 A
	During	87.6 ± 9.38 A
	After	30.1 ± 5.96 B
Station 7		
Turbidity	Before	61.1 ± 7.48 A
	During	34.6 ± 5.30 AB
	After	18.6 ± 2.67 B
Station 22		
Turbidity	Before	15.9 ± 4.95 AB
	During	18.2 ± 3.23 A
	After	5.3 ± 1.25 B
Station 31		
Turbidity	Before	29.7 ± 2.80 A
	During	22.4 ± 1.20 B
	After	14.4 ± 1.46 C
Turbidity	Before/Control	21.5 ± 2.57 AB
	Before/Impact	38.0 ± 4.98 A
	During/Control	19.3 ± 1.27 B
	During/Impact	25.0 ± 2.03 AB
	After/Control	6.7 ± 0.53 C
	After/Impact	22.2 ± 2.88 AB
Station 36		
Turbidity	Before/Control	18.7 ± 4.79 AB
	Before/Impact	no estimate
	During/Control	20.0 ± 3.21 A
	During/Impact	15.5 ± 3.90 AB
	After/Control	5.8 ± 1.25 B
	After/Impact	4.9 ± 1.41 B

At Stations 21_C, 22_I, 31_I, 35_C, 36_I, and 44_C, turbidity also decreased significantly after construction ended for at all three impact stations (Table 4). A significant influence of LOOP pipeline construction on turbidity was detected at Stations 31_I and 36_I (i.e., the construction phase interacted with spatial patterns of control and impact stations to indicate significant LOOP-related impacts on turbidity). Mean turbidity decreased significantly after construction at the control stations, but remained significantly higher at Station 31_I. At Station 36_I, mean turbidity decreased after construction ended (Table 4).

Species Composition and Biomass

A total of 2,528,703 organisms was sampled in 3,193 trawls collected between February 1978 and December 1995. The total biomass collected was 39,396 kilograms. Forty of the 288 taxa collected were included in the overall analyses based on minimum criteria for CPUE (> 90 individuals/hr) and frequency of occurrence in samples (> 7.5%) (Tables 5 and 6). The additional 248 uncommon and rare taxa collected are listed in Appendix I. Among the 40 selected taxa, the most abundant was anchovy spp., which accounted for 535,258 individuals. Atlantic croaker had the highest total biomass, with 11,039 kg collected (Table 6). Commercially and recreationally important species collected included Atlantic croaker, brown shrimp, white shrimp, blue crab, Gulf menhaden, spotted seatrout, and southern flounder. The four most abundant taxa (i.e., anchovy spp., Atlantic croaker, brown shrimp, and roughneck shrimp spp.) accounted for over 50% of the total catch by number, the 21 most abundant taxa accounted for over 90% of the total catch by number, and the 40 selected taxa accounted for 99.84% of the total catch by number (Table 5). All 40 of the most abundant taxa were estuarine and/or marine; no freshwater species were common enough to be included in the analysis.

In the factor analysis (Table 1, Figures 2b, 2c), fishes and macroinvertebrates separated strongly along the large-scale spatial (Factor 1) and productivity-salinity (Factor 2) axes, but less so along the seasonal axis (Factor 3). Marine fishes such as longspine porgy, rock sea bass, and largescale lizardfish were distributed towards the offshore, high salinity stations, whereas more euryhaline fishes, such as Atlantic croaker, southern flounder, spotted seatrout, and gafftopsail catfish were more abundant at the middle and inshore zones at the moderate and lower salinity

Table 5. A selected list of 40 nekton species and higher taxa organized by rank abundance and frequency of occurrence. A total of 2,528,703 fishes and invertebrates was collected. Frequency of occurrence is the percentage of trawls in which the taxon occurred out of a total of 3,193 trawls.

Common Name	Scientific Name	Number	Percent of Total	Cumulative Percent	Percent Frequency of Occurrence
Anchovy spp.	*Anchoa mitchilli & A. hepsetus*	535,258	21.17	21.17	73.44
Atlantic croaker	*Micropogonias undulatus*	356,991	14.12	35.28	59.72
Brown shrimp	*Penaeus aztecus*	267,198	10.57	45.85	54.78
Roughneck shrimp spp.	*Trachypeneus* spp.	165,578	6.55	52.40	32.63
White shrimp	*Penaeus setiferus*	144,580	5.72	58.12	52.58
Gulf butterfish	*Peprilus burti*	90,379	3.57	61.69	32.04
Bigeye searobin	*Prionotus longispinosus*	89,369	3.53	65.23	28.53
Sea catfish	*Arius felis*	83,674	3.31	68.53	34.89
Atlantic cutlassfish	*Trichiurus lepturus*	70,127	2.77	71.31	42.56
Blue crab	*Callinectes sapidus*	63,238	2.50	73.81	37.61
Spot	*Leiostomus xanthurus*	59,885	2.37	76.18	32.20
Atlantic brief squid	*Lolliguncula brevis*	48,927	1.93	78.11	52.15
Lesser blue crab	*Callinectes similis*	42,520	1.68	79.79	36.74
Rough scad	*Trachurus lathami*	40,850	1.62	81.41	10.15
Sand seatrout	*Cynoscion arenarius*	40,317	1.59	83.00	44.28
Longfin squid	*Loligo pealeii*	35,869	1.42	84.42	16.66
Lesser rock shrimp	*Sicyonia dorsalis*	32,287	1.28	85.70	13.28
Star drum	*Stellifer lanceolatus*	30,416	1.20	86.90	14.97
Fringed flounder	*Etropus crossotus*	30,197	1.19	88.09	42.53
Gafftopsail catfish	*Bagre marinus*	30,137	1.19	89.29	7.92
Longspine porgy	*Stenotomus caprinus*	27,191	1.08	90.36	8.77
Atlantic bumper	*Chloroscombrus chrysurus*	25,454	1.01	91.37	19.10
Silver seatrout	*Cynoscion nothus*	21,783	0.86	92.23	20.89
Bay whiff	*Citharichthys spilopterus*	20,538	0.81	93.04	44.85
Atlantic threadfin	*Polydactylus octonemus*	18,365	0.73	93.77	7.70
Least puffer	*Sphoeroides parvus*	17,521	0.69	94.46	41.56
Iridescent swimming crab	*Portunus gibbesii*	16,619	0.66	95.12	21.30
Mantis shrimp	*Squilla empusa*	16,205	0.64	95.76	24.37
Gulf menhaden	*Brevoortia patronus*	15,562	0.62	96.37	17.57
Shoal flounder	*Syacium gunteri*	15,021	0.59	96.97	15.82
Largescale lizardfish	*Saurida brasiliensis*	13,118	0.52	97.49	9.83
Southern kingfish	*Menticirrhus americanus*	11,999	0.47	97.96	21.86
Tonguefish spp.	*Symphurus* spp.	10,317	0.41	98.37	33.73
Rock sea bass	*Centropristis philadelphica*	6,903	0.27	98.64	15.63
Inshore lizardfish	*Synodus foetens*	6,241	0.25	98.89	23.58
Bighead searobin	*Prionotus tribulus*	5,936	0.23	99.12	18.26
Pink shrimp	*Penaeus duorarum*	5,699	0.23	99.35	8.83
Banded drum	*Larimus fasciatus*	5,426	0.21	99.56	14.59
Spotted seatrout	*Cynoscion nebulosus*	4,990	0.20	99.76	6.39
Southern flounder	*Paralichthys lethostigma*	1,892	0.07	99.84	11.74

Table 6. Mean CPUE and biomass (± SE) and total biomass for 40 common taxa collected in the LOOP monitoring program between February 1978 and December 1995.

Taxa	Mean Hourly CPUE	Mean Biomass per Trawl (g)	Total Biomass (kg)
Bay & striped anchovy	1,154.4 ± 65.27	588.45 ± 36.23	1,468
Atlantic croaker	810.7 ± 73.06	6,072.32 ± 719.97	11,039
Brown shrimp	423.5 ± 53.01	623.08 ± 71.87	1,659
Roughneck shrimp spp.	630.2 ± 67.79	608.94 ± 76.53	638
White shrimp	233.3 ± 24.07	424.37 ± 27.24	1,064
Gulf butterfish	360.0 ± 49.85	1,735.06 ± 186.88	1,702
Bigeye searobin	396.7 ± 92.38	1,022.7 ± 131.48	927
Sea catfish	321.7 ± 74.96	2,840.5 ± 351.45	2,994
Blue crab	235.4 ± 21.37	1,439.9 ± 98.86	1,666
Atlantic cutlassfish	186.6 ± 14.43	3,133.8 ± 396.19	4,535
Spot	253.8 ± 45.50	2,032.8 ± 416.04	1,994
Atlantic brief squid	128.4 ± 5.39	353.4 ± 14.81	563
Sand seatrout	148.6 ± 8.30	522.7 ± 31.62	601
Lesser blue crab	505.5 ± 80.40	2,113.1 ± 327.66	687
Rough scad	124.0 ± 12.65	947.7 ± 75.54	1,284
Longfin squid	270.1 ± 19.73	978.8 ± 81.09	520
Lesser rock shrimp	319.5 ± 43.14	232.8 ± 32.35	97
Gafftopsail catfish	268.3 ± 54.93	741.6 ± 139.96	343
Star drum	92.9 ± 5.22	307.9 ± 18.72	406
Fringed flounder	510.0 ± 106.98	2,150.5 ± 434.00	520
Atlantic bumper	388.5 ± 48.68	913.4 ± 96.14	256
Longspine porgy	191.4 ± 26.24	1,388.4 ± 160.93	809
Atlantic threadfin	134.0 ± 12.42	1,168.7 ± 163.5	773
Silver seatrout	62.1 ± 3.25	159.8 ± 9.42	222
Bay whiff	371.8 ± 94.55	630.6 ± 149.55	134
Gulf menhaden	58.4 ± 3.28	90.0 ± 7.21	114
Least puffer	99.2 ± 20.35	120.8 ± 16.08	81
Iridescent swimming crab	84.9 ± 8.47	168.2 ± 17.08	129
Mantis shrimp	152.5 ± 32.28	307.1 ± 67.55	162
Shoal flounder	119.1 ± 7.55	484.6 ± 30.33	245
Largescale lizardfish	167.1 ± 19.55	250.2 ± 32.70	79
Southern kingfish	72.1 ± 9.34	726.1 ± 83.07	475
Tonguefish spp.	46.0 ± 3.22	116.7 ± 7.11	119
Rock sea bass	55.7 ± 9.49	201.0 ± 26.31	100
Bighead searobin	34.4 ± 1.99	413.7 ± 22.95	303
Banded drum	45.2 ± 4.62	85.0 ± 8.18	45
Inshore lizardfish	64.5 ± 9.98	155.7 ± 27.73	56
Pink shrimp	55.6 ± 5.10	215.7 ± 57.02	93
Spotted seatrout	100.6 ± 34.09	516.9 ± 119.73	102
Southern flounder	21.4 ± 2.01	1,063.7 ± 103.37	392

stations (Fig 2b). Most of the invertebrate taxa were more abundant at the offshore, high salinity stations, but penaeid shrimp and blue crab were more abundant at the more inshore stations (Figure 2c). Temporal segregation of three species of penaeid shrimp was reflected by separations along the seasonality axis, with brown shrimp more abundant in summer, white shrimp more abundant in fall, and pink shrimp more abundant in winter samples.

In the MANOVA used to predict CPUE by species, as many as five of the six environmental variables contributed significantly (i.e., predicted the CPUE) in models for the 37 species analyzed (Table 7). Means were calculated for anchovy spp., roughneck shrimp spp., and tonguefish spp., but comparisons of their means were not made because of the difficulty of interpreting results at a generic level. For all other taxa, station depth made the greatest contribution, followed in turn by salinity, water temperature, turbidity, dissolved oxygen, and chlorophyll *a*.

In a GLM analysis of differences in environmental variables among size classes of the 37 species examined, significant differences were detected for 29 species (Table 8). Ontogenetic shifts were noted for seven of the 37 species and for all six environmental variables. As Atlantic croaker increased in size, they were collected from deeper, warmer, clearer, more saline water. Larger blue crab were collected from clearer, warmer, more saline water with lower dissolved oxygen concentrations than smaller crabs. The two larger size classes of lesser blue crab were more abundant in deeper, clearer water than the two smaller classes. As sand seatrout and inshore lizardfish grew, they were collected from progressively deeper, clearer, more saline waters with lower chlorophyll *a* concentrations. Bay whiff were collected from deeper, more saline water as they grew. As Gulf menhaden grew they were found in waters with higher chlorophyll *a* concentrations, and banded drum were collected from deeper water as they grew.

Table 7. Environmental means (± SE) for 40 common taxa collected in the LOOP monitoring program between February 1978 and December 1995. Signs indicate a significant (GLM, $p < 0.05$, adjusted) contribution to the distribution of that taxa, with either a positive coefficient (+) or a negative coefficient (-). Anchovies, roughneck shrimp, and tonguefish were not included in this analysis (see text).

