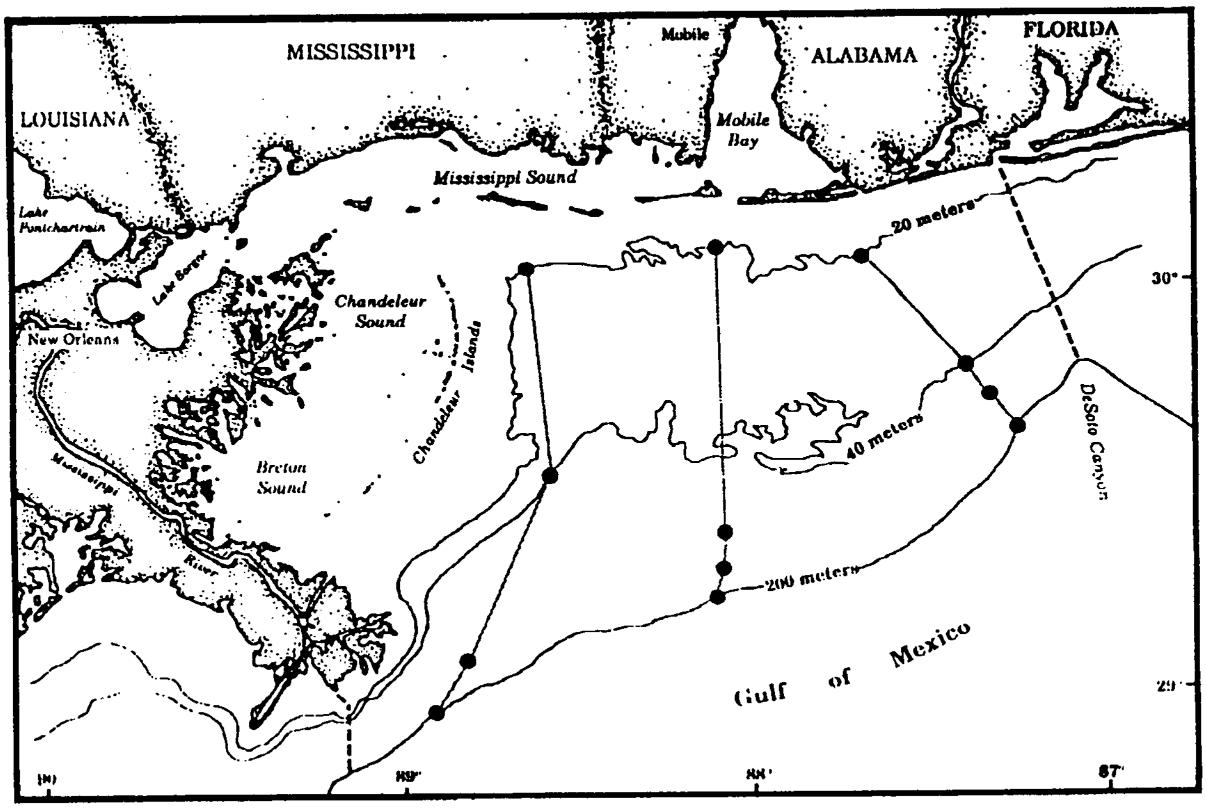
OCS Study
MMS 91-0063

Mississippi-Alabama Continental Shelf Ecosystem Study Data Summary and Synthesis

Volume II: Technical Narrative



MMS
U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Mississippi-Alabama Continental Shelf Ecosystem Study Data Summary and Synthesis

Volume II: Technical Narrative

Editors

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11.0 SATELLITE OCEANOGRAPHY

Andrew Vastano, Charlie Barron, Cynthia Lowe, and Evelyn Wells

11.1 Introduction

Circulation studies of the northeastern Gulf of Mexico were initially approached in terms of hydrography and inferences drawn on the basis of known property distributions and the temperature or salinity characteristics of observations (Chew 1961; Drennan and Demoran 1961). Early drift bottle experiments found evidence for seasonal and mesoscale circulation variability in the vicinity of the Mississippi Delta. Chew et al. (1962) reported a stagnation region south of the Delta and bottle recoveries both east and west of the Delta from an eastern release area. This investigation also found evidence for movement of surface waters southward towards the Loop Current. Drennan (1963) presented results from a drift bottle and hydrographic study that focused on surveys near the Delta and bottle returns from the Delta to Pensacola, Florida. The data were interpreted as evidence for seasonal surface drift variations east of the Delta. The bottle and shipboard surveys indicated a flow reversal from northeastward (March-June) to southwestward (August-October). Tolbert and Salsman (1964) reported the results of drift bottle releases off Panama City, Florida, from September, 1960, to December, 1962. The analysis supported the presence of Loop Current eddies off the west coast of Florida as well as in the region between the Delta and Cape San Blas, Florida. This study also gave evidence for westward flow near the Delta on drift paths to Texas landfalls.

The application of high resolution infrared radiometry to satellite observations of the sea surface temperature (SST) distributions in the region was made by Huh et al. (1978). Surveillance during the winter of 1976-77 revealed a seasonal progression of SST distributions on the continental shelf between the Delta and Florida as thermodynamic and circulation processes modified the atmosphere and ocean. The study identified characteristic cross-shelf surface temperature profiles that show the presence of mesoscale and submesoscale frontal features. A distributional study of the Loop Current, gyres and fronts was made for the eastern Gulf of Mexico by Vukovich et al. (1979) with infrared satellite images and *in situ* observations. The results document winter northward penetration of the Loop Current, Loop Current, the development of warm core eddies from the Current, and the intrusion of Loop Current plumes moving northward along the Florida continental shelf. An intrusion of this nature in February, 1977, was studied by Huh et al. (1981) and characterized as a relatively rare northward excursion of modified Loop Current water. The intrusion proceeded shoreward from 29°N as a warm, saline water mass over the axis of De Soto Canyon, reached the coast at Choctawachee Bay within ten days in the form of a hammer-head jet, and moved westward as a sequence of submesocale eddies attached to the primary front. The cross-shelf component of advection was as high as 20 cm/s and a ship STD survey showed the intrusion to be approximately 70 m thick at its core. The movement of the intrusion along the Canyon axis was suggested as a possible preferred route traveled under topographic influence. Schroeder et al. (1987) addressed the question of entrainment of coastal and shelf water by the Loop Current with analyses of inadvertent buoy detachments and subsequent sightings for the period November, 1976, to February, 1982. The observations were interpreted as evidence for a pattern in which wind-driven circulation brings shelf water to the shelf-break where entrainment is possible by Loop Current intrusions.

Circulation in northeastern Gulf of Mexico has temporal characteristics that reflect both atmospheric and oceanic forcing on seasonal as well as episodic scales. The detection and analysis of the latter phenomena requires observations with regional spatial coverage and submesoscale resolution. Previous studies have used satellites with such instrumentation to identify a range of physical features through surface signatures detected by visible and infrared sensors. There are methods that employ sequential Advanced Very High Resolution Radiometer (AVHRR) images to compute advective estimates of surface flow vectors (Vastano and Borders 1984; Emery et al. 1986) and develop synoptic flow vector distributions over a region (Vastano and Reid 1985). The objective of this work is to apply the interactive visualization technique used by Vastano and Borders to examine surface flow pattern characteristics for the northeastern Gulf of Mexico with submesoscale spatial and daily temporal resolutions and to compare the patterns with the results of previous studies.

11.2 Loop Current Intrusions

The interval between October and June is one of significant SST signatures in the northeastern Gulf of Mexico. The MAMES AVHRR image archive (Appendix E) obtained during the 1987-88 and 1988-89 intervals has been examined for sea surface expressions of circulation and associated patterns. Both Vukovich (1979) and Huh et al. (1981) were concerned with the penetration of Loop Current intrusions into the northeastern portion of the Gulf. Vukovich catalogued these events and the generation of anticyclonic gyres by Current instabilities with VHRR satellite imagery during the four-year interval, 1973-1977. The MAMES study was conducted with AVHRR (channel four, 11 micrometer) infrared scenes with 1.1 kilometer resolution and twice-daily repetition provided by each operational NOAA TIROS constellation satellite. Figure 11-1 shows a contained Loop Current passage through the Gulf of Mexico taken on 03 April, 1983. While remnants of intrusions are evident reaching to the Texas-Louisiana Shelf and seaward of the Florida Shelf, the SST distribution indicates relatively isolated, colder shelf waters in the MAMES area and an intermediate, mixed water mass reaching southward to entrainment over the northern Loop Current boundary. On 14 January 1986, the surface signature of a developing warm-core ring was clear in the eastern Gulf (Figure 11-2). The anticyclonic circulation around the ring entrained intermediate temperature slope water southward to the region between the ring and the Loop Current. The SST distribution also infers that a portion of the shelf's response has taken the form of cross-shelf motion to the shelf-break south of Mobile Bay. Figure 11-3 provides an SST pattern that shows a well-developed penetration of Loop Current waters on 23 February, 1982. The northward intrusion followed a pathway along the axis of De Soto Canyon described by Huh et al. (1981) and reached the shelf-break south of the Mississippi and Alabama barrier island system. These three examples of Loop Current behavior have manifold variations in detail but stand as characteristic patterns in terms of influence on the MAMES area. Dynamic response can be generated within the area by localized mechanisms as well. Mesoscale and submesoscale circulation features can develop on the shelf during atmospheric forcing episodes as continental polar air breaks out over the Gulf. Mississippi River outflow has the potential to generate distinct eddy

DATE OF PASS: APRIL 3, 1983 (JULIAN DAY 93)
TIME OF PASS (GMT) 20:23:32

Figure 11-1. AVHRR infrared image taken at 2032GMT hrs Julian Day 093 1983 (April 3). The continuous grey scale palette represents the warmest temperature as black and coldest as white.

DATE OF PASS: JANUARY 14, 1986 (JULIAN DAY 14)
TIME OF PASS (GMT) 20:08:31

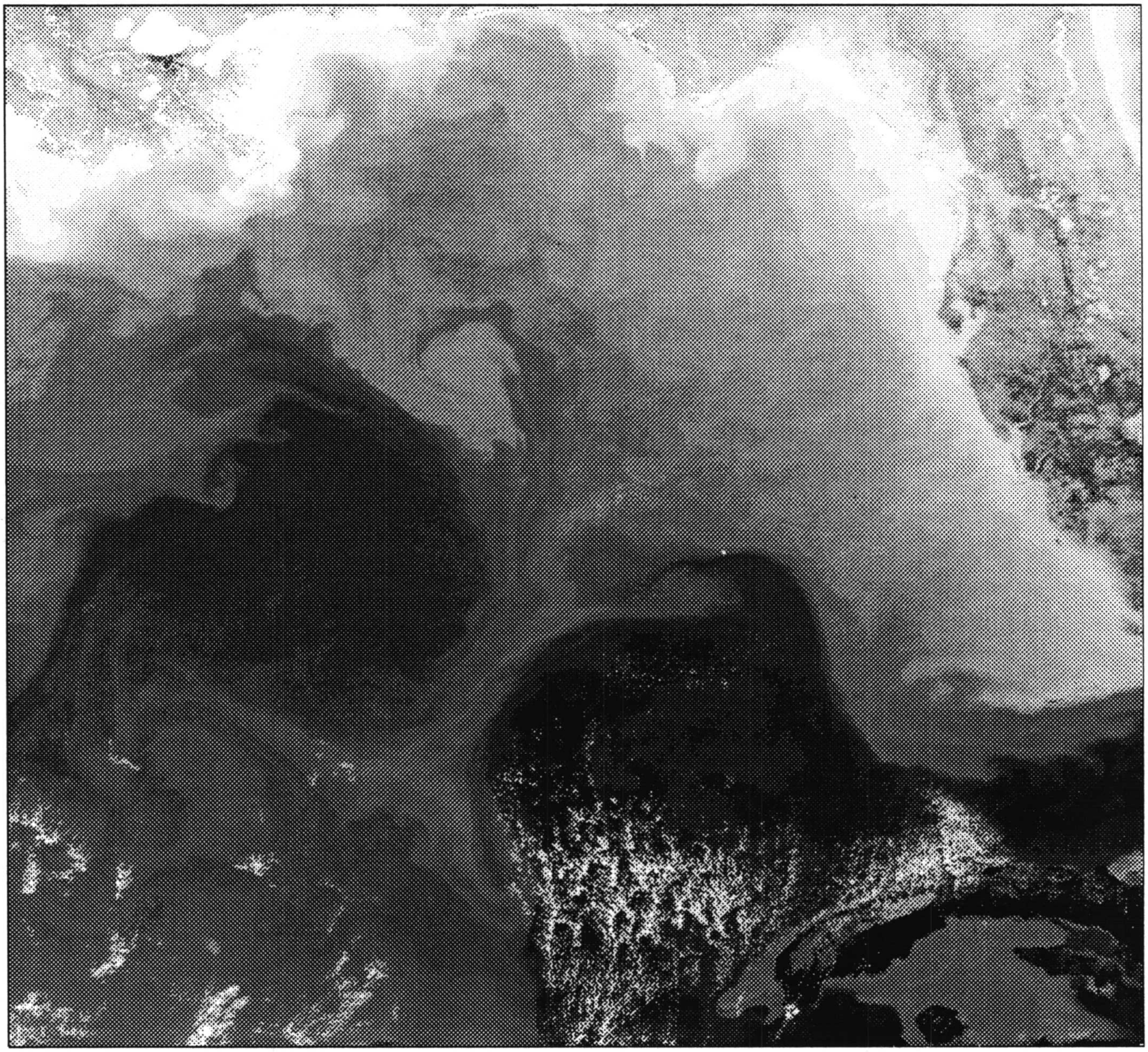


Figure 11-2. AVHRR infrared image: 2008GMT Julian Day 014, 1986 (Jan 14).

DATE OF PASS: FEBRUARY 23, 1982 (JULIAN DAY 54)
TIME OF PASS (GMT) 09:16:44

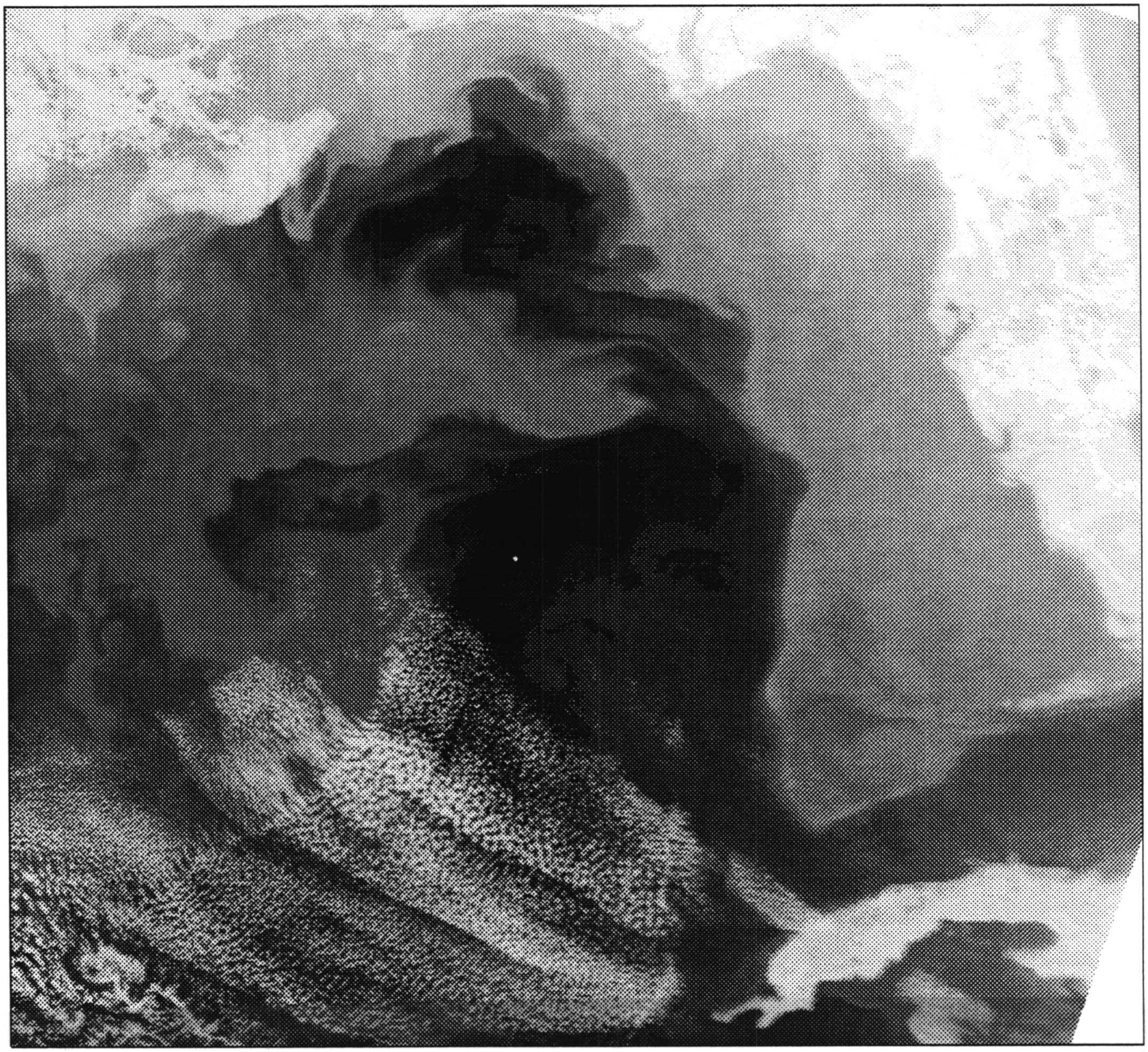


Figure 11-3. AVHRR infrared image: 0916GMT Julian Day 054, 1982 (Feb 23).

features over the shelf and slope when adjacent flow regimes do not disperse the fresher waters by turbulent diffusion. The satellite image sequence gathered during 1987-1989 indicates that features of this nature can pervade the MAMES area and dominate the flow regimes.

The analysis of Loop Current positions in the northeastern Gulf performed by Vukovich et al. (1979) identified northern boundaries by discontinuities in image gray scale values when warmer Loop Current water was juxtaposed with colder shelf or slope waters. The rationale for this technique was given by Maul (1974) wherein surface thermal discontinuities were associated with the Current's 22°C isotherm at 100 m depth. The results of the study agreed with work by Molinari et al. (1977) as to the propensity for northern penetrations in winter. An index compiled in this manner has the advantage of an appeal to a readily identifiable strong gradient for position determination. However, infrared images of the MAMES area often indicate diluted Loop Current waters that are significantly warmer than shelf or slope waters. Although less precise in terms of specific, observable position, a useful alternative index has been used to indicate the northern extent of Loop Current-related waters in the MAMES area. Figure 11-4 presents the northern extreme of Loop Current intrusions based on: (1) a continuous boundary reaching the Loop Current proper and (2) a two centigrade degree difference or less with waters within the images' northern Loop Current boundary. On this basis, intrusive warm waters were observed north of 29.5°N in December, 1987; January, March and May, 1988; and February, March and May, 1989. The approach additionally reveals a sustained presence of Loop Current-related waters north of 29°N from mid-November, 1987, to mid-January, 1988, and January to mid-March, 1989.

11.3 Flow Patterns

Six sequences have been selected from the SST image archive for 1988 to represent sea surface flow (SSF) patterns generated in the northeastern Gulf of Mexico. Each image has been rendered twice, once in a continuous gray scale palette that presents cold waters in lighter shades and warm waters darker to illustrate the SST distribution, and again, with a repetitive palette that provides more detailed resolution of the SST

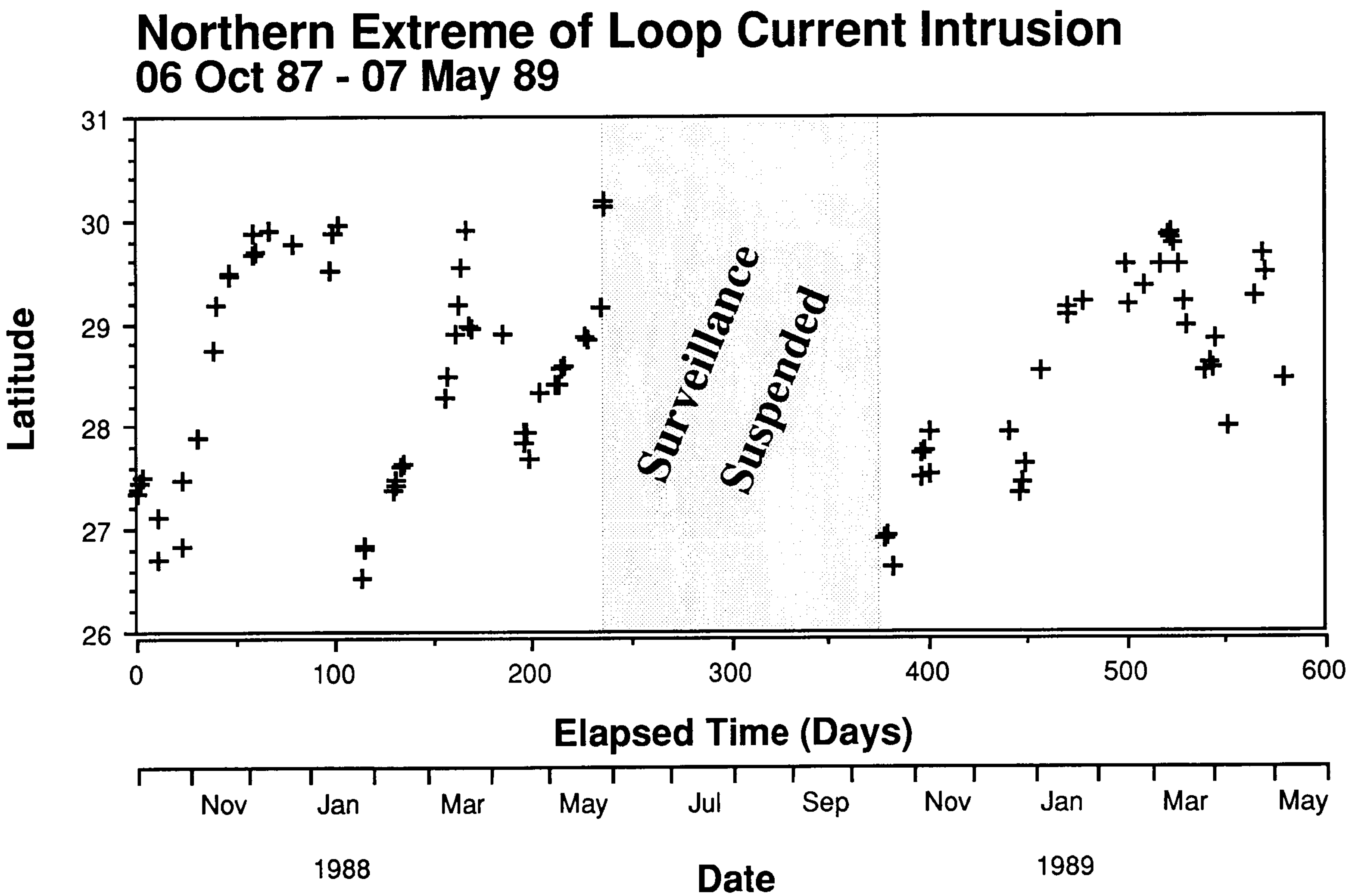


Figure 11-4. Loop Current intrusions into the northeastern Gulf of Mexico during the October-May intervals of 1987-88 and 1988-89.

structure and tends to reveal cloud cover by a fractal pattern. These sequences provide structure and flow realizations at submesoscale resolutions that offer confirming or alternative explanations for previous interpretations of circulation results. The SST images and SSF patterns are shown in Figures 11-5 to 11-34.

11.3.1 11-12 January (Figures 11-5 to 11-7)

January 11-12 marked the approach to seaward of a cold front as an atmospheric low pressure area intensified over the central portion of the continent. On 12 January, five m/s winds from the south-southeast were indicated over the western portion of the MAMES area. The Loop Current was south of 28°N at this time and cooler waters closely mark the shelf and shelf-break. The counterclockwise rotating eddy in place over the head of De Soto Canyon had surface speeds that reached 25 to 30 cm/s on the western portion of its periphery. A stagnation point in the flow field nearshore, off Mobile Bay, marks a divergence in the flow pattern with waters moving west along the coast and then south along the Chandeleur Islands. The eastward counterpart flow continues over the eddy at the head of the Canyon and joins a broad offshelf movement of waters to the east off Cape San Blas. The surface flow pattern in the northwestern MAMES area is an example of the prefrontal response discussed by Schroeder et al. (1985) in which movement is induced to the north and then westward by surface winds. Tolbert and Salsman (1964) suspected that features such as the De Soto Canyon eddy would persist and accordingly suggested that semipermanent eddies could be present between the Mississippi River delta and Cape San Blas. It is clear from the MAMES area image archive that there are several instances of eddies near the head of De Soto Canyon that are similar to the one shown in Figures 11-5 and 11-6.

11.3.2 28-29 January (Figures 11-8 to 11-10)

The weather pattern preceding 28-29 January placed the MAMES area under a high pressure cell that imposed westerly winds of two to five m/s over the shelf. A shift to steady easterly winds at speeds of two to five m/s was observed at Mobile on 28, 29 and 30 January.

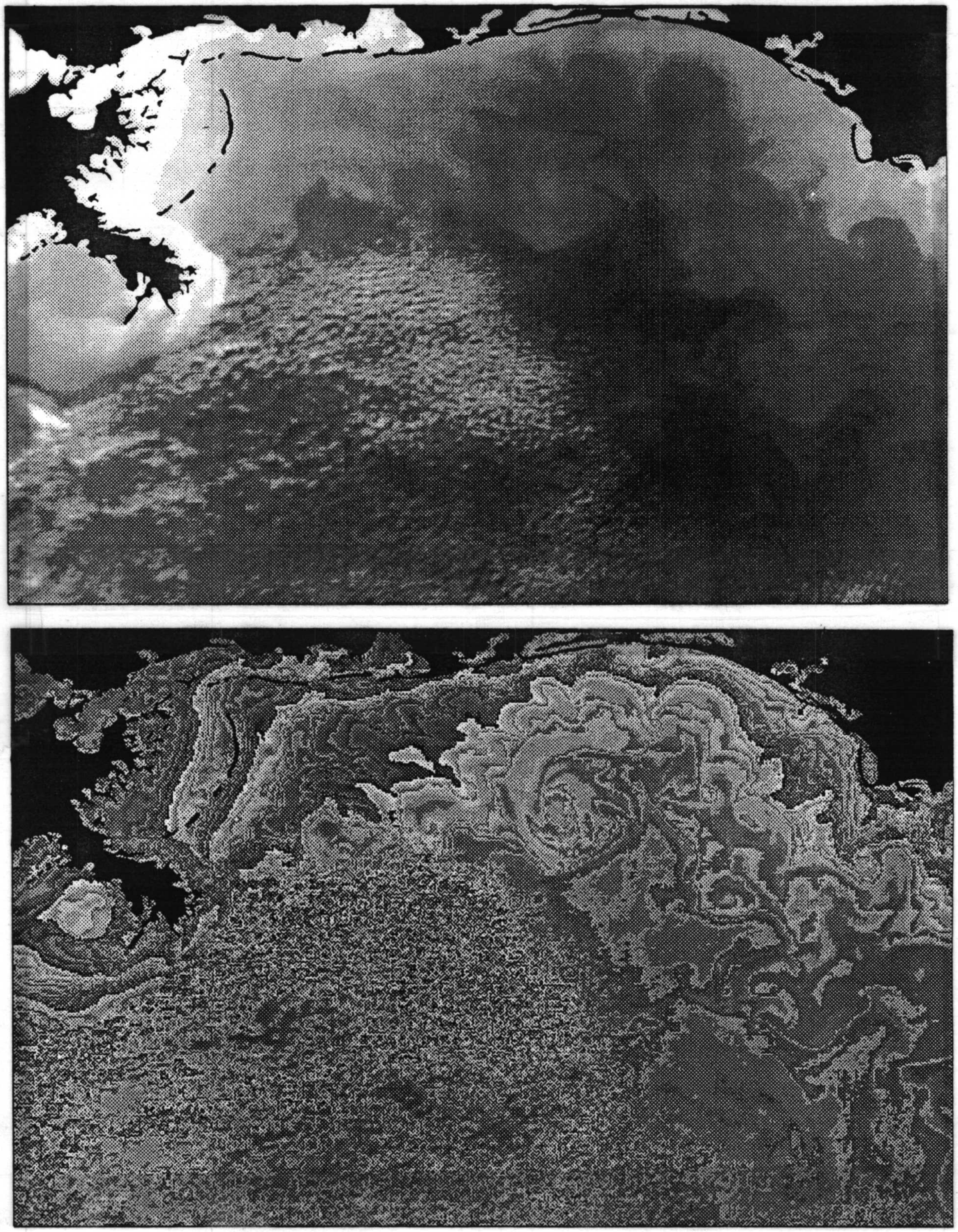


Figure 11-5. MAMES area AVHRR infrared image: 2038GMT Julian Day 011, 1988 (Jan 011).

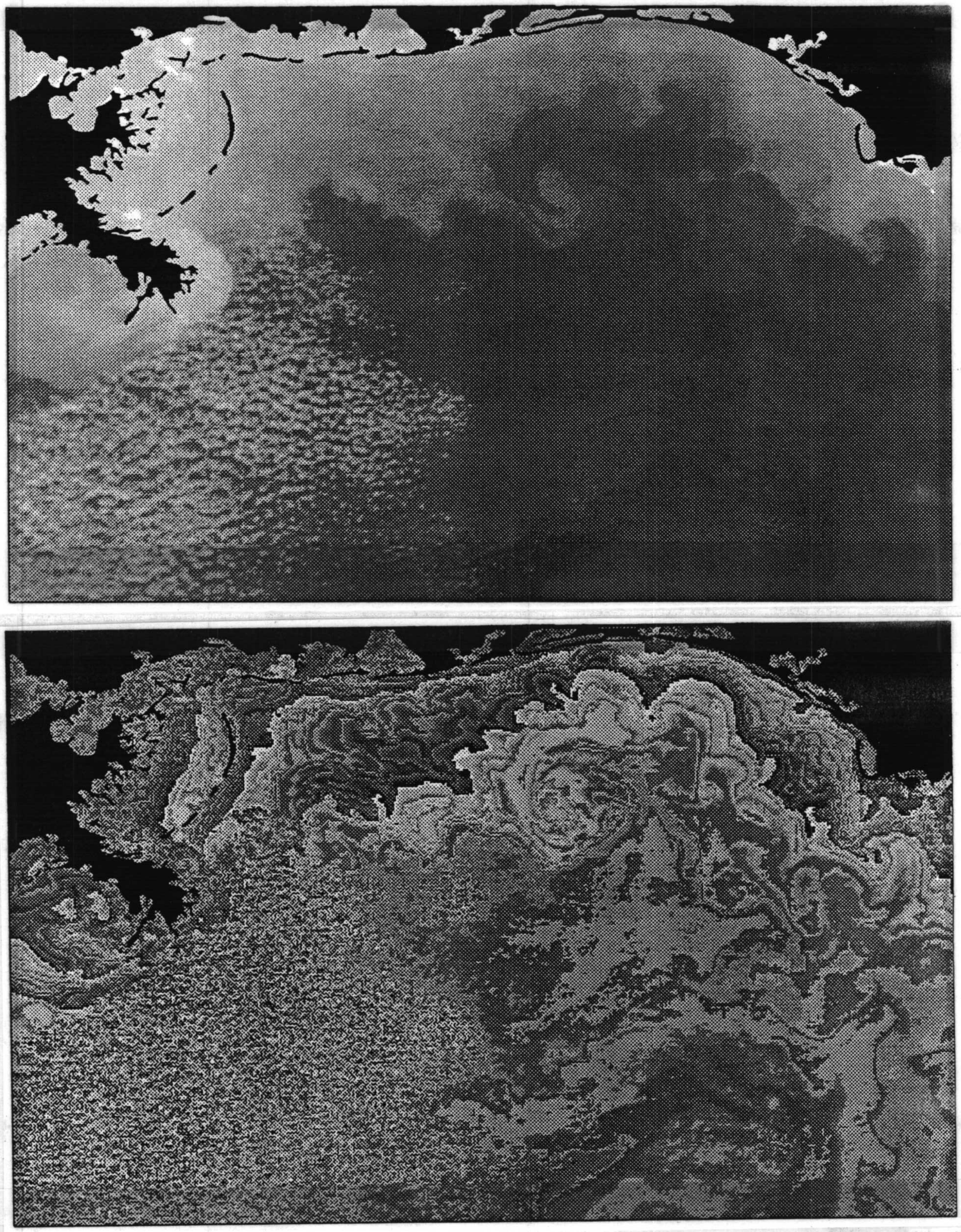


Figure 11-6. MAMES area AVHRR infrared image: 0053GMT Julian Day 012, 1988 (Jan 12).

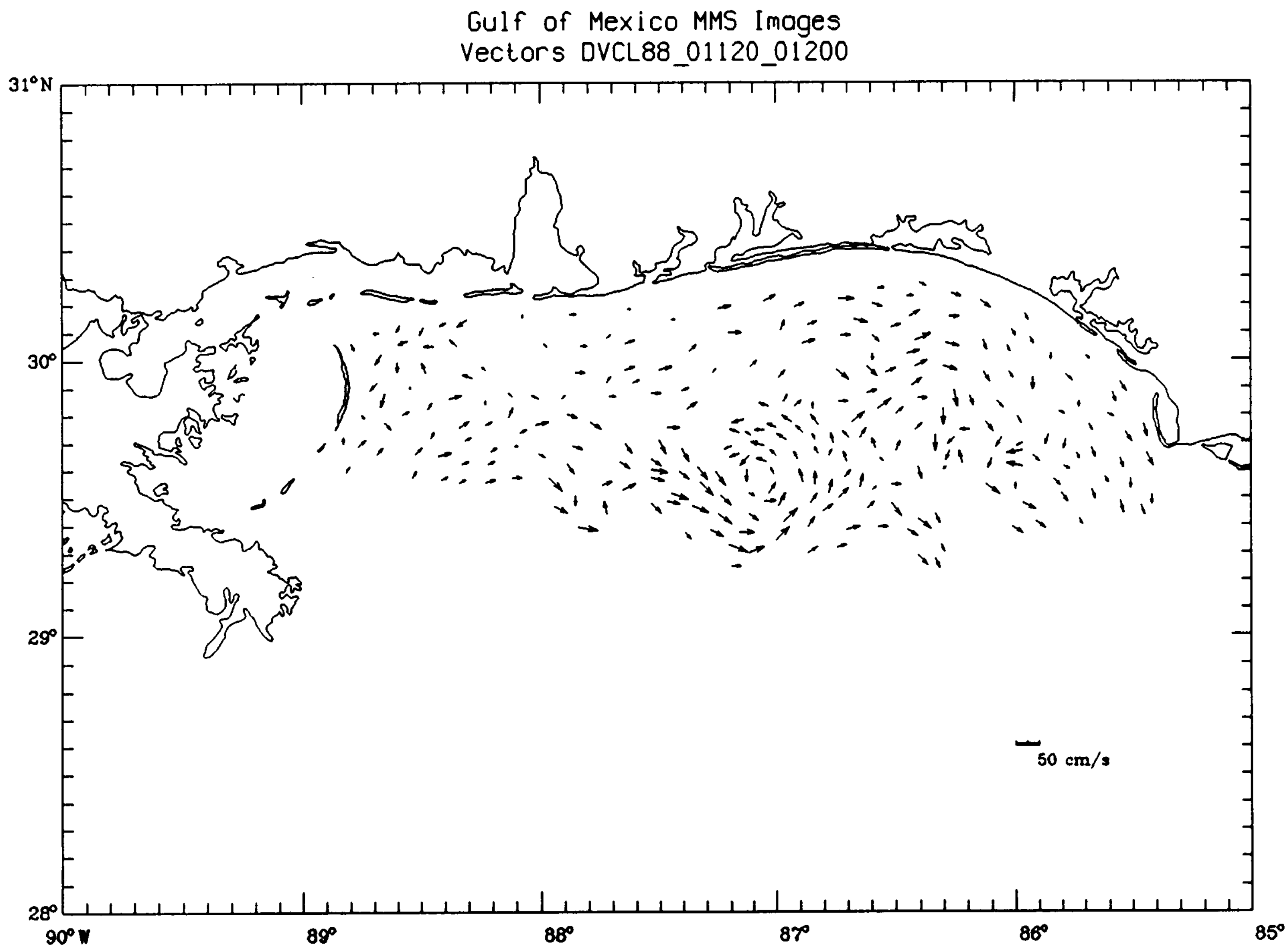


Figure 11-7. MAMES area surface flow pattern: 11-12 Jan, 1988.

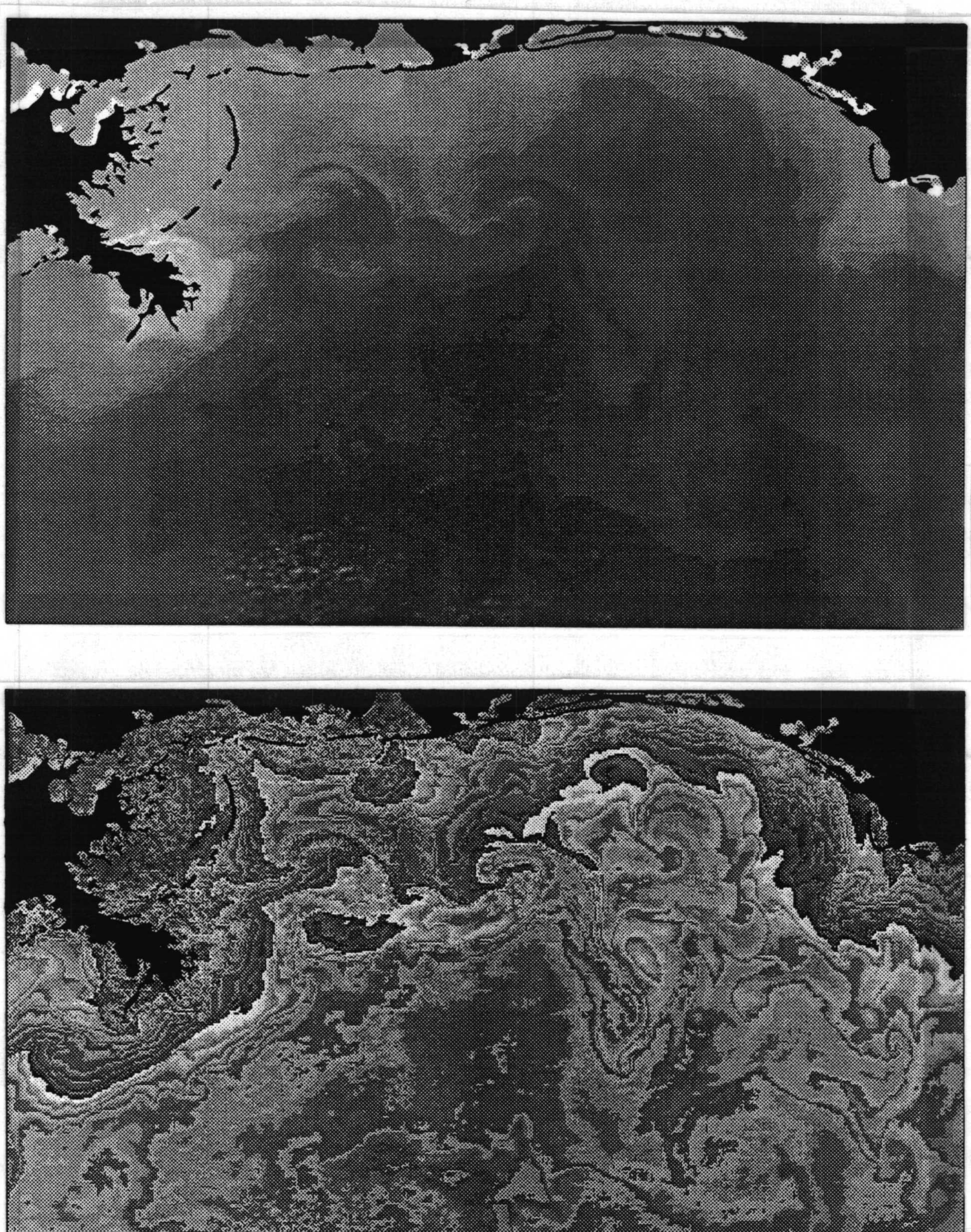


Figure 11-8. MAMES area AVHRR infrared image: 0937GMT Julian Day 028, 1988 (Jan 28).

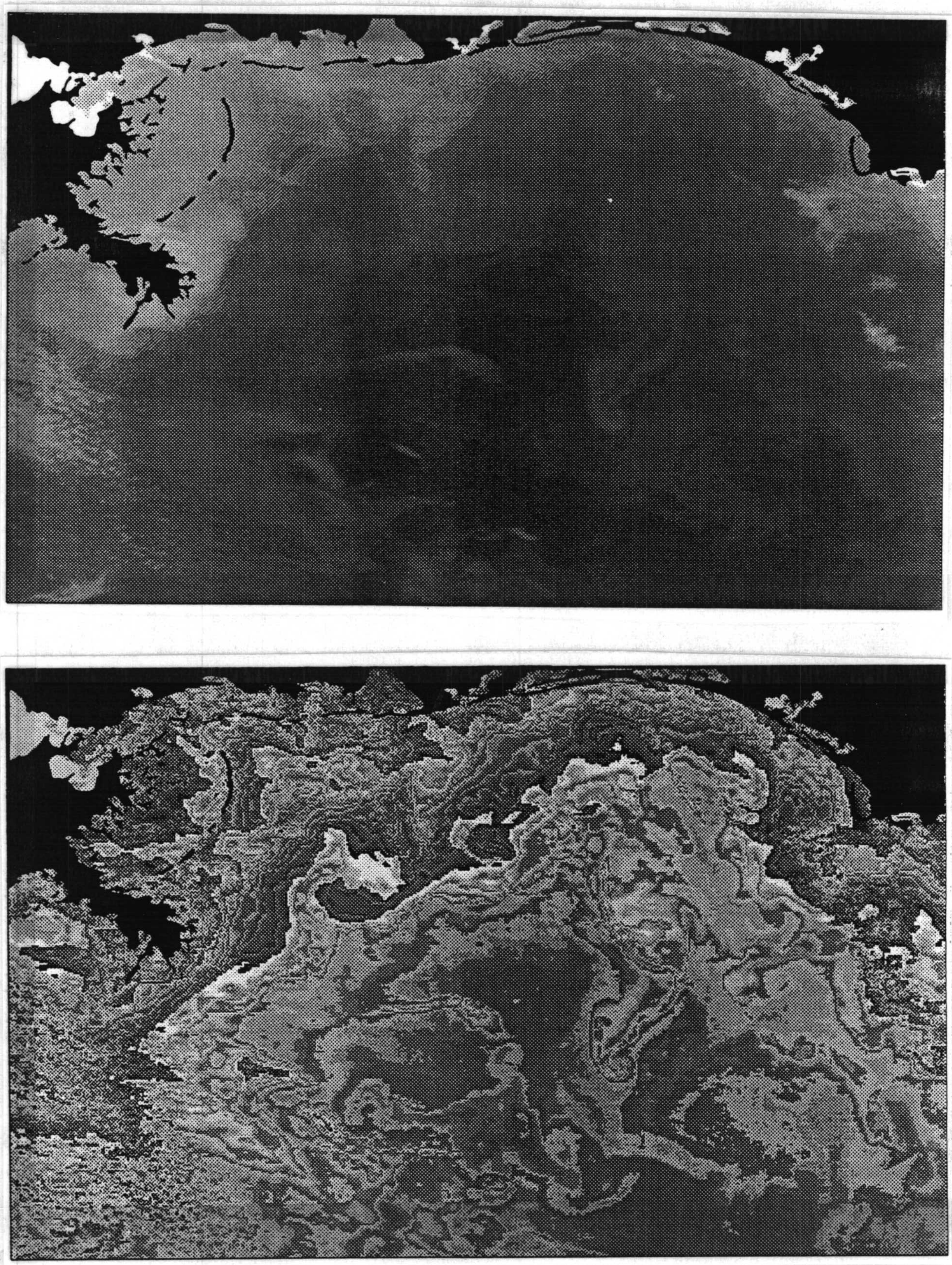


Figure 11-9. MAMES area AVHRR infrared image: 0926GMT Julian Day 029 ,1988 (Jan 29).

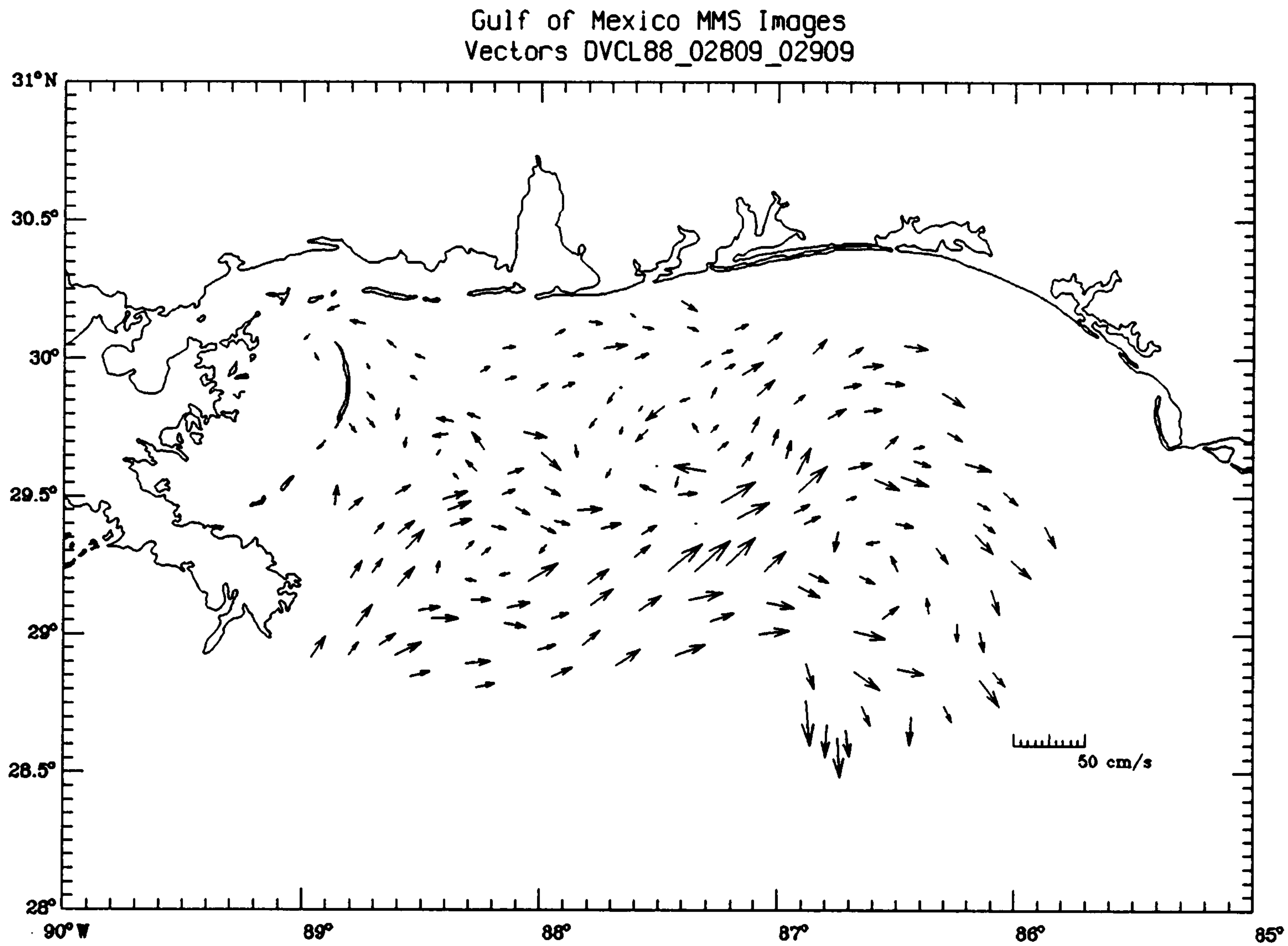


Figure 11-10. MAMES area surface flow pattern: 28-29 Jan, 1988.

The SST patterns on 28 and 29 January show two salient features. On 28 January, a distinct cross-shelf plume began at the northwestern coastline, issued offshore south of Mobile Bay, and crossed the shelf-break to develop paired vortices, west and east near the slope region. Another plume of cool water extends further south into the Gulf off De Soto Canyon and the SST distribution on 29 January indicated further penetration of this plume to the south. The nearshore temperature field showed a westward shear of the cross-shelf plume. The SSF pattern extracted from the image pair shows the water movement in accord with these temperature pattern shifts as well as nearshore flow to the west entering the northern reaches of Breton Sound, and a flow stagnation point off Mobile similar to that noted for the 11-12 January sequence.

11.3.3 12-14 February (Figures 11-11 to 11-16)

The passage of a cold front outbreak to the southwest on 11-12 February, and the establishment of a weak high pressure system centered off the Mississippi River delta forced MAMES area shelf waters with northwesterly winds and then rotated counterclockwise to southeasterly winds of five to eight m/s on 14 February. The four satellite images selected for this interval present the development and intensification of plume, a stationary eddy and strong eastward flow from the Delta. On 12 February, the penetration of warmer shelf waters was evident into Mississippi Sound through the passages at Cat, Ship, Horn, and Petit Bois Islands and into Mobile Bay through Main Pass. Wind regimes such as those observed in this time interval were noted by Schroeder and Wiseman (1986) as capable of forcing a shelf-to-estuary exchange within two days at Main Pass. With the wind shift, the image for 13 February clearly shows the formation of an offshore plume composed of waters that issued and spread southward from Mississippi Sound, Mobile and Perdido Bays. In addition, smaller cold water plumes have spread south-southeast from the entrances of Pensacola and Choctawatchee Bays.

The SSF distributions for 12-13 and 13-14 February show a nearly stationary De Soto Canyon eddy south of Pensacola Bay and the southeastward progress of cold water along the continental slope off Cape

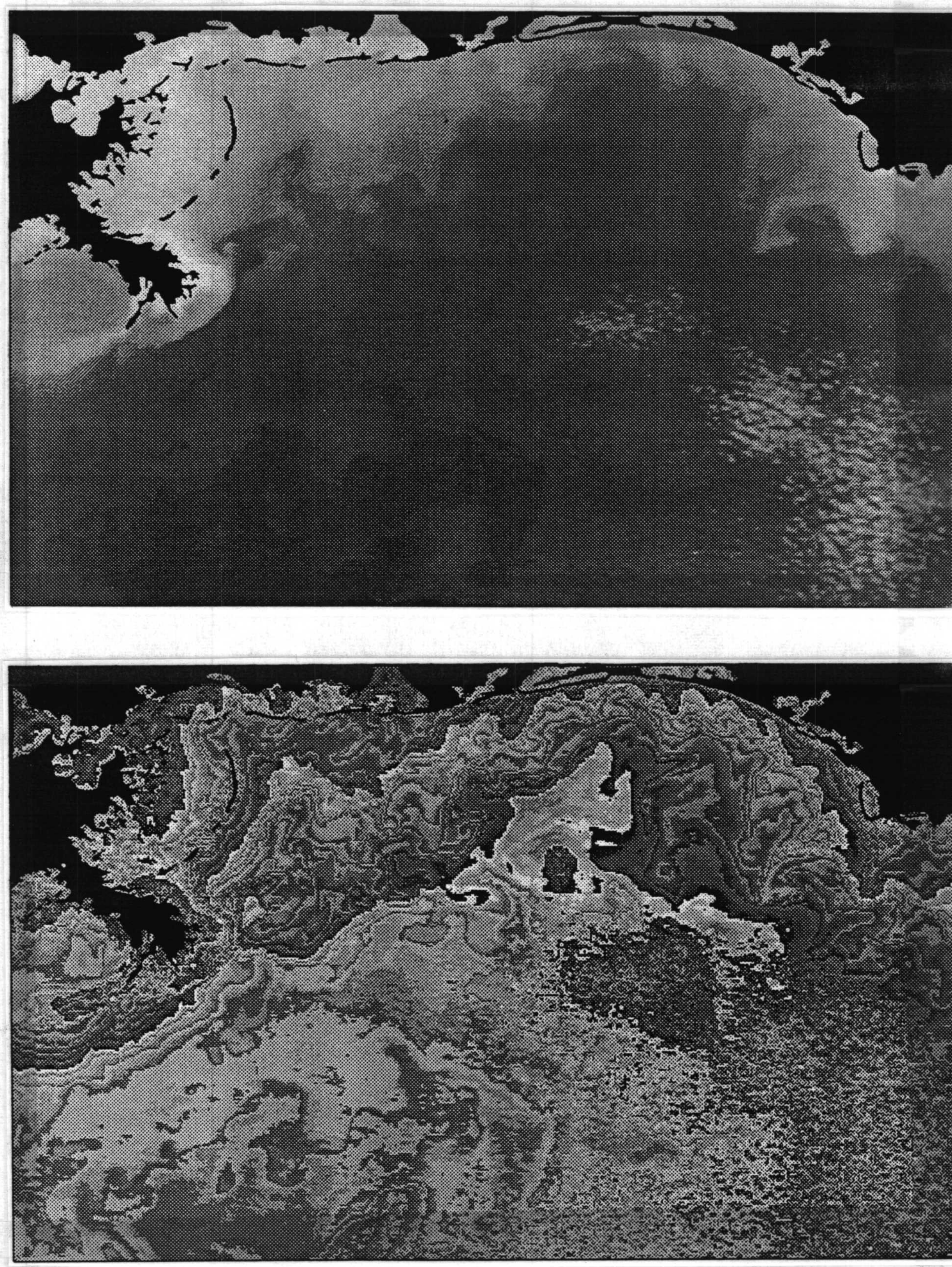
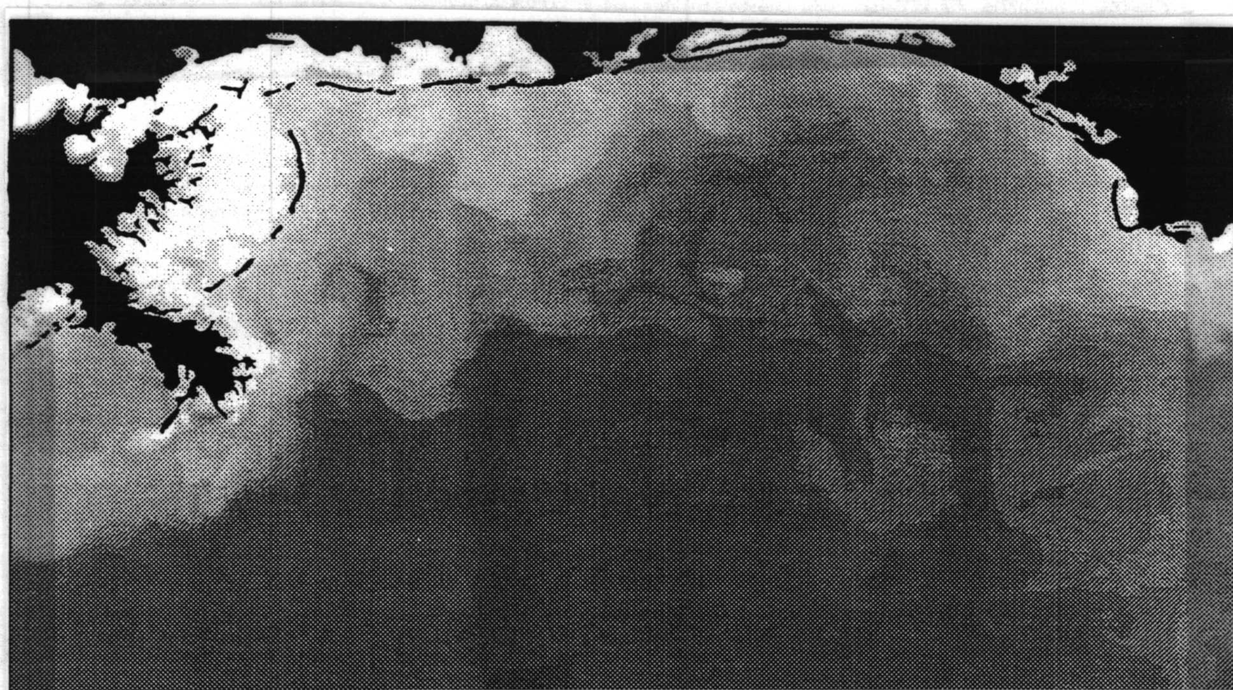


Figure 11-11. MAMES area AVHRR infrared image: 2134GMT Julian Day 043, 1988 (FEB 12).



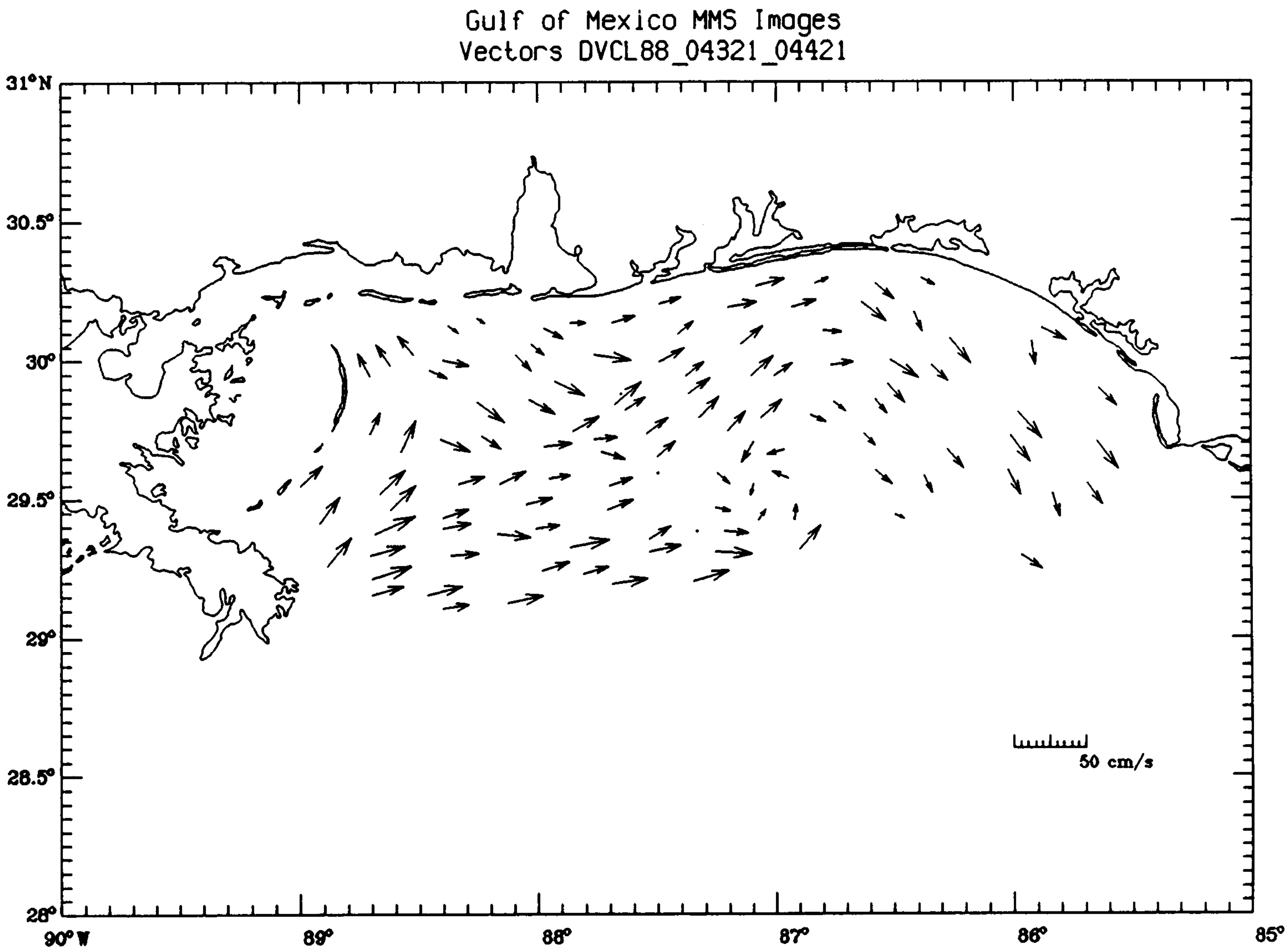


Figure 11-13. MAMES area surface flow pattern: 12-13 FEB, 1988.

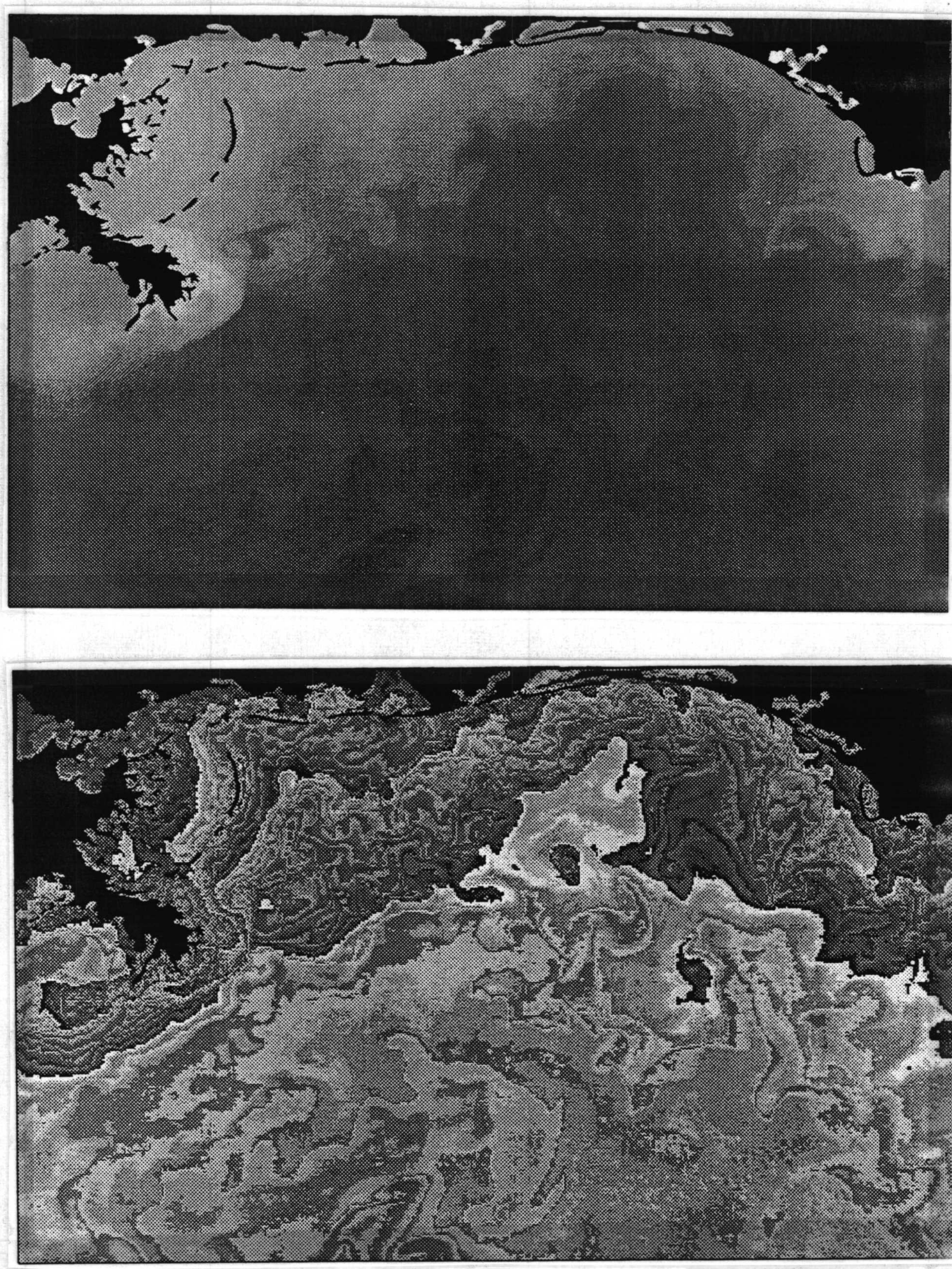


Figure 11-14. MAMES area AVHRR infrared image: 0057GMT Julian Day 044, 1988 (FEB 13).

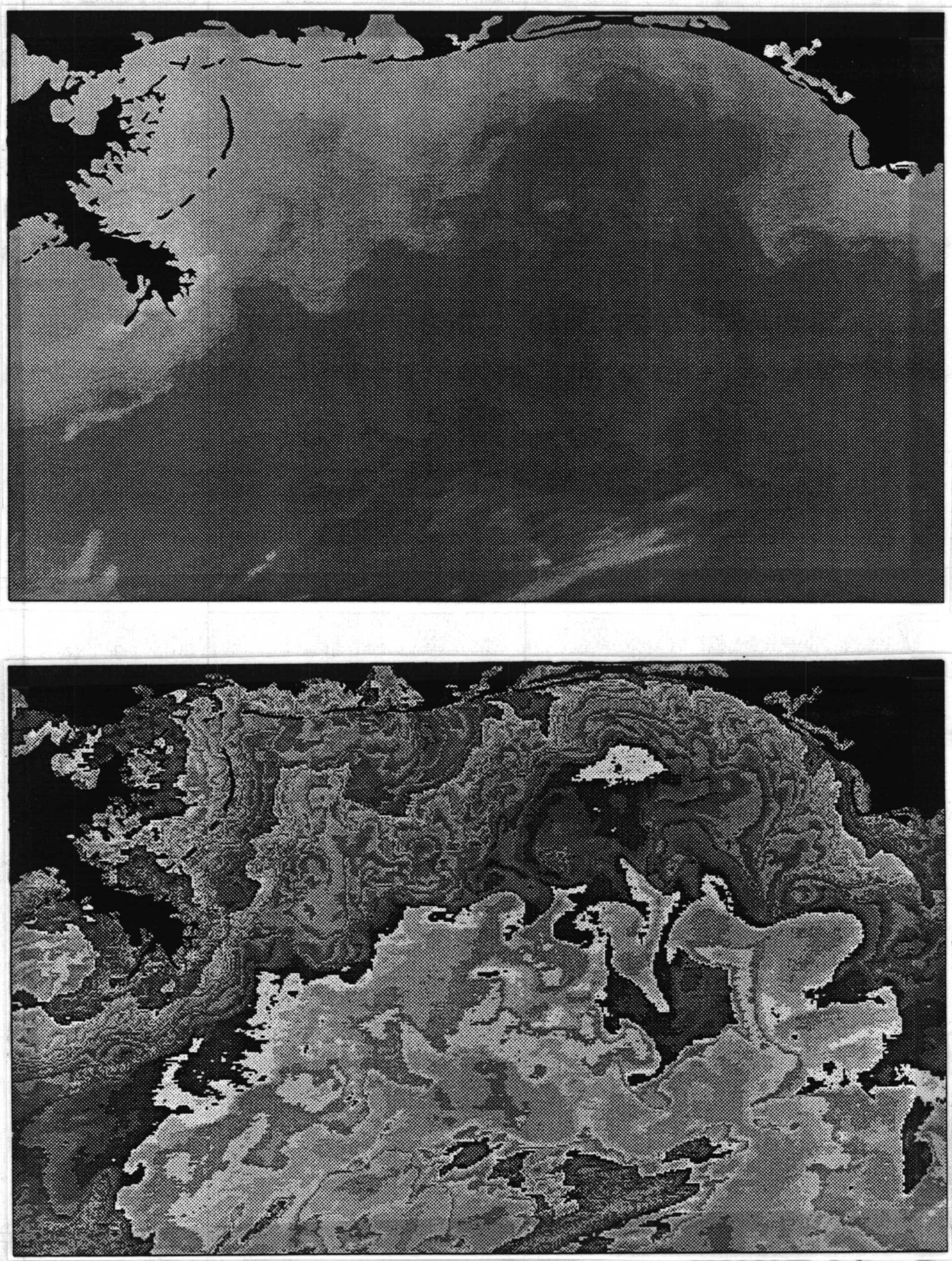


Figure 11-15. MAMES area AVHRR infrared image: 0036GMT Julian Day 045, 1988 (FEB 14).

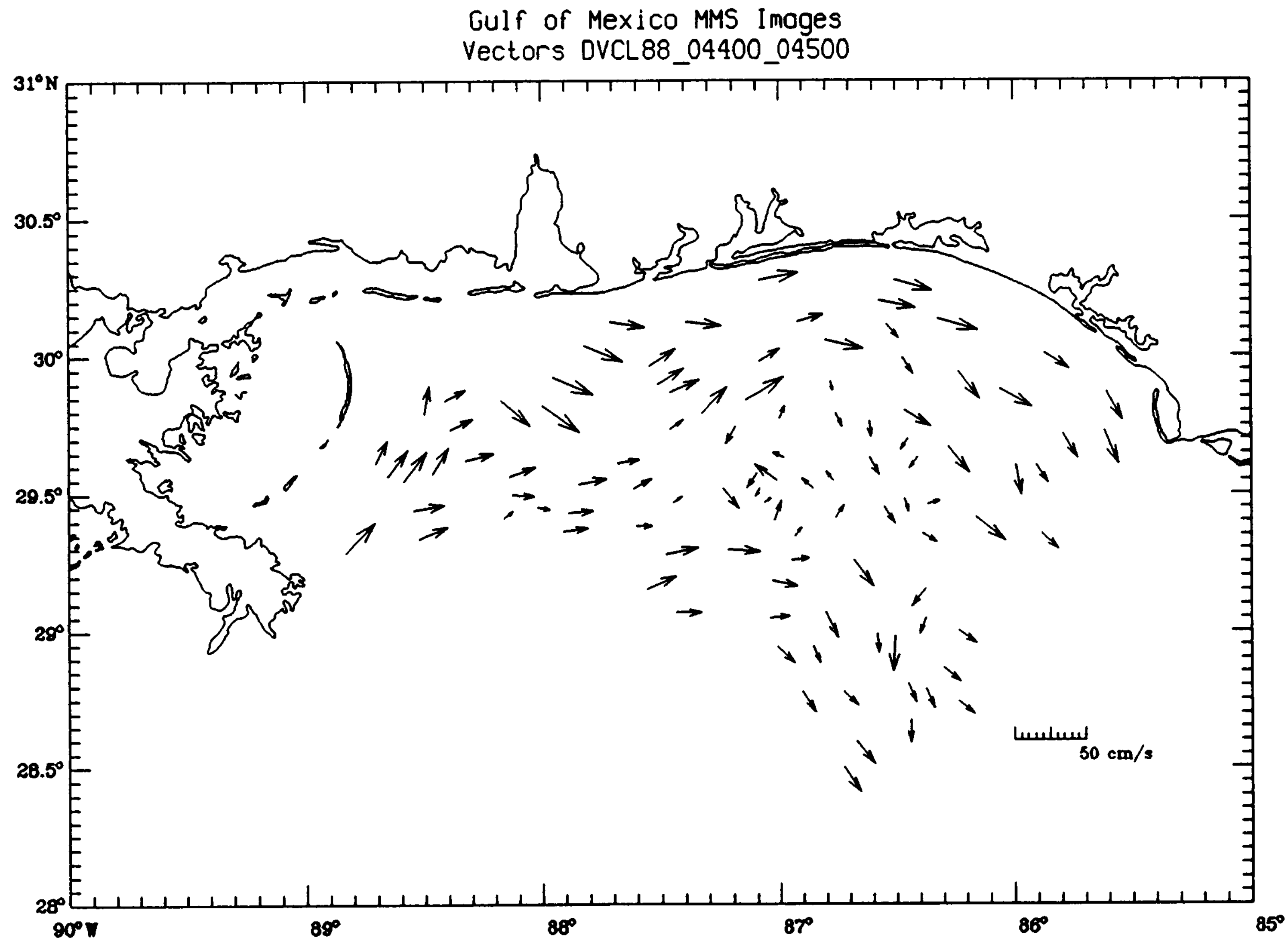


Figure 11-16. MAMES area surface flow pattern: 13-14 FEB, 1988.

San Blas. The eastward flow from the Mississippi River delta correlates well with the shelf-break to De Soto Canyon where it bifurcates around the eddy. The SSF pattern in the eastern portion of the latter image pair indicates a continuation of the southern branch, shearing the cold plume from its source.

11.3.4 10-14 March (Figures 11-17 to 11-20)

The springtime weather pattern produced two cold front outbreaks over the MAMES area on 9-10 and 12-13 March. On 14 March, persistent postfrontal northwesterly winds maintained speeds of seven to eight m/s. However, the dominant mechanism during this sequence was a Loop Current intrusion that forced the shelf waters of the MAMES area as it approached from the south off the Mississippi River delta and moved eastward over the continental slope. Figures E-89, 90, 93 and 94 in Appendix E present the parent eastern Gulf of Mexico images that were subsampled for Figures 11-17 and 11-18. The SST images and the SSF pattern for 10-11 March show the Loop Current intrusion of warm water off the Delta with an associated clockwise circulation immediately to the east. The latter feature's flow pattern promoted movement of nearby cold shelf waters southward as a plume toward the northern boundary of the Loop Current at 27°N. The SSF pattern indicates that the waters on the shelf were undergoing coherent north-northeastward motion shoreward, eastward flow along the shoreline, and southeastward movement past Cape San Blas. The centroid of the counterclockwise rotating eddy over De Soto Canyon was advected north-northeastward at a speed of 23 cm/s from 10 to 14 March, essentially over the canyon axis. The shoreward movement of this eddy feature is similar in direction and speed to the 1977 penetration of a Loop Current intrusion studied by Huh et al. (1981). The advection of the eddy suggests that the intrusions can force water masses shoreward without significantly reaching over the shelf-break.

11.3.5 05-10 November (Figures 11-21 to 11-31)

The weather over the MAMES area was marked on 06 November by prefrontal passage northwesterly winds at 10 m/s that rotated counter-clockwise to southerly at 5 to 8 m/s and steadied through 10 November. A

Figure 11-17. MAMES area AVHRR infrared image: 2143GMT Julian Day 070, 1988 (MAR 10).

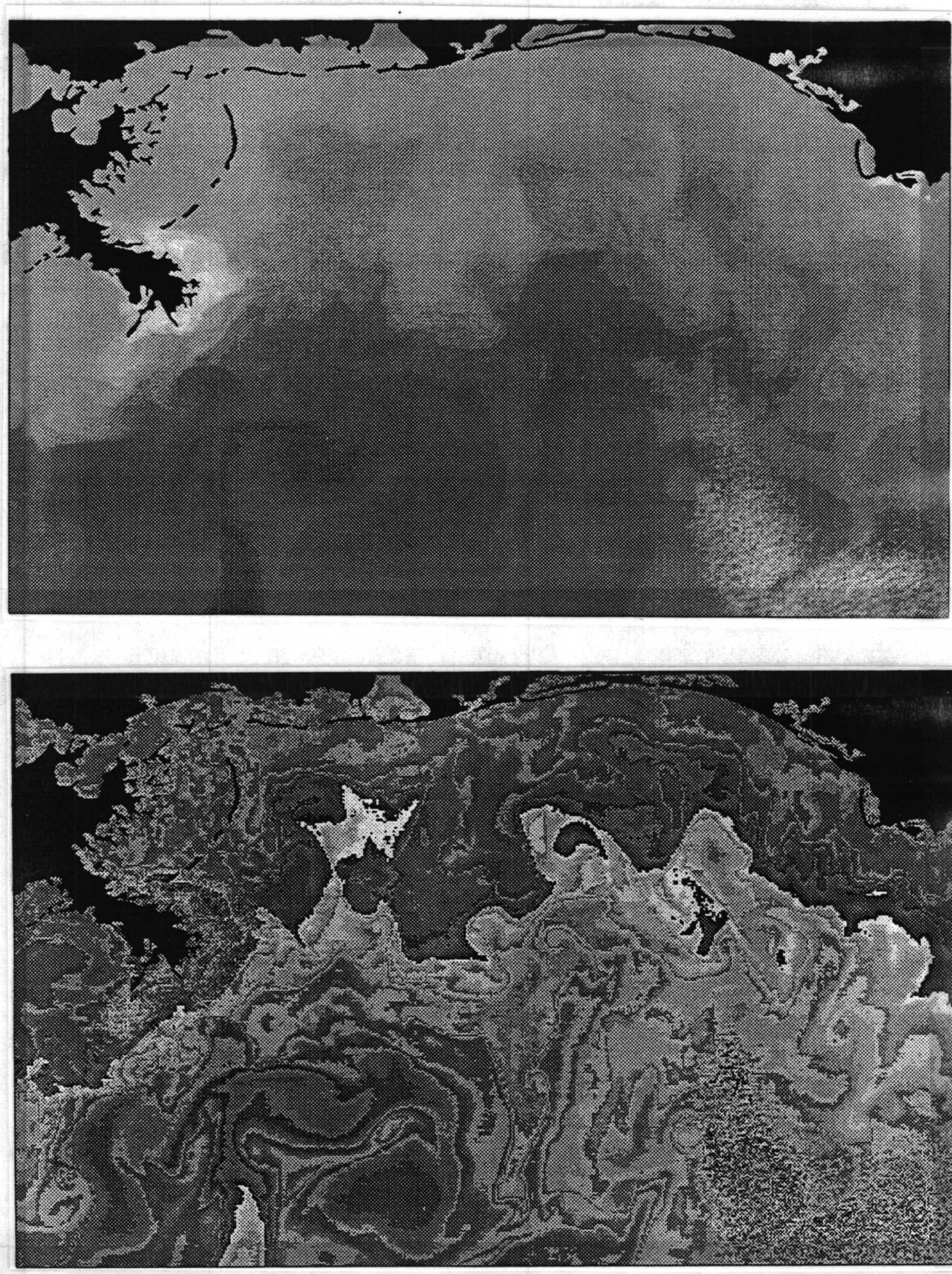


Figure 11-18. MAMES area AVHRR infrared image: 1335GMT Julian Day 071, 1988 (MAR 11).

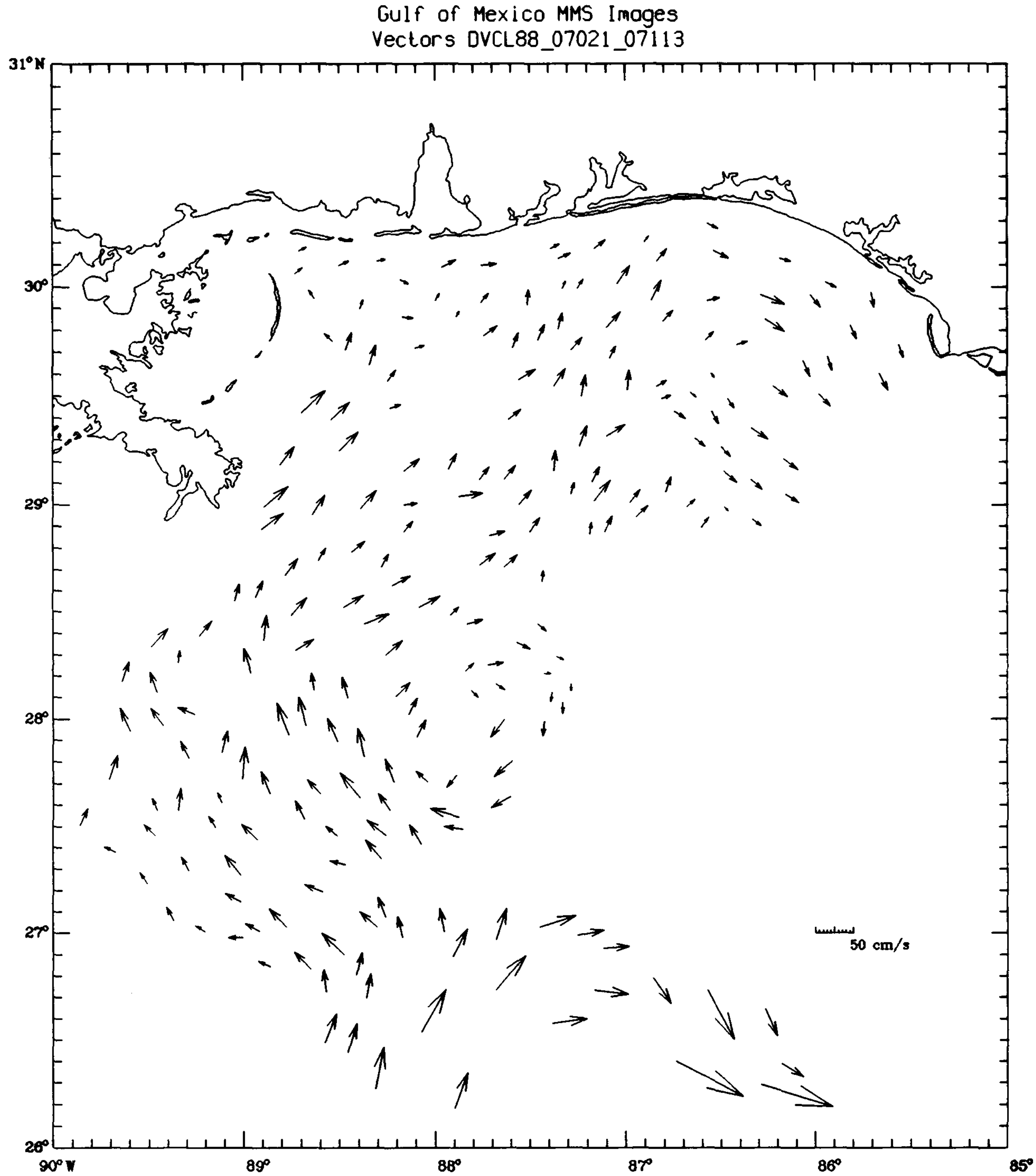


Figure 11-19. MAMES area surface flow pattern: 10-11 MAR, 1988.

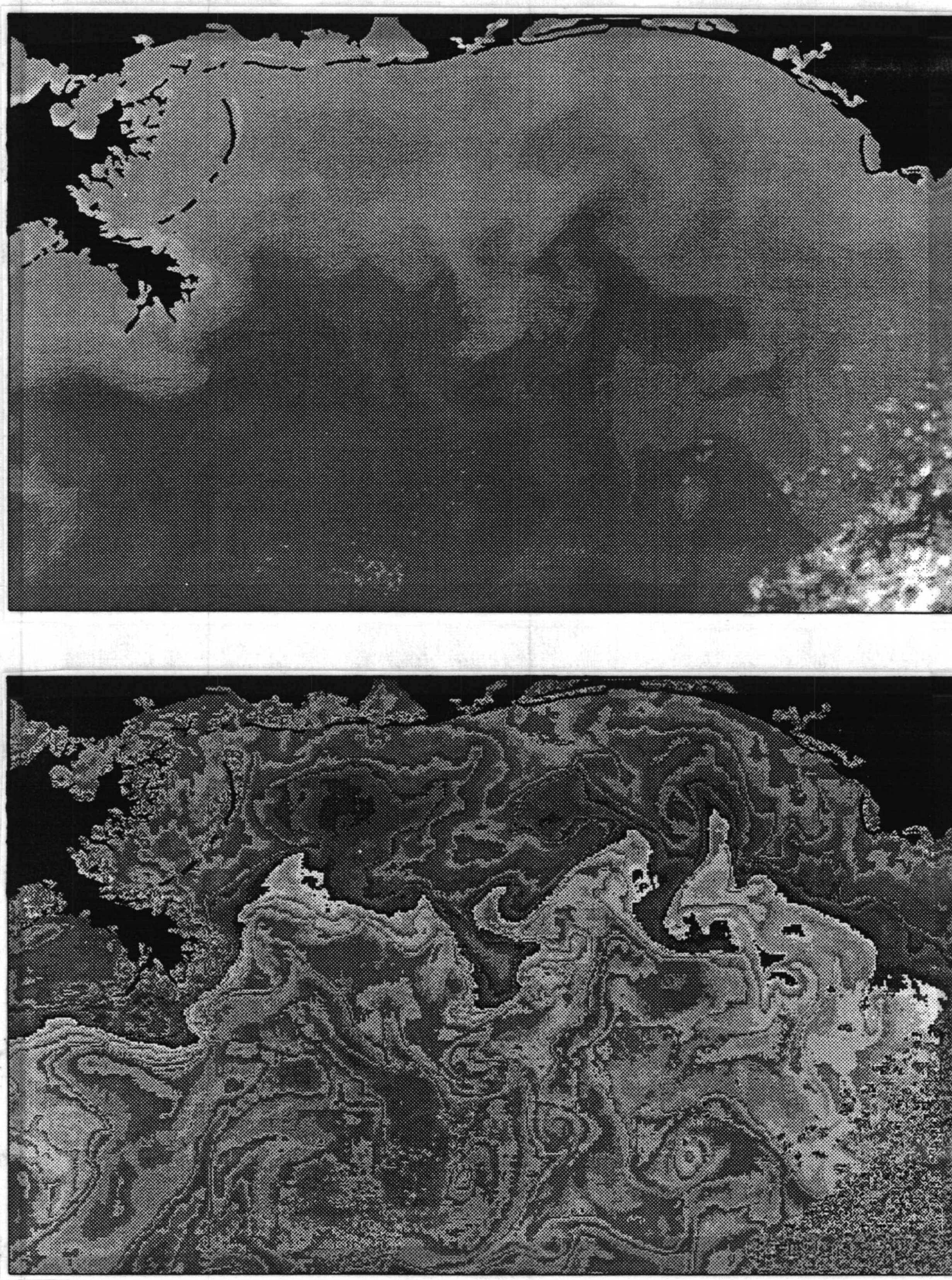


Figure 11-20. MAMES area AVHRR infrared image: 0941GMT Julian Day 074, 1988 (MAR 14).

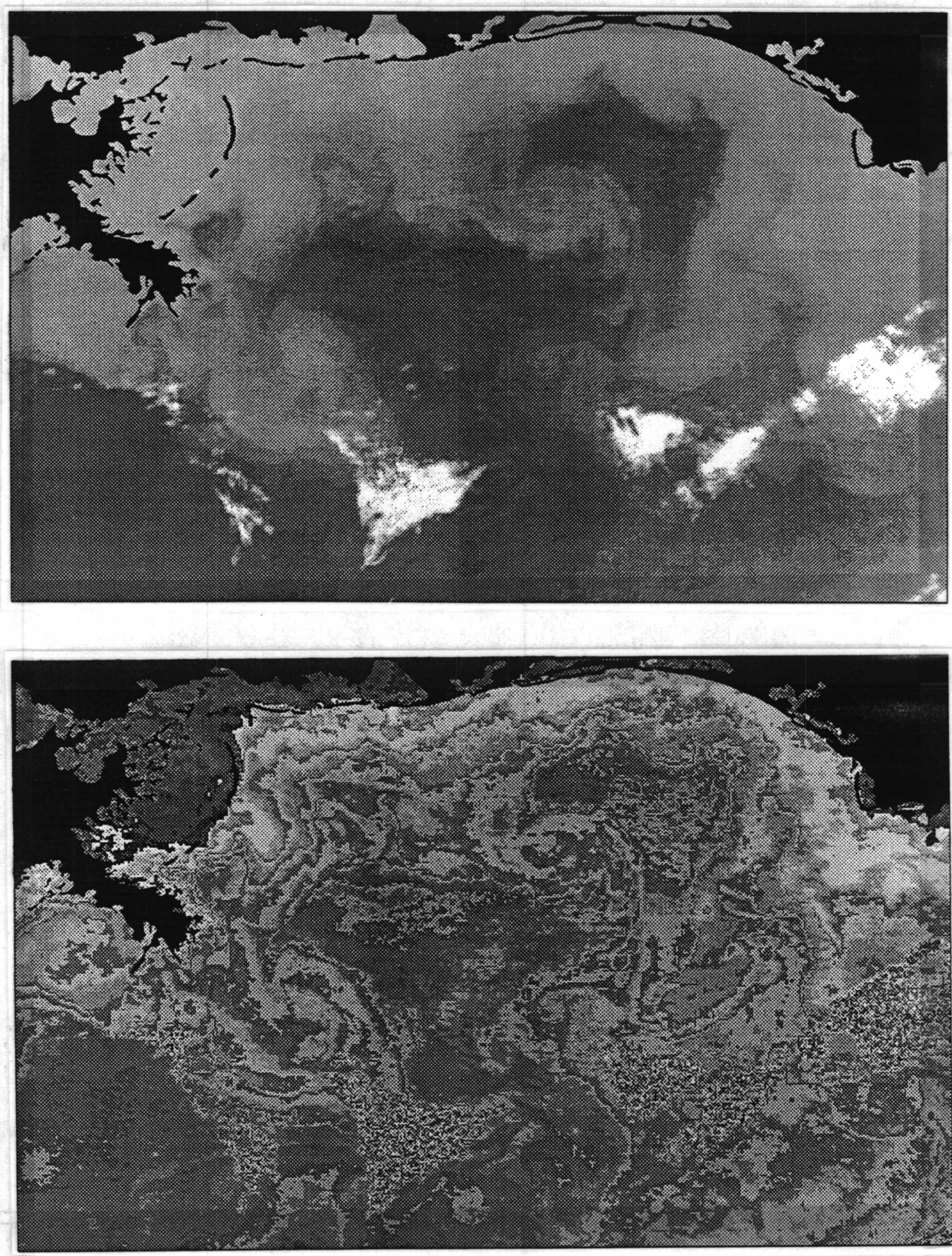


Figure 11-21. MAMES area AVHRR infrared image: 2144GMT Julian Day 310, 1988 (NOV 05).

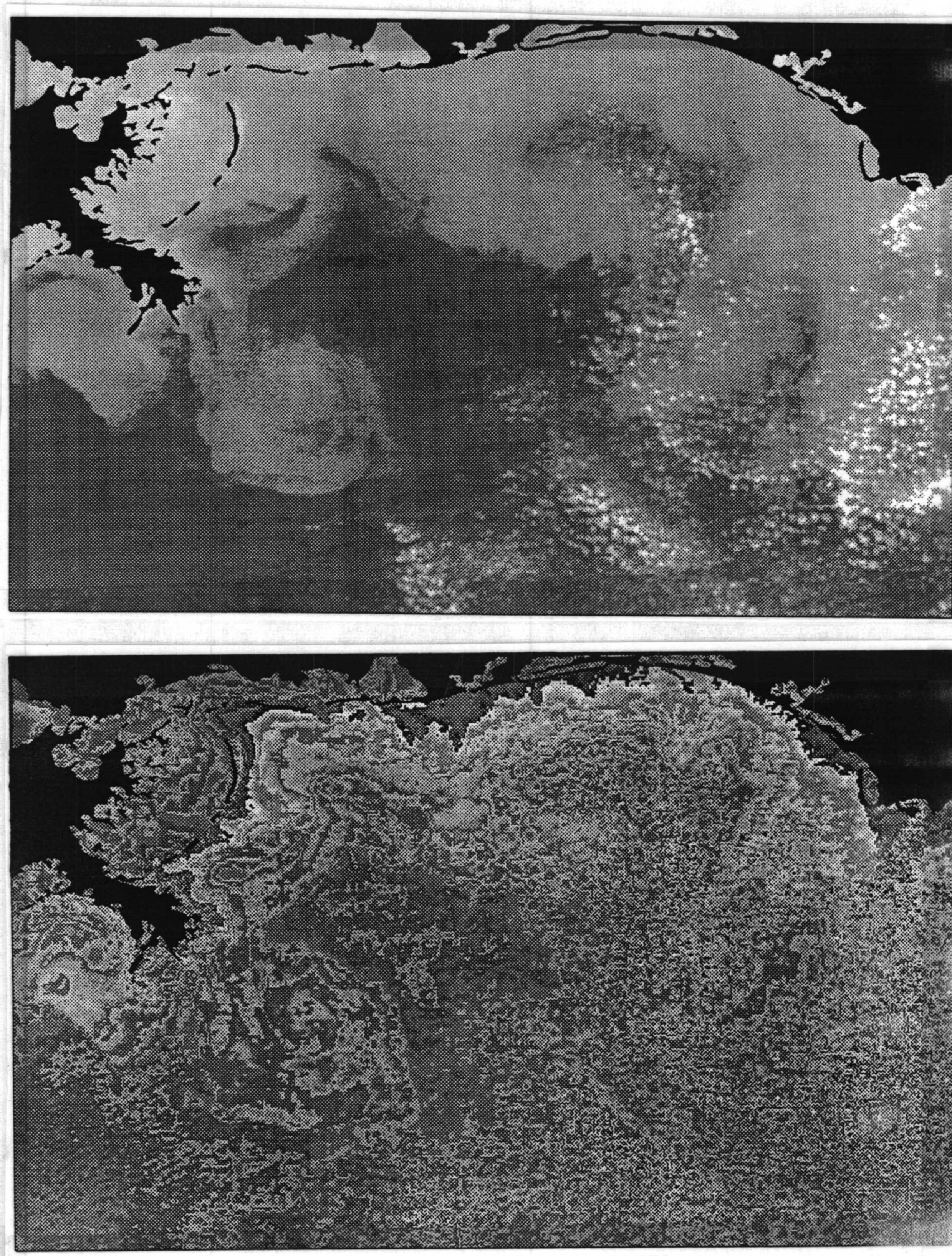


Figure 11-22. MAMES area AVHRR infrared image: 2133GMT Julian Day 311, 1988 (NOV 06).

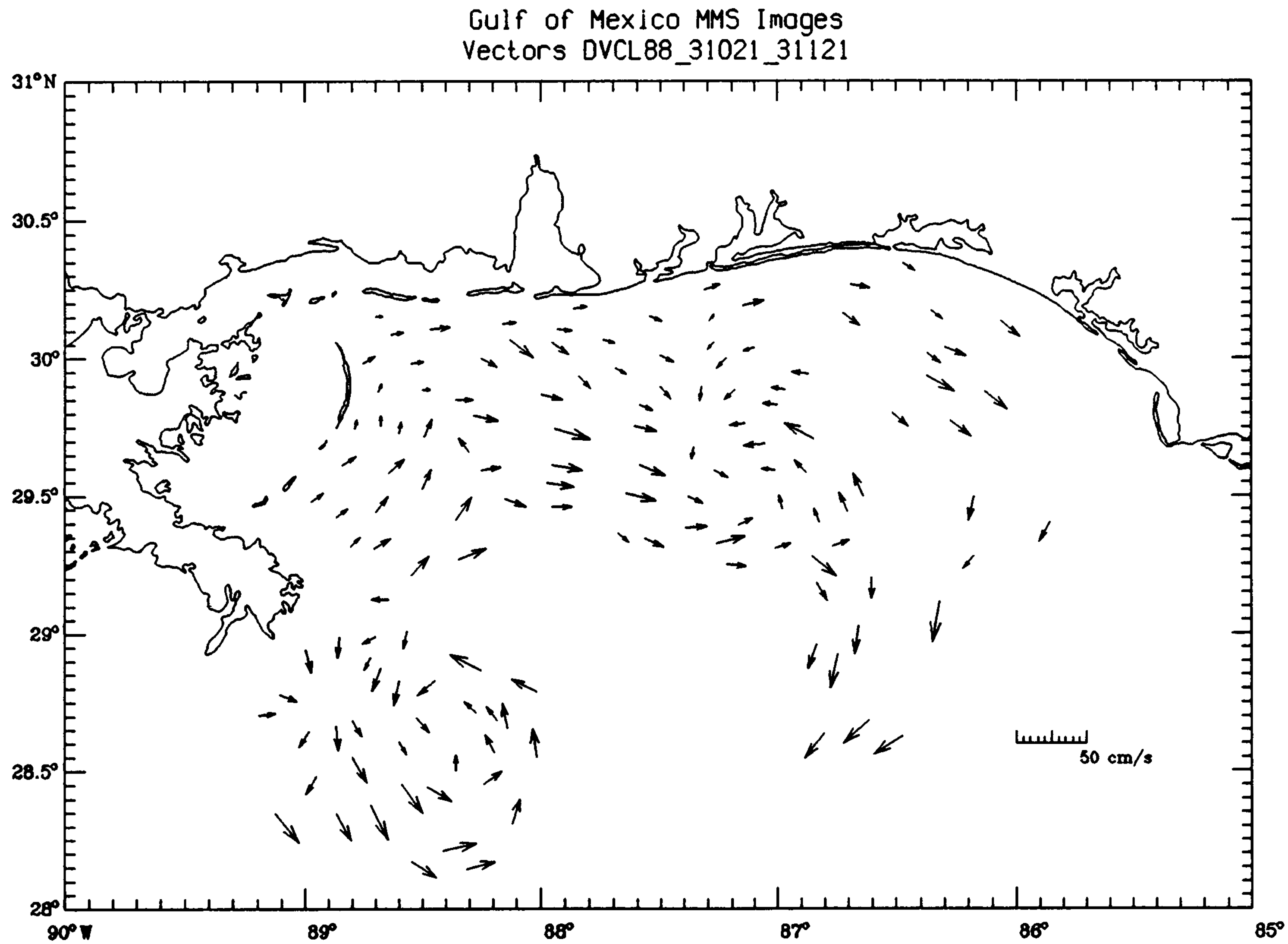


Figure 11-23. MAMES area surface flow pattern: 05-06 NOV, 1988.

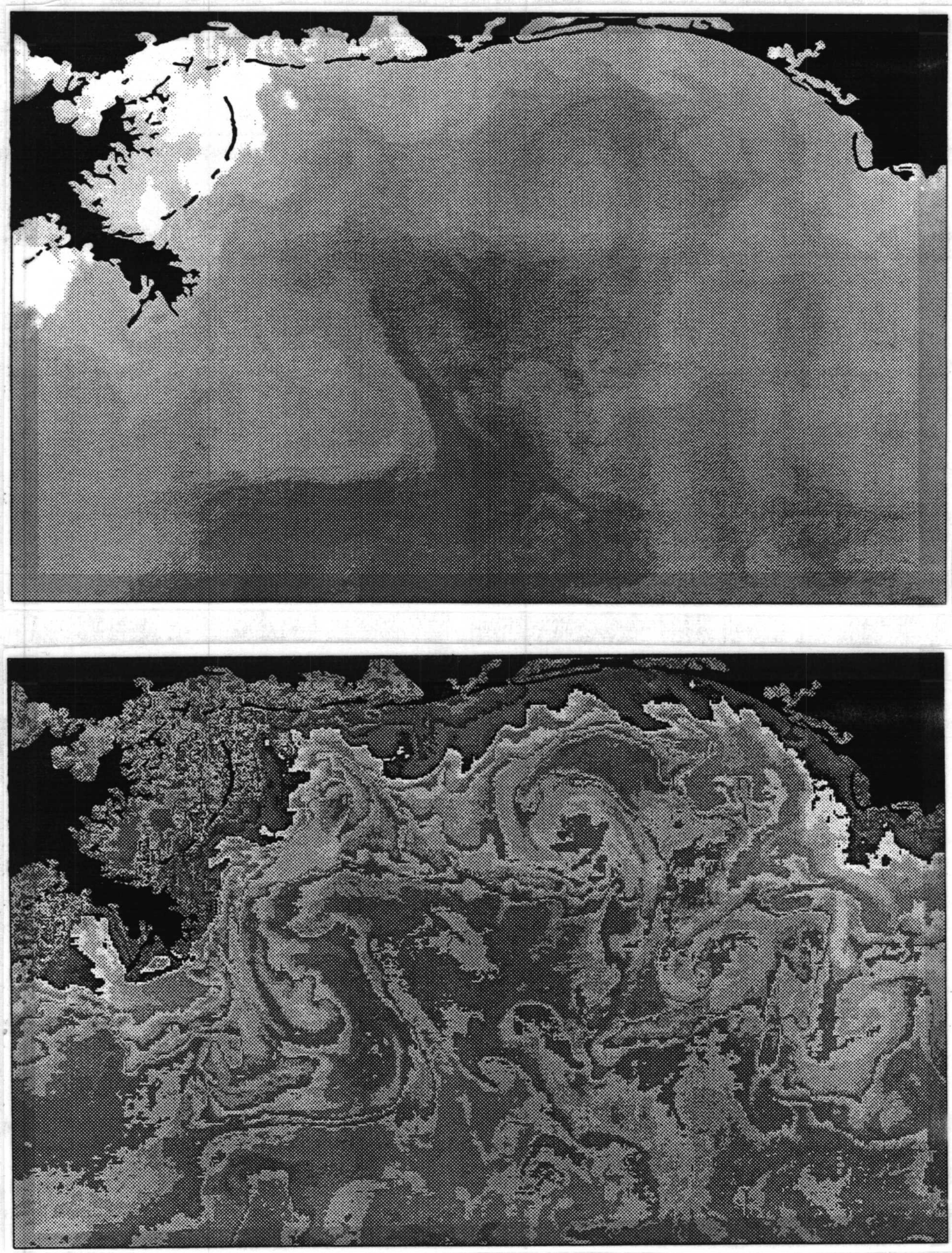


Figure 11-24. MAMES area AVHRR infrared image: 2121GMT Julian Day 312, 1988 (NOV 07).

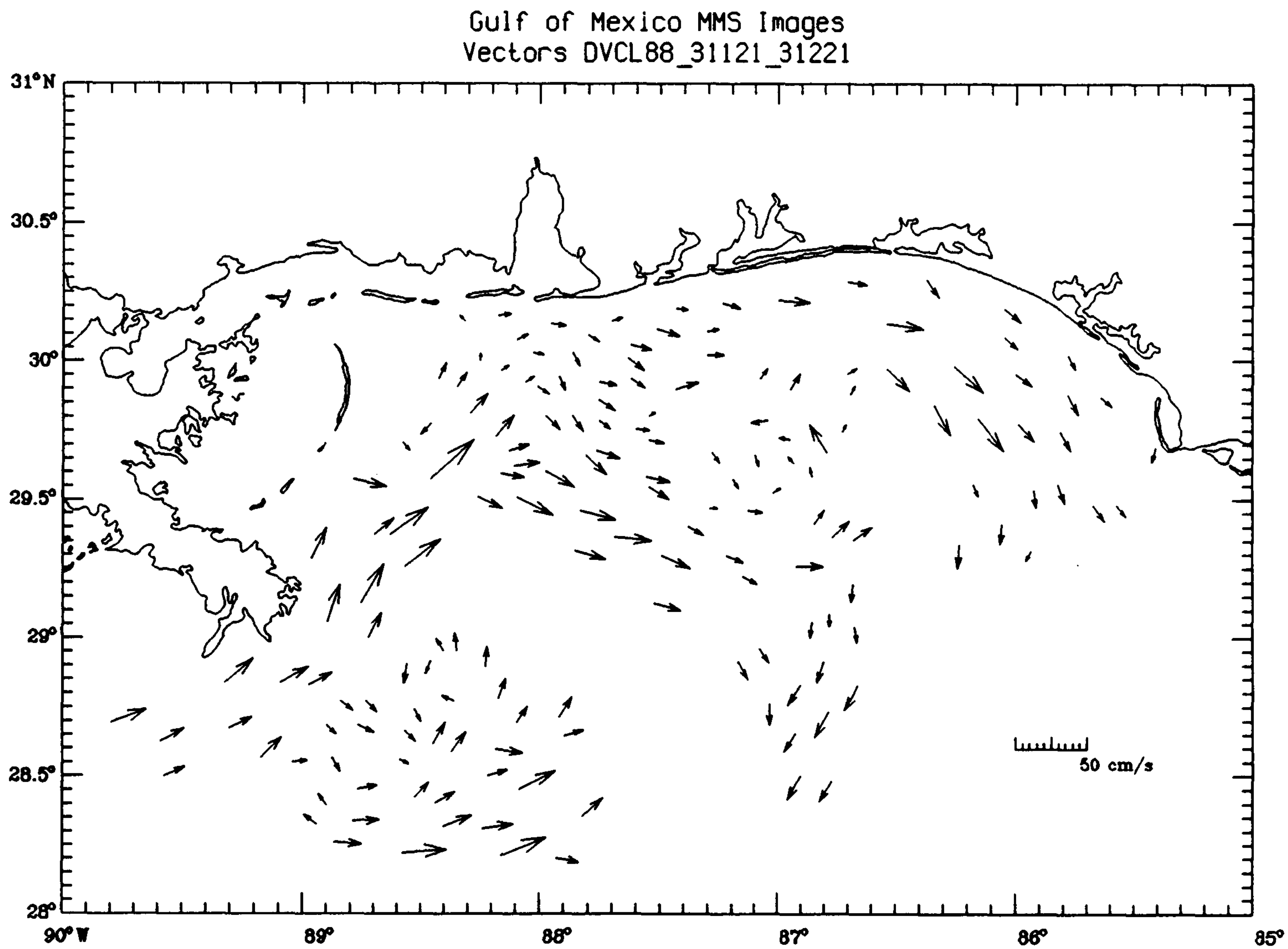


Figure 11-25. MAMES area surface flow pattern: 06-07 NOV, 1988.

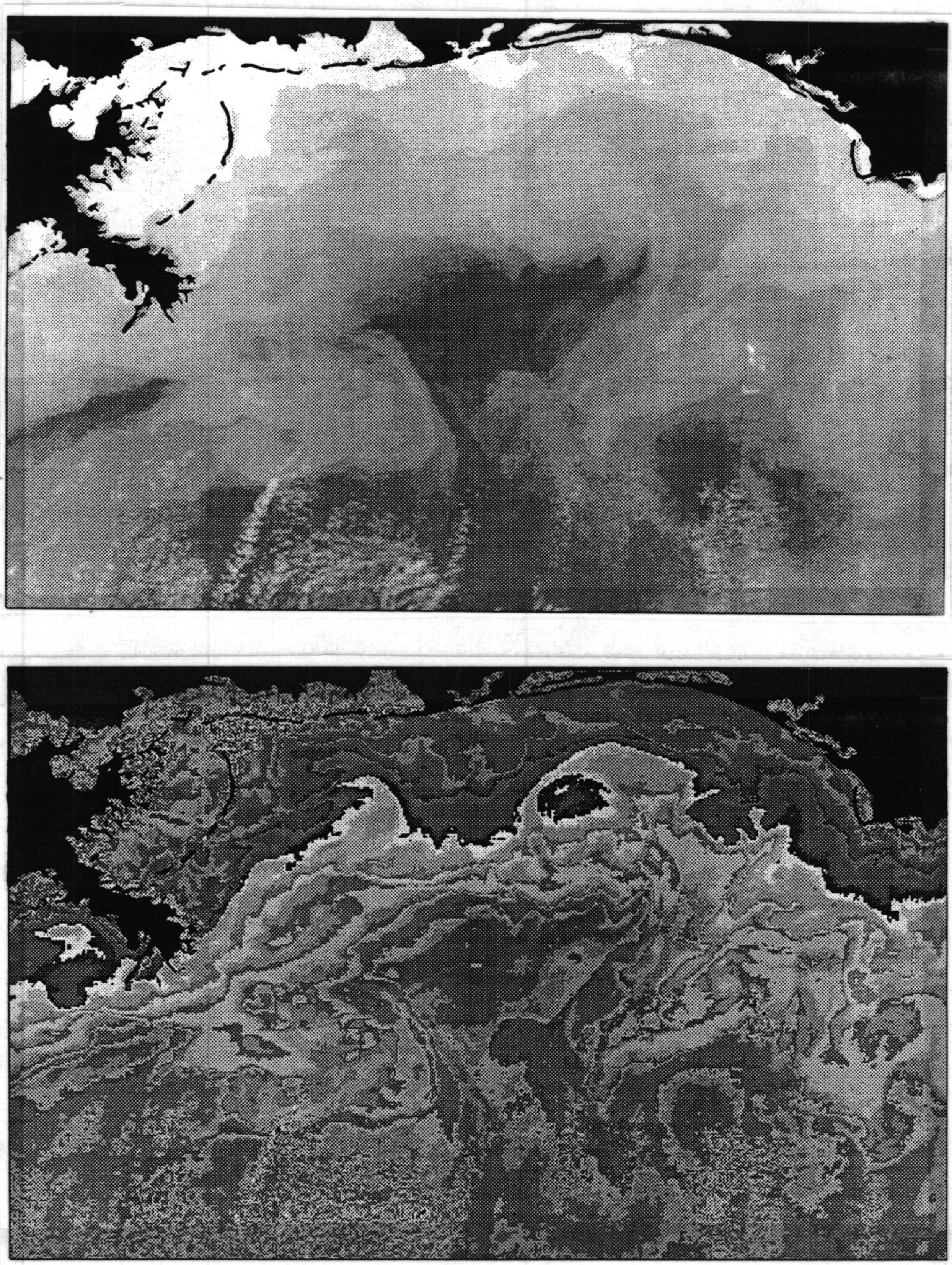


Figure 11-26. MAMES area AVHRR infrared image: 1859GMT Julian Day 313, 1988 (NOV 08).

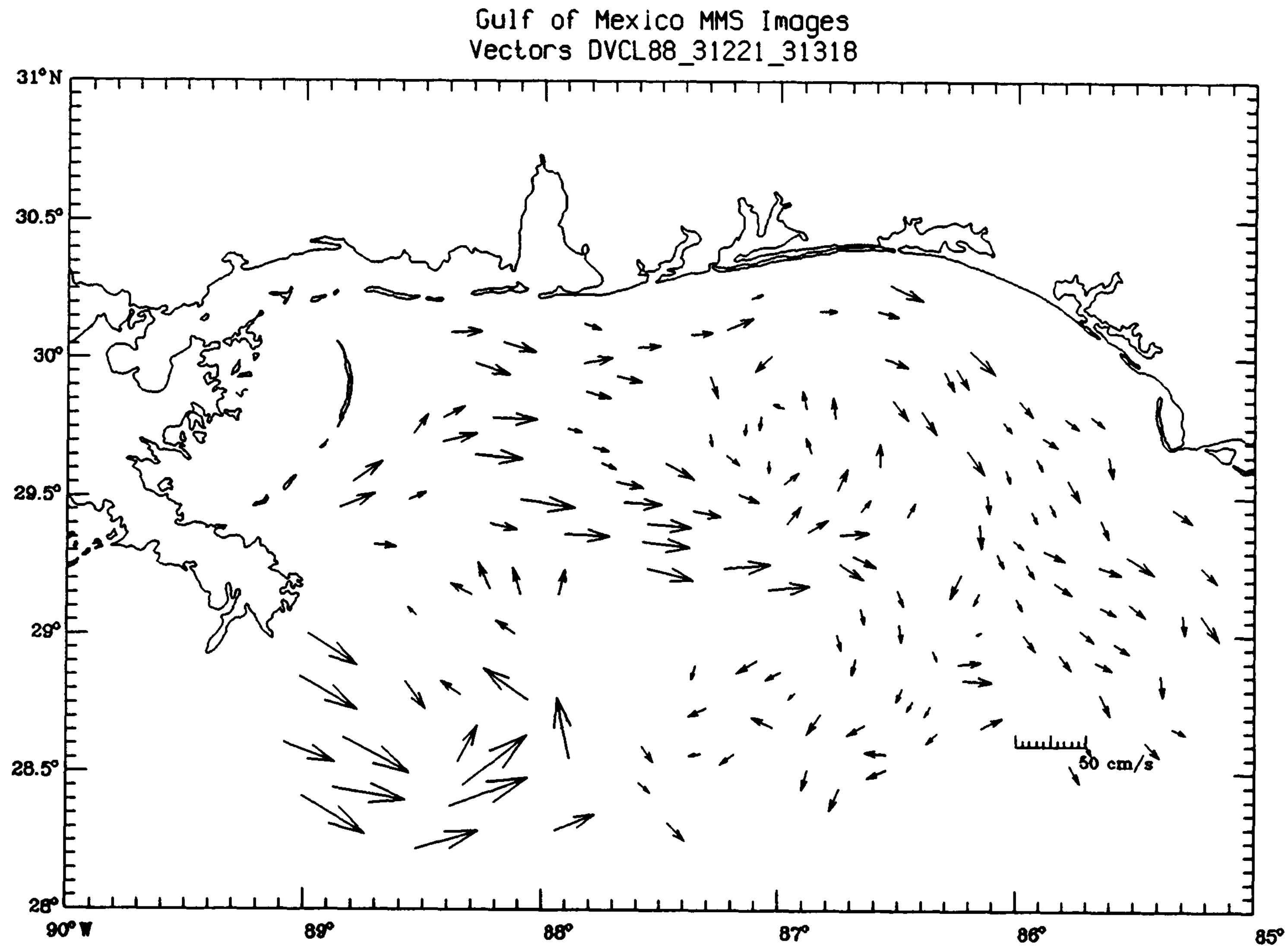


Figure 11-27. MAMES area surface flow pattern: 07-08 NOV, 1988.

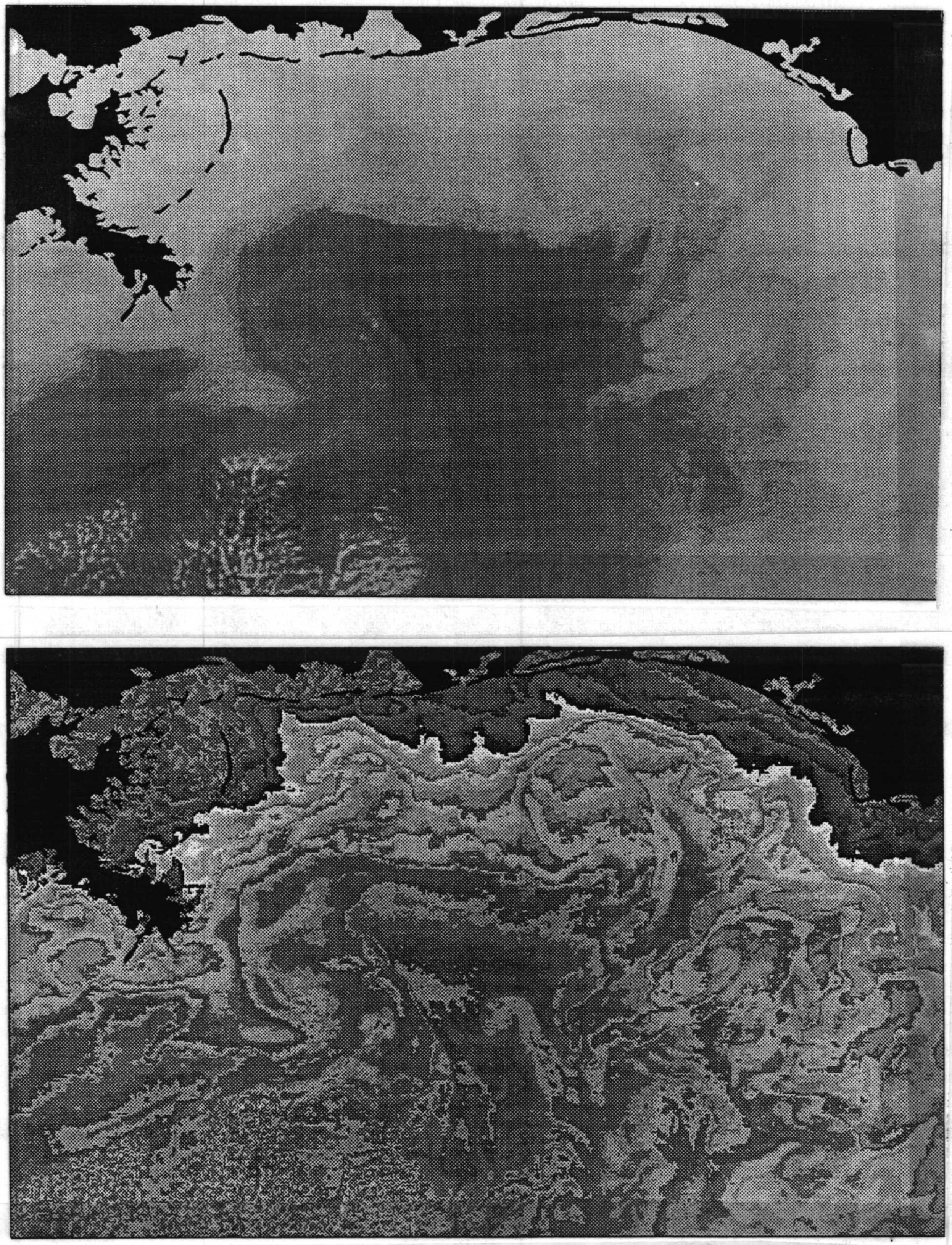


Figure 11-28. MAMES area AVHRR infrared image: 0114GMT Julian Day 314, 1988 (NOV 09).

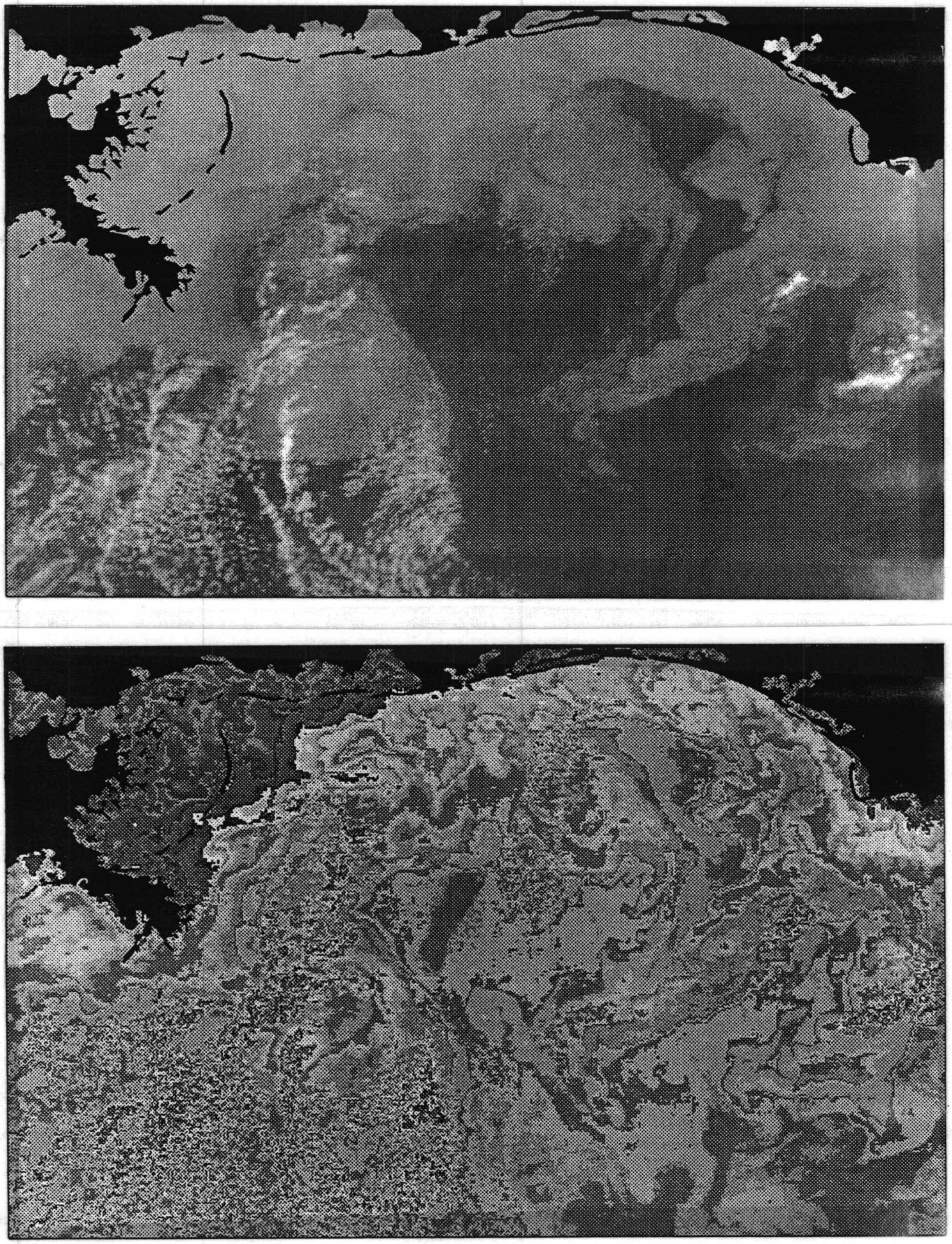


Figure 11-29. MAMES area AVHRR infrared image: 0052GMT Julian Day 315, 1988 (NOV 10).

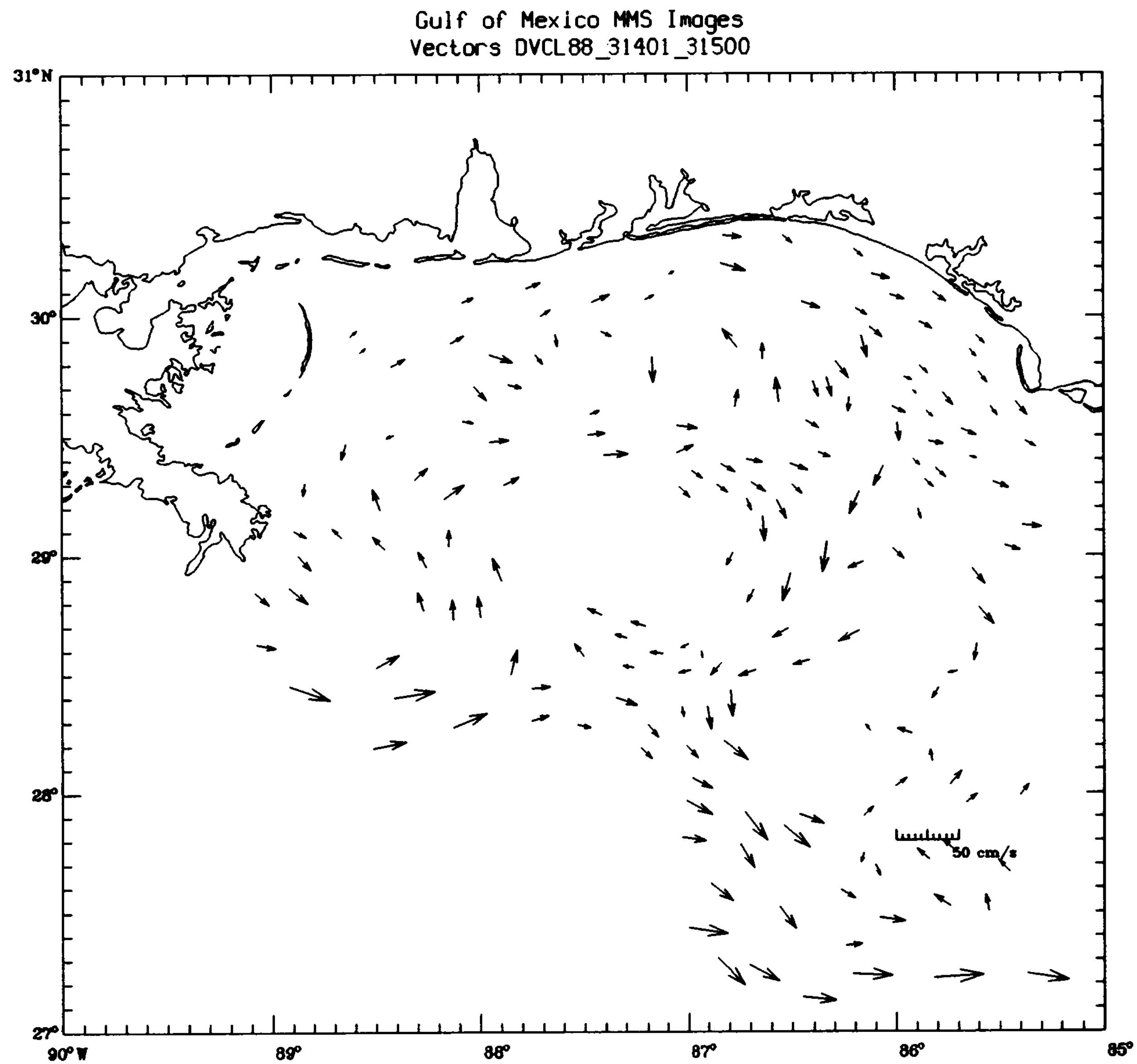


Figure 11-30. MAMES area surface flow pattern: 09-10 NOV, 1988.

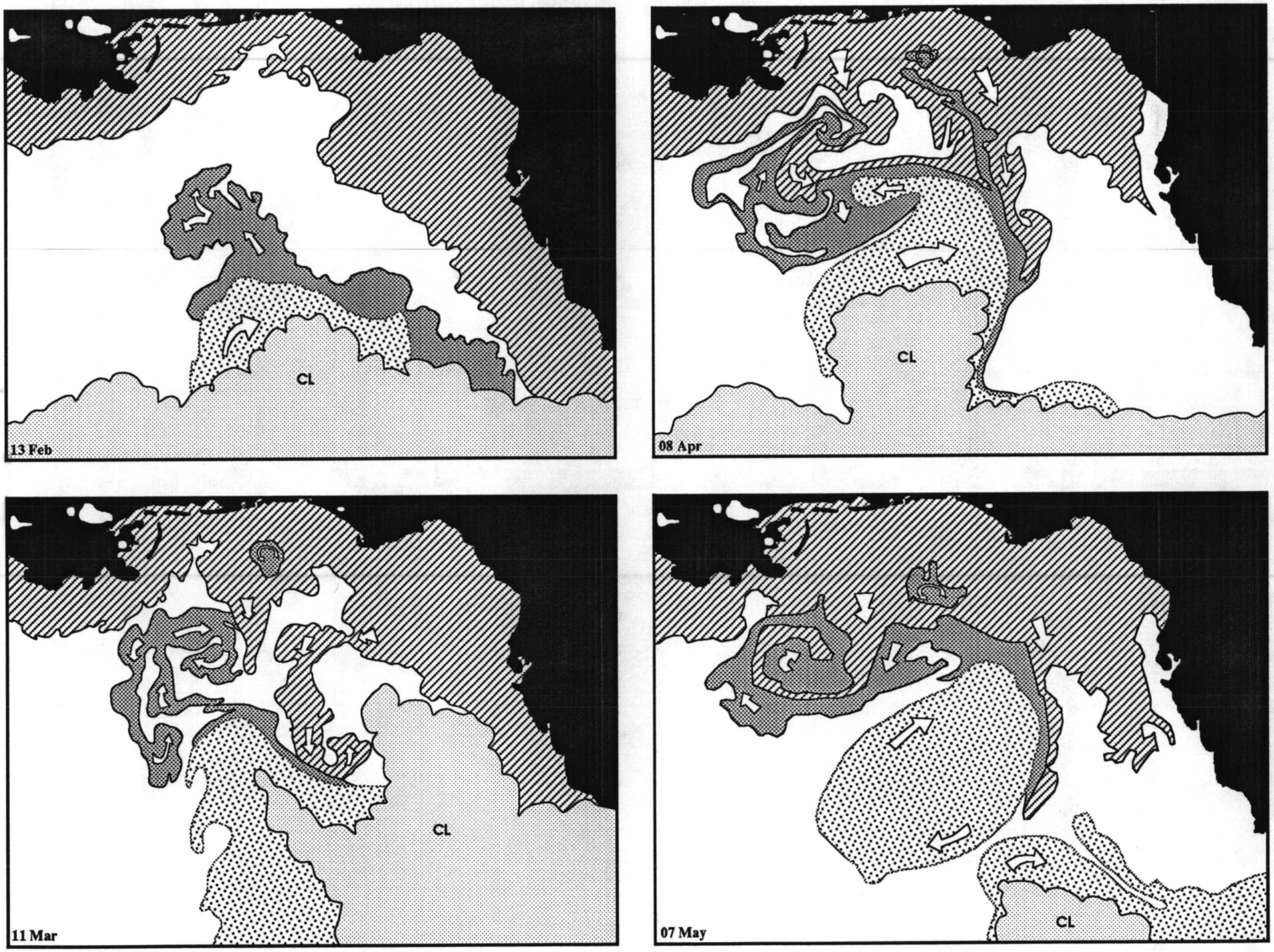


Figure 11-31. Schematic representations of a Loop Current Intrusion and associated offshore, shelf water plumes taken from satellite infrared imagery on 13 February, 11 March, 08 April, and 07 May 1988. Shelf waters are represented by coarse stripe shading, the intrusive waters by fine stripe, Loop Current and Loop Current eddy by course dot, and cloudy regions by fine dot shadings.

Loop Current intrusion with a weak surface temperature signal approached the Mississippi River delta from the south to within 150 km of South Pass.

The SST distributions for 05-10 November show two counterclockwise rotating cold eddies seaward of the shelf edge. On 05 November, the westernmost is adjacent to the Mississippi River delta and linked by cooler waters to the outflows from South Pass and Pass á Loutre. The eastern eddy lies on the axis of De Soto Canyon south of Pensacola Bay and, immediately to the east, a cold plume extends south-southwestward and seaward from the broad flow regime that passes and rounds Cape San Blas. Four SSF patterns for this sequence portray the isolation of the eddy off the Mississippi River delta from River outflows by strong flow rounding the Delta from the western Gulf on 07 November, import of waters from west of the Delta on 08 and 09 November, and a shear distortion of the eddy to the southeast on 10 November. The flow regime at the Delta on 07 November bifurcated into a northeast branch that passed along the coast to the east and an easterly branch along the shelf edge that turned southward to join the cold plume of Cape San Blas. The eastern eddy formed a stationary region of counter-clockwise flow between the branches of the western Gulf water intrusion.

The development of a counterclockwise rotating eddy infused with Mississippi River outflow off the Mississippi River delta appears to be an example of a *stagnant region south of the Delta* found during a drift bottle experiment and noted by Chew et al. (1962). The four schematics shown in Figure 11-31 were drawn from the satellite images on 13 February, 11 March, 8 April, and 7 May. The features and flow indications in the figure depict the approach of a Loop Current intrusion toward the MAMES area and the development of a clockwise eddy that remained immediately south of the Mississippi River Delta from mid- March to mid-May. During this interval, outflow from the passes, flow from the western Gulf and the Louisiana Bight, and shelf waters moving southward to the east of the Chandeleur Islands were alternatively mixed into the eddy feature. The northward extension of the Loop Current and the Loop Current eddy were associated with a persistent shelf water plume that moved seaward along their eastern sides throughout the sequence. This type of eddy is also an example of the stagnation point discussed by Chew et al. (1962). In addition, the western paths that were taken by drift bottles released near the Delta could reasonably use either type of eddy to attain westerly paths by seaward advection and turbulent diffusion.

11.3.6 25-26 December (Figures 11-32 to 11-34)

An occluded front passed seaward over the MAMES area on 25 December and established 2 to 5 m/sec northeast winds that shifted to east winds on 26 December. The effects of these winds were accompanied by the penetration of a Loop Current intrusion that entered the MAMES area from the southeast, along the Florida continental slope, past Cape San Blas.

The SST images for 25-26 December indicate that the Loop Current intrusion followed the eastern edge of De Soto Canyon northward. A cold water plume extended southward from Mobile Bay and appeared to have been generated by wind regimes associated with the frontal passage. A major shelf-to-slope exchange extended southward toward the Loop Current. The SSF distribution shows that a southerly current flowed along the seaward side of the Chandeleur Islands toward the Mississippi River delta and turned to the southeast to join the exchange region. This sequence demonstrates an instance in which east-to-west flow dominated the MAMES area coastline from the longitude of Choctawachee Bay to that of Mississippi Sound. This nearshore portion of the pattern was anticipated in the report of Tolbert and Salsman's drift bottle studies (1964).

11.4 Trajectory Analysis

The four SSF patterns for the 05-10 November sequence provide an opportunity to examine the paths of water parcels distributed over the MAMES area. A spline interpolation in space and time was used to generate flow velocities within the region. A fourth-order Runge-Kutta integration scheme utilized the velocity information to conduct trajectory computations for surface water parcels over the MAMES area. The results presented in Figure 11-35 portray the convergence of parcels into the eddy off the Mississippi River delta and the eddy over De Soto Canyon. The sensitivity of a parcel's entrainment in regard to its initial position is evident at the northeastern side of the Mississippi River delta eddy where a difference less than twenty-five kilometers permitted movement away from the eddy and

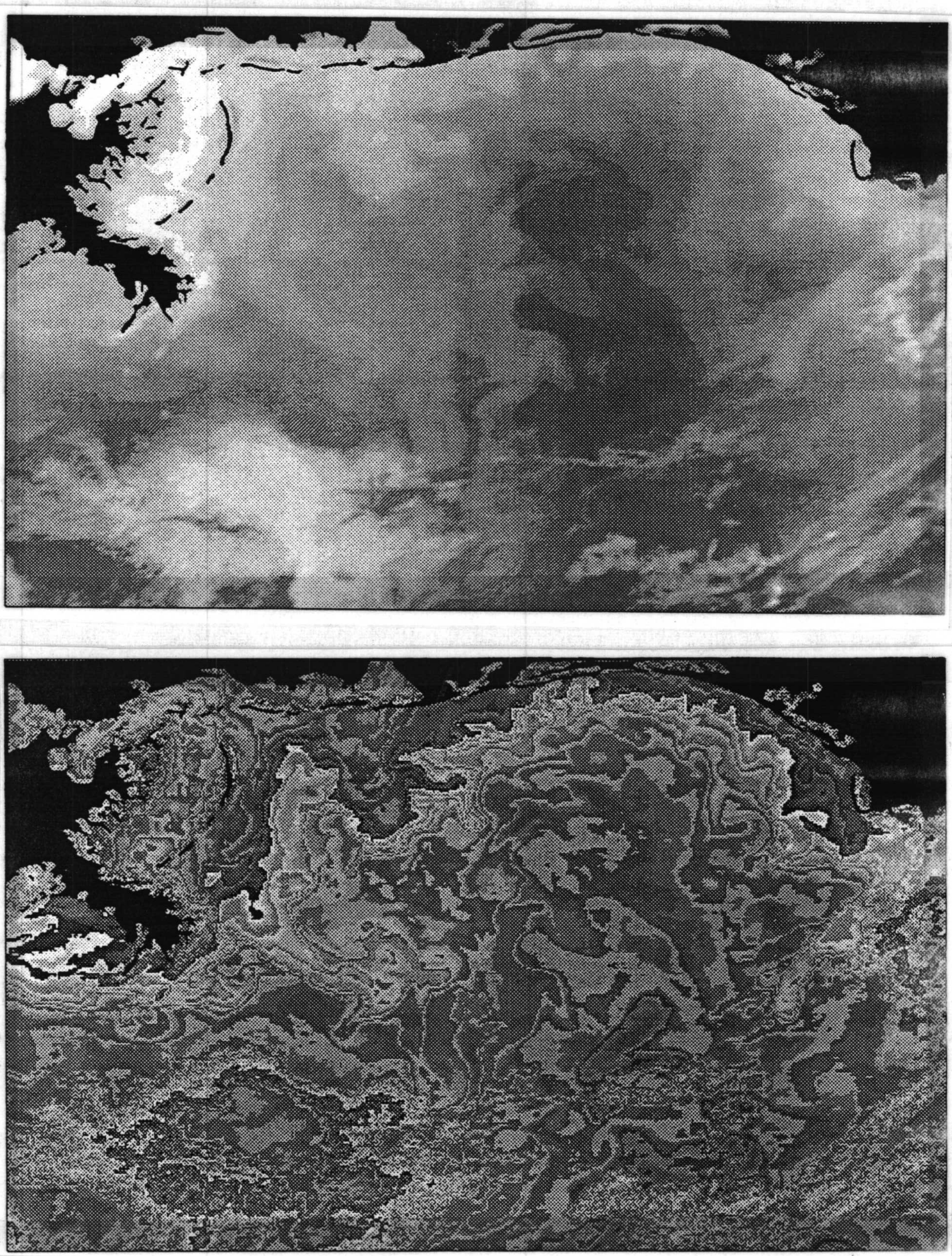


Figure 11-32. MAMES area AVHRR infrared image: 1934GMT Julian Day 360, 1988 (DEC 25).

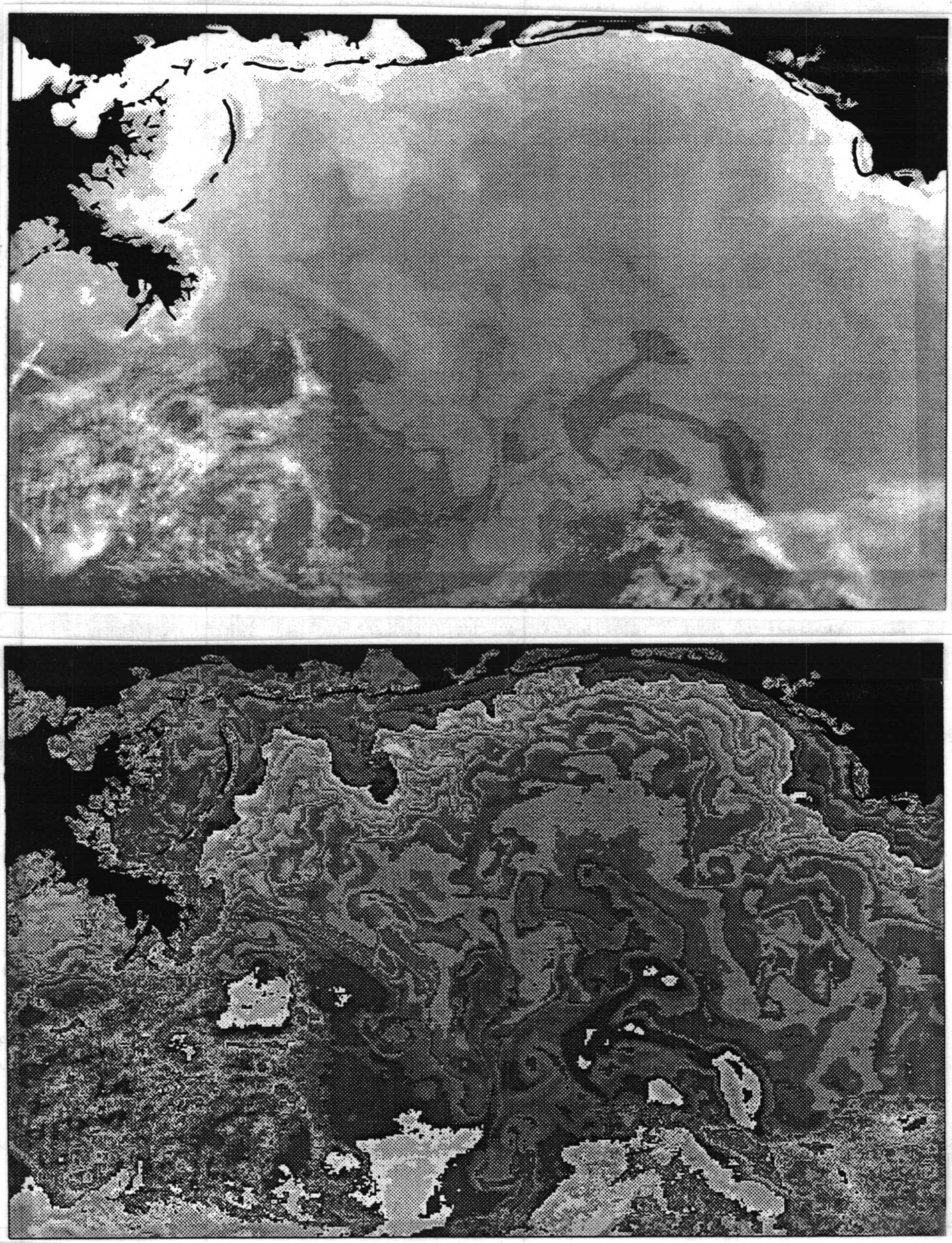


Figure 11-33. MAMES area AVHRR infrared image: 1924GMT Julian Day 361, 1988 (DEC 26).

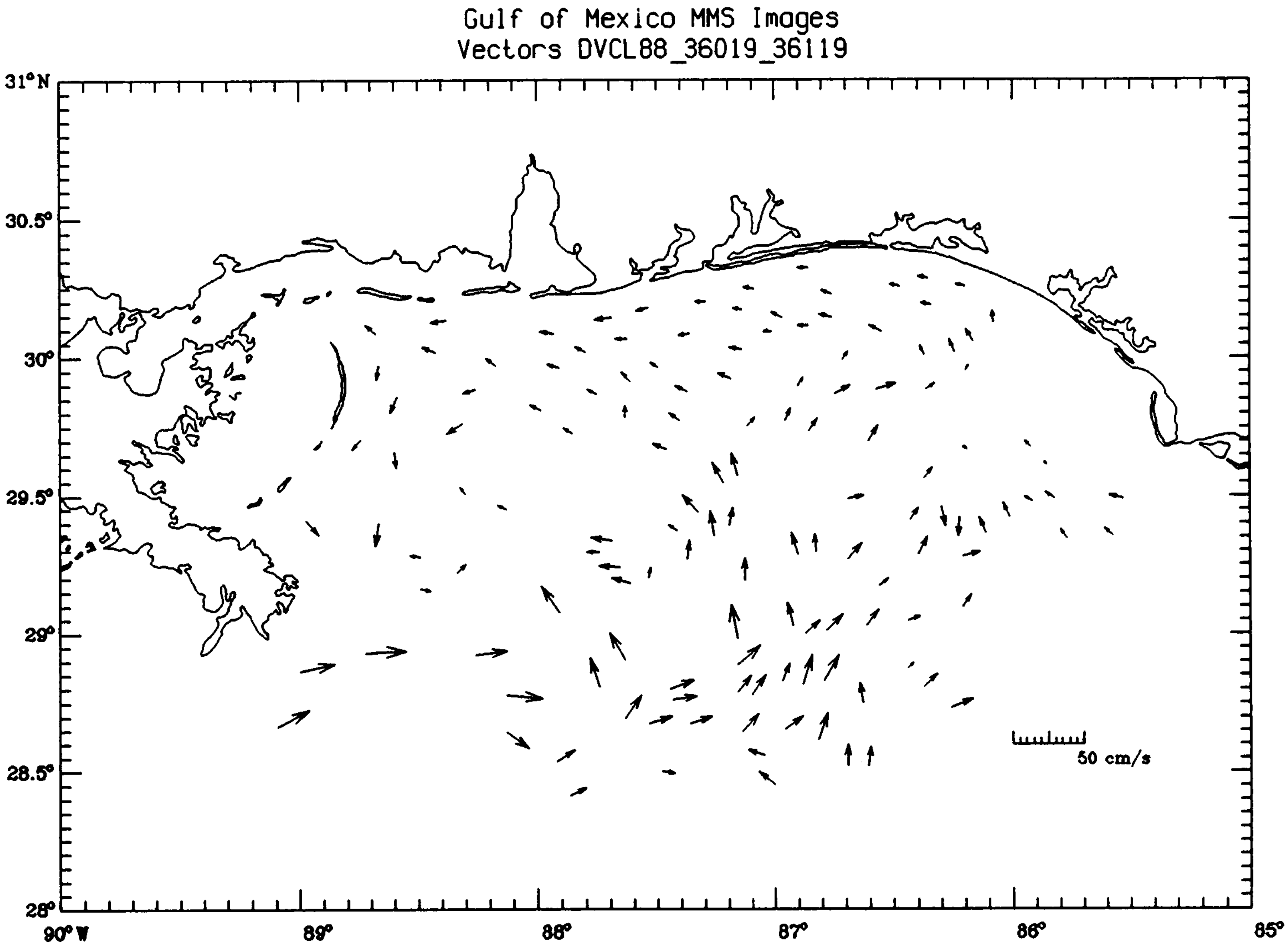


Figure 11-34. MAMES area surface flow pattern: 25-26 DEC, 1988.

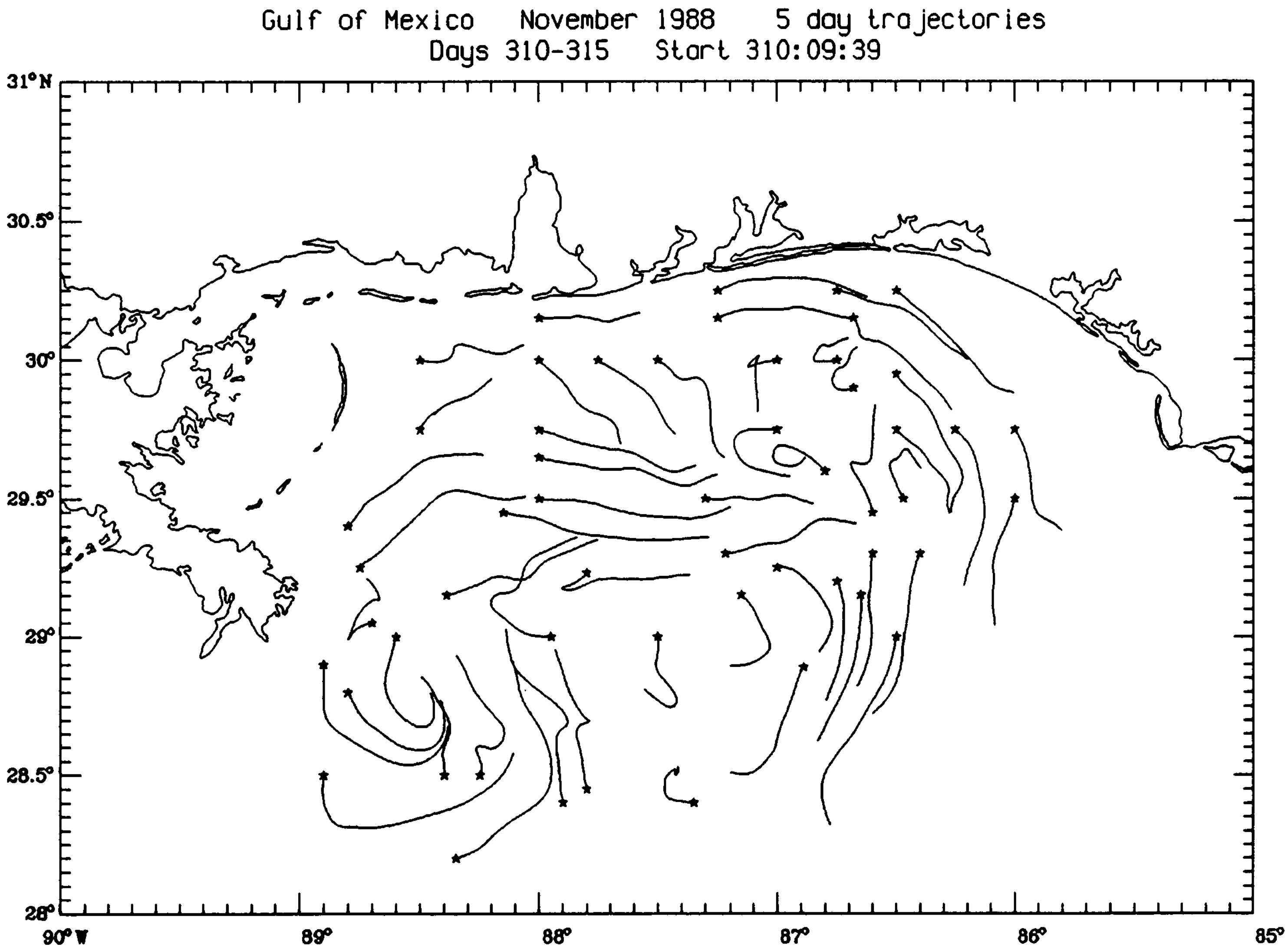


Figure 11-35. Five day MAMES area flow trajectories computed with SSF distributions for 5-6, 6-7, 7-8, and 9-10 November 1988.

northwestward towards the shelf. A similar measure of entrainment is present in the southeastern quadrant of the De Soto Canyon eddy. The parcel paths outline the eastward flow along the shelf-break and the seaward flow off the shelf in the cold water plume. The trajectory analysis demonstrates a potential for concentration and retention of chemical and biological constituents within these eddies. These computations give an initial, realistic assessment of several distribution mechanisms and their potential for impact on the surface layer of the MAMES area.

11.5 Conclusions and Summary

NOAA Satellite AVHRR infrared (channel four, 11 micrometer) surveillance of the eastern Gulf of Mexico began in October 1987 and continued to May 1989 with a suspension due to near-isothermal sea surface temperature conditions from May 1988 to October 1989. The image archive provides sea surface temperature distributions that show a sequence of episodic intrusions of Loop Current related waters. Sequential images taken a day apart during the Spring and Fall of 1988 have been analyzed for sea surface flow distributions over the northwestern Gulf of Mexico. The cases include the intervals of January 11-12, January 28-29, February 12-14, March 10-14, November 05-10, and December 25-26. Sea surface flow patterns extracted from image pairs indicate that the study area consistently contains mesoscale and submesoscale fronts, plumes and eddies. The analyses resolve cross-shelf motion, shelf and slope water exchanges, flow along the shelf-break, and eddies off the Mississippi River Delta and over the head of De Soto Canyon. Trajectories calculated with a sequence of four flow distributions over a five day interval in November 1988 show a pattern of convergence into a cyclonic eddy southwest of the Delta and an exchange of shelf to oceanic waters off Cape San Blas, Florida.

12.0 GEOLOGICAL CHARACTERIZATION

W. W. Sager, W. W. Schroeder, J. S. Laswell, and R. Rezak

12.1 Introduction

Geological characterization within the study area was achieved mainly using geophysical instruments: a 100 kHz side-scan sonar and a 3.5 or 4.0 kHz subbottom profiler. The geophysical data were collected along ship tracks mainly parallel to the shelf break trend (Figure 3-1) and spaced at intervals allowing complete coverage with the side-scan sonar. In all, 1520 nm (2817 km) of trackline data were collected. Most of these data (1501 nm; 2777 km) were collected in a reconnaissance mode with a sonar swath-width of 600-800 m and the remainder (19 nm; 35 km) were detailed surveys designed for a closer examination of interesting features (Figure 3-2). These data were used to produce maps of three types of information: bathymetry, side-scan sonar image mosaics, and reflection character, which are presented in an atlas format (Laswell et al. 1990). A limited amount of ground truthing was accomplished during several ROV (remotely-operated vehicle) cruises using Smith-MacIntyre grab samples, dredge samples, and underwater video photography.

12.2 Methods

12.2.1 Bathymetry

Bathymetry data were determined from the subbottom seismic profiler records, which were obtained using either an EDO-Western 4.0 kHz or Raytheon CESP 3.5 kHz echo-sounder with a 10 kilowatt booster amplifier. The seismic profiles were recorded on an analog electrostatic plotter, 20 inches in width. Event marks were printed at shotpoint locations for correlation and interpolation of the data with the navigation. Bathymetry values were determined by digitizing the distance on the records between the outgoing acoustic pulse and the echo from the seafloor and converting this distance to two-way travel time. After correcting for the depth of the transducer, the two-way travel time was converted to depth by integrating a function of sonic velocity versus depth derived from temperature and salinity soundings (Chen and Millero 1977). The temperature and salinity versus depth measurements were made near the study area (Mooring Station C; 29° 23.9'N, 87° 20.7'W) during March and August 1988 (Appendix C in Brooks et al. 1990b). Figure 12-1 shows a flow chart of the bathymetry data processing.

In general, the error limits on a given bathymetric sounding are different in the horizontal and vertical directions. The digitizer used to measure the seismic records has an accuracy of about 0.01 inches. This corresponds to an accuracy of 2.5 m in distance (for a vessel speed of 8 knots, less for slower speeds) and 0.1 m in depth. Consequently, the horizontal positions of the bathymetry points appear to be limited in accuracy by the navigation system, which yields a horizontal standard deviation of 5-8 m. Considering the accuracy of the navigation system, no correction was made for the 9 m horizontal distance between the navigation antenna and the subbottom profiler towfish.

Though relative changes in depth are measurable with a precision of about 0.1 m, the absolute accuracy of the depth values are limited by several factors: transducer depth variations caused by changes in vessel speed, tides, wave action, and changes in the acoustic velocity profile versus depth. Estimates of the maximum ranges of the first three factors were relatively simple to make and are 0.4 m, 0.8 m, and 0.5 m, respectively. The effect of temperature and salinity changes is more difficult to quantify because no measurements of these quantities versus depth were made during the course of the geophysical surveys. However, the maximum changes in temperature and salinity recorded at a mooring within the main survey area during the geophysical surveys were 3.8° C and 7.6 $^{0}/oo$ (Appendix C in Brooks et al. 1990b). Such changes would cause 0.8% and 0.6% shifts, respectively, in the acoustic wave velocity (Chen and Millero 1977) and produce the same error in both the two-way travel time and depth. At 100 m depth, these errors would be 0.8 m and 0.6 m. Assuming that all of the errors mentioned above represent 95% confidence intervals and that they are uncorrelated, the standard deviation of a depth near 100 m is approximately 0.7 m.

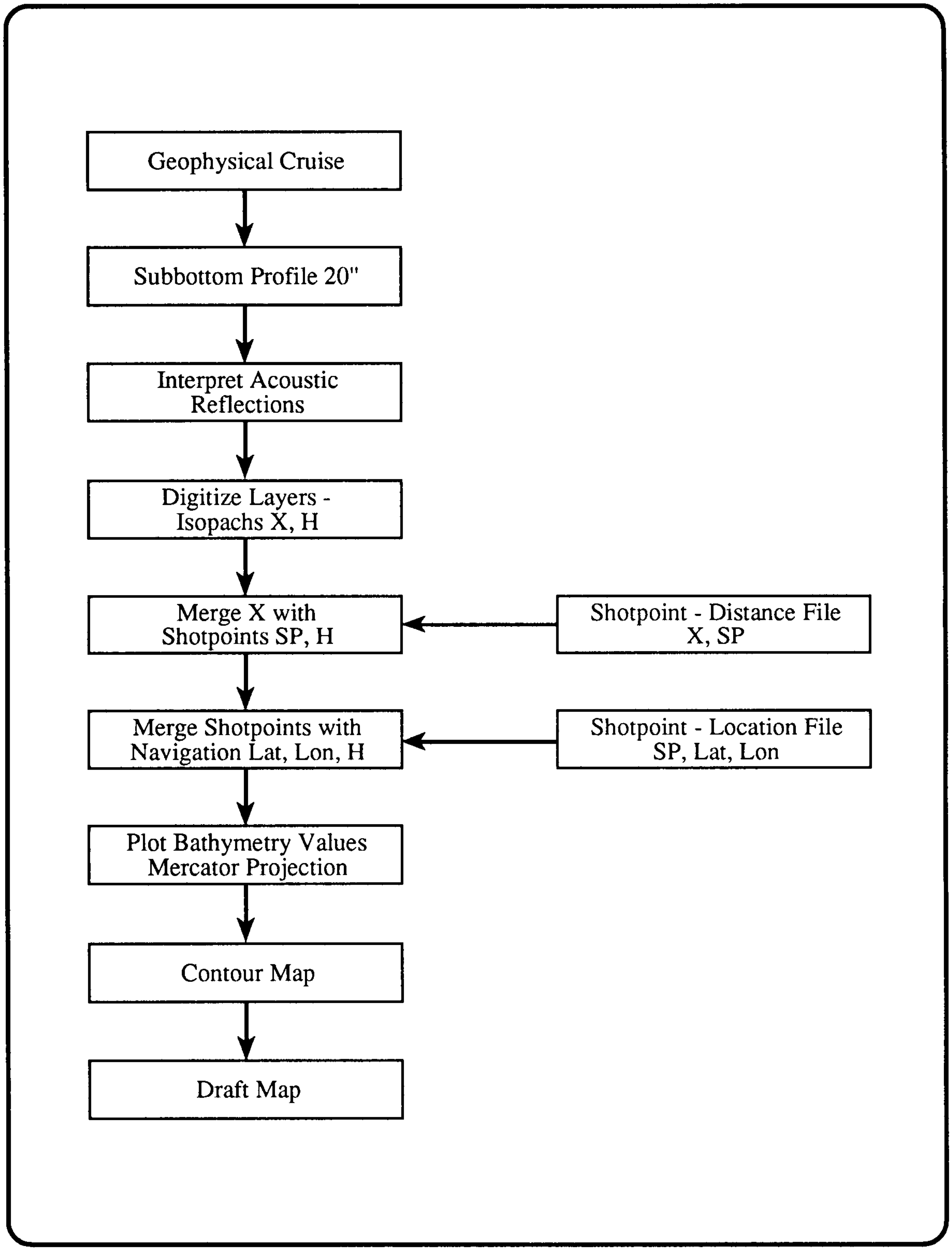


Figure 12-1. Flow chart showing the steps used in processing bathymetry data.

12.2.2 Side-Scan Sonar

Side-scan sonar data were collected and recorded in both analog and digital forms using an EG&G model 260 system operating at frequency of 100 kHz. Acoustic "images", in which dark areas have high reflectivity and light areas have low reflectivity, were made with a 10-inch electrostatic plotter. These records were processed to correct for vessel speed, remove the water column, and correct for slant-range distortions. The end result was an image that is analogous to an "aerial photograph" illuminated from the ship track.

The side-scan images were studied in two ways: small scale and large scale. On a small scale, the records were studied individually for details about seafloor features and characteristics. On the large scale, information from the individual records was combined to show regional variations. Because the original side-scan data was at a scale in which 8 inches equalled from 100 to 400 m (approximately 1:984 to 1:3940), the problem was to reduce the records in such a way as to preserve as much of the detail as possible. The solution was to break the data into blocks approximately 5 nm (9.3 km) on a side (scales ranging from 1:19,200 to 1:28,570) and print these in an atlas of geophysical data (Laswell et al. 1990).

The geophysical data atlas contains side-scan sonar data in several formats: mosaics, interpretation maps, and detailed survey images. The mosaics contain the records from many lines laid out in their proper geographic positions; in all 21 mosaics were constructed (Figure 3-2). Overlaid on these images are map coordinates, scales, and bathymetric contours. The interpretation maps abstract the information about feature locations and variations in seafloor reflectivity. Each interpretation map corresponds to a mosaic and is printed at the same scale. Finally, the detailed survey images are mosaics of much smaller areas, usually containing records of 2-3 adjacent lines, encompassing features imaged with smaller side-scan swath widths during the detailed surveys (Figure 3-2).

The mosaics were constructed in the following manner (Figure 12-2). The original side-scan records were photographed with a continuous-flow camera onto microfilm, a reduction of 75%. A base map of shotpoints was plotted at the appropriate scale and a mylar sheet with registration marks was placed on top of it. All base maps were plotted using a standard

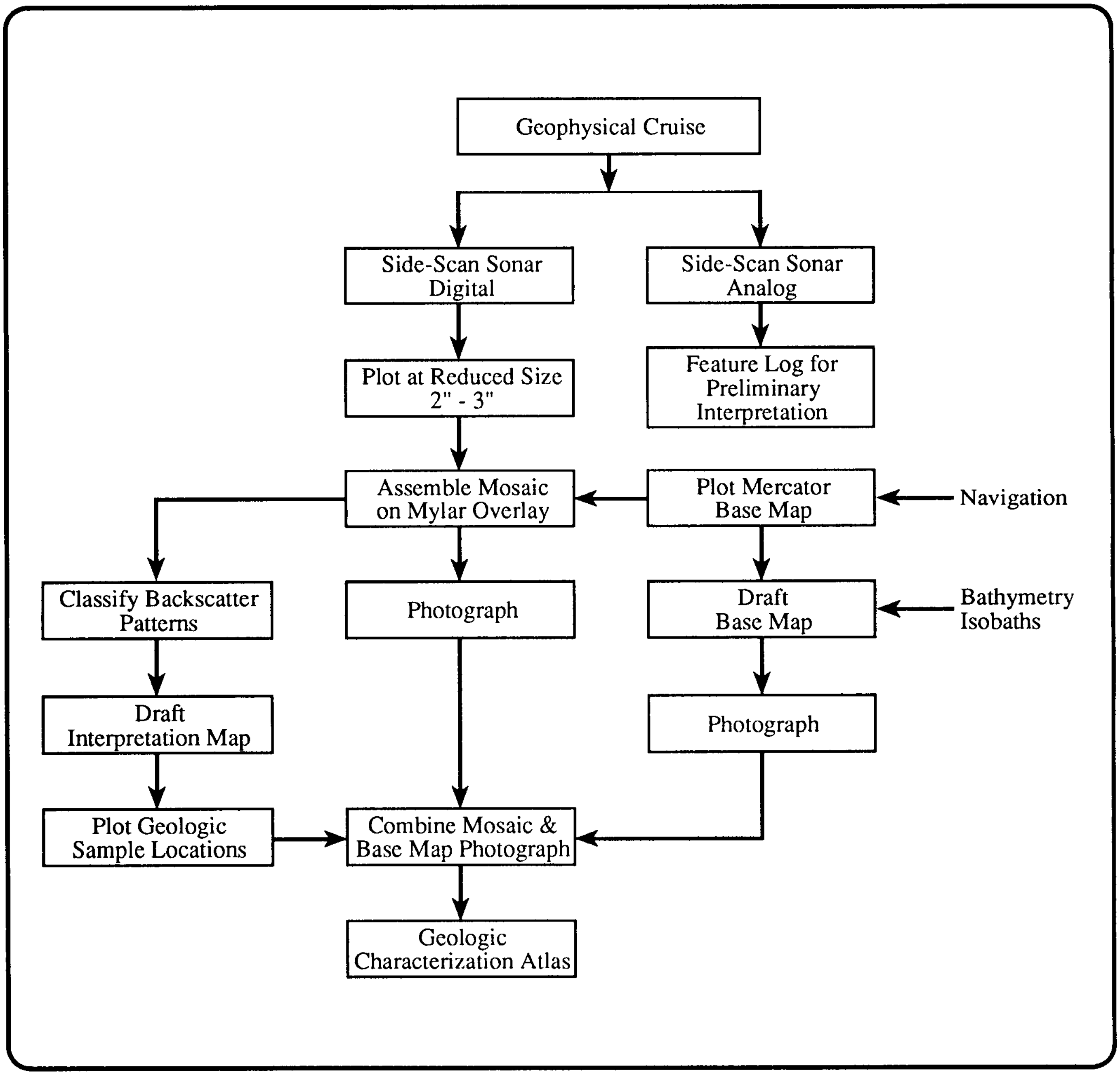


Figure 12-2. Flow chart showing the steps used in processing side-scan sonar data.

Mercator projection on a Clarke 1866 ellipsoid (Deetz and Adams 1969). The reduced records were taped to the mylar sheet with the shotpoint marks on the records registered with the shotpoint locations on the navigation plot after allowing for "layback", the distance between the ship and the side-scan sonar towfish. Where features were visible at the edges of two adjacent records, the images were adjusted to align the features. This was rare in the reconnaissance surveys because at the edges of the records the incidence angle of the acoustic waves was small, so only large features returned sufficient acoustic enery to be visible. Once the mosaics were completed, 5-m bathymetry contours were drawn at the same scale. The bathymetric maps were drawn with latitude and longitude ticks as well as UTM northing and easting coordinates. Both the mosaic and bathymetry maps were photographed at the same scale and the negatives combined to make one map. The result was a side-scan mosaic overlain by bathymetry contours and a coordinate grid. An example mosaic is shown in Figure 12-3.

Because the side-scan sonar mosaics are not easily interpreted by the untrained eye, interpretation maps were drawn at the same scale as the mosaics. These maps outline areas of the seafloor with differing reflectivity (backscatter) patterns. They also show the locations of bathymetric features and indicate their heights. Interpretation maps were not made for mosaics 16-21 because they contained no topographic features or reflectivity variations. An example interpretation map is shown in Figures 12-4, 12-5.

The accuracy of the positions of backscatter boundaries and topographic feature locations in the side-scan sonar image mosaics is mainly limited by two factors: error in determining layback and deflection of the sonar towfish from the ship track by cross currents. Layback, the distance from the ship to the towfish, was calculated by counting the number of turns of cable deployed and multiplying by the circumference of the side-scan sonar winch drum. The error in determining the circumference should be less than 5%. In the worst case, with approximately 457 m (1500 feet) of cable deployed. This would translate into a layback error of about 23 m (75 feet). Typically, in water shallower than about 120 m only 305 m or less (1000 feet) of cable was in use, implying a layback error of 15 m (50 feet).

It was impractical to monitor the position of the side-scan sonar towfish, so cross-track error, caused by currents pushing the towfish

Figure 12-3. Side-scan sonar image mosaic 5, northeast corner of main survey area. Image shows reflection patterns R1, R3, R4, R7, R8, R9, and R10. See text for discussion of reflection patterns. All side-scan mosaics are shown in Laswell et al. (1990).

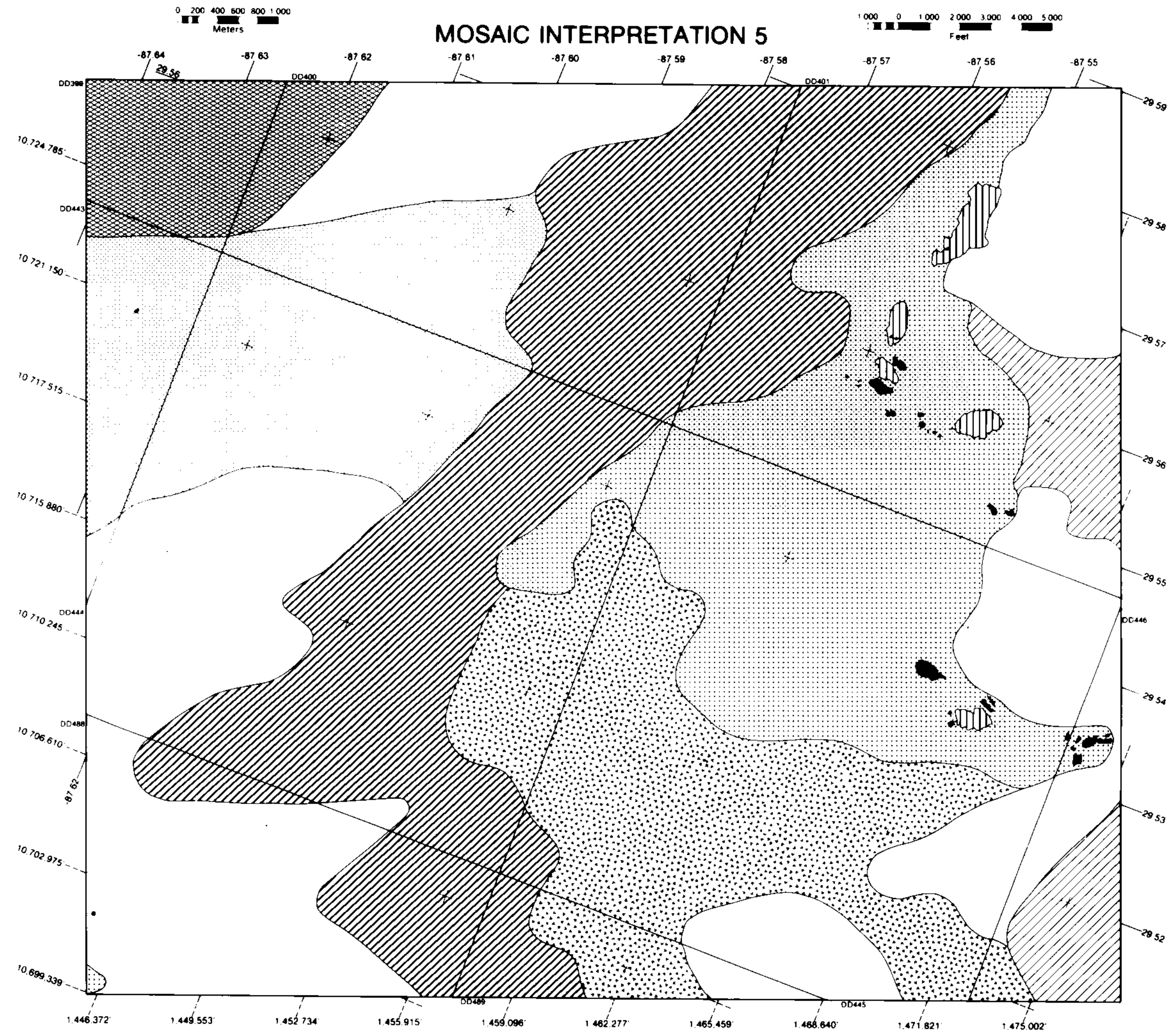
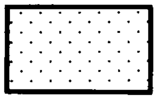


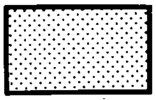
Figure 12-4. Interpretation map for side-scan sonar image mosaic 5. See Figure 12-5 for legend. All mosaic interpretation maps shown in Laswell et al. (1990).