Common Name	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Bay & striped anchovy	4.6 ± 0.12	16.8 ± 0.17	22.8 ± 0.12	22.4 ± 0.41	7.8 ± 0.04	11.7 ± 0.21
Atlantic croaker	10.6 ± 0.25 +	22.7 ± 0.16 -	23.2 ± 0.11 -	20.7 ± 0.51 +	7.4 ± 0.04 -	10.1 ± 0.21
Brown shrimp	4.4 ± 0.11	21.2 ± 0.09 +	26.3 ± 0.06 +	22.2 ± 0.32	7.5 ± 0.03 -	12.9 ± 0.14 +
Roughneck shrimp spp.	26.4 ± 0.31	22.9 ± 0.23	23.6 ± 0.16	7.2 ± 0.31	8.7 ± 0.07	7.9 ± 0.30
White shrimp	4.5 ± 0.09	25.2 ± 0.09 +	22.0 ± 0.12 -	27.1 ± 0.40 -	7.4 ± 0.03 -	10.4 ± 0.16 +
Gulf butterfish	28.2 ± 0.26 +	26.1 ± 0.16 +	24.2 ± 0.12 -	3.1 ± 0.15 -	7.8 ± 0.05	5.1 ± 0.23 +
Bigeye searobin	30.5 ± 0.17 +	26.6 ± 0.18	28.4 ± 0.09	2.4 ± 0.13	7.1 ± 0.05	4.1 ± 0.20
Sea catfish	5.2 ± 0.10 -	26.4 ± 0.13 +	21.3 ± 0.14 +	19.6 ± 0.38	7.4 ± 0.04	8.8 ± 0.20
Atlantic cutlassfish	26.4 ± 0.30 -	26.5 ± 0.16 -	22.6 ± 0.16	4.6 ± 0.25 +	8.2 ± 0.06 -	6.6 ± 0.26 +
Blue crab	2.9 ± 0.06 +	19.1 ± 0.17 +	21.8 ± 0.13	37.0 ± 0.59	7.7 ± 0.04	12.4 ± 0.20
Spot	4.8 ± 0.20 -	24.0 ± 0.16 +	24.9 ± 0.13 +	18.0 ± 0.38	7.6 ± 0.06 -	13.1 ± 0.26 +
Atlantic brief squid	18.2 ± 0.26 +	26.2 ± 0.11 +	21.8 ± 0.11	9.9 ± 0.27	8.5 ± 0.04	7.9 ± 0.21
Lesser blue crab	18.9 ± 0.35 +	24.9 ± 0.15 +	23.7 ± 0.14 +	12.8 ± 0.41 +	7.7 ± 0.05	8.0 ± 0.20 +
Rough scad	32.4 ± 0.14 +	23.5 ± 0.42 +	25.0 ± 0.21	4.1 ± 0.31	8.3 ± 0.10	7.1 ± 0.39
Sand seatrout	10.7 ± 0.27 +	24.5 ± 0.16 -	25.5 ± 0.13	22.1 ± 0.49	7.2 ± 0.05	9.9 ± 0.23
Longfin squid	31.6 ± 0.16 +	26.1 ± 0.16 -	27.0 ± 0.14	1.9 ± 0.08	7.9 ± 0.06	4.0 ± 0.20
Lesser rock shrimp	31.8 ± 0.26 +	25.2 ± 0.33	23.2 ± 0.23	4.2 ± 0.39	9.1 ± 0.11	6.9 ± 0.40
Star drum	6.5 ± 0.15 -	25.3 ± 0.20	27.0 ± 0.20 +	40.7 ± 1.04	7.2 ± 0.07 -	13.3 ± 0.33 +
Fringed flounder	23.4 ± 0.31	26.3 ± 0.13 +	23.3 ± 0.14	8.6 ± 0.37	8.1 ± 0.05 +	5.8 ± 0.17
Gafftopsail catfish	2.8 ± 0.07 +	20.7 ± 0.25 +	30.6 ± 0.08	34.2 ± 1.25	5.9 ± 0.07	15.5 ± 0.29
Longspine porgy	32.5 ± 0.16 +	26.8 ± 0.38 +	28.8 ± 0.14 +	2.3 ± 0.19	7.1 ± 0.08 +	2.6 ± 0.23
Atlantic bumper	11.6 ± 0.34 +	26.7 ± 0.17 -	27.3 ± 0.13 +	9.9 ± 0.40	7.4 ± 0.06	8.9 ± 0.43 -
Silver seatrout	19.5 ± 0.43 -	26.9 ± 0.16 +	21.5 ± 0.19 +	7.0 ± 0.31	7.8 ± 0.07	7.2 ± 0.29
Bay whiff	17.1 ± 0.33 +	24.5 ± 0.15 +	25.2 ± 0.13 -	15.8 ± 0.46 -	7.5 ± 0.04 -	8.1 ± 0.19
Atlantic threadfin	4.3 ± 0.29 +	17.8 ± 0.37	26.2 ± 0.16 +	22.7 ± 1.30	7.8 ± 0.09 -	18.3 ± 0.79
Least puffer	15.4 ± 0.37 -	25.2 ± 0.16 -	20.9 ± 0.16 -	14.7 ± 0.54	8.0 ± 0.05 -	8.0 ± 0.23 +
Iridescent swimming crab	20.1 ± 0.50 +	26.5 ± 0.17 +	21.5 ± 0.17	8.9 ± 0.52	8.2 ± 0.06 -	6.3 ± 0.20 +
Mantis shrimp	25.5 ± 0.36 +	22.6 ± 0.22	24.8 ± 0.18 -	8.2 ± 0.46	7.8 ± 0.08	8.0 ± 0.26
Gulf menhaden	2.4 ± 0.08 +	15.6 ± 0.25 +	17.9 ± 0.30	37.5 ± 1.09	8.0 ± 0.07	8.6 ± 0.43
Shoal flounder	32.3 ± 0.13 +	26.8 ± 0.21 -	25.0 ± 0.17	2.9 ± 0.14	8.1 ± 0.07	4.3 ± 0.22
Largescale lizardfish	33.1 ± 0.12 +	27.4 ± 0.20 -	27.2 ± 0.20	1.6 ± 0.09	7.8 ± 0.09	3.3 ± 0.25
Southern kingfish	3.8 ± 0.12 -	26.0 ± 0.16 +	20.6 ± 0.20	22.3 ± 0.55	7.2 ± 0.05	7.9 ± 0.21
Tonguefish spp.	12.0 ± 0.32	24.7 ± 0.17	21.0 ± 0.16	19.1 ± 0.64	8.1 ± 0.05	9.6 ± 0.32
Rock sea bass	31.6 ± 0.22 +	27.0 ± 0.27	27.3 ± 0.20	3.0 ± 0.25	7.4 ± 0.07	3.0 ± 0.21
Inshore lizardfish	27.0 ± 0.42 -	26.3 ± 0.19 +	25.2 ± 0.20 -	6.6 ± 0.43	7.8 ± 0.07	5.3 ± 0.25 +
Bighead searobin	5.3 ± 0.18	24.4 ± 0.22 +	19.1 ± 0.16	21.3 ± 0.81	8.0 ± 0.06 +	11.5 ± 0.58
Pink shrimp	3.3 ± 0.15 +	23.8 ± 0.23 +	20.6 ± 0.18 +	24.0 ± 0.81	8.1 ± 0.07	15.6 ± 0.74 +
Banded drum	10.0 ± 0.34 -	27.1 ± 0.27 +	20.5 ± 0.21 -	16.8 ± 0.66	8.2 ± 0.09	8.5 ± 0.63
Spotted seatrout	2.5 ± 0.06 -	28.2 ± 0.35	14.2 ± 0.22 -	17.1 ± 0.90	7.94 ± 0.11	7.0 ± 0.40
Southern flounder	6.3 ± 0.46	24.0 ± 0.36 +	21.0 ± 0.32	29.0 ± 1.13	7.58 ± 0.08 -	9.8 ± 0.46
F value (MANOVA)	285.21	60.67	33.42	14.50	4.92	4.66
P > F	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Table 8. Weighted means (± SE) of environmental variables used by four size classes of 40 common taxa collected in the LOOP monitoring program. N is the number of independent samples from which the size classes were collected and Total Number is the number of individuals collected, adjusted for subsampling. If the overall test for differences in mean depths among size classes was significant ($p < 0.0013$), a Least Squares Means test was used *a posteriori* to identify significant differences. Significance levels in the posterior test were adjusted with the Tukey-Kramer correction, and significant differences among size classes within species are indicated by differing letters reading vertically. Size classes with fewer than 50 independent observations were excluded from posterior testing.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Bay and striped anchovy								
< 15 mm	3	22.86	1.6 ± 0.06	11.8 ± 4.41	23.9 ± 1.50	12.8 ± 5.68	6.6 ± 0.41	7.5 ± 1.57
$15 \le x < 30$ mm	402	30,515.08	1.9 ± 0.06	11.1 ± 0.37	23.8 ± 0.32	20.9 ± 1.14	6.9 ± 0.09	10.2 ± 0.44
$30 \le x < 100$ mm	3,443	461,328.39	3.8 ± 0.09	18.4 ± 0.20	22.4 ± 0.14	23.7 ± 0.48	8.0 ± 0.04	12.4 ± 0.26
≥ 100 mm	565	43,391.28	29.8 ± 0.28	25.3 ± 0.22	23.9 ± 0.21	3.2 ± 0.22	8.5 ± 0.10	5.3 ± 0.29
Atlantic croaker								
< 15 mm	17	68.69	4.9 ± 1.09	15.3 ± 3.26	18.5 ± 0.93	45.8 ± 6.68	8.6 ± 0.26	4.9 ± 1.97
$15 \le x < 30$ mm	234	3,727.29	2.7 ± 0.17 A	16.2 ± 0.71 A	14.8 ± 0.28 A	44.0 ± 2.82 A	8.4 ± 0.13 A	8.6 ± 0.62 AB
$30 \le x < 100$ mm	1,399	131,497.90	3.3 ± 0.09 A	21.0 ± 0.26 B	20.7 ± 0.16 B	27.2 ± 0.90 B	7.6 ± 0.06 A	11.5 ± 0.36 A
≥ 100 mm	1,391	221,697.13	21.4 ± 0.36 B	26.0 ± 0.17 C	25.8 ± 0.13 C	11.0 ± 0.50 C	7.2 ± 0.06 B	7.8 ± 0.24 B
Brown shrimp								
< 15 mm	1	17.00	2.4 ± ----	22.4 ± ----	19.7 ± ----	47.0 ± ----	8.5 ± ----	7.5 ± ----
$15 \le x < 30$ mm	42	271.79	2.5 ± 0.62	15.8 ± 1.08	23.6 ± 0.51	33.6 ± 3.50	7.2 ± 0.20	12.9 ± 1.41
$30 \le x < 100$ mm	1,592	217,275.52	3.5 ± 0.10 A	20.8 ± 0.13 A	26.3 ± 0.08	22.2 ± 0.44	7.4 ± 0.04	13.7 ± 0.20 A
≥ 100 mm	1,242	49,633.65	9.2 ± 0.30 B	22.9 ± 0.15 B	26.5 ± 0.10	20.6 ± 0.47	7.4 ± 0.04	11.4 ± 0.23 B

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Roughneck shrimp spp.								
< 15 mm	4	4.00	10.1 ± 0.82	29.9 ± 2.01	23.5 ± 1.54	2.8 ± 0.48	6.9 ± 0.15	2.9 ± 0.42
15 ≤ x < 30 mm	128	763.81	8.3 ± 0.28	28.5 ± 0.44	17.7 ± 0.31	19.0 ± 1.77	8.5 ± 0.14	7.7 ± 0.73
30 ≤ x < 100 mm	1,454	164,643.90	27.5 ± 0.30	22.3 ± 0.25	24.1 ± 0.17	6.6 ± 0.30	8.7 ± 0.07	8.0 ± 0.32
≥ 100 mm	24	166.28	31.4 ± 0.91	26.8 ± 0.83	23.8 ± 1.15	1.9 ± 0.46	8.7 ± 0.44	5.5 ± 1.46
White shrimp								
< 15 mm	1	1.00	8.9 ± ----	29.1 ± ----	18.7 ± ----	2.2 ± ----	7.2 ± ----	3.2 ± ----
15 ≤ x < 30 mm	33	66.00	4.7 ± 0.64	18.1 ± 1.07	24.8 ± 1.06	24.7 ± 3.58	7.7 ± 0.29	17.0 ± 3.79
30 ≤ x < 100 mm	955	109,591.84	3.2 ± 0.07 A	25.3 ± 0.14	20.5 ± 0.21 A	26.7 ± 0.63 A	7.6 ± 0.05	9.3 ± 0.22
≥ 100 mm	1,423	34,921.09	10.2 ± 0.24 B	25.7 ± 0.14	22.6 ± 0.12 B	19.6 ± 0.48 B	7.7 ± 0.04	10.2 ± 0.25
Gulf butterfish								
< 15 mm	6	7.00	8.8 ± 1.24	24.6 ± 3.21	21.2 ± 2.49	8.0 ± 3.41	9.0 ± 0.54	10.6 ± 6.39
15 ≤ x < 30 mm	159	544.95	7.3 ± 0.32 A	26.7 ± 0.52 AB	18.9 ± 0.34 A	13.5 ± 1.12 A	9.1 ± 0.17 AB	10.8 ± 1.19 AB
30 ≤ x < 100 mm	751	45,606.15	27.6 ± 0.43 B	27.4 ± 0.23 A	22.2 ± 0.14 A	3.1 ± 0.24 B	7.5 ± 0.06 A	4.0 ± 0.26 A
≥ 100 mm	563	44,220.91	28.9 ± 0.35 B	24.8 ± 0.24 B	26.4 ± 0.17 B	3.4 ± 0.22 B	8.0 ± 0.08 B	6.1 ± 0.38 B
Bigeye searobin								
< 15 mm	2	2.00	2.7 ± 0.91	19.3 ± 3.05	23.1 ± 2.35	74.0 ± 3.00	6.8 ± 0.80	14.7 ± 6.70
15 ≤ x < 30 mm	36	177.17	11.4 ± 1.32	23.2 ± 1.37	23.0 ± 0.62	12.0 ± 2.48 A	8.8 ± 0.21	12.5 ± 2.64
30 ≤ x < 100 mm	740	65,825.94	30.2 ± 0.26	26.7 ± 0.26	28.6 ± 0.11 A	2.3 ± 0.20	7.0 ± 0.07	3.9 ± 0.29
≥ 100 mm	644	23,363.89	31.1 ± 0.22	26.2 ± 0.24	26.9 ± 0.18 B	3.0 ± 0.19	7.4 ± 0.08	4.8 ± 0.26

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Sea catfish								
< 15 mm	1	1.00	2.7 ± ----	22.5 ± ----	30.8 ± ----	36.0 ± ----	6.2 ± ----	77.7 ± ----
15 ≤ x < 30 mm	2	17.10	2.6 ± 0.69	26.6 ± 1.05	31.5 ± 0.32	44.6 ± 14.56	4.9 ± 1.96	22.1 ± 6.00
30 ≤ x < 100 mm	798	47,283.24	5.0 ± 0.16 A	26.5 ± 0.24	20.3 ± 0.21 A	21.9 ± 0.69 A	7.5 ± 0.07	8.9 ± 0.30
≥ 100 mm	970	36,372.52	6.2 ± 0.15 B	26.2 ± 0.14	23.3 ± 0.18 B	15.1 ± 0.40 B	7.3 ± 0.06	8.5 ± 0.28
Atlantic cutlassfish								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	1	1.00	9.1 ± ----	24.7 ± ----	8.7 ± ----	22.00 ± ----	9.2 ± ----	10.8 ± ----
30 ≤ x < 100 mm	47	149.81	25.0 ± 1.54	24.3 ± 0.85	25.6 ± 0.47	4.84 ± 1.23	7.9 ± 0.28	4.3 ± 0.84
≥ 100 mm	1,194	69,976.19	26.4 ± 0.31	26.5 ± 0.16	22.5 ± 0.17	4.67 ± 0.26	8.2 ± 0.06	6.7 ± 0.27
Blue crab								
< 15 mm	170	739.65	2.0 ± 0.06 A	10.1 ± 0.69 A	14.6 ± 0.39 A	62.7 ± 3.42 A	9.29 ± 0.14 A	16.6 ± 1.93
15 ≤ x < 30 mm	610	7,138.78	2.5 ± 0.07 A	15.1 ± 0.41 B	17.5 ± 0.25 A	50.5 ± 1.64 A	8.48 ± 0.08 A	10.9 ± 0.54
30 ≤ x < 100 mm	1,570	28,005.84	2.7 ± 0.07 A	19.4 ± 0.27 C	22.3 ± 0.20 B	33.9 ± 0.89 B	7.39 ± 0.06 B	12.7 ± 0.28
≥ 100 mm	971	27,354.00	4.3 ± 0.20 B	22.5 ± 0.20 D	24.3 ± 0.19 C	27.0 ± 0.69 C	7.51 ± 0.06 B	12.4 ± 0.27
Spot								
< 15 mm	1	6.00	10.7 ± ----	30.7 ± ----	19.7 ± ----	16.00 ± ----	10.2 ± ----	2.8 ± ----
15 ≤ x < 30 mm	2	6.00	2.9 ± 4.49	20.6 ± 5.85	13.3 ± 3.70	30.25 ± 8.23	7.3 ± 1.69	2.2 ± 0.33
30 ≤ x < 100 mm	290	22,650.22	2.4 ± 0.04 A	22.6 ± 0.34 A	25.3 ± 0.19	20.52 ± 0.86 A	7.0 ± 0.12 A	14.9 ± 0.57 A
≥ 100 mm	945	37,222.78	8.6 ± 0.34 B	25.1 ± 0.18 B	24.3 ± 0.19	15.43 ± 0.44 B	7.6 ± 0.06 B	10.4 ± 0.28 B

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Atlantic brief squid								
< 15 mm	49	156.93	8.4 ± 0.63	25.1 ± 0.55	25.8 ± 0.46	8.0 ± 1.47	8.0 ± 0.37	11.0 ± 1.89
15 ≤ x < 30 mm	538	3,551.35	11.1 ± 0.43 A	27.9 ± 0.22 A	23.1 ± 0.20 A	13.9 ± 0.68 A	7.7 ± 0.10 A	8.7 ± 0.52
30 ≤ x < 100 mm	2,543	44,238.88	18.9 ± 0.32 B	26.0 ± 0.14 B	21.3 ± 0.14 B	9.5 ± 0.35 B	8.6 ± 0.05 B	7.8 ± 0.25
≥ 100 mm	263	979.84	17.6 ± 0.75 B	25.7 ± 0.33 AB	21.8 ± 0.34 AB	10.6 ± 0.74 AB	8.7 ± 0.11 AB	8.8 ± 0.84
Lesser blue crab								
< 15 mm	62	203.97	4.7 ± 0.45 A	23.3 ± 1.23 AB	20.0 ± 0.76	26.2 ± 2.32 A	8.1 ± 0.20	8.2 ± 1.03 AB
15 ≤ x < 30 mm	500	7,542.06	6.3 ± 0.33 A	24.1 ± 0.27 A	22.9 ± 0.26	23.1 ± 0.89 A	7.6 ± 0.08	10.6 ± 0.35 A
30 ≤ x < 100 mm	1,502	34,114.27	25.3 ± 0.40 B	25.6 ± 0.18 B	23.6 ± 0.19	7.7 ± 0.41 B	8.0 ± 0.07	6.8 ± 0.26 B
≥ 100 mm	129	659.68	25.4 ± 1.17 B	25.2 ± 0.53 AB	23.5 ± 0.55	8.4 ± 0.92 B	8.0 ± 0.17	7.9 ± 0.77 AB
Rough scad								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	1	3.00	33.5 ± ----	13.1 ± ----	21.7 ± ----	4.0 ± ----	7.4 ± ----	4.3 ± ----
30 ≤ x < 100 mm	166	7,620.09	32.7 ± 0.17	28.1 ± 0.44 A	25.0 ± 0.37	2.4 ± 0.29 A	7.5 ± 0.14 A	4.1 ± 0.59 A
≥ 100 mm	269	33,226.91	32.1 ± 0.18	21.8 ± 0.55 B	25.8 ± 0.25	5.4 ± 0.40 B	8.6 ± 0.11 B	8.4 ± 0.50 B
Sand seatrout								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	54	130.68	2.9 ± 0.32 A	17.7 ± 1.15 A	24.7 ± 0.94	41.3 ± 4.61 A	7.6 ± 0.45	15.0 ± 1.84 A
30 ≤ x < 100 mm	1,069	20,892.84	9.5 ± 0.41 B	24.4 ± 0.27 B	25.1 ± 0.21	22.5 ± 0.73 B	7.3 ± 0.06	10.2 ± 0.36 B
≥ 100 mm	1,037	19,293.48	15.5 ± 0.40 C	25.5 ± 0.17 C	25.7 ± 0.17	16.6 ± 0.66 C	7.3 ± 0.07	8.1 ± 0.27 C

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Longfin squid								
< 15 mm	2	2.02	18.6 ± 13.32	25.0 ± 0.74	27.7 ± ----	4.0 ± 0.00	7.9 ± 1.13	8.7 ± 6.48
15 ≤ x < 30 mm	65	374.43	29.9 ± 0.93	28.1 ± 0.71	26.8 ± 0.44	1.3 ± 0.20	7.4 ± 0.20	3.3 ± 0.84
30 ≤ x < 100 mm	811	30,141.26	31.4 ± 0.22	26.3 ± 0.22	26.7 ± 0.19	1.9 ± 0.09	7.8 ± 0.08	4.0 ± 0.26
≥ 100 mm	289	5,351.28	32.3 ± 0.24	25.5 ± 0.26	27.7 ± 0.19	2.2 ± 0.20	8.0 ± 0.10	4.0 ± 0.35
Lesser rock shrimp								
< 15 mm	2	2.00	10.8 ± 0.15	30.3 ± 1.45	16.2 ± 1.35	6.5 ± 0.50	8.1 ± 0.15	1.7 ± 0.20
15 ≤ x < 30 mm	37	93.99	9.5 ± 0.51	27.4 ± 0.74	19.1 ± 0.67	11.5 ± 3.32	9.0 ± 0.30	6.7 ± 1.25
30 ≤ x < 100 mm	545	32,190.08	32.1 ± 0.24	25.2 ± 0.35	23.1 ± 0.24	4.0 ± 0.40	9.1 ± 0.12	7.0 ± 0.43
≥ 100 mm	1	1.00	32.6 ± ----	20.0 ± ----	14.5 ± ----	4.1 ± ----	7.3 ± ----	1.2 ± ----
Star drum								
< 15 mm	1	1.00	10.7 ± ----	25.3 ± ----	27.4 ± ----	2.0 ± ----	7.8 ± ----	6.9 ± ----
15 ≤ x < 30 mm	18	132.12	6.2 ± 0.74	18.6 ± 2.17	23.9 ± 1.46	27.7 ± 7.91	9.3 ± 0.58	12.0 ± 1.93
30 ≤ x < 100 mm	390	19,204.86	5.9 ± 0.17 A	25.6 ± 0.30	27.1 ± 0.28	40.8 ± 1.41	7.1 ± 0.09	14.6 ± 0.46 A
≥ 100 mm	347	11,078.02	7.7 ± 0.30 B	24.6 ± 0.27	26.7 ± 0.29	39.0 ± 1.61	7.5 ± 0.13	11.7 ± 0.49 B
Fringed flounder								
< 15 mm	1	1.00	5.5 ± ----	17.5 ± ----	27.0 ± ----	23.0 ± ----	7.2 ± ----	7.6 ± ----
15 ≤ x < 30 mm	10	12.00	2.1 ± 0.10	22.6 ± 1.87	19.6 ± 2.79	30.2 ± 5.16	8.2 ± 0.50	8.7 ± 2.75
30 ≤ x < 100 mm	1,097	11,543.93	11.6 ± 0.39 A	25.6 ± 0.18	21.1 ± 0.21 A	19.2 ± 0.73 A	7.8 ± 0.06	8.2 ± 0.30 A
≥ 100 mm	834	18,640.07	29.8 ± 0.28 B	26.5 ± 0.20	24.3 ± 0.19 B	3.3 ± 0.23 B	8.2 ± 0.07	5.0 ± 0.23 B

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Gafftopsail catfish								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
30 ≤ x < 100 mm	105	5,629.28	3.0 ± 0.12	19.2 ± 0.54	30.8 ± 0.10	37.8 ± 2.21	5.8 ± 0.14	15.7 ± 0.55
≥ 100 mm	242	24,507.72	2.8 ± 0.09	21.2 ± 0.29	30.5 ± 0.11	32.8 ± 1.49	6.0 ± 0.09	15.3 ± 0.37
Longspine porgy								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
30 ≤ x < 100 mm	319	26,658.03	32.3 ± 0.19	26.5 ± 0.45	29.1 ± 0.13 A	2.5 ± 0.23	7.1 ± 0.09	2.7 ± 0.28
≥ 100 mm	86	532.97	33.9 ± 0.21	29.6 ± 0.51	23.1 ± 0.52 B	2.6 ± 0.26	7.9 ± 0.20	2.0 ± 0.30
Atlantic bumper								
< 15 mm	2	19.76	2.5 ± 0.27	21.5 ± 0.96	30.1 ± 0.00	16.5 ± 2.19	7.0 ± 0.35	---- ± ----
15 ≤ x < 30 mm	75	347.78	5.0 ± 0.43 A	23.5 ± 0.53 A	29.0 ± 0.25 A	22.5 ± 1.96 A	7.7 ± 0.28 A	14.7 ± 1.57 A
30 ≤ x < 100 mm	400	9,503.81	5.3 ± 0.23 A	27.3 ± 0.22 B	26.9 ± 0.23 B	16.5 ± 0.70 B	6.8 ± 0.07 B	10.1 ± 0.52 A
≥ 100 mm	380	15,582.65	18.1 ± 0.54 B	26.0 ± 0.26 C	28.0 ± 0.14 C	5.1 ± 0.32 C	7.8 ± 0.09 A	7.1 ± 0.59 B
Silver seatrout								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	11	120.43	8.2 ± 0.89	19.2 ± 1.62	25.7 ± 0.83	9.9 ± 0.79	7.4 ± 0.31	16.6 ± 1.73
30 ≤ x < 100 mm	449	6,966.30	14.4 ± 0.67 A	26.2 ± 0.30	20.8 ± 0.28 A	9.8 ± 0.61 A	7.7 ± 0.10	9.5 ± 0.45 A
≥ 100 mm	516	14,696.06	22.9 ± 0.53 B	27.2 ± 0.20	22.4 ± 0.25 B	6.1 ± 0.40 B	8.0 ± 0.09	5.8 ± 0.39 B

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Bay whiff								
< 15 mm	3	3.00	3.7 ± 0.94	16.0 ± 8.06	22.4 ± 2.80	13.7 ± 2.19	6.2 ± 1.47	10.8 ± 6.64
15 ≤ x < 30 mm	44	95.32	2.2 ± 0.17	16.5 ± 1.12	18.0 ± 0.82	36.2 ± 4.06	8.7 ± 0.25	7.7 ± 1.11
30 ≤ x < 100 mm	1,250	11,445.90	11.7 ± 0.39 A	23.4 ± 0.21 A	25.2 ± 0.18	20.6 ± 0.68 A	7.3 ± 0.05 A	9.5 ± 0.28 A
≥ 100 mm	772	8,993.77	25.1 ± 0.45 B	25.6 ± 0.22 B	25.0 ± 0.19	8.2 ± 0.53 B	8.0 ± 0.08 B	6.9 ± 0.28 B
Atlantic threadfin								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
30 ≤ x < 100 mm	126	15,539.99	3.5 ± 0.17 A	18.6 ± 0.56	25.4 ± 0.27 A	23.4 ± 2.11	7.9 ± 0.14	19.8 ± 1.26 A
≥ 100 mm	170	2,825.01	11.0 ± 0.92 B	19.2 ± 0.55	28.5 ± 0.14 B	21.5 ± 1.75	7.4 ± 0.13	11.9 ± 0.69 B
Least puffer								
< 15 mm	12	15.00	2.7 ± 0.81	20.1 ± 1.71	24.9 ± 0.97	15.0 ± 2.41	5.4 ± 0.45	5.9 ± 1.37
15 ≤ x < 30 mm	94	238.57	4.9 ± 0.83 A	18.5 ± 0.75 A	26.9 ± 0.55 A	33.2 ± 2.55 A	7.3 ± 0.17	13.3 ± 1.00
30 ≤ x < 100 mm	1,651	17,196.23	16.8 ± 0.40 B	25.5 ± 0.17 B	20.6 ± 0.17 B	13.6 ± 0.55 B	8.1 ± 0.05	7.7 ± 0.23
≥ 100 mm	30	71.20	9.1 ± 2.13	26.4 ± 0.90	20.3 ± 1.16	13.0 ± 2.91	7.5 ± 0.22	6.0 ± 1.06
Iridescent swimming crab								
< 15 mm	8	26.50	22.6 ± 5.04	23.7 ± 0.98	27.5 ± 2.30	7.6 ± 5.08	7.1 ± 0.56	3.8 ± 1.97
15 ≤ x < 30 mm	230	3,211.28	14.0 ± 0.95 A	26.3 ± 0.33	22.1 ± 0.38	17.1 ± 1.37 A	7.8 ± 0.12	7.4 ± 0.44
30 ≤ x < 100 mm	823	13,381.23	23.5 ± 0.55 B	26.7 ± 0.21	21.1 ± 0.19	5.6 ± 0.43 B	8.3 ± 0.08	5.8 ± 0.23
≥ 100 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Mantis shrimp								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
$15 \leq x < 30$ mm	6	8.13	16.3 ± 4.09	19.5 ± 3.62	24.8 ± 2.51	9.6 ± 3.06	9.9 ± 1.38	13.6 ± 2.62
$30 \leq x < 100$ mm	827	14,276.79	24.9 ± 0.42	23.0 ± 0.25	25.0 ± 0.21	8.0 ± 0.54	7.8 ± 0.09	8.3 ± 0.34
≥ 100 mm	294	1,920.46	26.1 ± 0.71	23.3 ± 0.44	23.3 ± 0.32	7.5 ± 0.79	8.2 ± 0.17	7.4 ± 0.46
Gulf menhaden								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
$15 \leq x < 30$ mm	46	2,438.44	2.2 ± 0.09	13.5 ± 0.43	20.5 ± 0.95	40.0 ± 3.00	7.6 ± 0.18	2.5 ± 0.82
$30 \leq x < 100$ mm	349	9,615.38	2.0 ± 0.06 A	14.7 ± 0.38 A	17.9 ± 0.54	40.5 ± 1.71 A	8.0 ± 0.12 A	9.2 ± 0.51 A
≥ 100 mm	354	3,508.18	4.8 ± 0.24 B	24.4 ± 0.36 B	20.4 ± 0.31	20.4 ± 1.25 B	8.7 ± 0.11 B	16.1 ± 0.89 B
Shoal flounder								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
$15 \leq x < 30$ mm	1	1.00	33.5 ± ----	30.7 ± ----	19.1 ± ----	0.0 ± ----	7.9 ± ----	0.5 ± ----
$30 \leq x < 100$ mm	398	6,200.64	31.9 ± 0.23	26.6 ± 0.30	23.6 ± 0.27 A	3.3 ± 0.23	8.3 ± 0.11	4.4 ± 0.33
≥ 100 mm	445	8,819.35	32.4 ± 0.16	27.0 ± 0.28	26.0 ± 0.21 B	2.5 ± 0.18	8.0 ± 0.09	4.1 ± 0.30
Largescale lizardfish								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
$15 \leq x < 30$ mm	2	4.18	28.0 ± 4.65	23.7 ± 1.64	21.5 ± 6.13	3.6 ± ----	9.4 ± 2.30	12.5 ± 11.49
$30 \leq x < 100$ mm	322	9,192.79	33.0 ± 0.15	27.0 ± 0.27	27.1 ± 0.26	1.7 ± 0.15	7.7 ± 0.12	3.5 ± 0.32
≥ 100 mm	186	3,921.03	33.3 ± 0.21	28.1 ± 0.29	27.5 ± 0.30	1.5 ± 0.11	7.9 ± 0.14	3.1 ± 0.40