Reflection Patterns:

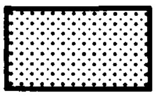
R1 Low reflectivity. Homogeneous light area on side-scan record, usually showing featureless seafloor and yielding weak seafloor echo.



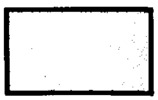
R2 Moderate reflectivity. Homogeneous, often featureless seafloor yielding moderate acoustic echo.



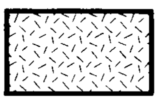
R3 Moderate to high reflectivity. Homogeneous, often featureless seafloor yielding moderately strong acoustic echo. Greater reflectivity than R2, but less than R4.



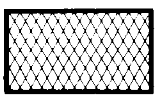
R4 High reflectivity. Homogeneous, often featureless seafloor yielding strong acoustic echo. Seafloor appears black on side-scan records.



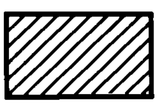
R5 Patchy reflectivity. Discontinuous, but predominantly strong acoustic echo. Areas of high reflectivity are ususally equidimensional, hundreds of meters across, and display no preferred trend.



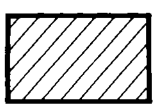
R6 Moderate reflectivity with linear, high-reflectivity patches. Seafloor dominantly low to moderate reflectivity. High-reflectivity patches usually lineated, can occasionally be traced between adjacent tracks, and often show predominant trend consistent within small area. Overall trends are variable.



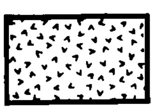
R7 Mottled reflectivity. Discontinuous moderate to high acoustic return. Areas of high reflectivity are usually equidimensional and show no preferred trend, but are smaller in size than R5.



R8 Linear reflectivity, large features. Predominantly strong acoustic reflectivity with lanes of lower reflectivity. Lineations are subparallel, trending generally northeast. Lineations are wide and long, measuring about 150-200 m across and 500-1500 m in length, on average.



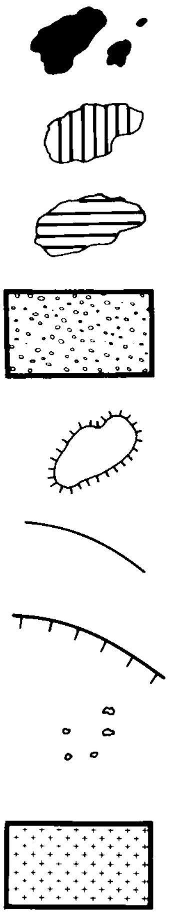
R9 Linear reflectivity, small features. Similar to R8 except that areas of strong reflectivity are smaller and shorter, averaging about 50-75 m across and less than 500 m in length. Area of low to moderate reflectivity between linear features is greater than in R8.



R10 - Confused reflectors. Seafloor with varying, but predominantly strong, reflectivity with characteristics similar to R7-R9. Reflectivity features are quasi-linear, but do not have a coherent trend.

Figure 12-5. Legend for side-scan sonar interpretation maps (Figures 12-4, 12-16, also mosaics in Laswell et al. (1990) and summary maps (Figures 12-7, 12-8 and 12-17).

Topographic Features:



Reef-like feature. Height less than 5 m or uncertain.

Reef-like feature. Height between 5-10 m.

Reef-like feature. Height greater than 10 m.

Reef-like features. Pattern shows fields of small features, a few meters in height and diameter, too numerous to show individual features.

Sediment mound. Teeth point downhill.

Ridge, symmetric.

Ridge, asymmetric. Teeth show escarpment and point downhill.

Depressions (mosaic interpretation map; each depression shown)

Depressions (summary map, p. 38; pattern shows limits of depression fields, not individual features)

Sample Stations:

○	Rock Dredge
□	Smith-MacIntyre Grab
★	ROV (remotely operated vehicle)

Coordinates:

VK693	Lease Block Number (VK = Viosca Knoll; DD = Destin Dome; MP = Main Pass)
29.31	North Latitude (decimal degrees)
-87.95	West Longitude (decimal degrees)
10,616,411'	UTM Northing (Feet)
1,372,734'	UTM Easting (Feet)

Figure 12-5. Cont'd.

laterally off-line, is difficult to estimate. This error is potentially troublesome because it can be large and it also causes an error in layback determination. It is worst when the ship is cruising at low speed (drag on the towfish is at a minimum) and when there is a large amount of cable deployed. Both of these conditions occured simultaneously while surveying in deeper water. However, if a maximum cable deflection of 10° is assumed, the cross-track error with 457 m (1500 feet) of cable deployed is 79 m (260 feet) and the layback is reduced by 7 m (23 feet). In a more typical shallow water, high speed survey mode, with 305 m (1000 feet) of cable deployed and a cable deflection of less than 5°, the cross-track error is only 27 m (87 feet) and the reduction of the layback is 1.1 m (4 feet).

12.2.3 Summary Maps

Summary maps of bathymetry, seafloor reflection character, and topographic features were constructed to give an overall view of the distributions of these data across the entire survey area. These data were traced from the mosaics, photographically reduced to about 20% of their original size, and assembled into maps. The maps were drafted and photographically reduced once again to their final size. The summary maps are shown later in this report, but can also be found in the geophysical data atlas (Laswell et al. 1990).

12.2.4 High Resolution Subbottom Profiles

High resolution seismic reflection data were collected during the geophysical surveys mainly using an EDO-Western 4.0 kHz echo sounder with a 10 kilowatt booster amplifier. A Raytheon PTR-105 3.5 kHz echo sounder had to be pressed into service during cruise 88-MMS-G2A after a weather-related failure of the other unit. Reflection profiles were collected in analog fashion using either an EDO or EPC 20-inch electrostatic plotter. The profiles were analyzed using standard seismic-stratigraphic techniques to define the facies and layering of the uppermost sediment strata. In the study area, the seafloor is unusually reflective, usually limiting seismic penetration to less than 10-15 m.

12.2.5 Sediment Texture

Textural analyses of the Smith-MacIntyre grabs have been completed and the results are listed in Table 12-1. The sediment data have been synthesized with the side scan and subbottom data. However, from interactions between the groups working on the sediment analyses and geophysical data, a picture is beginning to emerge. Sediment samples typically contain sand with variable amounts of silt and clay. Biologic debris is also a component of the sediments, with shell "hash", consisting mainly of molluscan fragments, being common. The primary difference between the areas of high and low reflectivity noted in the side-scan sonar records seems to be the content of shell hash. The high reflectivity sediments have it in abundance and the low reflectivity sediments do not.

Table 12-1. Smith-MacIntyre Sediment Analysis.

SAMPLE ID	% GRAVEL	% SAND	% SILT	% CLAY
SM-1	3.4	91	4.6	1
SM-2	3.7	90.4	4.9	1
SM-3	7	88.3	4.5	0.2
SM-4	3.3	80.1	8.5	8.1
SM-5	3.7	79.7	8.5	8.1
SM-6	13.6	60.3	14.6	11.5
SM-7	23.6	52.9	12.9	10.7
SM-8	11.4	55.1	17.9	15.6
SM-9	0	51.1	26.3	22.5
SM-10	0	54.9	24.4	20.5
SM-11	11.7	24.8	33.4	30.1
SM-12	13.1	30.2	30.3	26.4
SM-13	3.9	47.3	25.3	23.5
SM-14	3.5	39.1	30.3	27.1
SM-15	6.6	40.3	27.5	25.6
SM-16	0.01	55.3	24.2	19.4
SM-17	13	64.8	11.9	10.2

12.2.6 Ground Truth

During the Year 2 ROV cruises, 88-MMS-ROV-1 and 88-MMS-ROV-2, geologic samples were obtained partly for the purpose of ground truthing the side-scan sonar records. Additionally, the ROV stations provided extensive underwater video records which show seafloor geologic and geomorphologic features. On cruise 88-MMS-ROV-1, 16 rock dredge stations and 16 Smith-MacIntyre grab stations were completed. During cruise 88-MMS-ROV-2, grab and rock dredge samples were collected at two sites. Most of the dredges returned various biologic samples and debris such as shell hash (see Table 12-2 in Brooks et al. 1990a). Several, however, also recovered fragments of indurated material, mostly bioclastic limestones, shelly sandstones, and mudstones.

12.3 Results

12.3.1 Bathymetry

The bathymetry of the study area is characterized by broad expanses of virtually flat seafloor punctuated by small topographic features. On a large scale, the gently sloping continental shelf gradually gives way to the moderate incline of the continental slope (Figure 12-6). The shallowest depths, slightly less than 50 m, were recorded on the north side of the main survey area. The deepest depths were measured in the southwest and southeast corners of the main survey area, where the seafloor is slightly deeper than 260 m and 340 m, respectively. Depths in the east and west extension parts of the survey, which were designed to follow the shelf-edge, range from 60-120 m. The most interesting feature of the broad-scale bathymetry is that the contours in the main survey area show two seaward bulges (Figure 12-6). These are apparently the topographic expressions of two Late Pleistocene fluvial delta lobes (see Section 12.3.3, High Resolution Seismic Profiles).

Three types of short-wavelength topographic features were found: (1) reef-like mounds, (2) ridges, and (3) shallow depressions. The reef-like mounds are the most widespread and also display the greatest variation in size. They are equidimensional to slightly elongate, usually occur in clusters, and are found in water depths shallower than 120 m. The smallest are only a few meters in diameter and about 1 m in height. The largest are as much as 18 m in height and greater than half a kilometer across. These features include those that Ludwick and Walton (1957) termed "pinnacles" (features

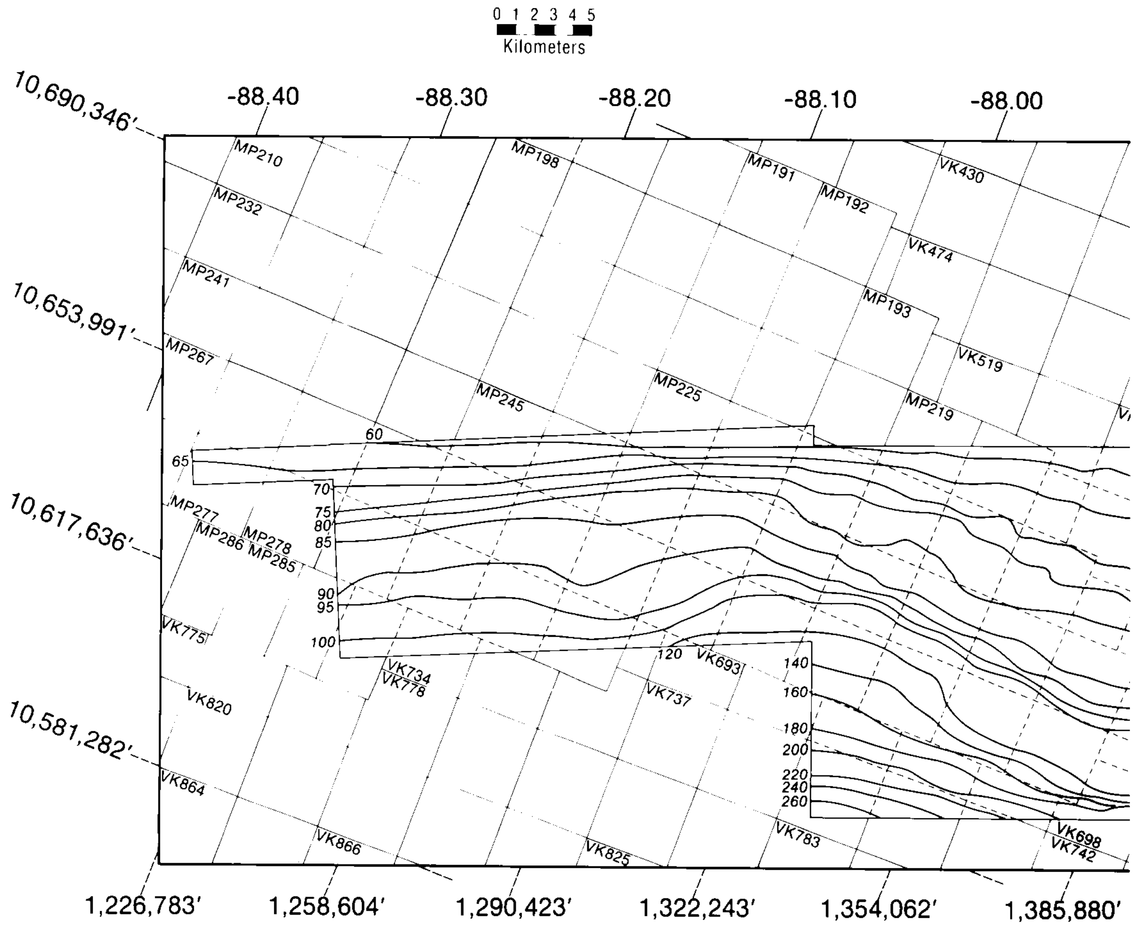


Figure 12-6. **Bathymetry contours in the study area. Contours (heavy lines) are shown and labeled at 5-m intervals. Medium straight lines denote survey boundaries. Light (and dashed) lines show OCS lease block boundaries. Selected lease blocks are labeled ("VK" denotes "Viosca Knoll"; "MP" - "Main Pass", and "DD" - "Destin Dome").**

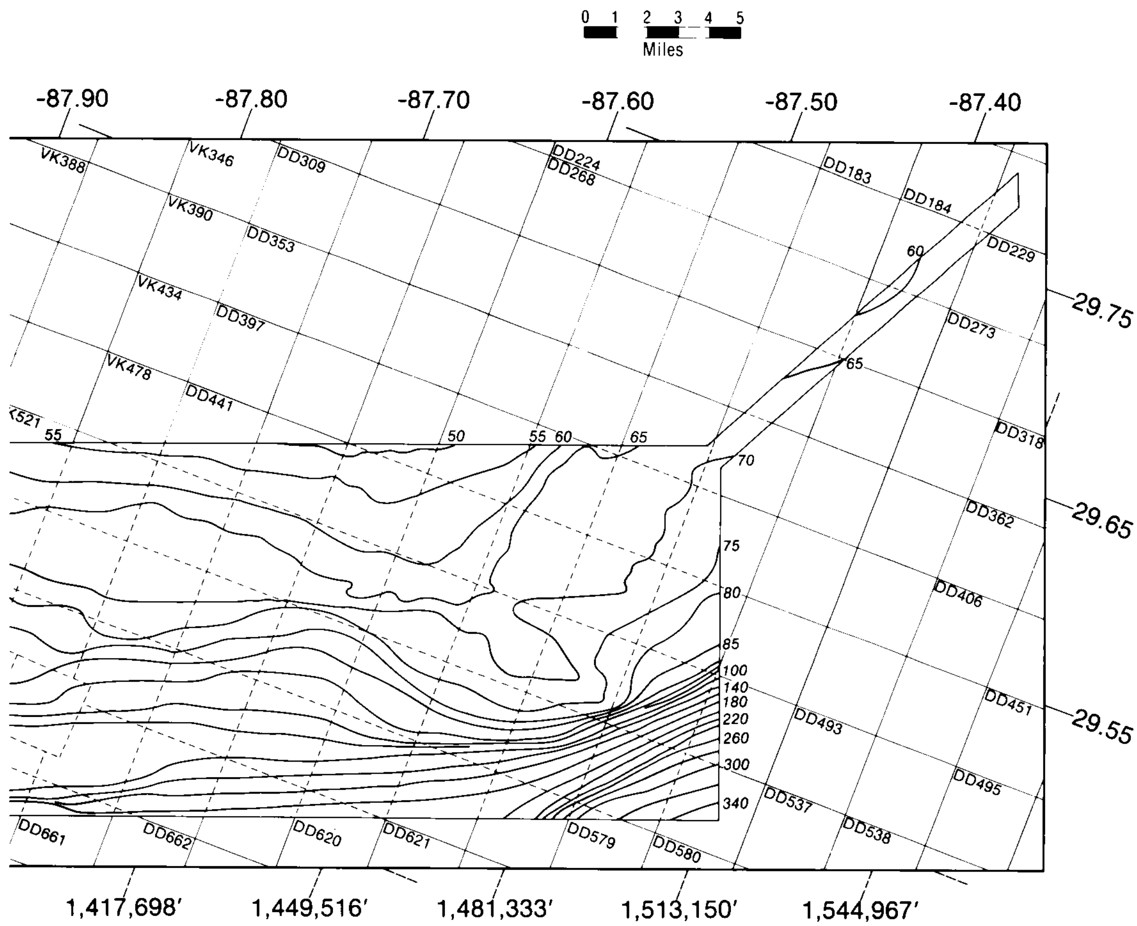


Figure 12-6. Cont'd.

at 105-120 m depth around 29.32° N, 87.79° W), which they hypothesized were drowned calcareous reefs not yet extinct. Indeed, the ground truth studies with the ROV underwater video photography, dredges, and grab samples confirm this hypothesis and imply that all of these features are coral-algal reefs (see Section 13, Topographic Features Characterization - Biological). However, because the preponderance of these features have only been observed with geophysical methods, it cannot be said with certainty that they are all reefs. Thus, the modifier "reef-like" is more appropriate.

The survey showed that the reef-like mounds are more extensive than described by Ludwick and Walton (1957). Most, but not all, of these are found along two major depth bands, 105-120 m and 74-82 m, thought to be the result of sea level stillstands. The deeper set of reef-like mounds, the "pinnacles" of Ludwick and Walton (1957), extend laterally parallel to the isobaths for over 15 nm (28 km). Farther landward, features of the 74-82 m group follow the isobaths in a sinuous path over 38 nm (70 km) long (Figures 12-7 and 12-8). This group contains the large reef-like features known to local fishermen as the "forty-fathom fishing ground". The reef-like mounds are not strictly limited to these two depth bands. In the west extension, two clusters of such features are found at depths between 87-94 m. Additionally, in the main survey area, several clusters of reef-like mounds were landward of the 74-82 m group, at water depths of 60-70 m (Figures 12-7 and 12-8).

Of the reef-like features, two sub-groups are particularly interesting: patch reefs and flat-topped reefs. The patch reefs are equidimensional in plan view, 2-12 m in diameter, and 3-4 m in height (Figure 12-9). Though small reef-like features of this size occur in many parts of the survey area, there are several fields in which they are particularly abundant (Figure 12-7), with densities of 35-70 features per 0.01 km^2. These patch-reef fields are located along the 74-82 m isobath trend of reef-like features. Why they formed precisely where they did and in such abundance is not clear, though dense accumulations of living reefs can be found elsewhere (e.g., Bermuda; see Morris et al. 1977).

The flat-topped reefs (Figure 12-10) also occur along the 74-82 m isobath trend. Although there are others, seven were crossed with the subbottom profiler and hence were measured accurately (Table 12-2).

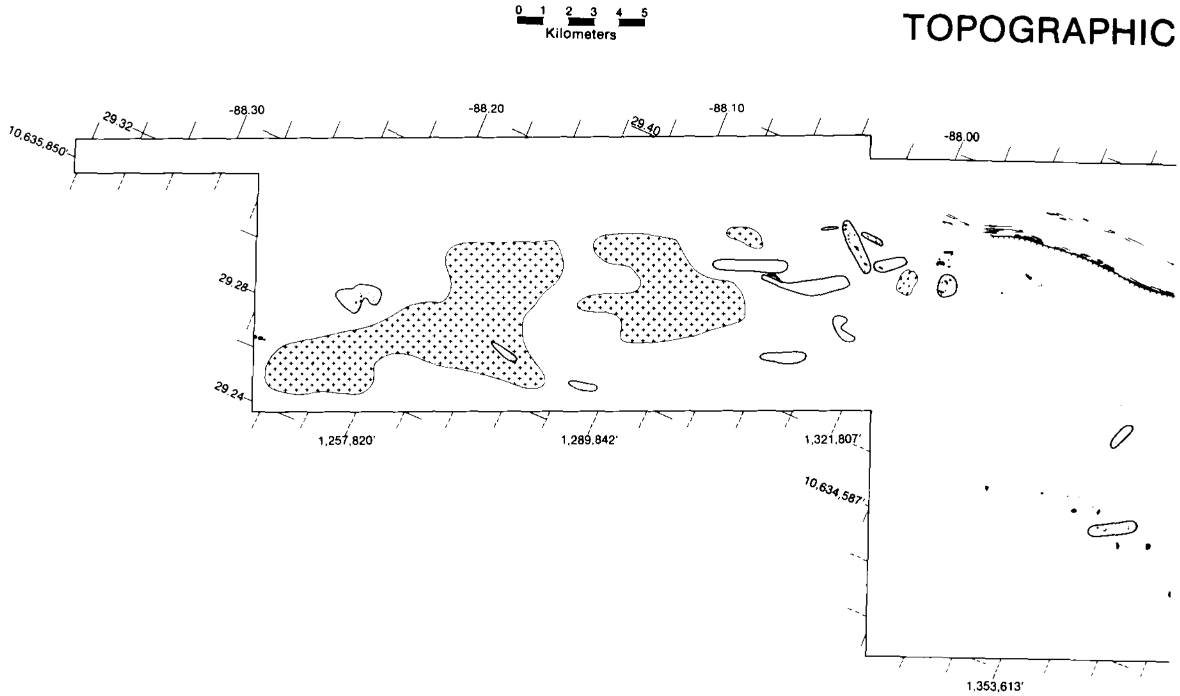


Figure 12-7. **Summary of topographic features in the study area. Black spots are larger reef-like topographic features.** Small reef-like topographic features are enclosed by heavy lines. Ridges shown by light lines. Escarpment shown by line with teeth pointing downhill. Closed contour with teeth denotes sediment mound with the teeth pointing downhill. Areas with gravel pattern are dense fields of small reef-like mounds. Areas with "+" pattern are fields of shallow depressions. **A larger version of this figure is printed in Laswell et al. (1990).**

FEATURES

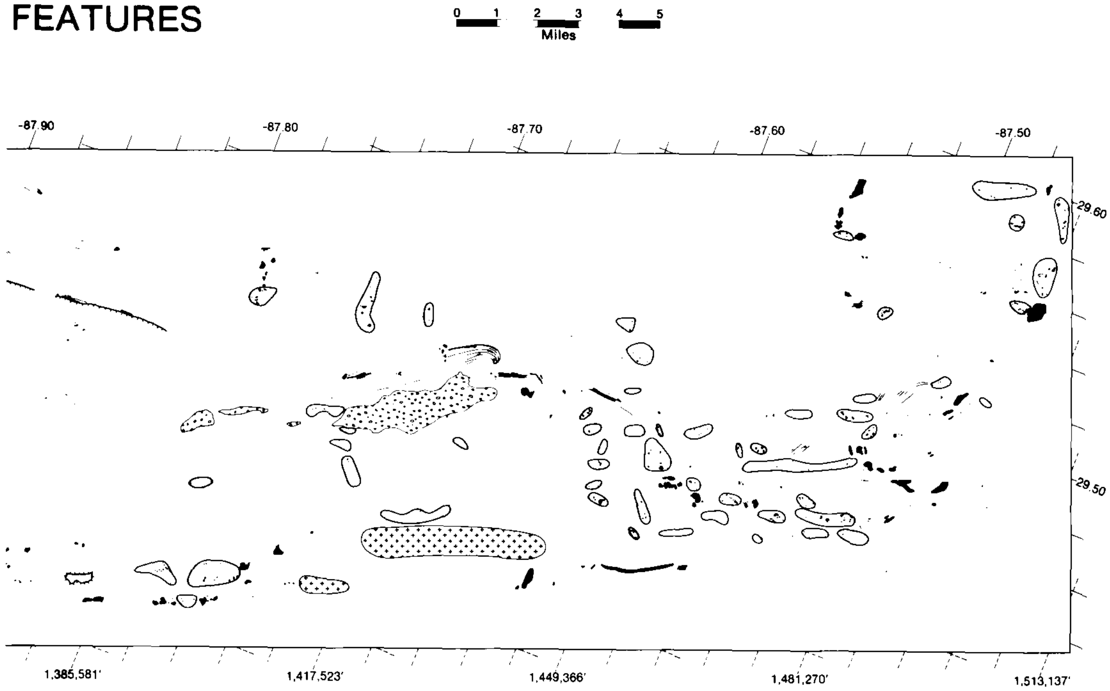


Figure 12-7 cont'd

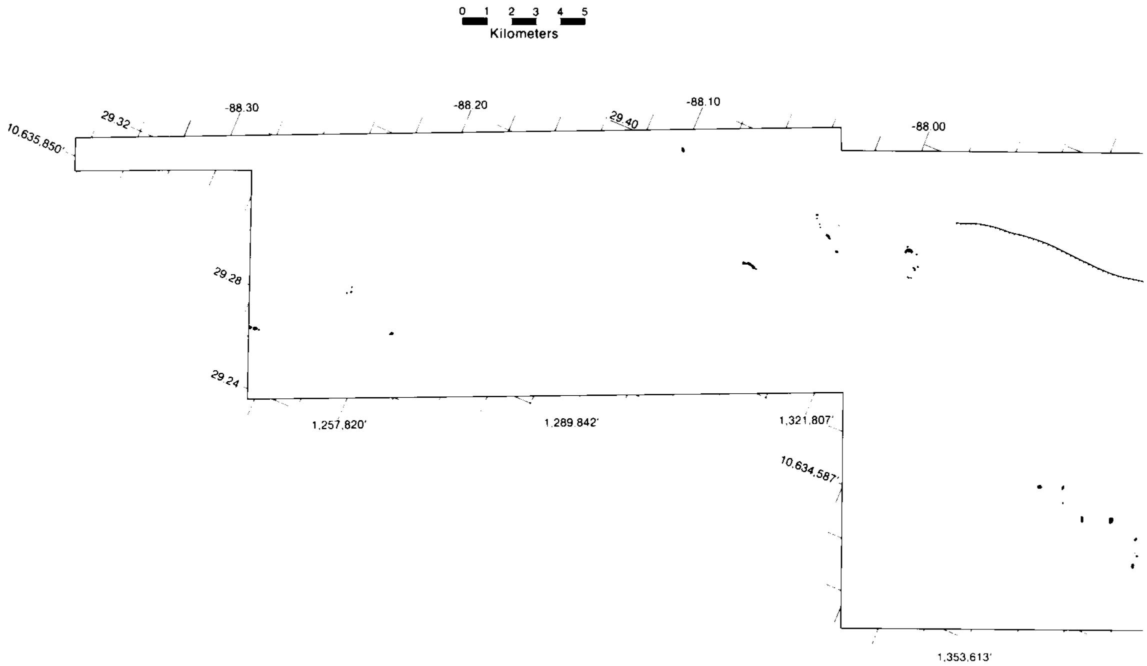


Figure 12-8. Summary of topographic features in the study area with heights greater than 5 m. Legend the same as figure 12-7. A larger version of this figure is printed in Laswell et al. (1990).

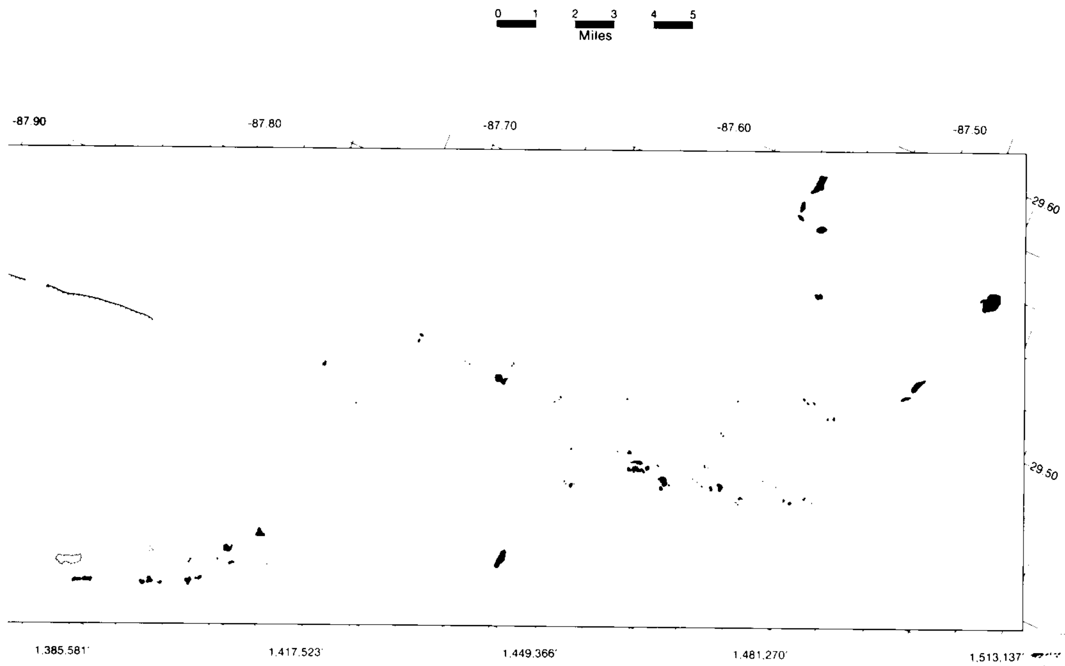


Figure 12-8 cont'd

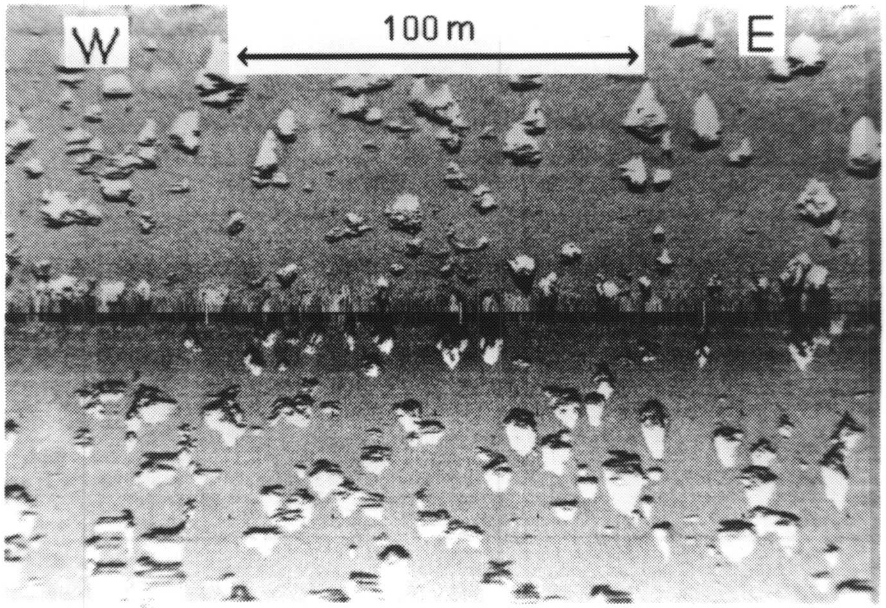


Figure 12-9. Side-scan sonar image of dense field of small-patch reef-like topographic features, detailed survey DS-3. Line at center is ship track.

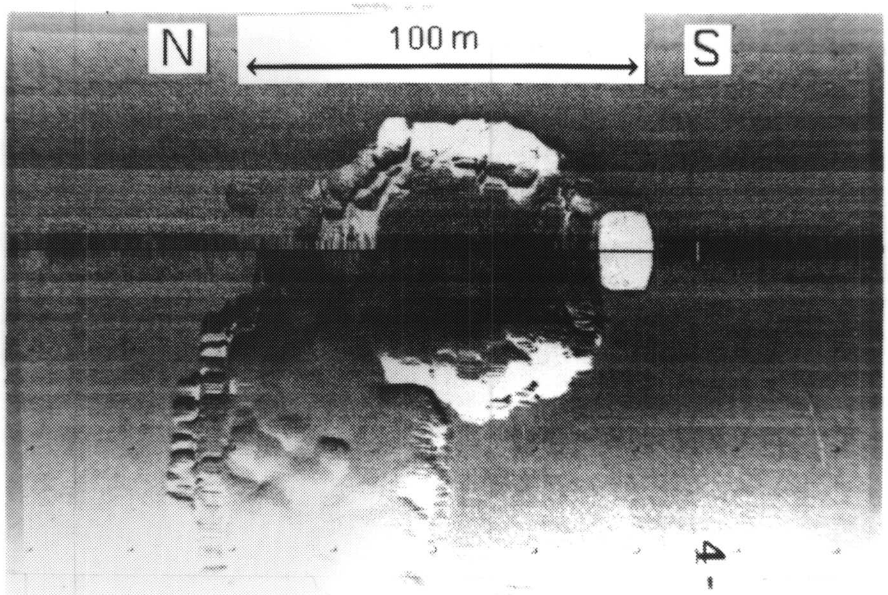


Figure 12-10. Side-scan sonar image of flat-topped reef-like topographic features, detailed survey DS-2. Line at center is ship track.

Table 12-2. Flat-topped Reef Parameters.

No.	Location		Diameter (m)	Relief (m)	Top Depth (m)	Base Depth (m)
	Lat (°N)	Lon (°W)				
1	29.455	87.658	700	8	78.5	70.5
2	29.440	87.572	700	8	74.5	66.5
3	29.452	87.555	75	7	74.0	67.0
4	29.446	87.590	300	11	76.0	65.0
5	29.446	87.545	500	14	79.5	65.5
6	29.403	87.944	125	12	78.0	66.0
7	29.397	87.910	125	13	79.0	66.0

These features are large (75-700 m in diameter, 7-14 m in height) and subcircular in plan view. Their bases are at depths ranging from 74-80 m and their flat tops are all at essentially the same depth, an average of 66 m (Figure 12-11), implying a sea level constraint on their height.

The second type of topographic feature, ridges (Figure 12-12), are also found almost exclusively along the same isobath trend, at depths of 68-76 m. These features have large aspect ratios: lengths typically 1 km or greater versus widths of a few tens of meters. Furthermore, they often occur in parallel with up to 6-8 ridges in association. Most of the ridges are low, on the order of a meter in height, and symmetric in cross-section. However, one long ridge in the western part of the main survey, at about 29.43°N, 87.98°-87.80°W, is asymmetric with an escarpment of up to 8 m height facing seaward. Like the tops of the flat-topped reef features, the bases of the large ridge features are all at virtually the same depth (Figure 12-11). This implies that this feature is also associated with sea level, perhaps an indurated beach sand dune.

Shallow depressions are the third type of topographic feature found in the study area. They are small, usually 10 m in diameter or less, and although they occur occasionally as symmetrical craters, more often they are irregularly shaped with bumpy rims. Furthermore, they do not show up clearly as depressions on the subbottom records, but do have interior shadows on the side- scan records, so they are shallow, probably less than a meter in depth. The depressions are found in large numbers in several fields particularly in the western extension part of the survey area (Figures

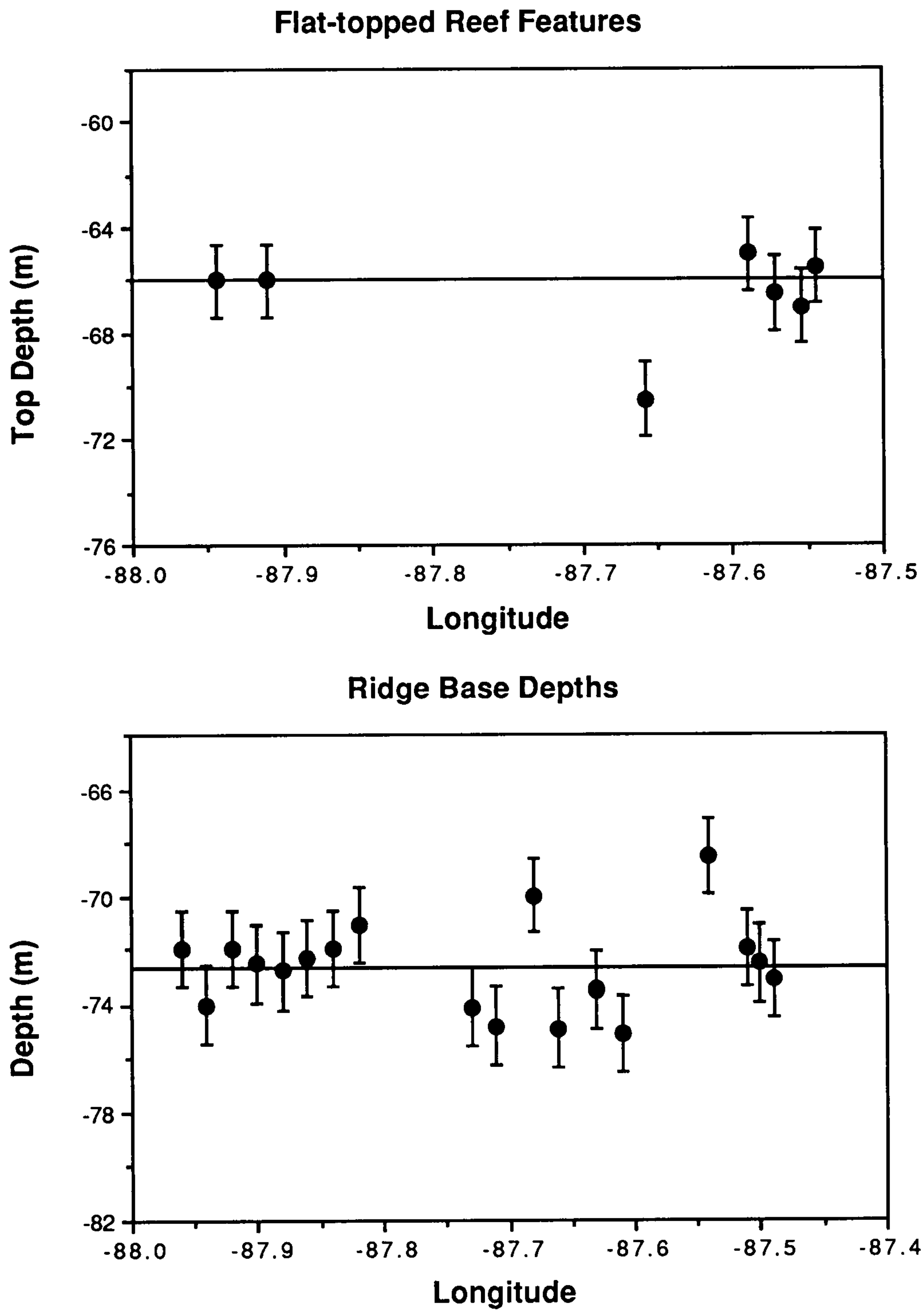


Figure 12-11. Plot of depths of tops of flat-topped reef-like topographic features (top) and bases of ridges (bottom) versus longitude. Horizontal line is average depth, 66.0 m above and 72.7 m below.

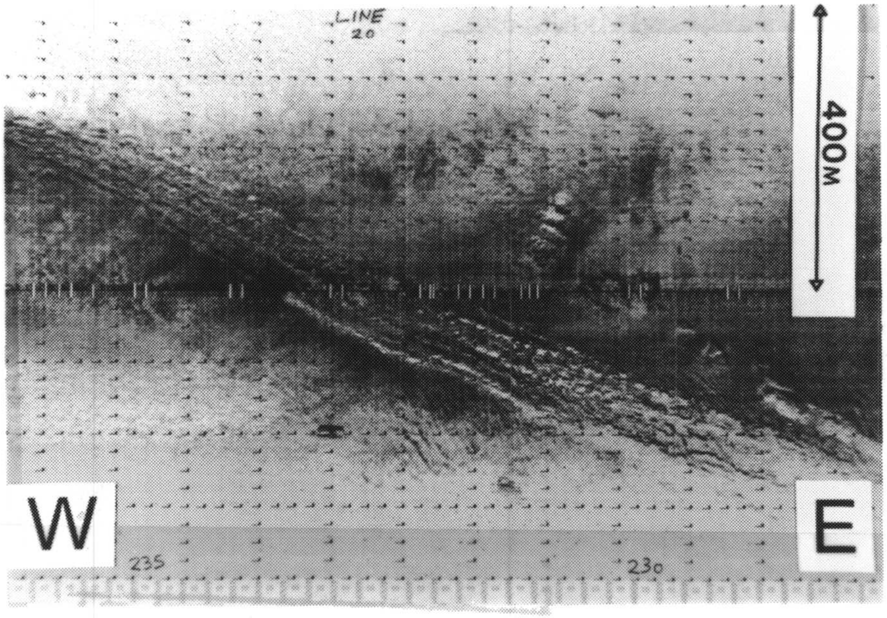


Figure 12-12. Side-scan sonar images of large ridge feature. (top) Image from reconnaissance survey (Line 20) showing multiple ridges make up the feature. (bottom) Image from detailed survey (DS-1) highlighting escarpment on west side of ridge. Line in center of both images is ship track.

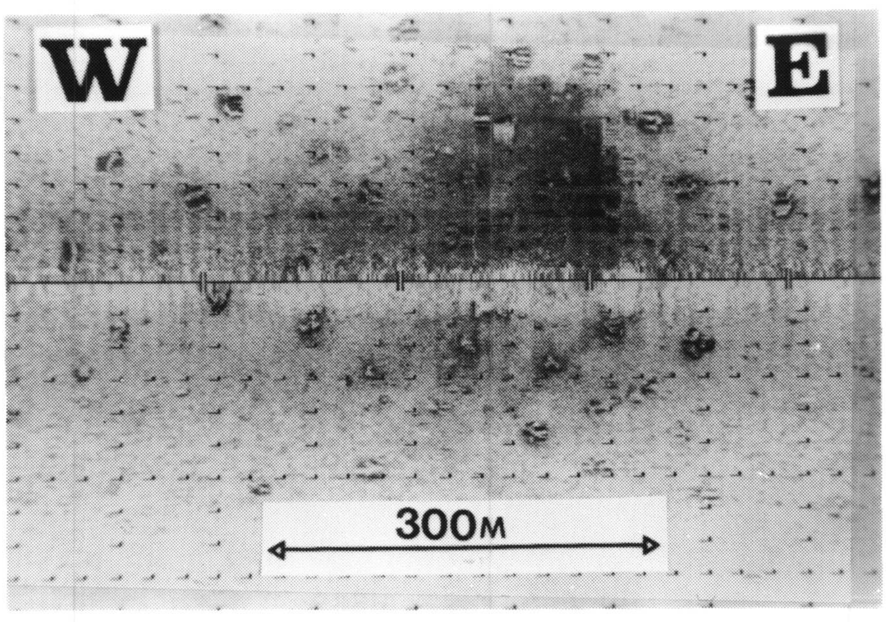


Figure 12-13. Side-scan sonar image of dense field of small, shallow depressions, west extension survey. Line at center is ship track.

12-7 and 12-13). The morphologies of these features is similar to craters and pockmarks caused by gas seeps in other continental shelf areas around the world (Hovland and Judd 1988). Unlike the other topographic features in this study, the depression fields do not clearly follow isobaths, implying that their formation was not controlled by sea level. If they are indeed gas seep features, they were probably associated with a gas-charged sediment stratum.

12.3.2 Side-scan Sonar

The topographic features observed in the side-scan sonar and subbottom profiler records are only part of an interesting geologic story. One of the most impressive aspects of the side-scan sonar image mosaics is the complex variability of the seafloor reflection character. Ten different types of acoustic backscatter, not caused by topography, were recognized in the study area (see Laswell et al. 1990).

R1-Low reflectivity. Homogeneous light area on side-scan record, usually showing featureless seafloor and yielding weak seafloor echo. (Figures 12-3, 12-4, 12-14 and 12-15)

R2-Moderate reflectivity. Homogeneous, often featureless seafloor yielding moderate acoustic echo. (Figures 12-14 and 12-15)

R3-Moderate to high reflectivity. Homogeneous, often featureless seafloor yielding moderately strong acoustic echo. Greater reflectivity than R2, but less than R4. (Figures 12-3 and 12-4)

R4-High reflectivity. Homogeneous, often featureless seafloor yielding strong acoustic echo. Seafloor appears dark on side-scan records. (Figures 12-3, 12-4, 12-14 and 12-15)

R5-Patchy reflectivity. Discontinuous, but predominantly strong acoustic echo. Areas of high reflectivity are usually equidimensional, hundreds of meters across, and display no preferred trend. (Figures 12-14 and 12-15)

R6-Moderate reflectivity with linear, high-reflectivity patches. Seafloor dominantly low to moderate reflectivity; high-reflectivity patches usually lineated and can occasionally be traced across adjacent ship tracks. Within a limited area, the linear patches often show a

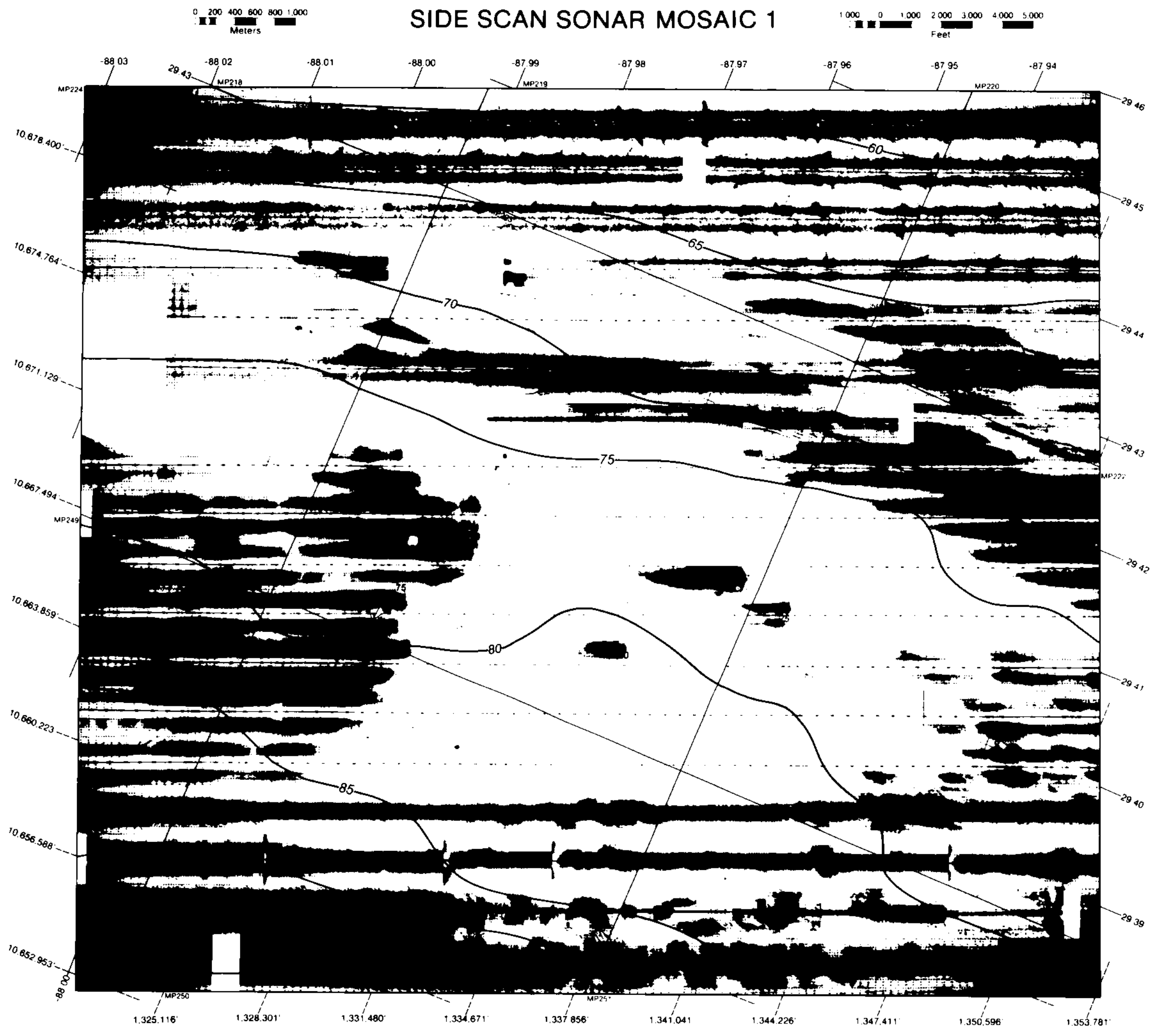


Figure 12-14. Side-scan sonar image mosaic 1, northwest corner of main survey area. Image shows reflection patterns R1, R2, R4, R5, R6, and R7. See text for discussion of reflection patterns. All side-scan mosaics are shown in Laswell et al. (1990).

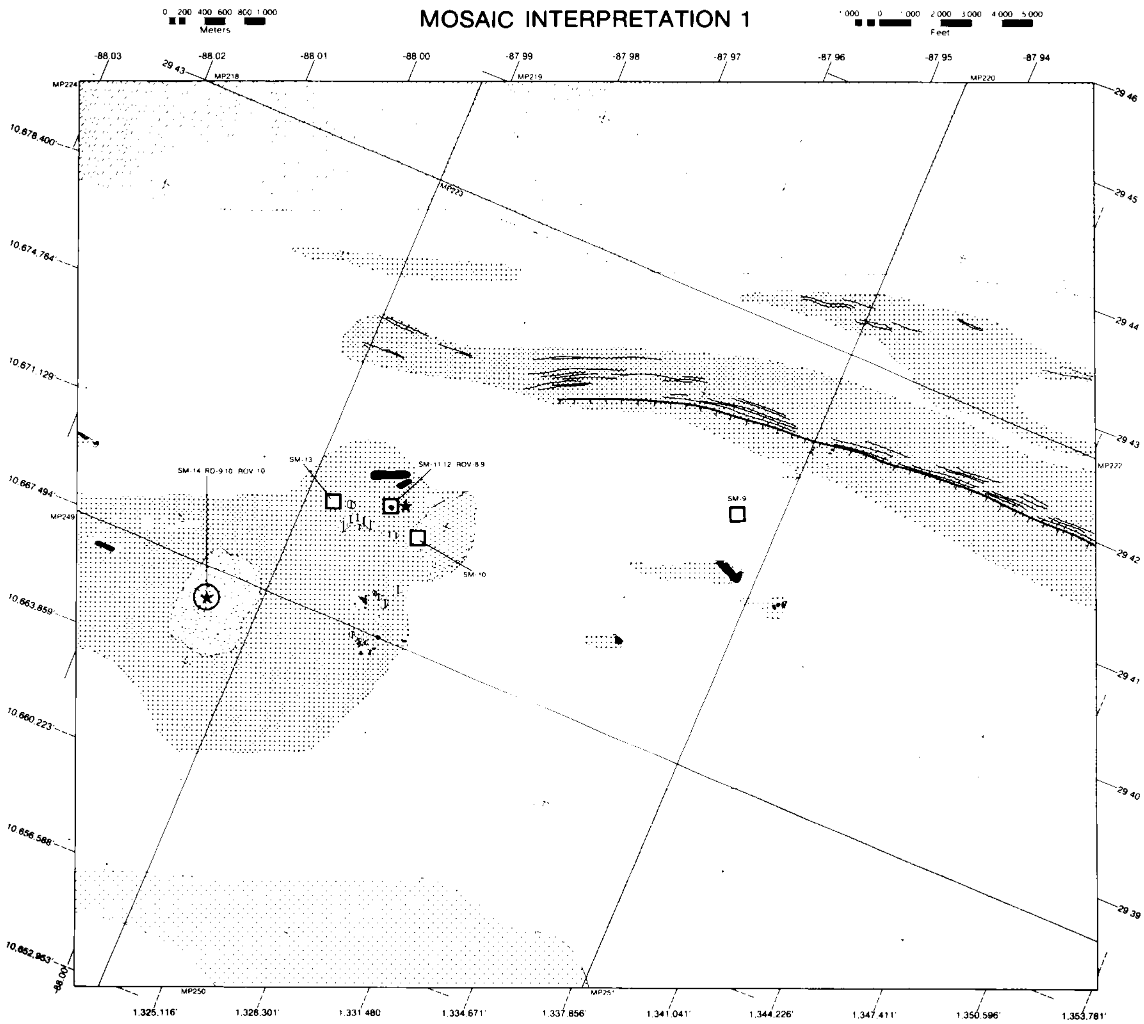


Figure 12-15. Interpretation map for side-scan sonar image mosaic 1. See Figure 12-5 for legend. All mosaic interpretation maps shown in Laswell et al. (1990).

predominant trend; however, overall trends are variable. (Figures 12-14 and 12-15)

R7-Mottled reflectivity. Discontinuous moderate to high acoustic return. Areas of high reflectivity (called "pox" in previous reports, Brooks et al. 1989) are usually equidimensional and show no preferred trend, but are smaller in size than those of R5. (Figures 12-3, 12-4, 12-14 and 12-15)

R8-Linear reflectivity, large features. Predominantly strong acoustic reflectivity with lanes of lower reflectivity. Lineations are subparallel, trending generally northeast. Lineations are wide and long, measuring 150-200 m across and 500-1500 m in length, on average. (Figures 12-3 and 12-4)

R9-Linear reflectivity, small features. Similar to R8, except that areas of strong reflectivity are smaller and shorter, averaging about 50-75 m across and less than 500 m in length. Area of low to moderate reflectivity between linear features is greater than in R8. (Figures 12-3 and 12-4)

R10-Confused reflectors. Sealfoor with varying, but predominantly strong, reflectivity with characteristics similar to R7-R9. Reflectivity features are quasi-linear, but do not display coherent trends. (Figures 12-3 and 12-4)

Figure 12-16 summarizes the distributions of the different reflection character types within the study area. These variations are undoubtedly the result of differences in surficial sediment composition and texture, perhaps associated with regional hydrographic variations. Unfortunately, this project did not contain enough ground truthing samples to be able to characterize the various reflective patterns in detail. It appears that sand, silt, and shell hash are the major components of the surficial sediments. Shell hash seems to be abundant where high-reflectivity sediments are found. Furthermore, there is also a strong correlation between topographic features and areas of high seafloor reflectivity. Virtually every patch of high reflectivity seafloor contains either reef-like topographic features, some large and some small, or ridges; however, the areas of high reflectivity are often much larger than the area occupied by the topographic features.

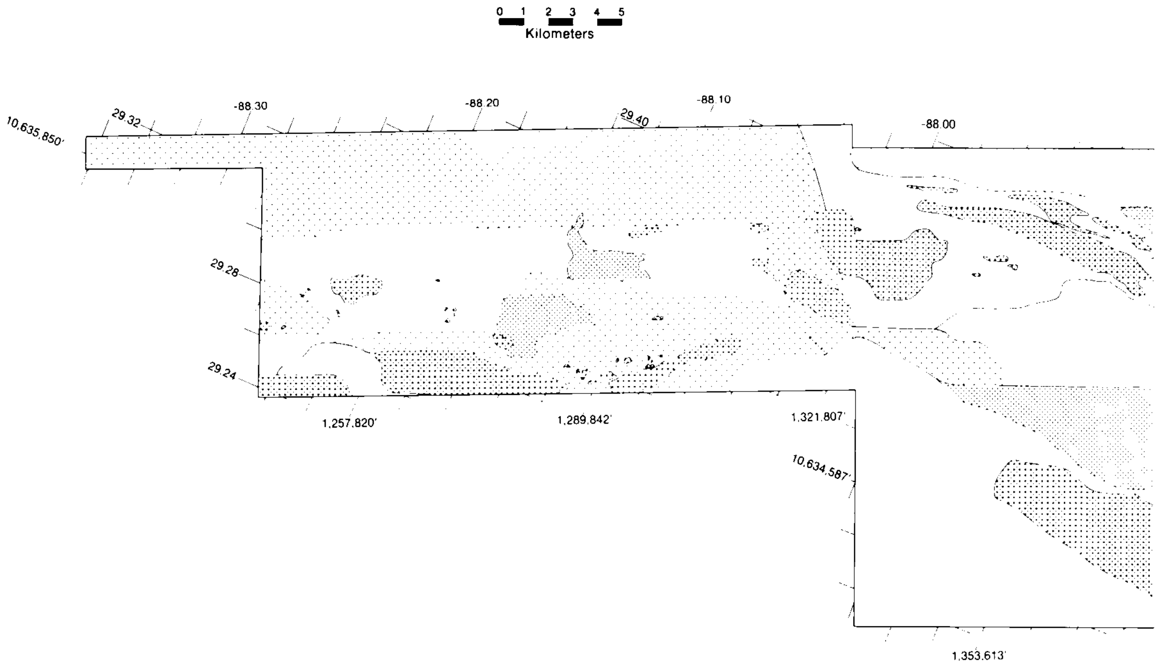


Figure 12-16. Distribution of acoustic reflectivity (backscatter) patterns in the study area. Legend for patterns is shown in Figure 12-5. Reflection patterns are discussed in text. A larger version of this map is printed in Laswell et al. (1990).

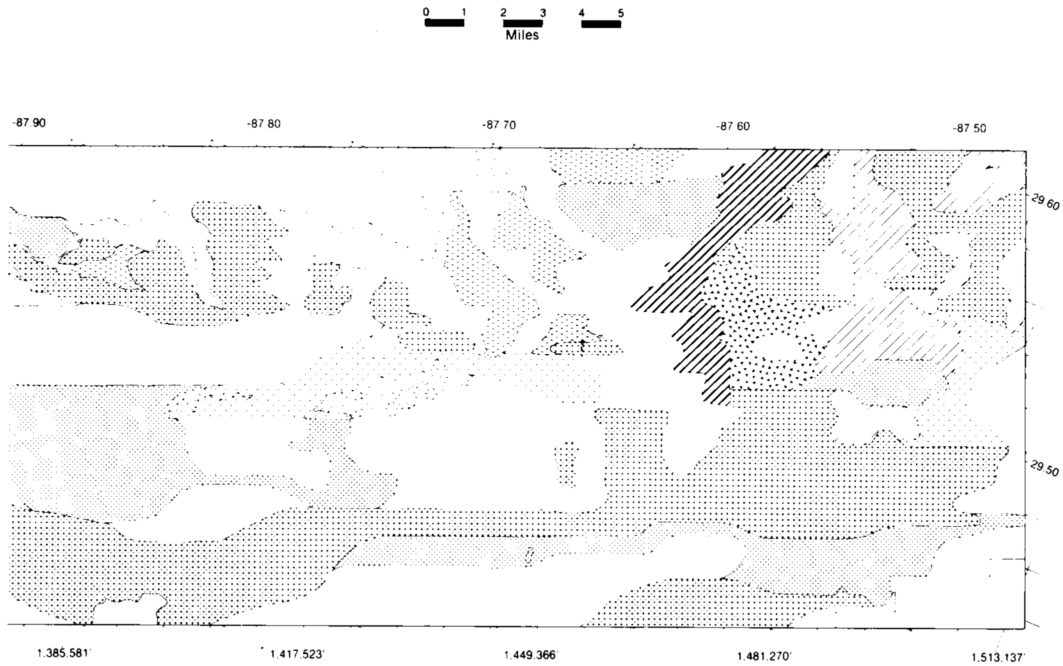


Figure 12-16 cont'd

The strength of the seafloor backscatter in the study area is probably related to the concentration of shell hash. Whereas areas of low reflectivity appear to correspond to zones of clean sand, the addition of shell hash and other biologic fragments seem to give rise to higher reflectivity. Current and wave sorting as well as biological activity may cause the linear bands (R6, R8-R9) and mottling (R5, R7, R10) observed in many areas.

Sea level and its changes appear to have played a large role in shaping the distribution of sediment reflectivity patterns. First, there are the bands of topographic features, believed to have formed at lower stands of the sea during the last ice age and subsequent deglaciation. Associated with these are bands of moderate and high seafloor reflectivity. Second, all of the lineated reflection patterns (R6, R8-R10), thought to result from sediment composition and texture variations, are found on the shallow side of the survey area, in water less than about 75 m deep. This association suggests a link to present sea level. A possibility is that these features result from sediment sorting caused by large storm waves. If this is so, the great depth of some of these features implies that they can only be affected by the largest waves, perhaps from strong hurricanes. Consequently, the pattern mapped in 1987 and 1988 may be ephemeral, created during the last major hurricane and bound to be rearranged by the next.

12.3.3 High Resolution Seismic Profiles

Sediments in the study area proved to be difficult to image with high-resolution seismic techniques. Generally, acoustic wave penetration was low, only about 5 m on the north side of the survey. However, this improved somewhat towards the shelf-edge where 15-30 m of acoustic penetration was recorded.

Delta foreset beds are imaged in the southern part of the main survey area. They are steepest near the shelf-edge, but become conformable landward. They show that the main survey area contains at least two delta lobes which form the seaward bulges observed in the bathymetry. The fluvial nature of these sediment lobes is underscored by channel features observed occasionally in the seismic data.

The seismic reflection records show two prominent erosional unconformities, A (the older and deeper) and B (see Laswell et al. 1990).

The unconformities truncate the foreset beds of both delta lobes on the seaward side of the main survey area. Unconformity A lies just beneath the seafloor under the 105-120 m bases of the reef-like topographic features (the "pinnacles" of Ludwick and Walton 1957) and forms the upper surface of the western delta lobe. Unconformity A must have been formed during a Late Pleistocene sea level lowstand. We assume because the deeper reef-like features overlying it do not appear to have been eroded by wave action, this must have been the lowstand of the most recent ice age at 21,500 y.b.p. (Bard et al. 1990) when the sea stood approximately 120 m below present sea level (Fairbanks 1989).

The eastern delta lobe sediments appear above unconformity A, and so they must be Holocene in age. Their maximum thickness is about 0.03 seconds (two-way travel time) or approximately 25 m. This delta is topped by unconformity B, upon which sit the reef-like topographic features of the "forty-fathom fishing ground", at 74-82 m depth. Therefore, unconformity B must have formed during a temporary reversal of the regression following the last ice age. The depth of this surface suggests that this was likely the Younger Dryas climate event (Fairbanks 1989), a brief cold period that occurred from about 11,000-13,500 y.b.p. (ages according to Bard et al. 1990). Thus, the eastern delta lobe must have formed between about 21,500 and 13,500 y.b.p. and the reef-like features that sit atop it must be younger than 11,000 years in age.

The sediments lying atop unconformity B are thin and patchy, as are those atop A, where sediments from the eastern delta lobe are not present. This indicates that with the exception of the eastern delta lobe, the study area has not been the site of significant Holocene sediment deposition. Neither the foreset beds, channels, nor unconformities can be traced far enough landward to pinpoint the sources of these the two observed delta lobes. However, like the Lagniappe Delta found to the west of this survey (Kindinger 1988; 1989a; 1989b), they may have been formed of sediments from the paleo Mobile, Pascagoula, Pearl, or Mississippi rivers.

12.3.4 Discussion and Conclusions

Sea level has been the primary agent influencing the geology of the study area. The shelf edge morphology is partly the result of two fluvial delta lobes deposited on the outer shelf during sea level lowstands. Each delta is truncated by an erosional unconformity, one probably formed during the most recent sea level lowstand of the Late Pleistocene (21,500 y.b.p., Bard et al. 1990), the other during the Younger Dryas climate event (13,500-11,000 y.b.p, Bard et al. 1990). Moreover, concentrations of topographic features that appear to be corralline algae-coral reefs formed directly atop both unconformities, one group at depths of 105-120 m, the other at depths of 74-82 m.

After the last ice age ended, sea level rose and caused the shoreline to march across the shelf. During this time, reefs formed at locations where these organisms could find a suitable substrate on which to grow. As a result, reef-like topographic features are found scattered across the study area. However, the greatest concentrations of topographic features were formed along isobaths at which sea level, and hence the shoreline, was stable for a period of time. The deepest band of concentrated topographic features, with basal depths of 105-120 m, is located in the southwest portion of the main survey. This group includes the "pinnacles" described by Ludwick and Walton (1957). They probably formed during the slow rise in sea level at the beginning of the deglaciation after the last ice age.

Following the end of the last glacial period, sea level rose slowly for about 5,000 years (Fairbanks 1989), but then began a period of swift rise. Consequently, reef growth could not keep pace with the rise in sea level. Furthermore, with the eastern delta lobe dumping sediments onto the outer shelf, increased turbidity may have inhibited reef growth within most of the study area. However, recent sea level research indicates that a cold spell, called the Younger Dryas event, punctuated the warming trend at approximately 13,500-11,000 y.b.p. (Bard et al. 1990) with sea level about 65-75 m deeper than today in Barbados (Fairbanks 1989). This depth corresponds to the dense concentration of reef-like features and ridges along the 74-82 m isobath. It appears that sea level oscillated for a short period (Dansgaard et al. 1989; Fairbanks 1989) effectively stabilizing sea level and affording reef building organisms time to proliferate and grow. Moreover, sediments deposited after the Younger Dryas event are thin, implying that the eastern delta lobe was cut off from its source, so the water turbidity probably decreased, favoring renewed reef growth.

After the Younger Dryas, the rapid rise in sea level appears to have resumed, leaving the 74-82 m reefs declining in progessively deeper water. A few groups of other reefs grew landward of the 74-82 m isobath, probably where they could find suitable substrate on which to grow, as the shoreline moved north.

Sea level also appears to have controlled the distribution of surface sediments, as indicated by variations in the character of the acoustic backscatter of the seafloor. Many of the areas of high reflectivity are associated with the reef-like topographic features and ridges and presumably formed at the same time. High acoustic reflectivity appears to be related to the concentration of shell hash and other biologic debris, so these areas of highly reflective seafloor may be areas of current or ancient biologic activity. Additionally, the study area contains several types of lineated seafloor backscatter patterns which are limited to the northern part of the study area in water depths less than 75 m. These are thought to result from sorting caused by large storm waves. They may be ephemeral features only as old as the last major hurricane to pass through the region.

13.0 TOPOGRAPHIC FEATURES CHARACTERIZATION - BIOLOGICAL

Stephen R. Gittings, Thomas J. Bright, and William W. Schroeder

13.1 Introduction

South of Mobile Bay, there are extensive areas of low relief calcareous outcrops of unknown origin, between 18 and 40 m, known locally as "broken bottoms" or "ragged bottoms" (Schroeder et al. 1988a, b). Additional rock outcrops have been reported on the shelf edge and continental slope in depths of 73 to 365 m in the area from south of Mobile Bay (Ludwick and Walton 1957; Moore and Bullis 1960; Ballard and Uchupi 1970) and eastward toward DeSoto Canyon (Shipp and Hopkins 1978). The rim of DeSoto Canyon is composed of flat limestone blocks encrusted with biota of various invertebrate groups (Shipp and Hopkins 1978). Some hardgrounds in the Mississippi Bight may represent "drowned reefs" or "paleo-reefs" (Ludwick and Walton 1957; Ballard and Uchupi 1970). Some of these, especially in deeper water, may have begun development on hard substrates provided by authigenic carbonate production (Roberts et al. 1988).

Ludwick and Walton (1957) used echo sounding to survey the outer continental shelf between the Mississippi River and Cape San Blas, Florida. They noted a zone of prominences they called "pinnacles" 1.6 km wide and discontinuous with 16-40 km gaps in depths from 73-100 m. The average relief of the pinnacles was 10 m, but some were over 15 m tall. These pinnacles were thought to be calcareous biogenic structures that formed during the last sea level low stand of the Pleistocene. Biological sampling of the pinnacles, some of which were surveyed in this study, has been conducted using rock dredges (Ludwick and Walton 1957) and combinations of dredges, and television and still cameras (Woodward-Clyde Consultants 1979; Continental Shelf Associates 1985a; Schroeder, pers. comm.). Biotic assemblages were considered to be of tropical Atlantic origin and dominated by ahermatypic hard corals (e.g. *Oculina*?, ivory branching coral), octocorals, crinoids, and hydroids. Other organisms included antipatharians, various crabs, asteroids, ophiuroids, and fishes commonly associated with hard bottom habitats in the Gulf of Mexico. The biotic assemblage is considered by Continental Shelf Associates (CSA 1985a) to be comparable to that of the "transitional antipatharian zone" described by Rezak et al. (1985) at depths below 82 m at the Flower Garden Banks off Texas. In fact, both the Flower Gardens and the pinnacles surveyed by CSA have a number of reef-dwelling species in common, including *Chaetodon aya* (Bank butterflyfish), *Holanthias martinicensis* (Roughtongue bass), *Antipathes furcata* and *Cirrhipathes* sp. (antipatharians), a number of alcyonaceans, and some ahermatypic corals, among other taxa.

Within the boundaries of the Mississippi-Alabama Marine Ecosystems Study, MMS requested complete side-scan coverage and selective video reconnaissance of topographic features in the following area (Figure 13-1):

	Latitude	Longitude
Northwest Corner	29°25'24"N	88°01'48"W
Southwest Corner	29°14'24"N	87°56'54"W
Southeast Corner	29°26'06"N	87°23'36"W
Northeast Corner	29°36'40"N	87°28'30"W

This 1620 km^2 area contains a number of sites of known or suspected hard bottoms. Many topographic features within this area are of sufficient relief that they could support communities distinct from those of surrounding habitats. Such hard bottom areas often contain biological communities of sensitive nature. That is, they are composed of organisms intolerant of unnatural perturbations such as may occur with anthropogenic insult. Such areas, termed "live-bottom areas" by MMS are defined as "...those areas which contain biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, or corals living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography; or areas whose lithotope favors the accumulation of turtles, fishes, and other fauna." (MMS 1987). The reconnaissance carried out by Texas A&M was designed to evaluate the nature and extent of live-bottom assemblages in the area outlined above.

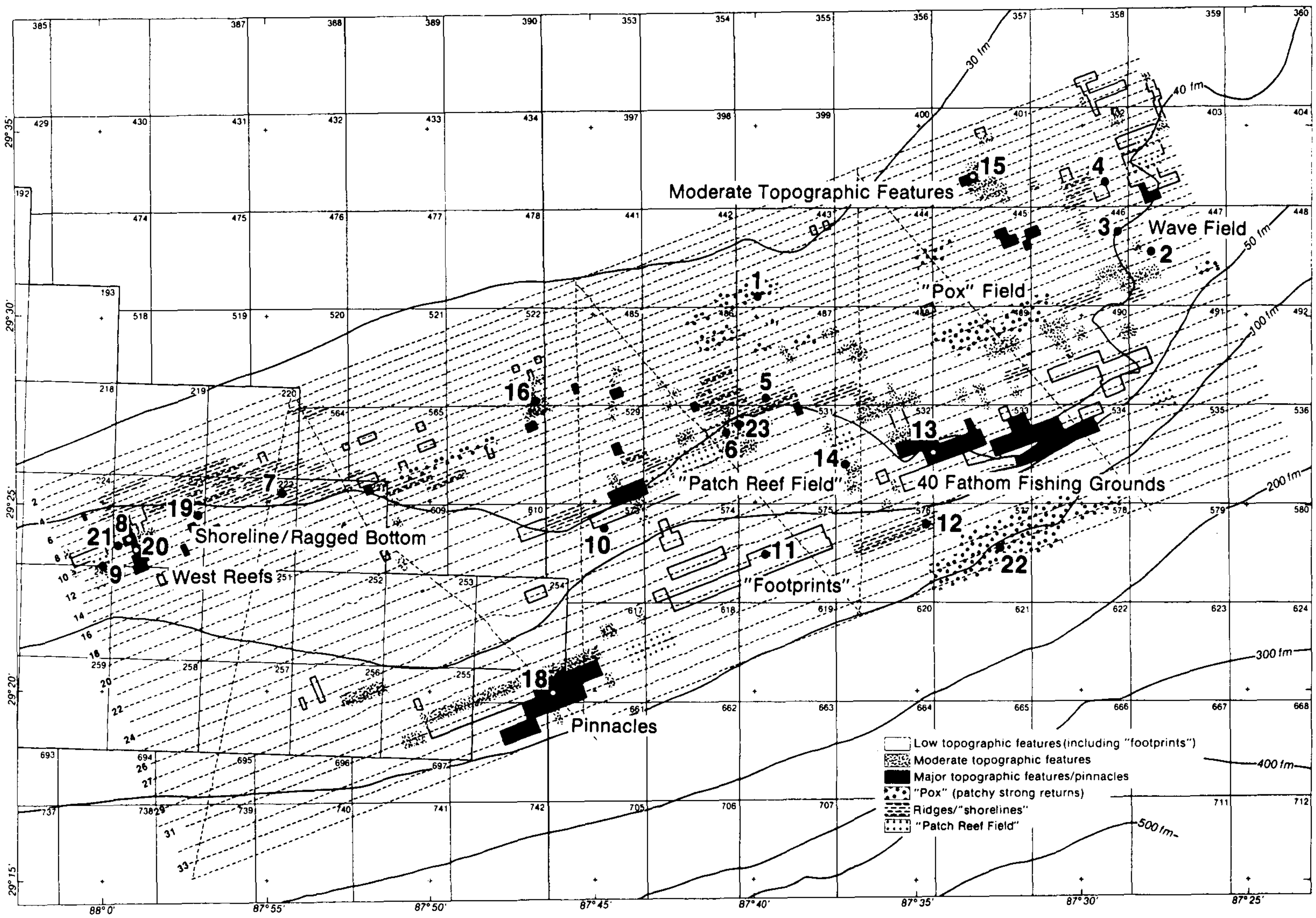


Figure 13-1. Map of hard bottom study region, showing preliminary feature interpretation and sample site locations.

13.2 Methods

13.2.1 Survey Sites

Survey station locations are shown in Figures 13-1 and 13-2. Surveys on two cruises in 1988 were conducted at locations shown in Figure 13-1 with topographic relief varying from virtually none (sand and muddy bottom areas) to over 18 m relief (pinnacle reefs). Within this range existed very low topographic features (up to two meters relief), moderate features with two to six meters relief and larger reef structures with up to 18 m relief. Hard bottom areas ranged from isolated features to continuous, linear series of ridges or outcrops nearly 20 km long. Structural complexity on the tops of large features varied from virtually flat reef tops to very rugged, irregular topography. The survey sites visited were chosen after analysis of side-scan and subbottom acoustic records. The features provided a continuum of topographic relief and habitat complexity over which live bottom community comparisons could be made.

Surveys in 1989 were conducted on six unique reef and bank features outside the initial survey area (Figure 13-2). All of these were west of the initial study area. Two sites were isolated reefs and four were larger banks. At least three of the banks apparently resulted from salt diapirism, as suggested by the presence of peripheral petroleum platforms. The sites were chosen 1) because they were topographic highs varying in character, 2) they were fortuitously located on an east-west transect from 27 to 70 km away from the Mississippi Delta, and 3) because some have experienced hydrocarbon production activities for many years, possibly allowing assessment of long-term environmental effects of such activity.

13.2.2 Remotely Operated Vehicle (ROV)

A modified Benthos RPV-2000, remotely operated underwater vehicle was used for site survey work (Figure 13-3). The camera capability consisted of a Subsea Model CM-8 low light sensitive S.I.T. black-and-white video camera, a 3-CCD Photosea 3000 series color video camera and a

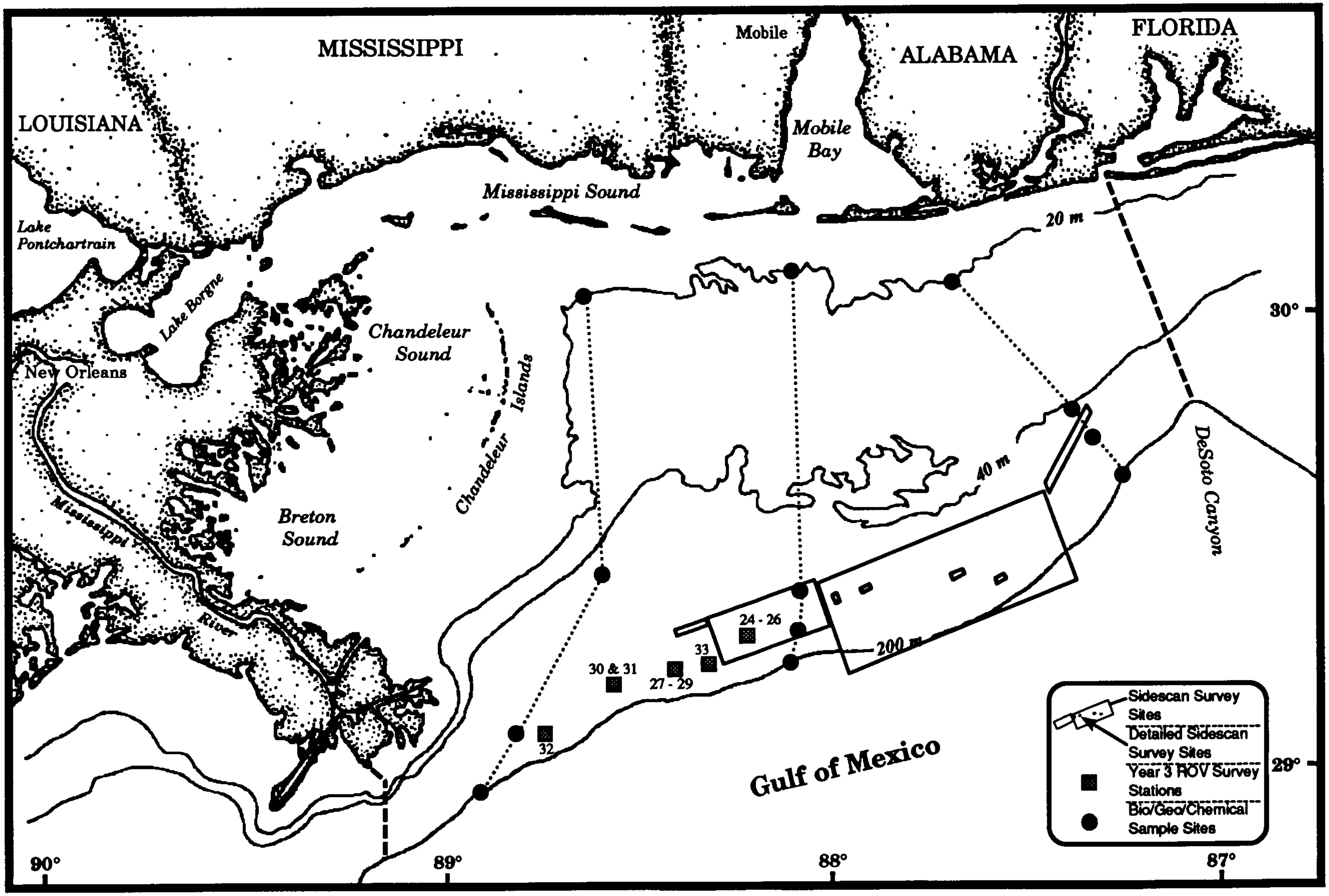


Figure 13-2. Map of Mississippi-Alabama Marine Ecosystem Study area, showing locations of reefs and banks surveyed during 1989 ROV cruise (Stations 24-33) relative to side-scan survey areas and bio/geo/chemical sample stations.

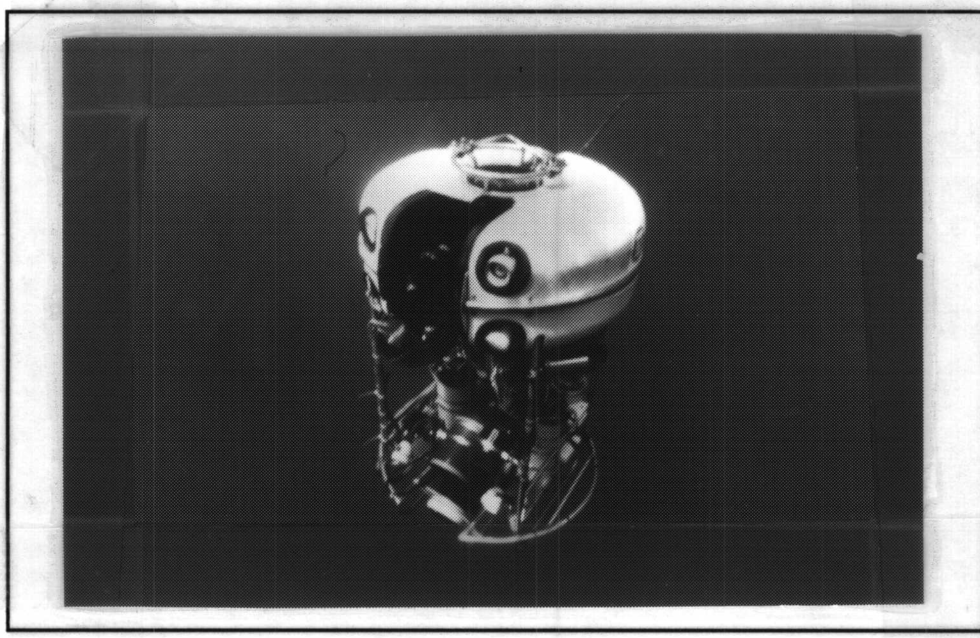


Figure 13-3. Modified Benthos RPV-2000 remotely operated underwater vehicle. Note frame has been extended to accommodate video and still cameras.

Photosea 2000 Series 35 mm stereo camera (Figure 13-4). Lighting on the unit consisted of three banks of two Birns Snooperette flood lights each and two strobes. The color video camera was a modified Sony DXC-3000 3-CCD video unit. Two underwater optical lasers were installed adjacent to the video/stereo package near the bottom of the ROV and in a parallel configuration at a prescribed spread (15 cm), which allowed size and scale determinations on video images. The ROV was acoustically tracked with ultra-short baseline navigation using a Ferranti/ORE Trackpoint II system.

Predetermined sites were surveyed using the ROV, providing video footage and still photographs of bottom surficial geology and topography and biological communities. Video footage was recorded on 60-minute, 3/4 inch U-matic format tapes and backed up concurrently on T120 VHS format tapes. Verbal annotations were also recorded. Video data also included time, depth, and date.