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Southern kingfish								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	15	139.30	2.6 ± 0.37	27.7 ± 1.12	18.7 ± 1.50	17.5 ± 2.11	6.5 ± 0.22	6.0 ± 0.84
30 ≤ x < 100 mm	347	2,851.88	3.3 ± 0.10 A	24.6 ± 0.31 A	24.1 ± 0.38 A	23.7 ± 0.91	6.8 ± 0.09 A	8.6 ± 0.40
≥ 100 mm	544	907.82	4.9 ± 0.20 B	26.2 ± 0.19 B	19.5 ± 0.20 B	21.4 ± 0.74	7.6 ± 0.07 B	8.0 ± 0.29
Tonguefish spp.								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	8	13.00	3.4 ± 0.81	24.2 ± 2.18	19.0 ± 1.85	22.6 ± 6.27	7.5 ± 0.85	6.7 ± 1.95
30 ≤ x < 100 mm	639	3,976.22	6.3 ± 0.26	23.7 ± 0.30	19.9 ± 0.26	28.4 ± 1.44	7.9 ± 0.07	11.4 ± 0.62
≥ 100 mm	827	6,327.47	18.6 ± 0.47	25.2 ± 0.20	21.7 ± 0.20	12.5 ± 0.57	8.4 ± 0.09	8.7 ± 0.32
Rock sea bass								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	6	15.54	14.3 ± 3.90	30.0 ± 2.13	19.9 ± 2.62	4.8 ± 2.56	7.6 ± 0.50	4.2 ± 2.32
30 ≤ x < 100 mm	307	4,776.14	31.6 ± 0.34	26.8 ± 0.42	28.9 ± 0.14 A	2.7 ± 0.34	7.1 ± 0.08 A	2.9 ± 0.29
≥ 100 mm	300	2,111.32	31.1 ± 0.35	27.2 ± 0.27	22.2 ± 0.36 B	3.8 ± 0.38	8.4 ± 0.11 B	4.7 ± 0.36
Inshore lizardfish								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	2	3.00	3.4 ± 1.36	16.6 ± 3.76	20.4 ± 0.33	26.3 ± 23.10	11.5 ± 2.26	34.7 ± 9.00
30 ≤ x < 100 mm	125	343.07	17.9 ± 1.41 A	23.5 ± 0.58 A	26.8 ± 0.45	13.8 ± 1.64 A	7.7 ± 0.16	8.3 ± 0.96 A
≥ 100 mm	703	5,894.92	27.9 ± 0.42 B	26.6 ± 0.20 B	24.8 ± 0.22	5.6 ± 0.43 B	7.9 ± 0.08	5.1 ± 0.26 B

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Bighead searobin								
< 15 mm	3	3.00	9.1 ± 1.52	28.2 ± 4.40	18.2 ± 2.29	21.3 ± 10.09	7.0 ± 0.96	3.3 ± 0.86
15 ≤ x < 30 mm	75	184.20	5.4 ± 0.41 A	24.3 ± 0.85	17.3 ± 0.49 A	24.7 ± 2.61	8.8 ± 0.27	12.1 ± 2.88
30 ≤ x < 100 mm	612	5,280.03	5.4 ± 0.18 A	24.9 ± 0.25	18.5 ± 0.17 A	20.9 ± 1.06	8.0 ± 0.08	10.6 ± 0.63
≥ 100 mm	154	468.78	9.8 ± 0.93 B	23.4 ± 0.47	23.8 ± 0.43 B	18.6 ± 1.31	7.7 ± 0.14	11.0 ± 0.74
Pink shrimp								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
30 ≤ x < 100 mm	202	2,892.12	2.9 ± 0.08	23.4 ± 0.34	20.6 ± 0.28	23.2 ± 1.00	8.1 ± 0.10	15.7 ± 1.09
≥ 100 mm	184	2,806.88	4.3 ± 0.40	23.7 ± 0.32	20.6 ± 0.26	24.2 ± 1.27	8.0 ± 0.11	14.4 ± 0.91
Banded drum								
< 15 mm	3	3.00	3.8 ± 0.86	24.4 ± 6.35	23.6 ± 2.86	39.3 ± 23.45	7.0 ± 0.55	8.5 ± 2.32
15 ≤ x < 30 mm	50	180.65	5.3 ± 0.39 A	25.8 ± 0.95	24.1 ± 0.67 A	19.9 ± 2.22 A	7.7 ± 0.30	7.5 ± 1.77
30 ≤ x < 100 mm	429	4,045.54	8.2 ± 0.20 B	27.6 ± 0.31	18.8 ± 0.21 B	16.8 ± 0.79 A	8.2 ± 0.12	8.7 ± 0.80
≥ 100 mm	137	1,196.80	23.1 ± 0.99 C	26.9 ± 0.56	24.5 ± 0.39 A	9.4 ± 0.98 B	8.4 ± 0.16	5.4 ± 0.61
Spotted seatrout								
< 15 mm	1	1.00	11.0 ± ----	24.6 ± ----	27.2 ± ----	10.0 ± ----	7.5 ± ----	14.8 ± ----
15 ≤ x < 30 mm	2	4.00	8.4 ± 4.45	23.9 ± 1.22	28.1 ± 1.56	11.0 ± 1.73	6.3 ± 2.12	14.7 ± 0.26
30 ≤ x < 100 mm	44	1,651.92	2.2 ± 0.10 A	31.5 ± 0.50 A	14.8 ± 0.31	13.1 ± 1.47 A	7.8 ± 0.16	5.2 ± 0.53 A
≥ 100 mm	192	3,333.08	2.7 ± 0.08 B	25.2 ± 0.44 B	14.5 ± 0.33	22.5 ± 1.32 B	8.0 ± 0.14	8.7 ± 0.57 B

Table 8: Continued.

Common Name	N	Total Number	Depth	Salinity	Water Temperature	Turbidity	Dissolved Oxygen	Chlorophyll *a*
Southern flounder								
< 15 mm	0	0.00	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----	---- ± ----
15 ≤ x < 30 mm	4	4.45	3.4 ± 0.57	21.4 ± 7.19	20.0 ± 4.20	40.3 ± 18.23	6.9 ± 0.99	5.0 ± 2.02
30 ≤ x < 100 mm	37	72.00	3.6 ± 1.21	16.1 ± 1.57	22.2 ± 0.75	27.5 ± 3.16	7.7 ± 0.19	13.1 ± 1.43
≥ 100 mm	350	1,815.55	6.5 ± 0.49	24.7 ± 0.33	21.1 ± 0.34	28.8 ± 1.22	7.6 ± 0.09	9.9 ± 0.48

Construction Impacts on Nekton

The MIXED model BACI analysis also revealed significant effects on the relative abundance (i.e., CPUE) of five of 37 species at five of the eight impact stations (Table 9 and Appendix II). No differences in the diversity indices (i.e., species diversity, richness, and evenness), totals (i.e., total individuals, total fishes, total invertebrates, and total decapods), or the proportions of rare species were detected. The analyses identified five significant temporal differences related to construction and two significant interactions that indicated LOOP impacts. At Station 33_I, spotted seatrout CPUE was significantly higher than at the control stations (Stations 3_C, 5_C, and 43_C) although it decreased significantly after construction ended. No comparisons were possible for the pre-construction phase because of the short time period available for sampling at the pipeline station during that phase. At Station 36_I southern flounder CPUE decreased significantly between the construction phase and after construction, whereas it remained constant at the control stations. As at Station 33_I, no pre-construction estimates could be made at the pipeline station due to scant pre-construction sampling. The temporal terms for several species' analyses were significant, but the responses differed among species and none were found in this analysis attributable to LOOP construction activities (Appendix II).

In a similar analysis of species by size classes, significant interaction terms were detected for seven of 37 species (Table 10), and significant main effects (i.e., temporal or spatial terms) were detected for sixteen species (Appendix III). At Station 31_I, small lesser blue crab (< 15 mm) were significantly more abundant after construction at the impact station than at the control station. Southern kingfish between 30 and 100 mm were more abundant at the impact station before construction than during or after, whereas mean CPUE was near zero at the control stations for all phases (Table 10). At Station 33_I, small lesser blue crab (< 15 mm), large bay whiff (≥ 100 mm), and spotted seatrout between 30 and 100 mm were significantly more abundant during construction at the impact station, but declined after construction ended. Large mantis shrimp (≥ 100 mm) were more abundant at the impact station (Station 33_I) than at the control stations during and after construction, but no estimates were available for the pre-construction phase. At Station 36_I, large southern flounder (≥ 100 mm) were significantly more abundant during construction at the impact station, but declined after construction ended. At

Table 9: Construction-related trends in nekton species abundances in the BACI analysis with significant effects (MIXED, $p < 0.05$). Effects with a slash (e.g., Before/Control) signify a significant interaction between temporal and spatial effects. Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically.

Station and Species	Effect	CPUE ± SE
Station 33		
Spotted seatrout	Before	no estimate
	During	24.3 ± 7.26 A
	After	4.0 ± 0.74 B
Spotted seatrout	Before/Control	0.7 ± 1.07 A
	Before/Impact	no estimate
	During/Control	0.0 ± 0.75 A
	During/Impact	48.7 ± 14.48 B
	After/Control	0.9 ± 0.35 A
	After/Impact	7.1 ± 1.39 C
Station 36		
Southern flounder	Before	no estimate
	During	0.9 ± 0.39 A
	After	0.8 ± 0.15 B
Southern flounder	Before/Control	0.0 ± 0.00 AB
	Before/Impact	no estimate
	During/Control	0.3 ± 0.15 AB
	During/Impact	3.9 ± 1.77 A
	After/Control	0.6 ± 0.18 B
	After/Impact	1.0 ± 0.26 B

Table 10 Construction-related trends in nekton species size class abundances in the BACI analysis with significant effects (MIXED, $p < 0.05$). Effects with a slash (e.g., Before/Control) signify a significant interaction between temporal and spatial effects. Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically.

Station, Species Size class	Effect	CPUE ± SE
Station 31		
Lesser blue crab	Before	0.0 ± 0.00 AB
< 15 mm	During	0.0 ± 0.00 A
	After	2.4 ± 1.62 B
Lesser blue crab	Before/Control	0.0 ± 0.00 A
< 15 mm	Before/Impact	0.0 ± 0.00 AB
	During/Control	0.0 ± 0.00 A
	During/Impact	0.0 ± 0.00 A
	After/Control	0.8 ± 0.30 A
	After/Impact	30.8 ± 30.8 B
Southern kingfish	Before	0.3 ± 0.30 A
$30 \leq x < 100$ mm	During	0.1 ± 0.07 B
	After	0.1 ± 0.05 B
Southern kingfish	Control	0.0 ± 0.00 A
$30 \leq x < 100$ mm	Impact	0.3 ± 0.21 B
Southern kingfish	Before/Control	0.0 ± 0.00 A
$30 \leq x < 100$ mm	Before/Impact	1.5 ± 1.50 B
	During/Control	0.0 ± 0.00 A
	During/Impact	0.3 ± 0.25 A
	After/Control	0.1 ± 0.05 A
	After/Impact	0.0 ± 0.00 A

Table 10. Continued.

Station, Species Size class	Effect	CPUE ± SE
Station 33		
Lesser blue crab	Before	no estimate
< 15 mm	During	0.1 ± 0.09 A
	After	0.6 ± 0.24 B
Lesser blue crab	Before/Control	0.0 ± 0.00 A
< 15 mm	Before/Impact	no estimate
	During/Control	0.0 ± 0.00 A
	During/Impact	2.0 ± 2.00 B
	After/Control	0.6 ± 0.25 A
	After/Impact	0.0 ± 0.00 A
Bay whiff	Before	no estimate
≥ 100 mm	During	1.6 ± 0.89 A
	After	1.0 ± 0.27 B
Bay whiff	Before/Control	0.0 ± 0.00 A
≥ 100 mm	Before/Impact	no estimate
	During/Control	0.7 ± 0.57 A
	During/Impact	20.0 ± 14.42 B
	After/Control	0.9 ± 0.27 A
	After/Impact	2.0 ± 2.00 A
Mantis shrimp	Before	no estimate
≥ 100 mm	During	0.4 ± 0.26 A
	After	0.2 ± 0.11 B
Mantis shrimp	Before/Control	0.0 ± 0.00 A
≥ 100 mm	Before/Impact	no estimate
	During/Control	0.4 ± 0.26 A
	During/Impact	2.0 ± 2.00 B
	After/Control	0.1 ± 0.05 A
	After/Impact	2.5 ± 2.02 B

Table 10. Continued.

Station, Species Size class	Effect	CPUE ± SE
Station 33		
Spotted seatrout	Before	no estimate
30 ≤ x < 100 mm	During	15.6 ± 3.09 A
	After	0.6 ± 0.33 B
Spotted seatrout	Before/Control	0.4 ± 0.54 A
30 ≤ x < 100 mm	Before/Impact	no estimate
	During/Control	0.0 ± 0.38 A
	During/Impact	31.1 ± 6.16 B
	After/Control	0.2 ± 0.17 A
	After/Impact	1.0 ± 0.61 A
Station 36		
Southern flounder	Before	no estimate
≥ 100 mm	During	0.9 ± 0.39 A
	After	0.8 ± 0.15 B
Southern flounder	Before/Control	0.0 ± 0.00 AB
≥ 100 mm	Before/Impact	no estimate
	During/Control	0.3 ± 0.15 AB
	During/Impact	3.9 ± 1.77 A
	After/Control	0.6 ± 0.18 B
	After/Impact	1.0 ± 0.26 B
Station 53		
Atlantic brief squid	Before	no estimate
≥ 100 mm	During	21.6 ± 21.61 A
	After	2.8 ± 0.63 B
Atlantic brief squid	Control	2.6 ± 0.76 A
≥ 100 mm	Impact	3.6 ± 1.25 B

Table 10. Continued.

Station, Species		
Size class	Effect	CPUE ± SE
Station 53		
Atlantic brief squid	Before/Control	no estimate
≥ 100 mm	Before/Impact	no estimate
	During/Control	0.0 ± 0.00 A
	During/Impact	43.2 ± 43.22 B
	After/Control	2.6 ± 0.77 A
	After/Impact	2.9 ± 1.00 A
Station 54		
Atlantic brief squid	Control	2.6 ± 0.76 A
≥ 100 mm	Impact	3.1 ± 1.25 B
Atlantic brief squid	Before/Control	no estimate
≥ 100 mm	Before/Impact	no estimate
	During/Control	0.0 ± 0.00 AB
	During/Impact	20.3 ± 20.3 B
	After/Control	2.6 ± 0.77 A
	After/Impact	2.8 ± 0.66 A

Stations 53_I and 54_I, large Atlantic brief squid (≥ 100 mm) were also significantly more abundant during construction at the impact station, but declined after construction ended. Significant temporal effects were detected for size classes of several species, but the responses differed among species (Appendix III) and interaction terms were not detectably significant.

Brine Discharge Impacts

In the MIXED model BACI analysis of the potential influence of brine discharge at Station 36_I, we analyzed three periods of brine discharge for influences on common species and size classes: a period of no discharge from February 1978 to April 1980, a high discharge period of 8,708,511 ± 748,246 gal/day from May 1980 to December 1982, and a lower and intermittent discharge period of 658,131 ± 118,837 gal/day from January 1983 to December 1995. Significant interaction terms were observed for two species (Table 11). Gulf menhaden between 30 and 100 mm were significantly more abundant at the brine discharge area (Station 36_I) before the discharge began, and dropped to near zero during the discharge phase. Southern flounder followed a similar pattern, with high CPUE at Station 36_I before the high discharge period relative to the control stations and declining after the discharge began at Station 36_I. Only the largest size class of southern flounder was collected in the brine discharge area, so the means and test results (i.e., significance values) were the same for this size class as for the entire species in this area. No significant main or interaction terms were noted for the comparisons of community diversity indices (i.e., species diversity, evenness, and richness) or the contribution of rare species. Significant temporal terms were observed for three of 37 species and for size classes of five species, but the responses differed among species (Appendix IV), and the interaction terms were not significant, so the patterns could not be ascribed to LOOP-related impacts.

The only environmental variable for which we detected a significant effect of brine discharge at Station 36_I was surface turbidity. Mean turbidity levels decreased significantly (LSMeans, $p < 0.05$) between the periods of heavy (8,708,511 ± 748,246 gal/day) and moderate (658,131 ± 118,837 gal/day) discharge, but we did not detect a significant interaction term, so based on this analysis the difference in turbidity could not be attributed to brine discharge. Mean levels before and during the period of high discharge were 20.8 ± 4.52 and 17.7 ± 3.21 NTU, respectively, but declined to 5.3 ± 1.20 NTU after the high discharge period.

Turbidity-Related Impacts

Because we detected significant influences of LOOP construction and operation on turbidity levels (but on no other environmental variables) at two impact stations, we included turbidity as a covariable in additional BACI analyses at those stations to distinguish between the influence of turbidity and LOOP construction and operation. By accounting for the variability in species and size class abundances attributable to changes in turbidity, influences due to LOOP construction and operation not related to turbidity can be detected. In the analyses of the 37 species at Station 31_I including turbidity, a significant interaction was detected for lesser blue

Table 11. Brine discharge-related trends in nekton species size class abundances in the BACI analysis with significant effects (MIXED, $p < 0.05$) before, during and after the main brine discharge from May 1980 to December 1983. Effects with a slash (e.g., Before/Control) signify a significant interaction between temporal and spatial effects. Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically.

Species	Effect	CPUE ± SE
Gulf menhaden $30 \leq x < 100$ mm	Before	0.2 ± 0.12 A
	During	0.0 ± 0.00 B
	After	0.0 ± 0.01 B
Gulf menhaden $30 \leq x < 100$ mm	Before/Control	0.1 ± 0.12 AB
	Before/Impact	0.5 ± 0.50 A
	During/Control	0.0 ± 0.00 B
	During/Impact	0.0 ± 0.00 B
	After/Control	0.0 ± 0.02 B
	After/Impact	0.0 ± 0.03 B
Southern flounder ≥ 100 mm *	Before	1.0 ± 0.46 A
	During	0.5 ± 0.20 B
	After	0.8 ± 0.18 B
Southern flounder ≥ 100 mm *	Before/Control	0.2 ± 0.16 A
	Before/Impact	5.8 ± 2.91 B
	During/Control	0.2 ± 0.11 A
	During/Impact	1.7 ± 0.89 A
	After/Control	0.8 ± 0.24 A
	After/Impact	0.9 ± 0.22 A

* The only size class collected was ≥ 100 mm. Therefore, the comparison for southern flounder species would have the same numbers.

crab (< 15 mm) that paralleled the results of the analysis without turbidity (Table 10). In contrast, no significant interactions were detected for southern kingfish, which had significant temporal, spatial, and interaction terms in the analysis without turbidity (Table 10). We interpreted this to mean that the response of southern kingfish was related to the change in turbidity, whereas the response of lesser blue crab was not. In similar additional analyses of the 37 species at Station 36_I during the construction phase, only southern flounder (all in the size class ≥ 100 mm) had a significant interaction term, but when turbidity was included in the model, no significant terms were detected. We interpreted this to mean that the response of southern flounder was related to the change in turbidity at this station. In the analysis without turbidity of brine discharge at Station 36_I, Gulf menhaden between 30 and 100 mm and southern flounder ≥ 100 mm had significant interaction terms, whereas no significant interactions were detected when turbidity was added to the model. Again, we interpreted this to mean that the responses of Gulf menhaden and southern flounder were related to the change in turbidity. The only significant effect detected for the brine discharge at Station 36_I was a temporal effect for star drum ≥ 100 mm. Their mean CPUE was 46.7 ± 38.76 individuals per hour before brine discharge and declined significantly from 46.6 ± 10.67 during brine discharge to 18.5 ± 9.79 after the high discharge period.

Oil Spill Impacts

Only two offshore oil spill events were considered to be large enough to test for impacts using the BACI format: spills of 16,758 gal. on April 2, 1983 and 21,000 gal. on October 21, 1985. These spills were tested with the terminal stations, 52_C, 53_I, 54_I, and 55_I. Other industrial spills were either too small or did not occur near appropriate paired control and impact stations. Although several main effects were detected, none of the following differences could be attributed to the oil spill events because none of the interaction terms were significant (Table 12). Lesser rock shrimp (all in the size class between 30 and 100 mm) and longfin squid between 30 and 100 mm were significantly more abundant after the 1983 spill event, but no interactions between control and impact stations were detectably significant. Longfin squid between 30 and 100 mm were significantly more abundant after the 1985 spill event (Table 12). Bighead searobin, most of which were in the ≥ 100 mm size class, were less abundant after the 1985 spill, but again no significant interactions were detected. Turbidity decreased significantly (from 5.5 ± 0.99 to 1.8 ± 0.73 NTU) after the 1985 spill event, but this effect could not be

Table 12: Oil spill-related differences in environmental variables and nekton taxa in the BACI analysis with significant effects (MIXED, $p < 0.05$). Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically by variable.

Spill Date & Amount	Variable and Size class (for taxa)	Effect	Mean ± SE
2-April-1983 16,758 gal.	Longfin squid $30 \leq x < 100$ mm	Before After	62.4 ± 22.81 A 198.0 ± 15.85 B
	Lesser rock shrimp $30 \leq x < 100$ mm	Before After	2.4 ± 1.73 A 221.3 ± 31.70 B
	Lesser rock shrimp All sizes	Before After	2.4 ± 1.73 A 221.3 ± 31.70 B
21-October-1985 21,000 gal.	Longfin squid $30 \leq x < 100$ mm	Before After	120.7 ± 22.60 A 207.6 ± 17.91 B
	Bighead searobin ≥ 100 mm	Before After	1.1 ± 0.31 A 0.7 ± 0.41 B
	Bighead searobin All sizes	Before After	1.1 ± 0.31 A 0.8 ± 0.41 B

attributed to the oil spill event. In more restricted time frames, when the BACI tests were performed on data within three years of each spill, no significant effects were detected for species or environmental variables for the 1983 or 1985 spills.

To evaluate changes in sensitivity with increased sampling frequency in a response plan, we used Atlantic brief squid (≥ 100 mm), a common species at the offshore port stations, which had a marginally significant interaction term ($p > 0.067$) for a moderate oil spill (October 21, 1985). The current data set with 220 samples was sufficient to detect a CPUE difference of about 85% between stations before and after the spill. To detect a 50% change in the CPUE of Atlantic brief squid CPUE the sample size would have to be about 430 for the six year period surrounding the spill (three years before and three years after).

DISCUSSION

The analysis of the demersal nekton data collected over 18 years for the LOOP monitoring program identified significant construction-related influences for two species (i.e., spotted seatrout and southern flounder) and several size classes of seven species (i.e., lesser blue crab, southern kingfish, bay whiff, mantis shrimp, spotted seatrout, southern flounder, and Atlantic brief squid). Significant brine-discharge-related influences were detected for size classes of two species (i.e., Gulf menhaden and southern flounder). No significant influences were detected on abundances of demersal nekton from the three largest oil spills. Nevertheless, temporal trends were identified for several species during both construction and operation periods.

No significant influences of LOOP pipeline construction or operation on community structure, measured by species diversity, richness, and evenness, were detected. Additionally, no influences on total number of organisms, total fishes, total invertebrates, total decapods, or rare species were detected. Most of the 37 species analyzed, including the analyses by size classes, were also not detectably influenced by LOOP pipeline construction or operation.

Only a few significant influences on nekton abundance patterns were detected, and most of these could not be definitively attributed to the construction or operation of LOOP. The inability to estimate species abundances before construction at many of the impact stations because of the short pre-construction sampling period limited the capability of the BACI analyses to detect construction impacts on demersal nekton. For example, spotted seatrout CPUE was significantly greater during construction at Station 33_I than at the control stations, but decreased significantly after construction ended (Table 9). Since no before-construction estimate was available at the impact stations for this species, it remains unclear as to whether there was a positive influence during construction or a negative influence after construction.

The BACI analyses of nekton data generated by the 18 year-long Environmental Monitoring Plan was able to convincingly demonstrate no less than 13 statistically significant LOOP-related impacts caused by construction and brine discharge for eight species and ten size classes among the 37 important species examined; nevertheless, additional impacts may have gone undetected. Thus, although we believe that the design and execution of the monitoring program was good, a *caveat emptor* is in order. In scientific terms, failure to statistically reject the null hypothesis of no impact is an equivocal result: an impact is not demonstrated, but the absence of an impact is not proven. A failure to detect a real interaction in a statistical analysis can result either because the available data does not provide sufficient power to detect the impact, or because the event had no discernable impact. Therefore, that we were unable to detect and statistically demonstrate additional LOOP-related impacts should not be taken as evidence that more did not occur. Where the data sets were fully adequate, tests that did not indicate impacts do lead to a reasonable conclusion that impacts did not occur. However, where the data sets were too limited to convincingly demonstrate the presence or absence of statistical significance, it is not reasonable to conclude that no impacts occurred. A number of factors in the monitoring program design may have hindered the detection of LOOP-related impacts. In environmental monitoring the reasons for low power in tests are high variability, typical of demersal nekton populations, and small sample sizes. High variability cannot be controlled by the investigators, but can be offset if sample sizes are made large by either intensive sampling or long-term sampling. Nevertheless, in the case of the LOOP Environmental Monitoring Plan, several factors may have contributed to the high variability in species estimates:

1. Station coverage was sparse in the inshore zone, with no nekton samples collected from the Clovelly Storage Dome and no samples from the LOCAP pipeline. Since regulatory guidance established monitoring stations before the locations of LOOP facilities were finalized, the selection of nekton stations was originally determined, in part, based on feasibility and environmental impact studies conducted in preparation for the proposal to construct and operate LOOP. Logistical and safety considerations also reduced the available sites that could be used for control and impact stations (e.g., limited trawlable bottom near Clovelly, except in heavily-traveled canals).

2. The lack of an *a priori* designation of control and impact station associations for the analyses forced us to take a less appropriate approach to match similar control and impact stations. We used the environmental data collected during all phases of the monitoring plan to group stations by similarity because not enough data were available

from the before-construction phase. This has the disadvantage of grouping stations that were by definition similar, after the fact (i.e., *a posteriori*), thus reducing the chance that a LOOP-related-influence could be detected and making the analysis more conservative in favor of LOOP (i.e., no impact). Additionally, it should be noted that *a priori* designation is not always possible and the events being tested may determine which stations are appropriate impact and control stations. A control station for testing the construction phase may be near enough to a future large oil spill for it to be used as an impact station to test for significant influences.

3. The short time period of sampling at some stations before LOOP construction and the absence of before-construction sampling at others resulted in a poorly characterized baseline for comparisons at those stations. As a result, significant influences during or after construction could not be satisfactorily characterized as positive or negative. Low or non-existent replication at the sampled stations, and discontinuous sampling at some stations throughout the monitoring program lead to large variances in estimates of species' abundances, reducing the precision of the analysis (i.e., making it more difficult to detect a difference).

4. A LOOP-related impact on a scale large enough to influence the designated control stations would reduce the observed difference between control and impact stations and reduce the likelihood of detecting an impact.

5. Additionally, subsampling the trawl catches was deemed necessary, but had the disadvantage of increasing the variability in catch estimates by introducing an additional source of error (i.e., the within trawl error between subsamples).

Recommendations related to improving spatial and temporal coverage, improving the characterizations of nekton patterns of distribution and abundance, and the identification of appropriate controls are discussed in the technical information section (Task3) that follows.

In the oil spill analyses, we did not detect any significant interactions, but the data would only convincingly detect an 85% change in the CPUE for a typical species (e.g., Atlantic brief squid). The current sampling intensity generates 144 samples over three years after a possible impact event (e.g., a moderate to major oil spill), whereas 430 samples are required to detect a 50% change in CPUE. Specific recommendations to improve the sampling intensity are provided in the technical information section.