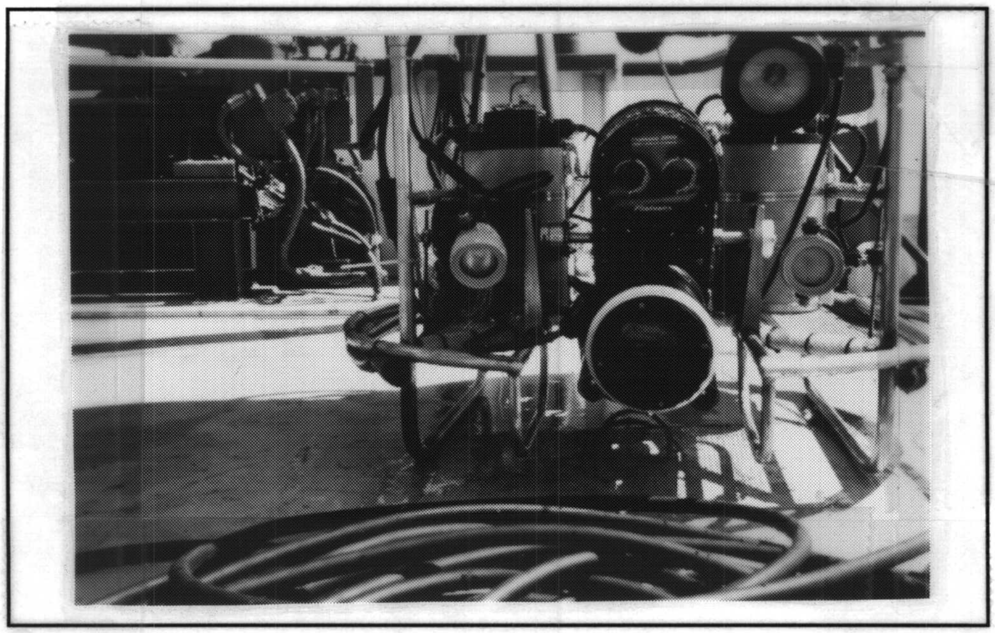


Figure 13-4. Video (lower) and stereo (upper) cameras mounted near base of ROV. Tips of the two lasers mounted under video camera can be seen. Small lights adjacent to camera package are 80-watt floods. Light at upper right is 100 watt-second strobe.

13.2.3 Rock Dredge

Short rock dredge transects (5-10 minutes each) were made during some site surveys. The dredge typically provided small samples of what were the dominant hard bottom fauna inhabiting the topographic features of the study area. The samples were also analyzed for their geologic characteristics.

The rock dredge had an opening which measured 0.70 m by 0.32 m and a collection cage depth of one meter. The mesh of the cage had openings of 12.7 mm by 38.1 mm. The number of collections varied between sites. A total of 17 successful dredge samples were collected from 10 of the 33 stations surveyed during three cruises.

13.2.4 Smith-Macintyre Grabs

Seventeen successful grab samples were taken at 15 different stations. In some cases the grab was used to collect hard bottom organisms from reefs with topography rugged enough to preclude rock dredging. In these cases, samples sometimes consisted of repeated collections of small numbers of organisms. In hard bottom areas, dozens of grab attempts were unsuccessful. The grab was also used to test sediment texture for ground truth of side-scan sonar records.

13.2.5 Hook-and-Line

In order to acquire information on the species of some of the near bottom nekton associated with the features in the study area, we collected fish using hook-and-line gear. We were particularly interested in comparing species caught on hook-and-line and those observed during ROV surveys. Fishing was conducted during the evening or morning hours, or when other equipment could not be used. Descriptions of six of the 32 stations visited include data from fishing efforts.

13.2.6 Reconnaissance Surveys

All ROV cruises (88-MMS-ROV-1, 88-MMS-ROV-2 and 89-MMS-ROV-3) were conducted aboard the R/V TOMMY MUNRO (chartered from the Gulf Coast Research Laboratory). The first cruise began on 19 July, and ended on 23 July 1988. The objective was to visit as many of the different types of features observed on side-scan sonar records (collected on geological cruises 87-MMS-G1 and 88-MMS-G1A) as possible. During this cruise, seven of 18 planned ROV sites were successfully surveyed, and bottom samples were acquired at these and other sites. In all, 15 rock dredges and 15 bottom grabs were collected.

On the second cruise (88-MMS-ROV-2, 23-27 September 1988), the proposed site reconnaissance sequence was finished. Ten additional stations were surveyed using the ROV, and rock dredge and grab samples were collected at two sites (Figure 13-1).

A third ROV cruise was conducted between 19 June and 1 July 1989. The objectives with respect to biological reconnaissance were to survey topographic features outside the original hard-bottom study area, namely those between the original area and the Mississippi River (Figure 13-2).

In all, reconnaissance surveys using the ROV were conducted at 27 sites over three cruises. At five stations, either dredge or grab sample alone were obtained. The length of surveys at each site depended on factors that controlled the ability to identify and classify the biotic communities (e.g. water clarity, bottom topography and community complexity). Adequate coverage of individual hard bottom features required one- to three-hour surveys with camera-to-subject distances of one to three meters. Closer approaches and camera zooming were occasionally necessary for organism identification. Stereo photographs were taken frequently at sites where water clarity was sufficient for high quality photos.

ROV survey patterns of the bottom were monitored using the acoustic tracking system. Attempts were made to achieve nearly complete site coverage by plotting the ROV cruise track on a transparent overlay on the tracking system display, which shows the ROV location relative to the mother ship.

13.2.7 Laboratory Analysis of Samples

Rock dredge and grab samples were sorted in the laboratory and species identifications made to the lowest feasible taxa for all samples collected during the first ROV cruise. These collections were valuable to the video and photographic analysis in that they often contain species that are commonly observed on tapes and slides. Taxonomic assistance for ahermatypic stony corals was provided by Walter C. Jaap, and for octocorals by Jennifer Wheaton (both of the Florida Marine Research Institute, St. Petersburg, FL). Assistance in fish identification from video tapes and photographs was provided by Dr. John McEachran, Dr. Ian MacDonald, and Mr. George Dennis.

Data were recorded using a database management program, called Reflex Plus, on a Macintosh computer. Records of observations made on video tapes and photographic records included time, descriptions of the habitat, organism identification, a qualitative descriptor of frequency for that species or taxon, quantity (where appropriate), depth of observation, and comments relating to the observation. The database also contained information regarding ROV dive numbers, station numbers, visibility during dives, shallowest and deepest depths at each site (e.g. feature crests and bases), length of surveys, and human impacts or disturbance at the sites. All of these data were also entered into computer files in the database.

A list of bottom types was compiled from initial review of video tapes. The categorization considers bottom hardness, topographic relief, and detail of the surface (Table 13-1).

Qualitative descriptors for taxa at each station were modifications of those used by Starck (1968) for fish frequency at Alligator Reef, in Florida, and Dennis (1985) for fish abundances on hard banks in the northwest Gulf of Mexico. It was important to understand these terms as defined in this study because they were commonly used in site descriptions. They were:

Rare - seldom observed, or a very small percentage of observations at a site; usually only once or twice at any given station, but possibly several times at sites with very high overall abundances.

Occasional - Sporadic observations, usually at irregular intervals; generally several observations, or a higher number at stations with very high overall abundances, but not common.

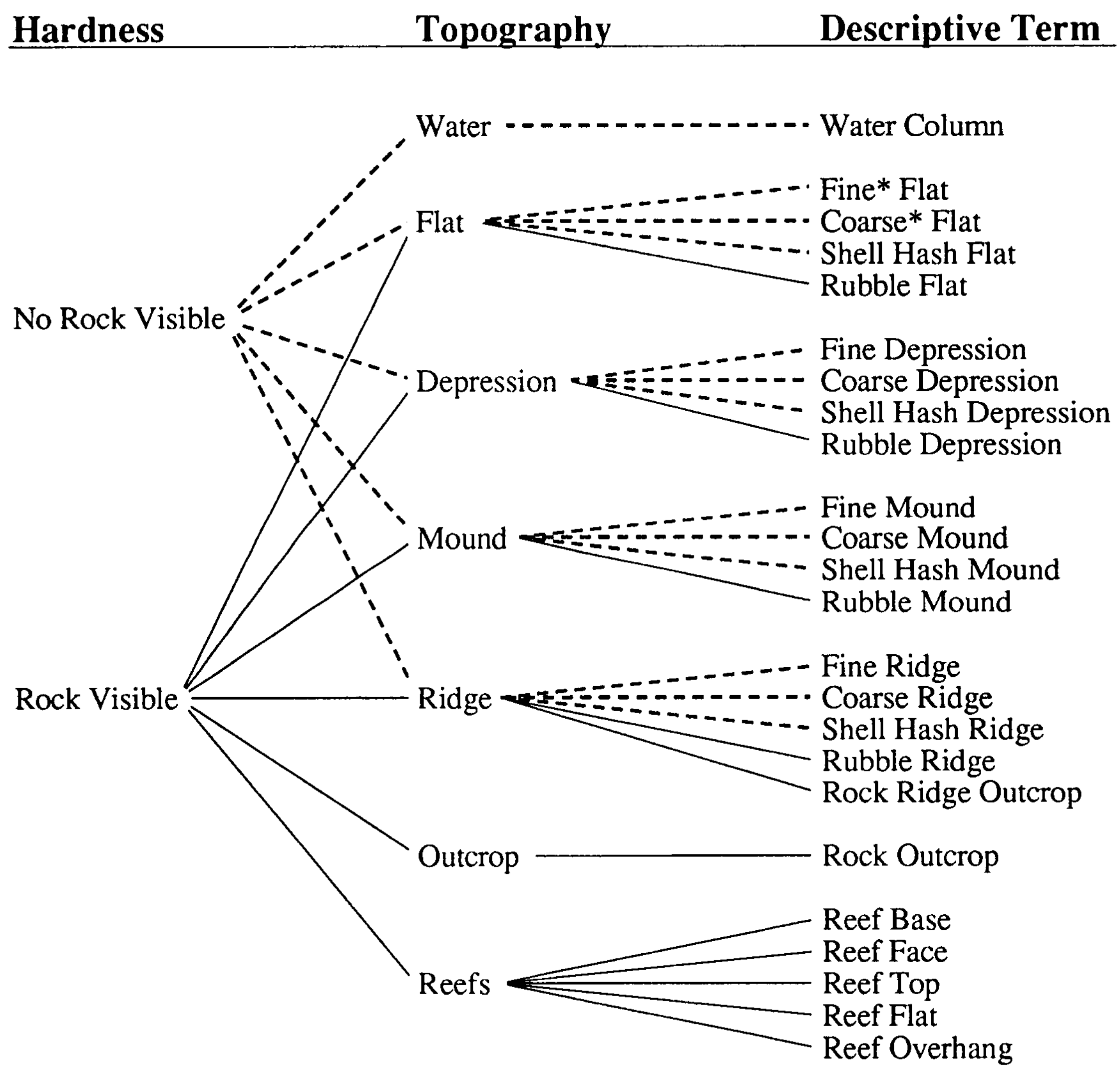
Common - encountered regularly; seen in a large portion of their preferred habitat at a survey site. For purposes of this study, we consider "frequent" and "common" (used by Starck [1968] and Dennis [1985]) to be synonymous.

Abundant - a regularly encountered species observed in high numbers, representing a high percentage of observations.

13.2.8 Biological Community Composition

For each station visited, the information resulting from video tape, stereo photograph and sample analyses was synthesized into a site description. The standard format for presentation of site descriptions included most or all of the following information: location, date of survey, total hours of video acquired, total number of ROV dives, time of survey, visibility, side-scan interpretation, depth, relief, bottom types encountered, attached epifaunal assemblage, biotic zonation, associated benthic invertebrates, fish and nekton encountered, frequency, human impacts, and comparison with other sites.

Table 13.1. Bottom type descriptive terms used in video and photographic analyses.



*"Fine" and "Coarse" refer to apparent sediment texture

Comparisons between sites and categories of features were made on the basis of habitat and community characteristics, biotic zonation and the factors which most likely influenced biotic assemblages. Habitat differences included sediment texture, the extent of outcrops or reefs, topographic complexity, vertical relief, crest depth, relative depth of turbid water layers, and the nature of the overlying water mass. Biological community characteristics that could be compared between stations and feature categories were species composition, apparent abundances, apparent diversity, and the number of distinct biotic assemblages. Biotic zonation comparisons were made with respect to the composition, number, extent, and depth of zones, and the parameters that most affected the observed zonation.

13.2.9 Associations with Environmental Parameters

It is likely that variations in the geologic structure of topographic features and the physical and chemical regime of specific localities within the study area governed the nature of biotic assemblages present. Some of the factors which were likely to be of consequence in this study area were amount of relief (which influences the number of refuges for motile organisms), feature crest depth (which is especially important to light penetration), surrounding depth, substrate type, proximity to turbid water masses (e.g. Mississippi River plume), particulate load of the water, proximity to the nepheloid layer, temperature, salinity, and seasonal variability of the four latter factors (Rezak et al. 1990). Correlations between some of these factors and biotic composition and zonation patterns are discussed.

13.2.10 Comparison of Features to Other Gulf of Mexico Topographic Prominences/Zoogeographic Affinities

One objective was to determine the biogeographic affinities of assemblages on outer continental shelf topographic features within the Mississippi Bight. Comparisons were made primarily with the findings of other Gulf of Mexico benthic investigations, including those carried out in the northwestern Gulf of Mexico on salt-diapiric structures and on south Texas relict coralgal reefs (e.g. Rezak and Bright 1978, 1983; Bright et al.

1984; Rezak et al. 1985), on other hard substrates in the northeastern Gulf (Moore and Bullis 1960; Schroeder et al. 1988a, b), and on live-bottom areas on the Florida shelf (e.g., at the Florida Middle Ground; Hopkins et al. 1981). Communities in this region were also compared to those at similar depths on hard substrates off eastern Florida (Avent et al. 1977; Reed 1980).

13.2.11 Community Health (Condition)

The evaluation of the health, or condition, of hard bottom communities generally involved a subjective comparison of a given area to similar habitats observed in the past. Objective criteria that could be incorporated into this evaluation included: (1) the evidence of mass mortalities having occurred [e.g. sea grasses (Tutin 1938); sponges (Galtsoff 1940); sea urchins (Lessios et al. 1983, among others)], (2) abnormally high cover or abundances of atypical species (Hughes et al. 1987), (3) the deterioration of individual organisms or colonies (e.g. zooxanthellae expulsion in corals under stress; Jaap 1979), (4) storm impact (Glynn et al., 1964 and many others), and human impact such as anchor damage (Davis 1977; Gittings and Bright 1986), other mechanical impact (reviewed by Gittings 1988), and pollution (e.g. solid wastes, hung and discarded fishing nets, etc.).

During video tape analyses, such observations at ROV sites were noted and were presented in station descriptions. This provided a partial record of both natural and human impacts in these habitats. The information may be useful as baseline data on community condition for future studies.

13.3 Results

The features chosen for reconnaissance represented a cross-section of hard bottom and soft and sandy bottom areas within the study region. The locations of the sites are given in Appendix D and Figures 13-1 and 13-2. The following features were sampled using the ROV, rock dredges, or bottom grabs:

- one area of acoustically transparent sediment, which generally indicated fine textured, soft bottom (Station 19);
- one "wave field" (closely spaced, low relief sand waves on bottom; Station 3);

- two areas of patchy hard bottom returns (Stations 1 and 22);
- two areas that may be part of a "sediment apron" of relatively coarse sand surrounding a reef structure (the sediment produced very strong returns on side-scan records; Stations 20 and 21);
- one field containing what appeared to be small depressions in the bottom (Station 11);
- three sites along an apparently continuous paleo-shoreline (this might have been a still-stand erosional feature; Stations 4, 5, and 7);
- one site along a shorter, deeper ridge or paleo-shoreline (Station 12);
- two fields of reefs comparable in size to present-day lagoonal patch reefs (Stations 6, 9, and 10, and a dredge sample at 23);
- two areas containing features of low topographic relief (Stations 2 and 24);
- two features of moderate topographic relief (Stations 15 and 16);
- four features of major topographic relief (one over 18 m tall; some are smooth-topped, some knobby, some broad, and some spire-like; Stations 8, 13, 14, 18, 25, and 26);
- three apparently diapiric banks containing reef and hard bottom outcrops (Stations 27-32); and
- one bank of unknown origin containing reef-like structures (Station 33).

13.3.1 Site Descriptions

13.3.1.1 **Station 1** - Pox Field

Video Survey - Station 1 was located at 29°30.50'N, 87°39.95'W. The survey started at 0843 on 20 July 1988 and ended at 1135 (video records totaled 2.70 hours). The area was 57-58 m deep and consisted of moderately bioturbated, shelly sand. Variability in the amount of shell material in the sand may account for the patchy strong returns seen on the side-scan records, but this variability could not easily be detected on video records. In one area, however, there seemed to be somewhat higher levels of shell hash on the surface of the bottom sediments. Continental Shelf

Associates (1985b) noted similar, but possibly darker, "polka dot" sonar returns on side-scan records from the southwest Florida shelf and found them to be associated with live-bottom areas. They also make reference to "similar, though less distinct, patterns..." off northwest Florida, the cause of which was unknown.

Sandy mounds in the present study area were seldom taller than five to seven centimeters or broader than 10-12 centimeters. Numerous small holes (probably fish and callianasid shrimp burrows) and one burrow surrounded by small rocks were seen. Several depressions were observed approximately 30 cm across and 15 cm deep, filled with rubble and algal, sponge, or gorgonian coral debris. No rock outcrops were seen and there was little evidence of subsurface hard bottom (e.g. only one attached hard bottom organism, a white sea whip (*Elisella funiculina*?), was seen projecting through overlying bottom sediments). There were no sand waves on the bottom. The only sign of anthropogenic debris was one piece of rope on the bottom.

At least three species of sea stars were observed. One species (*Astropecten*? sp.) was common, but not abundant. Many sea star-shaped depressions were observed. Other organisms included several squid, one 20-25 cm pennatulacean (sea pen), two featherduster polychaete worms, one pycnogonid (sea spider) measuring over 10 cm, and one olive shell (Olividae). One orange, tubular sponge was seen, measuring 15-20 cm tall and 20-25 cm wide, having six spires. Two other sponge species were found, one a brown tubular colony and the other a small brown knobby colony. Fish included *Prionotus* sp. (sea robin; occasional), *Serranus phoebe*, (tattler; occasional), Synodontidae (lizardfish; 5 observations, including *Synodus intermedius* [Sand diver]), *Centropristis ocyurus* (bank sea bass, rare; 3), flounders (3), and *Equetus punctatus* (high hat; 1).

Grab Characterization - Grabs 1 and 2 consisted of medium to coarse sand, fine shell hash, some medium shell fragments, and one disarticulated shell valve.

13.3.1.2 **Station 2** - Low Topographic Features

Video Survey - An area of mostly coarse, shelly sand, but with scattered low topographic features with up to about 0.5 meter relief, was surveyed during Dive 2 (29°31.78'N, 87°27.98'W). The survey started at 1634 on 20 July 1988 and ended at 1831. Total video time was 1.93 hours. Visibility during the survey was very good. The depth of the bottom varied only slightly from 73 m (±0.5 m). Features on the bottom were often mounds covered by a veneer of coarse sand, or depressions with exposed rubble or rock. Some mounds were capped by fine sand. Other features were low ridges of coarse sand, possibly covering hard substrata. Where hard bottom organisms were observed at the site, there was probably a hard substrate beneath the sandy veneers that acted as sites of attachment. The fact that patches of hard bottom organisms existed on and followed topographic relief seems to support this. The most prolific growth, however, was observed on mounds and in depressions that clearly had rock outcrops or large accumulations of rubble.

Bottom types noted in video tapes included:

- Coarse flats - fields of coarse sand (about 95 percent of the survey area);
- Coarse depressions - averaging less than 0.5 m wide;
- Coarse mounds - less than 0.3 m high and averaging one meter wide;
- Rubble flats - rubble lying on top of the flat, sandy bottom;
- Rubble depressions - rubble exposed in depressions;
- Rubble mounds - accumulations of rubble (<0.3 m relief and 1 m wide);
- Coarse ridges - ridges to 0.3 m high covered by coarse sand; and
- Rock outcrops.

Based on a preliminary analysis of side-scan records, it was believed that this survey area contained a moderate topographic feature. During the video survey, the feature was not encountered, but it may have been nearby.

This might explain the presence of a large number of features of low topographic relief and low rock outcrops. One portion of the survey site consisted of a large number of small exposed features. It is possible that this area may have been close to the moderate topographic feature.

Cover by hard substrates in the area averaged less than five percent of the seabottom. Where hard bottom organisms existed there was typically exposed rock, rubble, or sand covered mounds probably consisting of hard substrates with a coarse sand veneer. Exposed rock and rubble was either above the surface of surrounding sand (mounds) or in depressions. In nearly all cases, the presence of exposed hard bottom coincided with the occurrence of attached suspension-feeding epifauna. Abundance of epifauna varied with the amount of exposed rock. Diversity was quite variable, even between features with similar topography.

Hard bottom epifauna were distributed in patches ranging in size from less than 10 cm to nearly two meters in diameter. Several dozen of these were observed in the two hour survey. Distance between the patches ranged from less than one meter to over 15 m, and averaged around 10 meters. Most high density patches were dominated by comatulid crinoids and also consisted of *Antipathes* sp. A (bushy antipatharian corals), *Cirrhipathes* sp. (coiled antipatharian sea whip), *Elisella* sea whips (*E. barbadensis*, *E. elongata*, and *E. funiculina*?), and *Thesea*? sp. (small branching paramuriceid gorgonians). Other high density patches appeared to have equally high populations of comatulid crinoids and *Antipathes* spp. Patches of lower density were dominated either by crinoids, by *Thesea* and *Antipathes* and having few or no crinoids, or by *Antipathes* spp. or *Thesea* spp. Only one patch was dominated by *Elisella* sp. Very small patches that existed in small depressions or on small rubble accumulations were dominated by comatulid crinoids. *Cirrhipathes* colonies were frequently observed, within and outside of patches, probably attached to hard substrates beneath the sand.

Epifauna associated with the patches included several species of small unidentified crabs, gorgonocephalids (basket stars; occasional), branching foliose bryozoans growing on rocks or gorgonian skeletons (occasional), calcareous sponges (probably three or four species with no more than two individuals of any species), sea stars (rare: three were seen), and possibly two solitary corals (possibly the caryophylliid, *Oxysmilia* sp.). Three pennatulaceans (sea pens) were seen near patches. One seemed to be over 30 cm tall. The others were approximately 15 cm tall.

Fish species associated with the low topographic features and attached epifauna were: *Pristigenys alta* (short bigeye, common; observed at about half of the hard bottom patches), *Serranus phoebe* (tattler; common), *Liopropoma eukrines* (wrasse bass, occasional; 5), *Chaetodon aya* (bank butterflyfish, occasional; 5), *Chromis enchrysurus* (yellowtail reeffish, occasional; 4), *Centropristis ocyurus* (bank sea bass, occasional; 4), an orange scorpaenid (scorpionfish, rare; 2), *Halichoeres bivittatus* (slippery dick, rare; 2), a mottled flounder (rare; 1), and *Synodus intermedius* (sand diver lizardfish, rare; 1 on sand). *Calamus bajonado* (jolthead porgy) was a common nektonic species. There was no indication of human interference at this station.

Dredge Characterization - Rock Dredge 3 contained coarse to medium-grain sand, a sea urchin (*Stylocidaris affinis*), a sea biscuit (*Brissopsis* sp.) and a crinoid (?*Comactinia echinoptera)*, which was commonly seen on hard substrates throughout the study area. Also included were serpulid worm tubes, bioclastic shell material, scaphapods (two live *Dentalium laqueatum*), the gastropods *Crucibulum auricula*, *Murex recurvirostris*, *Turritella exoleta*?, *Polystira vibex*, *Distorsio clathrata*, and the pelecypods *Tellina squamifera*, *Tellina* sp., *Ventricolaria rigida*?, *Chione clenchi*, *Macrocallista maculata*, *Pitar* sp., *Anadara notabilis*, and the pectinids *Chlamys benedicti*, *Argopecten gibbus*?, and *Argopecten* sp.

Grab Characterization - Grab 3 contained coarse sand, fine shell hash, and shell fragments.

13.3.1.3 **Station 3** - Wave Field

Video Survey - The wave field survey site was located at 29°32.12'N, 87°28.97'W. The area consisted of mostly coarse sand with a mixture of silt. Depth varied between 71 and 72 meters. Mounds surrounding invertebrate burrows (probably callianassid shrimp) were abundant. These mounds were up to 15 cm tall, but averaged 10 cm in height. Depressions measuring approximately one meter across and 0.3 m deep were also observed. Some contained small accumulations of debris. Holes occupied by eels and fish were frequently seen. No hardgrounds were encountered. The wave features observed on side-scan survey records were not detected during the ROV survey.

This wave field was surveyed at night, between 2356 hours on 7/20/88 and 0159 hours on 7/21/88. Video records total 2.03 hours. Visibility was very good, except when silt was resuspended by ROV motors or fish activities.

Benthic activity was very high, due to the time of the survey. Video records at similar sites during the day indicated little biological activity (e.g. Station 1). Over 350 fish and invertebrate observations were recorded at this station (172 per hour; most observations were of fish which were feeding, and much activity near the limits of the camera's field of view was not recorded). Only 97 observations were recorded at Station 1 (36 per hour), most of which were inactive sea stars.

The most common invertebrates were two species of ommastrephid squid (both common) which were seen swimming individually or in small schools of up to 12 individuals; some were sitting on the bottom bobbing up and down, or feeding on benthic organisms. Two other species were seen, one small and red and the other large and red with white iridescent spots (both rare). Other observations consisted of white brittle stars (*Ophiothrix?* sp.) with long arms extending up into the water column (occasional: 18), *Clypeaster* sp. (domed sand dollars, occasional; 13), tan sea urchins with medium length spines (occasional; 10), an orange portunid crab (rare; 4), a white, stalked sea anemone with long tentacles (rare; 2), a red pagurid crab (rare; 1), a majid crab (rare; 1), *Scaphella dubia kieneri* (Keiner's volute, rare; 1), and a crinoid with orange arms and black pinnules (?*Comactinia echinoptera*, rare; 1). Several other small crabs were also seen but could not be identified.

Fish were very conspicuous at the site. At least 19 species were seen. The most abundant was *Decapterus* spp. (scads, abundant; over 55 separate observations). *D. punctatus* (round scad) appeared to dominate the genus. The scads were commonly seen in the water column well above the bottom, but often came to the bottom, apparently attracted to the lights of the ROV. No feeding by these fish was observed.

The urophycids were also abundant. At least two species were seen in the 53 observations. *Urophycis floridanus* (southern hake; common) accounted for 31 sightings and a second species with large blotches of dark coloration on its sides (occasional) accounted for at least five others. These fish were commonly seen searching for food along the bottom. Some were also seen with their heads protruding from burrows in the bottom.

Ophichthid eels were common (36 observations). The most conspicuous was *Ophichthus ocellatus* (spotted snake eel, common; 32). An ophidiid eel (*Lepophidium jeannae*, the mottled cusk eel) was rare, but was seen at least three times. These eels were commonly seen swimming very near the bottom, probably in search of food. One charged, collided with, and attempted to bite the video camera lens. Moray eels (Muraenidae) of the genus *Gymnothorax* were also seen (occasional: eight). The only species that could be identified was *G. ocellatus* (ocellated moray, rare: 1).

Another common fish was *Centropristis ocyurus*, (bank sea bass; 32). This is the only species common at both this site and similar sites surveyed during daylight hours.

Other fish sightings included *Synodus* sp. (small lizardfish, occasional; 13), *Menticirrhus* sp. (whiting, occasional; 5), flounders (occasional; 5), scorpaenids (scorpionfish, rare; 4), *Synodus intermedius* (sand diver lizardfish, rare; 3), *Peprilus burti* (Gulf butterfish, rare; 3), ogcocephalids (batfish, rare; 2), *Prionotus* sp. (sea robins, rare; 2), *Diplectrum bivittatum* (dwarf sand perch, rare; 1), *Sarda sarda* (Atlantic bonito, rare; 1), *Hoplunnis macrurus* (silver conger, rare; 1), an unidentified serranid (sea bass, rare; 1), and an unidentified sparid (porgy, rare; 1).

There was no indication of human interference at this station.

Grab Characterization - Grab 4 contained coarse sand and shell fragments.

13.3.1.4 **Station 4** - Shoreline/Ragged Bottom

Video Survey - An area of ragged bottom was surveyed at 29°33.48'N, 87°29.60'W on 21 July 1988. Survey time totaled 1.78 hours. The dive took place during daylight between the hours of 1130 and 1320.

Depth at the site varied negligibly from 66 meters. The site consisted of greater than 95 percent coarse, flat sandy bottom. Less than five percent of the area consisted of hardgrounds or live-bottom assemblages. Hard areas appeared to be rock outcrops. All were of relief less than 0.5 meters. Some were small and apparently isolated outcrops. One feature was semi-continuous and linear in nature and presumably part of what has tentatively been termed a paleo-shoreline. Most live-bottom areas were on exposed rock, but a small number were low mounds covered by sand. The most prolific growth was on a linear series of rock outcrops of approximately 0.5 m relief. A few live-bottom assemblages existed on apparently flat sandy bottoms. In these cases, rock probably existed beneath the sand veneer. Other assemblages were associated with sandy depressions in which hard rock substrates may have been exposed. In the two latter cases, however, the areal extent of the assemblages was less than one square meter.

Bottom types noted in video records included:

- Coarse flats - greater than 95 percent of the area surveyed;
- Coarse depressions - very few were noted, averaging <0.5 m wide;
- Coarse mounds - less than 0.5 m high and one to two meters in diameter (few were seen);
- Rubble flats - small pieces of rubble lying on sand;
- Rubble depressions - burrows under large pieces of rock or rubble;
- Rock outcrops - isolated features - most common observation;and
- Rock outcrops with linear orientation - paleo-shoreline? (contained the majority of hard bottom organisms in the area).

Live bottom assemblages were typically dominated by comatulid crinoids (probably three species). Where crinoids did not dominate, small gorgonians such as *Thesea* sp. and *Bebryce* sp. did. Associated attached benthic organisms included white *Elisella* spp. (sea whips; common), *Cirrhipathes* sp. (coiled sea whips; occasional), sponges (at least three species; occasional), and *Antipathes* sp. A (bushy antipatharians; occasional).

One patch of a pink/purple coralline algae was also seen, suggesting that some carbonate production may presently be occurring on exposed surfaces in this area. It also suggests that water clarity may remain high for relatively long periods of time in this region.

Associated motile benthos included gorgonocephalids (basket stars, rare; 4), *Hermodice carunculata* (fire worms, rare; 3), *Scaphella dubia kieneri* (Kiener's volute, a gastropod, rare; 1), and *Stenorhynchus seticornis* (arrow crab, rare; 1).

At least 15 fish species were observed. Typically, each live bottom observation included sightings of virtually the same suite of three fish species. There was a fairly equitable distribution of *Pristigenys alta* (short bigeye, common; 38), *Chaetodon aya* (bank butterflyfish, common; 28), and *Chromis enchrysurus* (yellowtail reeffish, common; 24), at each live-bottom patch. At least one of each species occurred at nearly all patches. More individuals occurred on denser or larger patches, or at small patches with burrows or depressions, presumably because of a higher number of refuges. Other fish species varied in their consistency but were loyal to live-bottom patches. These included *Serranus phoebe* (tattler, occasional; 19), *Centropristis ocyurus* (bank sea bass; all 5 were seen at two sites), *Halichoeres* sp. (wrasses, rare; 5 at one site), *Muraena retifera* (reticulate moray, rare; 1), *Holacanthus bermudensis* (blue angelfish, rare; 1), *Holanthias martinicensis* (roughtongue bass, rare; 1), and one unidentified wrasse (rare).

Species having no apparent hard bottom fidelity (generally fish passing through the area) included *Hemanthias aureorubens* (streamer bass; one school of 26), *Seriola dumerili* (greater amberjack, rare; 2), and *Seriola rivoliana* (Almaco jacks, rare; 2). Sandy bottom associated species included *Synodus intermedius* (sand diver lizardfish, rare; 1), and an unidentified Synodontidae (lizardfish, rare; 1).

Other observations included one string of *Busycon* sp. (whelk, a gastropod) egg capsules on a sand bottom, and a sea urchin test adjacent to a rock outcrop.

The only evidence of human impact at this site was an aluminum can on a sand bottom adjacent to a small rock outcrop.

The biological assemblages of this site were very similar to those at Station 2, an area of low topographic features not associated with this paleo-shoreline. It is likely that the similar nature of the rock substrates at the two sites, and possibly their proximity, accounts for the similarity in biological composition and density. The sandy areas surveyed at this site are more similar to those at Station 1 (Pox Field) than Station 3 (Wave Field). This is probably because Station 1, like the present area, was surveyed during daylight (0843-1130) rather than at night, as was Station 3 (2356-0159 hours).

Dredge Characterization - Rock Dredge 4 contained the echinoderms *Stylocidaris affinis* (1), ?*Comactinia echinoptera* (1), *Asteroporpa annulata* (2), and *Narcissia trigonaria* (2). It also contained *Stenorhynchus seticornis* (arrow crab), two small bryozoan mounds, one small foliaceous bryozoan colony, coarse sand, fine shell hash, and shell fragments.

Grab Characterization - Grab 5 contained coarse sand and a polychaete, the fireworm, *Hermodice carunculata*.

Fishing - A number of *Rhomboplites aurorubens* (vermilion snapper) and *Centropristis ocyurus* (bank sea bass) were caught at this station.

13.3.1.5 **Station 5** - Shoreline North of Patch Reef Field

Video Survey - An area of hardgrounds apparently representing outcroppings of a paleo-shoreline was surveyed at 29°27.86'N, 87°39.29'W. The survey was conducted on 21 July 1988. The video records total 1.80 hours. The ROV dives (two deployments) took place between 1819 and 2237 hours.

Depth at the base of the shoreline feature was 66.7 m (219 feet). The shallowest hard substrate was at 63.7 m (209 feet), but the majority of observations were made at depths of 64 to 66 meters. Most of the survey area consisted of rugged hard substrates. Some sand was encountered in depressions between outcrops, but no areas of extensive sandy bottom were encountered.

Bottom types noted in video records included:

- Fine sediments - "silt aprons" at base of rock outcrops, fine sediment in small depressions, and fine veneer covering some rock outcrops (references to "silt" are somewhat misleading and may not be accurate in the sedimentologic sense, since a distinction between silt and other fine sediments cannot be easily made using video observation techniques).;

- Coarse flats - sandy bottom between outcrops;
- Rubble flat - small area with cobble-size rubble accumulation ; and
- Rock outcrops - generally along a semi-continuous ridge.

Turbidity at the site was quite high during both ROV deployments. Visibility on the bottom seldom reached two meters. Above 63 m depth, however, the water was clear. Surveys conducted two months later near this site were in much clearer water, illustrating the transitory nature of such conditions.

The turbidity at this site resulted in rather blurry video records. Even with this difficulty, however, the records indicate a fairly diverse assemblage on these rock prominences. Gorgonians and antipatharians dominated the biological assemblage. *Antipathes* sp. A (bushy antipatharians) were common, as was *Cirrhipathes* sp. (coiled sea whips), *Thesea*? spp. and possibly *Nicella guadalupensis* (small orange sea fans). Also frequently observed were small patches of an orange sponge encrusting rock outcrops. Other attached epibenthos included comatulid crinoids, the sea whip *Elisella barbadensis*, white encrusting sponges, *Rhizopsammia manuelensis* (a black, ahermatypic stony coral), a white sea fan, and possibly *Oculina*? sp. (all occasional). Rarely occurring attached epibenthos included solitary white stony coral polyps (4), pennatulaceans (3 sea pens), vase sponges (2), branched and tubular sponges (2), *Neopycnodonte cochlear* (an offshore oyster species which grows in clumps), several species of gorgonian sea fans, two to three species of large globose sponges (one black, and two yellow to white), patches of coralline algae, and *Siphonogorgia agassizii*? (an orange, fruticose alcyonacean).

Associated benthic invertebrates included gorgonocephalids (basket stars; occasional), a species of sea star with pale annulations on each arm (occasional; 5), two species of sea urchins (rare; 1 each), *Stenorhynchus seticornis*, the arrow crab (rare; 1), and a pagurid hermit crab (rare; 1). One string of *Busycon* egg capsules was also seen.

The fish and nekton were fairly diverse at this station (at least 22 species). Most species, however, were only occasionally or rarely observed.

The only frequently encountered species was a small unidentified nektonic species (possibly an atherinid; silverside) that darted in and out of view of the camera. Occasionally observed species included *Holanthias martinicensis* (roughtongue bass; 12), *Rhomboplites aurorubens* (vermilion snapper; 9), *Chaetodon aya* (bank butterflyfish; 7), juvenile *Caranx* sp. (jacks; 5), synodontids (lizardfish; 5), *Liopropoma eukrines* (wrasse bass; 4), *Serranus phoebe* (tattlers; 4), and a species of schooling serranids (several observations of schools).

Rare fish and nekton dominated the species list and included *Micropogonias undulatus* (Atlantic croaker; one school of 4, and 1 solitary), *Pristigenys alta* (short bigeye; 2), *Stenotomus caprinus* (longspine porgy; 3), *Centropristis ocyurus* (bank sea bass; 1 confirmable, and 3 questionable observations), *Rachycentron canadum* (cobia; 2), *Diplectrum bivittatum*? (dwarf sand perch; 1), *Epinephelus nigritus*? (Warsaw grouper?; 1), *Apogon pseudomaculatus* (twospot cardinalfish; 1), an unidentified holocentrid (squirrelfish; 1), *Prionotus* sp. (sea robin; 1), *Peprilus burti* (Gulf butterfish; 1), *Decapterus punctatus*? (round scad; 1), and possibly *Centropristis philadelphica* (rock sea bass; 1). One unidentified squid was also noted.

The only evidence of human interference at this site was one piece of rope or cable on a rock outcrop.

The nature of this paleo-shoreline and the fauna associated with the feature were similar to the patch reefs (Station 6) in some respects. The vertical relief was comparable (around three meters), as was the nature of the bottom. The dominant epifauna were also similar. The patch reefs differed from this area, however, in their horizontal extent and their discontinuous nature. The shoreline appeared to consist of a continuous hard bottom along which relief may have varied, but bottom type remained similar. Between patch reefs, on the other hand, there were extensive areas of coarse sand.

Dredge Characterization - Rock Dredge 5 contained large shell fragments, some cemented together. Rock Dredge 6 contained large shells and fragments, as well as bioclastic material. Organisms in the dredge included a tan branching sponge, the echinoderms, *Asteroporpa annulata* (1), ?*Comactinia echinoptera* (4), and a golden crinoid (possibly *Antedon* sp.; one). Bryozoans included one encrusting form, small branched colonies and one massive branching form. There were also thin antipatharian skeletons, one thick branching antipatharian (similar to precious black coral), the foram *Homotrema rubrum*, an encrusting white sponge, a solitary coral of the family Dendrophyllidae, and an oyster shell (*Neopycnodonte cochlear*).

Grab Characterization - Grab 6 contained coarse sand, fine shell hash and shell fragments.

13.3.1.6 **Station 6** - Patch Reefs (formerly called Boulder Field)

Video Survey - Side-scan records suggested that this site contained hundreds of small, roughly circular patches of hard bottom. Measurements from side-scan and subbottom records indicated that most features were less than 10 meters across and less than 3 m high.

The site was surveyed on three different occasions. Video records made on 22 July 1988 totaled 1.96 hours and were made between 0157 and 0356 hours at 29°26.63'N, 87°41.15'W. On 26 September 1988, records totaled 1.04 hours (between 2010 and 2131 hours). Due to the high turbidity during these visits, it was difficult to determine whether the observations on this dive confirmed interpretations of side-scan records. Visibility during the first visit was nil on the bottom at 75.6 m (248 feet) and less than one meter up to two meters above the bottom, making most video images unclear. The depth at the top of this turbid water layer varied between 73 and 74 m. Video records on 27 September totaled 2.08 hours (0848-1052 hours). The total survey time at the site was 5.08 hours.

Reefs were densely packed, and were isolated structures separated by expanses of coarse shelly sand bottom. During one visit, we encountered 14 reefs in a 60 m diameter area. The bases of the reefs visited on the first and third dives were all slightly below 75 m. Reef tops varied in depth from 72.5-73.5 m. At the location visited on the second dive (26 September), the reefs visited had bases in 72 m of water.

Most reefs averaged slightly over two meters in height. The reef faces were invariably rugged and generally vertical, and very cavernous. Most had overhangs a meter or so above the bottom. The tops were generally three to ten meters in horizontal extent, and in some cases were rather smooth.

Where the bases of reef were visible, "silt aprons" often existed. These consisted of fine sediments that appeared to extend up to 0.5 m up the reef face and the same distance out over the surrounding coarse sand bottom.

The depth of the tops of these reefal features was approximately 3-6 meters below the deepest portion of the shoreline feature surveyed at a site just to the north (Station 5). The shape of these features, their frequency, and their location relative to the paleo-shoreline suggested that they may represent drowned lagoonal patch reefs that existed in a pre-Holocene bay or lagoon, possibly behind a larger reef system. Similar reefs are abundant, for example, in shallow water on the Bermuda Platform (Ginsburg and Schroeder, 1969; Morris et al., 1977). The smaller Bermuda patch reefs are similar in size to those observed in this study. Also on the Bermuda Platform, there exist "cup reefs", or "boilers", which are of similar size and shape, grow in clusters in some places, and are composed primarily of encrusting coralline algae (*Lithothamnium*), vermetid gastropods, and *Millepora* corals.

There was significant vertical variation in the cover and frequency of hard-bottom organisms on the patch reefs. Biotic assemblages on reef tops were dominated by gorgonian and antipatharian corals, and ahermatypic scleractinian (stony) corals. The non-stony coral community included *Antipathes* sp. A (bushy antipatharians; common to abundant), *Cirrhipathes* sp. (common), *Elisella barbadensis* (common), white branching gorgonians (possibly *Muricea* sp.; occasional), *E. funiculina*? (occasional), *Bebryce* sp. (occasional), possibly *Thesea* spp. (occasional), *Nicella* sp. (rare), *E. elongata* (rare), and large orange sea fans (rare). Hard corals were limited to *Rhizopsammia manuelensis* (common, but less abundant than on reef faces). Apparent on some patch reefs were encrusting orange (common) and white (rare) sponges.

Exceptions to the above pattern of reef top community development occurred on reefs with limited reef top area. These reefs were dominated by the hard coral *Rhizopsammia manuelensis* and contained a limited number of species that dominated larger features. These *Rhizopsammia*-dominated areas looked much like those seen on the upper reef face of the other patch reefs, and on the reef faces and tops of the pinnacles farther offshore, all of which were characterized by rugged topography rather than flat, hard-bottom substrates.

The reef faces, or sides, of the patch reefs (Figure 13-5) were dominated by *Rhizopsammia manuelensis* (common on reef faces). The relative frequency of this coral was considerably higher than on the tops of the patch reefs. Other hard corals included well developed *Oculina*? colonies (common), clusters of solitary white scleractinian corals (occasional, but sometimes in large concentrations), *Oxysmilia*-like solitary corals (occasional; 8), *Madrepora carolina* (rare compared to *Oculina*), and orange solitary corals (four were seen in one cluster). Octocorals included *Elisella barbadensis* (common), small branching octocorals (e.g. *Bebryce* and *Thesea*; occasional), white branching gorgonians (occasional), *Nicella* sp. (rare), and one bushy orange sea fan. Antipatharians included *Antipathes* sp. A (bushy form; common) and *Cirrhipathes* sp. (common). Two alcyonarian species, *Nidalia occidentalis* (2), and *Siphonogorgia agassizii* (1), were seen on a reef face. Encrusting sponges were occasionally seen (orange, white and yellow colonies), as well as one large clump of oysters, *Neopycnodonte cochlear*.

The abundance of the hard coral *R. manuelensis* decreased significantly on reef faces with depth as the bottom was approached. Furthermore, cover in general was low on reef faces. Most of the rock area was devoid of conspicuous macrofauna. Cover and diversity decreased with depth and became nearly zero within approximately 0.2 m of the bottom. The base of the reefs (i.e. the lower 0.2 m or so) was rarely occupied. Taxa observed on the lower reef face included solitary hard corals (*Oxysmilia*? sp.), the octocorals *Bebryce* sp., *Nicella* sp., white branching gorgonians, and large orange sea fans, and the antipatharians *Cirrhipathes* sp. and *Antipathes* sp. A (bushy form). All these organisms were considered rare. One probable coralline algae crust was observed at 72.5 m on an overhang.

Sandy habitats between features were characterized by predominantly coarse-grained sediments with considerable rubble and silt accumulations surrounding most features. Rubble was occasionally occupied by small octocorals. Most observations in these habitats were of fish. Few motile benthos were observed (only one hermit crab).

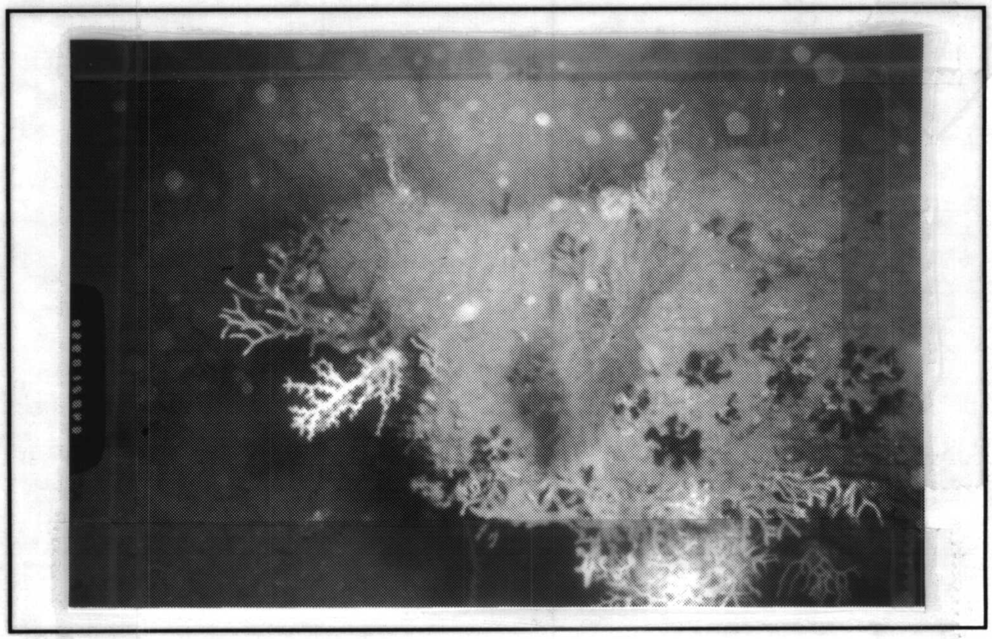


Figure 13-5. Overhang and small portion of reef top of a patch reef at Station 6 (72.2 m). Small black corals are *Rhizopsammia manuelensis*. Other organisms are *Madrepora carolina* (zigzag-shaped white coral colony), *Oculina*? sp. (thin-branched coral), *Antipathes* sp. A (bushy antipatharian, center), and ?*Astrophyton* sp. (a gorgonocephalid basket star, lower right).

Motile epifauna associated with the reef top areas (those areas populated by gorgonians, antipatharians, and hard corals) were relatively few. The fauna included gorgonocephalids (basket stars; 16), unidentified ophiuroids (brittle stars; occasional) on gorgonians, brown basket stars on sea fans (2), an unidentified orange and white sea star (1), and *Scaphella junonia* (a volute gastropod; 1).

Motile epifauna associated with reef face surfaces included gorgonocephalids (basket stars; occasional), three crinoid species (three tan specimens, one gray, and one black, all of which were considered rare), unidentified asteroids (2), and *Diadema antillarum* (black, long-spined sea urchin; 1).

At least 24 species of fish were observed during the patch reef field surveys. The fish fauna associated with reef tops included *Holanthias martinicensis* (roughtongue bass; abundant), *Hemanthias aureorubens* (streamer bass; occasional), *Liopropoma eukrines* (wrasse bass; 3), two species of unidentified Holocentridae (squirrelfish on reef top and reef face; 2); *Chaetodon ocellatus* (spotfin butterflyfish; 2); possibly an undescribed *Anthias* sp. (mentioned by Robins et al. 1986, pg. 144; 2 observed), *Centropristis ocyurus* (bank sea bass; 2), *Apogon pseudomaculatus* (twospot cardinalfish; 1), and *Serranus phoebe* (tattler; 1).

Fish were fairly rare on reef faces, but included *H. martinicensis* (occasional), *Menticirrhus saxatilis*? (whiting; 1) and *Equetus punctatus* or *E. umbrosus* (high hat or cubbyu; 1), *Chaetodon aya* (bank butterflyfish; 1), an orange scorpaenid (scorpionfish; 1), *Pristigenys alta* (short bigeye; 1), and *Liopropoma eukrinès* (wrasse bass; 1).

Fish species associated with sandy bottoms included *Serranus phoebe* (tattlers; 7), *Synodus intermedius* (sand diver lizardfish; 3); unidentified synodontids (lizardfish; 3), *Serranus tabacarius*? (tobaccofish; 1), and *Prionotus* sp. (sea robin; 1).

Water column species included carangids (possibly *Trachurus lathami*, the rough scad; common between 74 and 76 m), unidentified, small, darting, silverside-like fish (Atherinidae) also seen at Station 5 (at times common at), *Peprilus triacanthus* (butterfish, two schools), *Rhomboplites aurorubens* (vermilion snapper; 4), *Peprilus burti* (Gulf butterfish; 3), unidentified sparids (porgies: 2), and *Stenotomus caprinus* (longspine porgy; 1).

There were no indications of human interference noted during any dives at this ROV site.

Grab Characterization - Smith-Mac Grab 7 contained coarse sand, fine shell hash, shell fragments, and a small silt/clay fraction. It was most likely taken from an area of sandy bottom between patch reefs.

13.3.1.7 **Station 7** - Shoreline in Western Portion of Study Area

Video Survey - This portion of the supposed paleo-shoreline was chosen for video reconnaissance because subbottom data indicated an increase in depth of some eight meters over a distance of 100 to 200 m across the feature. It seemed a likely area for considerable hard bottom exposure and benthic community development. Depth in the survey area (29°25.33'N, 87°54.68'W) ranged from 65.8-67.7 m with depth increasing rapidly to the southwest. Two circular areas with diameters approximately 100 m each and separated by 40 m were surveyed. Survey time was from 0758 to 1037 (2.03 hours of video records). Turbidity was high with visibility near the bottom less than two meters.

Hardgrounds were abundant. Hard substrates consisted of areas with rubble on coarse flat bottom, hard surfaces covered with fine sandy veneers, and rock outcrops up to one meter in height. One outcrop had a small "silt apron" around its base, suggesting the accumulation of fine sediments by the feature. Another outcrop had a small, 0.3 m overhang approximately 0.5 m above the bottom. In addition to hardgrounds, three 10-15 cm tall mounds were seen in coarse sediments between rocky features. The nature, extent, and diversity of the biological communities on hardgrounds suggests that burial of these substrates is not a common event, despite their low topography. This does not preclude the possibility that these features may be affected by storm events. The slope of the substrate in this region, however, may prevent the accumulation of sediments.

All hard bottoms had surprisingly well developed gorgonian and antipatharian communities. This development included higher diversity and higher abundances than observed in other areas of comparable topography. This assemblage was dominated by *Antipathes* sp. A (bushy form), *Thesea*? sp., and *Bebryce*? sp. (all common). These organisms were present and occasionally abundant in all areas containing hard substrates. Other species included small white sea fans (occasional), at least two species of white branching gorgonians (occasional; 14), *Cirrhipathes* sp. (occasional), large orange gorgonians (occasional), thick-branched brown gorgonians (occasional), *Nicella guadalupensis* (occasional), very densely branched, bush-shaped coral colonies (occasional), brown, sparsely branched sea fans (*Nicella*? sp., rare), *Elisella barbadensis* (rare; 4), pinnate gorgonians (rare; 3 on one rock outcrop), a thin gorgonian? with very long, non-branching axial rods (rare; two groups), large brown sea fans (rare; 3), and *Nidalia occidentalis* (mushroom-shaped alcyonacean corals; 2). Due to the poor visibility, there were undoubtedly also unrecognized species.

Hard corals were apparently rare, or possibly occasional, on the outcrops along this shoreline. *Rhizopsammia manuelensis* was seen on only five occasions and was not abundant. The only other coral observed was a solitary, white polyp with a diameter of two to three centimeters (*Oxysmilia*? sp.).

The sponge fauna was more diverse here than on any other low topographic features surveyed. The fauna included both orange and white encrusting colonies (occasional), white globose colonies (occasional; 8), orange globose colonies (occasional; 7), pale globose colonies (rare; 4 at one outcrop), orange branched colonies (occasional; 4), and black sponges (rare; 2).

Invertebrates associated with hardgrounds included orange comatulid crinoids with black pinnules (?*Comactinia echinoptera*, occasional; 9), pennatulaceans (sea pens, occasional; 6), gorgonocephalids (basket stars, occasional; 4), tan comatulid crinoids (rare; 1), *Busycon* sp. (rare; 1), a sea star (one Goniasteridae, rare; 2), and *Stenorhynchus seticornis* (arrow crab, rare; 1).

The fish fauna appeared rather depauperate at this site. Species included *Centropristis ocyurus* (bank sea bass, occasional; 13), *Serranus phoebe* (tattler, occasional; 5), *Holanthias martinicensis* (roughtongue bass, rare; 2), another Serranidae (sea bass, rare; 2), *Pristigenys alta* (short bigeye, rare; 2), *Apogon* sp. (cardinalfish, rare; at least 2 in a depression), possibly *Microspathodon chrysurus* (yellowtail damselfish, rare; 2), a Sparidae (porgy, rare; 2), *Chromis enchrysurus* (yellowtail reeffish, rare; 1), *Liopropoma eukrines* (wrasse bass, rare; 1), another Labridae (wrasse, rare; 1), and a Muraenidae (moray eel, in a burrow, rare; 1).

Comparison of data from this site with those from other sites of comparable topography suggests not only a relatively high diversity here, but also lower abundances of the same species dominant at other sites. In particular, very few crinoids, only four *Elisella barbadensis* colonies, and two *P. alta* (short bigeyes) were observed at this survey site. Along with *Thesea* sp. (Paramuriceidae), and the antipatharians *Antipathes* sp. A and *Cirrhipathes* sp., these species were conspicuous at other outcrops along paleo-shorelines and on low topographic features. Interestingly, where *P. alta* were seen at this site, they co-occurred with *Chromis enchrysurus*, the yellowtail reeffish, just as they did on other low topographic features.

The only sign of human interference at this station was a (metal?) bar approximately 0.5 m long and two to three centimeters in diameter lying on a rubble covered bottom.

Dredge Characterization - Rock Dredges 7 and 8 were taken at this site. Both contained diverse collections. Rock Dredge 7 contained the gastropods *Scaphella junonia* (two, one live), *Polystira* sp. (live), *Terebra floridana* (live), and *Cassus* sp. (fragment), the pelecypods *Astropecten nitidus*, *Plicatula gibbosa*? (attached to *Oculina diffusa* fragment), *Ventricolaria rigida*, *Ventricolaria rugatina* , *Eucrassatella speciosa* (live), *Lyropecten nodosus*, and other Pectinidae. It also contained the hermit crab *Dardanus insignis* (in *Polystira* sp.), *Ogcocephalus nasutus* (shortnose batfish), and a small, purple globose sponge.

The coral fragments in Dredge 7 were particularly interesting. They consisted of the telestacean *Telesto flavula*? (live), fragments of *Oculina diffusa* (dead), the solitary Caryophylliidae *Paracyathus pulchellus* (one live, five dead), and the agariciid *Agaricia fragilis* (dead). The presence of *Telesto* suggests that some of the low cover observed on hard substrates may consist of this species. The occurrence of *Oculina* and *P. pulchellus* in sediments supports our identification of the species on reef substrates. The occurrence of *A. fragilis*, a hermatypic (reef-building) species found on actively growing coral reefs suggests a potential relationship between hard substrata in the study region and reef-building corals.

Rock Dredge 8 contained the echinoderm *Linkia nodosa* Perrier, *Brissopsis* sp., and an echinoid test. It also contained a convoluted tan sponge, a golfball-size mass of serpulid worms, branching bryozoans, branching hydroids, the gastropod *Phalium* sp. (fragment), the pelecypods *Ventricolaria rigida* (three live, 17 valves) and *Amygdalum sagittatum*?, a platyhelminth, the crab *Rochinia tanneri*, and a number of colonies of the paramuriceid coral *Bebryce cinerea*. It is likely that *Bebryce cinerea* was among the species making up the low understory of many hard substrates in the study area.

Grab Characterization - Grab 8 contained coarse sand, fine shell hash, shell fragments, and a small silt/clay fraction.

13.3.1.8 **Station 8** - West Reefs

Video Survey - Station 8 was located in an area containing reefs of major topographic relief in the western portion of the study area seaward of the paleo-shoreline. The crests of the shallowest reefs were at depths of approximately 63 m (nearly coincident with, but shallower than, the depth of the nearby paleo-shoreline) and their bases were at approximately 75 m. Some have rugged reef tops while others were decidedly flat-topped. Individual reefs may be over 100 m across. At least one formation existed that appeared to contain several separate reefs crowded together. This formation is over 500 m long. All reefs seemed to contain rugged, and in some places, nearly vertical reef faces. They were surrounded by smaller outcrops, rubble, and expanses of coarse-grained sediments.

On 22 July 1988, an attempt was made to survey a large, flat-topped feature in this study area, and the ship was anchored at 29°24.12'N, 87°58.94'W. A large reef was not encountered during this survey, but a series of smaller outcrops up to 1m in relief were surveyed. These were presumably close to larger features. The visibility during this dive was less than 1 m. After a 1.02 hour survey, a critical component of the ROV system failed which forced a delay in the completion of the survey.

On 23 September 1988, the survey was resumed. One of the flat-topped features was located at 29°24.02'N, 87°59.04'W and a video survey was begun was begun at 1328. The survey was completed at 1654. Video records during the second cruise totaled 3.17 hours.

The tops of the features (Figures 13-6 and 13-7) were inhabited by large populations of octocorals, antipatharians, and crinoids. The octocorals were dominated by *Bebryce cinerea*?, which covered much of the bottom on the flat reef tops. Larger octocorals were also present and included several species of large red or white sea fans, *Nicella* sp. (a smaller sea fan), *Elisella barbadensis* and *E. elongata* (sea whips), and possibly *Scleracis guadalupensis* (a small red sea fan). Approximately four comatulid crinoid species were present on the reef flats (one orange and black, one yellow, and one orange, all common; and one gray, occasional). Antipatharians included *Cirrhipathes* sp. and *Antipathes* sp. A (both common). Also

Figure 13-6. Reef flat community at 66.1 m on one portion of flat-topped reef at Station 8, showing dominant crinoid species (orange arms with black pinnules) and a low-growing octocoral (possibly *Bebryce cinerea*).

Figure 13-7. Another area on top of reef at Station 8, at 65.5 m, showing several species of gorgonians. Low-growing colonies may be *Bebryce cinerea*. Colonies in foreground and on right are yellow. Colony left of center may be *Nicella guadalupensis*.

common on the reef flat was gorgonocephalids (white basket stars), which were attached to large octocorals and antipatharians. Sponges were rare on the reef tops. Hard corals occurred on the reef flat, but populations appeared to be inhibited by accumulations of sediment. Only *Rhizopsammia manuelensis* was observed (occasional). Coralline algae were rare compared to abundances observed on similar flat-topped features at other stations (only three observations, and these were isolated patches 1-4 cm across). Coralline algae crusts were observed only on rugged surfaces, where sediment accumulation did not occur. The maximum depth of occurrence was 70 m.

Sediment accumulations on these reef tops distinguished them from other flat-topped reefs in the study area, such as those at the 40-Fathom Fishing Grounds (Station 13 below), where countless crevices and holes in the reef flat were occupied by benthic invertebrates. Distinguishing characteristics at Station 8 were low diversity on the reef top, limited coralline algae, dominance by a low-growing octocoral (*Bebryce cinerea*), and an unusually large population of fish over the reef top and over the reef shoulder at the top of the reef face.

The shallowest depth recorded on the reef top was 63.4 m. The community changed abruptly below approximately 66 m, where *Bebryce*, the dominant octocoral cover, and sediment accumulations disappeared. Sediment accumulations probably decreased due to the change in slope at this depth, where the nearly vertical reef face began.

Reef face communities were distinctly different than those on the top reefs. They started at 65.8-66.4 m and were of a higher diversity and lower density than top reef assemblages. The reef face (Figure 13-8) was dominated by ahermatypic scleractinian corals (especially *Rhizopsammia manuelensis* and *Oculina*? sp., but also including clusters of white ahermatypic corals observed in higher frequency on other large reefs and pinnacles). Reef faces also contained antipatharians (*Cirrhipathes* sp. and *Antipathes* sp. A), octocorals (the same species as the top reef, with the exception of *Bebryce*), alcyonarian corals (*Siphonogorgia agassizii*; rare), and comatulid crinoids. Some encrusting and upright sponges were present, but fewer than observed on the reefs at the 40 Fathom Fishing Grounds.

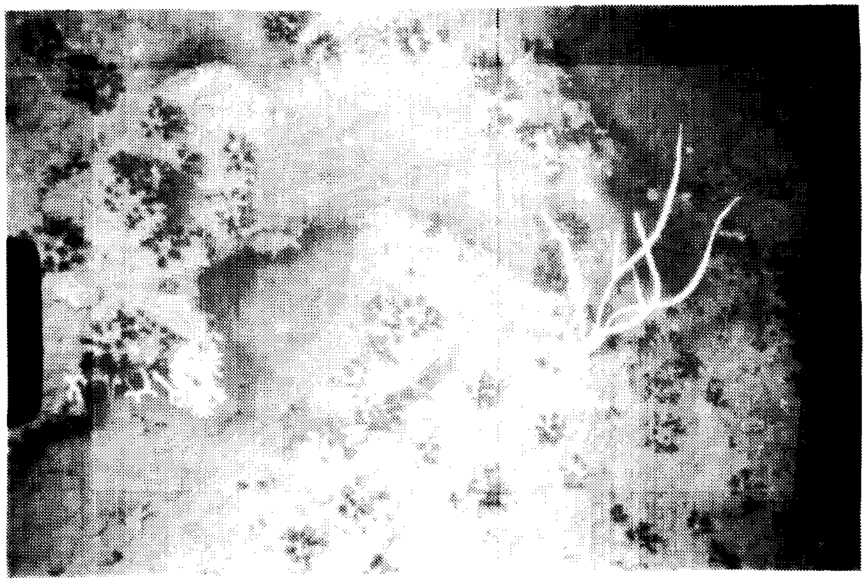


Figure 13-8. Reef face at Station 8, at 68.9 m, showing *Rhizopsammia manuelensis* (black corals), *Elisella elongata* (branched sea whip), *Antipathes* sp. A (bushy antipatharian causing blur in upper center of photo), *Oculina*? sp. (white branching coral, left center), and *Liopropoma eukrines* (wrasse bass, center).

Surprisingly, *Madrepora carolina*, an ahermatypic colonial coral found on other large reefs, and even smaller reefs at Station 9 (two kilometers to the southwest), was not encountered at Station 8. Other reef face organisms included the sea urchins *Stylocidaris affinis* (occasional), *Diadema antillarum* (occasional), *Eucidaris tribuloides* (rare), an orange sea star (1), a Goniasteridae sea star (1), *Stenorhynchus seticornis* (arrow crab; rare), and *Scaphella* sp. (volute, a gastropod; 1).

The lower meter or so of reef face contained a depauperate epibenthic assemblage. This area was probably affected intermittently by resuspended bottom sediments. An apron of fine sediment surrounding the larger reefal features suggested at least temporary accumulation of fine resuspended material. This apron was 1-2 m wide.

Invertebrates observed in the sandy habitats surrounding the large reefs included unidentified orange hermit crabs (occasional), and one pennatulacean (sea pen). On rubble and small rock outcrops in this habitat, a low diversity assemblage of attached invertebrates included *Nicella* sp. and other sea fans, antipatharians (*Cirrhipathes* sp. and *Antipathes* sp. A), and crinoids (at least three species). One rubble mound was habitat for two octopi approximately 20 cm across.

The fish density at this station may have been the highest of any observed in the main study area (activity at the 40-Fathom Fishing Grounds may have been lower due to the time of the survey, however). At least 22 species were recorded. The top and shoulders of the reefs were occupied by dense schools consisting of a number of species. Many appeared to be juveniles of dominant species elsewhere on the features (similar to the pinnacles of the West Addition at Stations 25 and 26). Dominant species included *Holanthias martinicensis* (the roughtongue bass; abundant here, common at other depths), *Rhomboplites aurorubens* (vermilion snapper; common at all depths) and *Hemanthias aureorubens* (the streamer bass; common here, occasional at other depths). *Chaetodon aya* (occasional) and one *Holacanthus bermudensis* (blue angelfish) were seen within these schools. The schools contained mostly small individuals (less than 20 cm). *Liopropoma eukrines* (wrasse bass) and *Equetus umbrosus* (cubbyu) were occasionally seen at all depths. *Serranus phoebe* (tattler) and *Centropristis ocyurus* (bank sea bass) were occasional at reef depths, but common in sandy habitats surrounding the structures. *Pristigenys alta* (short bigeye) was occasionally seen on the reef, but was more frequently observed on low relief reefs in the area. This was similar to observations at other low relief stations surveyed earlier in the study. Schooling *Seriola dumerili* (amberjack) and *Decapterus*? (scad) were occasional, mostly seen over the reef flat or shoulder. Sparids (porgies; occasional) occurred at all depths. *Chromis enchrysurus* (yellowtail reeffish) was occasionally seen on the reef flats and reef face. Scorpaenids (scorpionfish; 3) were only seen on ledges on the reef face. *Chaetodon ocellatus* (spotfin butterflyfish; 2) was also seen only on the reef face. *Chaetodon sedentarius* (reef butterfly; 1) was observed near the base of the reef. One *Gymnothorax moringa* (spotted moray) was in a hole on the reef face. Observations of *Synodus intermedius* (sanddiver lizardfish; occasional) and unidentified flounder (2) were limited to sandy habitats surrounding the reefs. A large grouper or snapper was seen near the reef face. One *Lutjanus campechanus* (red snapper) was seen at 71 m.

The only signs of human intrusion at this location were two cables or ropes draped over small reefs and two apparent anchor drags in the sand (one may have been caused by our ship).

Grab Characterization - Grabs 11 contained *Oculina*? on a shell fragment and Grab 12 contained fine to medium sand, some silt and clay, encrusting bryozoans, and ahermatypic corals. The corals included *Paracyathus pulchellus* and *Rhizopsammia manuelensis*.

13.3.1.9 **Station 9** - West Patch Reef Field

Video Survey - Approximately 2 km southwest of Station 8, an area was surveyed that appeared on side-scan records to be similar to, but less extensive than, the Patch Reef Field (Station 6). Reefs seemed to be of moderate topographic relief, but areally restricted. Video surveys were conducted on 23 September 1988. A total of 1.85 hours of bottom observations were made. The surveys were conducted between 1951 and 2314 hours.

The maximum bottom depth was 76 m and consisted of a mixture of coarse grained sediments containing shell hash, oyster shells, and silt. The largest feature had a base depth of 75 m and crested near 71.5 m. No features had flat reef tops. Furthermore, features at this site were not similar to reefs of the Patch Reef Field. Whereas the patch reefs were fairly consistent in size, shape, vertical relief, surface texture, etc., features at this site ranged from very small, nearly buried rock outcrops to 3m tall reefs. At Station 6, few low features were encountered. Though features were numerous at Station 9, they appeared to be spaced more randomly than at Station 6, with intermediate sediments containing more reefal debris. Vertical reef faces were rare, and reef tops were irregular. These features could be the remains of poorly developed patch reefs (i.e., poorly developed when compared to those of Station 6). Silt aprons were observed near the bases of some small features.

Epifauna on these reefs consisted of species observed on other features, but frequency and diversity differed markedly. The assemblage was more diverse than that on smaller or isolated low topographic features, and less diverse that that on larger features. Species composition was most similar to that at nearby Station 8 (see above), but abundances were lower for most species due to limited substrate. Most outcrops were dominated by gorgonian corals, but only one species was considered abundant (*Bebryce cinerea?*, the same species that dominated the reef flat at Station 8). A few other gorgonian species were also seen including *Elisella barbadensis*, *E. elongata*, a white, sparsely branched fan-type gorgonian (all common), and *Nicella?* sp.(occasional). Antipatharians included *Cirrhipathes* sp. and *Antipathes* sp. A (both occasional).

Among the stony corals, *Rhizopsammia manuelensis* was the most abundant, especially on larger features. It was, however, also abundant on some small features. White ahermatypic corals were patchily distributed, were frequently observed, and were abundant on a few features, especially on reef tops and overhangs which occurred on some larger features. *Oculina?* sp. and *Madrepora carolina* were occasionally observed, and like other corals were more abundant on larger features. *Oculina?* sp. was the more abundant of the two.

Associated invertebrates included gorgonocephalids (basket star, common), crinoids (occasional, one? species), hermit crabs (occasional on sand, rare on reefs), shrimp (some gravid, crawling over reefs) and oyster shells (occasional; 6 observations), anemones or large solitary corals (occasional; 4), large squids on the bottom (occasional; 4), *Stenorhynchus seticornis* (arrow crab; 3), two yellow/orange ball shaped sponges (rare), *Scyllarides nodifer* (a shovelnose lobster; 1), goniasterid sea star (1), an unidentified red sea star (1), and an unidentified white sea star with very long arms (1). Shells occupied by hermit crabs included several whelk shells (including *Busycon* sp.), *Scaphander punctostriatus*, and *Scaphella* sp.

Noteworthy observations included the limited crinoid diversity, limited sponge fauna (only two colonies were found), the occurrence of a large oyster bed adjacent to a reef, and the occurrence of *Siphonogorgia agassizii*, an orange alcyonarian. No coralline algae crusts were found. The oyster bed was particularly interesting for several reasons. First, it was the only extensive bed observed isolated from major rocky features. Furthermore, death for some animals may have been recent, since many shells had shiny interiors. This suggests that the oyster bed is an active one. In addition, associated invertebrate assemblages were considerable and active on the bed. Observations included attached stony corals and octocoral fans, arrow crabs, a scyllarid lobster, at least two species of sea stars, and gravid shrimp crawling over the bed.

Aside from scad (*Decapterus*? sp.), no fish species were considered abundant around these features. Reef associated species were generally those observed at other sites, particularly the larger reefs. Observations on rocky features included unidentified sparids (porgies, occasional), *Pristigenys alta* (short bigeye; occasional), orange scorpaenids (scorpionfish; occasional), *Holanthias martinicensis* (roughtongue bass; occasional, most inactive and within crevices and holes in the features), *Equetus umbrosus* (cubbyu; 3), *Rhomboplites aurorubens* (vermilion snapper; 3), holocentrids (squirrelfish; 2), apogonids (cardinalfish; 2), unidentified groupers (2), *Chaetodon aya* (bank butterflyfish; one pair), *Lutjanus campechanus* (red snapper; 2), *Centropristis ocyurus* (bank sea bass; 2), *Equetus punctatus* (high hat; 1), one unidentified lutjanid? (snapper), and *Equetus* sp. (drum; 1). Observations in predominantly sandy habitats included Synodontidae lizardfish (common), and *Prionotus* sp. (sea robins, occasional). Water column observations (i.e. no apparent association with particular bottom habitats) included *Seriola dumerili* (occasional; 5), *Peprilus burti* (Gulf butterfish; 2), and *Diapterus olisthostomus* (Irish pompano; 1).

During the survey, no indications of human interference were observed.

Dredge Characterization - Dredges 9 and 10 contained bioclastic material, shell hash, cemented shell and coral debris. Corals included *Madracis* cf. *brueggemanni* (branch fragments) with *Paracyathus pulchellus* attached.

Grab Characterization - Grab 14 contained coarse sand, fine shell hash, and a minor silt/clay fraction.

13.3.1.10 **Station 10** - Western Portion of Patch Reef Field

Video Survey - This area of patch reefs was approximately 6 km southwest of the patch reef field at Station 6, but appeared to be more or less a continuation of the same field. A reconnaissance survey was conducted on 24 September 1988 between 0503 and 0657 hours. Videotape records total 1.85 hours.

The deepest bottom depth encountered was 73.7 m. The survey area had a large number of low relief features, most between 0.5 and 1 m high. The largest and shallowest crested at 67.5 m and was 3.8 m tall. The few features taller than 2 m had bases in depths shallower than 72 m. Beyond this depth, there were more features of low relief and more coarse sand bottom. Base depths varied from 70 to 74 m. Surrounding sediments near hard bottoms appeared to contain higher levels of silt than areas away from the reefs, and the bases of reefal structures were frequently covered by "silt aprons" extending upward less than 0.5 m. These aprons were narrower than 0.5 m. They may be the result of accumulation by the reefs of resuspended fine sediments in a transitive nepheloid layer.

During the survey a distinct nepheloid layer existed. At the beginning of the survey, the layer was approximately 4 m thick and turbidity was very high. Visibility was less than one meter. Two hours later, the nepheloid layer was 2-3 meters thick, but turbidity was much lower near the bottom. Visibility was approximately three meters. However, based on the density of epifaunal assemblages, the diversity of the assemblage, and the size of individual organisms, the nepheloid layer did not appear to have a strong controlling influence in this area. It is possible that the high turbidity observed during the ROV survey may not have reflected average conditions in the area.

Benthic biological communities and fish populations were composed of species found on other hard-bottom structures, particularly those on high relief features. Epibenthic assemblages were fairly dense, especially on features of highest relief, but densities were not as high as those on larger features in the area. This suggested that the relatively low relief of these features compared to larger structures may limit community development.

Rocky features in the survey site were occupied by many of the same types of organisms found on the pinnacles 10 km to the south. Like the patch reefs at Station 6, most features, especially those with relief greater than 0.5 m, were dominated by *Rhizopsammia manuelensis*. This coral was abundant in places, but was considered common in general. Other stony corals included *Oculina*? sp. (common, especially on overhangs on larger reefs), and *Madrepora carolina* (occasional). Some *Oculina* colonies were fairly large. *Madrepora* colonies were not as large as those seen on larger reefs elsewhere in the study area.

Gorgonians, antipatharians, and comatulid crinoids were present on virtually all outcrops and dominated those of low relief. Virtually all hard substrates had epifaunal assemblages consisting of some of these organisms, suggesting rare burial of these surfaces. The gorgonian fauna was more diverse than observed on features of low relief elsewhere in the study area. Some species included *Elisella elongata* and *E. barbadensis* sea whips (both common), *Nicella* sp. sea fans (common), brown sea fans (common), *Bebryce*? (common), large orange sea fans (occasional), and probably unrecognized species. Antipatharians included *Cirrhipathes* sp. coiled sea whips (common), *Antipathes* sp. A (bushy; common), and *Antipathes* sp. B (sparsely branched; occasional). At least four species of comatulid crinoids were seen. Ranked in order of abundance they were ?*Comactinia echinoptera*? (orange and black; common), a black species (occasional), an orange species (occasional), and a gray species (rare). Two colonies of the alcyonarian *Siphonogorgia agassizii* were seen on the face of one reef at 70 and 71 m. Coralline algae may have been absent, but two questionable observations suggested a minimal presence (maximum depth 71 m).

Encrusting sponges were frequently observed on these features, but no upright colonies were seen. Encrusting colonies included orange and white sponges (both common), and yellow sponges (occasional).

Feature-associated invertebrates included gorgonocephalids (basket stars; common), white brittle stars on gorgonians (occasional), shrimp (one group of 10-20 crawling over a reef), *Asteroporpa annulata* (an annulated brittle star which clings to gorgonians and antipatharians; at least 1), a goniasterid sea star (1), a large octopus (1), and *Diadema antillarum* (black sea urchin; 1).

The fish fauna was fairly diverse, but densities were not as high as observed on larger features in the study area. Species associated with reefal features included *Holanthias martinicensis* (common, many inactive in crevices), *Pristigenys alta* (short bigeye; 4), *Chaetodon aya* (bank butterflyfish; 3), an unidentified blotchy holocentrid? (squirrelfish?; 3), orange Scorpaenidae (scorpionfish; 2), *Rhomboplites aurorubens* (vermilion snapper; 1), *Equetus umbrosus* (cubbyu; 1), *Centropristis ocyurus* (bank sea bass; 1), and one apogonid (cardinalfish). Species in sandy habitats were *Synodus intermedius* (sanddiver lizardfish; 3), *Serranus phoebe* (tattler; 3), and *Ogcocephalus* sp. (batfish; 1). Water column species included *Decapterus*? sp. (scad; occasional), Atherinidae (silversides; occasional), and what appeared to be a small *Thunnus thynnus* (0.5 m long bluefin tuna, a rare species).

A number of discarded fishing lines were seen wrapped around reef features in the survey area. These had no apparent effect on epifaunal assemblages and seemed to be immobilized by the reefs. No other signs of human interference were observed.

Dredge Characterization - Rock Dredge 11 contained recent and relict shell fragments, bioclastic nodules and a mud lump.

Grab Characterization - Grab 15 contained coarse sand, some silt and clay, and fine shell hash.

13.3.1.11 **Station 11** - Footprints

Video Survey - This site was chosen because the side-scan records indicated a number of anomalies resembling depressions in the bottom on the order of 10 m across and deep enough to produce side-scan "shadows" in their centers. They were called "footprints" because they appeared to be oblong rather than circular. The survey was conducted on 24 September 1988 between 0851 and 0955 hours. Video records total 1.04 hours.

The bottom depth during the survey varied negligibly from 95.5 m. Turbidity was fairly high and visibility was generally less than one meter. The bottom appeared to consist of a mixture of medium-grained sand and finer sediments. Shell hash was rare. Bioturbation was moderate. Small burrows were abundant and one larger burrow approximately 8 cm across was observed. Mounds and small depressions were occasionally seen. Four coiled sea whips (*Cirrhipathes* sp.) were seen protruding through the sand, but no hard bottom was detected at this site. Though one serranid (?*Centropristis ocyurus*), one flounder, and one detached crab leg were seen, virtually no biological activity was detected on the seafloor. This may have been partly due to the fact that the survey took place during the day (between 0851 and 0954 hours).

We did not detect the unusual features noted on side-scan records during this survey. Also, there were no indications of human activities in the area.

Dredge Characterization - Dredge 12 contained two rock fragments, a bioclastic nodule, and whole and broken shells.

13.3.1.12 **Station 12** - Snake Ridge

Video Survey - Side-scan records from this site suggested a sinuous ridge nearly 4 km long running northeast-southwest, apparently having highly reflective sediments and exposed, patchy hard bottom on the seaward side, and less reflective sediments landward. Depth recordings made during 88-MMS-ROV-2 suggested that the ridge appearance was probably caused by a change in slope that occurs coincidentally with the feature. That is, depth increases rapidly as one crosses the feature from the north side.

The survey site was located on this steep slope. The survey was conducted on 24 September 1988 between 1346 and 1433 hours. Video records total 0.78 hours. The deepest survey depth was 118 m and occurred at the south boundary of the station. The shallowest depth was 109 m 50-75 m to the north (suggesting an 11-16° slope). Depth records showed that the top of this slope was at approximately 102 m and indicated a seaward slope of over 10°. Unfortunately, we were not able to locate the ship over this depth and did not survey the top of the slope.

On the south side of the ridge at Station 12, sediments were medium to coarse with abundant rubble and shell hash. A number of fish burrows were encountered (four averaging 20 cm across). Observations in soft bottom habitats included *Serranus phoebe* (tattler; 2), an orange Scorpaenidae (scorpionfish; 1), flounder (1), sea star (1), and a gray sea whip (1).

Epifauna on rubble was sparse, but included attached solitary white corals (*Paracyathus pulchellus*?; occasional), an orange solitary coral (1), and small orange (2) and white (1) gorgonian sea fans.

One small rock outcrop (<0.5 m relief) was seen at 116 m, which contained one or two short bigeyes (*Pristigenys alta*), small orange gorgonian sea fans, and *Paracyathus*? sp. ahermatypic corals. No *Rhizopsammia*, *Madrepora*, or *Oculina* corals were found on any rubble or on the outcrop.

Water column observations included one possible Haemulidae (grunt) and one unidentified large fish.

No indications of human interference were observed.

Dredge Characterization - Dredge 13 contained two bioclastic nodules. Dredge 14 contained clay, shells, and rock fragments.

Grab Characterization - Grab 16 contained medium sand, and fine shell fragments.

13.3.1.13 **Station 13** - 40 Fathom Fishing Grounds (Eastern Reconnaissance Site)

Video Survey - The reefs in this area had base depths of 73 to 79 m and crest at various depths depending on the extent of reef development. The shallowest reef visited (this station) crested at 62.5 m and was 15 m tall with an extensive flat reef on top and a number of sand flats. This and other accordant reefs (i.e., same crest depths), namely those surveyed at Station 8 forty kilometers to the west, all appeared to contain flat reef tops. They also appeared to be the largest reefs, by base area, of the region. Those with crests below approximately 63 m had more rugged topography on their tops and were generally smaller in total area.

Reconnaissance of this reef took place on 24 September (2045-2334 hours) and 25-26 September 1988 (2019-0042 hours). Approximately 5.5 hours of video tape was recorded. Surveys of reef top communities occupied approximately 2.7 hours. Surveys of reef face, reef base, and surrounding rocky and sandy habitats occupied the remaining time.

Reef flat communities (between 62.5 and 67 m) on these features were the most highly developed in the study area (Figures 13-9 through 13-11). Very little hard-bottom space was vacant. The community was a lush assemblage of gorgonian corals, antipatharians, many types of sponges, several species of crinoids, bryozoans, holothurians, sea urchins, basket stars

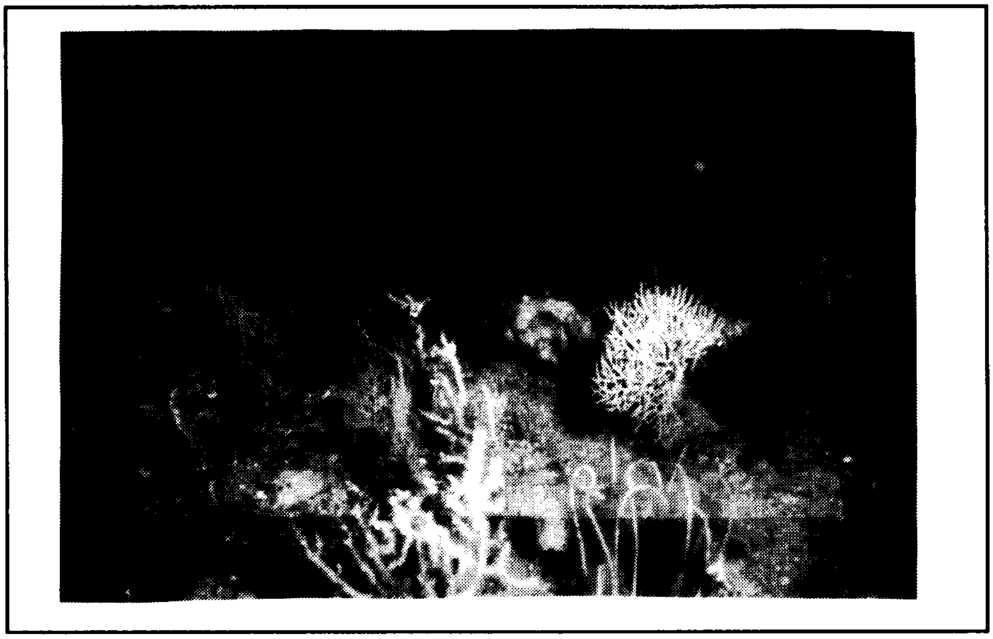


Figure 13-9. Reef flat at Station 13 (40-Fathom Fishing Grounds; 64.6 m), showing several species of octocorals, crinoids, and knobby sponge (center).

Figure 13-10. Reef flat at Station 13, at 64.3 m, showing *Elisella* sp. (sea whips), a grey comatulid crinoid (foreground), *Nicella* sp. (sea fan in foreground), and other gorgonian coral colonies.