Although the stations along the pipeline corridor generally grouped well with control stations, some impact stations were associated with only marginally adequate control stations. For example, Station 33_I was associated with Station 5_C in Caminada Pass as well as with Stations 3_C and 43_C, which were both located offshore. Whereas these stations had similar characteristics based on the six included environmental variables, they were probably exposed to different tidal flow regimes than Station 33_I, which was located in a flotation canal.

Ontogenetic shifts (i.e., size related patterns) were detected for several species, most notably sciaenid fishes (i.e., drums and croakers) and blue crab. Many sciaenids included in the analysis used increasingly deeper, less turbid water as they grew. For example, Atlantic croaker segregate by life stage, moving offshore as they grow (Pattillo *et al.* 1997). They moved from shallow stations with high turbidity to deeper stations with low turbidity. Sand seatrout, silver seatrout, and banded drum also exhibited this pattern. Spotted seatrout, however, used shallower, more turbid water as they grew, which probably reflects an increased tolerance of low salinity by adults (Lassuy 1983). Blue crab juveniles migrated into upper estuaries (shallower, less saline). Blue crab males prefer low-salinity waters, and are common in estuaries throughout their lives. Females migrate offshore into higher salinity waters after mating because of the relatively high salinity requirements of their eggs (Hill *et al.* 1989).

Three species of penaeid shrimp were collected in numbers sufficient for analysis. White, pink, and brown shrimp avoid intense competition through spatial and temporal habitat partitioning (Bielsa *et al.* 1983). Habitat segregation among penaeid shrimp was evident from the factor analysis plot (Figure 2c, Table 8). Most individuals of the three species of penaeid shrimp collected were juveniles, which use low salinity estuaries as nursery habitat (Pattillo *et al.* 1997). Brown shrimp are more abundant in the summer and move offshore as adults, whereas white shrimp remain in estuaries longer and are more abundant in the fall (Pattillo *et al.* 1997). Pink shrimp are nocturnal, but may be negatively influenced by brown shrimp (Pattillo *et al.* 1997).

The brine discharge also had significant influences on size classes of two species. Both Gulf menhaden (between 30 and 100 mm) and southern flounder ($\geq$ 100 mm) decreased significantly at the brine diffuser station (Station 36_I) during the period of high discharge, but neither was abundant at the control stations. The results of the analyses including turbidity as a covariable for these species suggest that these responses were probably related to the observed changes in turbidity.

Nekton species and size classes within species respond to environmental gradients. For estuarine species the most important variables are salinity and temperature, followed, generally, by other abiotic variables and then by biotic variables (Moyle and Cech 1996). Environmental gradients along the pipeline corridor generally followed expected patterns based on the overall salinity gradient (Baltz et al. 1993). Freshwater input influences many other gradients, including turbidity and chlorophyll *a* concentrations. The primary sources of fresh water in the inshore and middle portions of the study area are precipitation (160 cm/y) and exchange with the Gulf of Mexico through tidal forcing and storm surges associated with meteorological events (Baumann 1987; Madden and DeLaune 1987). The inverse relationships of salinity with turbidity and chlorophyll *a* levels (Table 1) probably results from nutrient depletion with increasing distance and time as coastal waters move away from the nutrient source. Most of the nutrients are used rapidly, increasing chlorophyll *a* levels near nutrient sources, and suspended particulates settle out with time (Day et al. 1987). Another factor influencing these variables is water depth. High winds associated with weather events such as frontal passages can resuspend sediments more readily in shallow water than in deeper water. Since deeper stations were located offshore in the Gulf of Mexico, depth was positively related to salinity.

Turbidity is important in many systems because it provides cover for nekton, especially during early life-history stages (Cyrus and Blaber 1992). Therefore it should be noted that turbidity was the only environmental variable significantly influenced by the construction of the LOOP pipeline. Whereas significant decreases in turbidity were detected after construction ended at six impact stations, significant interactions indicated an influence of LOOP pipeline construction at only two impact stations. Construction-related activities such as digging and canal dredging probably increased turbidity through suspension of sediments. No significant changes in turbidity were detected at the offshore LOOP terminal stations (Stations 52_C, 53_I, 54_I, and 55_I). These stations were in 30 m of water so no dredging was necessary, and exchange rates in offshore waters are generally higher which disperse point source effects more quickly. One strong significant long-term influence was detected for Station 31_I: turbidity levels decreased after the construction period ended at the control stations (Stations 21_C, 35_C, and 44_C), but remained high at the impact station (Station 31_I). Station 31_I was located near the beach and was exposed to greater mixing energy than stations farther from shore (Figure 1). The construction of the pipeline may have altered the bathymetry of the area in such a way as to make the sediments more prone to resuspension, or it may have created an access for more turbid water.

When turbidity was included as a covariable in the analyses of size classes and species at the stations where turbidity was significantly influenced, it accounted for the observed nekton patterns, and, consequently, many significant species and size class interactions were no longer significant. This does not mean that there was no impact, rather it indicates that the changes in turbidity explained the observed abundance patterns more effectively than the LOOP construction alone. At Station 31_I, for example, the interaction term for southern kingfish was significant in the analysis without turbidity, but not in the analysis including turbidity. Thus, the observed changes in southern kingfish CPUE were probably due to changes in turbidity. Nevertheless, the turbidity changes were probably a result of LOOP construction, so the changes in southern kingfish CPUE were LOOP-related impacts. The interaction term for lesser blue crab at Station 31_I, however, remained significant. This result also indicated a direct LOOP-related impact.

CONCLUSIONS

The construction and operation of the LOOP pipeline did significantly influence some nekton species abundances, but the analyses were not as robust as possible because of factors related to the monitoring program design. The most notable impacts included a significantly negative influence on southern flounder resulting from brine discharge and a positive short-term influence of construction on spotted seatrout at Station 33_I. Some of the apparently positive influences, however, may translate to negative or neutral impacts away from the particular impact station. This is because the locally increased relative abundance of a size class or species may influence densities elsewhere. Individuals responding to locally favorable conditions may be drawn from nearby locations where densities diminish and the overall density of the population remains unchanged. Therefore, we cannot conclude that apparent positive LOOP-related effects are enhancements to the nekton populations or to the whole nekton community.

From of a total of over 2,200 comparisons, only 14 significant interactions were detected. There are several possibilities as to why we did not detect more significant differences. It is, of course, possible that LOOP did not impact any more demersal nekton. Nevertheless, the variability of the CPUE estimates was high due to the natural variability inherent in nekton populations, low trawl replication, and discontinuous monthly sampling. Significant temporal effects for size classes and species without significant interaction terms may still be related to the LOOP pipeline if the sphere of influence of the LOOP construction and operation extended to the chosen control stations. If control stations were even slightly influenced by LOOP activities, then the sensitivity of the BACI comparisons would be reduced. Another possibility is that short term impact events, such as oil spills, may not have occurred at a sensitive stage in the life cycle of the observed species. The absence of an impact from an oil spill does not necessarily indicate that the system is insensitive to the spill, but may only be less sensitive to the spill at certain times of the year, when sensitive life history stages of nekton species are not present. Additionally, the tested oil spills were relatively small. Larger spills would probably have a greater influence on demersal nekton.

Several recommendations to improve the monitoring design are reported in the following section and are related to improving spatial and temporal coverage, improving the characterizations of nekton patterns of distribution and abundance, and the identification of appropriate control stations. Those should lead to even more convincing analyses of the monitoring data in the event of future impacts and satisfy the objectives of the Environmental Monitoring Plan.

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APPENDIX I:

Additional taxa collected (not included in the analyses) during the LOOP monitoring program between February 1978 and December 1995. N is the number of independent observations.

Common name	Scientific Name	N	Total Number
Longnose anchovy	*Anchoa nasuta*	151	33,922
Silver perch	*Bairdiella chrysoura*	290	19,233
Flat anchovy	*Anchoviella perfasciata*	43	18,908
Atlantic spadefish	*Chaetodipterus faber*	468	16,812
Round herring	*Etrumeus teres*	124	14,954
Southern hake	*Urophycis floridana*	301	13,142
Undetermined squid	*Loligo* spp.	27	10,792
Seabob	*Xiphopenaeus kroyeri*	107	10,186
Blue catfish	*Ictalurus furcatus*	102	9,444
Dwarf sandperch	*Diplectrum bivittatum*	235	9,348
Blackear bass	*Serranus atrobranchus*	145	8,980
Mantis shrimp	*Squilla chydaea*	144	8,364
Pinfish	*Lagodon rhomboides*	236	7,704
Channel catfish	*Ictalurus punctatus*	55	7,644
Atlantic moonfish	*Selene setapinnis*	272	7,143
Hogchoker	*Trinectes maculatus*	296	7,138
Undetermined rock shrimp	*Sicyonia* spp.	45	7,044
Singlespot frogfish	*Antennarius radiosus*	183	5,412
Scaled sardine	*Harengula jaguana*	173	5,387
Grass shrimp	*Palaemonetes pugio*	120	5,356
Pancake batfish	*Halieutichthys aculeatus*	231	4,952
Mexican flounder	*Cyclopsetta chittendeni*	182	4,914
Blackedge cusk eel	*Lepophidium graellsi*	48	4,898
River shrimp	*Macrobrachium ohione*	79	4,734
Sheepshead	*Archosargus probatocephalus*	237	4,094
Threadfin shad	*Dorosoma petenense*	84	4,076
Sharptail goby	*Gobionellus hastatus*	136	3,939
Grass shrimp	*Palaemonetes vulgaris*	92	3,782
Harvestfish	*Peprilus alepidotus*	160	3,452
Arrow squid	*Loligo pleii*	22	3,440
Ragged goby	*Bollmannia communis*	145	3,322
Lined sole	*Achirus lineatus*	199	3,313
Dwarf goatfish	*Upeneus parvus*	82	3,304
Smoothhead scorpionfish	*Scorpaena calcarata*	111	3,212
Gulf stone crab	*Menippe adina*	120	3,071
Blackwing searobin	*Prionotus rubio*	116	2,896

Butterfish	*Peprilus triacanthus*	8	2,714
Atlantic stingray	*Dasyatis sabina*	158	2,591
Red snapper	*Lutjanus campechanus*	110	2,474
Portunus spinimanus	*Portunus spinimanus*	108	2,472
Rough silverside	*Membras martinica*	11	2,404
Chub mackerel	*Scomber japonicus*	42	2,352
Smooth puffer	*Lagocephalus laevigatus*	116	2,211
Yellow box crab	*Calappa sulcata*	134	1,762
Wenchman	*Pristipomoides aquilonaris*	72	1,756
White elbow crab	*Leiolambrus nitidus*	74	1,708
Portunus spinicarpus	*Portunus spinicarpus*	66	1,638
Florida lady crab	*Ovalipes floridanus*	79	1,632
Portly spider crab	*Libinia emarginata*	94	1,604
Shortwing searobin	*Prionotus stearnsi*	64	1,588
Spanish sardine	*Sardinella aurita*	56	1,522
Bearded brotula	*Brotula barbata*	109	1,378
Longnose spider crab	*Libinia dubia*	94	1,339
Atlantic thread herring	*Opisthonema oglinum*	81	1,307
Spanish mackerel	*Scomberomorus maculatus*	84	1,240
Mud crab	*Rhithropanopeus harrisii*	46	1,232
Gulf hake	*Urophycis cirrata*	30	1,202
Brown rock shrimp	*Sicyonia brevirostris*	27	1,112
Atlantic midshipman	*Porichthys plectrodon*	98	1,110
Ocellated flounder	*Ancylopsetta quadrocellata*	53	1,056
Gulf squareback crab	*Speocarcinus lobatus*	42	1,046
Guaguanche	*Sphyraena guachancho*	75	978
Spiny flounder	*Engyophrys senta*	32	916
Skilletfish	*Gobiesox strumosus*	58	914
Calico box crab	*Hepatus epheliticus*	54	858
Striped mullet	*Mugil cephalus*	35	844
Bank cusk eel	*Ophidion holbrooki*	25	824
Blue runner	*Caranx crysos*	48	804
Crested cusk eel	*Ophidion welshi*	47	782
Gulf toadfish	*Opsanus beta*	54	776
Crevalle jack	*Caranx hippos*	54	770
Shrimp eel	*Ophichthus gomesi*	82	747
Undetermined *Portunus* spp.	*Portunus species*	12	744
Undetermined grass shrimp	*Palaemonetes* spp.	8	716

Black drum	*Pogonias cromis*	63	698
Lookdown	*Selene vomer*	49	664
Smooth mud crab	*Hexapanopeus angustifrons*	36	664
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	68	662
Planehead filefish	*Monacanthus hispidus*	59	640
Spotted porcelain crab	*Porcellana sayana*	28	634
Offshore lizardfish	*Synodus poeyi*	8	608
Lane snapper	*Lutjanus synagris*	55	596
Inland silverside	*Menidia beryllina*	16	552
Pistol shrimp	*Alpheus heterochaelis*	41	540
Darter goby	*Gobionellus boleosoma*	33	538
Ridgeback mud crab	*Panopeus turgidus*	22	528
Grass shrimp	*Palaemonetes intermedius*	23	520
Chain pipefish	*Syngnathus louisianae*	64	517
Silver jenny	*Eucinostomus gula*	52	510
Spotted scorpionfish	*Scorpaena plumieri*	21	500
Leopard searobin	*Prionotus scitulus*	10	468
Spotted whiff	*Citharichthys macrops*	46	456
Naked goby	*Gobiosoma bosci*	42	447
Batfish	*Ogcocephalus declivirostris*	19	402
Atlantic mud crab	*Panopeus herbstii*	22	398
Sargassum swimming crab	*Portunus sayi*	17	376
Red drum	*Sciaenops ocellatus*	12	352
Skipjack herring	*Alosa chrysochloris*	12	330
Round scad	*Decapterus punctatus*	11	328
Gray triggerfish	*Balistes capriscus*	30	312
Spotfin mojarra	*Eucinostomus argenteus*	25	310
Southern stargazer	*Astroscopus y-graecum*	33	300
Flatback mud crab	*Eurypanopeus depressus*	19	276
Bluefish	*Pomatomus saltatrix*	19	254
Ladyfish	*Elops saurus*	17	240
Bluntnose jack	*Hemicaranx amblyrhynchus*	28	222
Gizzard shad	*Dorosoma cepedianum*	11	216
Fringed sole	*Gymnachirus texae*	23	204
King mackerel	*Scomberomorus cavalla*	8	194
Bigeye	*Priacanthus arenatus*	17	188
Florida stone crab	*Menippe mercenaria*	6	186
Clown goby	*Microgobius gulosus*	9	182

Gray snapper	*Lutjanus griseus*	13	172
Bigeye scad	*Selar crumenophthalmus*	15	164
Undetermined batfish	*Ogcocephalus* spp.	14	144
Undetermined clupeid	Clupeidae	2	144
Banded snapping shrimp	*Alpheus armillatus*	4	120
Oystershell mud crab	*Panopeus simpsoni*	6	116
Cownose ray	*Rhinoptera bonasus*	12	112
Green porcelain crab	*Petrolisthes armatus*	9	108
Green goby	*Microgobius thalassinus*	6	106
Lobate mud crab	*Eurypanopeus abbreviatus*	10	106
Mexican searobin	*Prionotus paralatus*	5	100
Freckled blenny	*Hypsoblennius ionthas*	13	96
Sharksucker	*Echeneis naucrates*	12	96
Banded porcelain crab	*Petrolisthes galathinus*	4	96
Elbow crab	*Solenolambrus typicus*	11	96
Elbow crab	*Solenolambrus tenellus*	10	88
Striped burrfish	*Chilomycterus schoepfi*	12	84
Blackedge moray	*Gymnothorax nigromarginatus*	7	84
White mullet	*Mugil curema*	6	82
Pigfish	*Orthopristis chrysoptera*	12	80
Feather blenny	*Hypsoblennius hentzi*	7	80
Short bigeye	*Pristigenys alta*	4	80
Violet goby	*Gobioides broussoneti*	10	78
Yellow conger	*Hildebrandia flava*	8	78
Surf mole crab	*Albunea gibbesii*	4	78
Neopanope texana	*Neopanope texana*	8	74
Freshwater goby	*Gobionellus shufeldti*	10	72
Florida pompano	*Trachinotus carolinus*	8	70
Delta shrimp	*Macrobrachium acanthurus*	3	70
Stippled spoon-nose eel	*Echiophis punctifer*	5	68
Bonnethead (shark)	*Sphyrna tiburo*	2	64
Flecked box crab	*Hepatus pudibundus*	5	62
Cobia	*Rachycentron canadum*	7	58
Undetermined spider crab	*Libinia* spp.	5	58
Undetermined flounder	Flounder spp.	4	56
Pistol shrimp	*Alpheus floridanus*	4	56
Sand perch	*Diplectrum formosum*	3	56
Polka dot batfish	*Ogcocephalus radiatus*	5	56

Purse crab	*Persephona punctata*	6	54
Coarsehead ladycrab	*Ovalipes stephensoni*	7	54
Speckled swimming crab	*Arenaeus cribrarius*	4	52
Unidentified mud crab	Xanthidae	4	52
Barbfish	*Scorpaena brasiliensis*	2	48
Splitlure frogfish	*Antennarius scaber*	3	48
Crested blenny	*Hypleurochilus geminatus*	7	44
Sargassum shrimp	*Leander tenuicornis*	2	42
Lined seahorse	*Hippocampus erectus*	4	42
Peppermint shrimp	*Lysmata wurdemanni*	4	42
Frillfin goby	*Bathygobius soporator*	3	40
Spotted drum	*Equetus punctatus*	3	40
Cubbyu	*Equetus umbrosus*	1	40
Emerald sleeper	*Erotelis smaragdus*	5	38
Broadback mud crab	*Eurytium limosum*	2	38
Unidentified snapping shrimp	Alpheidae	5	38
Undetermined goby	Gobiidae	3	34
Striped snapping shrimp	*Alpheus formosus*	2	32
Spotted gar	*Lepisosteus oculatus*	4	30
Code goby	*Gobiosoma robustum*	6	30
Gulf pipefish	*Syngnathus scovelli*	5	29
Remora	*Remora remora*	2	28
Flame box crab	*Calappa flammea*	5	28
Atlantic bonito	*Sarda sarda*	1	28
Reticulate goosefish	*Lophiodes reticulatus*	6	28
American eel	*Anguilla rostrata*	3	26
Southern stingray	*Dasyatis americana*	2	24
Undetermined *Ovalipes* spp.	*Ovalipes* spp.	2	24
Blue spotted cornetfish	*Fistularia tabacaria*	3	24
Luminous hake	*Steindachneria argentea*	4	24
Coastal mud shrimp	*Upogebia affinis*	3	22
Vermilion snapper	*Rhomboplites aurorubens*	3	20
Calocaris lobster	*Calocaris hirsutimana*	2	20
Undetermined octopus	Octopoda	1	20
Roughtail stingray	*Dasyatis centroura*	2	20
Ocellated moray	*Gymnothorax saxicola*	4	20
Dana swimming crab	*Callinectes danae*	2	18
Three-eye flounder	*Ancylopsetta dilecta*	1	16

Northern sennet	*Sphyraena borealis*	2	16
Undetermined searobin	*Prionotus* spp.	3	16
Shortnose gar	*Lepisosteus platostomus*	2	12
Undetermined eel spp.	Eel spp.	1	12
Band tail searobin	*Prionotus ophryas*	2	12
Striped porcelain crab	*Porcellana sigsbeiana*	2	12
Roundel skate	*Raja texana*	1	12
Banded eel	*Ophichthus rex*	1	12
Knobbed mud crab	*Hexapanopeus paulensis*	1	12
Green snapping shrimp	*Alpheus normanni*	2	12
Unidentified elbow crab	Parthenopidae	2	12
Undetermined stone crab	*Minippe* spp.	1	12
Yellow jack	*Caranx bartholomaei*	2	10
False arrow crab	*Metoporhaphis calcarata*	2	10
Furrowed mud crab	*Panopeus occidentalis*	2	10
Red swamp crawfish	*Procambarus clarki*	1	8
Scalloped hammerhead	*Sphyrna lewini*	1	8
Humpback shrimp	*Solenocera vioscai*	1	8
Lancer stargazer	*Kathetostoma albigutta*	1	8
Antenna codlet	*Bregmaceros atlanticus*	1	8
Fivespine purse crab	*Myropsis quinquespinosa*	1	8
Bluegill	*Lepomis macrochirus*	1	6
Redear sunfish	*Lepomis microlophus*	1	6
Spotted sunfish	*Lepomis punctatus*	1	6
Flathead catfish	*Pylodictis olivaris*	1	6
Alligator gar	*Lepisosteus spatula*	1	6
Golden topminnow	*Fundulus chrysotus*	1	6
Undetermined mojarra	*Eucinostomus* spp.	1	6
Gulf flounder	*Paralichthys albigutta*	1	6
Sheepshead minnow	*Cyprinodon variegatus*	1	6
Gulf killifish	*Fundulus grandis*	1	6
Fat sleeper	*Dormitator maculatus*	1	6
Smooth elbow crab	*Heterocrypta granulata*	1	6
Undetermined *Squilla* spp.	*Squilla* spp.	1	6
Dwarf seahorse	*Hippocampus zosterae*	1	6
Lyre goby	*Evorthodus lyricus*	1	6
Spotfin flounder	*Cyclopsetta fimbriata*	1	6
Cryptic teardrop crab	*Pelia mutica*	1	6

Sargassumfish	*Histrio histrio*	1	6
Undetermined jack	Carangidae	1	6
Redleg humpback shrimp	*Exhippolysmata oplophoroides*	1	6
Mysid shrimp	Mysidacea	1	6
Spotted snake eel	*Ophichthus ophis*	1	6
Alabama shad	*Alosa alabamae*	1	4
Blacktip shark	*Carcharhinus limbatus*	1	4
Undetermined blenny	Blenny spp.	1	4
Spinycheek scorpionfish	*Neomerinthe hemingwayi*	1	4
Anchor tilefish	*Caulolatilus intermedius*	1	4
Saltmarsh mud crab	*Panopeus obesus*	1	4
Squaliform shark	Squaliformes	1	4
Unidentified squid	Coleoidea	1	4
Pygmy sea bass	*Serraniculus pumilio*	1	4
Golden coral shrimp	*Stenopus scutellatus*	1	4
Squid spp.	*Pickfordiateuthis*	1	4
Undetermined penaeid shirmp	*Penaeus* spp.	1	4
Arrow crab spp.	Majidae spp.	1	4
Whitespotted soapfish	*Rypticus maculatus*	1	4
Banded puffer	*Spoeroides spengleri*	1	4
Arrow crab	*Stenorhynchus seticornis*	1	4
Undetermined pipefish	Syngnathidae	1	4

APPENDIX II:

Construction-related trends in nekton species abundances in the BACI analysis with significant main effects (MIXED, $p < 0.05$) not reported in Table 9. Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically.

Station and Species	Effect	CPUE ± SE
Station 33		
Mantis shrimp	Before	no estimate
	During	2.6 ± 1.02 A
	After	1.1 ± 0.55 B
Station 36		
Blue crab	Before	no estimate
	During	13.8 ± 4.26 A
	After	3.6 ± 1.27 B
Station 54		
Iridescent swimming crab	Before	no estimate
	During	7.3 ± 5.31 A
	After	70.6 ± 18.56 B

APPENDIX III:

Construction-related trends in nekton species size class abundances in the BACI analysis with significant main effects (MIXED, $p < 0.05$) not reported in Table 10. Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically.

Station, Species Size class	Effect	CPUE ± SE
Station 22		
Blue crab	Before	0.3 ± 0.27 AB
15 ≤ x < 30 mm	During	8.7 ± 4.04 A
	After	0.3 ± 0.16 B
Pink shrimp	Before	0.0 ± 0.0 AB
30 ≤ x < 100 mm	During	0.2 ± 0.17 A
	After	0.0 ± 0.0 B
Station 33		
Spot	Before	no estimate
≥ 100 mm	During	26.3 ± 14.90 A
	After	5.4 ± 1.20 B
Atlantic brief squid	Before	no estimate
30 ≤ x < 100 mm	During	41.9 ± 14.25 A
	After	30.9 ± 6.27 B
Mantis shrimp	Before	no estimate
30 ≤ x < 100 mm	During	2.1 ± 0.93 A
	After	0.9 ± 0.45 B
Station 36		
Blue crab	Before	no estimate
15 ≤ x < 30	During	4.6 ± 1.75 A
	After	1.0 ± 0.70 B
Blue crab	Before	no estimate
30 ≤ x < 100	During	5.4 ± 2.15 A
	After	1.1 ± 0.27 B
Station 53		
Gulf butterfish	Before	no estimate
30 ≤ x < 100 mm	During	125.9 ± 90.61 A
	After	283.5 ± 101.9 B

APPENDIX IV:

Brine discharge-related trends in nekton species abundances in the BACI analysis with significant effects (MIXED, $p < 0.05$) not reported in Table 11 for before, during and after the main brine discharge from May 1980 to December 1983. Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically.

Species	Effect	CPUE ± SE
Sand seatrout All sizes	Before	52.9 ± 22.42 A
	During	81.1 ± 23.60 A
	After	25.4 ± 3.08 B
Silver seatrout All sizes	Before	0.0 ± 0.00 A
	During	14.4 ± 7.36 A
	After	48.0 ± 9.56 B
Southern kingfish All sizes	Before	9.6 ± 3.19 A
	During	10.6 ± 1.97 AB
	After	13.8 ± 2.57 B

APPENDIX V:

Brine discharge-related trends in nekton species size class abundances in the BACI analysis with significant effects (MIXED, $p < 0.05$) not reported in Table 11 for before, during and after the main brine discharge from May 1980 to December 1983. Significant differences (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) among means are indicated with different letters reading vertically.

Species	Effect	CPUE ± SE
Spot 30 ≤ x < 100 mm	Before	0.6 ± 0.60 AB
	During	0.9 ± 0.54 A
	After	0.1 ± 0.04 B
Sand seatrout 30 ≤ x < 100 mm	Before	21.7 ± 11.00 A
	During	31.7 ± 9.84 A
	After	7.4 ± 1.42 B
Sand seatrout ≥ 100 mm	Before	31.0 ± 13.23 A
	During	49.3 ± 14.80 A
	After	18.0 ± 2.70 B
Star drum ≥ 100 mm	Before	46.7 ± 38.76 A
	During	46.6 ± 10.67 A
	After	18.6 ± 9.79 B
Silver seatrout 30 ≤ x < 100 mm	Before	00 ± 0.00 A
	During	0.9 ± 0.45 A
	After	21.7 ± 3.83 B
Southern kingfish 30 ≤ x < 100 mm	Before	9.0 ± 3.18 A
	During	9.8 ± 1.94 AB
	After	12.8 ± 2.53 B

TECHNICAL INFORMATION FOR THE LOOP MARINE AND ESTUARINE MONITORING PROGRAM REVISION

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INTRODUCTION

The Louisiana Offshore Oil Port (LOOP LLC.) is licensed under the federal Deepwater Ports Act (33 U.S.C. 1501, *et seq.*) and the Louisiana Offshore Terminal Act (LA R.S. 34:3101 *et seq.*) to construct and operate facilities in coastal Louisiana for off-loading oil tankers, transporting oil ashore through pipelines, and temporarily storing oil before ultimate shipment to refining centers located nationwide. Both the state and federal licenses required environmental monitoring of LOOP construction and operational activities. As part of the Environmental Monitoring Plan, demersal nekton (i.e., bottom oriented fishes and large invertebrates that are active swimmers but susceptible to trawl capture) were sampled at monthly intervals at several stations along the LOOP pipeline and in adjacent areas. This chapter meets the requirements defined in Task 3 of the data analysis of the LOOP marine and estuarine monitoring program for 1978 to 1995.

SIGNIFICANT RESULTS

We detected several significant construction-related trends in nekton species and size class abundances in the BACI analysis. Summaries of 11 LOOP impact findings for species and size classes with significant (MIXED, $p < 0.05$, Dunn-Šidák adjustment) interaction terms indicate that LOOP construction influenced the CPUE of important nekton species. An additional 13 temporal or spatial effects (i.e., main effects) associated with impacts (i.e., interactions) were also detected. Significant interactions (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) that imply LOOP impacts, the significant effects (i.e., spatial, temporal, or interaction), the trend direction, if any, and probable causes of the observed effects are indicated:

Station[a]	Species	Size Class (mm)	Significant Effect	Trend	Cause of Difference
Station 31					
	Lesser blue crab	< 15	Temporal	Increase	LOOP construction
			Interaction	Increase	LOOP construction
	Southern kingfish	30 to 100	Temporal	Decrease	LOOP turbidity increase

		Spatial	High at impact	Non-LOOP
		Interaction	Decrease	LOOP turbidity increase
Station 33				
Lesser blue crab	< 15	Temporal	Increase *	Non-LOOP
		Interaction	Decrease *	LOOP construction
Bay whiff	≥ 100	Temporal	Decrease *	LOOP construction
		Interaction	Decrease *	LOOP construction
Mantis shrimp	≥ 100	Temporal	Decrease *	Non-LOOP
		Interaction	No trend *	Non-LOOP
Spotted seatrout	30 to 100	Temporal	Decrease *	LOOP construction
		Interaction	Decrease *	LOOP construction
Spotted seatrout	All sizes	Temporal	Decrease *	LOOP construction
		Interaction	Decrease *	LOOP construction
Station 36				
Southern flounder	≥ 100	Temporal	Decrease *	LOOP turbidity increase
		Interaction	Decrease *	LOOP turbidity increase
Southern flounder	All sizes	Temporal	Decrease *	LOOP turbidity increase
		Interaction	Decrease *	LOOP turbidity increase
Station 53				
Atl. brief squid	≥ 100	Temporal	Decrease *	LOOP construction
		Spatial	High at impact	LOOP construction
		Interaction	Decrease *	LOOP construction
Station 54				
Atl. brief squid	≥ 100	Spatial	High at impact	LOOP construction
		Interaction	Decrease *	LOOP construction

[a] Impact station compared to appropriate control station(s).