Figure 13-11. Reef flat at Station 13 (63.7 m), showing *Pristigenys alta* (short bigeye), coralline algae crusts, globose sponges (left center), comatulid crinoids, *Elisella* sp. (sea whips), *Nicella* sp. (small sea fans, one at base of sea whip in center), and white vase sponge (background).

(gorgonocephalids), patches of coralline algae, and fish. The most abundant benthic organisms on reef flats were small brown sea fans (possibly *Bebryce cinerea*), *Nicella guadalupensis* (small red sea fan), small beige sea fans, and a gray comatulid crinoid (all abundant). Common benthic organisms, listed roughly in decreasing order of abundance, included coralline algae, an orange comatulid crinoid, purple sponge colonies (low growing), *Elisella barbadensis* (sea whips), maroon sponges, small white sea fans, large orange sea fans (some 60 cm tall), and large white vase sponges (largest approximately 30 cm across). A larger number of species were considered occasional, including *Cirrhipathes* (coiled sea whips), large globose sponges (tan, often topped with sediments), smaller globose sponges (white), branched orange sponges, both yellow and black comatulid crinoids, sparse white gorgonian fans, *Elisella elongata* (sea whips), white upright branching sponges, large bryozoan colonies, ?*Narcissia trigonaria* (an asteroid), an orange holothuroid with maroon markings, and white ophiuroids (usually wrapped around gorgonians). Many species were considered rare on reef flats (generally observed one or two times), including an unidentified asteroid, two species of tan comatulids, an octopus, *Stylocidaris affinis* (a sea urchin), species of globose sponges (yellow, orange, dark gray, and black), *Peyssonnelia* sp. (a red alga), purple branched gorgonians, ?*Eucidaris tribuloides* (a sea urchin), *Neopycnodonte cochlear* (oyster clumps attached to gorgonian skeleton), shrimp (2; one gravid), unidentified hermit crabs, *Antipathes* sp. (one colony), *Madrepora carolina* (1), an orange and black comatulid (1) that dominated some other reefs, and an unidentified brachyuran. No stony corals were observed on the reef top. Furthermore, with the exception of *Cirrhipathes*, only one antipatharian (*Antipathes* sp.) was seen.

The fish fauna of the reef flat was diverse and overall population very high. The fauna was dominated by a huge population of *Holanthias martinicensis* (roughtongue bass; abundant). Nearly all available crevices were occupied during our night survey by resting fish, most of which were *H. martinicensis*. At least 23 other species were observed in reef flat habitats, including *Chaetodon aya* (bank butterflyfish; common; 26), *Chaetodon sedentarius* (reef butterflyfish; common; 18), *Pristigenys alta* (short bigeyes; common), Scorpaenidae (an orange scorpionfish; occasional; 14), *Rhomboplites aurorubens* (vermilion snapper; occasional, but many were probably in crevices and uncounted), *Equetus umbrosus* (cubbyu; occasional; 8), *Chromis enchrysurus* (yellowtail reeffish; occasional; 7); *Apogon pseudomaculatus* (twospot cardinalfish; occasional; 6), *Ogcocephalus* sp. (batfish; occasional; 5), *Hemanthias aureorubens* (streamer bass; occasional, but many in crevices), *Holocentrus ascensionis* (squirrelfish; occasional; 4), *Serranus phoebe* (tattler; 3), Muraenidae (eel; 3), *Seriola dumerili* (greater amberjack; 3), *Sphoeroides spengleri* (bandtail puffer; 1), *Lactophrys polygonia* (honeycomb cowfish; possibly the first record for the Gulf of Mexico; 1), flounder (1), Carangidae (possibly *Selar crumenophthalmus*, bigeye scad; 1), *Holocentrus bullisi* (deepwater squirrelfish; 1), *Lutjanus campechanus* (red snapper; 1), *Ophidion holbrooki* (bank cusk eel; 1), *Scorpaena plumieri*? (spotted scorpionfish; 1), *Prionotus* sp. (sea robin; 1), Holocentridae (1), and Tetraodontidae (puffer; 1),

Notably, few ahermatypic scleractinian corals were seen on reef flats. They may be affected by sediments that have accumulated on the reefs. On the sides and edges of the reef, however, stony corals dominated the assemblage. The hard coral fauna on reef faces (69-77.5 m) was dominated by *Rhizopsammia manuelensis* (common). *Oculina*? sp. and ahermatypic solitary corals were also seen (occasional), but mostly on and under overhangs. *Madrepora carolina* was observed on a nearby reef, but could not be confirmed on the face of the largest reef. Coralline algae crusts were common on the upper reef face, but decreased in number with depth. They were observed as very limited crusts at 78 m at this station, which was the deepest observation of coralline algae in the study area. Other conspicuous benthic organisms included orange encrusting sponges (common), *Nicella guadalupensis* (occasional), *Elisella barbadensis* (sea whips; occasional), two species of *Antipathes* (antipatharians; occasional), a gray comatulid (occasional), ?*Comactinia echinoptera* (an orange and black comatulid; occasional), *Diadema antillarum* (occasional), ?*Narcissia trigonaria* (sea star; occasional), tan long-spined sea urchins (occasional), white and yellow encrusting sponges (occasional), octopi (2), shrimp (2), and a tan comatulid crinoid (1).

On horizontal surfaces, which were scattered throughout the depth range of the reef face, organisms that dominated reef flat assemblages were found (e.g. large orange gorgonian sea fans, other gorgonian corals, *Elisella* spp., and *Cirrhipathes* sp.). These organisms were less abundant or even absent on vertical surfaces at these depths. This reflects the strong influence of habitat structure on the competitive success of various types of benthic organisms.

Fish assemblages on reef faces appeared depauperate during the survey. The only species observed were *Holanthias martinicensis* (occasional), and *Equetus umbrosus* (rare). It is likely that fish that might have been present in this area during the daytime were in crevices on the reef flat during the night (e.g. vermilion snappers, streamer bass, and other species).

Small, low relief reefs surrounded many of the larger reefs in the area. These features generally had less than two meters relief and were less than five meters in horizontal extent. Some consisted of what appeared to be rubble that may have broken off larger features. Regardless of origin, these surfaces provided habitat for a relatively rich assemblage of benthic organisms and fish.

The community on these features was composed of both reef flat and reef face organisms. For example, organisms characteristic of the reef face included the ahermatypic stony corals *Madrepora carolina* (common), *Rhizopsammia manuelensis* (occasional), and ?*Oxysmilia* (a solitary coral; 2), and orange encrusting sponges. Gorgonian corals and sponges more often found on the reef flat included ?*Bebryce cinerea* (abundant), *Elisella barbadensis* (common), *Nicella guadalupensis* (common), large yellow sea fans (2), a large white gorgonian (1), and tube sponges. Additionally, two species of *Antipathes* and *Cirrhipathes* sp. were considered common. Two species of comatulid crinoids were considered common (one black, one orange) and two were considered occasional (one orange and black, one yellow). Associated invertebrates included shrimp (3), *Stylocidaris affinis* (sea urchin; 1), and *Stenorhynchus seticornis* (arrow crab; 1). Fish associated with these features included *H. martinicensis* (abundant), *Equetus umbrosus* (4), orange Scorpaenidae (scorpionfish; 2), *Seriola dumerili* (1), *Chaetodon aya* (1), *C. sedentarius* (1), *Pristigenys alta* (1), *Decapterus* sp. (1), and *Chilomycterus antillarum* (web burrfish; 1).

The structure of the reef faces at this station was nearly identical to reef faces seen at Station 8 (West Reefs), Station 18 (Pinnacles), and Stations 25 and 26 (West Addition Pinnacles). All had rugged, sometimes overhanging, rocky faces. In many places, reef faces were vertical. While benthic communities were fairly well developed in certain areas on the reef faces, large patches of what appeared to be heavily bioeroded reef rock containing virtually no epifauna suggest the reef faces may be gradually deteriorating. Distinctions from other large features included the extraordinary diversity and community density on the reef flats at this station. More species appeared to coexist on the reef flat here than on the reef flats of Station 8 (West Reefs). Also, less fine sediment covered reef surfaces at this station than at West Reefs, probably allowing development of coralline algae crusts (these were not observed at West Reefs).

The lack of stony corals on the reef flat suggests either intense space competition or excessive sediment loads. These corals coexist with "reef flat" organisms on low topographic features elsewhere and on low relief features around the base of the larger reefs at this station. In all these areas, the influence of resuspended sediment appeared to be stronger than on reef flats at this station. This, as well as the apparently healthy coralline algae community on the reef tops, suggests that space competition may in fact preclude stony coral community development on these reefs.

No anthropogenic debris was observed on reef flats. Fishing line was occasionally found along reef faces. Isolated debris was found most commonly around the base of the features. Observations included a large plastic? bag, a plastic cup, a one quart oil can, and a broken plastic plate. Most of this probably was discarded from boats fishing the reefs.

Dredge Characterization - Dredges 16 and 17 contained diverse samples from the reef flat of Station 13, mostly consisting of sponges and gorgonian corals.

Grab Characterization - Grab Sample 17 was composed of the material collected in 23 grab attempts made on the reef top at this station. Sixteen of these attempts contained samples. All were combined. The sample confirmed the presence of coralline algae and contained one small frond of a leafy green alga.

13.3.1.14 **Station 14** - 40 Fathom Fishing Grounds (Western Reconnaissance Site)

Video Survey - This site was located at 29°26.20'N, 87°37.28'W, or approximately 4.5 km WSW of Station 13. A survey was conducted between 0414 and 0620 hours on 26 September 1988. The reef feature at this site crested at 64.6 m, or about 2 m deeper than Station 13. The reef top was relatively flat, though not as extensive or as flat as the reef flat at Station 13. The reef face was extremely rugged, in some places vertical, but more often ruggedly terraced or tapered. The reef face habitats ended in 76 m of water, where coarse sediments marked the reef base.

Faunal and floral assemblages were in some ways similar to those at Station 13, as would be expected due to the nature, depth range, and proximity of these sites. For example, the reef flats were densely populated (Figures 13-12 and 13-13). Especially abundant at Station 14 were gorgonians, crinoids, and antipatharians. Furthermore, reef flat assemblages gave way to reef face assemblages in more rugged or vertical reef face habitats. Reef face assemblages were composed of stony corals that were

Figure 13-12. Reef flat at Station 14 (65.5 m), showing three species of comatulid crinoids, a hook-shaped sponge, *Cirrhipathes* sp. (coiled sea whips), coralline algae crusts, and a large white sea fan (background, parallel to line of view).

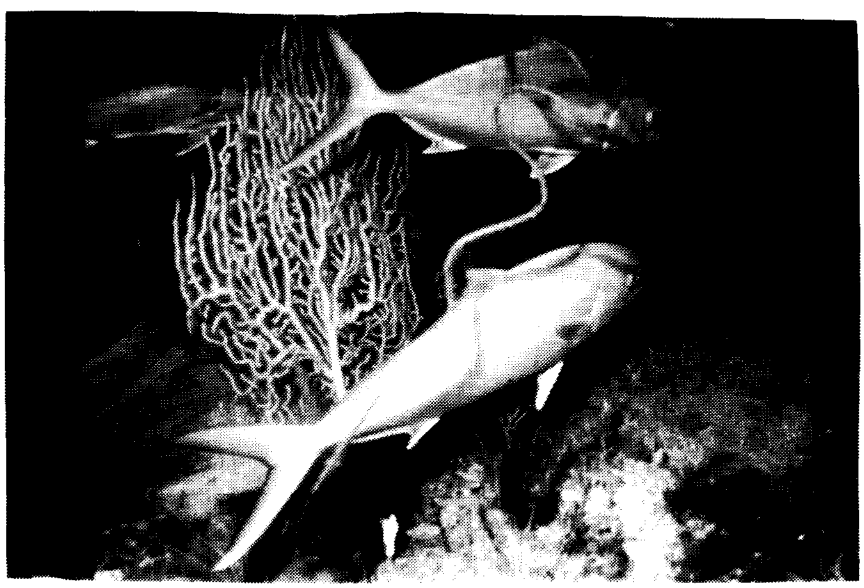


Figure 13-13. *Seriola dimerili* (greater amberjacks) on reef flat at Station 14 (66.1 m), along with large orange sea fan, *Antipathes* sp. B (sparsely-branched antipatharian, lower left), and orange comatulid crinoids (beneath lower jack).

absent from the reef flat, encrusting sponges, and a few species of gorgonians, crinoids, and antipatharians found also on the reef flat.

While their similarities are considerable, some important differences existed between Stations 13 and 14. Particularly, the sponge community at Station 14 was much less developed than at Station 13. Fewer than five large upright sponges were observed, where dozens existed at Station 13. Sponges as a group on the reef flat at Station 14 would be considered occasional, whereas they would be considered abundant at Station 13. No individual species, even encrusting sponges, were considered more than occasional on the reef flat.

The dominant organisms on the reef flat (Figure 13-14) at Station 14 were small gorgonian sea fans (*Nicella guadalupensis*, *Bebryce cinerea*? and a beige sea fan), gorgonian sea whips (*Elisella barbadensis*), the antipatharian *Antipathes* sp. A (bushy form), and a gray comatulid crinoid (all abundant). No stony corals were recorded from the reef flat. With the exception of *Antipathes* sp., relative frequencies of the dominant species appeared to be comparable to Station 13. Surprisingly, however, only one colony of *Antipathes* sp., abundant at this station, was encountered on the reef flat at Station 13. Thus, the most significant differences between the two stations, with respect to benthic organisms, appear to be the depauperate sponge fauna and the dense antipatharian assemblage at Station 14 relative to Station 13.

Organisms considered common on the reef flat included the antipatharian *Cirrhipathes* sp., large white and large orange gorgonian sea fans, *Elisella elongata* (branching gorgonian sea whip), three comatulid crinoids (orange, black, and tan forms), gorgonocephalids (basket stars), and coralline algae (not nearly as conspicuous as at Station 13). Benthic organisms considered occasional included large red and large yellow gorgonian sea fans, a black and white comatulid crinoid, a black and orange comatulid, *Antipathes* sp. B (sparsely branched species), orange-topped sponges, and orange encrusting sponges. Rare organisms included a purple gorgonian (1), a large knobby sponge (2), a white vase sponge (1), a white

Figure 13-14. Reef face at Station 14 (69.2 m), showing at least two comatulid crinoid species, a cluster of white solitary corals (lower center), *Antipathes* sp. A (bushy antipatharian, left), and *Elisella* sp. (sea whip, upper left).

upright, branching sponge (1), a branched tube sponge (1), a round *Ircinia*-like sponge (1), a maroon-topped sponge, *Eucidaris tribuloides* (pencil urchin; 1), and shrimp (1).

Fish on the reef flat were somewhat less abundant and the assemblage less diverse than observed at Station 13, but species were not considerably different and patterns of dominance (with some exceptions) appeared similar. Observations (ranked roughly in decreasing abundance) included *Holanthias martinicensis* (roughtongue bass; common); *Seriola dumerili* (greater amberjack; common; followed the ROV and used the lights to spot prey), *Pristigenys alta* (short bigeye; common), unidentified Holocentridae (common; 14), *Rhomboplites aurorubens* (vermilion snapper; occasional), *Chaetodon aya* (bank butterflyfish; occasional), *Apogon pseudomaculatus* (twospot cardinalfish; occasional), *Lactophrys quadricornis* (scrawled cowfish; 1), *Equetus umbrosus* (cubbyu; 1), an orange Scorpaenidae (scorpionfish; 1), and an unidentified scad (a carangid; 1).

The lower diversity and frequency of fish at this station may result in part by the apparently limited number of crevices in the reef flat compared with Station 13. It appeared that the reef flat at this station contained significantly more sediment than Station 13. This sediment probably limits populations of fish such as *H. martinicensis*, *Hemanthias aureorubens*, and *R. aurorubens*, all of which which were observed in abundance in small crevices at Station 13. Increased sediment may also explain fewer observations of coralline algae on the reef flat at this station. The frequency of coralline algae crusts on the reef faces, where sediments do not accumulate, appeared to be comparable at both stations.

Reef face assemblages at Station 14 were rather diverse, owing to diverse habitat characteristics along the edges of these features. In some places reef faces were vertical. Communities there were dominated by the stony corals *Rhizopsammia manuelensis* (common), *Oculina*? sp. (occasional), and small solitary corals (two or three species; occasional), encrusting sponges (orange, yellow, and white; all common), and coralline algae (occasional). Surprisingly, no *Madrepora carolina* was observed (common at Station 14). In places along the reef face where horizontal surfaces or outcrops with rugged topography occurred, the above species, along with a number of species more typically associated with the reef flat occurred. These species included *Nicella guadalupensis* (common), *Elisella barbadensis* (common), gray comatulid crinoids (common), *Antipathes* sp. A (bushy form; common), *Antipathes* B (sparsely branched form; occasional), *Cirrhipathes* sp. (occasional), black, tan, yellow, orange, and black and orange comatulid crinoids (all occasional), a striking blue alcyonarian? coral (1), and *Siphonogorgia agassizii* (1). Also observed were *Diadema antillarum* (long-spined sea urchins; common), and unidentified asteroids.

Fish species associated with reef face habitats at this station included *Holanthias martinicensis* (roughtongue bass; common), *Rhomboplites aurorubens* (vermilion snapper; occasional), *Pristigenys alta* (short bigeye; 3), *Serranus phoebe* (tattler; 1), *Liopropoma eukrines* (wrasse bass; 1), *Chaetodon aya* (bank butterflyfish; 1), and an unidentified Sciaenidae (drum; 1).

On sand flats adjacent to these features, a small number of organisms were seen, including one black crinoid, a large (but not well developed) orange sea fan, an orange scorpaenid (scorpionfish), and *Ogcocephalus corniger* (longnose batfish; 1).

Only one sign of human interference existed at this station. A beer can was seen at the base of the reef. Surprisingly, no fishing line was observed, whereas it was relatively common at Station 13.

13.3.1.15 **Station 15** - Moderate Features (Eastern Features)

Video Survey - Two sites classified as moderate features (Stations 15 an 16) appeared on side-scan records to represent geological structures intermediate in size between low and high topographic features. Station 15 was surveyed on 26 September 1988, between 0836 and 1047 hours. Video records cover 2.08 hours. Water clarity during this period was exceptional, with visibility over 30 m.

The base depth of the largest features, at Station 15, was between 62.7 an 64.3 m. The depth of the relatively flat reef top was between 59.4 and 61.3 m. Thus vertical relief was up to five meters. The reefs visited had base diameters of ten to twenty meters. Small outcrops 0.5 to 1.5 m tall and 1 to 2 m across surrounded the larger reefs. One unique, spire-like feature was surveyed that had a diameter of 1-2 meters and height of 3.5 m. There was no evident association between features at this station and other geologic structures in the study region. That is, they appeared to be isolated structures. They existed well behind (i.e. shoreward of) the paleo-shoreline, in shallower water, and were approximately 13 km north of Stations 13 and 14.

Surrounding sediments at Station 15 appeared to be coarse with little fine fraction and had small ripples, and mounds and depressions caused by biological activity. The sides of the features were rugged compared to their flat tops, much like larger reef features observed elsewhere in the region.

The flat reef top area supported a gorgonian dominated assemblage similar in some respects to those observed at Stations 8, 13, and 14, but with much lower population levels and density. The assemblage was dominated by an abundant small purple, branching octocoral. Epifauna considered common included the antipatharians *Cirrhipathes* and *Antipathes* sp. A (bushy form), *Elisella barbadensis* (sea whips), and possibly *Bebryce cinerea*. A few small white gorgonians were also seen. The only large gorgonians observed were white sea fans (occasional). Sponges were rare. Observations included two vase sponges (one small and one relatively large). Only one crinoid (black) was seen.

Observations of the invertebrate community associated with the reef flat were limited to several gorgonocephalid basket stars attached to octocorals (occasional), two *Scyllarides? nodifer* (shovelnose lobster), and one large *Diadema antillarum* (black sea urchin).

Fish associated with the reef flats included *Chromis enchrysurus* (yellowtail reeffish; occasional), *Bodianus pulchellus* (spotfin hogfish; 2), two unidentified wrasses with two spots (one on its caudal peduncle and one behind its pectoral fin), *Chaetodon aya* (bank butterflyfish; 2), *Calamus bajonado* (jolthead porgy; 1), and *Serranus phoebe* (tattler; 1).

Sand, which was more abundant on the reef top than had been seen at higher relief stations, may inhibit community development on these reefs. The comparatively low relief of these features and their flat tops may enhance the accumulation of this sediment. No coralline algae, and no solitary hard corals were observed on reef flats.

Reef faces were dominated by the solitary hard coral *Rhizopsammia manuelensis*, the only epifauna considered abundant. Organisms considered common (roughly in order of decreasing abundance) included crustose coralline algae (more than found at most other survey sites, possibly because the site was shallower), orange encrusting sponges, the antipatharians *Cirrhipathes* and *Antipathes* sp. A (bushy form), and the octocoral *Elisella barbadensis* (*E. elongata* was absent from this station). Attached benthic organisms considered occasional on reef faces included *Oculina*? sp. and white encrusting sponges. Rare epifauna included one large orange sea fan and small purple gorgonians which dominated the reef flat community. Surprisingly, only one crinoid (yellow) was seen attached to the face of one reef feature.

Reef face associated motile invertebrates included *Diadema antillarum* (long-spined sea urchin, occasional; 8), *Stenorhynchus seticornis* (arrow crab, rare; 2), *Stylocidaris affinis* (a sea urchin, 1), and *Scyllarides? nodifer* (shovelnose lobster; 1).

Fish associated with the reef face habitat included a dark pomacentrid (possibly the yellow damselfish, *Pomacentrus planifrons*; abundant), *Holanthias martinicensis* (roughtongue bass, nearly all were juveniles;

common), *Chaetodon aya* (bank butterflyfish, common; 10), *Liopropoma eukrines* (wrasse bass, occasional; 6), *Pristigenys alta* (short bigeye, occasional; 6), *Chaetodon ocellatus* (spotfin butterflyfish, occasional; 5), *Apogon pseudomaculatus* (twospot cardinalfish, occasional; 3), *Serranus phoebe* (tattler, occasional; 3), *Bodianus pulchellus* (spotfin hogfish; 1), *Holocentrus ascensionis*? (squirrelfish; 1), *Apogon maculatus* (flamefish; 1), an unidentified Ostraciidae (cowfish; 1), and an orange Scorpaenidae (scorpionfish; 1).

The epifaunal assemblage on the isolated spire-like feature was similar to that on reef faces on other features, but there was an abundance of white solitary corals coexisting among *Rhizopsammia manuelensis* corals. These corals were not seen on other reef face surfaces. The feature harbored a unique assemblage of fish, including a school of unidentified dark or black sciaenids (drums), a number of *Chromis enchrysurus* (yellowtail damselfish), *Hemanthias aureorubens* (streamer bass; 3), and *Centropristis ocyurus* (bank sea bass; 1).

Sediments surrounding these features were coarse, with very little rubble. Organisms observed in these habitats included *Serranus phoebe* (tattler; 3), *Centropristis ocyurus* (bank sea bass; 1), a synodontid (lizardfish; 1), *Eucidaris tribuloides* (a sea urchin; 1), and a tan sea star (1). No attached epifauna, such as gorgonians or antipatharians, were seen in sandy habitats away from reefal features.

Species observed only in the water column above these features included *Seriola dumerili* (greater amberjacks; common), sparids (porgies; occasional), Pomacanthidae (probably *Holacanthus bermudensis*, a blue angelfish; 1), and an unidentified Lutjanidae (snapper; 1).

Human interference at this station was limited to scattered debris. Observations included a plastic cup, a deteriorated aluminum can, and a board, all of which were lying on sand adjacent to moderate features. No fishing lines or cable were seen.

13.3.1.16 **Station 16** - Moderate Features (Western Features)

Video Survey - Station 16, twenty-four kilometers to the southwest of Station 15, and at the same depth, was quite different. Side-scan sonograms indicated what appeared to be moderate features on the bottom. A number of isolated features were encountered, but most were low topographic features with relief less than 0.5 m and horizontal extent less than 10 m. Most were classified as coarse mounds or coarse ridges, since sediment covered most low relief features. Some rock outcrops were observed, however. Only one of these substrates had relief greater than 1 m above the bottom. It had slightly under 2 m relief, rugged vertical sides, and a flat reef top area cresting at 62.8 m. Its areal extent appeared to be greater than 10 m. Surrounding depth at Station 15 ranged from 64 to 65.5 m. Observations at this site were made between 1447 and 1611 hours on 26 September 1988 (1.4 hours of video records were made).

Hard-bottom organisms were present on all topographic features at the survey site, even those covered by sand veneers. These organisms were undoubtedly attached to subsurface features. Since community boundaries were fairly large (ten or more meters across), these subsurface features may have been relatively large. Community development was poor and diversity low on most features, especially those covered by sediments, and appeared to be comparable to that on low topographic features at Stations 2 and 6. Between patches of hard-bottom organisms were expanses of silt-laden coarse sediments. Siltation on these low topographic habitats, along with limited substrate availability, may limit community development.

Features at this site were dominated by small, poorly developed gorgonians (possibly *Bebryce* sp., or *Thesea* sp.), the antipatharians *Antipathes* sp. and *Cirrhipathes* sp., and orange encrusting sponges (all common). Occasional organisms included white encrusting sponges, the octocoral *Elisella barbadensis*, and globose sponges (probably 2 or 3 species). Single observations included a yellow encrusting sponge and a tan vase sponge.

The largest feature in the area, a solitary reef with approximately 2 m relief, and a flat reef top several tens of square meters in extent, was distinct from surrounding smaller outcrops. The rugged, overhanging sides of this reef, and the nature of the top of the feature, were much like those observed in the Patch Reef Field (Station 6). Reef face and overhanging surfaces were dominated by clusters of solitary white corals, and had scattered *Rhizopsammia manuelensis* and *Oculina*? sp. coral colonies. They also contained encrusting white and orange sponges. The reef flat contained a relatively large number of large orange sea fans, white gorgonians, *Bebryce* or *Thesea*-like gorgonians, and several upright sponges. Sediment accumulations on the reef top were significant, resulting in limited roughness in the habitat. No coralline algae were observed.

Fish associated with most features in the area included *Centropristis ocyurus* (bank sea bass, common; 18), *Serranus phoebe* (tattler, common; 16), *Pristigenys alta* (short bigeye, occasional; 5), *Diplectrum bivittatum*? (dwarf sand perch, occasional; 4), synodontids (lizardfish, occasional; 3), and *Equetus punctatus* (high hat, rare; 1). The dominant species here were the same as observed elsewhere on low topographic features in the study area. On the largest feature, however, the fish fauna was somewhat distinct, and included *Holanthias martinicensis* (roughtongue bass; approximately 10), *Liopropoma eukrines* (wrasse bass; 4), and *Apogon pseudomaculatus* (twospot cardinalfish; 4). All of these are characteristic of the larger topographic features in the study area. Variability on the scale observed at this station illustrates the controlling influence of habitat types on species composition and dominance.

Sandy habitats between features consisted of an abundance of mounds and depressions, suggesting significant biological activity. Observations in these areas included hermit crabs (4), and the fish *Serranus phoebe* (11), *Centropristis ocyurus* (6), synodontids (nine including three *Synodus intermedius*, the sand diver lizardfish), flounders (3), and a large skate (Rajidae, nearly one meter across).

The only water column observations were of unidentified carangids (jacks). Approximately five of these fish were seen.

Only one observation was made of human waste. A plastic bag was seen on sand between small topographic features.

13.3.1.17 **Station 17** - Patch Reef Field

This station description is included with Station 6, since this survey was conducted at nearly the same location.

13.3.1.18 **Station 18** - Pinnacles

Video Survey - The pinnacles, which were first described by Ludwick and Walton (1957), are tall, thin biogenic prominences arising from present-day depths of 99 to 109 m. Over 100 of these features exist in an area 5 by 5 nautical miles at the edge of the continental shelf south of Mobile Bay. This area was surveyed in detail by Ludwick and Walton. The shallowest pinnacle mapped peaked at 87.8 m. The tallest was over 16 m, but the average height was 9 m.

Reef rock was found to contain the remains of crustose coralline algae (*Lithothamnium*), serpulid worm tubes, bryozoans, ahermatypic corals, and forams (Ludwick and Walton, 1957). No living calcareous algae were found, suggesting that the pinnacles are not living reefs and should be considered at a stage intermediate between living and fossil geological structures. Our observations support the absence of living coralline algae on the features.

On 88-MMS-ROV-2, we surveyed a pinnacle located at 29°19.94'N, 87°46.37'W. Time of the survey was between 0303 and 0530 hours. Video records total 2.40 hours. This location coincided with a pinnacle mapped by Ludwick and Walton that peaked at 49.5 fm (90.5 m). In fact, this was the shallowest depth recorded during our survey of the feature. It was among the three shallowest peaks noted in the 1957 survey. The surrounding depth was between 102 and 105 m. The pinnacle was approximately 12-15 m tall.

Unlike some geologic features surveyed at Stations 8, 13, and 14, the pinnacle tops are not accordant. Pinnacle peaks depths range from 88.7 to 109 m for those shoreward of the 120 m contour. Furthermore, based on previous mapping and more recent video surveys, the tops of the features do not have extensive reef flats like Stations 8, 13, and 14. Reef flats at those stations may be caused by either truncation during low sea level stands, or by upward growth to sea level followed by death due to rapid sea level rise. Regardless, it is likely that these mechanisms did not affect top reef topography of the pinnacles.

Since very few horizontal surfaces are available on the pinnacles, biological communities are composed of those species able to attach and grow on rugged, often vertical, and frequently, overhanging reef rock. The assemblage resembles in some respects those inhabiting the reef faces (not reef flats) of the other large reef structures in the study region, namely, Stations 8 (West Reefs), 13, and 14 (40 Fathom Fishing Grounds), 25 and 26 (West Addition Pinnacles), and to some extent, Stations 6 (Patch Reefs) and 15 (a moderate feature). But community development on the surfaces of the pinnacles is extraordinary compared to most of these other stations, especially on the upper reef faces and the reef tops (Figures 13-15 through 13-18). This development is manifested in comparatively high biomass, substantial cover, and large, well developed organisms.

Virtually all the dominant species on the pinnacles are suspension-feeding invertebrates. The dominant organisms are the ahermatypic stony corals *Rhizopsammia manuelensis* and *Madrepora carolina*, the orange gorgonian sea fan *Nicella guadalupensis*, and the alcyonarian coral *Siphonogorgia agassizii* (all abundant). Other ahermatypic scleractinian corals included large clusters of small (<1 cm) white solitary corals (abundant on the upper reef face and on overhangs, rare elsewhere), small white caryophylliid? solitary corals (isolated individuals; common), *Oculina*? sp. (occasional), large solitary white corals of the family Caryophylliidae (2-3 cm diameter corallites, occasional; 19 observations), coral clusters composed of several 2-3 cm diameter polyps (occasional; 7), and very large solitary corals similar to *Scolymia* spp. (approximately 10 cm diameter corallites, these could be anemones, rare; 3).

Though octocorals were fairly abundant on the pinnacles, especially on and near the summits, species diversity appeared low compared to that on the reef flats of other large features. Other than the dominant and most abundant species (*N. guadalupensis*), octocorals observed on the pinnacles included *Elisella barbadensis* (common), white sea fans (*Muricea*? sp., a few over a meter across, but most smaller; common), small tan sea fans (probably *Thesea* and *Bebryce* sp.), large yellow sea fans (common), *Elisella elongata* (rare; 1), and a sparsely branched gorgonian not observed elsewhere (rare; 1).

Antipatharians were, surprisingly, rare on the pinnacles. Only one species, *Cirrhipathes* sp., was observed, and colonies were rare, most occurring near the reef base or on small features adjacent to the larger

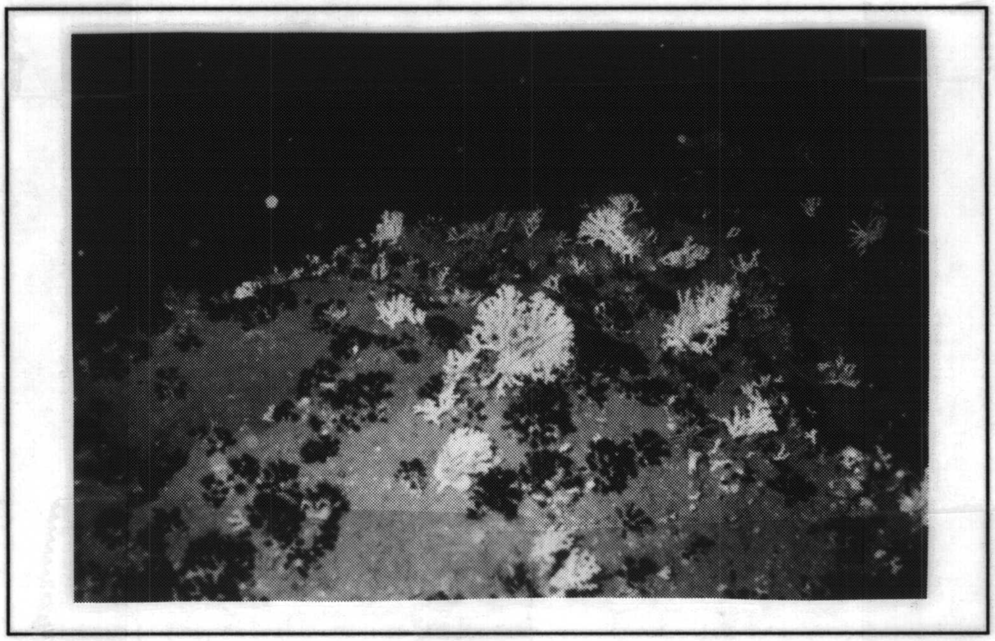


Figure 13-15. Pinnacle reef top at Station 18, at 91.1 m. This portion of the reef top is dominated by *Rhizopsammia manuelensis* (black corals) and *Madrepora carolina* (white bushy corals)

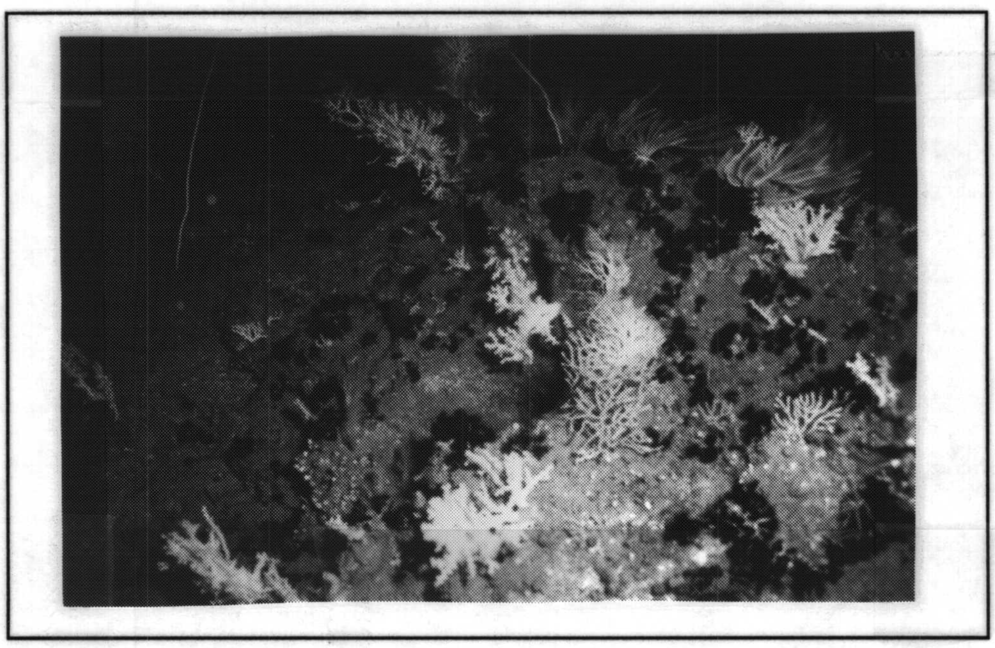


Figure 13-16. Area on a sloping, upper reef face of a pinnacle at Station 18 (95.4 m). Though dominated by *Rhizopsammia manuelensis* (black corals) and *Madrepora carolina* (white bushy corals), this area also contains comatulid crinoids (upper right), small sea fans, elisellid sea whips, a cluster of white solitary corals (lower left), and ?*Astrophyton* sp. (basket star, upper edge).

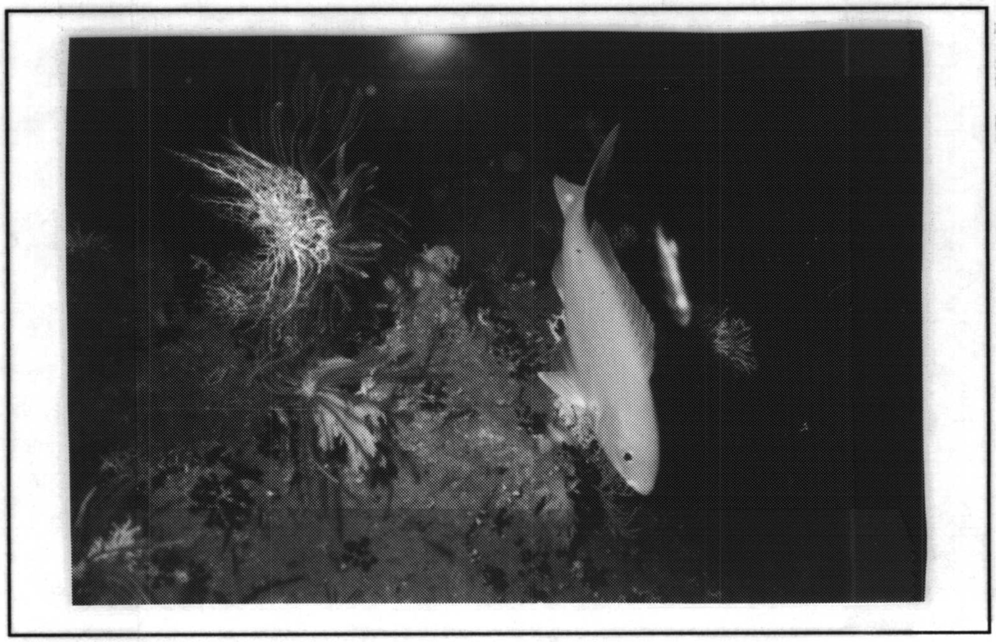


Figure 13-17. *Rhomboplites aurorubens* (vermilion snapper) at 94.8 m on pinnacle reef face (Station 18). Also shown are *Rhizopsammia manuelensis* (black corals), comatulid crinoids, ?*Astrophyton* sp. (white basket star), *Nicella* sp. (sea fans, one beneath fish's mouth), an unidentified silverside-like fish (near snapper's dorsal fin), and possibly *Oculina* sp. (white coral colony in background right of center).

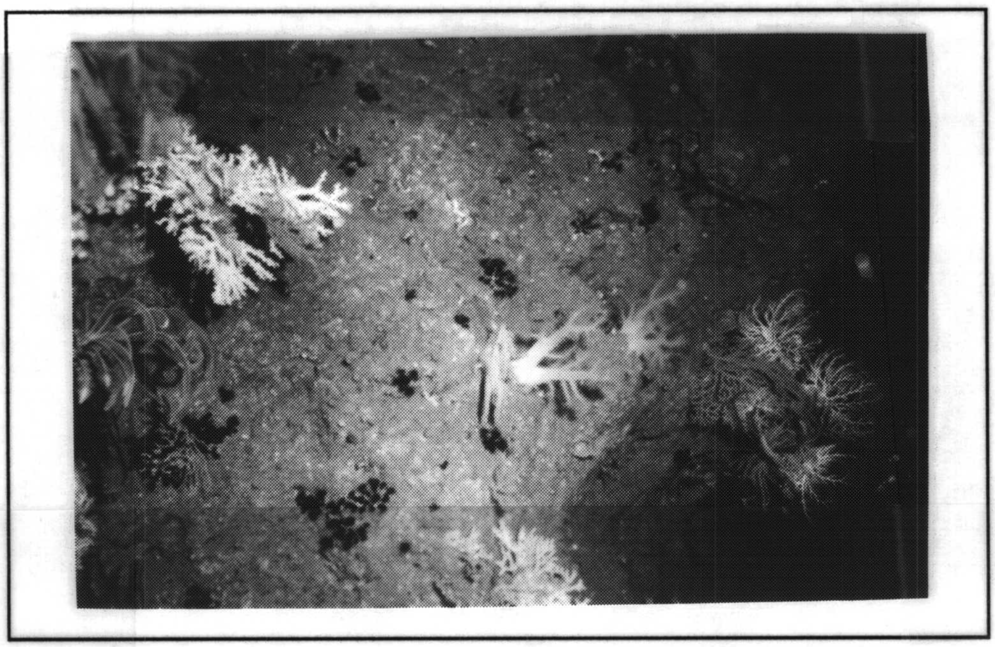


Figure 13-18. Pinnacle reef face at 93.3 m at Station 18, showing three colonies of *Siphonogorgia agassizii* (two upright and one flaccid, center), *Rhizopsammia manuelensis* (black corals), *Madrepora carolina* (white coral colony, upper left), comatulid crinoids (left center), *Oculina*? sp. (lower center), and ?*Astrophyton* sp. (white basket stars, right) on a gorgonian.

pinnacles. No *Antipathes* spp. colonies were observed. Both these genera were considered occasional, common, or abundant on other large features in the study area.

The sponge fauna was also depauperate on the pinnacles. Only two encrusting forms were noted in video observations. White encrusting sponges were considered occasional and a yellow encrusting species was rare. No orange sponges, which were frequently observed on shallower features, were seen at this station. Furthermore, no upright sponges were observed. This was not surprising on reef face surfaces, since upright colonies rarely occurred elsewhere on these rugged surfaces. But a few colonies might have been expected on some of the horizontal surfaces (limited as they are) associated with these features, especially near the tops of the pinnacles.

The alcyonarian *Siphonogorgia agassizii*, a true soft coral without the skeletal framework of gorgonian corals, was among the more conspicuous epifauna of the pinnacles and was considered abundant. Another alcyonarian, *Nidalia occidentalis*, a more or less mushroom-shaped coral, was considered occasional (6 observations). *Siphonogorgia* colonies were seen in two states. Approximately half of the colonies observed were upright and fairly rigid, with polyps extended. The other colonies seen were distinctly flaccid, hanging limply over the surrounding substrate. It is assumed that the upright colonies were feeding, as corals often do at night, while the others were not.

One other form of attached benthos was observed. Clumps of *Neopycnodonte cochlear* oysters were occasionally seen attached to living or dead gorgonian skeletons or to reef rock.

Benthic organisms associated with the pinnacles included what appeared to be five comatulid crinoid species, each identified by arm and pinnule coloration and pinnule characteristics (nine presumed species were noted throughout the study). These included a tan, densely pinnate species (abundant), orange and black (common), light gray (common), black (occasional), and black and white (rare) species. Also seen were the sea urchins *Stylocidaris affinis* (common), *Diadema antillarum* (occasional; 10), and *Echinometra lacunter*? (occasional; 7), the ophiuroid gorgonocephalid (basket stars, up to 12 on one large gorgonian sea fan; common), shrimp (occasional; 8), white brittle stars on gorgonian corals (occasional; 7), and an unidentified majid? (spider crab; 1).

Fish density at this station was not as high as that on the broader, flat-topped reefs at Stations 8 and 13, but was comparable to Station 14. The time of the survey may have contributed to this observation. Station 8 and 13 were surveyed in the afternoon and evening, respectively. Stations 14 and 18 were surveyed in the early morning (approximately 0300 to 0630). Limited fish activity during the early morning may have caused densities to appear low.

The fish fauna of the pinnacles was dominated by *Holanthias martinicensis* (roughtongue bass; common), as on other large features. Most of these were inactive during the survey and many may have been hiding in holes in the reef. Other species included *Chaetodon aya* (bank butterflyfish, occasional; 13), *Pristigenys alta* (short bigeye, occasional; 11), an orange scorpaenid (scorpionfish, occasional; 9), *Rhomboplites aurorubens* (vermilion snapper, occasional; 8), unidentifiable silverside-like fish (occasional, sometimes in schools), *Equetus umbrosus* (cubbyu, occasional; 4), a dark sciaenid (drum, rare; 3), ?*Serranus tabacarius* (tobaccofish, occasional; 3), a muraenid eel (pale green with a black margin on the dorsal fin and a pale face; 1), and *Urophycis* sp. (possibly *U. earlii*, Carolina hake; 1). One unidentified sparid (porgy) and one *P. alta* were also observed over sand away from the pinnacles.

Analysis of video tape data corroborates the finding by Ludwick and Walton (1957) of an absence of living coralline algae on the pinnacles.

Despite the absence of coralline algae, the reef face community on the pinnacles appeared to be more highly developed than communities on the other reefs in that densities appeared higher, especially near the reef summits, and larger colonies were more frequently observed. One factor likely contributing to this superior development is a larger amount of rugged reefal substrate than other reefs. Another may be the pinnacles' shelf-edge locations, which may result in generally clearer water, less frequent episodes of turbid water, a more favorable current regime, and possibly episodic upwelling.

Though species richness on the pinnacles is high compared to most features surveyed, it may not be the highest of all the features in the study area. For example, compared to the flat-topped features at Station 13, the pinnacles were species-poor with respect to coralline algae, sponges, gorgonians, and antipatharians. All of these were among the dominant species of the reef flats at Station 13. In fact, the lack of this habitat type at the pinnacles may have contributed to the lack of representatives of some of these groups, primarily sponges and gorgonians. Coralline algae may have been limited by depth. The reason for the absence of antipatharians is uncertain, since many of these colonies were observed at other stations on reef face surfaces to depths of at least 78 m.

Observations of human intrusion in these habitats was limited to discarded, or tangled fishing lines or cable. A number of these observations were recorded, some probably repeat sightings of the same line. No apparent damage to any reef structure or organisms resulting from this debris was evident.

13.3.1.19 **Station 19** - Grab Sample Station - Between Station 7 and Station 8

Grab Characterization - Station 19 (29°24.66'N, 87°57.17'W) was in the western portion of the study area between Stations 7 (Western Shoreline) and 8 (West Reefs). The side-scan record from the station suggested non-reflective sediments and no topographic relief. We took a grab sample (Grab 9) and confirmed the presence of fine sand containing some silt and clay. Such sediment would be expected to produce this signature on side-scan records.

13.3.1.20 **Station 20** - Grab Sample Station - Near Station 8

Grab Characterization - Station 20 (29°23.89'N, 87°58.88'W) was located approximately 600 m east of a large, flat-topped reef (Station 8; West Reefs). The intent was to sample reflective sediments adjacent to the feature and confirm the presence of coarse, sandy sediments, as would be predicted from the sonogram. It was subsequently determined, however, that the sample was taken near the border between two areas with distinct side-scan returns. One area produced of very strong returns (non-reflective sediments) while the other produced patchy strong records (alternating reflective and non-reflecting sediments). The grab sample (Grab 10) consisted of fine sand containing some silt and clay. It is likely, therefore, that the sample was taken from soft, reflective sediments within the area producing the patchy side-scan sonogram.

13.3.1.21 **Station 21** - Grab Sample Station - Sediment Apron

Grab Characterization - Station 21 (29°23.88'N, 87°59.54'W) was also located adjacent to Station 8. It was approximately 600 m west of a large, flat-topped feature in highly reflective sediments which appeared to compose a "sediment apron". Station 8 and other topographic features in the study area commonly exhibited sediment aprons several hundred meters long on their west and southwest sides, with limited expression on the east sides. The station consisted of coarse sand and shell hash (Grab 13), which accounts for the strong reflections in side-scan records.

13.3.1.22 **Station 22** - Rock Dredge Sample Station - 94-Fathom Pox Field

Dredge Characterization - Station 22 (29°23.89'N, 87°32.42'W) was the deepest station sampled in the study. Side-scan records indicated an area of patchy strong returns in the area. This signature was similar to that at Station 1, but was at 172 m. The sample (Dredge 15) contained castings, bioclastic nodules, and shells. Grab samples from Station 1 (Grabs 1 and 2) included medium to coarse sand, fine shell hash, shell fragments and one disarticulated shell.

13.3.1.23 **Station 23** - Rock Dredge Sample Station - North Side of Patch Reef Field

Dredge Characterization - Station 23 (29°27.12'N, 87°40.44'W) was located between Stations 6 (Patch Reef Field) and 5 (Shoreline North of Patch Reef Field). Two rock dredges were attempted at this site. The first dredge (Dredge 1) returned empty and may have been dragged over an area of clean sediment. No shell hash or other material was dredged. The second attempt at this location (Dredge 2) resulted in the dredge hanging on a reef. After about two hours of ship maneuvering and tugging, the dredge had to be sacrificed. The effort, however, underscores the variable nature of the bottom over very limited areas in this portion of the study region.

13.3.1.24 **Station 24** - Features near West Addition Pinnacle 1

Video Survey - The features observed at this station (29°18.09'N, 88°12.41'W) were very close to a large pinnacle over 15 m tall that was the initial objective of the dive (Pinnacle 1). The anchorage placed the ship 150-200 m north of the pinnacle. Most features at this site were small and low (0.3-0.5 m high). Only one large feature was observed. It had over four meters relief, rugged, often overhanging sides, and limited reef top area.

An ROV survey of the area was conducted between 0643 and 0823 hours on 22 June 1989. Video records total 1.67 hours.

Surrounding depths in the area were between 81 and 82 m. The largest reef had a summit depth of 76.8 m. Sediments surrounding the features contained large amounts of shell hash and rubble. There appeared to be a rather high content of fine material in the sediment, judging from the nature of resuspended material caused by disruption of the bottom. Biological observations on these sediments were limited to hermit crabs (1) and *Synodus intermedius* (sand diver lizardfish; 1).

Surprisingly, the small topographic features observed were dominated by large white gorgonian sea fans (common) commonly associated with large features in the study area (particularly the flat-topped features of the 40-Fathom Fishing Grounds). Solitary black corals, *Rhizopsammia manuelensis*, and solitary white corals also were occasionally observed on these features. This was unlike assemblages seen on other low topographic features, which were considered depauperate in most cases, presumably because of frequent sediment resuspension, or even occasional burial. Organisms associated with these features included ophiuroids (attached to sea fans; 1 observation), and *Holanthias martinicensis* (roughtongue bass; 3).

The largest feature observed at the station contained a more diverse and better developed epifaunal community, the reef face consisting of the stony corals *Rhizopsammia manuelensis* (abundant), *Oculina*? sp. (occasional), and *Madrepora carolina* (1). Gorgonian corals included unidentified small brown gorgonians (possibly *Bebryce* sp.; abundant), *Nicella* spp. (common), and *Elisella barbadensis* (occasional). Large clusters of *Neopycnodonte cochlear* oysters also occurred on the reef face and overhangs. No antipatharian corals or encrusting sponges were noted.

The only associated motile invertebrate observed was the black sea urchin, *Diadema antillarum* (1). Notably, no crinoids were seen on any of the features.

Associated fish species included *Holanthias martinicensis* (roughtongue bass; common), *Chaetodon aya* (bank butterflyfish; 1), *Liopropoma eukrines* (wrasse bass; 1), an orange scorpaenid (scorpionfish; 1), and an unidentified striped serranid (sea bass; 1).

Water column fish species included occasional schools of ?*Pristipomoides aquilonaris* (wenchman), and *Seriola dumerili* (greater amberjacks; 4).

The only sign of human intrusion was a cable or longline draped over the largest feature. It appeared to have no influence on surrounding habitats.

13.3.1.25 **Station 25** - West Addition Pinnacle 1

Video Survey - Two ROV dives were made in the immediate vicinity of a tall pinnacle located at 29°17.91'N, 88°12.41'W (Figure 13-19). The first was made on 25 June 1989 at 29°17.98'N, 88°12.41'W, which was a site on the deeper portions of the north side of the pinnacle. Observations recorded during this dive were on low topographic features at 80-84 meters surrounding the taller feature. The survey was made between 0408 and 1024 hours (1.8 hours of video was recorded). The second dive was made directly on the feature on 28 June. This survey was conducted between 0946 and 1305 hours (3.3 hours of video).

West Addition Pinnacles

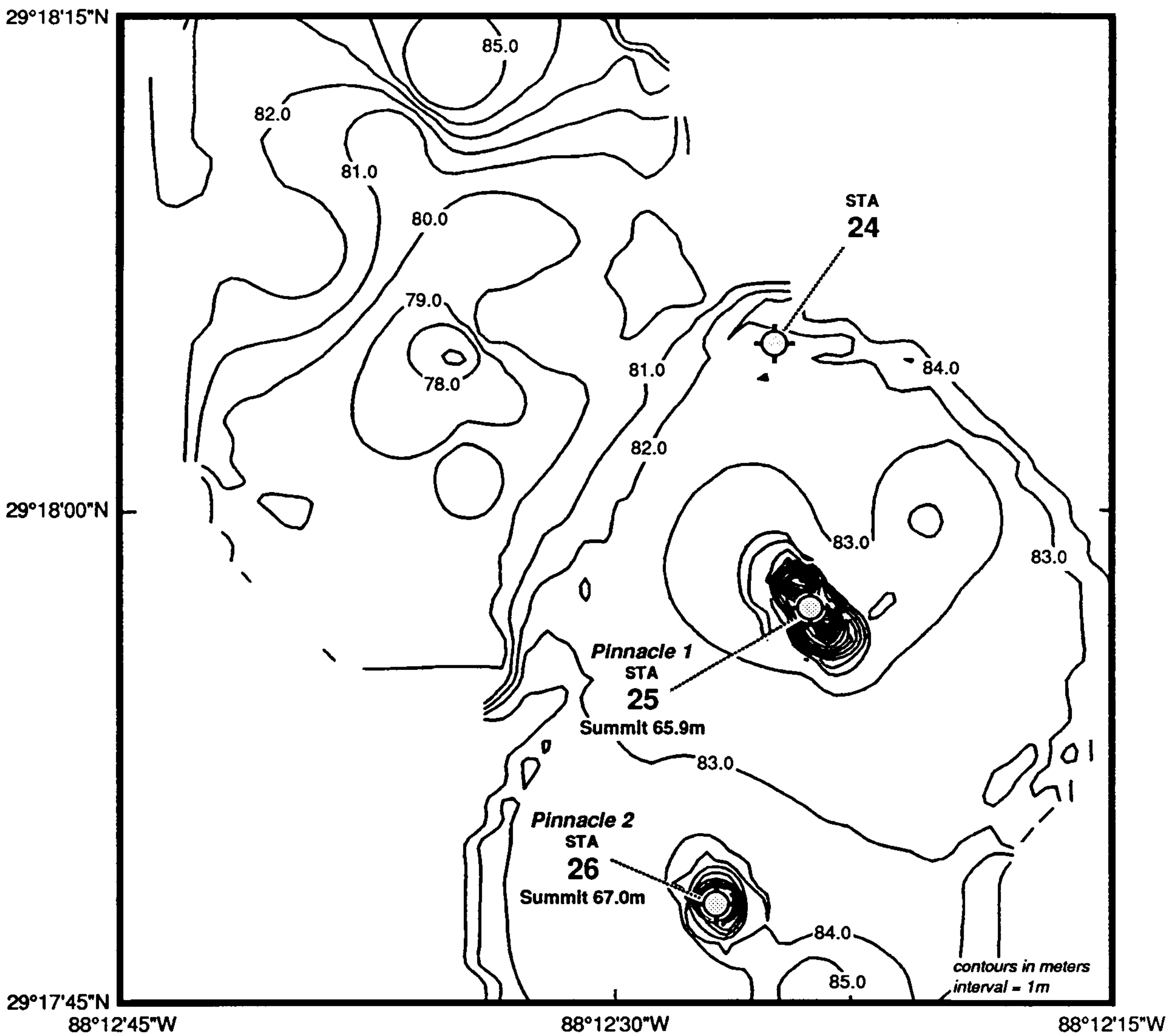


Figure 13-19. Contour map of pinnacles in the "West Addition" study site, based on fathometer survey of the area prior to ROV deployment.

The pinnacle summit was at a depth of 66.5 m. The maximum depth surveyed on the north side of the pinnacle was 84 m. The pinnacle height, therefore, approximated 17.5 m. The walls of the feature were typically vertical and often overhanging, though some terrace-like flat areas were observed along the reef face. On one end of the pinnacle, two spires formed an impressive double arch up to 2 m across and 2-3 m tall at a depth of approximately 74 m.

A diverse fauna occupied this pinnacle. One notable exception was the unexplained absence of comatulid crinoids, a characteristic that distinguished this feature not only from other features in the region in general, but also from Pinnacle 2, less than 300 m to the south. This was particularly surprising because the diversity of other faunal groups at this station was significantly higher than that on Pinnacle 2.

With the exception of the crinoid species, and four incidental species which were observed on single occasions on Pinnacle 2, all species which occurred on Pinnacle 2 also occurred on Pinnacle 1. In addition, at least 24 species were observed on Pinnacle 1 which were not encountered on Pinnacle 2. Dominant species, however, were similar on the two features. Most of the additional species on Pinnacle 1 were rare or occasionally occurring among the more conspicuous dominant organisms. Some of the apparent higher diversity might be accounted for by the additional survey time at this site, which was nearly twice that of Pinnacle 2. Survey time on the pinnacle itself, however, was only 25% greater than on Pinnacle 2.

The reef top on this feature was dominated by *Rhizopsammia manuelensis* (a black solitary coral; abundant), white solitary corals (abundant), and in places, by *Antipathes* sp. A (bushy antipatharian; abundant). Other conspicuous fauna included *Nicella guadalupensis* (small orange sea fans; common), small white octocorals (common), *Oculina*? sp. (occasional), and small yellow gorgonian sea fans (occasional). Rare species included yellow globose sponges (mottled by darker blotches on surface; 3), *Antipathes* sp. B (sparsely branched form; 2), *Oxysmilia*-like solitary corals (2), a brown gorgonian sea fan (1), and a tan spire shaped sponge (1). Coralline algae crusts were observed to a depth of 68 m on the reef top, but were sparse.

The reef face was dominated by *Rhizopsammia manuelensis* (abundant, though not as abundant as on the reef top), clusters of white solitary corals (abundant on overhangs, common elsewhere), *Madrepora carolina* (abundant), and *Neopycnodonte cochlear* (oysters, also abundant on overhangs; Figure 13-20). Other fauna on the reef face included *Oculina*? sp. (common), *Nicella guadalupensis* (common), *Bebryce*? sp. (common on flat surfaces), *Antipathes* sp. A (bushy form; common on flat surfaces, rare elsewhere), small tan gorgonian sea fans (common on flat surfaces), *Elisella barbadensis* (sea whips, common on deep portions, occasional elsewhere), small yellow gorgonian sea fans (common on deep portions), orange encrusting sponges (common), small white octocorals (occasional), tan globose sponges (occasional), yellow globose and encrusting sponges (occasional), white encrusting sponges (occasional), *Cirrhipathes* sp. (coiled sea whips, patchily distributed; 5), *Antipathes* sp. B (sparsely branched form; 1), and *Oxysmilia*-like solitary corals (1).

Epibenthos associated with these habitats included *Stylocidaris affinis* and *Diadema antillarum* (sea urchins; common at all depths), tan ophiuroids (brittle stars, attached to gorgonians; common), gorgonocephalid (basket stars; occasional), *Asteroporpa annulata* (black and white annulated brittle stars; 5), holothuroids (sea cucumbers; 3), Scyllaridae (shovelnose lobsters, probably *Scyllarides nodifer*; 2), hermit crabs (2; one in *Busycon* shell, and *Dardanus insignis*), *Spondylus americanus* (American thorny oyster; 1), *Stenorhynchus seticornis* (arrow crab; 1), shrimp (1), *Polystira* or *Fusinus* sp. (turret or spindle shell; 1), goniasterid? sea stars (1), an unidentified red sea star (1) and an unidentified white sea star (1).

Fish were extremely abundant around these pinnacles, especially over the reef tops, where tens of thousands of fish occurred in dense schools. Most appeared to be juvenile *Holanthias martinicensis* (roughtongue bass), *Paranthias furcifer* (creole-fish), *Halichoeres* spp. (wrasses), and possibly *Rhomboplites aurorubens* (vermilion snapper). Adults of all these species were conspicuous on the reef top and elsewhere around the features. Juveniles hovered near the reef surfaces and darted for cover at any disturbance. Larger fish hovered above these dense schools. At least 26 species were encountered at this pinnacle. They included *H. martinicensis* (abundant, especially on the reef top), *P. furcifer* (common above reef),

Figure 13-20. Portion of reef face at 75.0 m on pinnacle at Station 25 dominated by *Neopycnodonte cochlear* (oyster). Also shown are scattered solitary white corals (right), *Oculina*? sp. (white branched coral, center), and *Chaetodon aya* (bank butterflyfish).

Liopropoma eukrines (wrasse bass, common, all depths), *Chaetodon aya* (bank butterflyfish; common), *Chromis enchrysurus* (yellowtail reeffish; common on reef top, occasional elsewhere), *Halichoeres* spp. (wrasses, including at least *H. cyanocephalus*, the yellowcheek wrasse, and *H. bathyphilus*, the greenband wrasse; common on reef top, occasional elsewhere), *R. aurorubens* (occasional, all depths), *Hemanthias aureorubens* (streamer bass; occasional), *Mycteroperca phenax* (scamp, occasional; 9), *Chaetodon sedentarius* (reef butterflyfish, occasional; 9), holocentrids (either *Plectrypops retrospinis* [cardinal soldierfish], or *Corniger spinosus* [spinycheek cardinalfish]; occasional; 9), sparids (porgies, occasional; 8), *Centropristis ocyurus* (bank sea bass, occasional; 7), *Pristigenys alta* (short bigeye, most on reef top; 7), *Holacanthus bermudensis* (blue angelfish, occasional; 6), unidentified grouper (possibly *Mycteroperca bonaci* [black grouper]; 3), *Equetus umbrosus* (cubbyu; 2), *Chilomycterus* sp. (burrfish; 2), *Serranus phoebe* (tattler; 1), *Apogon pseudomaculatus* (twospot cardinalfish; 1), *Antennarius ocellatus* (ocellated frogfish on the reef top; 1), an orange scorpaenid (scorpionfish; 1), *Ogcocephalus corniger* (longnose batfish; 1), and *Canthigaster rostrata*? (sharpnose puffer; 1). A conspicuous water column fish was *Seriola dumerili* (amberjack; occasional).

The low topographic features around the base of the pinnacle were dominated by *Rhizopsammia manuelensis* (common) and small, tan gorgonian sea fans (common). Other epifauna included the ahermatypic corals *Madrepora carolina* (occasional), solitary caryophylliid corals (occasional), and *Oculina*? sp. (rare), the octocorals *Nicella* sp. (occasional) and *Elisella barbadensis* (occasional), and a coiled antipatharian sea whip, *Cirrhipathes* sp. (rare; 1).

Associated epifauna on these low features included white ophiuroids (4), *Stylocidaris affinis* (sea urchins; 4), and gorgonocephalid (basket stars; 1). Fish associated with the features included *Holanthias martinicensis* (roughtongue bass (occasional), and *Lutjanus campechanus* (red snapper; 1).

Rubble was common in sand around the base of the features. Fauna associated with these "rubble flats" included the sea urchins *Eucidaris tribuloides* (4) and *Stylocidaris affinis* (3), and Nephtheid? soft corals (patches occasional, but dense). Fish included one unidentified sparid (porgy; 1).

Human intrusion at this station was manifested in eight observations of lost cable or longlines, and one of a ladder step lying on the reef top. No apparent long-term impacts seem to have resulted from this debris.

Characteristics that distinguish the communities on this pinnacle from those on the pinnacles at Station 18 are the lack of crinoids, the lack of *Siphonogorgia agassizii*, poor development of the octocoral community, dominance of portions of the reef top by an antipatharian (*Antipathes* sp. A) rather than gorgonians, and the enormous fish population (especially juveniles). Hard coral populations and communities appeared to be similar to those at Station 18.

Fishing - A number of fish not seen during the video survey were caught by hook-and-line at this station, including *Rachycentron canadum* (cobia; 2), *Caranx crysos* (blue runner; 1), *Scomberomorus cavalla* (king mackerel; 1), *Pomatomus saltatrix* (bluefish; 1), and *Lobotes surinamensis* (tripletail; 1). Also caught were several *Rhomboplites aurorubens* (vermilion snappers) and *Calamus bajonado* (jolthead porgies).

13.3.1.26 **Station 26** - West Addition Pinnacle 2

Video Survey - One dive was made on this pinnacle, which is located at 29°17.78'N, 88°12.44'W; Figure 13-19). The dive was made on 25 June 1989 between 1514 and 1813 hours (2.6 hours of video records).

The pinnacle at this site was tall, with vertical and often overhanging sides. In places, the sides were interrupted and flat areas and secondary summits occurred. One vertical crack was identified in the structure itself. The feature was surrounded by low topographic features. The summit of the pinnacle was at 67 m. The maximum depth around the base was 85 m. Thus the vertical extent of the pinnacle was 18 m, or roughly equal to that of Pinnacle 1. The summit area was fairly limited, being less than 10 meters across, but the surface was relatively smooth.

Sediments surrounding the features were coarse and contained large amounts of shell hash and rubble. Coral remains were also abundant in the sediments.

Like Pinnacle 1, this feature was dominated by the black ahermatypic stony coral, *Rhizopsammia manuelensis*, which occurred at all depths and even dominated low topographic features below 80 m. This coral was particularly abundant on the reef face and reef top. Also similar to Pinnacle 1, the relatively flat reef top and the sloping flanks of the reef top (Figure 13-21) were occupied by the antipatharian coral, *Antipathes* sp. A (bushy form; also abundant). *Antipathes* was considered occasional in other habitats of this pinnacle. Colonies were generally restricted to flat surfaces such as those on the reef top and on low topographic features around the base of the pinnacle. Other epibenthic species in the low diversity community on the summit of the feature included white solitary corals (common), *Oculina*? sp. (rare), and coralline algae (sparse, to a depth of 71.3 m).

A low diversity community also occupied the sides of the features. Species included *Rhizopsammia manuelensis* (abundant), clusters of white solitary corals (common in general, and abundant on overhangs, their preferred habitat; Figure 13-22), *Neopycnodonte cochlear* oysters (also prefer overhangs, where they are abundant), white solitary corals (common), *Madrepora carolina* (common), *Oculina*? spp. (possibly two species;

Figure 13-21. Top of pinnacle at Station 26, at 68.6 m, showing *Rhizopsammia manuelensis* (black corals), *Antipathes* spp. A (bushy antipatharian, lower margin) and B (sparsely-branched, center), *Diadema antillarum* (black sea urchin, right of center), *Stylocidaris affinis* (sea urchin at base of antipatharian in center), *Scyllarides nodifer*? (shovelnose lobsters, two in lower center), and small schooling fish (mostly *Holanthias martinicensis*, roughtongue bass).

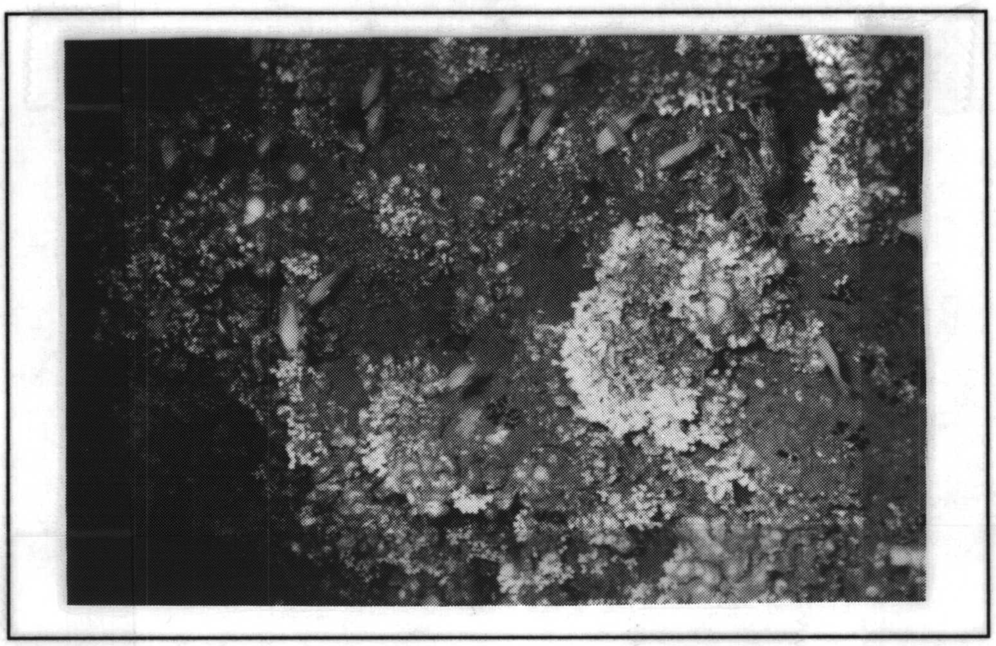


Figure 13-22. Portion of reef face on pinnacle at 75.6 m at Station 26 dominated by clusters of white solitary corals. Fish are *Holanthias martinicensis* (roughtongue bass).

occasional, especially on deeper surfaces), *Nicella guadalupensis* (occasional, mostly on deeper surfaces), orange and yellow encrusting sponges (occasional), small yellow globose sponges (occasional), small tan globose sponges (rare), white encrusting sponges (rare), solitary *Oxysmilia*-like corals (rare; 4), *Antipathes* sp. B (sparsely branched, rare; 2), small coral clusters (rare; 1), small tan and white gorgonian sea fans (rare; 1 each), and a small *Scolymia*-like coral (possibly an anemone, rare; 1).

Associated epibenthos included the sea urchins *Stylocidaris affinis* (common), *Diadema antillarum* (common), and *Eucidaris tribuloides* (rare; 3), comatulid crinoids (orange and black, 8; black, 6; yellow, 1; gray, 1), *Scyllarides* sp. (shovelnose lobster; 2), gorgonocephalids (basket stars; 3), holothuroideans (sea cucumbers; 3), shrimp (2), *Stenorhynchus seticornis* (arrow crab; 2), *Spondylus americanus* (American thorny oyster; 1), and an unidentified crab (1).

Like Pinnacle 1, fish were very conspicuous at this site, especially over the pinnacle summit. The majority appeared to be juveniles of species conspicuous on the reef top and elsewhere around the pinnacle. Species diversity, however, was lower than on Pinnacle 1. Seventeen fish species were encountered on this survey, including *Holanthias martinicensis* (roughtongue bass; abundant, especially on the reef top), *Paranthias furcifer* (creole-fish; abundant), *Rhomboplites aurorubens* (vermilion snapper; common), *Hemanthias aureorubens* (streamer bass; common), *Mycteroperca phenax* (scamp; occasional), *Liopropoma eukrines* (wrasse bass, occasional; 10), holocentrids (either *Plectrypops retrospinis* [cardinal soldierfish] or *Corniger spinosus* [spinycheek cardinalfish]; occasional; 9), *Chaetodon aya* (bank butterflyfish; 4), unidentified grouper (possibly *Mycteroperca bonaci* [black grouper]; 4), an orange scorpaenid (scorpionfish; 3), *Centropristis ocyurus* (bank sea bass; 3), sparids (porgies; 3), *Serranus phoebe* (tattler; 2), *Chromis enchrysurus* (yellowtail reeffish; 2), *Ogcocephalus corniger* (longnose batfish; 2), *Holacanthus bermudensis* (blue angelfish; 1), and a gray muraenid eel (1).

On flat sandy areas surrounding the pinnacle, rubble was commonly seen. This included coral debris, dislodged oyster clumps, and other reef material. Organisms occupying these areas included orange and black comatulid crinoids (common; 12), *Nicella guadalupensis* (orange sea fan; 4), black crinoids (1), and *Ogcocephalus corniger* (longnose batfish; 2).

Anthropomorphic debris at this station was fairly abundant compared to other sites surveyed. Most, however, was in the form of cables or longlines draped or wrapped on the features. Approximately six separate observations were made of cables. Some of these may have been repetitive observations of different portions of the same cable or longline. Other debris included a pile of approximately 1" nylon line and a piece of stainless steel rod.

The most striking characteristics of this pinnacle were the absence or rarity of certain species that were found to be more abundant on other similar features. *Elisella* sea whips, *Cirrhipathes* coiled sea whips (antipatharians) and *Siphonogorgia* (an alcyonarian coral) were absent. Gorgonian corals were rare in general. Other comparatively rare groups included crinoids, sponges, and the hard corals *Madrepora* and *Oculina*. Interestingly, however, crinoids were found at this station, and not at Pinnacle 1, which was located less than 300 m north.

13.3.1.27 **Station 27** - Mountain Top - Bank 3 (first of three stations)

Video Survey - We conducted a preliminary fathometer survey of this bank to determine the extent and depth of the feature prior to conducting the ROV survey (Figure 13-23). The bank appears to be nearly 1.6 km (north to south) by 1.0 km (east to west), and is oval. Minimum depth is 53 m. Surrounding depth is nearly 110 m. At the time of the survey, there were three production platforms near the bank (on the north, northeast, and east sides).

The following description covers one of three stations occupied on this bank. In all, four dives were made on the bank. Two were made at this station. The coordinates of these dives were 29°13.98'N, 88°25.82'W, and 29°14.01'N, 88°25.78'W. ROV dives were made between 0159 and 0358 on 26 June 1989 and between 0217 and 0435 on 28 June. Video records at Station 27 total 4.02 hours.

Mountain Top (Bank 3)

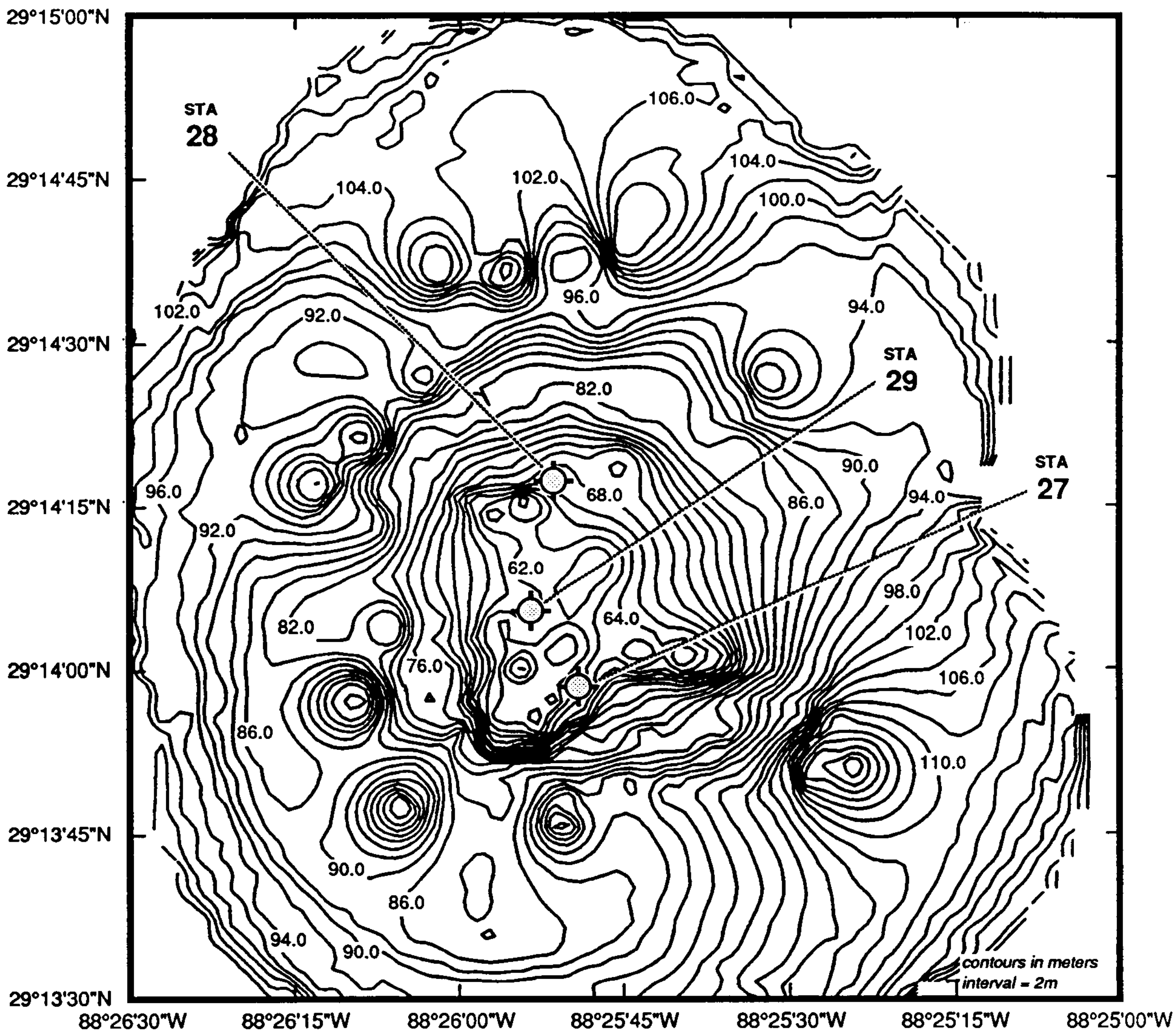


Figure 13-23. Contour map of Mountain Top (Bank 3), based on fathometer survey of the area prior to ROV deployment. Stations 27-29 were located on this bank.

The principal character of interest at this station was the occurrence of numerous bacterial mats and gas seeps. At this location, the bank is composed of a hard rocky surface with occasional fissures and holes. Along some of these cracks, surrounding many holes, and even on flat bottoms, were dense accumulations of white filaments (Figure 13-24) which were easily dislodged by water currents. Associated with many of these mats were gas seeps, where intermittent streams of bubbles were seen (25 gas seep observations). We presume the mats are composed of sulfide oxidizing bacteria (probably *Beggiatoa* sp.) and elemental sulfur. Similar mats have been studied at a brine seep at 72 m on a flank of the East Flower Garden Bank, in the northwestern Gulf of Mexico (e.g. Powell et al., 1983) and on the continental slope of the Gulf of Mexico and elsewhere. The gas is probably biogenic, resulting from microbial decomposition of organic matter in underlying anoxic sediments. Previous studies have shown similar seeps on salt dome-associated banks to be composed of over 98% methane with traces of ethane and propane (e.g. Bernard et al., 1976).

The nature of the seepage providing sulfides to the bacteria on the bank is not clear. In many cases, the white mats surrounded central, dark areas. While small brine accumulations might appear as dark pools, no brine seeps were evident. The occurrence of bacterial mats around fissures, as well as gas seeps surrounded by small bacterial mats, suggest that reduced compounds may be supplied in the dissolved form.

Because this survey was conducted from a ship at anchor, we were not able to determine the areal extent of these bacterial communities.

Bottom features at the study site included extensive rocky substrates, scattered sandy bottom areas, and isolated rock outcrops up to 2 m tall. Vertical surfaces were not as prominent as occurred on the pinnacles elsewhere in the study area (no surfaces over 3 m tall occurred at this station). Numerous cracks existed in the bank surface.

Depth at the survey site was between 58 and 64 m. Throughout this range, coralline algae, considered abundant, dominated benthic habitats. These pink or purple crustose algae covered most of the surface at much of the site, and probably included *Lithothamnium* and *Peyssonnelia*, among other corallines. Many crusts occurred alongside bacterial mats and gas seeps.

Figure 13-24. Unidentified "seep" at 62.8 m at Station 27, surrounded by white filamentous bacteria (probably *Beggiatoa* sp., a sulfide oxidizer). The dark area in the center could be anoxic or too toxic for growth of *Beggiatoa* or metazoans. Also shown are *Elisella* sp. (sea whip) and *Hermodice carunculata* (fireworm).

The benthic fauna was fairly diverse at this station, but frequency of most species was low compared to other large hard-bottom features in the study area. In fact, no species were considered abundant. It is not known whether the presence of dissolved compounds associated with bacterial production might reduce surrounding epibenthic populations. It seems unlikely, however, since many benthic organisms were observed in close proximity to bacterial mats and gas seeps with no apparent effects, and fish were seen ingesting the flocculent material comprising the bacterial mats (six observations). Studies done elsewhere suggest enhanced secondary production in the vicinity of such bacterial communities (e.g. Gittings et al., 1984).

Surprisingly, some species that dominated other hard-bottom features in the study area were absent here, namely the hard corals *Rhizopsammia manuelensis*, *Madrepora carolina*, and *Oculina*? sp. This station (Figure 13-25) was dominated by antipatharians (*Cirrhipathes* sp. and at least two species of *Antipathes*), as well as gorgonian corals (small tan sea fans, pale

Figure 13-25. Flat portion of the bank at Station 27, at 59.1 m, showing considerable epifaunal and coralline algae community development. Shown are *Antipathes* sp. A (bushy antipatharian, left), a large sponge (upper center), gorgonian sea fans, and possibly *Agaricia* sp. (lettuce coral, a reef-building species; center).

yellow sea fans, and the sea whip, *Elisella elongata*; all distributed patchily), and orange encrusting sponges (all common). "Occasional" epibenthic organisms included *Elisella barbadensis* (sea whip), *Nicella* sp. (small orange sea fans), large orange sea fans, large white sea fans, and white encrusting sponges. Rare species included upright, orange finger-shaped sponges (4), a tan globose sponge (2), a branching red sponge (1), a white barrel sponge (1), a red globose sponge (1), a yellow multi-tubed sponge (1), a *Scolymia*-like solitary coral? (possibly an anemone; 1), a small white coral cluster (1), a solitary *Oxysmilia*-like coral (1), a possible *Agaricia* sp. coral colony (a reef building coral; 1), a branching massive bryozoan (1), and the bivalve *Spondylus americanus* (American thorny oyster; 2).

Reef-associated invertebrates were dominated by comatulid crinoids, but crinoid frequency was not nearly as high as on many other high relief features in the study area. Approximately four species of crinoids were seen including tan (common), orange (rare; 4), orange and black (2), and gray (1) individuals. Other invertebrates included the sea urchins *Stylocidaris affinis* (common; 23), *Diadema antillarum* (2), and an unidentified pencil urchin (2), the echinoderms, gorgonocephalids (basket stars; occasional on upright corals), sea stars (2) and brittle stars (1), squid (occasional; 10), shrimp (rare; 4), *Hermodice carunculata* (fireworm; 2), and an octopus (1).

Though fairly diverse, fish were not as abundant at this station as at other stations in the study site. At least 25 species were observed. Though *Holanthias martinicensis* (roughtongue bass) was the dominant species, it was considered only common. Other species included *Pristigenys alta* (short bigeye, common; 20), *Chaetodon aya* (bank butterflyfish, occasional; 10), *Decapterus* sp. (scad, occasional; approximately 10), *Apogon pseudomaculatus* (two-spot cardinalfish, occasional; 9), an orange Scorpaenidae (scorpionfish, occasional; 9), *Priacanthus arenatus* (bigeye, occasional; 10), *Rhomboplites aurorubens* (vermilion snapper, occasional; 6), *Fistularia petimba*? (red? cornetfish, occasional; 6), *Apogon maculatus* (flamefish, occasional; 5), *Lutjanus cyanopterus* (cubera snapper, occasional; 5), *Seriola dumerili* (amberjack, rare; 4), *Paranthias furcifer* (creole-fish, rare; 3), *Equetus umbrosus* (cubbyu, rare; 3), *Chaetodon sedentarius* (reef butterflyfish; 2), *Canthigaster rostrata* (sharpnose puffer; 2), *Chilomycterus schoepfi* (striped burrfish; 2), *Ogcocephalus corniger* (longnose batfish; 2), *Muraena retifera* (reticulate moray; 2), an unidentified eel (possibly *Moringua edwardsi*, spaghetti eel; 2), *Lutjanus campechanus* (red snapper; 1), *Serranus phoebe* (tattler; 1), *Apogon pillionatus* (broadsaddle cardinalfish; one identified, but probably many more of these small fish), *Lactophrys* sp. (cowfish; 1), and a gadid (possibly *Steindachneria argentea*, the luminous hake; 1).