* Species estimates were not available for the before-construction phase, so trends refer to the after-construction and during-construction phases.

We also detected significant (MIXED, $p < 0.05$, Dunn-Šidák adjustment) LOOP-related influences of brine discharge at the brine diffuser (Station 36_I) on size classes of two species, gulf menhaden and southern flounder. Both impacts were also associated with significant downward temporal trends. Significant interactions (LSMeans, $p < 0.05$, Tukey-Kramer adjustment) that imply LOOP impacts, the significant effects (i.e., spatial, temporal, or interaction), the trend direction, if any, and probable causes of the observed effects are indicated:

Species	Size Class	Significant Effect	Trend	Cause of Difference
Gulf menhaden	$30 \leq x < 100$ mm	Temporal	Decrease	LOOP turbidity increase
		Interaction	Decrease	LOOP turbidity increase
Southern flounder	≥ 100 mm *	Temporal	Decrease	LOOP turbidity increase
		Interaction	Decrease	LOOP turbidity increase

* The only individuals collected were in the size class ≥ 100 mm; therefore, the comparisons for southern flounder species were identical.

LOOP-INDEPENDENT RESULTS

We detected significant construction-related temporal trends for 11 size classes of seven species that did not have significant interaction terms (i.e., LOOP-related impacts were not detected). Although these trends could not be attributed directly to LOOP construction, they indicate the dynamic nature of marine and estuarine nekton populations:

Station[a]	Species	Size Class (mm)	Trend
Station 22			
	Blue crab.	15 to 30	High during
	Pink shrimp	30 to 100	High during
Station 33			
	Spot	≥ 100	Decrease *
	Atlantic brief squid	30 to 100	Decrease *
	Mantis shrimp	30 to 100	Decrease *
		All sizes	Decrease *
Station 36			
	Blue crab	15 to 30	Decrease *
		30 to 100	Decrease *
		All sizes	Decrease *
Station 53			
	Gulf butterfish	30 to 100	Increase *
Station 54			
	Iridescent swimming crab	All sizes	Increase *

	30 to 100	Increase *

[a] Impact station compared to appropriate control station(s).

* Species estimates were not available for the before-construction phase, so trends refer to the after-construction and during-construction phases.

We also detected significant brine discharge-related temporal trends at the brine diffuser station (Station 36_I) for nine size classes of five species that did not have significant interaction terms:

Species	Size Class (mm)	Trend
Sand seatrout	$30 \leq x < 100$	Decrease
	≥ 100	Decrease
	All sizes	Decrease
Silver seatrout	$30 \leq x < 100$	Increase
	All sizes	Increase
Southern kingfish	$30 \leq x < 100$	Increase
	All sizes	Increase
Spot	$30 \leq x < 100$	Decrease
Star drum	≥ 100	Decrease

In the analyses of two oil spill events at the offshore oil port, we did not detect any significant interactions for any of the size classes of the 37 species analyzed. Nevertheless, we did detect significant temporal trends for six size classes of three species:

Spill Date & Amount	Species	Size Class (mm)	Trend
2-April-1983 16,758 gal.	Longfin squid	$30 \leq x < 100$	Increase
	Lesser rock shrimp	$30 \leq x < 100$	Increase
		All sizes	Increase
21-October-1985 21,000 gal.	Longfin squid	$30 \leq x < 100$	Increase
	Bighead searobin	≥ 100	Decrease
		All sizes	Decrease

No significant LOOP-related spatial, temporal, or interaction effects on community descriptors (i.e., species diversity, richness, and evenness, total individuals, total fishes, total invertebrates, total decapods, and contribution of rare species) were detected for the construction or operation phases, and we did not detect significant effects for the majority of the size classes or species. Nevertheless, this does not necessarily lead to the conclusion that LOOP-related construction, brine discharges, and/or oil spills were benign. While the impact events may not have been demonstrated to be biologically significant for many nekton species, a variety of factors could reduce the sensitivity of BACI analyses to detect significant events, including inadequate number of spatial or temporal samples to test a particular impact, the absence of appropriate impact and control stations, discontinuity in the monthly sampling at some stations, and the possibility of a LOOP-related influence on a scale large enough to include the designated control stations. Thus failures to reject the null hypothesis in most instances, tested on most species and size classes, do not mean that the null hypothesis was correct.

Given that the original objectives of the LOOP Environmental Monitoring Plan are still relevant, it is vital to continue to monitor for LOOP-related impacts on the nekton community, species, and size classes. The existence of significant temporal and spatial trends and our finding 13 impacts provide further justification for continuing to monitor LOOP activities, because the baseline for future comparisons must be current for reliable analyses. Continued sampling will reduce the variability in the data, resulting in a more robust assessment of future potential impact events, and reliance on the existing baseline is not a tenable option because the baseline is shifting (i.e., many significant temporal and spatial trends were detected).

RECOMMENDATIONS

We have identified possible improvements to the sampling program that relate to temporal and spatial patterns of sampling, sample replication, and the number of environmental variables measured in conjunction with demersal nekton trawls.

- **The monitoring of nekton associated with the LOOP pipeline should be continued on a monthly basis each year, with increased replication in the event of a potential impact.**

Environmental monitoring is intended to provide data for the detection of impacts, and to provide a baseline for restoration in the event of an impact. A potential impact event may be associated with clearly defined temporal and spatial events, such as construction and post-construction phases. In this case the clearly defined periods can be tested as "before" and "after," which facilitates statistical testing. Impacts may also be associated with less clearly defined temporal and spatial events such as relatively small, chronic spills. The gradual changes occasioned by this type of event are much more difficult to detect and require long, continuous periods of sampling to develop trend analyses. In the case of the LOOP project, the most important reason for monitoring is to provide a continuous baseline of the status of the environment to meet all four of the objectives of the Environmental Monitoring Plan. A continuous baseline of data preceding a biologically significant, but non-catastrophic event will be necessary to determine the impact of the event and the measures necessary for mitigation and restoration.

Continuing the nekton sampling protocol is also vital for understanding the influences of LOOP-related activities. The Gulf coastal waters are biologically dynamic. We detected significant temporal trends for 21 size classes of 17 species that did not detectably result from LOOP-related activities. This suggests that species abundances are changing over time. As the baseline shifts, continued monitoring is needed to maintain the validity of the pre-impact data base in the event of a future LOOP impact. To ensure an accurate assessment of potential impacts, data reflecting current conditions are required. Many of the stations were discontinued in the early 1980's. For example, sampling at Stations 17_C and 19_I was discontinued in January 1982, and the data collected from those stations are now outdated because of changing temporal and spatial patterns of nekton distribution and abundance. While appropriate to assess influences related to the initial LOOP construction phase, the now terminated data sets are inadequate to provide a baseline for future potential impacts. Old data probably will not provide convincing results in a changing baseline situation. Testing the effects of future impacts against data over a decade old will reduce the accuracy of the analyses, and will cast considerable doubt on the conclusions.

The present level of monthly sampling seems adequate for maintaining a robust baseline, but resource managers should consider a response plan to increase the frequency of sampling in the event of a major, but non-catastrophic, impact (e.g., a moderate to major oil spill) for more statistical sensitivity. In order to conduct a powerful BACI analysis with a chance of detecting a 50 % change in CPUE of a typical species, three years of post-impact data would be compared to the preceding nine years of data. This requires continuous, long-term baseline data at control and impact stations. Under the current sampling intensity, the three years after a potential impact event at the offshore port would only generate 144 samples with 2 control and 2 impact stations (currently there are one control and three impact stations, but see recommendations for the Offshore Port below). To evaluate changes in sensitivity with increased sampling frequency in a response plan, we used Atlantic brief squid ($\geq$ 100mm), a common species at the offshore port stations, which had a marginally significant interaction term ($p > 0.067$). The current data set with 220 samples was sufficient to detect a CPUE difference of about 85 % between control and impact stations before and after a moderate oil spill (21 October, 1985). To detect a 50 % change in the CPUE of Atlantic brief squid CPUE the sample size would have to be about 430. Because of the transient nature of most impacts, a three year time frame for impact assessment should be used for planning. By sampling three times per month at four stations for three years, 432 samples can be collected. Alternatively, with only one sample per station per month, either nine years of data would be needed, which would be insensitive to short-term effects, or three times the number of impact and control stations would be required.

- **If additional major construction is proposed, sampling at appropriate impact stations and control stations should be conducted for at least two years, twice monthly, to ensure adequate before-construction data for impact analysis (higher sampling rates over one year would be a less powerful alternative).**

The lack of adequate pre-construction estimates of species abundances at many of the impact stations limited the utility of the BACI analyses. Pre-construction estimates are vital to the BACI analysis because the pre-impact measurements are used as a reference for subsequent comparisons. The estimates from the control stations do not always adequately represent conditions at the impact stations prior to the impact. Without an adequate pre-impact estimate, a convincing assessment of the observed differences at the impact station may not be possible. The purpose of the BACI analysis is to test for impacts that are demonstrated by a change at the impact station that does not correspond to changes at the control stations. For example, a convincing assessment of a positive or negative impact on southern kingfish can be made at Station 31_I, because the before-construction phase was adequately characterized. Southern kingfish between 30 and 100 mm were significantly more abundant at Station 31_I than at the control stations prior to construction, but significantly less abundant during and after construction. This interaction between the temporal and spatial effects indicates a negative impact due to construction. In contrast, at Station 33_I, the lack of adequate sampling before construction precluded accurate impact assessment on spotted seatrout which were significantly more abundant during and after construction at Station 33_I than at the control stations (see Table 9 in Task 2 report). If the mean CPUE at Station 33_I before construction was near zero, as it was at the control stations, then LOOP construction would have been interpreted as having had a net positive influence on spotted seatrout. Moreover, if the mean CPUE at Station 33_I was near 49 individuals per hour before construction, as it was during construction, then spotted seatrout would have decreased in the post-construction phase (a negative influence). Without the pre-construction estimate, we can only deduce that spotted seatrout mean CPUE decreased after construction relative to during construction. The recommended two-year bimonthly sampling protocol will provide 48 seasonally balanced samples at each station, which should provide adequate data for a more robust analysis of the influence of the new construction.

- **Control stations without appropriate impact station pairings should be discontinued, unless these stations are necessary for the evaluation of impacts related to variables in other datasets (e.g., Plankton, Water Chemistry, etc.).**

Several nekton stations in the sampling design could not be incorporated into the analyses. Stations 1_C, 4_C, 37_C, 41_C, and 42_C were not similar enough to any other stations to be grouped, and were excluded from the BACI analysis. Serious consideration should be given to dropping these stations for nekton sampling and other monitoring components if no valid reason can be identified for retaining them. Alternatively, they may be grouped with new impact stations to provide a more robust baseline for the control stations in an impact assessment.

- **Additional impact and control stations are necessary inshore of Station 7_I.**

Currently, coverage along the pipeline north of Station 7_I is nonexistent. Only one impact station, Station 19_I, existed inshore from Station 7_I, and it was discontinued in 1982. This arrangement leaves over 30 km of the LOOP pipeline, as well as the entire LOCAP pipeline, unmonitored. Since this area of the pipeline is unmonitored for nekton, no impact assessment of a potential pipeline failure or oil spill along the corridor could be made. Coverage at locations where the pipeline crosses a lake or major bayou is essential to provide adequate data for impact assessment. Specifically, impact and control stations should be established in the canal system surrounding the Clovelly Dome Terminal. This terminal was the site of recurring minor and moderate oil spills, but these could not be assessed because no nekton samples were collected from the area. If a large spill were to occur, no baseline data would be available for impact assessment. Consideration should also be given to adding two impact and four control stations in the middle and inshore zones where coverage is currently scant. Perhaps sampling could be restarted at Station 15_I as an impact station, with Station 14_C as its control, or Stations 1_C and 41_C could be paired with Station 38_I at the freshwater intake for the Clovelly Dome Terminal.

- **An additional control station is required in conjunction with the Offshore Oil Port, and one of the impact stations could probably be dropped.**

Only one control station (Station 52_C) exists for the three monitored Offshore Platform stations (Stations 53_I, 54_I, and 55_I). Because this control station is east of the pipeline, an additional station should be established west of the pipeline. The Gulf coastal waters have large-scale gradients related, in part, to the Mississippi River plume. A single control station cannot adequately account for these gradients, whereas two stations, straddling the pipeline, could. It is necessary to account for the influence of these gradients on nekton so that an observed difference between the control and impact stations will not wrongfully be attributed to LOOP activities. If necessary, station 55_I could be dropped, because of its proximity to Station 53_I, and because it has the least complete data.

- **Assignment of control stations to impact stations for comparisons should be made *a priori*, if possible.**

Significant differences in environmental conditions between control and impact stations in all three zones were detected for depth, but these differences were probably due to the lack of an *a priori* selection of stations as control or impact for this analysis. Choosing stations based on environmental similarity after all the samples have been collected reduces the likelihood of finding a LOOP-related impact because we are restricted to trying to detect differences between the most similar stations. If the observed environmental similarity used to group stations was enhanced by LOOP, the species and community differences will be minimal. Association of control and impact stations should have been made *a priori* or at least based on pre-construction data analysis; however, the lack of adequate pre-construction sampling did not permit this designation method. This problem should be addressed in the establishment of future stations, but the *a posteriori* association has the effect of making our current identification of LOOP impacts more conservative in favor of LOOP.

- **Monitoring of the current environmental variables, species, and sizes, used in the nekton data analyses should continue.**

The list of environmental variables measured with nekton samples, including water temperature, salinity, dissolved oxygen, turbidity, depth, and chlorophyll *a*, should be continued, and not reduced, with continued monitoring. The identification of species should be continued and improved in the case of important species (i.e., anchovy species, roughneck shrimp species, and tonguefish species). During continued monitoring, the lengths (sizes) of individuals should continue to be measured at 1 mm intervals, as initiated in January 1992, and weights should continue to be measured in grams.