This station contained several (5) piles of shell and rubble of unknown origin. Each was approximately one meter across and 0.5 m high, and circular or elliptical. The rubble appeared to consist of shells, reef rock, and coral skeletons, among other items. No organisms were clearly associated with the mounds.

More debris was observed here than at any other station. Most was lost or discarded fishing line (9 observations). Other debris included aluminum cans (5), cloth or plastic sheets (2), an oil filter (1), and a plastic hose? fitting (1). Though oil platforms exist near the bank, the majority of discarded material appeared to be derived from fishing activity. As with other bank surveys near producing oil fields, few observations were made of industry related debris or effects.

13.3.1.28 **Station 28** - Mountain Top - Bank 3 (second of three stations)

Video Survey - This area of the bank, approximately 500 m NNW of Station 27 and 300 m north of Station 29, was surveyed on 27 June 1989. The survey was conducted between 1121 and 1510 hours. Bottom video records total 2.74 hours. Visibility during the dive was less than 3 meters.

Unlike Station 27, no bacterial mats were observed at this station. Furthermore, the bottom character was different from Station 27, insofar as large expanses of relatively flat hard bottom was not seen here. Depth varied from 66.4 to 76 m, with numerous small pinnacle-like features, the tallest being 6 m high. Most, however, were less than 2 m tall. Many of the features had the rugged vertical sides characteristic of other pinnacles in the study area, and limited reef top areas. Between the features were sand flats and in some cases rubble flats. Such features are similar in nature to those observed on the deeper portions of carbonate-capped diapiric banks in the northwestern Gulf of Mexico (see Rezak et al., 1985), where they were called "partly drowned" or "drowned" reefs (depending on the occurrence or lack of coralline algae, respectively).

Biotic assemblages inhabiting these features were similar to those at Station 27, with several notable exceptions. First, no bacteria or gas seeps were observed. Second, some corals were seen here that were conspicuously absent at Station 27, including seven *Oculina*? sp. colonies, and one cluster of *Rhizopsammia manuelensis*. Coralline algae crusts were not nearly as well developed at this station, but this might be expected since the shallowest surfaces at this station were over 8 m deeper than at Station 27.

Coralline algae was observed at this station to a depth of at least 71 m, and one questionable observation was made on top of a small pinnacle at 74.7 m. This suggests a slightly shallower maximum depth for coralline algae than Stations 13 (78 m) and 14 (75.2 m), but slightly deeper occurrence than Stations 25 (68 m) and 26 (71.3 m).

Community development at Station 28 was not as impressive as occurred on pinnacles and other large reefal features elsewhere in the study area (namely Stations 8, 13, 14, 18, 25, and 26) or even Station 29 on the top of this bank. Epibenthic assemblages were dominated by the antipatharians *Cirrhipathes* sp. and *Antipathes* sp. A (bushy), and orange encrusting sponges (all common). Though conspicuous, these organisms were seldom densely distributed. Other common organisms, but less abundant, were yellow and white encrusting sponges, and *Antipathes* sp. B (sparsely branched antipatharian). Benthic organisms considered occasional included orange octocoral sea fans (some large; patchy occurrences, generally with two to four per patch), *Oculina*? sp. (7), *Nicella* sp. (orange sea fans; at least 5), small ahermatypic coral clusters (4), *Spondylus americanus* (American thorny oyster; 4), and possibly *Elisella barbadensis* (octocoral sea whip). Rare benthos included solitary, *Oxysmilia*-like corals (3), smaller solitary corals (2), a nephtheid? soft coral (1), a small orange globose sponge (1), and a yellow mat-like sponge (1).

At least four comatulid crinoid species were observed. These animals dominated the group of motile organisms associated with the features. Tan crinoids and the species with orange arms and black pinnules were common. A black species was occasional (4), and a single yellow crinoid was seen. Other associated species included *Diadema antillarum* (black sea urchin, common; 23), gorgonocephalids (white basket stars, occasional; 8), *Stylocidaris affinis* (a sea urchin, rare; 1), a white asteroid with red blotches (rare; 2), a black basket star (1), and *Charonia variegata* (Triton's trumpet, a snail; 1).

Approximately 17 species of fish were observed. *Holanthias martinicensis* dominated the group (juvenile and adult roughtongue bass; common, but abundant in some places). Abundance was fairly high, though not as high as occurred on the pinnacles at Stations 25 and 26. It was, however, much higher than that at Station 27, only 500 m to the south of this station. It may be that the higher relief at stations containing pinnacle features promotes the occurrence of larger schools of these bass. Other fish included *Hemanthias aureorubens* (streamer bass, possibly common, but poor visibility made identification difficult), *Pristigenys alta* (short bigeye, occasional; 13), *Equetus umbrosus* (cubbyu, occasional; 13), *Chaetodon aya* (bank butterflyfish, occasional; 6), *Chaetodon sedentarius* (reef butterflyfish, occasional; 4), *Serranus phoebe* (tattler, rare; 3), *Liopropoma eukrines* (wrasse bass, rare; 2), *Lutjanus campechanus* (red snapper, rare; 2), *Priacanthus arenatus* (bigeye, rare; 2), orange scorpaenids (scorpionfish, rare; 2), dark sciaenids (drum, rare; 2), *Rhomboplites aurorubens* (vermilion snapper, rare; 1), *Ogcocephalus corniger* (longnose batfish, rare; 1), *Apogon* sp. (cardinalfish, rare; 1), and *Urophycis floridana*? (southern? hake; 1). One school of *Seriola dumerili* (amberjack; approximately 12) was seen in the water column.

Very little debris was encountered here. Observations were limited to two lengths of cable seen on the bottom.

Fishing - Hook-and-line fishing produced a number of *Rhomboplites aurorubens* (vermilion snapper), *Pomatomus saltatrix* (bluefish), and *Epinephelus nigritus* (Warsaw grouper, approximately 40 pounds).

13.3.1.29 **Station 29** - Mountain Top - Bank 3 (third of three stations)

Video Survey - The third site surveyed on this bank was at 29°14.09'N, 88°25.91'W, or approximately 300 m south of Station 28 and 200 m northwest of Station 27. The site was very near the bank's summit. The actual summit could not be surveyed due to fishing boat activity. Regardless, the minimum depth at the station was 53 m on top of one small pinnacle, which is the same as the summit depth. The survey was conducted between 1933 and 2058 hours on 27 June 1989. Video records total 1.39 hours. Visibility was approximately 5 m.

The survey area contained a number of small reefs and pinnacles surrounded by sand flats containing significant amounts of rubble and coarse sand. No pinnacles observed were over 4 m tall, but all were occupied by extensive coralline algae crusts, and lush invertebrate and fish assemblages. The density of these groups was comparable to the assemblages on the reef flats on the flat-topped feature at Stations 13. Unlike other features with similar bottom types, however, no *Rhizopsammia manuelensis*, *Madrepora* *carolina*, and very few, if any, *Oculina* sp. or solitary coral colonies occurred, and gorgonian assemblages were depauperate. No bacterial mats or gas seeps were seen at this station.

Biotic assemblages on the pinnacles and smaller rock features were dominated by coralline algae (Figure 13-26) and comatulid crinoids (a black and orange species and a tan species). All these were considered abundant. Massive tan bryozoan? colonies, unidentified gorgonian? sea feathers, orange and yellow encrusting sponges, *Cirrhipathes* sp. (coiled antipatharian sea whips), orange mounding sponges, black comatulid crinoids, and orange comatulids were considered common. Interestingly, on the features above approximately 55 m, the large orange gorgonian sea fans so conspicuous on many features elsewhere in the study area were not observed. They were considered common below this depth at this station. A second antipatharian sp., *Antipathes* sp. B (sparsely branched) was common, especially on rubble and low topographic features. It was considered occasional on larger features. Organisms considered occasional included a white comatulid crinoid, *Elisella* sp. (octocoral sea whip), an unidentified white bushy colony (possibly a coral or ectoproct), *Spondylus americanus* (American thorny oyster; 7), and white upright sponges (3). Rare epibenthos included white solitary corals (1 cluster), an *Oculina*? sp. coral colony, *Elisella elongata* (branched sea whip), *Nicella* sp. (small red sea fan; 1), and a yellow, volcano-shaped sponge (1).

On some shallow reef surfaces, a sometimes thick mat of unidentified material was observed. This material could be leafy algae, hydroids, or low growing, small octocorals. We also observed two of the same type of rubble piles seen at the other stations on this bank.

Motile benthic organisms associated with these features included *Stylocidaris affinis* (sea urchin, very patchy distribution; abundant on some features, absent on others), gorgonocephalids (white basket stars, occasional; 9), orange basket stars (3), a black basket star (1), a red sea star (1), an unidentified white and black brittle star, and *Hermodice carunculata* (fireworm; 1).

At least 14 fish species were observed. *Holanthias martinicensis* (roughtongue bass; common) dominated the assemblage, as at other stations of comparable bottom type and depth. Occasional species included *Chromis*

Figure 13-26. Portion of Station 29 at 55.8 m, covered nearly entirely by coralline algae crusts (including *Lithothamnium* and *Peyssonnelia*) and encrusting sponges (orange and yellow forms). Fish are mostly *Holanthias martinicensis* (roughtongue bass).

enchrysurus (yellowtail reeffish; 4), *Lactophrys quadricornis* (scrawled cowfish; 4), and *Pristigenys alta* (short bigeye; 3). Rare species included *Chaetodon sedentarius* (reef butterflyfish; 2), *Mycteroperca microlepis* (gag grouper; 1), *Serranus phoebe* (tattler; 1), *Chaetodon aya* (bank butterflyfish; 1), *Holacanthus bermudensis* (blue angelfish; 1), *Holocentrus rufus* (longspine squirrelfish; 1), *Equetus umbrosus* (cubbyu; 1), *Apogon* sp. (cardinalfish; 1), and *Paranthias furcifer* (creole-fish; 1). *Seriola dumerili* (amberjack) schools were occasionally observed in the water column and near the bottom.

Only one sign of human debris was observed. This was a cable lying on a sand flat. Much of the cable appeared to be buried in sand.

Fishing - At this station, we caught many *Rhomboplites aurorubens* (vermilion snapper), two small sharks, *Paranthias furcifer* (creole-fish), an ophidiid (cusk eel), and *Balistes capriscus* (gray triggerfish).

13.3.1.30 **Station 30** - Horseshoe Bank - Bank 1 (first of two stations)

Video Survey - This diapiric bank is located approximately 35 km east of the Mississippi River delta, and crests at approximately 55 m (Figure 13-27). It has a landward surrounding depth of 74 m and drops off to seaward to 100 m within 1.3 km of the crest. At the time of the survey, eight petroleum platforms surrounded the bank.

The bank was visited on two occasions and at two locations, Stations 30 and 31. Station 30 was surveyed on 26 June 1989, between 1338 and 1442 hours. Video tape records during this dive total 1.04 hours. The station location was 29°12.80'N, 88°33.85'W, or approximately 0.8 km north of the bank summit.

In this region of the bank, the bottom consisted of coarse, shelly sediments with substantial silt. Visibility during the dive was less than 3 m, and variable, depending on the amount of silt disturbed by the ROV. Depth during the survey ranged from 65 to 66 m. Numerous depressions (common, most less than 0.5 m across and 0.2 m deep) and some mounds (3) were seen, as well as evidence of significant recent bioturbation by infaunal organisms. Some rubble was also seen, some of which harbored hard-bottom organisms. No rock outcrops, however, were observed.

Soft-bottom organisms at the site included hermit crabs (occasional), turrid gastropods (2), and unidentified gastropods (common), and the fish *Serranus phoebe* (tattler, occasional; 6), *Serranus* sp. (rare; 2), sparids (porgies; 2), *Serranus notospilus* or *atrobranchus* (saddle bass or blackear bass; 1), *Ogcocephalus* sp. (batfish; 1), a diodontid (burrfish or porcupine fish; 1), and a flounder (1).

On rubble, the most commonly observed organisms were comatulid crinoids. Three species were seen, including orange and black (occasional; 5), black (rare; 1), and yellow (1) crinoids. In addition, three specimens of the octocoral sea whip, *Elisella barbadensis* were attached to pieces of rubble.

One aluminum can was observed, but not other indications of man-induced disturbance.

Horseshoe Bank (Bank 1)

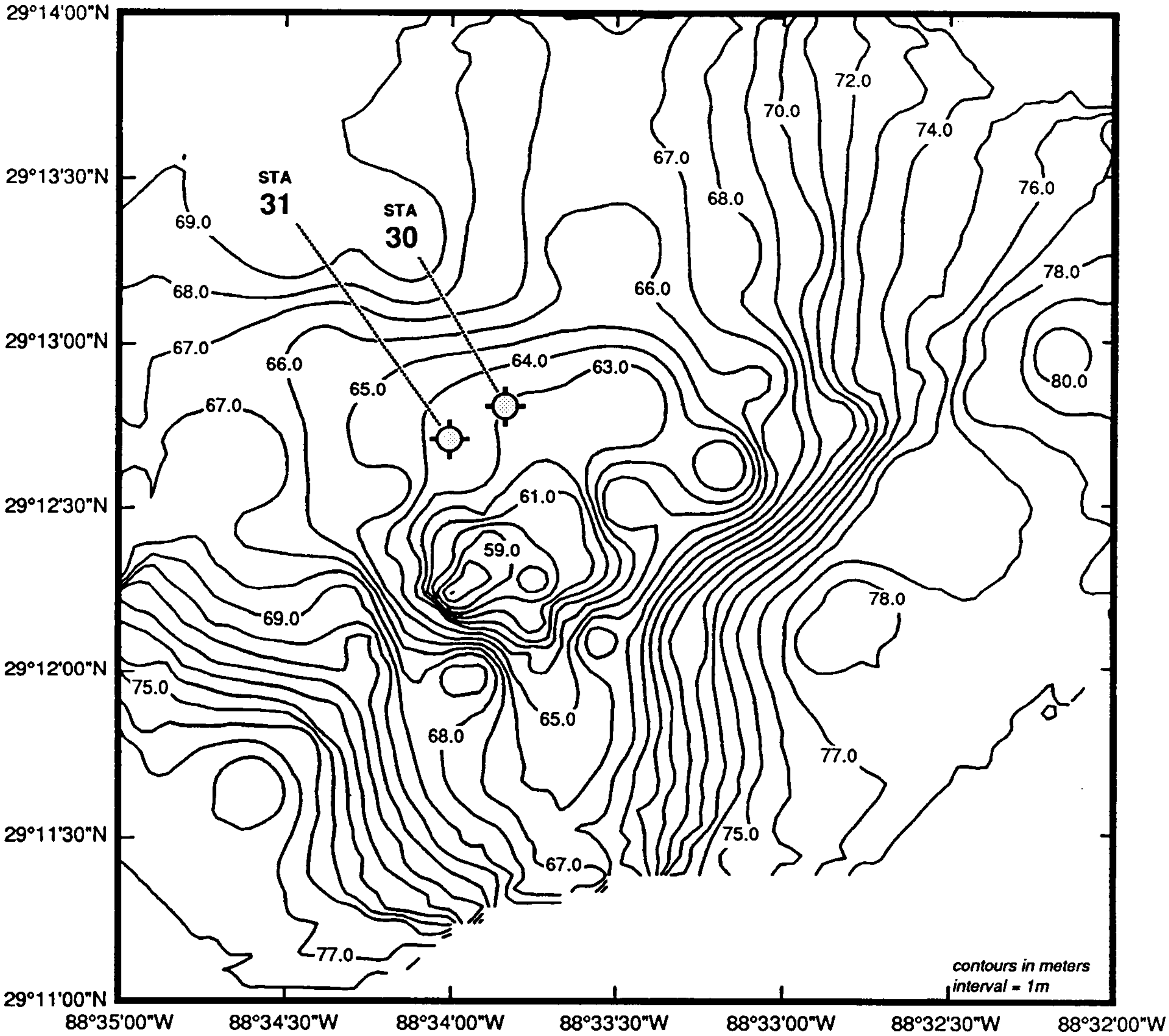


Figure 13-27. Contour map of Horseshoe Bank (Bank 1), based on fathometer survey of the area prior to ROV deployment. Stations 30 and 31 were located on this bank.

Fishing - Hook-and-line fishing produced *Calamus bajonado* (jolthead porgies), *Centropristis ocyurus* (bank sea bass), *Lutjanus campechanus* (red snapper), and *Balistes capriscus* (gray triggerfish).

13.3.1.31 **Station 31** - Horseshoe Bank - Bank 1 (second of two stations)

Video Survey - On 27 June 1989, we returned to this bank for a second survey and chose an area with a more rugged bottom than had been surveyed at Station 30. This area was between Station 30 and the bank's summit, approximately 400 m southwest of Station 30 and 600 m north of the summit. Minimum depth at the station was 62.5 m, or approximately seven meters below the summit depth. Maximum depth during the survey was 66 m. The survey was conducted between 0352 and 0458 hours. Video records total 1.1 hours.

The station consisted of numerous low to moderate topographic features. No reefs were taller than three meters. Most were rugged, consisting of holes and overhangs and up to several meters in diameter. Between the features was sediment similar to that observed at Station 30 (i.e. shelly sand with considerable silt). Visibility on the dive was less than three meters.

A fairly diverse assemblage of invertebrates and fish was found on these reefs, but density was not as high as on any other large features, and coral species that dominated other features of similar size were absent or rare here (Figure 13-28). The assemblage was dominated by comatulid crinoids. Five species were considered common (orange and black, yellow, black, tan, and orange crinoids). Also considered common were *Antipathes* sp. A (bushy antipatharian), orange encrusting sponges, and small yellow/orange sea fans (possibly several species). Occasionally observed organisms included coralline algae (small isolated crusts), *Elisella barbadensis* (octocoral sea whips; 6), white encrusting sponges, *Antipathes* sp. B (a sparsely branched antipatharian; 3), and *Oculina*? sp. (3). Rare epibenthos and associated invertebrates included a white comatulid crinoid (1), a white gorgonian sea fan (1), *Nicella* sp. (red gorgonian sea fan; 1), a

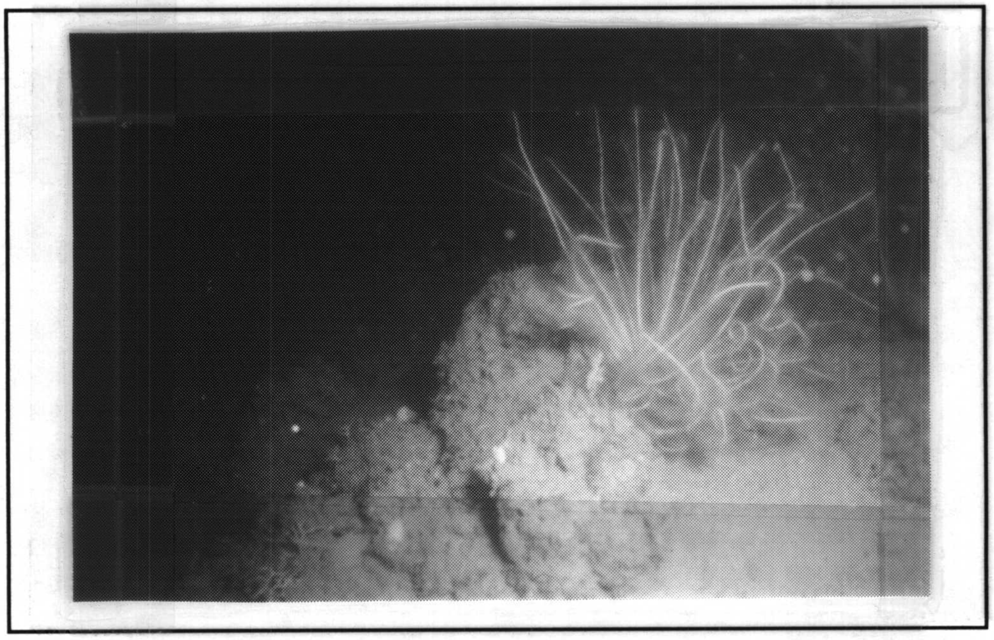


Figure 13-28. Low topographic feature at 65.2 m at Station 31, on Horseshoe Bank (Bank 1), showing a low density epifaunal community consisting of a large, gray comatulid crinoid, small coralline algae crusts, and small gorgonians (lower left).

yellow encrusting sponge (1), a white bushy coral? or ectoproct? (1), and a cluster of white solitary corals (1).

Associated invertebrates included *Diadema antillarum* (black sea urchin, occasional; 6), squid (some on bottom, some swimming; occasional), a black basket star (1), and a large majid crab (1).

Fish associated with these features (11 species) included *Rhomboplites aurorubens* (vermilion snapper, occasional; 6), *Decapterus*? sp. (scad, occasional; 3), *Trichiurus lepturus* (Atlantic cutlassfish; occasional), *Holanthias martinicensis* (roughtongue bass, rare; 2), *Balistes capriscus* (gray triggerfish; 2), *Chaetodon aya* (bank butterflyfish; 1), *Equetus umbrosus* (cubbyu; 1), *Apogon* sp. (cardinalfish; 1), an orange scorpaenid (1), a grammistid (soapfish; 1), and a holocentrid (squirrelfish; 1).

The lack of the hard corals *Rhizopsammia manuelensis* and *Madrepora carolina*, lack of the antipatharian *Cirrhipathes* sp., limited coralline algae, limited *Oculina*, and poor development of the gorgonian assemblage all suggest relatively poor conditions for reef community development. While turbidity limits light penetration, inhibiting algae growth, sedimentation often limits coral growth. Such factors may be influenced by the proximity of the bank to the Mississippi River. Development on this bank appeared to be intermediate between the very poor development on Sandpile Bank (Station 32 below) and that at stations farther to the east.

No bacterial mats or gas seeps were observed at either of the stations surveyed on this bank. However, a much more extensive area would need to be surveyed in order to address this. It is also possible that the bank's summit or other places on the bank contain more extensive hard-bottom areas and considerably better community development. Assessment of these attributes would also require a more widespread reconnaissance.

Aside from one aluminum can on the bottom, there were virtually no signs of human intrusion at these stations. This may reflect poor fishing on the bank, which also supports limited community development.

13.3.1.32 **Station 32** - Sandpile Bank - Bank 2

Video Survey - This bank was investigated in 1956 by Parker and Curray, who found the surface of the bank to be composed primarily of silty sand rather than the calcareous debris typical of many other northern Gulf topographic highs. The bank is approximately 21 km east of Southeast Pass on the Mississippi Delta, and is centered on 29°04.5'N, 88°43.5'W. It crests near 84 m, has a landward surrounding depth of 98 m, and a seaward drop to 200 m within 2.5 km of the crest (Figure 13-29). The bank is of diapiric origin and is approximately 3 km across. A broad shallow area 1.2 km by 0.6 km, trending northeast/southwest, occupies the top of the feature in a depth range of 84 to 86 m. At the time of the ROV survey (26-27 June 1989), three oil platforms were located on the west side of the bank and one was on the north side.

The ROV survey was conducted in the center of the shallowest area of the bank at 29°04.57'N, 88°42.98'W between 2324 hours on 26 June and 0027 hours on 27 June. Video records totalled 1.04 hours. Water clarity was very low (visibility was less than 1.5 m). Depth during the survey remained constant at 86 m.

Sandpile Bank (Bank 2)

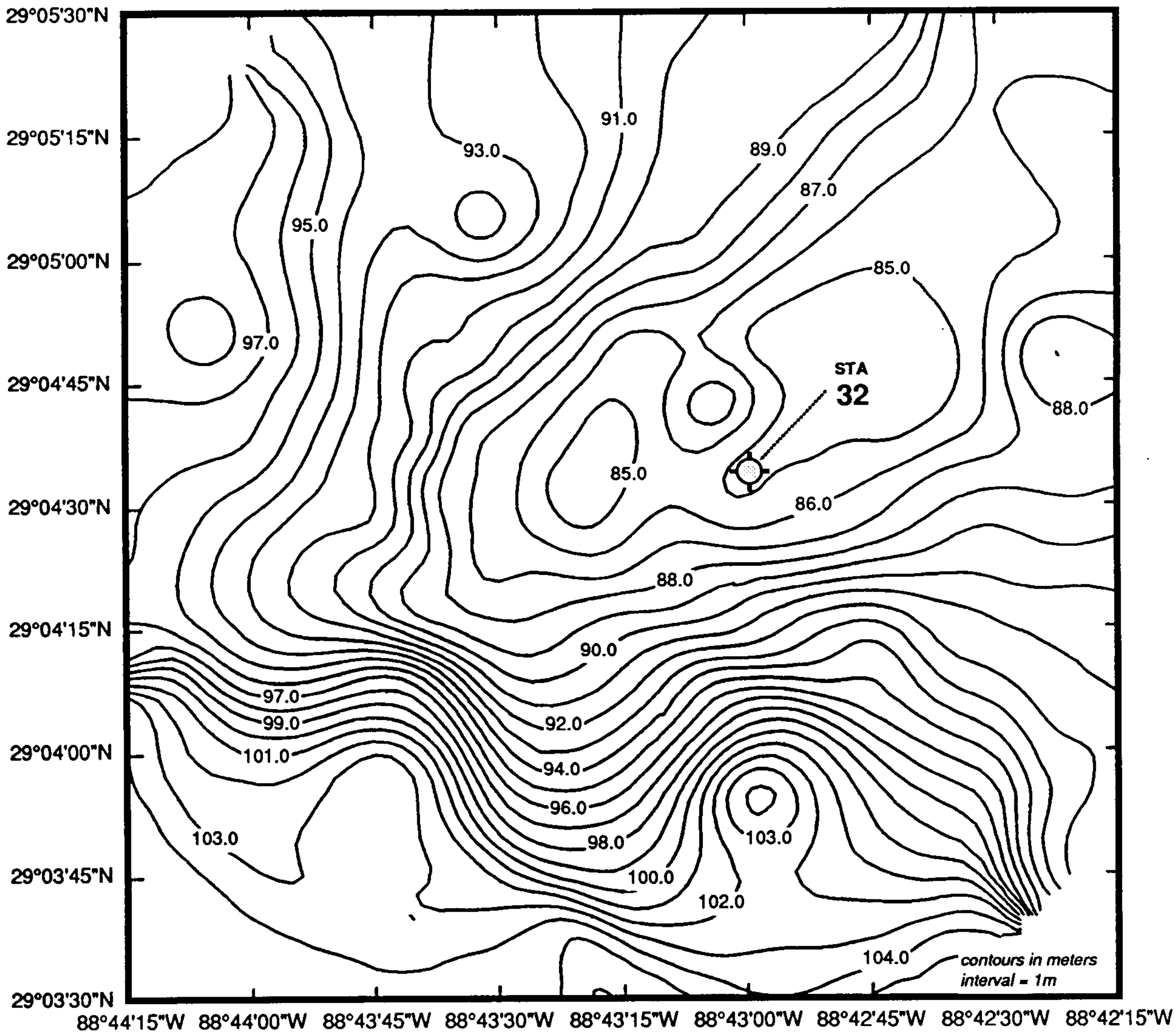


Figure 13-29. Contour map of Sandpile Bank (Bank 2), based on fathometer survey of the area prior to ROV deployment. Station 32 was located on this bank.

We observed no hard bottom areas during the survey. The bottom was composed of what appeared to be medium grain sand and silt. This silt, and strong currents combined to limit visibility.

The most abundant organisms in benthic habitats were *Cirrhipathes* sp. (coiled sea whips, occasional; 11), which did not appear to be attached to hard surfaces. While these substrates may have been buried under sediment, the lack of surface manifestations of subsurface hard bottom features suggests otherwise. Furthermore, organisms were isolated from each other. One would expect patchy distributions of such organisms if buried hard bottoms occurred. Other benthos included one species of sea urchin (also isolated occurrences, occasional; 10), and large squid lying on the bottom (15-20 cm; 2). Benthic fish included *Centropristis ocyurus* (bank sea bass; 1), *Prionotus* sp. (sea robin; 1), and a flounder (1). All these species were typically seen in other sandy bottom habitats throughout the study area.

By far the most abundant fish species observed at the site was *Decapterus*? sp. (scad). Scad often dominated other soft bottom stations in the study area during night surveys. These fish followed the ROV lights in large schools. *Rhomboplites aurorubens* (vermilion snapper; common, but many may have been repeat observations) were observed within these schools of scad, as well as one juvenile(?) scombrid (mackerel; 0.3 m long). *Trichiurus lepturus* (Atlantic cutlassfish) were frequently observed in the water column, as well as two large schools of small squid, and one larger squid (appeared to be a different species).

One observation of anthropomorphic debris was made. The item was not identified, but looked somewhat like a pail tilted and partially buried in the sand.

13.3.1.33 **Station 33** - 36-Fathom Ridge

Video Survey - On 28 June 1989, we crossed a tall, narrow feature while traveling between stations. The base depth of the feature was approximately 90 m. The crest depth was 66 m. We returned later to map and survey the feature, which is a north-south oriented ridge nearly 1 km long, but less than 250 m wide (Figure 13-30). The summit did not appear

36-Fathom Ridge

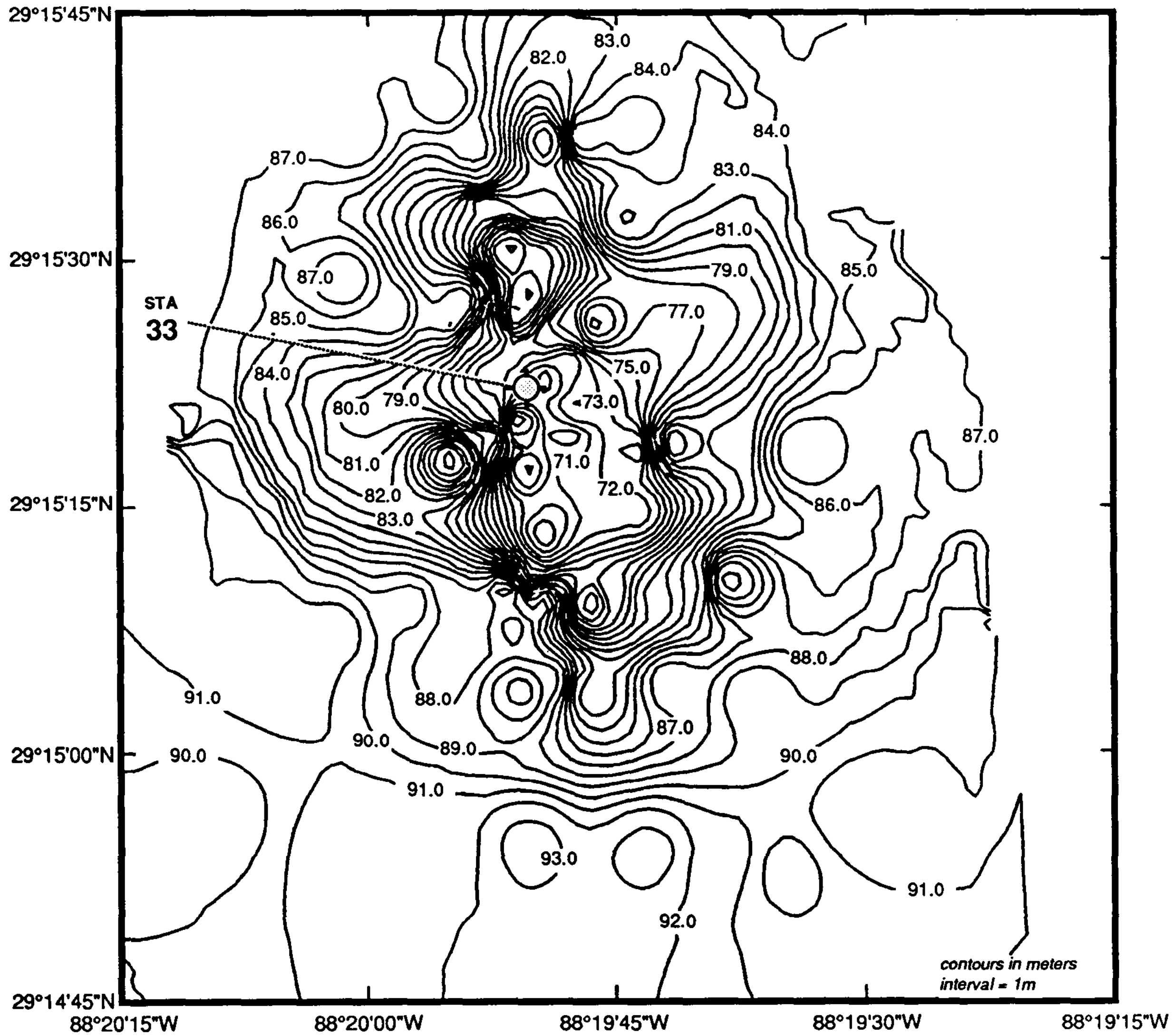


Figure 13-30. Contour map of 36-Fathom Ridge based on fathometer survey of the area prior to ROV deployment. Station 33 was located on this bank.

to be flat-topped. The origin of the feature was not apparent, but the lack of oil production in the area suggests that it may be unrelated to salt diapirism.

The ridge was surveyed on 28 June, between 1957 and 2141 hours. Video records total 1.71 hours. The survey location was 29°15.37'N, 88°19.84'W, near the center of the ridge.

Depth during the ROV dive was between 68 and 72.5 m. Most of the bottom was rocky, with no pinnacle-like features, or reefs with more than two meters vertical relief. Sandy areas were composed of shelly sand with very little silt, resulting in relatively good visibility during the dive (greater than 4 m). Like other rocky features, many holes and crevices were seen on vertical surfaces. Reef top areas were relatively flat.

Community development appeared to vary somewhat with depth. The densest assemblages occurred on reef top surfaces near 68 m. Density decreased with depth. The development of individual coral colonies followed a similar pattern, with the largest occurring on the shallowest surfaces.

The epibenthic community consisted of many species that were considered common, but none that were considered abundant. Common benthos included coralline algae (to at least 72.5 m, the base of features surveyed), orange encrusting sponges, large white and large orange gorgonian sea fans, small tan gorgonian sea fans, *Elisella barbadensis* (sea whips), several comatulid crinoid species (black, orange and black, orange, tan, and gray, roughly in order of decreasing abundance), the antipatharians *Cirrhipathes* sp. (coiled sea whips) and *Antipathes* sp. A (bushy form), and the ahermatypic hard coral *Rhizopsammia manuelensis*.

The few epibenthic organisms considered occasional included pale yellow sea fans, solitary white stony corals, *Nicella* sp. (small red sea fans), *Antipathes* sp. B (sparsely branched antipatharian; 6), and *Elisella elongata* (branched octocoral sea whip; 4). Rare epibenthos included white, ball-shaped sponges (2), a yellow, ball-shaped sponge (1), a yellow comatulid crinoid (1), and a *Scolymia*-like coral? (a large, single-polyp coral; possibly an anemone).

Associated invertebrates included gorgonocephalids (basket stars, usually attached to gorgonians or antipatharians; common), *Stylocidaris affinis* (sea urchin, occasional; 6), *Diadema antillarum* (black sea urchin, occasional; 4), white ophiuroids (brittle stars, occasional; 3), squid (occasional; 3), *Stenorhynchus seticornis* (arrow crab, rare; 2), shrimp (rare; 2), a large, tan gorgonian sea fan (1), an orange sea star (1), an orange basket star (1), and a hermit crab (1).

At least 18 fish species were seen, including *Holanthias martinicensis* (roughtongue bass, numerically dominant fish, but only occasional), *Rhomboplites aurorubens* (vermilion snapper, occasional; 9), unidentified holocentrids? (squirrelfish?, occasional; 9), *Decapterus*? sp. (scad, occasional in the water column; 7), *Ogcocephalus corniger* (longnose batfish, occasional; 5), orange scorpaenids (scorpionfish, occasional; 5), *Chaetodon aya* (bank butterflyfish, occasional; 4), *Pristigenys alta* (short bigeye, occasional; 4), *Priacanthus creunatus* (glasseye snapper, occasional; 3), *Trichiurus lepturus* (Atlantic cutlassfish, occasional; 3), *Muraena retifera* (reticulate moray, occasional; 3), *Serranus phoebe* (tattler, rare; 2), *Equetus umbrosus* (cubbyu, rare; 2), sparids (porgies, rare; 2), *Chaetodon sedentarius* (reef butterflyfish; 1), *Aulostomus maculatus* (trumpetfish; 1), *Apogon pseudomaculatus* (twospot cardinalfish; 1), *Apogon* sp. (cardinalfish; 1), and *Mustelus* sp. (dogfish shark, possibly *M. canis*, the smooth dogfish; 1).

Though the species encountered here were not markedly different from those seen on other high relief topographic features, the overall abundance of fish seemed quite low, especially with regards to *H. martinicensis*, and small reef fish, such as damselfish and those too small for identification. Abundance was somewhat higher, however, than at Station 31 (Horseshoe Bank), 20 km west. But it was lower than Station 27 (Mountain Top), a bank 8 km west.

The ahermatypic stony coral, *Rhizopsammia manuelensis* was intermediate in apparent abundance between that observed at Station 28 (Mountain Top), where only one cluster was observed, and Stations 25 and 26 (West Addition Pinnacles), where they dominated the hard surfaces.

Frequency and individual development of the organisms on the top of the feature were only slightly lower than that on the flat-topped features at stations 8, 13, and 14. The limited sponge community on this feature further distinguished it from Station 13. These differences might be due to slightly deeper survey depths (68 m here, vs. 63 on the other stations) or proximity to the Mississippi River.

This station was almost free of signs of human intrusion. Only one fishing line was observed. This may reflect limited fishing activity and limited fish populations.

Fishing - Fish caught on this feature included several *Rhomboplites aurorubens* (vermilion snapper), *Lutjanus campechanus* (red snapper; 1), and *Scomberomorus cavalla* (king mackerel; 1).

13.4 Discussion

13.4.1 Biological Community Composition/Feature Categories

Benthic biotic assemblages on hard bottom areas within the Mississippi-Alabama study region consisted of predominantly suspension-feeding invertebrates. Epibenthos included gorgonian corals, ahermatypic scleractinian corals, antipatharian corals, sponges, comatulid crinoids, bryozoans, alcyonarians, and oysters (roughly in this order of abundance), though occurrence varied significantly between the sites. Coralline algae crusts were common on hard bottom features shallow enough to allow sufficient light penetration and of sufficient vertical relief to reduce the effects of smothering by fine sediments. They may have been absent on hard bottoms below approximately 78 meters and were absent from some features as shallow as 62 m. Though hermatypic corals can occur at depths surveyed in this study (e.g. Reed 1985), only two genera (*Agaricia* and *Stephenocoenia*) were found.

Frequency and diversity varied considerably between features. Both appeared to increase with the amount of exposed hard bottom, rugosity, and the complexity of the features (i.e. the number of bottom types available to hard bottom organisms). Even very small outcrops and very low topographic features, however, were barren only when sediment blanketed them completely. Most contained a low diversity assemblage consisting of some of the epibenthos mentioned above (usually crinoids, gorgonians, or antipatharians), and associated invertebrates (mostly occasional sightings of crabs, molluscs, and echinoids). Nekton typically included short bigeyes (*Pristigenys alta*), yellowtail reeffish (*Chromis enchrysurus*), bank butterflyfish (*Chaetodon aya*), and tattlers (*Serranus phoebe*). On bottom features of intermediate size and complexity (e.g. outcrops along the paleo-shoreline, the moderate features, patch reefs and features near pinnacles or other large reefs), diversity and frequency of benthic epifauna, associated benthos, and associated nekton were higher.

Table 13-2 lists information with regard to the abiotic and biotic character of stations surveyed using video and still photography. Abiotic parameters include, among other things, a ranking of the stations by amount of relief, which takes into consideration the vertical and horizontal extents of hard bottom specifically surveyed (not necessarily the horizontal extent of features in the broader geologic sense). Also given is the relative frequency of selected invertebrate and fish taxa which were considered to be the most important contributors to biological assemblages in the area. Relative frequencies used in station descriptions (i.e. rare, occasional, common, and abundant) were assigned a number from 1 (rare) to 4 (abundant). These numbers were summed for invertebrates and fish, then totalled for all organisms to enable the comparison of the levels of community development at different stations (Appendix D lists the frequencies all recognized taxa from all stations for invertebrates and fish).

Due to considerable variation between populations on different features, comparisons of relative frequencies for individual taxonomic groups or species do not clearly illustrate relationships between frequency and topographic relief or other abiotic factors. The summed frequencies for invertebrates and fish, however, show that relief strongly affects the potential for community development on a hard-bottom feature. Figure 13-31 illustrates the gradual increase in frequency sums for both invertebrates and fish with increasingly extensive hard bottom features through the study area. Stations lacking significant relief also lacked organisms with any more than rare or occasional occurrence. With increasing relief, the frequency of occurrence of a higher number of species increased, resulting in higher summed frequencies.

Figure 13-32 compares actual measurements of vertical relief at each station with the summed frequencies of taxa shown in Table 13-2. Grouped data points indicate values from three basic feature categories, those of low (<2 m), moderate (2-6 m), and high (to 18 m) topographic relief. The data show not only highest frequency sums on taller features, but also suggest that the range of summed frequencies decreases with increasing relief.

Table 13-2. **Ranked relief, vertical and horizontal relief, frequencies of selected taxa, and total frequencies and numbers of taxa for invertebrates, fish, and total organisms at all station visited during ROV surveys. Frequency values are as follows: 0 = absent, 1 = rare, 2 = occasional, 3 = frequent, 4 = abundant. Invertebrate and fish frequencies are totals of respective taxa. Total frequency is total of invertebrates and fish frequencies. Coralline algae values are included in table, but not used in calculating totals.**

					Invertebrate Frequencies									
Sta.	Relief Rank	Vert. Relief	Horiz. Relief	Cor. Algae	*Antipathes* spp.	*Cirrhi-pathes*	Comatulid Crinoids	*Elisella* spp.	Gorg. Fans	*Madrepora carolina*	*Oculina*? spp.	*Rhizop-sammia*	Encrust. Sponge	Upright Sponge
32	1	0.0	0	0	0	2	0	0	0	0	0	0	0	0
1	2	0.0	0	0	0	0	0	1	0	0	0	0	0	1
11	3	0.0	0	0	0	2	0	0	0	0	0	0	0	0
30	4	0.2	0.5	0	0	0	0	2	0	0	0	0	0	0
3	5	0.3	0.5	0	0	0	1	0	0	0	0	0	0	0
12	6	0.5	0.5	0	0	0	2	0	1	0	0	0	0	0
2	7	0.5	1	0	4	4	4	4	0	0	0	0	0	1
4	8	0.5	2	1	2	2	4	3	0	0	0	0	0	2
7	9	1.0	2	0	3	2	1	1	2	0	0	1	2	2
24	10	4.0	2	0	0	0	0	2	3	1	2	4	0	0
16	11	2.0	10's	0	3	3	0	2	3	0	2	2	3	3
9	12	3.5	5	0	2	2	1	4	2	2	2	2	0	1
27	13	2.0	100's	4	3	3	3	3	3	0	0	0	3	2
33	14	2.0	10's	3	3	3	4	3	3	0	0	3	3	1
31	15	3.0	5	2	3	0	4	2	3	0	2	0	3	0
5	16	3.0	2	1	3	3	2	2	3	0	2	2	3	2
6	17	3.0	5	0	2	2	0	3	1	2	2	3	0	1
15	18	3.0	20	3	4	3	1	3	2	0	2	4	3	1
10	19	3.8	2	0	3	2	3	4	3	2	3	3	4	0
29	20	4.0	100's	4	3	3	4	2	3	0	1	0	3	3
28	21	6.0	100's	3	4	3	4	3	2	0	2	1	4	2
18	22	15.0	10's	0	0	1	4	3	4	4	2	4	2	0
8	23	12.0	100's	1	3	3	3	0	4	0	3	2	2	2
14	24	12.4	100's	3	4	3	4	4	4	0	2	3	3	2
13	25	15.0	100's	3	2	2	4	3	4	3	2	3	3	4
25	26	17.5	10's	2	4	2	0	3	4	4	3	4	3	2
26	27	18.0	10's	2	4	0	3	0	2	3	3	4	2	1

		Fish Frequencies						Number of Taxa			Frequency Sums		
Sta.	Relief Rank	*Holan-thias*	*Chaet-odon*	*Heman-thias*	*Liopro-poma*	*Pristi-genys*	*Rhombo-plites*	Invert Taxa	Fish Taxa	Total Taxa	Invert. Freq.	Fish Freq.	Total Freq.
32	1	0	0	0	0	0	3	4	7	11	2	3	5
1	2	0	0	0	0	0	0	7	7	14	2	0	2
11	3	0	0	0	0	0	0	1	2	3	2	0	2
30	4	0	0	0	0	0	0	7	6	13	2	0	2
3	5	0	0	0	0	0	0	6	19	25	1	0	1
12	6	0	0	0	0	1	0	6	5	11	3	1	4
2	7	0	2	0	2	3	0	13	11	24	17	7	24
4	8	1	3	2	0	3	0	13	15	28	13	9	22
7	9	1	0	0	1	1	0	29	10	39	14	3	17
24	10	3	1	0	1	0	0	12	8	20	12	5	17
16	11	2	0	0	2	2	0	17	11	28	21	6	27
9	12	2	1	0	0	2	2	23	9	32	18	7	25
27	13	3	2	0	0	3	2	38	25	63	20	10	30
33	14	2	2	0	0	2	2	31	18	49	23	8	31
31	15	1	1	0	0	0	2	23	11	34	17	4	21
5	16	2	2	0	2	1	2	29	22	51	22	9	31
6	17	4	2	2	2	1	2	18	24	42	16	13	29
15	18	3	3	2	2	2	0	24	22	46	23	12	35
10	19	3	1	0	0	2	1	27	15	42	27	7	34
29	20	3	2	0	0	2	0	27	14	41	22	7	29
28	21	3	2	3	1	2	1	29	17	46	25	12	37
18	22	3	2	0	0	2	2	32	12	44	24	9	33
8	23	4	2	3	2	3	3	21	21	42	22	17	39
14	24	3	2	0	1	3	2	42	14	56	29	11	40
13	25	4	3	2	0	3	2	52	25	77	30	14	44
25	26	4	3	0	3	2	4	41	25	66	29	16	45
26	27	4	2	3	2	0	3	30	17	47	22	14	36

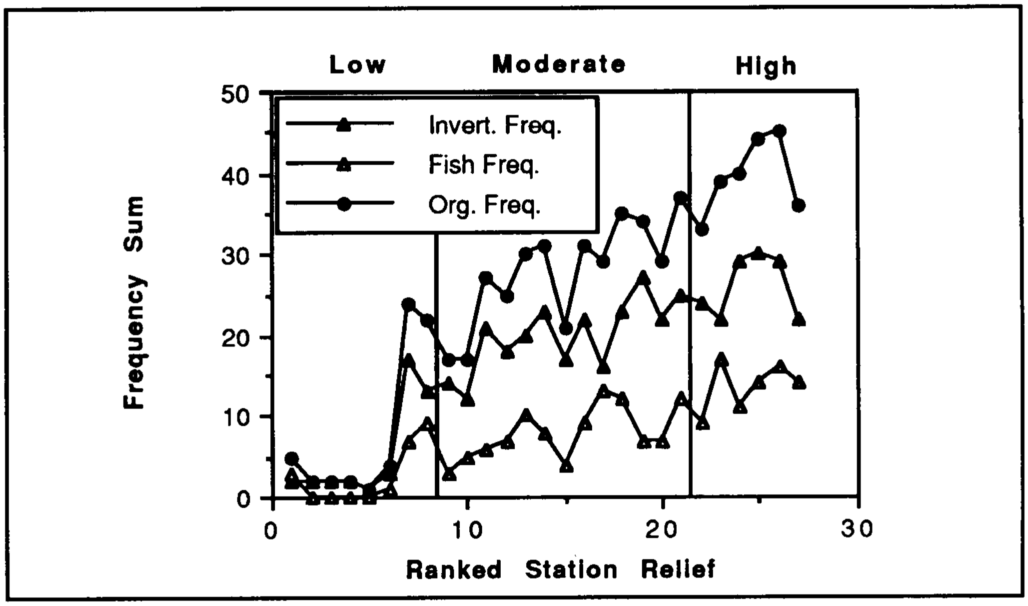


Figure 13-31. Graph of the sums of frequency values for selected invertebrates, fish, and total organisms (except coralline algae) as functions of relief of stations surveyed using video and still photography (an x-axis value of 1 indicates the station with the least relief, a value of 27 the station with the most).

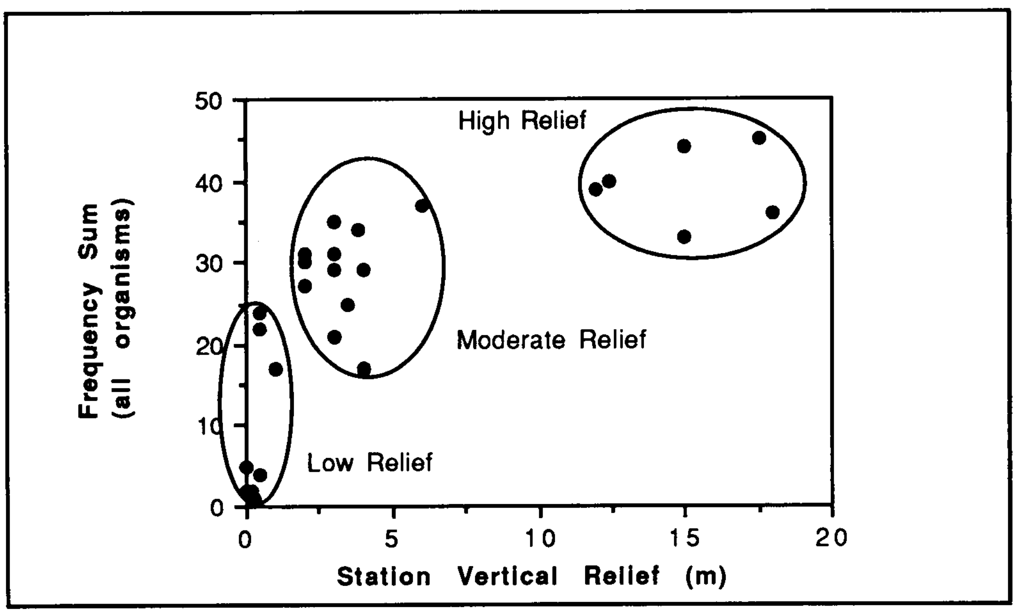


Figure 13-32. Sum of frequency values for all organisms (fish and invertebrates) as a function of vertical relief at stations surveyed in this study. Ovals surround data points from features with low, moderate, and high topographic relief.

That is, high relief stations all had high summed frequencies (high diversity and high population density). Low relief stations sometimes had very low summed frequencies (low diversity and density) and sometimes had diversity and frequency similar to stations of at least moderate relief.

The approximate number of invertebrate and fish taxa recorded from each station is also given in Table 13-2. Figure 13-33 shows that species the presence of this recognizable reef-flat community on flat-topped features distinguishes them from pinnacle-type features. For this reason, two categories of high topographic features, flat-topped and pinnacle-type structures, are recognized because of their distinct biological characteristics.

Fauna associated with epibenthic communities varied in type. Some were suspension feeders, such as the basket stars (including gorgonocephalids, frequently attached to gorgonian corals), crinoids, serpulid worms, pennatulaceans, and some ophiuroids. Some were sandy bottom deposit feeders, such as the echinoids *Clypeaster* sp., *Brissopsis* sp., and holothuroideans. Most others were probably omnivorous, opportunistic scavengers, such as the gastropods *Scaphella* spp., sea stars, *Stenorhynchus seticornis* (the arrow crab, Williams 1984), and other crabs (e.g. *Rochinia tanneri* and pagurid hermit crabs). Sea urchins are typically considered grazers. Filamentous and leafy algae were not significant components of hard bottom communities, suggesting that sea urchins may also depend on opportunistic scavenging. One predatory invertebrate may be the fire worm, *Hermodice carunculata*, a polychaete which is known to feed on corals. The fish fauna probably consisted of infaunal feeders, browsers, and predators. Appendix D lists all fish species observed during detailed analysis of video tapes from ROV stations and from hook-and-line fishing efforts.

13.4.2 Longitudinal Variation

Considering only features with considerable vertical or horizontal extent, and thus, those with the potential for hard-bottom community development, the extent of epibenthic and associated faunal community development appeared to be poorest at Station 32 (Sandpile Bank), and progressively higher at Stations 31 (Horseshoe Bank), 29 (Mountain Top), 33 (36-Fathom Ridge), and 25 and 26 (West Addition Pinnacles). These

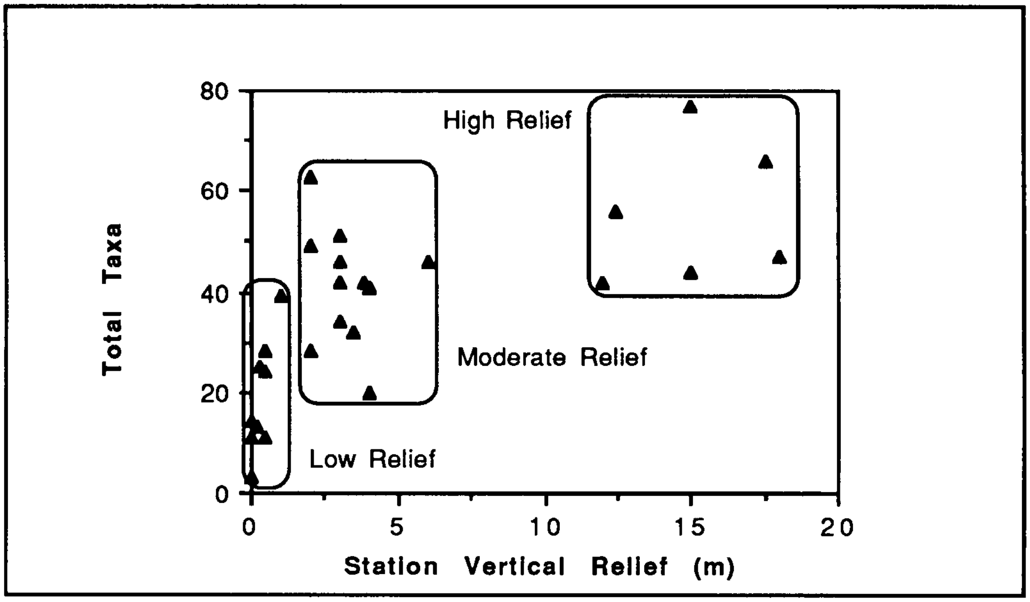


Figure 13-33. Total number of taxa observed at each station as a function of vertical relief.

stations were located 27, 37, 50, 58, and 70 km east of the Mississippi River Delta, respectively. It is likely that the Mississippi River plume influences the long-term average water quality (e.g. salinity and turbidity) over this longitudinal range, resulting in diminished developmental potential on features closer to the Delta.

For example, the ahermatypic stony coral, *Rhizopsammia manuelensis*, an important epibenthic contributor on most moderate and high relief hard-bottom features in the study area, was absent at Stations 32 (Sandpile Bank) and 30 and 31 (Horseshoe Bank). Only one cluster was observed at Station 28 (Mountain Top). Frequency at Station 33 (36-Fathom Ridge; common) was intermediate between that observed at Station 28 (rare) and Stations 25 and 26 (West Addition Pinnacles; abundant). The coral dominated the hard-bottom assemblage on the latter stations and on most high relief stations farther east. This is significant since a pattern emerges suggesting a critical limiting factor acting through this particular region for this species. As corals are commonly limited by water column sediment loads, one suspects that the influence of the Mississippi River diminishes through this area, though other potentially limiting factors cannot be ruled out (e.g. pollutants and salinity effects, among others). Biological patterns of longitudinal variation through the study area are illustrated in Table 13-3 for this and several other benthic organisms that occur in abundance on most high relief features in the study area.

The data suggest that the particular area over which the effects of the Mississippi River plume become limiting for conspicuous hard-bottom organisms varies with species. As a group, however, the influence occurred across a threshold area between the westernmost station (32), and Stations 25 and 26, where the sum of taxa frequencies peaked. East of Stations 25 and 26, taxa frequencies still varied considerably, but this was likely due to factors other than those influenced by the River. This "Mississippi Threshold", an area with average water quality that is suboptimal for hard-bottom community development, extends east of the Delta perhaps no greater than 70 km. Due to generally westward flowing river outflow, a comparable threshold is much broader to the west of the delta, perhaps limiting hard-bottom development over a distance of some 300 km (Rezak et al., 1985 [pg. 191-192], 1990).

On the Louisiana-Mississippi-Alabama continental shelf (LMAS), currents are seasonally variable. Eastward transport off the mouth of the Mississippi Delta, however, which could carry turbid, fresh water over the outer LMAS, is quite frequent (Chapter 10.0). Satellite (Chapter 11.0) and hydrographic data (Chapter 10.0), however, indicate that transport of freshwater to the east is limited. Mean circulation over the shelf is cyclonic most of the time. Events that influence the outer LMAS include frequent intrusions of eddies and filaments spawned from the Loop Current, and infrequent tropical cyclones. Both transport clear, oceanic water to the area. In 1988 and 1989, Loop Current-associated water masses were found 44% of the time on the LMAS slope (Chapter 10.0). Transport of Mississippi River water to the region may also be inhibited by the fact that the freshwater establishes a dynamic high upon discharge, resulting in clockwise flow. Since the boundary of this water mass is the delta, the tendency is for southward transport east of the delta and westward transport around its mouth. Thus, water conditions which could limit hard-bottom community development on the outer LMAS (mainly fresh or turbid conditions) are volumetrically less significant than in regions west of the delta.

Table 13-3. Relative abundance of selected invertebrates on the largest topographic features between the Mississippi River and the eastern edge of the hard-bottom study area (= absent, • = rare, •• = occasional, ••• = frequent, •••• = abundant). Frequency sum is the sum total of the frequency estimates for all selected taxa at each station.

Taxon	**Sta. 32** Sandpile Bank	**Sta. 30/31** Horseshoe Bank	**Sta. 27-29** Mt. Top Bank	**Sta. 33** 36-Fm Ridge	**Sta 25/26** Pinnacles 1 and 2	**Sta. 8/9** West Reefs Area	**Sta.18** Pinnacles	**Sta. 13/14** 40-Fm Fishing Gr.
Elisella spp.		• •	• • •	• • •	• • •	• • •	• • •	• • • •
Nicella sp.		•	• •	• •	• • •	• •	• • • •	• • • •
Rhizopsammia sp.			•	• • •	• • • •	• •	• • • •	• • •
Oculina? sp.		• •	• •		• • •	• • •	• •	• •
Madrepora carolina					• • • •	• •	• • • •	• • •
White coral clusters		•	• •	• •	• • • •	• • •	• • • •	• •
Encrusting sponges		• • •	• • •	• • •	• • •	• •	• •	• • •
Frequency Sum	**0**	**9**	**13**	**13**	**24**	**17**	**23**	**21**

The eastern edge of the Mississippi Threshold, up to 70 km east of the river delta, is coincident with a transition between prodelta clay deposits and the Mississippi-Alabama Sand Facies (Ludwick, 1964). Most of the hard bottoms with well developed reef invertebrate assemblages occurred within Ludwick's Mississippi-Alabama Reef and Interreef Facies, a band which occurs on the seaward edge of the Sand Facies. Those with limited development occurred on banks within prodelta clay deposits or in transitional area.

13.4.3 Associations with Environmental Parameters

East of the Mississippi Threshold, the effects of bottom sediments may be the principal environmental control giving rise to variation in hard bottom epibenthic community development at different sites. The variation between biotic assemblages at different sites correlated with such parameters as the areal extent of features, vertical relief, habitat complexity, and the nature of surrounding sediments. These factors, however, invariably result in differential sedimentation effects at different sites. Because all these habitats are dominated by suspension feeders, sedimentation can significantly influence population levels.

For example, both the sides and tops of high relief, pinnacle-like reefs were dominated by low growing, ahermatypic hard corals. The tops of reefs with extensive, flat summits were dominated by the taller gorgonian corals, as well as sponges and crinoids. Hard corals may have been limited on these reef flats by accumulations of sediment. Likewise, low topographic features and small outcrops had limited populations of hard corals and were generally dominated by gorgonians and antipatharians. It is likely that frequently resuspended sediments limit hard coral populations on these features.

The effects of resuspended sediments could be seen near the base of many topographic features. Within approximately 0.5 m of the surrounding bottom on some rocky features (i.e. reef bases), very little epibenthic growth was noted. Typical reef face assemblages existed above these levels. The lack of growth near reef bases is likely attributable to smothering of suspension feeding organisms. Furthermore, some features had accumulations of fine sediments around their bases. These "silt aprons" typically extended upward 0.2 to 0.5 m and outward from the reef base 0.5 to one meter. The accumulations are probably transitory, but recurrent.

Water depth did not appear to play a significant role in varying community development within the study area, with the exception of the occurrence of coralline algae and possibly one alcyonacean coral. Crusts of calcareous algae were not seen on the Pinnacles (over 90 m deep), but were observed to at least 78 m depth on reefs at the 40 Fathom Fishing Grounds. Occurrence throughout the study area, however, was not clearly related solely to depth of hard-bottom features. For example, corallines were abundant at Stations 27 and 29 (Mountain Top; 53-64 m), diminishing gradually between 53 and almost 75 m. Maximum depth of algae on the West Addition Pinnacles at Station 25 and 26, on 36-Fathom Ridge (Station 33), and at West Reefs (Station 8) was 71, 72.5, and 70 m, respectively. Crusts were also seen at 66 m on low features at Stations 4 and 5, and at 64 m on the moderate features at Station 15, but not at 73 m on top of the patch reefs. Based on data from nearby stations, the patch reefs are within the depth range of coralline algae in this part of the Gulf of Mexico. It is possible that algae populations may be limited on these reefs and on nearby features (e.g. outcrops along the shoreline surveyed at Station 7) by abiotic phenomena unique to this part of the study area (e.g. sedimentologic regime). Thus, throughout much of the study area, regional water clarity may limit the occurrence of calcareous algae to features above 78 m, but other subregional phenomena may limit or preclude its occurrence at shallower depths, even on fairly large topographic features.

The alcyonacean coral, *Siphonogorgia agassizii*, was more abundant on the Pinnacles (Station 18) than on any other high features, but it is not known whether the depth distribution of this species or other factors influenced its frequency. Other species making up the hard bottom assemblages were found at all depths and exhibited no apparent vertical zonation related to depth.

Had more depth variation occurred between features, zonation patterns might have been noted. Schroeder et al. (1988a) found that *Leptogorgia virgulata* and *Lophogorgia hebes*, both gorgonian corals, dominated biological assemblages on inner-shelf hard bottoms off Alabama to at least 35 meters. Shipp and Hopkins (1978) reported *Lophogorgia* spp. at 50-55 m depth on the northern rim of DeSoto Canyon. Other gorgonians, antipatharians, and ahermatypic corals (*Rhizopsammia manuelensis*, *Madrepora carolina* and *Oculina*? sp.) dominate the assemblage on features near the shelf edge (60-100 m). On a large reef at 230-280 m 74 km east of the Mississippi River, Moore and Bullis (1960) reported *Lophelia prolifera*, one of a number of ahermatypic species which also forms reefal structures elsewhere in deep water (e.g. Cairns and Stanley 1981; Newton et al. 1987). Though *Leptogorgia* and *Lophogorgia* may occur in the present study area, they were not documented during video surveys. *Lophelia* was not found in the study area.

13.4.4 Comparison of Features to Other Gulf of Mexico Topographic Prominences/Zoogeographic Affinities

The relationships between various hard bottom communities of the Gulf of Mexico and other Western Atlantic hard bottom assemblages have been investigated by Bright et al. (1984) and Rezak et al. (1985). Reefs in the southern Gulf are decidedly tropical in nature (Rezak et al. 1985), having community structure and dominance patterns similar to coral reefs in the Caribbean, the Florida Keys, and the Bahamas. Reefal assemblages in the northern Gulf of Mexico (including the Flower Garden reefs [Rezak et al. 1985] and the Florida Middle Ground [Hopkins et al. 1981]) are less diverse. Near-shore benthos (both hard and soft bottom organisms) in the northern Gulf are subjected to relatively high seasonal variability, resulting in an affinity to the warm temperate, Carolinian Province of the East Coast of the United States (Briggs 1974).

Based on community similarity, Bright et al. (1984) hypothesized that the tropical fauna and flora on reefs of the northwestern Gulf of Mexico are derived from reefs in the southern Gulf (those on the Campeche Bank and southwestern Gulf). Coral assemblages on the Florida Shelf are more likely derived from larval transport and recruitment of Caribbean biota via the Yucatan Current and the Loop Current in the eastern Gulf.

The topographic features near the edge of the continental shelf off Mississippi and Alabama may be of similar age and origin to those described in the northwestern Gulf of Mexico (south Texas relict carbonate banks of Rezak et al. 1985), off Cape San Blas, Florida, and on the east coast from North Carolina to south Florida (see references and Table 1 in Avent et al. 1977). The majority of these relict (early to mid-Holocene) reefs arise from bottom depths of 75 to 125 m, are 10 to 25 m tall, and exhibit ages of 10,000-20,000 years bp. The reefs were probably formed by coralline algae and possibly hermatypic corals near late Pleistocene shorelines. The presence of oceanic water masses near the shelf-edge shoreline during this period may have stimulated this growth (interestingly, many of the features have morphologies similar to present-day "pinnacles", "patch reefs", "table top reefs", and "cup reefs" found in shallow water on the Bermuda Platform [see Ginsburg and Schroeder 1969], which is influenced by the Gulf Stream). Reef building at these locations likely stopped because the features drowned during a period of rapidly rising sea level. Their surfaces are now occupied by a variety of tropical, subtropical, and warm temperate organisms, depending on their location and environmental extremes. Dominant organisms may include *Oculina* (e.g., Reed 1980), other ahermatypic scleractinian corals, coralline algae, gorgonian corals, antipatharians, crinoids, serpulid worms, sponges, and possibly others.

Few benthic organisms observed on the hard bottoms in the Mississippi-Alabama study area are typical, shallow-water, tropical reef species. In fact, none of the dominant species on features in the Mississippi Bight were found on the shallow portions of the Flower Garden Banks (Rezak et al. 1985) or the Florida Middle Ground (e.g. Grimm and Hopkins 1977), the nearest reefal environments to the study area. With the exception of coralline algae crusts, and several specimens of the hermatypic corals *Agaricia* spp. and *Stephanocoenia*? sp. (one dead; both genera are known on partly drowned reefs on banks in the northwestern Gulf of Mexico), no living hermatypic species were found. These features contain hard bottom communities similar to those on the deeper portions of topographic prominences in the northwestern Gulf of Mexico (see Rezak et al., 1985) and those on hard substrates on the northern rim of DeSoto Canyon (see Shipp and Hopkins, 1978), both of which consist of assemblages predominantly of tropical origin. More specifically, species composition is comparable to the Antipatharian Zones and the Nepheloid Zones on outer shelf, midshelf and south Texas banks described by Rezak and Bright (1978) and Rezak et al. (1985). Their description of the fauna inhabiting drowned reefs, which exist below 82-88 m on shelf-edge features in the northwestern Gulf, is nearly identical to many hard bottom site descriptions given here. These zones contain limited crusts of coralline algae, several species of ahermatypic hard corals, sizeable populations of octocorals, including sea whips (Ellisellidae) and fans (Paramuriceidae and Ellisellidae), and antipatharians, comatulid crinoids, encrusting sponges, and "expatriate" reef fishes.

Features in the present study area, however, also have some elements of Rezak and Bright's Algal-Sponge Zone. For example, some have considerable amounts of crustose coralline algae. This component of the community, however is not nearly as well developed on reefs in the Mississippi Bight (with the possible exception of one station, 27, at 58 m depth). On the other hand, development of the octocoral, sponge and crinoid assemblages on some reefs, primarily the reef flat communities at Stations 8, 13 and 14, appear to be more highly developed than those in comparable biotic zones on the banks of the northwest Gulf.

The depth of Antipatharian Zones on shelf-edge banks in the northwestern Gulf is 52 to over 90 meters. Observations made in this study were on features from 53 to over 100 meters. The description by Rezak et al. (1985) of the deeper portion of the Antipatharian Zone (80-90 m) and on drowned reefs at the Flower Gardens is very similar to observations made over all depths in the present study. Differences in the depth range of these communities undoubtedly reflect differences in water quality. In fact, the depth ranges of Antipatharian Zones of South Texas mid-shelf banks and some North Texas-Louisiana mid-shelf banks are coincident with depths in which similar communities were observed in the present study area.

Minnery et al. (1985) reported coralline algae crusts (*Lithothamnium* sp.) at depths over 100 m on shelf-edge banks in the northwestern Gulf (though cover is sparse below 82-88 m). On banks off South Texas, crusts are present but cover is sparse on the features' crests near 60 meters. On Sonnier Bank, a North Texas mid-shelf feature, encrusting corallines occur down to 47 meters. The depth distribution of corallines on mid-shelf banks is limited, however, by a thick nepheloid layer covering the lower portion of these banks.

On reefs in the northeastern Gulf, coralline algae was not seen below 78 meters. This suggests that characteristics of water quality, particularly light penetration, near topographic features on the shelf-edge off Mississippi and Alabama may be intermediate between shelf-edge and mid-shelf features off Texas and Louisiana, and varies with distance from the Mississippi River.

In the northwest Gulf, large areas on the deeper portions of topographic features are covered by a semi-permanent nepheloid layer that can be up to 20 m thick (Rezak et al., 1990). These hard bottoms are subjected to high turbidity, sedimentation, resuspension and secondary deposition. They typically consist of rock outcrops or drowned reefs containing a depauperate and variable epifaunal component, containing deep-water octocorals and solitary stony corals. Unlike banks in the northwestern Gulf, the effects of turbid water layers in the present study area seem to occur less frequently and to be limited to the lower portions of topographic features. Where heavy sedimentation by resuspended sediments was observed, however, depauperate communities similar to those inhabiting similar features in the northwestern Gulf were found.

13.4.5 Community Health (Condition)

Human interference in the form of discarded debris and community disturbance appeared to be minimal in virtually all habitats surveyed. Where debris was encountered, it was limited to individual articles (e.g., plastic cups, plastic bags, aluminum cans, or [metal?] bars), or cables or rope on the bottom and draping over reef structures. Monofilament line, lost longlines, and ropes or cables were seen at most stations containing topographic features. These are unlikely to cause mechanical damage at these depths once anchored against the reef. Though numerous oil platforms exist near three surveyed banks, the majority of discarded material on the features appeared to be derived from fishing activity.

The condition of individual organisms appeared normal. Evidence of disease on coral colonies or in solitary organisms was not noted. In fact, the development of some of the larger organisms or colonies suggests favorable environmental conditions. This was especially true on the larger reef structures, such as those at the 40 Fathom Fishing Grounds, West Reefs, and the various pinnacles surveyed. Low relief structures generally contained smaller organisms, probably because water-borne sediments affect these environments more than they do larger or taller structures.

Interestingly, long-spined sea urchins, *Diadema antillarum*, were observed at all but eight stations surveyed containing hard-bottom features. Relative frequency ranged from rare to common. Mass mortality of this species occurred throughout the Western Atlantic Ocean between January 1983 and August 1984. Over 98 percent of these sea urchins died on coral reefs throughout the region. Whether the individuals in the northeastern Gulf of Mexico were affected has not been reported, but CSA (1985a), who surveyed some reef features in this region using television, still cameras and dredges in November 1984, did not record *D. antillarum*. This region might be one of few places where considerable recovery of the *D. antillarum* population has occurred, or one of a very few places where the mortality was not extensive.

It is difficult to address the effect of fishing on reef fish populations in this area using observational data. Fishing boats were sighted on the Pinnacles, the 40 Fathom Fishing Grounds, Horseshoe Bank, Mountain Top, and 36-Fathom Ridge. Sightings of important commercial species were not common, but included amberjacks (*Seriola* spp., usually in schools), Atlantic bonito (*Sarda sarda*, in schools), red snapper (*Lutjanus campechanus*, rare), grouper (*Epinephelus* spp. and *Mycteroperca* spp.), cobia (*Rachycentron canadum*), drums (sciaenids), king mackerel (*Scomberomorus cavalla*) and possibly a bluefin tuna (*Thunnus thynnus*). The most abundant commercial species on these reefs appears to be vermilion snapper (*Rhomboplites aurorubens*, mostly small individuals) and porgies (mostly *Calamus bajonado*, the jolthead). These two species were by far the most commonly observed and were also the most commonly caught fish on hook-and-line.

On reefs where the most fishing appears to take place, the fewest observations of these commercial species were made (excepting vermilion snappers). Furthermore, these reefs contained the largest and densest populations of small reef fishes (especially roughtongue bass, *Holanthias* *martinicensis*). The frequency of fish in small size classes may be an indication of fishing pressure on these reefs.

13.5 Summary/Conclusions

Biological assemblages dominated by tropical hard bottom organisms and reef fishes occupy a variety of topographic features that exist between 53 and 110 m in the northeastern Gulf of Mexico between the Mississippi River and DeSoto Canyon. The origins of the carbonate features vary. Some are small, isolated, low to moderate reefal features or outcrops of unknown origin. Some appear to be hard substrates exposed by erosion during sea level still-stands along late Pleistocene shorelines. Others appear to be small reefs that existed near these shorelines. The largest reefal features appear to have been offshore reefs. Formation of the largest features probably occurred prior to the Holocene Transgression. Some additional growth of these features and growth of other smaller reefs on exposed substrates may have taken place during the early transgressional period. The structure of the summits of some reefs may also have been modified by Holocene erosional events following their initial period of growth (namely, the flat-topped reefs). Most features currently appear to be deteriorating under the influence of bioerosional processes. Hardbottoms and associated organisms also appear on at least two salt domes within 50 km of the Mississippi River Delta.

The hermatypes that contributed to the development of these structures probably included coralline algae, reef-building corals, bryozoans, foraminiferans, and molluscs, among others. Present-day production of calcium carbonate is probably limited to an impoverished calcareous algae population on features cresting above 78 meters (shallower in most areas). Features below this depth can most likely be considered completely drowned reefs.

The topographic features in the northeastern Gulf may be of similar age and origin to those that exist in a number areas along the outer continental shelf of the Gulf of Mexico and the east coast of the United States. The depth ranges of many of these features are similar, and most are non-growing reefs inhabited by tropical to warm temperate, hard bottom organisms most commonly found below the depths of living coral reefs.

Present-day biological assemblages on features in the northeastern Gulf are dominated by suspension feeding invertebrates. Populations are depauperate on features of low topography, those in habitats laden with fine sediments, and at the base of larger features (where resuspension of sediments limits community development). On larger features, the diversity and development of communities appears to depend on habitat complexity, that is, the number of habitat types available to hard bottom organisms, and to some extent, distance from the Mississippi River Delta. On reefs containing extensive reef flats on their summits, there are rich assemblages distinguished by a high relative frequency of sponges, gorgonian corals (especially sea fans), crinoids, and bryozoans. Due to the generally accordant depth of flat-topped reefs (62-63 m), coralline algae are also in abundance. Other organisms on reef flats include holothurians, basket stars, and myriads of fish (mostly *Holanthias martinicensis* [roughtongue bass], *Hemanthias aureorubens* [streamer bass] and *Rhomboplites aurorubens* [vermilion snapper]). On reefs lacking this reef flat habitat, as well as on reef faces of flat-topped features, the benthic community is characterized by a high relative frequency of ahermatypic corals (both solitary and colonial scleractinians). Other frequently observed organisms on these rugged, often vertical reef faces include crinoids, gorgonians, sea urchins, and basket stars. Their summits are also often occupied by dense schools of *H. martinicensis*, *H. aureorubens* (streamer bass), and *Paranthias furcifer* (creole-fish) among other species.

Human impact in these environments appeared to be minimal. Discarded debris or lost fishing gear (such as longlines), though present at many sites, was not abundant, and therefore poses little threat to the environment. Cables and lines can affect shallower reef communities, but probably have little impact at these depths once they become tangled on or lodged against reef structures. Fishing pressure on these relatively small features may reduce the population of the larger, commercially important species, and may explain the frequency of smaller individuals of unprofitable species on heavily fished reefs.

14.0 DATA MANAGEMENT AND DELIVERABLES

Gary A. Wolff

14.1 Introduction

The principal responsibilities of the data management group are: (1) the maintenance of a centralized data storage and retrieval system, (2) the control and protection of the data system, (3) the transmission of validated data to the National Environmental and Satellite Data Information Service (NESDIS) data bank in National Oceanic Data Center (NODC) format and the National Geographic Data Center (NGDC), and (4) programming support for project scientists. To meet these requirements, the data management section monitors and documents the flow of data from the initial sampling, analytical history, data entry, validation, and analysis to its final transmission and storage.

14.2 Methods

Data are received from components of the project on formatted data sheets, on-line data files or diskettes. As samples move through the processing procedure, a chain-of-custody is maintained so that the sample's location and status are continuously monitored. Table 14-1 shows the source and format of the data received from project tasks.

Several computer systems are used by data management to store and process the data, depending on the specific requirements. Diskette data are received in several micro formats (IBM Personal Computer, Macintosh) and transferred to VAX mainframe computers via a dedicated line with error checking data transmission software. Data are then transferred from the VAX to an AMDAHL computer through a BITNET line using system utilities. Data entry and processing are performed on all three systems (Macintosh, AMDAHL and VAX). Data sorting, merging, and statistical programming are primarily performed on the AMDAHL and VAX systems to use the speed and storage capabilities of the mainframes.

After entering the data on-line, a cycle of validation is initiated through the appropriate principal investigator and the data management

Table 14-1. Format and source of data received from project tasks.

TASK	FORMAT	SOURCE
SEDIMENTS		
HMWHC	Macintosh	Kennicutt
TRACE METALS	Macintosh	Presley
SEDIMENT ANALYSIS:		
Sediment Texture	Macintosh	Rezak
Total Organic Carbon	Macintosh	Kennicutt
Total Carbonate	Macintosh	Kennicutt
Carbon Isotope Ratios	Macintosh	Kennicutt
BIOLOGY		
MACROINFAUNA	Data Sheet	Harper
MACROEPIFAUNA	Data Sheet	Harper
DEMERSAL FISH TAXONOMY	Data Sheet	McEachran
FISH FOOD HABIT ANALYSIS	Data Sheet	Darnell
PHYSICAL OCEANOGRAPHY/ WATER COLUMN CHARACTERIZATION		
Currents	IBM Disk	Kelly
CTD	IBM Disk	Kelly
Dissolved Oxygen	IBM Disk	Kelly
Transmissivity	IBM Disk	Kelly
Nutrients	Data Sheet	Kelly
Meteorology	IBM Disk	Kelly
SATELLITE IMAGERY	Summary	Vastano
TOPOGRAPHIC FEATURES		
Geological	Summary	Sager/Rezak
Biological	Macintosh	Bright/Gittings

section to check for errors. With each cycle, the data are corrected by data management until they are error free. Validated data are then stored on computer files accessible to all project tasks.

Access to all data is provided for each task with a centralized computer account. Components of the project are provided with a personal AMDAHL or VAX account which contains or can access all validated data files. The principal investigator is able to directly access and incorporate supporting data into his analysis as needed.

Validated on-line data are formatted and copied to magnetic tape and forwarded to the specified data bank. Included with the tapes are:

1. Letter of Transmittal - a form which briefly states the contents of the tapes which is signed by data bank staff personnel and returned to the data management group as verification that the tapes have been received.
2. Cover Letter and Copy of Letter of Transmittal - this is sent separately and informs the data bank that a tape is en route.
3. Tape Dump - a hard copy of the actual contents of the data contained on the tape.
4. Data Documentation/Data Format - a form which gives specific information on the sampling parameters (location, type of vessel, etc.) and describes the data's format and variables. These will follow the format specified by NESDIS/NGDC.
5. File List - identifies the sequential location of specific files contained on the tape.

Copies of these forms are kept by the data management section, as well as the project manager, for every data transmittal. The tapes are sent by certified mail in clearly marked mailing cartons which describe the contents. The certified mail receipt serves as verification that tapes were sent to the data bank and the returned certified postcard, as well as the letter of transmittal, verifies that the data bank received the tapes. A continuous monitoring of the data from validated data copied onto magnetic tapes to their arrival at the data bank is thus established.

The data management section generates and updates a monthly inventory listing of the status of each project investigator's samples and data files. This file contains information on the current status of each task's data and is used as a cross-reference among the data management section, the principal investigators and the data bank to ensure the project's data are completely transmitted and accurately identified.

A Report of Observations/Samples Collected by Oceanographic Programs (ROSCOP), which describes the data variables and collection parameters in an encodable form for the data base, is sent shortly after the conclusion of each sampling cruise to the Contracting Officer's Technical Representative (COTR). An annotated chart showing the cruise trackline in the survey area accompanies the ROSCOP form. Appropriate abstract information is provided to the NEDRES office.

14.3 Results

Tables 14-2 summarizes the status of all data collected during the sampling period (Cruises 1 - 4) and the pre-award cruise (Cruise 0). Some categories of data (Satellite imagery, ROV) are received as a summary of the task's activities. Other data (e.g., meteorology) are incorporated into the synthesis report.

Table 14-2. Data Summary of Cruises 0-4

TASK	CRUISE 0			CRUISE 1			CRUISE 2			CRUISE 3			CRUISE 4		
	REC'D	VALID.	TRANS.	REC'D	VALID.	TRANS.	REC'D	VALID.	TRANS.	REC'D	VALID.	TRANS.	REC'D	VALID.	TRANS.
SEDIMENTS															
HMWHC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trace Metals	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sediment Analysis:															
Sediment Texture	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total Organic Carbon	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total Carbonate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Carbon Isotope Ratios	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BIOLOGY															
Macroinfauna	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Macroepifauna	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Demersal Fish Taxonomy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fish Food Habit Analysis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PHYSICAL OCEANOGRAPHY/															
WATER COLUMN															
CHARACTERIZATION															
Currents	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CTD	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Oxygen	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Transmissivity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nutrients	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Meteorology	X	X	X	X	X	X	X	X	X			X			X
SATELLITE IMAGERY	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOPOGRAPHIC FEATURES															
Geological	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Biological	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

15.0 SUMMARY AND SYNTHESIS

Rezneat M. Darnell

15.1 Background

The present interpretation of the ecology of the Mississippi-Alabama continental shelf incorporates both historical and newly acquired information. It examines the shelf system in relation to surrounding habitats and to external influences which affect the ecological conditions and processes. As background for the interpretation it is informative to examine briefly the ecological history of the area, natural catastrophism, and human influences. Particular consideration is given to the inshore environments (bays, estuaries, and sounds) because of their important relations with the adjacent shelf. Most of the inshore water masses are ultimately transported offshore where they become mixed with shelf waters. Therefore changes in the quality or quantity of inshore waters will be reflected in waters of the shelf. Secondly, estuary-related species historically make up a large component of the shelf biota (Darnell 1985), and any major changes in the environments or populations of the inshore nursery areas will likely result in changes in offshore populations of these species and in the food chains in which they are prominent.

15.1.1 Ecological History

During most of the Pleistocene period the Mississippi River debauched well to the west of the present delta, and the shoreline of the northern Gulf extended from Florida, across Alabama and Mississippi, and along the north shore of what is now Lake Pontchartrain. Associated with repeated advance and retreat of the continental ice sheets, the sea level receded nearly to the outer edge of the present continental shelf and then rose again to approximately its present stand. With each retreat of the sea the shelf became exposed to subaerial erosion and oxidation, and streams passing through the area carved deep valleys. Subsequent rises in sea level saw filling of the valleys and smoothing of the surface except for salient rocky outcrops and other topographic high features.

About 2,600-2,800 years ago, as a result of natural upstream damming, the Mississippi River adopted approximately its present course, and early distributaries extended eastward forming the St. Bernard and Lagniappe Deltas. Spreading sediments as far eastward as Mobile Bay, these deltas established the southern boundaries of Lakes Pontchartrain and Borgne and created the Biloxi Marshes. Southward development of the Mississippi River Delta and winnowing and redistribution of the soft sediments have created the barrier islands and other familiar geomorphic features to the north and west of the Mississippi-Alabama shelf.

During periods of major advance of the continental ice sheets when sea level stood near the shelf break, very cold winds from the continental high swept the northern Gulf coast and nearshore waters. As in the case of the terrestrial biota, most of the shallow water marine species must have retreated to refugia further south (off southern Florida and the Mexican coast)(Darnell and Kleypas 1987). Following the last glacial maximum, about 18,000 years ago, the sea level has risen to its present stand, and repopulation of the northern gulf shelf, bays, and estuaries has taken place. To these species have been added new tropical immigrants brought in by the Gulf Loop Current. Considering the variability of the environment, the recency of its availability, and the periodic addition of new faunal elements from the south, it is reasonable to conclude that processes of genetic adjustment are still underway.

This conclusion is borne out by the fact that at least the key species of the ecological system appear to exhibit R-type life history strategies. That is, they are opportunistic pioneering species with short life histories and high reproductive rates. They are adapted for rapid exploitation of new ecological opportunities and for persistence in the area despite local habitat loss, great variability in environmental factors, and the occasional occurrence of natural catastrophes. These key species include the brown and white shrimp, blue crab, gulf menhaden, sand seatrout, spot, Atlantic croaker, and striped mullet (all estuary dependent), as well as the longspine porgy and several flatfishes (non-estuary dependent). Despite wide annual variations in abundance, these species have persisted and flourished in the area and have contributed to the stability of the shelf ecological system.

15.1.2 Natural Catastrophism

The coastal environments of the northern Gulf of Mexico undergo regular cycles of seasonal changes in the atmospheric, hydrographic, and oceanographic factors, and the life histories of the various species likewise involve annual sequences of events in response to the regular environmental changes. However, on the continental shelf and in related coastal environments of the Mississippi-Alabama area certain major events occur on an irregular basis, and these episodic events may interrupt the normal biological patterns. Some are known to result in mass mortalities, and most likely place major stress on populations of the area. Biological effects of these events (summarized in Table 15-1) have not been well studied.

Cold Fronts

During exceptional winters major cold waves strike the northern Gulf coast and rapidly chill the estuarine and lagoonal waters. Invertebrates and fishes, immobilized by the sudden chill, are unable to escape, and they die in great numbers. Such events have been reported along most of the northern Gulf coast from south Texas through the Florida peninsula. Low temperature fish kills have been reported from coastal waters of Mississippi (Christmas 1973; Overstreet 1974), and from Mobile Bay (Reagan 1985; Johnson and Seaman 1986). No effects of low temperature have been reported for populations of the shelf, but it is likely that some tropical species which have become established on the shelves of south Texas and peninsular Florida are excluded from the Mississippi-Alabama shelf by exceptional extremely cold conditions.

Floods

Flooding of low coastal areas in the Mississippi Delta area was a normal occurrence prior to the construction of artificial levees. Today it occurs east of the Delta when the Bonnet Carré spillway is opened to permit floodwaters to pass through Lakes Pontchartrain and Borgne and Mississippi Sound to the Mississippi-Alabama shelf. Flooding may also occur when heavy rains fall in the drainage basins of the coastal streams, particularly the Pascagoula and Mobile Rivers, or when the coastal areas are themselves inundated from winter rainstorms or summer tropical depressions. The immediate physical

Table 15-1. Major catastrophic events which affect the environments and biota of the Mississippi-Alabama marine systems.

Catastrophic Events	Effects	
	Estuaries	Continental Shelf
Cold fronts	Recorded from Mississippi and Alabama Can cause mass mortality of invertebrates and fishes.	Not known to affect species on the shelf but may induce some stress. Probably limits establishment of tropical species in shallow water habitats.
Floods	Recorded around Mississippi River Delta, Lake Pontchartrain, Lake Borgne, Mississippi Sound, and Mobile Bay. Short term effect is to place much freshwater, sediment, and debris into estuaries, destroy bottom habitat and oyster reefs, and kill or chase out mobile species. Long term effect is to bury pollutants and increase fertility.	Recorded from the southwestern half of the shelf. Short term effect is to increase young fishes on the inner shelf and move older fishes to deeper water. Long term effect may be to increase fertility.
Major storms and hurricanes	Affect entire coastline. Cause major flooding and extensive habitat damage (sedimentation of bottoms, destruction of marshlands and submerged vegetation, burial of oyster reefs, and erosion of shorelands).	Affect the entire coastline. Induce strong currents; stir up bottom sediments to a depth of 80 m or more; may restructure barrier islands. Biological effects unknown.
Hypoxic events	Known from Lake Pontchartrain and Mobile Bay. May cause mass mortality of invertebrates and fishes.	Not known from the Mississippi-Alabama continental shelf.
Red tide outbreaks	Recorded from Chandeleur Sound, Lake Borgne, Mississippi Sound and Mobile Bay. Small fish kill reported.	Reported between and near barrier islands off Louisiana and Mississippi.

effects are to replace or greatly dilute the saline waters of bays, estuaries, and sounds; markedly increase the level of suspended sediments; reduce oxygen values in the hypolimnion; and deposit a carpet of new sediments on the bottom. Runoff erodes the banks and may bring much terrestrial debris into the bays and estuaries. Depending upon the season, the freshwater inflow may cause a dramatic temperature shift. These physical changes may also occur on the continental shelf if the flooding is persistent. Biological effects of flooding in the Mississippi-Alabama area have been reported by Butler (1952), Butler and Engle (1950), Christmas (1973), Dardeau *et al.* (1990), Dawson (1965), Gunter (1952; 1979), Hawes and Perry (1978), Poirrier and Mulino (1975; 1977), Russell (1977), and Stout (1990). Within bays and sounds marine plankton is replaced by freshwater species. Some benthic species die, and bottom areas suffer a reduction in species abundance and diversity. Immobile forms, such as the American oyster, are buried, and large populations simply perish. The young of estuary related species, such as shrimp and the Atlantic croaker, are unable to penetrate to the estuaries, and they remain on the inner continental shelf. Adults are forced to move to deeper waters of the middle or outer shelf. How much mortality occurs among these mobile species is not known, but certainly there must be major losses among the eggs, larvae, and juveniles which are barred from entering the nursery areas. The blanket of sediments laid down is generally rich in nutrients so that recovery begins the following year, and for a few years thereafter biological production may be higher than normal.

Major Storms

Major storms and hurricanes strike the northern Gulf coast with some frequency, and these are generally accompanied by high winds, torrential rains, elevated sea levels, heavy wave action, and extensive coastal flooding. Out on the continental shelves strong water currents are generated, and bottoms may be stirred to a depth of at least 80 m (262 ft) (Dinnel 1988). Impacts on coastal waters and on barrier islands and other land forms may be dramatic. Effects of major storms on the biota of bays and estuaries of the area have received little attention, but they have been addressed by Dardeau *et al.* (1990) and Stout (1990). Since the storms are generally accompanied by heavy precipitation, all the effects of flooding (discussed above) occur. In addition, the waves and strong water currents may cause direct physical damage to hard bottom species such as oysters, and they may also uproot submerged vegetation, tear up marshlands, and bury soft bottom species. There have been no reports on the effects of major storms on the biota of the Mississippi-Alabama continental shelf.

Hypoxic Events

Waters of the bays, lagoons, and continental shelf normally contain high levels of dissolved oxygen. However, under conditions of high organic loading, rapid bacterial decomposition, and poor circulation (often due to summer stratification of the water column), the oxygen in the near bottom waters may be reduced to very low levels (hypoxia) or used up completely (anoxia). Seawater is rich in sulfates, and under anoxic conditions the sulfate becomes chemically reduced to the highly toxic hydrogen sulfide gas and to metal sulfides, some of which are soluble in seawater. Depending upon the severity of the event, hypoxia may induce avoidance, stress, or death in a few sensitive species, or it may result in mass mortality in many species due to asphyxiation and hydrogen sulfide intoxication. In the general Mississippi-Alabama area hypoxia has been reported from Lake Pontchartrain (Junot *et al.* 1983; Poirrier 1979; and Sikora and Sikora 1982), St. Louis Bay, Biloxi Bay, Pascagoula River marshes (Christmas 1973), and Mobile Bay (Dardeau *et al.* 1990; Loesch 1960; May 1973; Schroeder and Wiseman 1988; and Schroeder *et al.* 1990). In Lake Pontchartrain low diversity in benthic communities accompanied hypoxic conditions. Small fish kills have been associated with hypoxia in Mississippi. In Mobile Bay severe summer hypoxia results in mass avoidance and mass mortality of many invertebrate and fish species. Hypoxic conditions have not been reported from the Mississippi-Alabama continental shelf area.

Red Tide Outbreaks

Phytoplankton blooms are a regular occurrence in the inshore and nearshore waters of the northern Gulf. Two of the phytoplankton species produce chemical substances into the water which are extremely toxic to other marine life. These are the dinoflagellates *Gonyaulax monilata* and *Ptychodiscus breve*. When appropriate conditions prevail extremely dense populations of one or the other species may develop in the surface waters, giving the waters a reddish tint. Hence, the occurrence is called a "red tide". Such events have been recorded off most of the coasts of the northern Gulf. In the Mississippi-Alabama area a single red tide event was reported by Perry *et al.* (1979) due to a bloom of *Gonyaulax monilata.* This bloom persisted for about two weeks until dissipated by a hurricane. It was most intense in the western sector of Mississippi Sound (south of St. Louis Bay), in the pass between Cat and Ship Islands, and in the upper portions of Chandeleur Sound. Lower concentrations extended eastward through Mississippi Sound into Alabama and on the nearshore shelf off Horn and Petit Bois Islands. Some of the Alabama blooms were apparently heavy. Only a small fish kill was reported.

Other Events

The present section has documented five types of natural catastrophic events which may affect coastal populations of the Mississippi-Alabama area. To these may be added two additional types of events. Prolonged droughts reduce the amount of freshwater entering coastal bays and estuaries leading to greatly elevated salinity levels in the inside waters. Populations of mobile and immobile estuarine species with low salinity tolerances become much reduced, and they are replaced by high salinity forms. Marine parasites and predators, normally excluded, range freely and exact a significant toll on oysters and other estuarine species. Another possibly significant event is the periodic intrusion of Loop Current water or of deep Gulf water (up De Soto Canyon). However, nothing is known about biological consequences of such intrusions.

Conclusions

The episodic events reported here often cause mass mortalities which can lead to major fluctuations in population abundances of the coastal species. Although the primary effects are generally felt by species inhabiting the inside waters, some of the events directly affect populations of the continental shelf. In either case, the ecological systems of the shelf are affected through reduction in food supplies and subsequent modification of the shelf food chains. Except for extreme cold weather which may limit the distribution of tropical species, none of the events is likely to eliminate species populations from the area. Although recovery from an event does eventually take place, during and after an event population levels may be reduced, and the individuals which do survive are likely under some measure of physiological stress. Thus, they would be more susceptible to additional stress imposed by human activities. Considering the wide fluctuations imposed upon the populations by natural events, discernment of the impacts of specific human activities may be extremely difficult.

15.1.3 Human Influences

Estuary related species of the Mississippi-Alabama area utilize four basic nursery areas and appear to migrate seaward through the passes as shown in Figure 15-1. Such migratory pathways would be consistent with adult distribution patterns observed on the continental shelf (Darnell 1985). In any event, this division of the nursery areas provides a convenient basis for discussion of the local human activities and their major environmental effects. These are summarized in Table 15-2.

Area 1. Mississippi River Delta through Biloxi Marshes

Human activities and their effects in this area have been addressed by Craig and Day (1977), Craig *et al.* (1979), Gagliano and van Beek (1970), and Rounsefell (1964). Leveeing of the lower Mississippi River during the past century has deprived much of the lower Delta of its normal annual nourishment of silt. As a result of this loss, subsidence and erosion are causing a land loss of over 14 ft per year (Gagliano and van Beek, 1970). The Mississippi River Gulf Outlet Canal (constructed in the early 1960s) and related waterways have modified drainage patterns and permitted saltwater encroachment well into the productive Biloxi Marshes.

Area 2. Lake Pontchartrain through Western Mississippi Sound

Human activities and environmental effects in this area have been discussed by Craig *et al.* (1979), Christmas (1973), Englande *et al.* (1979), Junot *et al.* (1983), Poirrier (1979), Sikora and Sikora (1982), Sikora *et al.* (1981), Stone (1980), Stone *et al.* (1982), and Turner *et al.* (1980). During the past four decades the environment of Lake Pontchartrain has been substantially modified by human activities. Levees and stone revetments placed along the south shore have cut off shallow wetlands and reduced wave erosion of the marshes. As a result, prime nursery areas have been sealed off, and the major source of organic detritus, formerly important in the local

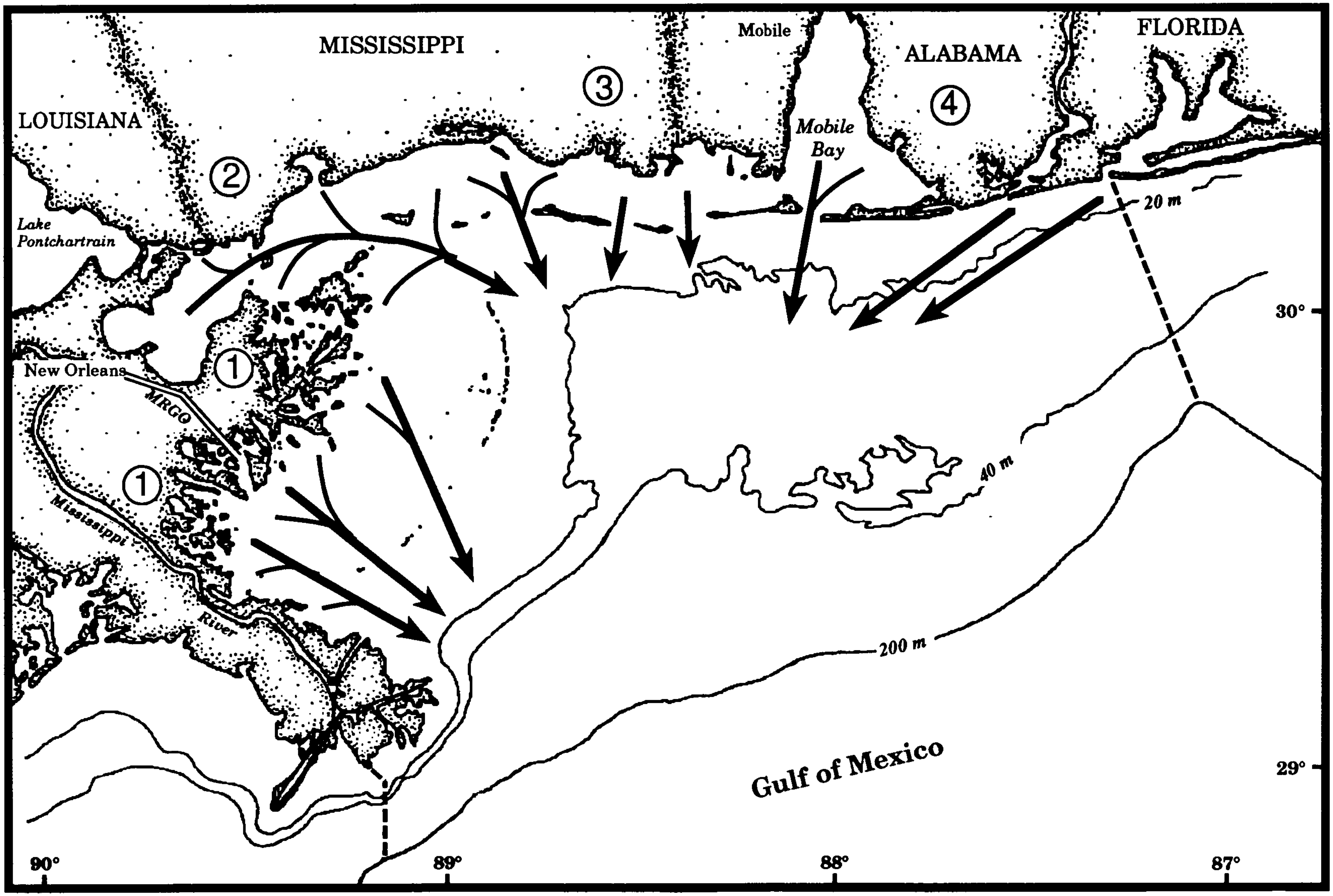


Figure 15-1. Estuarine nursery areas and presumed migratory pathways for estuary related species which inhabit the Mississippi-Alabama continental shelf; 1) Mississippi River Delta through Biloxi Marshes, 2) Lake Pontchartrain through western Mississippi Sound, 3) Central and eastern Mississippi Sound, 4) Mobile Bay through Pensacola Bay.

Table 15-2. Summary of human activities and major effects on estuarine and continental shelf environments of the Mississippi-Alabama area.

Human Activities	Major environmental effects
Estuarine areas	
Area 1. Mississippi River Delta through Biloxi Marshes	
- Leveeing of Mississippi River	- Loss of estuarine Habitat
- Channelization of marshes	- Saltwater encroachment
Area 2. Lake Pontchartrain through western Mississippi Sound	
- Leveeing and revetment of shorelines	- Loss of estuarine habitat
- Land development	- Reduction of submerged vegetation
- Shell dredging	- Loss of organic detritus food resource
- Dumping of municipal and industrial wastes	- Deterioration of soft bottoms
- Agricultural runoff	- Saltwater intrusion
	- Eutrophication
	- Creation of intensification of hypoxia
	- Accumulation of chemical pollutants
Area 3. Central and eastern Mississippi Sound	
- Land development	- Loss of estuarine habitat
- Dredging and spoil placement	- Interference with natural circulation
- Dumping of municipal and industrial wastes	- Creation or intensification of hypoxia
	- Chemical pollution
Area 4. Mobile Bay through Pensacola Bay	
- Land development	- Loss of estuarine habitat
- Dredging and spoil placement	- Reduction of submerged vegetation
- Channelization	- Modification of circulation
- Addition of municipal and industrial wastes	- Saltwater intrusion
- Agricultural runoff	- Creation or intensification of hypoxia
- Logging	- Chemical pollution
Continental shelf	
- Overfishing	- Drastic reduction in fish populations

food chains, has been eliminated. Persistent and extensive shell dredging has reduced most of the lake bottom to a thin clay gel incapable of supporting the weight of adult rangia clams. Virtual elimination of rangia and other benthic species has further reduced the food supply for estuary related species. Disposal into the lake of large volumes of domestic sewage (by municipalities of Jefferson Parish) and street runoff (by the City of New Orleans) have added organic matter and many chemical pollutants. Additional pollutants now enter the lake from agricultural and industrial sources along the northshore streams and from the Industrial Canal. The latter permits intrusion of a bottom saltwater wedge bringing various heavy metals and a high oxygen demand. Hypoxic areas ("dead zones") now occur periodically off the mouth of the Industrial Canal and extend well into the lake. Frequent openings of the Bonnet Carré Spillway during the past two decades have caused long periods of low salinity and high turbidity, and they have added fine sediments and additional chemical pollutants to the lake. Recent surveys have shown the submerged vegetation beds to be much reduced. As a result of these various human intrusions the usefulness of the lake as a nursery area for estuary related species has been greatly diminished.

The Pearl River marshes appear to be still largely intact, but sulfites and other chemicals from upstream paper mills and other industry may be reducing the quality of the water. Saint Louis Bay is affected by excess BOD loading, and hypoxic conditions with associated fish kills have been reported from this area.

Area 3. Central and Eastern Mississippi Sound

Human activities and their effects in this sector have been reported by Christmas (1973) and McBee and Brehm (1979). The increasing human population has given rise to considerable land development, dredging and spoil placement, and dumping of municipal and industrial wastes. Such activities have been particularly prominent around St. Louis Bay, Biloxi Bay, and lower reaches of the Pascagoula River. This has resulted in much loss of estuarine habitat, chemical pollution, and creation or intensification of local hypoxic events accompanied by fish kills. Channel dredging and spoil placement have modified circulation patterns within the bays and facilitated saltwater intrusion. Spoil banks extending across the eastern sector of

Mississippi Sound (off Pascagoula) have created a virtual dam resulting in separate circulation patterns east and west of the banks. Undoubtedly these spoil banks constitute a barrier to the movement of many marine species, as well.

Area 4. Mobile Bay through Pensacola Bay

Human activities and environmental effects in the eastern sector have been discussed by Dardeau *et al.* (1990), Friend *et al.* (1981), Horn (1990), Isphording and Flowers (1990), Schroeder *et al.* (1990), and Stout (1990). Mobile Bay has been extensively modified by land development, dredging and spoil placement, channelization, logging, influx of municipal and industrial wastes, and upstream channelization and agricultural runoff into the Mobile River. Documented changes in the bay include considerable loss of estuarine habitat and over 35 percent reduction of submerged vegetation beds. Remaining beds are being replaced by introduced and less desirable species. Circulation patterns have been altered by dredging and creation of spoil mounds, ridges, and islands. Channelization has facilitated saltwater intrusion. Chemical pollution of the waters, sediments, and oyster tissue is severe. Hypoxia in the bay appears to be a natural event, but it has certainly been exacerbated by human activities, especially through restriction of circulation and the addition of oxygen demanding chemicals. Perdido and Pensacola Bays are less severely affected by human activities, but land development has reduced estuarine habitat, and there is some municipal and industrial pollution.

Continental Shelf

The Mississippi-Alabama continental shelf has been modified by dredging and spoil disposal, channelization, creation of artificial reefs, and limited development of oil and gas resources. Whatever the local influences may have been, these activities are not considered to have caused major or widespread effects on the environment or biota. Commercial fishing on the shelf has been growing since the Second World War, and it has been particularly intense during the past decade and a half. Activities include purse seining for menhaden, trawling for demersal shrimp and fish species, and use of hook and line (trolling, bottom lining, and longlining) for reef related as well as coastal and offshore pelagic species. The port of

Pascagoula, Mississippi reports the third highest level of commercial fish landings in the nation (U.S. Department of Commerce 1987). Since 1980 there has been a dramatic increase in the harvest of reef related and pelagic species. Recreational fishing has also increased greatly during this period with more fisherman using party/charter boats and private or rented craft, many capable of harvesting deeper reefs and larger pelagic species. Incidental fish species taken in the menhaden fishery have been reported by Christmas *et al.* (1960), and those caught by bottom trawls are listed in Darnell (1985), Darnell and Kleypas (1987) and Franks *et al.* (1972). Invertebrates taken by bottom trawls have been reported by Defenbaugh (1976), Franks *et al.* (1972), and Soto (1972).

Intensified fishing efforts have been accompanied by alarming declines in the estimated sizes of remaining fish stocks (Browder *et al.* 1990; Brown *et al.* 1990). Data for these estimates, shown in Figures 15-2-15-5, encompass the shelf area from west of Barataria Bay, Louisiana to De Soto Canyon, and they are all pertinent to the Mississippi-Alabama shelf (Browder, personal communication). Between 1960 and 1988 the menhaden harvest more than doubled, and the shrimping effort almost quadrupled (Figure 15-2). Between 1972 and 1987 the biomass of bottom fishes declined from 116 kg/ha to around 26 kg/ha, approximately 22 percent of the original level (Figure 15-3). Between 1979 and 1986, despite greatly intensified fishing effort, the annual red snapper harvest declined from 16 million to about 4.5 million pounds (Figure 15-4). During the same period the spawning stock of king mackerel declined to about a third of its former level (Figure 15-5). Similar decreases have been observed in the Spanish mackerel as well as in offshore pelagic species (including bluefin tuna, swordfish, and others). Overfishing appears to be the primary reason for the declines. However, as noted earlier, there has been a simultaneous reduction in both the extent and quality of the nursery areas for estuary related species. Significant diminution in the annual crop of estuary related species would reduce the level of prey species and modify food chains of the continental shelf. This, in turn, would likely be reflected in food chains supporting the larger predators just beyond the shelf edge. Undoubtedly, both overfishing and inshore habitat deterioration are responsible for this decline of fish stocks.

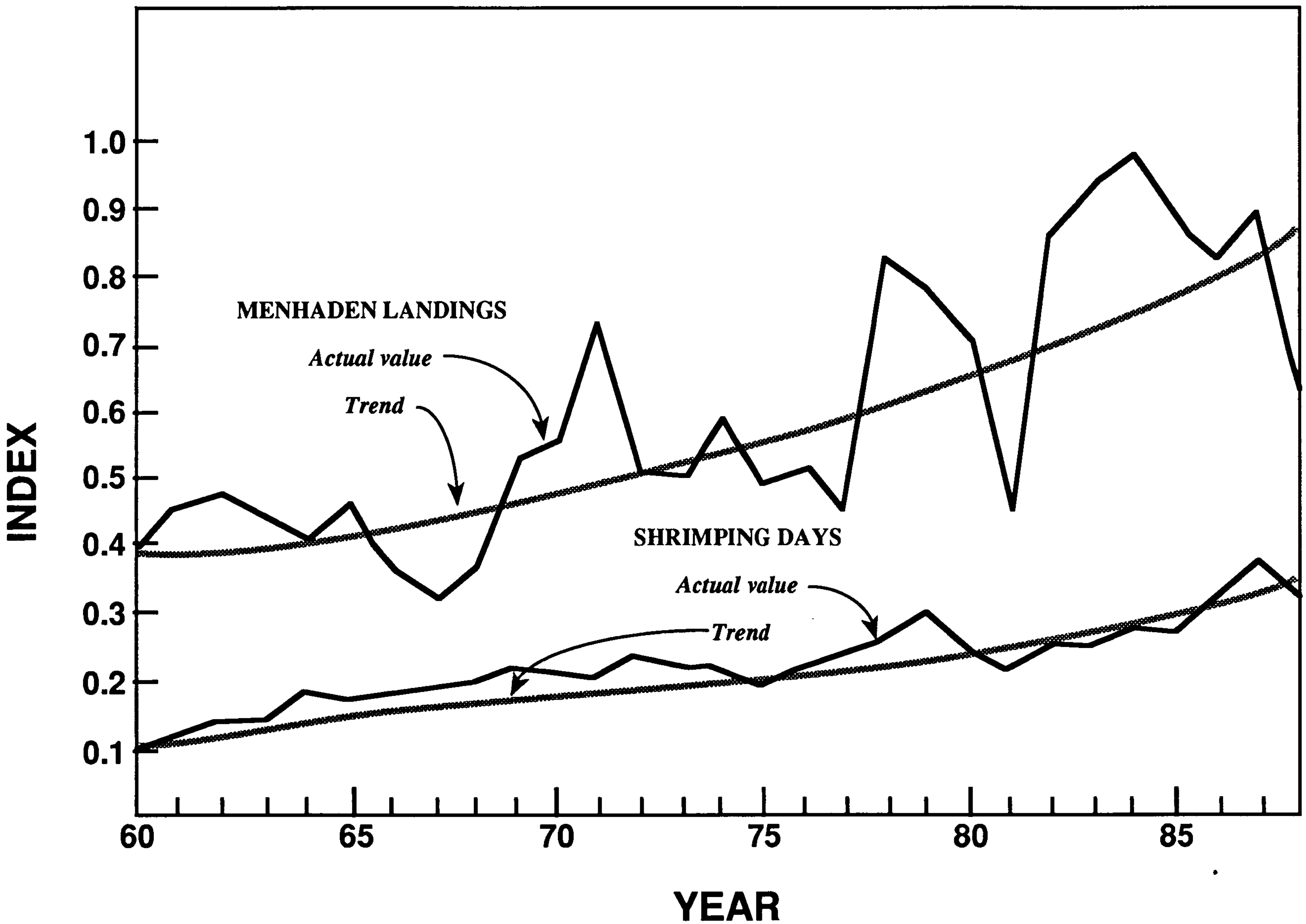


Figure 15-2. Trends in the harvest of menhaden and shrimping effort on the north central Gulf shelf between 1960 and 1988. (After Browder *et al.*, 1989 and Brown *et al.*, 1990).

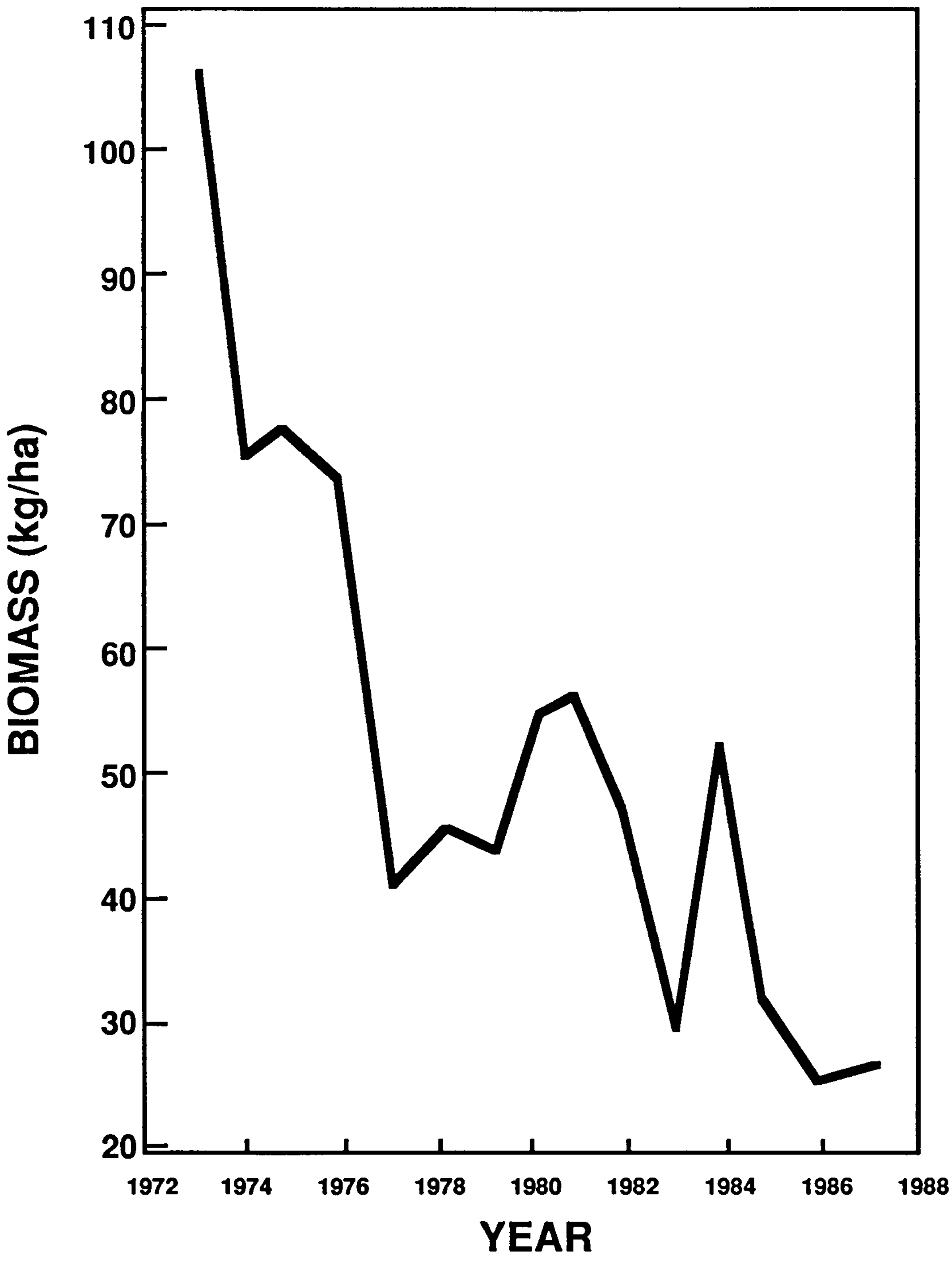


Figure 15-3. Estimated biomass of bottom fishes on the north central Gulf shelf between 1972 and 1987. (After Browder *et al.*, 1989 and Brown *et al.*, 1990).

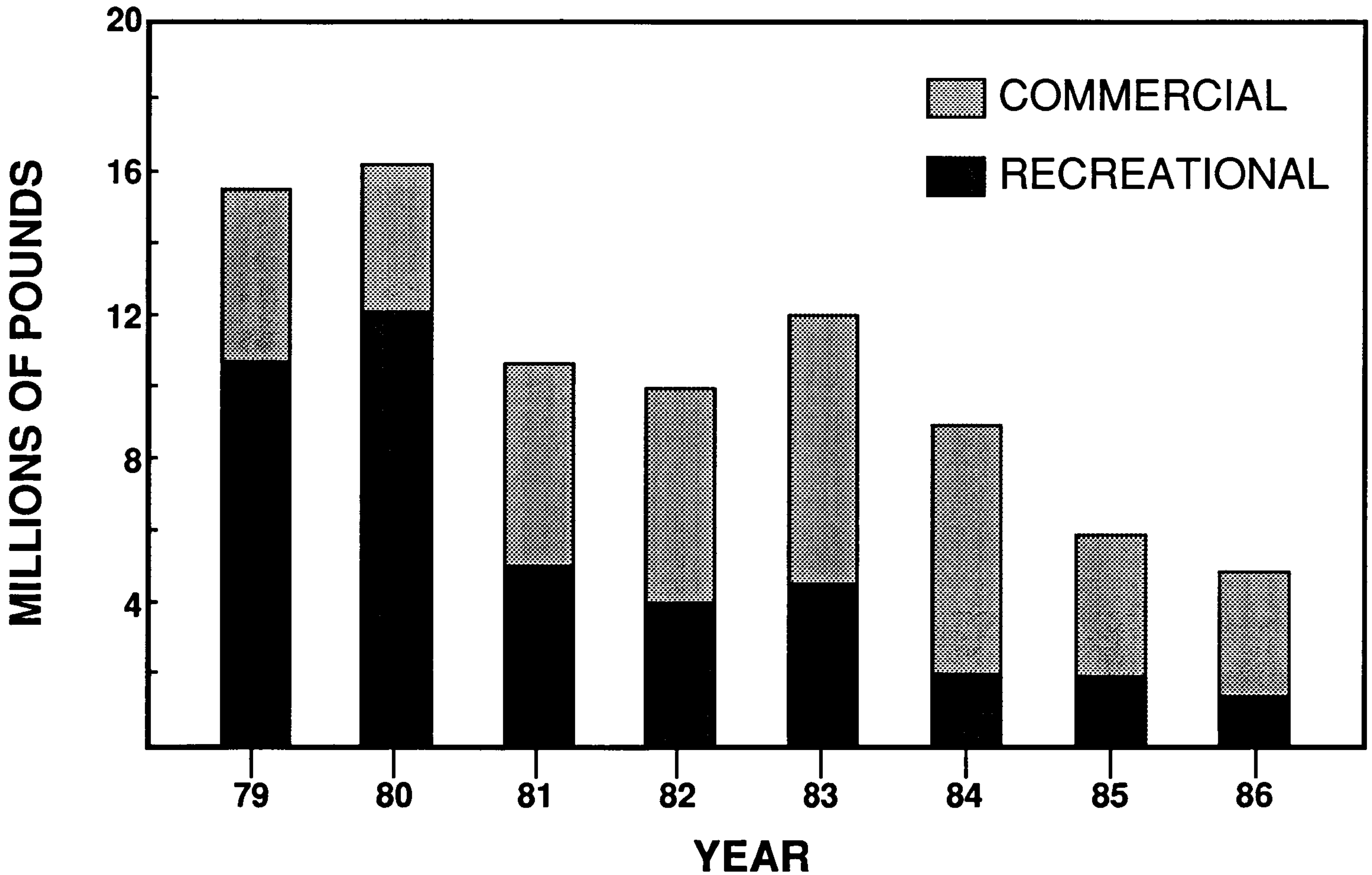


Figure 15-4. Commercial and recreational harvest of red snapper in the north central Gulf between 1979 and 1986. (After Browder *et al.*, 1989 and Brown *et al.*, 1990).

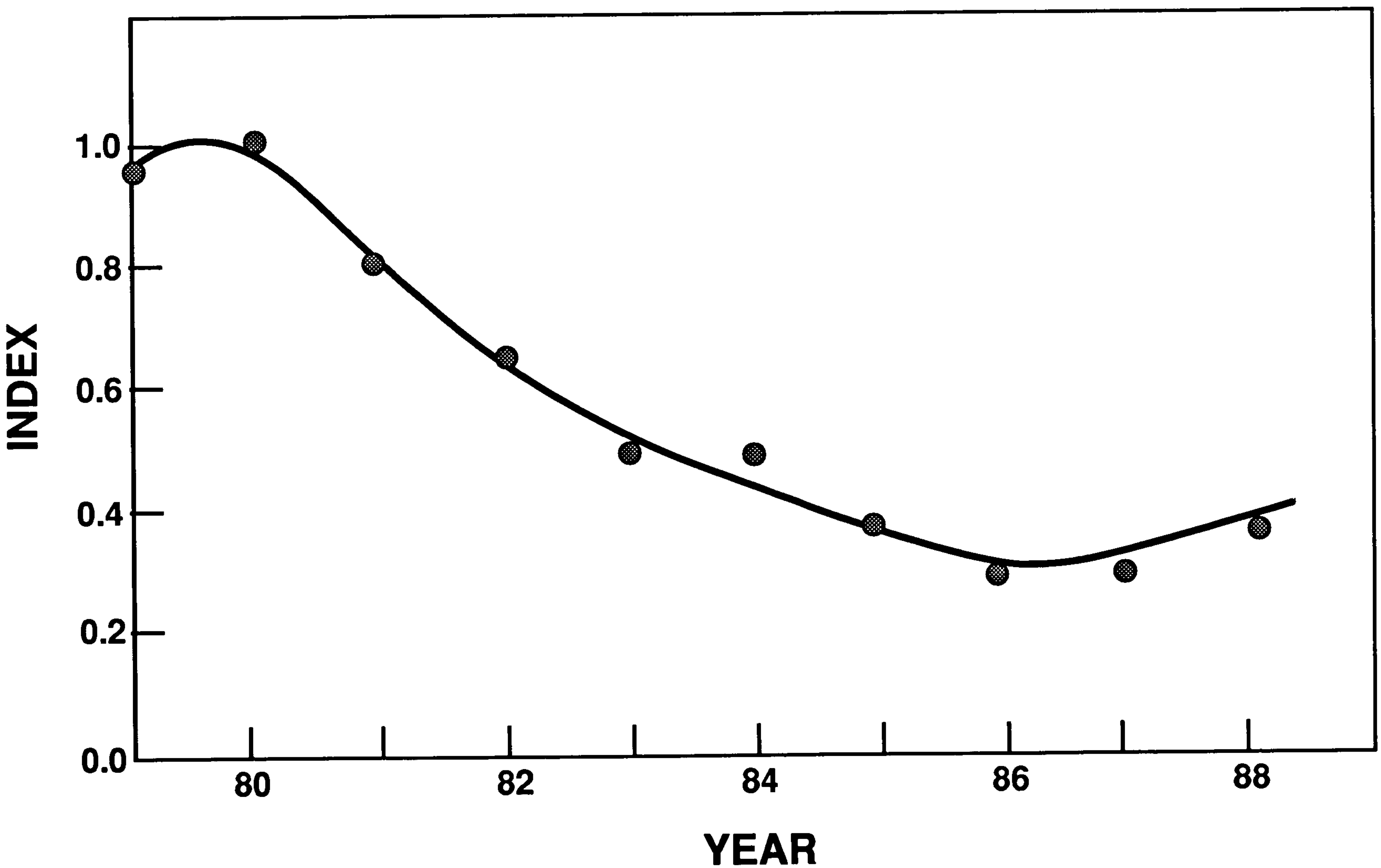


Figure 15-5. Estimated spawning stock of the king mackerel in the north central Gulf from 1979 through 1988 (After Browder *et al.* 1989 and Brown *et al.* 1990).

In conclusion, the continental shelf ecological system has undergone certain long term changes related to sea level stands, bottom subsidence, and Mississippi River sediment deposition. On shorter time scales the system is subject to modification by natural catastrophic events some of which may alter population levels over periods of one or two years. Imposed upon these natural trends and events is the recent massive intrusion by human activities which have had major effects upon both the nearshore and offshore environments and populations. The contributing factors are many and complex, and the biological data are too recent and unrefined to permit association of each cause with its specific effects or to understand synergistic effects of several factors acting in combination. It is against this background that efforts must be made to interpret the present day ecological systems of the Mississippi-Alabama continental shelf and their related coastal waters.

15.2 Physical Environment

The present section, treating the physical and chemical characteristics of the water column, is based upon data accumulated from measurements and samples taken at the regular transect stations as well as information from current meter moorings and satellite observations.

15.2.1 Water Masses and Circulation

The water masses of the Mississippi-Alabama shelf are quite dynamic and are responsive to several external forces. The most obvious of these are the wind (speed, direction, and persistence), major storms and hurricanes, the Gulf Loop Current (and its northern plumes and filaments), and deepwater currents of the Gulf. Wind was found to be highly correlated with surface currents at Mooring Station A (30 m) over periods of 2-10 days, but the correlation was much weaker over longer periods and at deeper stations. Tropical storms and hurricanes as far away as Yucatan were found to influence the currents and hydrography of the area. Such effects may be pronounced, increasing the speed and influencing the direction of currents to a depth of at least 57 m. Dinnel (1988) had earlier noted that major storms may stir the bottom to a depth of at least 80 m. Loop Current filaments frequently control water masses along the outer shelf, but they sometimes intrude across the shelf, essentially replacing most of the shelf water within a few days. Current measurements reveal that near-bottom water of the middle shelf flows southwesterly much of the time, whereas near-bottom currents at the 200 m depth persistently flow along the isobath toward the northeast. Thus, suspended matter and mobile sediment particles should be swept across mid-shelf towards the Mississippi River Delta, and deeper water particles should be swept from the area of station C-4 towards M-4 and D-4. As a result of the various currents and forces discussed above, the shelf waters appear to exhibit short residence times, being replaced frequently during the period of a year. In this respect, the influence of the Gulf Loop Current is substantial.

15.2.2 Temperature

Temperature characteristics of the Mississippi-Alabama shelf waters have been discussed by a number of investigators, and the historical literature has been summarized by Vittor and Associates, Inc. (1985) and by Darnell and Kleypas (1989). Nearshore surface waters to about 20 km offshore of the barrier islands tend to reflect fluctuations in air temperatures, but farther from shore the conformity decreases. Likewise, bottom waters tend to conform with surface waters at shallow depths, but they deviate progressively with depth and distance from shore. Stratification of the water column, which begins during late spring, may be well developed by late summer.

Synoptic surface and bottom temperature data from the present study are presented in Table 15-3 which also separates the information by seasons. Data for this table represent cruises B-3 and B-4 only, since these are the only cruises for which reliable and complete data sets are available. Summer surface temperatures averaged 29.0°C and were highest on the Chandeleur and lowest on the De Soto Canyon transect. Summer bottom temperatures at 20 m averaged only 19.2°C, and they decreased with depth, the 200 m stations averaging only 12.0°C. The difference between surface and bottom temperatures at this season ranged from 1.4°C at 20 m to 17.1°C at the 200 m depth. During the winter surface water temperatures averaged 20.0°C and were highest at stations 3 and 4 on the Chandeleur and Mobile transects. Nearshore waters were much colder, ranging from 16.9°C to

18.7°C. Winter bottom water temperatures averaged 17.2°C at the 20 m stations, rose to 18.0°C or above at the 60 and 100 m stations, and dropped to 14.1°C at a depth of 200 m. The difference between surface and bottom temperatures averaged less than 1.0°C at the 20 and 60 m stations but increased to 7.6°C at a depth of 200 m. On a seasonal basis the nearshore waters varied by 11.1°C at the surface and by 10.5°C at the bottom. At the deepest stations the surface waters changed seasonally by 7.4°C, but the bottom waters varied by only 2.0°C.

Characteristics of the water column reflect the water masses resident at the time of measurement and are subject to change as new water masses move in. It is noted that cruise B-4 (winter) was conducted during a period of Gulf water intrusion (as shown by satellite imagery), and the temperature and other characteristics measured during this period may be somewhat abnormal for the season. Nevertheless, the combined data set clearly shows the possibility of thermal stratification during the summer months, the general trends of surface and bottom changes, and the relative constancy of the deepwater temperatures.

Table 15-3. Surface and bottom water temperatures (°C) for regular stations on the Mississippi-Alabama continental shelf. The seasonal values are from two cruises only (B-3 and B-4). Higher values are shaded.

Surface

Sta.	Winter				Summer			
	C	M	D	$\bar{x}$	C	M	D	$\bar{x}$
1	18.7	16.9	18.3	18.0	29.7	28.9	28.7	29.1
2	17.4	18.4	20.5	18.8	29.7	28.3	28.0	28.7
3	21.0	22.7	20.3	21.3	29.5	29.2	28.9	29.2
4	23.5	21.1	20.5	21.7	29.2	29.1	28.9	29.1
$\bar{x}$	20.2	19.8	19.9	20.0	29.5	28.9	28.6	29.0

Bottom

1	17.1	16.6	18.0	17.2	28.0	27.2	28.0	27.7
2	18.8	18.0	18.7	18.5	20.3	20.5	18.9	19.9
3	17.8	17.6	18.7	18.0	16.1	17.1	18.8	17.3
4	13.5	15.6	13.3	14.1	10.3	14.5	11.2	12.0
$\bar{x}$	16.8	17.0	17.2	17.0	18.7	19.8	19.2	19.2

15.2.3 Salinity

Reviewing the historical literature, Vittor and Associates, Inc. (1985) concluded that the salinity patterns of the continental shelf off Mississippi and Alabama are highly variable due to river and tidal inlet plumes and aperiodic Loop Current intrusions. They also noted that under certain wind conditions freshwater discharge from the Mississippi River flows eastward across the shelf and that Mississippi River water has been detected as far as 75 km (45 mi) east of the nearest delta. Thus, salinity regimes of the shelf at any given moment result from freshwater outflows to the north and west and from high salinity inflows from the open Gulf. These water masses may remain relatively distinct, or they may result in zones of mixing.

Surface and bottom salinity data from the present study are presented in Table 15-4 which depicts the two seasons separately. Unfortunately, data gaps exist, particularly on the Chandeleur transect. The available data do not suggest that any cruise was particularly aberrant, and so for further analysis seasonal means will be based upon data from all the cruises.

Seasonal mean values for surface and bottom salinities for each station and transect are presented in Table 15-5. During the summer, surface salinity values ranged from 31.0‰ to 34.2‰ with lowest values occurring along the Chandeleur Transect and at the inshore stations of the other two transects. At this season bottom salinities varied from 33.2‰ to 36.6‰, and the lowest values appeared at all the inshore stations and at the deepest stations of the Chandeleur and De Soto Canyon transects. Winter surface salinity values ranged from 30.7‰ to 35.8‰ with the lowest values occurring at all the 20 m and 60 m stations (except D-2) and also at the 100 m station on the Mobile transect. Bottom salinities at this season varied from 34.6‰ to 36.3‰, and the lowest values occurred at all the inshore stations as well as at the deepest stations on the Chandeleur and De Soto Canyon transects.

During the summer mean salinity differences between surface and bottom values ranged from 0.8‰ (M-1) to 4.7‰ (C-4), and during the winter they ranged from 0.1‰ (C-4) to 3.9‰ (M-1). Stratification of any water column is based upon density differences which may be induced by temperature or salinity alone or by a combination of the two factors acting in conjunction. Data from the present study suggest that during the summer stratification of

Table 15-4. Surface and bottom salinities (‰) for each cruise and station, separated by season.

Surface

Winter

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-0	33.1	33.0	34.2	35.7	29.6	33.1	33.5	33.4	31.4	35.8	35.6	35.7
B-2	31.3	33.8	---	---	32.0	34.0	36.1	34.8	31.5	33.3	33.4	---
B-4	33.7	---	---	---	30.5	31.0	30.0	35.3	35.7	36.1	36.0	35.9
$\bar{x}$	32.7	33.4	34.2	35.7	30.7	32.7	33.2	34.5	32.9	35.1	35.0	35.8

Summer

B-1	32.3	33.1	33.8	---	31.9	34.5	34.4	34.4	32.8	33.5	34.4	34.9
B-3	32.5	30.8	30.7	31.0	32.4	33.9	32.5	33.0	33.0	34.2	33.1	32.8
$\bar{x}$	32.4	32.0	32.3	31.0	32.2	34.2	33.5	33.7	32.9	33.9	33.8	33.9

Bottom

Winter

B-0	33.9	36.3	36.1	35.2	35.5	36.3	36.0	35.7	34.6	36.1	36.1	36.0
B-2	35.7	36.2	---	---	32.9	36.3	36.3	36.1	35.4	35.7	35.9	35.2
B-4	34.3	---	---	---	35.4	36.1	36.4	36.1	35.9	36.3	36.2	35.9
$\bar{x}$	34.6	36.3	36.1	35.2	34.6	36.2	36.2	36.0	35.3	36.0	36.1	35.7

Summer

B-1	32.2	36.4	36.3	36.0	31.9	36.3	36.2	36.0	34.4	36.1	36.4	36.0
B-3	34.2	36.7	36.2	35.3	34.9	36.5	36.4	36.0	35.1	36.4	36.5	35.6
$\bar{x}$	33.2	36.6	36.3	35.7	33.4	36.4	36.3	36.0	34.8	36.3	36.5	35.8

Table 15-5. Mean seasonal surface and bottom salinities (‰) for the regular stations on the Mississippi-Alabama continental shelf. Higher values are shaded.

SURFACE

Sta.	Winter				Summer			
	C	M	D	$\bar{x}$	C	M	D	$\bar{x}$
1	32.7	30.7	32.9	32.1	32.4	32.2	32.9	32.5
2	33.4	32.7	35.1	33.7	32.0	34.2	33.9	33.4
3	34.2	33.2	35.0	34.1	32.3	33.5	33.8	33.2
4	35.7	34.5	35.8	35.3	31.0	33.7	33.9	32.9
$\bar{x}$	34.0	32.8	34.7	33.8	31.9	33.4	33.6	33.0

BOTTOM

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	34.6	34.6	35.3	34.8	33.2	33.4	34.8	33.8
2	36.3	36.2	36.0	36.2	36.6	36.4	36.3	36.4
3	36.1	36.2	36.1	36.1	36.3	36.3	36.5	36.4
4	35.2	36.0	35.7	35.6	35.7	36.0	35.8	35.8
$\bar{x}$	35.6	35.8	35.8	35.7	35.5	35.5	35.9	35.6

the water column occurred throughout the area due primarily to temperature differences. During the winter it may have occurred on the Mobile transect but not on the De Soto Canyon transect.

15.2.4 Light Transmission

Water clarity is inversely related to the amount of suspended matter in the water column. This, in turn, relates to sources of suspended material (rivers, plankton, and bottom sediments) and to stratification and the turbulent energy of the water (due to currents, internal waves, etc.). Bottom disturbance by schools of demersal animals may be locally important. Reviewing the historical literature, Vittor and Associates, Inc. (1985) described a bottom nepheloid layer as well as turbid lenses of brackish water near the surface. Offshore, clear water sometimes occurred between surface and bottom turbid layers. Surface light penetration off Mississippi and Alabama was considerably less than off West Florida, a few miles to the east.

Surface and bottom light transmission values for summer (B-3) and winter (B-4) cruises are presented in Table 15-6. For the instrument employed, pure water gives values around 91.3%. During the summer light transmission was fairly high at most stations, but low surface and bottom values were recorded at three isolated stations. However, during the winter low transmission values occurred at the surface of all stations on the Chandeleur and Mobile transects except C-3, and low bottom values were observed only at stations C-2 and C-4. Both surface and bottom values of all the De Soto Canyon stations were clear during the winter study period. The prevalence of high light transmission values, especially in the bottom waters, during both seasons is surprising in view of historical indications of a very turbid water column in this shelf area. The low transmission values at the deepest stations (D-4, summer and C-4, winter) may reflect the roiling action of deep bottom currents. High light transmission values of the bottom water during the winter likely reflect the fact that deep Gulf bottom water had intruded across the shelf during this period.

Table 15-6. Surface and bottom values for light transmission (%) for regular stations on the Mississippi-Alabama continental shelf. The seasonal values are from two cruises only (B-3 and B-4). Higher values are shaded.

SURFACE

Sta.	Winter				Summer			
	C	M	D	$\bar{x}$	C	M	D	$\bar{x}$
1	10.0	23.8	55.4	29.7	74.6	68.0	86.4	76.3
2	30.0	22.4	47.0	33.1	85.8	26.4	88.8	67.0
3	70.4	7.4	63.8	47.2	28.6	89.8	89.2	69.2
4	23.0	6.8	64.0	31.3	82.8	90.2	24.6	65.9
$\bar{x}$	33.4	15.1	57.6	35.3	68.0	68.6	72.3	69.6

BOTTOM

Sta.	Winter				Summer			
1	53.0	55.6	63.4	57.3	85.2	85.2	89.0	86.5
2	15.4	59.0	64.0	46.1	90.0	26.8	90.4	69.1
3	81.2	61.2	64.2	68.9	52.0	70.2	91.0	71.1
4	26.0	61.8	63.4	50.4	85.0	78.0	24.8	62.6
$\bar{x}$	43.9	59.4	63.8	55.7	78.1	65.1	73.8	72.3

15.2.5 Dissolved Oxygen

Values for dissolved oxygen in the bottom waters for all the cruises are presented in Table 15-7, and their mean station values, separated by season, are given in Table 15-8. The lowest readings observed during the summer months included values of 4.26 mg/l at station D-4 and several values in the range of 4.60 to 5.00 mg/l elsewhere. The lowest mean summer value was 4.70 mg/l. During the winter low values of 2.93 and 2.99 mg/l appeared at stations C-4 and M-4, and numerous values occurred in the range of 3.00 to 4.00 mg/l, all during cruise B-0. Low bottom oxygen values were widespread during this cruise, affecting all but the shallowest stations. Although it does appear to be possible for this shelf area to be affected by hypoxia during an unusual season, such events are not considered to be of frequent occurrence on the Mississippi-Alabama shelf.

Table 15-7. Bottom dissolved oxygen values (mg/l) for each cruise and station, separated by season.

Winter

	C				M				D			
Cruise No.	1	2	3	4	1	2	3	4	1	2	3	4
B-0	5.18	3.98	3.11	2.99	5.30	3.87	3.02	2.93	5.50	3.68	3.17	3.10
B-2	5.08	5.59	---	---	---	5.28	6.43	4.62	8.99	7.78	4.89	4.63
B-4	7.74	7.47	4.85	4.83	8.28	7.94	5.30	4.98	8.24	7.02	7.93	4.22
$\bar{x}$	6.00	5.68	3.98	3.89	6.79	5.70	4.92	4.18	7.56	6.16	5.33	3.98

Summer

B-1	---	4.70	4.62	4.82	---	5.80	4.63	4.70	7.77	---	5.48	4.60
B-3	7.00	6.40	4.78	4.84	5.88	6.13	6.00	5.69	6.05	6.44	5.23	4.26
$\bar{x}$	7.00	5.55	4.70	4.83	5.88	5.97	5.32	5.20	6.91	6.44	5.36	4.43

Table 15-8. Mean seasonal bottom dissolved oxygen values (mg/l) for the regular stations on the Mississippi-Alabama continental shelf. Higher values are shaded.

Sta.	Winter				Summer			
	C	M	D	$\bar{x}$	C	M	D	$\bar{x}$
1	6.00	6.79	7.56	6.78	7.00	5.88	6.91	6.60
2	5.68	5.70	6.16	5.85	5.55	5.97	6.44	5.99
3	3.98	4.92	5.33	4.74	4.70	5.32	5.36	5.13
4	3.89	4.18	3.98	4.02	4.83	5.20	4.43	4.82
$\bar{x}$	4.89	5.40	5.76	5.35	5.52	5.60	5.79	5.64

15.2.6 Dissolved Nutrients

Attention here is focused on nitrates and phosphates dissolved in the surface waters where they would be available to support phytoplankton populations. Dissolved nitrate values are presented in Tables 15-9 and 15-10, and the corresponding phosphate values are given in Tables 15-11 and 15-12. All cruises are included except cruise B-2 for the nitrates. For this cruise the values presented are generally at least an order of magnitude greater than corresponding values for the other cruises, and the data are listed with fewer significant figures, eliminating the possibility of calculating meaningful averages. Since this data set is considered to be aberrant, it is not used in the calculations.

The data reveal that nitrates were very low and uniformly distributed during the summer months. However, during the winter many values were high, often exceeding 1.0 μM/kg, especially along the Chandeleur transect and one station on the Mobile transect. Mean winter values on the De Soto Canyon transect were only slightly elevated over those of the summer. The influx of nitrate during the winter months appears to reflect outflow of nutrient rich waters from the north and west.

By contrast, surface phosphate values remained uniformly fairly low throughout both seasons, but they did show minor elevations at certain nearshore stations and on the Chandeleur transect. Phosphates are known to adsorb readily to the surface of clay particles, and it appears likely that surface phosphate levels were kept low by clay particle scavenging and subsequent sedimentation.

Table 15-9. Surface dissolved nitrate values (μM/kg) for each cruise and station, separated by season. Data for cruise B-2 are omitted for reasons discussed in the text.

Winter

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-0	1.32	1.47	0.47	1.59	0.29	0.12	0.26	0.08	0.08	0.19	0.20	0.04
B-4	0.08	1.85	0.28	0.31	0.27	0.10	1.26	0.18	0.16	0.25	---	0.18
$\bar{x}$	0.70	1.66	0.95	0.95	0.28	0.11	0.76	0.13	0.12	0.22	0.20	0.11

Summer

B-1	0.20	0.20	0.20	0.20	0.10	0.10	0.20	0.10	0.20	0.20	0.10	0.10
B-3	0.09	0.06	0.07	0.02	0.07	0.04	0.11	0.10	0.15	0.06	0.06	0.14
$\bar{x}$	0.15	0.13	0.14	0.11	0.09	0.07	0.16	0.10	0.18	0.13	0.08	0.12

Table 15-10. Mean seasonal surface dissolved nitrate values (μM/kg) for the regular stations on the Mississippi-Alabama continental shelf. Higher values are shaded.

Sta.	Winter				Summer			
	C	M	D	$\bar{x}$	C	M	D	$\bar{x}$
1	0.70	0.28	0.12	0.37	0.15	0.09	0.18	0.14
2	1.66	0.11	0.22	0.66	0.13	0.07	0.13	0.11
3	0.38	0.76	0.20	0.45	0.14	0.16	0.08	0.13
4	0.95	0.13	0.11	0.40	0.11	0.10	0.12	0.11
$\bar{x}$	0.92	0.32	0.16	0.47	0.13	0.11	0.13	0.12

Table 15-11. Surface dissolved phosphate values (μM/kg) for each cruise and station, separated by season.

Winter

Cruise No.	C 1	C 2	C 3	C 4	M 1	M 2	M 3	M 4	D 1	D 2	D 3	D 4
B-0	0.13	0.19	0.10	0.20	0.18	0.17	0.23	0.16	0.17	0.12	0.12	0.09
B-2	0.15	0.32	---	---	0.13	0.17	0.20	0.20	0.09	---	0.15	0.18
B-4	0.02	0.14	0.08	0.12	0.30	0.11	0.14	0.05	0.24	0.16	0.16	0.00
$\bar{x}$	0.10	0.22	0.09	0.16	0.20	0.15	0.19	0.14	0.17	0.14	0.14	0.09

Summer

B-1	0.18	0.27	0.20	0.28	0.15	0.09	0.06	0.03	0.15	0.15	0.05	0.09
B-3	0.15	0.26	0.12	0.37	0.23	0.14	0.13	0.14	0.25	0.14	0.08	0.26
$\bar{x}$	0.17	0.27	0.16	0.33	0.19	0.12	0.10	0.09	0.20	0.15	0.07	0.18

Table 15-12. Mean seasonal surface dissolved phosphate values (μM/kg) for the regular stations on the Mississippi-Alabama continental shelf. Higher values are shaded.

Sta.	Winter			
	C	M	D	$\bar{x}$
1	0.10	0.20	0.17	0.16
2	0.22	0.15	0.14	0.17
3	0.09	0.19	0.14	0.14
4	0.16	0.14	0.09	0.13
$\bar{x}$	0.14	0.17	0.14	0.15

Summer			
C	M	D	$\bar{x}$
0.17	0.19	0.20	0.19
0.27	0.12	0.15	0.18
0.16	0.10	0.07	0.11
0.33	0.09	0.18	0.20
0.23	0.13	0.15	0.17

15.3 Bottom Sediments

The present section will treat characteristics of the surface sediments as well as the high molecular weight hydrocarbons and heavy metals which are associated with the sediments. Attention will be focused on the distribution, magnitude, and seasonal patterns. The topographic high features studied in the present project will also be discussed briefly.

15.3.1 General Distribution of the Surface Sediments

The most comprehensive study of the distribution of the surface sediments of the Mississippi-Alabama shelf was published by Ludwick (1964), and this map has been presented in Figure 6-2. However, since depth contours are not shown it is difficult to visualize how the sediments vary in relation to the water depth and shelf morphology. To partially remedy this situation, three three-dimensional drawings have been prepared, each showing sediment patterns (as presented in Ludwick 1964), station locations, and the depth perspective (Figure 15-6 through 15-8). These figures are drawn to the same scale and show the transect stations in relation to the prevailing sediment types. The figures demonstrate the narrowing of the shelf towards the east, the prevalence of clay and silt facies to the west and sand sheet to the east, and the appearance of finer sediments toward the deeper areas of the outer shelf. Although the generally prevailing sediment types are shown, there is much variation at the local level, and samples taken during the present study do not match up entirely with those of Ludwick.

15.3.2 Sediment Characteristics

The various characteristics of the sediments taken during the present study at the twelve sampling stations have been averaged by season and are presented in Table 15-13. The table also highlights seasonal differences (i.e., summer minus winter values) for the various parameters. Each of the characteristics will be discussed briefly.

Clay

The clay fraction presents very clear distribution patterns. Highest clay levels are found toward the southwest, and lowest levels appear toward the northeast. This relationship holds during both seasons. There is also a general depth relationship. All of the 20 m stations show a relatively low clay content (<25%) and all of the 200 m stations have a relatively high clay content (>37%). The highest value (79%) is located closest to the Mississippi River Delta during the winter, and the next highest values occur at the adjacent stations. For most of the shallower stations the seasonal differences in clay content are minor, but at C-3 and all stations at the

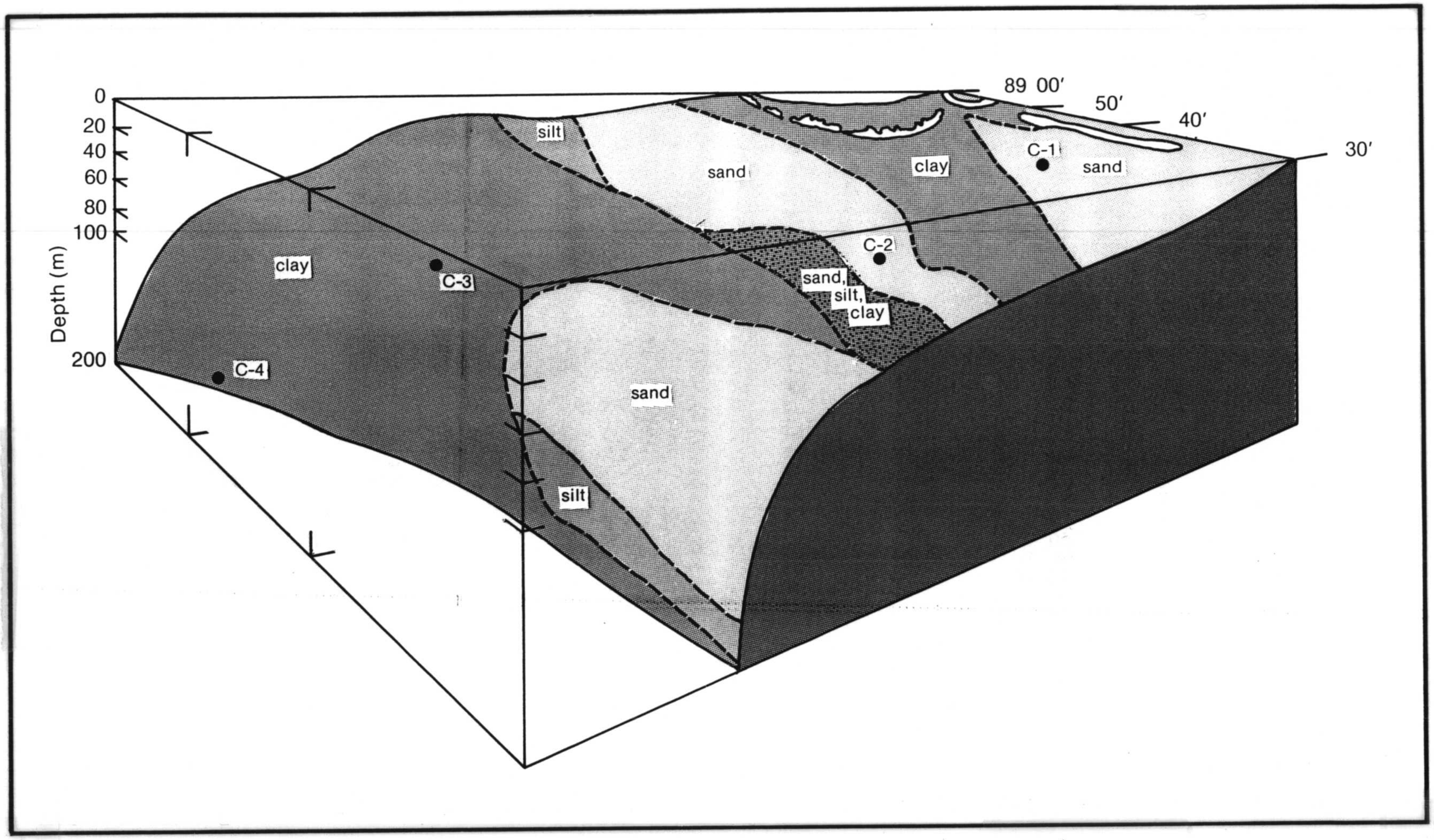


Figure 15-6. Perspective view of the continental shelf in the vicinity of the Chandeleur transect showing the spatial distribution of surface sediments as given by Ludwick (1964). Sampling stations C-1 through C-4 are indicated.

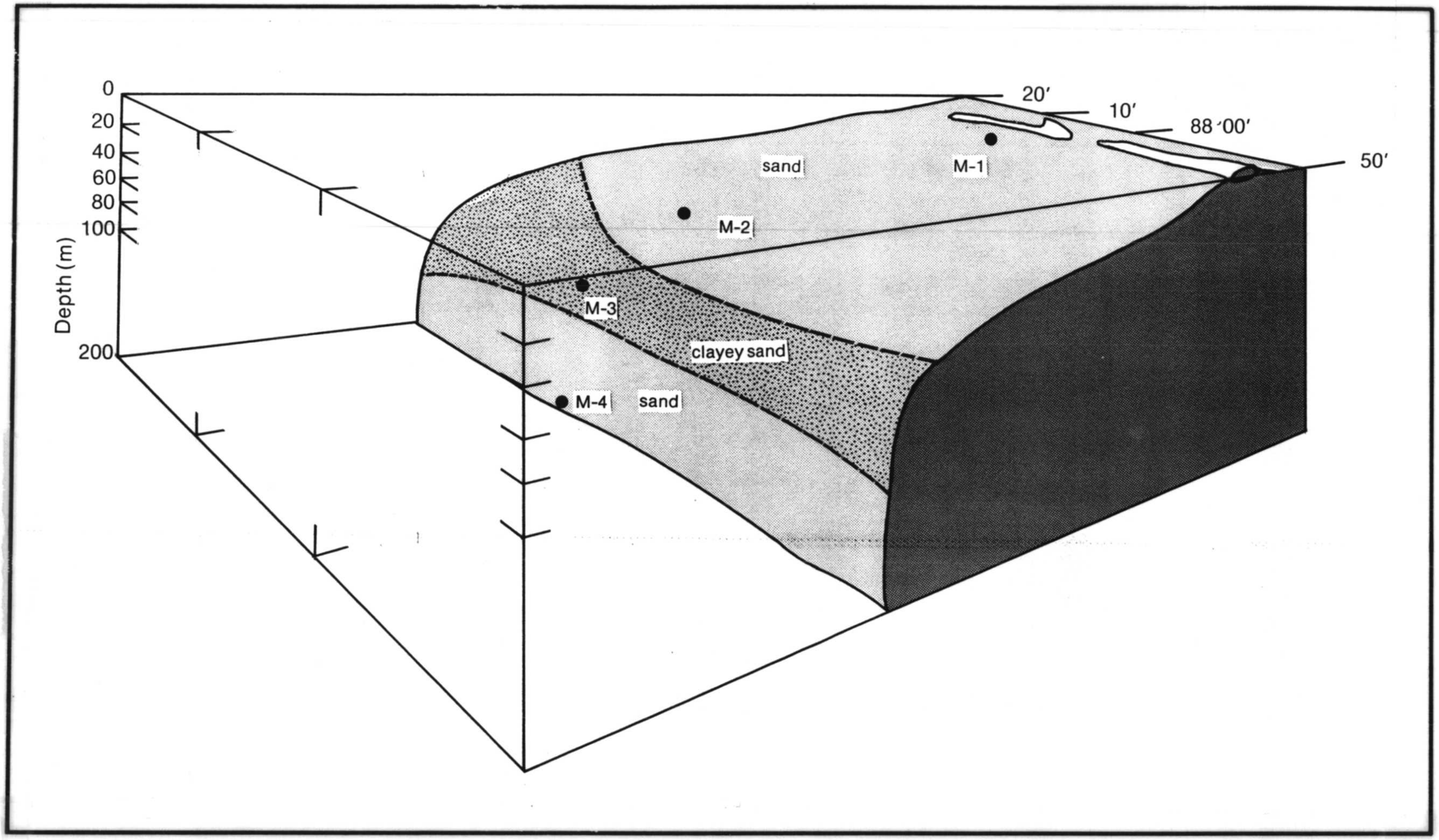


Figure 15-7. Perspective view of the continental shelf in the vicinity of the Mobile transect showing the spatial distribution of surface sediments as given by Ludwick (1964). Sampling stations M-1 through M-4 are indicated.

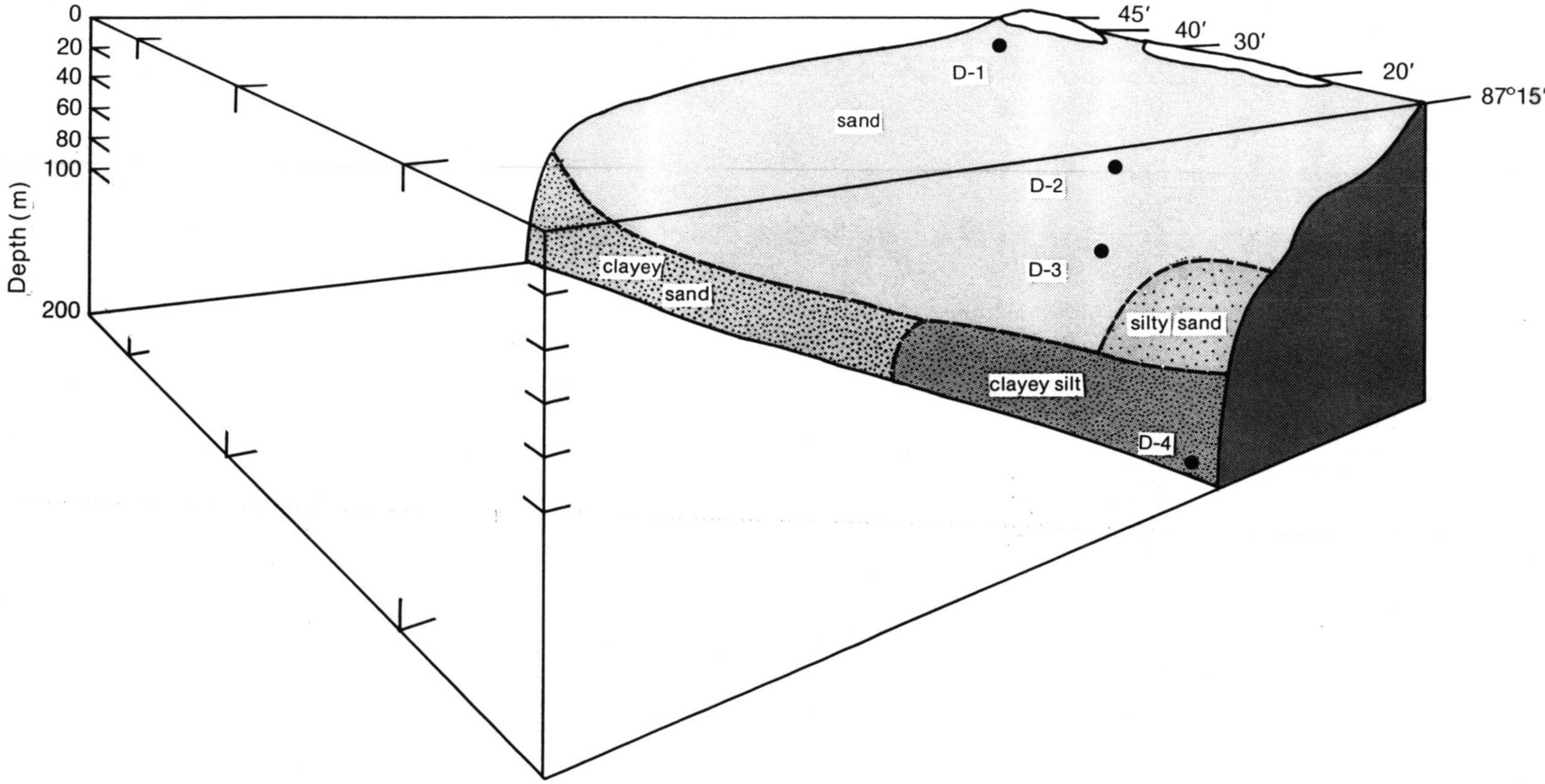


Figure 15-8. Perspective view of the continental shelf in the vicinity of the De Soto Canyon transect showing the spatial distribution of surface sediments as given by Ludwick (1964). Sampling stations D-1 through D-4 are indicated.

Table 15-13. Surface sediment data for the Mississippi-Alabama continental shelf. For each station the mean seasonal values are given for winter and summer and for the summer minus winter differences. For the winter and summer plots, the higher values are shaded. For the summer minus winter plots, the negative values are shaded.

%Clay

Winter

	C	M	D
1	23.6	13.5	5.2
2	38.4	9.3	6.2
3	69.2	28.3	17.9
4	79.1	71.2	46.9

Summer

	C	M	D
1	20.8	9.4	4.5
2	35.0	7.8	7.3
3	57.4	27.3	16.9
4	57.1	53.9	37.1

Summer - Winter

	C	M	D
1	-2.8	-4.1	-0.7
2	-3.4	-1.5	1.1
3	-11.8	-1.0	-1.0
4	-22.0	-17.3	-9.8

%Silt

Winter

	C	M	D
1	22.0	2.1	0.5
2	23.2	1.2	0.6
3	26.3	11.0	18.6
4	20.6	24.5	48.0

Summer

	C	M	D
1	16.8	1.2	0.3
2	40.5	0.8	0.6
3	32.0	13.1	6.1
4	42.7	40.2	53.6

Summer - Winter

	C	M	D
1	-5.2	-0.9	-0.2
2	17.3	-0.4	0.0
3	5.7	2.1	-12.5
4	22.1	15.7	5.6

%Sand

Winter

	C	M	D
1	52.1	80.2	75.4
2	36.5	89.0	78.2
3	4.4	59.8	53.2
4	0.2	4.2	4.5

Summer

	C	M	D
1	58.0	92.9	94.7
2	23.1	88.0	89.3
3	10.6	56.9	58.3
4	0.3	5.7	7.3

Summer - Winter

	C	M	D
1	5.9	12.7	0.8
2	-13.4	-1.0	11.1
3	6.2	-2.9	5.1
4	0.1	1.5	2.8

%Gravel

Winter

	C	M	D
1	0.3	3.6	0.4
2	1.2	0.5	14.9
3	0.1	0.7	9.4
4	0.1	0.6	0.1

Summer

	C	M	D
1	1.1	1.8	0.2
2	0.3	3.0	2.0
3	0.2	1.0	18.8
4	0.2	0.1	0.1

Summer - Winter

	C	M	D
1	0.8	-1.8	-0.2
2	-0.9	2.5	-12.9
3	0.1	0.3	9.4
4	0.1	-0.5	0.0

Mean ø

Winter

	C	M	D
1	3.3	2.0	1.9
2	3.6	1.6	1.1
3	4.4	2.8	2.0
4	4.0	4.3	4.7

Summer

	C	M	D
1	3.1	2.0	1.7
2	4.6	1.6	1.2
3	4.8	3.3	1.2
4	5.2	5.0	5.1

Summer - Winter

	C	M	D
1	-0.2	0.0	-0.2
2	1.0	0.0	0.1
3	0.4	0.5	-0.8
4	1.2	0.7	0.4

Table 15-13. cont'd.

Winter | Summer | Summer - Winter

$CaCO_3$

Winter

	C	M	D
1	6.2	3.8	0.7
2	7.5	5.0	19.5
3	3.6	15.7	64.7
4	3.4	9.8	51.3

Summer

	C	M	D
1	7.2	0.8	0.4
2	7.0	6.9	23.9
3	3.6	23.4	68.1
4	7.6	10.1	62.8

Summer - Winter

	C	M	D
1	1.2	-3.0	-0.3
2	-0.5	1.9	4.4
3	0.0	7.7	3.4
4	4.2	0.3	11.5

Organic Carbon

Winter

	C	M	D
1	0.7	0.3	0.1
2	0.9	0.2	0.2
3	1.3	0.3	1.5
4	1.0	1.0	2.6

Summer

	C	M	D
1	0.3	0.1	0.1
2	0.9	0.1	0.2
3	1.3	0.6	1.1
4	1.9	1.5	1.8

Summer - Winter

	C	M	D
1	-0.4	-0.2	0.0
2	0.0	-0.1	0.0
3	0.0	0.3	-0.4
4	0.8	0.5	-0.8

$\delta^{13}C$ (x -1)

Winter

	C	M	D
1	21.3	23.8	21.6
2	21.7	22.7	20.3
3	21.8	21.2	21.7
4	21.6	21.0	21.2

Summer

	C	M	D
1	23.0	23.2	21.7
2	22.7	20.5	22.6
3	22.3	22.3	21.5
4	22.7	22.1	22.5

Summer - Winter

	C	M	D
1	1.7	-0.6	0.1
2	1.0	-2.2	2.3
3	0.5	1.1	0.2
4	1.1	1.1	1.3

200 m depth, winter values exceeded those of the summer by about 10% or more. Since these finely particulate sediments limit oxygen penetration, they also limit the distribution of oxygen-dependent infauna.

Silt

The distribution of silt in the surface sediments roughly parallels that of clay. However, the summer values tended to exceed winter values along the Chandeleur transect and at all stations at the 200 m depth.

Sand

The distribution of sand in the surface samples was the inverse of the above patterns. The sand fraction was highest toward the northeast where the percentage of clay and silt was lowest. The small differences in seasonal percentages showed no real pattern.

Gravel

The gravel fraction, mostly biogenic carbonate material (coralline algae, mollusk shells, and bryozoan remains), was highest at stations D-3 and D-4, and these stations fell in the area of high carbonate sediments, discussed below. Seasonal differences tended to be small and suggest accidental collection of shell patches rather than general trends.

Phi

The statistic ϕ is a derived measure expressing particle size, and the larger the value of ϕ, the smaller the average particle sizes of the sample. Therefore, in the present study the distribution of ϕ values closely paralleled the distribution patterns of clay and silt. Although seasonal differences were small, summer values generally exceeded those of the winter.

Calcium Carbonate

During both seasons the percentage of calcium carbonate was highest (>15%) at stations M-3, D-2, D-3, and D-4, and at the latter two stations it exceeded 50%. The clear oceanic water in the vicinity of De Soto Canyon appears to be a more hospitable environment for mollusks and other calcareous species than is the more turbid, clay and silt laden water close to the Mississippi River.

Organic Carbon

During both seasons organic carbon values were highest at the deepwater stations (C-3, C-4, M-4, D-3, and D-4). The deepwater sediments are clearly the repository for organic material swept from the shallower shelf. During the summer the organic carbon values were elevated at the western stations (C-4 and M-4), whereas during the winter they were elevated toward the east (D-3 and D-4). This suggests some seasonal shift in the water currents responsible for deposition.

Delta C-13

All $\delta^{13}C$ Values are negative and are expressed as ‰. Values for temperate marine phytoplankton range from -18 to -24‰ but average about -21‰. Most terrestrial and riverine sources range higher (riverine and estuarine algae = -24 to -30, riverine POC = -25 to -27, riverine sediments = -25 to -27‰, and sewage = -24). Therefore, marine values above -21 are considered to be influenced by riverine or estuarine water and/or sediments.

Sediment samples analyzed during the present study show that during the winter all $\delta^{13}C$ values appear to represent marine phytoplankton except the two stations off Mobile Bay (M-1 and M-2) which show a terrestrial influence. This could come from Mobile Bay outflow or it could derive from winnowing and transport of Mobile Bay dredge spoil piles previously placed on the shelf. However, during the summer months evidence of terrestrial influence was widespread, affecting all stations on the Chandeleur transect, three on the Mobile transect, and two on the De Soto Canyon transect. The highest values occurred nearshore at stations C-1 and M-1.

15.3.3 High Molecular Weight Hydrocarbons

During the present study quantitative chemical analyses were conducted for a variety of high molecular weight hydrocarbons. The raw data are provided in the appendices, and some of the compounds are discussed in Chapter 4 of the present report. Four groups of hydrocarbons have been selected for discussion here because of their importance in terms of the goals of the project. These include the following: total extractable organic matter (EOM), total aromatics (PAH), unresolved complex mixture

(UCM), and odd-numbered alkanes of chain length n=23-31. The total extractable organic matter could be derived from either natural petroleum or from recent biological production and may represent a mixture of materials from both sources. The aromatic hydrocarbons and the unresolved complex mixture represent primarily derivatives of natural petroleum, and these could be derived from natural seeps or from transport and transfer activities (spillage, leakage, etc.). However, the odd-numbered alkanes of long chain length are considered indicative of plant bio-waxes of recent terrestrial origin. Thus, information concerning the concentrations and distribution patterns of these four chemical groups should provide insight into both the levels and sources of the high molecular weight hydrocarbons of this shelf area.

15.3.3.1 Distribution of Hydrocarbons by Cruise

In Tables 15-14 through 15-17, the hydrocarbon data are presented for each station of each cruise, and the cruises are reported by season. It is noted that for some of the groups the data for cruise B-4 display very high levels, so the winter data are presented in two ways. In the first case, station averages are provided for all three winter cruises. In the second case, data from cruises B-0 and B-2 are averaged and the average compared with data from cruise B-4. In the case of total extractable organic matter, data from cruise B-4 show no systematic pattern of deviation from the mean of the other two winter cruises. Therefore, in all subsequent analyses the mean of the three winter cruises will be employed. However, for the remaining three groups of hydrocarbons, data for cruise B-4 are remarkably different from the mean of cruises B-0 and B-2. The B-4 values are considerably elevated, especially for stations on the Chandeleur and Mobile transects. therefore, in subsequent analyses the B-4 data will be considered separately from the means of the other two winter cruises.

15.3.3.2 Hydrocarbon Distribution by Station, Transect, and Season

The distribution of the four hydrocarbon groups by station, transect, and season is presented in Table 15-18. The data represent seasonal means, but only for the total extractable organic matter are data from cruise B-4 included in the winter means. In the case of this particular hydrocarbon

Table 15-14. Sediment concentrations of total extractable organic matter (EOM)(ppm) for each cruise and station, separated by season. Data for the winter season are expressed in two ways: a) showing data for all three winter cruises separately, and b) comparing the mean densities for stations of the first two winter cruises (B-0 and B-2) with station densities of the last winter cruise (B-4).

Winter

	C				M				D			
Cruise No.	1	2	3	4	1	2	3	4	1	2	3	4
B-0	45	16	130	134	10	14	5	145	---	8	51	102
B-2	42	70	50	262	33	128	119	8	25	25	82	12
B-4	54	82	105	130	68	38	59	98	34	46	28	101
$\bar{x}$	47	56	95	175	37	60	61	84	30	26	54	72

Winter (modified)

(0 + 2)/2	44	43	90	198	22	71	62	77	25	17	67	57
B-4	54	82	105	130	68	38	59	98	34	46	28	101

Summer

B-1	38	88	70	124	10	18	55	87	20	7	8	188
B-3	63	69	179	136	42	25	53	64	32	17	57	98
$\bar{x}$	51	79	125	130	26	22	54	76	26	12	33	143

Table 15-15. Sediment concentrations of total aromatics (PAH)(ppb) for each cruise and station, separated by season. Data for the winter season are expressed in two ways: a) showing data for all three winter cruises separately, and b) comparing the mean densities for stations of the first two winter cruises (B-0 and B-2) with station densities of the last winter cruise (B-4). Values below the limit of detection are listed as zero.

Winter

	C				M				D			
Cruise No.	1	2	3	4	1	2	3	4	1	2	3	4
B-0	16	6	174	348	0	0	7	112	---	5	6	63
B-2	14	269	35	331	10	0	147	0	0	0	47	0
B-4	68	176	296	567	138	18	19	194	0	0	28	114
$\bar{x}$	33	150	168	415	49	6	58	102	0	2	27	59

Winter (modified)

(0 + 2)/2	15	138	105	340	5	0	77	56	0	3	27	32
B-4	68	176	296	567	138	18	19	194	0	0	28	114

Summer

B-1	76	263	288	514	0	6	97	279	6	0	45	192
B-3	113	243	496	673	0	0	130	280	32	0	68	118
$\bar{x}$	95	253	392	594	0	3	114	280	19	0	57	155

Table 15-16. Sediment concentrations of the total unresolved complex mixture (UCM)(ppm) for each cruise and station, separated by season. Data for the winter season are expressed in two ways: a) showing data for all three winter cruises separately, and b) comparing the mean densities for stations of the first two winter cruises (B-0 and B-2) with station densities of the last winter cruise (B-4).

Winter

	C				M				D			
Cruise No.	1	2	3	4	1	2	3	4	1	2	3	4
B-0	4	3	23	42	2	1	6	12	---	2	3	11
B-2	6	15	10	32	6	14	2	2	10	8	17	5
B-4	35	65	104	131	76	19	23	92	13	7	20	45
$\bar{x}$	15	28	46	68	28	11	10	35	12	6	13	20

Winter (modified)

(0 + 2)/2	5	9	17	37	4	8	4	7	10	5	10	8
B-4	35	65	104	131	76	19	23	92	13	7	20	45

Summer

B-1	5	14	12	17	3	3	6	12	2	2	4	14
B-3	19	35	52	66	17	7	23	22	8	6	21	29
$\bar{x}$	12	25	32	42	10	5	15	17	5	4	13	22

Table 15-17. Sediment concentrations of odd numbered alkanes of chain length n=23 through n=31 (ppb). Data for the winter season are expressed in two ways: a) showing data for all three winter cruises separately, and b) comparing the mean densities for stations of the first two winter cruises (B-0 and B-2) with station densities of the last winter cruise (B-4). Values below the limit of detection are listed as zero.

Winter

	C				M				D			
Cruise No.	1	2	3	4	1	2	3	4	1	2	3	4
B-0	155	40	220	769	96	82	310	242	---	28	139	133
B-2	205	350	176	1259	246	307	73	101	78	93	345	148
B-4	338	1555	1846	2487	1005	515	239	1590	26	255	123	622
$\bar{x}$	233	648	747	1505	449	301	207	644	52	125	202	301

Winter (modified)

(0 + 2)/2	180	195	198	1014	171	195	192	172	78	61	242	141
B-4	338	1555	1846	2487	1005	515	239	1590	26	255	123	622

Summer

B-1	409	426	522	512	192	217	245	376	212	216	140	219
B-3	268	959	800	1325	364	156	743	623	53	98	293	980
$\bar{x}$	339	693	661	919	278	187	494	500	133	157	217	600

Table 15-18. Seasonal distribution of high molecular weight hydrocarbon groups by station and transect. For the total extractable organic matter, winter month concentrations are based on data from all three winter cruises. For the remaining groups winter concentrations are based on data from Cruises B-0 and B-2 only, since data from Cruise B-4 for these groups are considered to be aberrant. Higher values are shaded.

TOTAL EXTRACTABLE ORGANIC MATTER (ppm)

Sta.	Winter				Summer			
	C	M	D	X	C	M	D	X
1	47	37	30	38	51	26	26	34
2	56	60	26	47	79	22	12	38
3	95	61	54	70	125	54	33	71
4	175	84	72	110	130	76	143	116
$\bar{x}$	93	61	46	66	96	45	54	65

TOTAL AROMATICS (ppb)

1	15	5	0	7	95	0	19	38
2	138	0	3	47	253	3	0	85
3	105	77	27	70	392	114	57	188
4	340	56	32	143	594	280	155	343
$\bar{x}$	150	35	16	67	334	99	58	164

UNRESOLVED COMPLEX MIXTURE (ppm)

1	5	4	10	6	12	10	5	9
2	9	8	5	7	25	5	4	11
3	17	4	10	10	32	15	13	20
4	37	7	8	17	42	17	22	27
$\bar{x}$	17	6	8	10	28	12	11	17

ODD NUMBERED ALKANES (n=23-31)(ppb)

1	180	171	78	143	339	278	133	250
2	195	195	61	150	693	187	157	346
3	198	192	242	211	661	494	217	457
4	1014	172	141	442	919	500	600	673
x	397	183	131	237	653	365	277	432

group the distribution patterns for the two seasons are remarkable similar. Hydrocarbon concentrations increase with depth, the highest concentrations generally occur on the Chandeleur transect, and the lowest concentrations tend to appear on the De Soto Canyon transect. This basic pattern holds true for all four groups. For the total extractable organic matter quantitative levels of the hydrocarbons for the two seasons are remarkable similar, but for all the remaining groups, mean summer values are roughly twice the winter values.

Together these data imply that the spring season of high river runoff annually charges the shelf with petroleum hydrocarbons and terrestrial plant bio-waxes and that the source of much of this material is to the west, i.e., the Mississippi River, Louisiana marshes, Gulf Outlet Canal, Pearl River and Lake Pontchartrain drainages, or a combination of these. The data clearly show that under normal conditions some of the hydrocarbon groups which accumulate on the shelf during the spring and summer months are largely biodegraded or swept away by the following winter.

15.3.3.3 Evidence of a Major Episodic Event

As mentioned earlier, for three of the four hydrocarbon groups the data from cruise B-4 were sharply elevated over those of the other two winter cruises. In Table 15-19 this is shown by transect where the increase is expressed in terms of both numbers and percentages. Numerically, the increase was greatest on the Chandeleur and least on the De Soto Canyon transect, but since the Chandeleur values were already high and those of De Soto Canyon very low, the percentage increase varied with respect to chemical group and transect. Nevertheless, all but two of the increases exceeded 100%, and they ranged over 800%. The mean increase was 276.9%, far exceeding normal variation observed during the study. The data, thus, appear to reflect a major intrusion by forces external to the system. The nature and significance of this event will be examined later in conjunction with other relevant information amassed during the project.

Table 15-19. A comparison of cruise B-4 data with the mean values for cruises B-0 and B-2 for three hydrocarbon groups. The information is expressed two ways: a) the numerical increase of B-4 values over the means for the other two cruises, and b) the percentage increase of B-4 data over the means for the other two cruises. The data are presented by transect.

Hydrocarbon group	C	M	D
Numerical increase			
Total aromatic hydrocarbons (ppb)	509	231	80
Unresolved complex mixture (ppm)	267	187	52
Odd numbered alkanes (n=23-31)(ppb)	4639	2619	504

Percentage increase			
Total aromatic hydrocarbons	85.1	167.4	129.0
Unresolved complex mixture	392.6	813.0	157.6
Odd numbered alkanes (n=23-31)	292.3	358.8	96.6

15.3.4 Trace Metals

During the present study fourteen different types of trace metals were analyzed in order to characterize the spatial and temporal patterns of these elements in sediments of the study area. Details of the analyses for all the metals are presented in Chapter 5.0 of the present report. Data for three of the metals (barium, cadmium, and iron) will be examined here to illustrate the types of results obtained.

In Table 15-20 through 15-22, data for the three trace metals are presented for each station of each cruise, and the cruises are separated by season. At two of the stations (Cruise B-0, station D-2 for barium and cruise B-3, station D-1 for cadmium) the values were originally listed as being below a certain number. In order to calculate seasonal mean values for each station it has been necessary to assign actual numbers, and it was arbitrarily decided to employ half the stated minimum value in each case. Since both values are quite small this procedure has had little effect on the overall results. Examination of the raw data reveals that within a given season the patterns are fairly consistent from cruise to cruise for each of the trace metals. Since no cruise appears to be highly deviant, seasonal means should be based upon all the data sets for a particular season.

Table 15-20. Sediment concentrations of barium (ppm) for each cruise and station, separated by season.

Winter

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-0	333	150	895	890	70	44	170	525	---	<18	125	195
B-2	335	455	605	940	45	95	195	405	39	24	55	180
B-4	155	660	755	790	295	85	150	420	45	16	55	190
$\overline{x}$	274	422	752	873	137	75	172	450	42	~16	78	188

Summer

B-1	310	510	910	770	75	95	180	510	55	10	50	140
B-3	185	440	720	790	90	65	250	390	42	31	75	165
$\overline{x}$	248	475	815	780	83	80	215	450	49	21	63	153

Table 15-21. Sediment concentrations of cadmium (ppb) for each cruise and station, separated by season.

Winter

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-0	49	19	130	204	13	4	50	143	---	90	83	148
B-2	23	64	50	99	21	11	48	101	8	11	31	105
B-4	20	55	99	181	28	24	37	78	8	19	123	165
$\overline{x}$	31	46	93	161	21	13	45	107	8	40	79	139

Summer

B-1	52	70	140	179	4	11	54	126	4	4	59	162
B-3	16	65	115	175	43	15	50	120	<10	41	105	135
$\overline{x}$	34	68	128	177	24	13	52	123	~5	23	82	149

Table 15-22. Sediment concentrations of iron (%) for each cruise and station, separated by season.

Winter

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-0	2.20	0.66	4.20	4.20	0.32	0.26	2.34	3.58	---	1.13	2.47	1.79
B-2	1.61	3.04	2.06	3.90	0.21	0.48	2.37	3.40	0.01	0.18	1.72	1.64
B-4	0.92	2.96	3.92	4.19	1.31	0.44	1.18	3.52	0.13	0.17	1.42	1.69
$\bar{x}$	1.58	2.22	3.39	4.10	0.61	0.39	1.96	3.50	0.07	0.49	1.87	1.71

Summer

B-1	2.02	2.80	3.80	4.10	0.35	0.49	2.40	3.38	0.20	0.13	2.39	1.64
B-3	0.90	2.93	3.77	4.02	0.38	0.36	2.45	3.34	0.09	0.75	1.80	1.62
$\bar{x}$	1.46	2.89	3.79	4.06	0.37	0.43	2.43	3.36	0.15	0.44	2.10	1.63

Table 15-23 provides information for all three trace metal species based upon the seasonal means. Here the information is presented by station and transect and separated by season. Despite the different physical and chemical properties of the various metals, the distribution patterns are remarkably similar, although they do vary in detail. For all the metals and for both seasons concentrations are greater on the Chandeleur than on either of the other two transects, and they tend to be greatest at the deepest stations on all transects. In the case of barium and iron, the lowest values generally occur on the De Soto Canyon transect, but for cadmium lowest values tend to be found on the Mobile transect. For iron the values are relatively high at the 100 m depth, and values at station D-3 exceed those at D-4 during both seasons. For all three metals seasonal differences tend to be quite small.

The results show that the trace metals are generally in greatest concentrations in areas of high clay and silt content and low in sandy areas. This simple pattern is complicated by other factors such as the high carbonate content of sediments near De Soto Canyon. Despite these minor variations, the concentrations of the trace metals appear to be well within the ranges of natural background levels on an unpolluted shelf.

Table 15-23. Seasonal distribution of three trace metals by station and transect. Higher values are shaded.

BARIUM

Sta.	Winter C	Winter M	Winter D	Winter X	Summer C	Summer M	Summer D	Summer X
1	274	137	42	151	248	83	49	127
2	422	75	~16	~171	475	80	21	192
3	752	172	78	334	815	215	63	364
4	873	450	188	504	780	450	153	461
$\bar{x}$	580	209	~81	~290	580	207	72	286

CADMIUM

Sta.	Winter C	Winter M	Winter D	Winter X	Summer C	Summer M	Summer D	Summer X
1	31	21	8	20	24	24	~5	~21
2	46	13	40	33	68	13	23	35
3	93	45	79	72	128	52	82	87
4	161	107	139	136	177	123	149	150
$\bar{x}$	83	47	67	65	102	53	~65	~73

IRON

Sta.	Winter C	Winter M	Winter D	Winter X	Summer C	Summer M	Summer D	Summer X
1	1.58	0.61	0.07	0.75	1.46	0.37	0.15	0.66
2	2.22	0.39	0.49	1.03	2.87	0.43	0.44	1.25
3	3.39	1.96	1.87	2.41	3.79	2.43	2.10	2.77
4	4.10	3.50	1.71	3.10	4.06	3.36	1.63	3.02
$\bar{x}$	2.82	1.62	1.04	1.82	3.05	1.65	1.08	1.93

15.3.5 Topographic Features

During the project a special study was conducted to provide high resolution geophysical data concerning the general topography and special topographic features south and southeast of Mobile Bay in the depth range of 38-330 m. The results have been presented in an atlas and are discussed in Chapter 12.0 of this report. The features were found to range from less than two to over 20 m in height. Most are patch reefs which may occur singly or in clusters, often along preferred isobaths. There are also numerous linear ridges and scarps up to eight meters in height. These appear to represent ancient shoreline ridges of sand, shell, and gravel which have become cemented together. In deeper water are found sharply peaked features called pinnacles, and these occur singly or in groups.

The arrangement of bottom reflectivities and topographic features along isobaths suggests several episodes of reef formation during pauses in the Holocene rise in sea level. The most obvious groups of features include the following:

Pinnacles - These are the deepest and apparently the oldest; ca. 105 m depth.
Patch reefs - These are at shallower depth and of intermediate age; ca. 65-75 m depth.
Ridges and scarps - These are the shallowest and youngest; ca. 60 m depth.

The general arrangement of these features is illustrated in Figure 15-9. The associated biological characteristics are discussed in a later section of this report.

15.4 The Biota

15.4.1 Phytoplankton and Primary Production

Very little work has been conducted on phytoplankton and primary production on the Mississippi-Alabama shelf, and no studies were undertaken during the present project. Historical data summarized by Vittor and Associates, Inc. (1985) provide the following picture. Both estuarine and open Gulf species are present. Estuarine forms include species of the genus *Cyclotella*, *Melosira*, and *Navicula*, whereas open Gulf forms represent species of the genera *Asterionella*, *Chaetoceros*, *Nitzschia*, *Skeletonema*, *Thalassionema*, and *Thalassiothrix*. In fresher areas maximum populations occur in the spring (January-June), and in more saline areas they appear in late spring. Diatoms comprise the bulk of the phytoplankton, although dinoflagellates also are represented.

Surface chlorophyll values tend to be highest in the winter and lowest in the fall. They range from 0.04 to 1.73 mg/m^3 and average 0.69 mg/m^3. This value is about three times that of the open Gulf but somewhat less than half that observed on the shelf west of the Mississippi River Delta. Only a

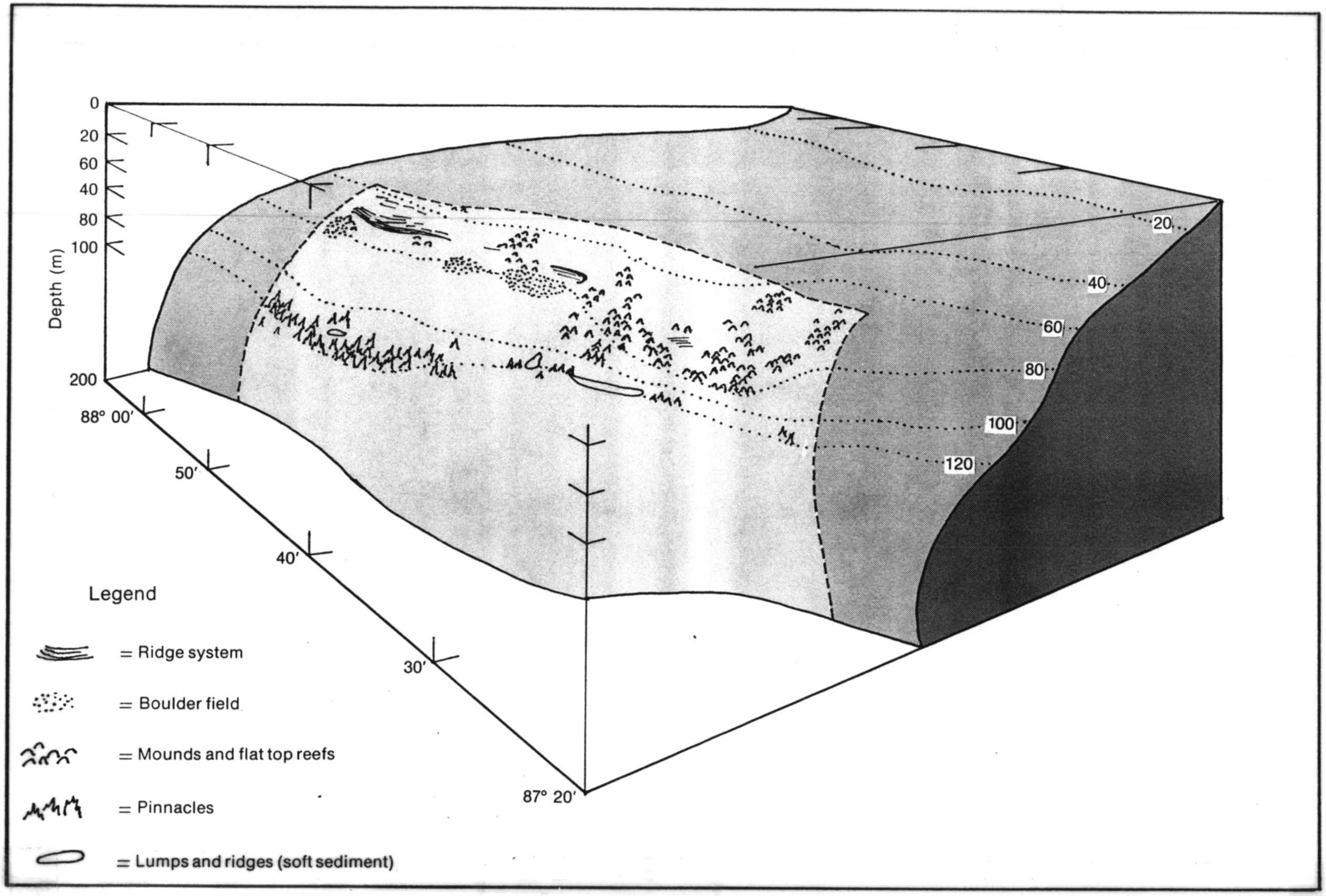


Figure 15-9. Perspective view of the central sector of the Mississippi-Alabama continental shelf showing the general distribution of different types of topographic features in the depth range of 60 - 120 m. Light shading indicates the area surveyed for topographic features.

few measurements of primary productivity have been made in the area. Carbon uptake in surface waters has been recorded as 8.1 mg $C/m^3/hr$. This is over an order of magnitude greater than average values for the open Gulf but only about a third of the average uptake rate recorded west of the Mississippi River Delta. The phytoplankton and primary production data base for the Mississippi-Alabama shelf is very thin, and for such a variable area much work remains to be done.

15.4.2 Zooplankton

As in the case of the phytoplankton, the zooplankton populations have been very poorly studied, and the subject was not addressed in the present project. Historical data summarized by Vittor and Associates, Inc. (1985) as well as studies by Franks *et al.* (1972) provide the following general information. As in the case of the phytoplankton, the zooplankton populations of the area represent a mix of estuarine and open Gulf species. Taxonomic diversity is quite high and includes eggs, larvae, juveniles, and adults of many invertebrate groups and fishes. Copepods are the dominant group in most samples, and prominent among these are the following: *Acartia tonsa* (nearshore), *Centropages furcatus, Conchoecia* sp., *Eucalanus elongatus, Oncaea* sp., *Paracalanus* sp., *Rhinocalanus coronatus*, and *Undinula vulgaris*. Seasonal changes in species composition and abundance are evident. Zooplankton volumes are highest nearshore and tend to decrease with distance from shore. Surface zooplankton volumes average 80-108 ml in waters shallower than 40 m, 67 ml at a depth of 55 m, and 36 ml at depths greater than 70 m. Zooplankton tends to be most abundant in the winter, fairly high during the summer, and least in the fall.

15.4.3 Nekton

As used here, the term nekton refers to larger free-swimming animals which, for at least a large portion of their lives, are found up in the water column and not intimately associated with the bottom. For the Mississippi-Alabama shelf area this group appears not to have been discussed in any detail in the historical literature, and it was not studied during the present project. However, the author's experience permits a brief treatment of the subject.

All evidence indicates that the Mississippi-Alabama shelf area is characterized by a diverse and abundant nektonic fauna. This includes medusae, ctenophores, cephalopods, cartilaginous and bony fishes, sea turtles, and marine mammals. A list of species known or assumed to be present in these waters is presented in Table 15-24. The bony fishes are particularly diverse, including at least 52 species representing 21 families. Some, such as the engraulids and atherinids, are limited to fairly shallow waters. Others, including the argentinids, sternoptychids, kyphosids, and some scombrids, xiphiids and istiophorids tend to be found only over deeper portions of the shelf. Many of the remaining groups range widely throughout the shelf waters. Some are estuary related, and some are basically tropical or oceanic species which inhabit this area only during the warmer months. A high degree of seasonality characterizes the nektonic fauna.

15.4.4 Macroinfauna

The macro-infauna is a very diverse group of small animals, largely invertebrates, which inhabit the surface sediments. In the present study it was found that polychaetes make up about 60% of all the specimens taken, and mollusks and crustaceans each constitute about 15%, so that together these three groups constitute about 90% of the fauna. The remaining 10% represents over a dozen different phyla (Table 15-25). Numerical dominance of the polychaetes was observed at every station.

In order to provide a precise basis for analyses, all infaunal data were normalized to standard density (number of individuals/square meter). The density of total invertebrates as well as polychaetes, mollusks, and crustaceans observed at each station during each of the five cruises is shown in Table 15-26. Total invertebrate densities ranged from a low of 38 to a high of 3,014 individuals/m^2. Exceptionally low densities occurred during cruise B-0 at the two shallowest stations on all three transects. Exceptionally high densities occurred during cruise B-2 at the shallowest and deepest stations of the Chandeleur Transect, at the shallowest station on the Mobile transect, and at the three shallowest stations on the De Soto Canyon transect. Almost all cases of exceptional density reflect major

Table 15-24. Common nektonic invertebrate and fish species known or assumed to be present in waters of the Mississippi-Alabama continental shelf. (Information from many sources.)

MEDUSAE

Aurelia aurita
Chrsaora quinquecirrha
Stomolophus meleagris

CTENOPHORES

Beroë ovata
Mnemiopsis mccradyi

CEPHALOPODS

Doryteuthis plei
Loligo pealei
Lolliguncula brevis

CARTILAGINOUS FISHES

Carcharhinidae
- Carcharhinus brevipinnis
- Carcharhinus falciformis
- Carcharhinus isodon
- Carcharhinus leucas
- Carcharhinus limbatus
- Galeocerdo cuvieri
- Mustelus canis
- Rhizoprionodon terraenovae

Sphyrnidae
- Sphyrna leweni
- Sphyrna tiburo

Myliobatidae
- Rhinoptera bonasus

Mobulidae
- Manta birostris

BONY FISHES

Elopidae
- Elops saurus
- Megalops atlanticus

Clupeidae
- Brevoortia patronus
- Etrumeus teres
- Harengula jaguana
- Opisthonema oglinum

Engraulidae
- Anchoa cubana
- Anchoa hepsetus
- Anchoa lyolepis
- Anchoa mitchilli

Argentinidae
- Argentina striata

Sternoptychidae
- Polyipnus asteroides

- Chlorophthalmus chrysurus
- Decapterus punctatus
- Hemicaranx amblyrhynchus
- Oligoplites saurus
- Selene setapinnis
- Seriola dumerili
- Seriola zonata
- Trachinotus carolinus

Coryphaenidae
- Coryphaena equisetius
- Coryphaena hippurus

Kyphosidae
- Kyphosus sectatrix

Mugilidae
- Mugil cephalus
- Mugil curema

Sphyraenidae
- Sphyraena barracuda
- Sphyraena guachancho

Table 15-24. Cont'd.

Exocoetidae	Polynemidae
Cypselurus cyanopterus	Polydactylus octonemus
Hirundichthys rondeleti	
Hyporhamphus unifasciatus	
Belonidae	Scombridae
Strongylura marina	Acanthocybium solanderi
	Euthynnus alletteratus
Atherinidae	Scomberomorus cavalla
Membras martinica	Scomberomorus maculatus
Menidia peninsulae	Thunnus albacares
	Thunnus atlanticus
Pomatomidae	
Pomatomus saltatrix	Xiphiidae
	Xiphias gladius
Rachycentridae	
Rachycentron canadum	Istiophoridae
	Istiophorus platypterus
Echeneidae	Makaira nigricans
Echeneis naucrates	Tetrapterus albidus
Carangidae	Stromateidae
Caranx crysos	Peprilus alepidotus
Caranx hippos	Peprilus burti
Caranx latus	

Table 15-25. Major groups of macro-infaunal organisms encountered in the present study.

- Protozoa
- Porifera
- Coelenterata
  - Hydrozoa
  - Anthozoa
- Platyhelminthes
- Nemertinea
- Aschelminthes
  - Nematoda
- Bryozoa
- Phoronida
- Brachiopoda
- Mollusca
  - Gastropoda
  - Bivalvia
  - Scaphopoda
  - Cephalopoda
- Sipunculida
- Echiurida
- Annelida
  - Polychaeta
  - Oligochaeta
- Arthropoda
  - Pycnogonida
  - Crustacea
    - Cirripedia
    - Copepoda
    - Ostracoda
    - Nebaliacea
    - Stomatopoda
    - Amphipoda
    - Isopeda
    - Cumacea
    - Tanaidacea
    - Mysidacea
    - Decapoda
  - Insecta
- Echincdermata
  - Holothuroidea
  - Ophiuroidea
  - Asteroidea
  - Echinoidea
- Chordata
  - Urochordata
  - Cephalochordata
  - Vertebrata
    - Osteichthys

Table 15-26. Macroinfaunal invertebrate densities (number/square meter) for each cruise and station, separated by season. Included are total invertebrates, polychaetes, mollusks, and crustaceans.

TOTAL INVERTEBRATES

Winter

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-0	155	162	199	114	571	134	316	194	63	38	292	117
B-2	3014	292	431	2505	2465	970	590	174	1421	2104	2014	194
B-4	1757	494	244	219	1767	1146	339	182	1849	354	307	234
$\bar{x}$	1642	316	291	946	1601	750	415	183	1111	832	871	182

Summer

B-1	636	284	214	160	1413	1580	436	503	2251	541	1338	105
B-3	374	337	438	144	1952	1822	372	301	1393	1303	596	264
x	505	311	326	152	1683	1701	404	402	1822	922	967	185

POLYCHAETES

Winter

B-0	117	124	155	109	486	100	235	162	48	10	215	84
B-2	2194	137	235	2455	1386	459	282	77	835	1344	1394	70
B-4	1229	272	189	182	1399	357	261	110	576	115	194	114
$\bar{x}$	1180	178	193	915	1090	305	259	116	486	490	601	89

Summer

B-1	387	214	170	105	746	596	251	384	1242	252	888	58
B-3	199	251	316	55	962	868	272	225	404	935	372	127
$\bar{x}$	293	233	243	80	854	732	262	305	823	594	630	93

MOLLUSKS

Winter

B-0	5	33	5	0	10	7	15	3	3	2	15	0
B-2	159	65	82	18	215	249	197	3	232	251	52	17
B-4	204	40	8	23	155	386	27	15	286	92	2	12
x	123	46	32	14	127	214	80	7	174	115	23	10

Table 15-26. Cont'd.

Summer

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-1	147	22	28	30	319	690	87	47	235	45	58	0
B-3	30	0	12	22	735	615	38	7	579	100	17	17
$\overline{x}$	89	11	20	26	527	653	63	27	407	73	38	9

CRUSTACEANS

Winter

B-0	20	33	18	3	25	13	18	10	2	3	10	13
B-2	586	30	58	15	267	204	32	28	155	309	346	23
B-4	241	152	30	2	115	299	32	13	516	117	82	27
$\overline{x}$	282	72	35	7	136	172	27	17	224	143	146	21

Summer

B-1	15	40	8	10	89	122	10	8	668	99	175	7
B-3	135	58	65	8	160	274	13	32	319	119	105	48
$\overline{x}$	75	49	37	9	125	198	12	20	494	109	140	28

increases in the polychaete populations. However, in several instances both mollusks and crustaceans contributed in a major way to density increases.

In order to observe patterns of distribution in relation to depth, transect, and season, the data from the different cruises were averaged by season (Table 15-27). Here it is seen that the total invertebrate density is greatest at those stations with coarse sediments (i.e., sand and shell). This pattern is also demonstrated fairly well by each of the major invertebrate groups (polychaetes, mollusks, and crustaceans). However, polychaetes also show a high density on fine sediments near the Mississippi River Delta (Station C-4), and this was due to a major increase of a single polychaete species during cruise B-2. The data do not show any clear evidence of seasonality.

Cluster analysis reveals three infaunal community types, each associated with a particular sedimentary regime. These are as follows:

Coarse bottom group - Stations C-1, M-1, D-1, M-2, D-2, and D-3;
Mixed bottom group - Stations C-2, C-3, and M-3; and
Fine bottom group - Stations C-4, M-4, and D-4.

Although the clusters varied somewhat with the seasons, the fine bottom group remained distinct throughout.

15.4.5 Macroepifauna

During the present study over 23,000 epifaunal invertebrates were taken representing about 310 recognizable species. Decapods included 43.2% of the species, mollusks 30.3%, and echinoderms 18.1%, and together these groups accounted for 91.6% of all the species identified. In terms of numbers of individuals, decapods made up 77.8%, echinoderms 9.8%, and mollusks 7.7%, and together these groups comprised 95.3% of the epifaunal individuals captured. Numerical dominance by the decapods was due primarily to the large numbers of shrimp taken.

Data for the macro-epifauna were normalized to the number of individuals/hectare to provide a precise basis for analysis. The densities of total invertebrates as well as decapods, echinoderms, and mollusks taken at each station during each of the five cruises are shown in Table 15-28 through 15-31. Higher densities were observed on cruises B-1 and B-2.

Table 15-27. Seasonal distribution of mean densities (number/square meter) of macroinfaunal invertebrates by station and transect. Higher values are shaded.

TOTAL INVERTEBRATES

Sta.	Winter				Summer			
	C	M	D	$\bar{x}$	C	M	D	$\bar{x}$
1	1642	1601	1111	1451	505	1683	1822	1337
2	316	750	832	633	311	1701	922	978
3	291	415	871	526	326	404	967	566
4	946	183	182	437	152	402	185	246
$\bar{x}$	794	737	749	762	324	1048	974	782

POLYCHAETES

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	1180	1090	486	912	293	854	823	657
2	178	305	490	324	233	732	594	520
3	193	259	601	351	243	262	630	378
4	915	116	89	373	80	305	93	159
$\bar{x}$	617	443	417	492	212	538	535	428

MOLLUSKS

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	123	127	174	141	89	527	407	341
2	46	214	115	125	11	653	73	246
3	32	80	23	45	20	63	38	40
4	14	7	10	10	26	27	9	21
$\bar{x}$	54	107	81	81	37	318	132	162

CRUSTACEANS

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	282	136	224	214	75	125	494	23
2	72	172	143	129	49	198	109	119
3	35	27	146	69	37	12	140	63
4	7	17	21	15	9	20	28	19
$\bar{x}$	99	88	134	107	43	89	193	108

Table 15-28. Total macroepifaunal invertebrate densities (number/hectare) for each cruise and station, separated by season. Data for the winter season are expressed in two ways: a) showing data for all three winter cruises separately, and b) comparing the mean densities of stations of the first two winter cruises (B-0 and B-2) with station densities of the last winter cruise (B-4).

Winter

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-0	297	152	341	308	39	208	356	---	216	107	38	456
B-2	113	38	725	2945	437	439	95	878	197	90	586	375
B-4	713	87	81	140	52	---	19	15	118	171	62	174
$\bar{x}$	374	92	382	1131	176	324	157	447	177	123	229	335

Winter (modified)

(0 + 2)/2	205	95	533	1627	238	324	226	878	207	99	312	416
B-4	713	87	81	140	52	---	19	15	118	171	62	174

Summer

B-1	963	728	1939	1136	300	376	418	429	348	192	93	49
B-3	226	1215	98	690	113	350	21	266	270	765	828	166
$\bar{x}$	595	972	1019	913	207	363	220	348	309	479	461	108

Table 15-29. Decapod densities (number/hectare) for each cruise and station, separated by season. Data for the winter season are expressed in two ways: a) showing data for all three winter cruises separately, and b) comparing the mean densities of stations of the first two winter cruises (B-0 and B-2) with station densities of the last winter cruise (B-4).

Winter

	C				M				D			
Cruise No.	1	2	3	4	1	2	3	4	1	2	3	4
B-0	201	95	319	104	32	130	327	---	151	37	6	64
B-2	91	28	671	2900	400	505	83	828	111	56	378	74
B-4	545	70	76	140	15	---	17	8	56	---	9	130
$\bar{x}$	279	64	355	1048	149	318	142	418	106	47	131	89

Winter (modified)

(0 + 2)/2	146	62	495	1502	216	318	205	828	131	47	192	69
B-4	545	70	76	140	15	---	17	8	56	---	9	130

Summer

B-1	608	408	1553	855	154	312	199	276	0	150	76	0
B-3	164	1164	59	20	84	317	9	167	100	400	426	48
$\bar{x}$	386	786	806	438	119	315	104	222	50	279	251	24

Table 15-30. Echinodern densities (number/hectare) for each cruise and station, separated by season. Data for the winter season are expressed in two ways: a) showing data for all three winter cruises separately, and b) comparing the mean densities of stations of the first two winter cruises (B-0 and B-2) with station densities of the last winter cruise (B-4).

Winter

	C				M				D			
Cruise No.	1	2	3	4	1	2	3	4	1	2	3	4
B-0	6	18	2	195	2	56	0	---	45	36	8	372
B-2	8	6	1	0	10	20	1	7	71	17	191	231
B-4	34	1	1	0	11	---	2	2	16	82	21	28
$\bar{x}$	16	8	1	65	8	38	1	5	44	45	73	210

Winter (modified)

(0 + 2)/2	7	12	2	98	6	38	1	4	58	27	100	302
B-4	34	1	1	0	11	---	2	2	16	82	21	28

Summer

B-1	174	47	354	231	16	21	30	10	187	37	12	12
B-3	1	3	1	470	12	23	2	17	104	281	194	47
$\bar{x}$	88	25	178	351	14	22	16	14	146	159	103	30

Table 15-31. Mollusk densities (number/hectare) for each cruise and station, separated by season. Data for the winter season are expressed in two ways: a) showing data for all three winter cruises separately, and b) comparing the mean densities of stations of the first two winter cruises (B-0 and B-2) with station densities of the last winter cruise (B-4).

Winter

Cruise No.	C				M				D			
	1	2	3	4	1	2	3	4	1	2	3	4
B-0	14	38	9	8	4	6	11	---	19	34	3	14
B-2	13	4	33	48	23	13	11	36	14	16	7	70
B-4	128	0	4	0	26	---	0	1	46	34	33	14
$\bar{x}$	52	14	15	16	18	10	7	19	26	28	14	33

Winter (modified)

(0 + 2)/2	14	21	21	24	14	10	11	36	17	25	5	42
B-4	128	0	4	0	26	---	0	1	46	34	33	14

Summer

B-1	144	150	8	49	128	38	171	132	161	4	3	38
B-3	46	12	37	200	11	9	11	74	67	58	183	69
$\bar{x}$	95	81	23	125	70	24	91	103	114	31	93	54

During the last cruise (B-4) total invertebrate densities were exceptionally low at the two deeper stations on all transects as well as at the shallowest station on the Mobile transect. This pattern was quite evident also for the decapods and somewhat less so for the echinoderms and mollusks. Possible reasons for this reduction are discussed later.

In order to ascertain distribution patterns in relation to depth, transect, and season the data for the different cruises within each season were averaged, and the results presented in Table 15-32. However, since data from cruise B-4 are considered to be aberrant, only cruises B-0 and B-2 are included in the winter values. The patterns for total invertebrates and decapods are quite similar. For these two groups the highest densities during the summer months occur at all depths on the Chandeleur transect, and during the winter highest densities occur at the two deeper stations on the Chandeleur transect and the deepest station on the Mobile transect. This may suggest a relationship between these groups and the Louisiana marshes during the summer and a migration to deeper water during the winter. The echinoderms show higher densities at the deepest stations and a relative avoidance of the Mobile transect. Mollusks were clearly more widespread and abundant during the summer months than during the winter, but otherwise they display no clear distributional patterns.

When viewed from the standpoint of total abundance, the epifauna does not display patterns clearly associated with sediment types. However, cluster analysis based upon species composition and abundance does reveal faunal association patterns which appear to be related to both sediment type and depth. The three groups sorted out by cluster analysis are as follows:

Group	Stations	Depth	Bottom types
1	C-1, M-1, D-1 and C-2	20-60 m	Sand, sandy mud
2	M-2, D-2 and D-3	60-100 m	Coarse sand, shell
3	C-3, M-3, C-4, M-4 and D-4	100-200 m	Very soft mud

Table 15-32. Seasonal distribution of mean densities (number/hectare) of macroinfaunal invertebrates by station and transect. Densities for the winter months are based on data from Cruises B-0 and B-2 only, since data from Cruise B-4 are considered to be aberrant. Higher values are shaded.

TOTAL INVERTEBRATES

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	205	238	207	217	595	207	309	370
2	95	324	99	173	972	363	479	605
3	533	226	312	357	1019	220	461	567
4	1627	878	416	974	913	348	108	456
$\bar{x}$	615	417	259	430	875	285	339	500

DECAPODS

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	146	216	131	164	386	119	50	185
2	62	318	47	142	786	315	279	460
3	495	205	192	297	806	104	251	387
4	1502	828	69	800	438	222	24	228
$\bar{x}$	551	392	110	351	604	190	151	315

ECHINODERMS

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	7	6	58	24	88	14	146	83
2	12	38	27	26	25	22	159	69
3	2	1	100	34	178	16	103	99
4	98	4	302	135	351	14	30	132
$\bar{x}$	30	12	122	55	161	17	110	96

MOLLUSKS

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	14	14	17	15	95	70	114	93
2	21	10	25	19	81	24	31	45
3	21	11	5	12	23	91	93	69
4	24	36	42	34	125	103	54	94
$\bar{x}$	20	18	22	20	81	72	73	75

15.4.6 Demersal Fish Fauna

15.4.6.1 Characteristics of the Total Catch

During the present study 207 fish species were identified from the trawl samples. An additional 84 species have been reported from previous trawling studies (Table 15-33) for a combined total of 291 species known to inhabit soft bottoms of the area. Inclusion of pelagic species and those which frequent rocky outcrops would bring the number to more than 350 fish species. The soft-bottom ichthyofauna clearly represents several groups including estuary related species, year around residents, seasonal transients, and occasional strays from other areas or habitats (rocky outcrops, eastern Gulf calcareous shelf, and deep Gulf and West Indian species). The following discussion will focus on those groups taken during the present study.

The Mississippi-Alabama shelf has long been noted for its high production of fishery resources, and prior studies have emphasized the prominence of estuary related species, especially fishes of the drum family (Sciaenidae). During the past two decades the shelf fish populations have been subject to heavy harvesting pressure. As shown earlier (Figure 15-3), in 1973 the biomass of bottom fishes was estimated to have been about 116 kg/ha. By 1977, it had dropped to 42 kg/ha, and by 1987 it stood around 26 kg/ha. In the present study the mean density of demersal fishes was only 6.22 kg/ha. This figure is considered to be a considerable underestimate and biased by at least three factors. The very small trawl employed in this study had a spread of only about 4 m (12 ft.) due to the use of very small trawl doors relative to the headrope length. This small trawl aperture undoubtedly permitted the escape of many larger and heavy-bodied fishes. In addition, the deeper stations (ca. 200 m) were relatively unproductive ($\bar{x}$ = 3.49 kg/ha) in relation to stations at shallower depths ($\bar{x}$ = 7.30 kg/ha) upon which most historical records are based. Finally, as will be noted below, the catch during one cruise was severely reduced, suggestive of a widespread catastrophic event, and inclusion of data from this cruise has further depressed the mean values. It is assumed that if the trawl aperture had been of standard size, if trawling had been limited to depths of 100 m or less, and if the exceptionally poor year had been omitted, the mean density estimate would probably have been two or three times the value actually obtained.

Table 15-33. List of fish species recorded from the Mississippi-Alabama continental shelf by Darnell (1985) and Darnell and Kleypas (1987) but which were not captured during the present study. Common names are given where available.

Scientific Name	Common Name
Carcharhinidae	Requiem sharks
Carcharhinus acronotus	blacknose shark
Carcharhinus limbatus	blacktip shark
Mustelus canis	smooth dogfish
Rhizoprinodon terraenovae	Atlantic sharpnose shark
Sphyrnidae	Hammerhead sharks
Sphyrna tiburo	bonnethead
Squatinidae	Angel sharks
Squatina dumerili	Atlantic angel shark
Rhinobatidae	Guitarfishes
Rhinobatos lentigenosus	Atlantic guitarfish
Torpedinidae	Electric rays
Narcine brasiliensis	lesser electric ray
Rajidae	Skates
Raja garmani	rosette skate
Dasyatidae	Stingrays
Dasyatis americana	southern stingray
Dasyatis sabina	Atlantic stingray
Dasyatis sayi	bluntnose stingray
Myliobatidae	Eagle rays
Rhinoptera bonasus	cownose ray
Anguillidae	Freshwater eels
Anguilla rostrata	American eel
Nettastomatidae	Duckbill eels
Hoplunnis diomedianus	blacktail pike-conger
Congridae	Conger eels
Eroconger syringinus	threadtail conger

Table 15-33. Cont'd.

Scientific Name	Common Name
Ophichthidae	Snake eels
Ophichthus gomesi	shrimp eel
Clupeidae	Herrings
Alosa chrysochloris	skipjack herring
Opisthonema oglinum	Atlantic thread herring
Sardinella aurita	Spanish sardine
Argentinidae	Argentines
Glossanodon pygmaeus	pygmy argentine
Myctophidae	Lanternfishes
Diaphus dumerili	
Ariidae	Sea catfishes
Bagre marinus	gafftopsail catfish
Lophiidae	Goosefishes
Lophius americanus	goosefish
Ogcocephalidae	Batfishes
Dibranchus atlanticus	offshore batfish
Ogcocephalus radiatus	polka-dot batfish
Gadidae	Codfishes
Urophycis regia	spotted hake
Macrouridae	Grenadiers
Hymenocephalus cavernosus	
Ophidiidae	Cusk-eels
Lepophidium profundorum	offshore cusk-eel
Exocoetidae	Flyingfishes
Hemirhamphus brasiliensis	ballyhoo
Caproidae	Boarfishes
Antigonia capros	deepbody boarfish
Syngnathidae	Pipefishes
Hippocampus zosterae	dwarf seahorse

Table 15-33. Cont'd.

Scientific Name	Common Name
Serranidae	Sea basses
Epinephelus niveatus	snowy grouper
Gonioplectrus hispanus	Spanish flag
Grammistidae	Soapfishes
Rypticus bistrispinus	freckled soapfish
Priacanthidae	Bigeyes
Priacanthus arenatus	bigeye
Apogonidae	Cardinalfishes
Apogon aurolineatus	bridle cardinalfish
Malacanthidae	Tilefishes
Caulolatilus microps	blueline tilefish
Pomatomidae	Bluefishes
Pomatomus saltatrix	bluefish
Rachycentridae	Cobias
Rachycentron canadum	cobia
Echeneidae	Remoras
Echeneis naucrates	sharksucker
Carangidae	Jacks
Caranx crysos	blue runner
Hemicaranx amblyrhynchus	bluntnose jack
Oligoplites saurus	leatherjacket
Selar crumenophthalmus	bigeye scad
Selene setapinnis	Atlantic moonfish
Seriola dumerili	greater amberjack
Lutjanidae	Snappers
Lutjanus synagris	lane snapper
Gerreidae	Mojarras
Diapterus plumieri	striped mojarra
Eucinostomus gula	silver jenny
Sparidae	Porgies
Calamus leucosteus	whitebone porgy
Pagrus pagrus	red porgy

Table 15-33. Cont'd.

Scientific Name	Common Name
Sciaenidae	Drums
Bairdiella chrysoura	silver perch
Cynoscion nothus	silver seatrout
Larimus fasciatus	banded drum
Pogonias cromis	black drum
Sciaenops ocellata	red drum
Stellifer lanceolatus	star drum
Mullidae	Goatfishes
Upeneus parvus	dwarf goatfish
Ephippidae	Spadefishes
Chaetodipterus faber	Atlantic spadefish
Labridae	Wrasses
Hemipteronotus novacula	pearly razorfish
Mugilidae	Mullets
Mugil cephalus	striped mullet
Sphyraenidae	Barracudas
Sphyraena guachancho	guaguanche
Uranoscopidae	Stargazers
Astroscopus y-graecum	southern stargazer
Blenniidae	Combtooth blennies
Parablennius marmoreus	seaweed blenny
Callionymidae	Dragonets
Callionymus agassizi	spotfin dragonet
Scombridae	Mackerels
Scomber japonicus	chub mackerel
Stromateidae	Butterfishes
Hyperoglyphe perciformis	barrelfish
Peprilus alepidotus	harvestfish
Scorpaenidae	Scorpionfishes
Pontinus castor	longsnout scorpionfish
Pontinus rathbuni	highfin scorpionfish

Table 15-33. Cont'd.

Scientific Name	Common Name
Triglidae	Searobins
Peristedion miniatum	armored searobin
Bothidae	Lefteye flounders
Citharichthys dinoceros	
Citharichthys gymnorhinus	anglein whiff
Monolene sessilicauda	deepwater flounder
Paralichthys lethostigma	southern flounder
Soleidae	Soles
Trinectes maculatus	hogchoker
Cynoglossidae	Tonguefishes
Symphurus pusillus	northern tonguefish
Triacanthodidae	Spikefishes
Parahollardia lineata	jambeau
Balistidae	Leatherjackets
Aluterus scriptus	scrawled filefish
Balistes capriscus	gray triggerfish
Ostraciidae	Boxfishes
Lactophrys quadricornis	scrawled cowfish
Tetraodontidae	Puffers
Sphoeroides nephelus	southern puffer
Diodontidae	Porcupinefishes
Chilomycterus schoepfi	striped burrfish

15.4.6.2 Distribution by Cruise, Station, and Season

The total fish catch broken down by cruise, station, and season has been presented in Table 8-3. Here data are given for number of species, number of individuals, and weight of the catch. The variability is fairly high as is typical of most trawl catch data. The salient feature which emerges from the table is the fact that the catch density on cruise B-4 for all stations except C-1 and C-2 is far below the average of stations from the other two winter cruises (B-0 and B-2). This phenomenon shows up in terms of numbers of species, numbers of individuals, and weight of the catch. A comparable reduction in epifaunal invertebrate catch was also observed on this cruise. Implications of this exceptional set of catch data are discussed in a later section.

Mean seasonal distribution patterns in relation to depth and transect are presented in Table 15-34. Since data from cruise B-4 are considered abnormal, the winter values are based only on data from cruises B-0 and B-2. Included in the table are information concerning the number of species, number of individuals, and weight of the catch. The number of species varied from 5 to 30. In the summer the most speciose stations included the three shallowest stations of the Chandeleur transect and the station at 100 m on the De Soto Canyon transect. In the former case there was probably some effect of the proximity of the Louisiana marshes, and in the latter case the high diversity probably reflects the variety of available habitats (sand and shell bottoms and rocky outcrops) from which the fish species could be drawn. During the winter species diversity was greatest at the three deepest stations of the Mobile transect as well as the 100 m station of the Chandeleur transect. The general reduction in diversity at the shallowest stations and increase in diversity at deeper stations during the winter suggests offshore migration to greater depths during the colder months, at least on the Chandeleur and Mobile transects.

The average density (no./ha) during the summer months was almost a third greater than during the winter months (445 vs. 345) which might be expected if many juveniles were present during the summer. Summer densities were highest at the three shallowest stations of the Chandeleur transect and at the 60 m station of the De Soto Canyon transect. At this

Table 15-34. Seasonal distribution of mean densities (number/hectare) of demersal fishes by station and transect. Densities for the winter months are based on data from Cruises B-0 and B-2 only, since data from Cruise B-4 are considered to be aberrant. Information is provided for number of species, number of individuals and total weight (kg). Higher values are shaded.

NUMBER OF SPECIES

Sta.	Winter				Summer			
	C	M	D	$\bar{x}$	C	M	D	$\bar{x}$
1	21	19	17	19	24	21	12	19
2	18	28	18	21	25	20	20	22
3	26	28	19	24	26	22	30	26
4	14	27	15	19	5	15	10	10
$\bar{x}$	20	26	17	21	20	20	18	19

NUMBER OF INDIVIDUALS

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	614	144	531	430	1546	452	136	711
2	133	425	176	245	555	314	724	531
3	686	503	241	477	558	244	415	406
4	249	254	174	226	94	157	142	131
$\bar{x}$	421	332	281	345	688	292	354	445

TOTAL WEIGHT (kg)

Sta.	Winter C	Winter M	Winter D	Winter $\bar{x}$	Summer C	Summer M	Summer D	Summer $\bar{x}$
1	6.3	3.6	5.7	5.2	14.7	7.1	3.6	8.5
2	1.8	9.9	5.0	5.6	7.1	2.8	21.1	10.3
3	14.1	14.7	5.6	11.5	11.2	7.5	9.2	9.3
4	4.6	5.9	3.8	4.8	3.0	4.5	1.2	2.9
$\bar{x}$	6.7	8.5	5.0	6.8	9.0	5.5	8.8	7.8

season the density closely paralleled diversity. However, during the winter the density distribution pattern was complex and not easily interpreted. The likely reason for this is that some of the fish species probably exist in schools during the colder months, causing catch densities to appear more patchy. On the Chandeleur and Mobile transects densities at the deeper stations increased during the winter which is again consistent with the idea of migration to greater depths at this season. Fishes on the De Soto Canyon transect could have found deep water by migrating to the Canyon itself.

The weight data show that during the summer the biomass was densest at 60 and 100 m on the De Soto Canyon transect and at 20 and 100 m on the Chandeleur transect. During the winter it was greatest at 60 and 100 m on the Mobile transect and at 100 m on the Chandeleur transect. Little importance is given to the weight data because the incidental capture of a few large individuals by the small trawl can heavily bias the results.

Data from size class analysis show that most of the demersal fish species of the Mississippi-Alabama shelf have short life histories, i.e., from one to two years (and occasionally three years). These data also suggest that in some species the spawning season is rather short, whereas in others it is more prolonged.

15.4.6.3 Residency Status of Fish Populations

It is of ecological interest to know whether the various fish populations remain as residents in a given shelf area or where there is considerable moving about. Firm information on this matter would have to come from tagging and recapture studies of individual species, but some insight may be gained from trawl catch data of the present study by simply determining where each species reached its maximum abundance during a given season. Those which reached maximum abundance in the same area during both winter and summer would be termed "year around residents," whereas those which reached maximum abundance in an area at only one season are referred to as either "summer residents" or "winter residents" in the area. This type of analysis has been conducted for the 100 most abundant species of fishes. In Table 15-35 through 15-38 the residency status is given in relation to depth, and in Tables 15-39 through 15-41 residency status is shown in relation to transect. Results of the two sets of

Table 15-35. Fish species which achieve maximum abundance at a depth of 20 m during at least one season of the year. Those species which reach maximum abundance at this depth during both winter and summer are referred to as year around residents. Those which achieve maximum abundance at this depth during only one season are called winter or summer residents. For brevity only the 100 most abundant species were considered.

Year around residents	
Harengula jaguana	Stenotomus caprinus
Anchoa hepsetus	Prionotus scitulus
Arius felis	Etropus crossotus
Diplectrum bivittatum	Etropus microstomus
Diplectrum formosum	Syacium gunteri
Chloroscombrus chrysurus	Symphurus plagiusa
Orthopristis chrysoptera	Sphoeroides parvus
Winter residents	
Raja eglanteria	Otophidium omostigmum
Anchoa cubana	Haemulon aurolineatum
Anchoa mitchilli	Lagodon rhomboides
Synodus foetens	Micropogonias undulatus
Trachinocephalus myops	Perprilus burti
Bregmaceros atlanticus	Etropus rimosus
Urophycis floridana	
Summer residents	
Gymnothorax nigromarginatus	Prionotus martis
Cynoscion arenarius	Prionotus rubio
Leiostomus xanthurus	Symphurus civitatus
Polydactylus octonemus	

Table 15-36. Fish species which achieve maximum abundance at a depth of 60 m during at least one season of the year. Designations are as given in Table 15-35.

Year around residents	
Gymnothorax saxicola	Bellator militaris
Saurida brasiliensis	Prionotus longispinosus
Synodus poeyi	Prionotus roseus
Ogcocephalus parvus	Engyophrys senta
Lepophidium jeannae	Syacium papillosum
Centropristis ocyurus	Symphurus parvus
Bollmannia communis	Symphurus pelicanus
Scorpaena calcarata	
Winter residents	
Synodus intermedius	Equetus umbrosus
Antennarius radiosus	Prionotus martis
Summer residents	
Raja eglanteria	Centropristis philadelphica
Hildebrandia flava	Serranus phoebe
Synodus foetens	Haemulon aurolineatum
Trachinocephalus myops	Prionotus stearnsi
Porichthys plectrodon	Etropus rimosus
Bregmaceros atlanticus	Paralichthys squamilentus
Lepophidium graellsi	Gymnachirus texae
Otophidium omostigmum	Symphurus diomedianus

Table 15-37. Fish species which achieve maximum abundance at a depth of 100 m during at least one season of the year. Designations are as given in Table 15-35.

Year around residents	
Hoplunnis macrurus	Serranus notospilus
Hoplunnis tenuis	Pristipomoides aquilonaris
Halieutichthys aculeatus	Scorpaena agassizi
Ogcocephalus corniger	Scorpaena brasiliensis
Ogcocephalus declivirostris	Peristedion gracile
Physiculus fulvus	Prionotus alatus
Ogcocephalus nasutus	Prionotus paralatus
Brotula barbata	Ancylopsetta dilecta
Serraniculus pumilio	Citharichthys cornutus
Serranus atrobranchus	Trichopsetta ventralis
Winter residents	
Gymnothorax nigromarginatus	Leiostomus xanthurus
Hildebrandia falva	Prionotus rubio
Porichthys plectrodon	Prionotus stearnsi
Synagrops bellus	Paralichthys squamilentus
Centropristis philadelphica	Gymnachirus texae
Cynoscion arenarius	Symphurus diomedianus
Summer residents	
Antennarius radiosus	Trachurus lathami
Steindachneria argentea	Lagodon rhomboides
Urophycis floridana	Equetus umbrosus
Bathygadus macrops	Micropogonias undulatus
Neobythites gillii	Peprilus burti
Synagrops spinosa	Pontinus longispinis

Table 15-38. Fish species which achieve maximum abundance at a depth of 200 m during at least one season of the year. Designations are as in Table 15-35.

Year around residents	
Zalieutes mcgintyi	Pikea mexicana
Urophycis cirrata	Bembrops anatirostris
Bathygadus melanobranchus	Monolene sp.
Coelorinchus caribbaeus	Poecilopsetta beani
Macrorhamphosus scolopax	
Winter residents	
Polyipnus asteroides	Macrorhamphosus gracilis
Bathygadus macrops	Synagrops spinosa
Lepophidium graellsi	Pontinus longispinis
Neobythites gillii	Symphurus civitatus
Summer residents	
Synagrops bellus	

Table 15-39. Fish species which achieve maximum abundance on the Chandeleur transect during at least one season of the year. Those species which reach maximum abundance on this transect during both winter and summer are referred to as year around residents. Those which achieve maximum abundance on this transect during only one season are called winter or summer residents. For brevity, only the hundred most abundant species were considered.

Year around residents	
Hildebrandia flava	Bollmannia communis
Harengula jaguana	Pontinus longispinis
Anchoa hepsetus	Prionotus rubio
Synodus foetens	Ancylopsetta dilecta
Antennarius radiosus	Engyophrys senta
Halieutichthys aculeatus	Etropus crossotus
Ogcocephalus declivirostris	Syacium gunteri
Bregmaceros atlanticus	Trichopsetta ventralis
Bathygadus macrops	Gymnachirus texae
Bathygadus melanobranchus	Symphurus civitatus
Brotula barbata	Symphurus diomedianus
Synagrops bellus	Symphurus pelicanus
Centropristis philadelphica	Symphurus plagiusa
Serranus atrobranchus	
Winter residents	
Hoplunnis macrurus	Orthopristis chrysoptera
Anchoa mitchilli	Lagodon rhomboides
Saurida brasiliensis	Peprilus burti
Coelorinchus caribbaeus	Etropus rimosus
Neobythites sp.	Monolene sp.
Chloroscombrus chrysurus	Sphoeroides parvus
Summer residents	
Ogcocephalus nastus	Stenotomus caprinus
Physiculus fulvus	Cynoscion arenarius
Steindachneria argentea	Leiostomus xanthurus
Urophycis cirrata	Polydactylus octonemus
Lepophidium graellsi	Prionotus paralatus
Synagrops spinosa	Paralichthys squamilentus
Diplectrum bivittatum	

Table 15-40. Fish species which achieve maximum abundance on the Mobile transect during at least one season of the year. Designations are as in Table 15-39.

Year around residents	
Hoplunnis tenuis	Peristedion gracile
Porichthys plectrodon	Prionotus stearnsi
Micropogonias undulatus	Symphurus parvus
Winter residents	
Gymnothorax saxicola	Equetus umbrosus
Ogcocephalus corniger	Leiostomus xanthurus
Ogcocephalus nasutus	Scorpaena calcarata
Physiculus fulvus	Bellator militaris
Urophycis cirrata	Prionotus alatus
Lepophidium jeannae	Prionotus longispinosus
Synagrops spinosa	Prionotus paralatus
Pikea mexicana	Citharichthys cornutus
Haemulon aurolineatum	Etropus microstomus
Stenotomus caprinus	Paralichthys squamilentus
Cynoscion arenarius	
Summer residents	
Saurida brasiliensis	Lagodon rhomboides
Zalieutes mcgintyi	Bembrops anatirostris
Coelorinchus caribbaeus	Peprilus burti
Neobythites gillii	Prionotus scitulus
Chloroscombrus chrysurus	Etropus rimosus
Trachurus lathami	Monolene sp.
Pristipomoides aquilonaris	Sphoeroides parvus
Orthopristis chrysoptera	

Table 15-41. Fish species which achieve maximum abundance on the De Soto Canyon transect during at least one season of the year. Designations are as in Table 15-39.

Year around residents	
Raja eglanteria	Diplectrum formosum
Gymnothorax nigromarginatus	Serraniculus pumilio
Synodus poeyi	Serranus notospilus
Trachinocephalus myops	Scorpaena agassizi
Arius felis	Scorpaena brasiliensis
Ogcocephalus parvus	Prionotus martis
Urophycis floridana	Prionotus roseus
Otophidium omostigmum	Syacium papillosum
Macrorhamphosus scolopax	Poecilopsetta beani
Centropristis ocyurus	
Winter residents	
Anchoa cubana	Macrorhamphosus gracilis
Polyipnus asteroides	Diplectrum bivittatum
Synodus intermedius	Pristipomoides aquilonaris
Zalieutes macgintyi	Bembrops anatirostris
Lepophidium graellsi	Prionotus scitulus
Neobythites gillii	
Summer residents	
Gymnothorax saxicola	Equetus umbrosus
Hoplunnis macrurus	Scorpaena calcarata
Ogcocephalus corniger	Bellator militaris
Lepophidium jeannae	Prionotus alatus
Pikea mexicana	Prionotus longispinosus
Serranus phoebe	Citharichthys cornutus
Haemulon aurolineatum	Etropus microstomus

analyses are given in Table 15-42. The accumulated information demonstrates how evenly the various species populations have spread out and occupied the various areas of the continental shelf, and it also reveals the seasonal mobility of the various fish species. In summary, the data show that about 45% of the species are year around residents at a given depth, and the remainder change depth with the seasons. The data also indicate that about 37% are residents on a given transect, and the rest change transects with the seasons. Thus, over half of the species appear to move around on a seasonal basis. Details of which species are residents and which are migrators are shown in the various tables.

15.4.6.4 Ichthyofaunal Associations

Fish population assemblages were examined by cluster analysis and by the use of similarity coefficients. In both cases there were real seasonal differences, undoubtedly resulting from population movements discussed above. Cluster analysis revealed two major depth-related assemblages, each with sub-groups. The first included all stations in the 20 and 60 m depth ranges as well as station D-3 in the 100 m depth range (i.e., stations C-1, M-1, D-1, C-2, M-2, D-2 and D-3). The second major assemblage included all stations in the depth range 100 and 200 m except station D-3 (i.e., stations C-3, M-3, C-4, M-4 and D-4). Within the first assemblage two sub-groups were evident, the first including stations C-1, M-1, D-1 and C-2; and the second including stations M-2, D-2 and D-3. Within the second assemblage the two sub-groups included C-3 and M-3; and C-4, M-4 and D-4. Stations C-1 and C-2 clustered very close together, and stations D-1 and D-4 were only weakly clustered within their respective groups.

Similarity coefficients between every pair of stations are presented in Table 15-43. In this table the higher the coefficient the greater the degree of similarity. The most relevant information is the similarity of a given station with its immediate neighbors, and this information is given by season in Figure 15-10. Seasonal differences are quite evident, but on the average stations C-1, M-1, C-2, M-2, D-2, C-3 and M-3 are all related at the 0.200 level or above. Within this group the strongest relationships (>0.250) exist between stations C-2, M-2, C-3 and M-3, and this relationship prevails during both summer and winter. The three deepest stations are also related

Table 15-42. Residency status of fish species at each depth and on each transect in relation to seasons of residence. Data are presented in terms of both number and percentage. Several species appeared in the collections during only one season. Only the one hundred most abundant species were considered.

Number of species which reach maximum abundance at a given depth.

Residency Status	Depth				Total
	20m	60m	100m	200m	
Year around	14	15	20	9	58
Winter Only	13	4	12	8	37
Summer Only	7	16	12	1	36
Total	34	35	44	18	

Percentage of species which reach maximum abundance at a given depth.

Residency Status	Depth				Total
	20m	60m	100m	200m	
Year around	41.2	42.9	45.5	50.0	44.9
Winter Only	38.2	11.4	27.3	44.4	30.3
Summer Only	20.6	45.7	27.3	5.6	24.8

Number of species which reach maximum abundance on a given transect.

Residency Status	Transect			Total
	C	M	D	
Year around	27	6	19	52
Winter Only	12	21	11	44
Summer Only	13	15	14	42
Total	52	47	44	

Percentage of species which reach maximum abundance on a given transect.

Residency Status	Transect			Total
	C	M	D	
Year around	51.9	14.3	43.2	36.5
Winter Only	23.1	50.0	25.0	32.7
Summer Only	25.0	35.7	31.8	30.8

Table 15-43. Bray-Curtis similarity coefficients, based upon species composition and abundances of demersal fishes, showing the similarity of each collecting station with every other station. Coefficients for the mean winter collections are given in the upper right half of the table and coefficients for the mean summer collections are given in the lower left half.

	C1	C2	C3	C4	M1	M2	M3	M4	D1	D2	D3	D4
C1	1.000	0.188	0.091	0.020	0.175	0.171	0.143	0.045	0.191	0.066	0.090	0.023
C2	0.172	1.000	0.222	0.030	0.226	0.305	0.261	0.107	0.088	0.143	0.212	0.027
C3	0.157	0.225	1.000	0.086	0.065	0.197	0.359	0.144	0.026	0.038	0.084	0.067
C4	0.003	0.010	0.205	1.000	0.021	0.021	0.139	0.439	0.003	0.006	0.020	0.330
M1	0.271	0.245	0.040	0.002	1.000	0.125	0.103	0.031	0.139	0.085	0.053	0.011
M2	0.071	0.203	0.130	0.015	0.199	1.000	0.274	0.033	0.190	0.243	0.182	0.010
M3	0.080	0.273	0.303	0.089	0.130	0.240	1.000	0.198	0.069	0.053	0.134	0.104
M4	0.010	0.053	0.128	0.275	0.013	0.057	0.170	1.000	0.004	0.018	0.064	0.299
D1	0.031	0.046	0.013	0.000	0.172	0.118	0.029	0.016	1.000	0.096	0.057	0.024
D2	0.094	0.055	0.113	0.000	0.125	0.193	0.115	0.012	0.069	1.000	0.213	0.006
D3	0.037	0.102	0.095	0.032	0.032	0.130	0.139	0.063	0.036	0.163	1.000	0.068
D4	0.001	0.014	0.034	0.103	0.007	0.021	0.076	0.180	0.000	0.002	0.030	1.000

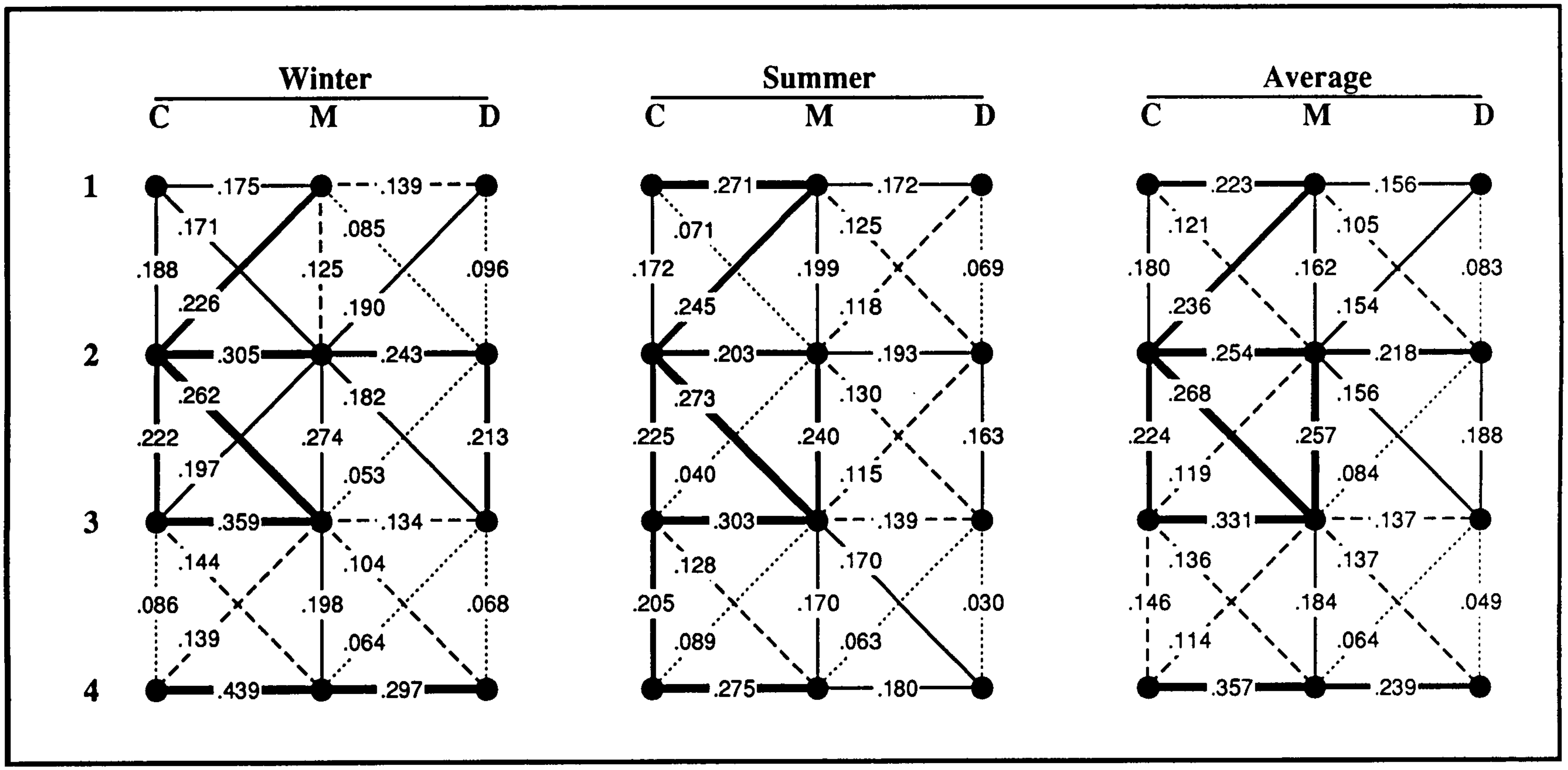


Figure 15-10. Diagrammatic representation of the Mississippi-Alabama shelf showing the similarity coefficients between each station and its nearest neighbors. Data are presented separately for winter, summer, and the winter-summer average.
(▬▬ ≥.250, ▬▬ .200 - .249, —— .150 - .199, ----- .100 - .149, ········ ≤.099).

at the 0.200 level, and within this group stations C-4 and M-4 are associated at a level above 0.350. Station D-3 shows a fair association with D-2 during the winter but not in the summer, and station D-1 is not closely associated with any other station at either season. On the basis of the above information the following conclusions are reached.

- A faunal association exists between stations C-1, M-1, C-2, M-2, C-3 and M-3.
- Another association exists between stations C-4, M-4 and D-4
- Station D-2 is associated with M-2 and D-3 in the winter only
- Station D-1 is not closely associated with any other station.

In general, this analysis points to the similarity of stations on the Chandeleur and Mobile transects and the uniqueness of stations on the De Soto Canyon transect.

15.4.6.5 Decline in Estuary Related Species

Noting the major decline in estimated density of demersal fishes during recent years (Figure 15-3), it is important to question whether this is due solely to intensive trawling on the continental shelf or whether reduction in the quantity and quality of estuarine habitat is also a contributing factor. Data from the present study shed much light on this question when compared with historical data from pre-1980 trawl surveys of the area [as reported in the Tuscaloosa Trend Report (Darnell 1985)]. In the earlier study the Atlantic croaker was numerically the second most abundant species (16.1%), the spot was fifth (3.0%), and the sand seatrout was thirteenth (1.5%). Together these three species made up 20.6% of the total catch. Additional estuary related sciaenids brought the total to 21.7% of the catch. In the present study the Atlantic croaker ranked fiftieth, the spot sixtieth, and the sand seatrout, sixty first. Together these three species accounted for only 1.3% of the total catch, and additional estuary related sciaenids brought the total up to only 1.4% of the catch. Although there has been a decline in the density of the total fish population of the continental shelf, there has been a very significant relative reduction in the estuary related sciaenids.

It can be argued that these sciaenids were selectively reduced because of their greater vulnerability to capture by bottom trawls. Hence, it is revealing to compare the relative rankings of the sciaenids with an abundant non-estuary related species which is also quite vulnerable to capture by trawls, i.e., the longspine porgy (*Stenotomus caprinus*). In the earlier study the estuary related sciaenids were 1.1 times as abundant as the longspine porgy, whereas in the present study their abundance was only 15.2% of that of the longspine porgy. Therefore, the selective reduction of the sciaenids cannot be due to their special vulnerability to bottom trawls, and it must be concluded that destruction of critical estuarine habitat has played a major role in the decline of these important species. These conclusions are further borne out by data provided in Table 15-44. Here the catches from the studies are compared on the basis of carefully paired samples.

Table 15-44. Comparison of the Tuscaloosa Trend and present data bases in terms of the catch density (number/hectare) of the estuary dependent sciaenid fishes. In the comparison the following species were involved: *Cynoscion arenarius*, *Larimus fasciatus*, *Leiostomus xanthurus*, *Menticirrhus americanus*, *Micropogonias undulatus*, *Pogonias cromis*, and *Stellifer lanceolatus*. For the Tuscaloosa Trend data base, stations were assigned as follows: 15-25 m = 20 m, 55-65 m = 60 m, and 90-100 m = 100 m.

	Winter			Summer		
	20 m	60 m	100 m	20 m	60 m	100 m
Tuscaloosa Trend	31.0	81.5	88.0	3.5	10.0	2.4
Present Study	5.1	1.4	12.3	4.6	0.2	3.0
Present as decimal of T.T.	0.16	0.02	0.14	1.31	0.02	1.25

15.5 Demersal Fish Food Analysis

One of the tasks of the present study was to investigate food habits of the demersal fish populations. Fishes are efficient samplers of the living and non-living organic materials within the system, and for the most part, their food materials can be identified. Thus, they provide a unique insight into the pathways by which nutrients and energy actually move through the ecological system. Specific goals of this task include the following:

- To determine the food habits of enough species (and size classes) to provide a reasonable picture of the overall trophic structure of the continental shelf ecosystem; and

- To provide information on trends, gradients, and local variations in food utilization patterns.

A total of 4,675 specimens of fishes was analyzed, and this number represented 28.9% of all the specimens captured. Forty-nine different species were examined, and these species together accounted for 78% of all the specimens taken. All of the top 25 species were examined except *Prionotus paralatus* about which there was some taxonomic question (i.e., is this species synonomous with *P. alatus*). Thus, the resulting information should provide a highly representative record of what is consumed by the demersal fish community. The food habits of individual species have been discussed in the fish food chapter, and the present discussion will focus upon broader, community-related results.

15.5.1 Food Group Utilization

Considering all the food of all the species examined, about 23% of the material was unidentifiable animal material. This appeared to consist largely of the flesh of polychaetes, shrimp, and fishes. Of the identifiable material crustaceans accounted for about 62%, fishes 19%, and polychaetes 17%, and together these three groups made up around 98% of the identifiable food items. Among the crustaceans about 7% of the material could not be ascribed to a particular group. Of the identifiable crustaceans shrimp made up about 63%, crabs 11%, and amphipods 10% for a combined total of 84% of the identifiable crustacean food. In the fish stomachs examined, the three most important items were shrimp 36%, fishes 19%, and polychaetes 17% for a total of 72% of the identifiable food. A great many other food items, belonging to a variety of taxonomic groups were encountered, but individually these represented very small percentages of the total food consumed.

The fish food may also be examined from the standpoint of ecological rather than taxonomic groupings. Of the identifiable food materials zooplankton constituted 2%, small benthic animals 9%, larger benthic infauna 18%, larger mobile animals (cephalopods, shrimp, crabs, and fishes) 70%, and organic detritus only 2%. Clearly the larger mobile fauna dominated the food of the demersal fishes, and this food was taken well up in the water column (supra-benthic environment) as well as on the bottom.

15.5.2 Food Utilization in Relation to Depth, Transect, and Station

Observed food distribution patterns in relation to depth and transect were tested for statistical significance by the Chi-Square method. Zooplankton, small benthic crustaceans, and small cephalopods were all consumed most heavily at the shallowest stations, and their consumption tapered off with depth. Fishes were consumed least at the shallowest stations but about equally at all other depths. Benthic microcrustaceans were eaten heavily at 20 and 100 m but lightly at 60 and 200 m. All the other groups tested (polychaetes, crustaceans in general, and larger mobile crustacean species) showed no significant deviations from the pattern of uniform consumption at all depths.

Transect patterns also produced interesting results. Fishes were consumed most heavily on the Chandeleur transect, zooplankton on the Mobile transect, and benthic micro-crustaceans on the De Soto Canyon transect. All other groups tested (cephalopods, polychaetes, crustaceans in general, small benthic crustaceans and larger mobile crustacean species) showed consumption patterns which were essentially uniform with respect to transect.

Further information derives from examination of those stations where maximum consumption of particular food items occurred. In the following list a given food item is followed by a number which represents the minimum percentage of this item in the food of fishes taken at the stations indicated.

- Polychaetes (30%); C-4 and M-4
- Calanoid copepods (14%); M-1
- Amphipods (10%); C-1 and D-1
- Shrimp (47%); C-3, D-2, D-3, D-4 (Note: The minimum percentage of shrimp at any station was 22%)
- Crabs (11%); C-3 and M-4

- Stomatopods (10%); C-2 and M-3
- Fishes (20%); C-2, C-3, M-2, D-4
- Organic detritus (2.8%); C-1, C-4, M-3, M-4, D-1

Thus, calanoid copepods and amphipods were consumed in abundance only at certain very shallow stations. Shrimp, although consumed heavily everywhere, were particularly prominent in the food at C-3 and the three deeper stations of the De Soto Canyon transect. Crabs achieved some importance at two deepwater stations. Stomatopods were taken most heavily at mid-depths. Fishes were most prominent at mid-depth and also at the deepest station on the De Soto Canyon transect. Although nowhere important, organic detritus was taken at two shallow and three fairly deep stations. These complex feeding patterns result from the availability of food items and availability of particular species and size classes coinciding at the same time and same station. However, it is almost axiomatic in shallow aquatic systems that if a food resource is available in reasonable supply there will be consumer species available to take advantage of the supply, and this results, in part, from long-term co-evolution of species within the system. Therefore, the patterns shown above are interpreted as representing primarily the places where particular food supplies are most available to the consumer species.

15.5.3 Station Grouping on the Basis of Fish Food Consumption

Cluster analysis, which was employed to determine species assemblages for the infauna, epifauna and demersal fishes, cannot be applied to the fish food data. However, principal components analysis is appropriate for such data, and it produces the same general types of results. Application of this technique to determine closeness of stations based upon similarity of food consumption patterns has revealed the following groups.

Group 1 - All stations on the Chandeleur and Mobile transects except C-3. Within this group C-1 and M-1 were somewhat distinct and distant from the remaining five stations.

Group 2 - Stations D-3 and D-4. Station C-3 clustered with this group due, in part, to the fact that large quantities of shrimp were consumed at all these stations, as noted above., However, since C-3 is geographically isolated from the other two stations it is considered to be a separate group.

Group 3 - Station D-1

Group 4 - Station D-2

Group 5 - Station C-3 (for reasons noted above)

15.5.4 Trophic Spectrum

A trophic spectrum analysis of the demersal fish community has been conducted. However, since results of this analysis relate intimately to the structure of the ecosystem as a whole, presentation and discussion of the trophic spectrum are deferred to the Ecosystem Synthesis section of this chapter.

15.6 Biota of Hard Bottoms and Topographic High Features

On the Mississippi-Alabama continental shelf rocky outcrops occur at depths of around 20 m off Mobile Bay, at various depths around the head of De Soto Canyon, and along most of the shelf at depths of 50-100 m. These features vary in size, composition, and vertical relief, some reaching a height of at least 20 m. They may occur singly, in groups or ridges, or in vast fields of individual outcrops. These features have been variously described as ragged bottoms, boulder fields, flat-top reefs, and pinnacles. Since they provide hard substrate for the attachment of sessile organisms, they support "live bottom" communities of especial interest. Attention is here focused on the biota of the live bottom communities in the depth range of 50-100 m.

It has been determined that biological abundance and species diversity increase in relation to the amount of solid substrate exposed and to the variety of habitats available. Thus, low relief features (<2 m high) are characterized by low biological abundance and diversity. Features of intermediate relief (2-6 m high) may exhibit low or high abundance and diversity depending upon habitat complexity. High relief features (>6 m) have dense and diverse biotas whose composition varies with habitat type (i.e., flat reef tops vs. ragged reef sides). Depth in the water column appears not to play a major role in determining species composition except in the case of coralline algae, which have not been encountered below a depth of 78 m. Since most of the major species are suspension feeders, susceptibility to sedimentation does appear to limit species composition. Areas closest to the Mississippi River Delta are most affected, and this influence extends eastward for up to 115 km (70 miles) from the Delta. Living hermatypic corals have not been observed on topographic features of the Mississippi-Alabama shelf.

The characteristic biotas of the different types of topographic features are detailed in Table 15-45. For each community type the biota potentially consists of coralline algae, attached invertebrates, mobile invertebrates, and the fish fauna. The latter includes species which swim or hover in the water column above the reef as well as those which live on the substrate or inhabit crevices. Large bacterial colonies are associated with gas and brine seeps over a salt dome. As an aid in the visualization of the distribution of biota on the larger features, based upon the best available information, sketches have been made of submerged landscapes showing flat-top reefs (Figure 15-11) and deepwater pinnacles (Figure 15-12).

The definitely identified reef fish fauna includes a total of 70 species. Of this number, exactly half have been taken by bottom trawls and are listed as soft bottom species (Table 15-46). The remaining 35 species appear to be unique to the rocky and topographic high habitats (Table 15-47). These include cryptic and hovering reef-related species, larger predatory forms of the open water column, and strays from other areas and habitats.

In the absence of edible vegetation, consumer species of the hard bottom communities are trophically dependent upon imported organic material. Suspension feeders, which strain small particles from the near-bottom water currents, constitute the dominant feeding group, and these include the sponges, antipatharians, gorgonians, ahermatypic corals, bryozoans, and comatulid crinoids, among others. Some deposit feeders (sand dollars and heart urchins) and scavengers (sea urchins) also are present. The fish community includes zooplankton feeders, infaunal grazers, browsers, and predators.

The invertebrate and fish faunas of the topographic features of the Mississippi-Alabama continental shelf bear a clear relationship with the faunas of other topographic features of the northwestern and eastern Gulf of Mexico as well as with those of the outer shelf reefs off the south Atlantic coast. These communities are considered to be highly sensitive to human

Table 15-45. Characteristic biota of the different types of topographic features of the Mississippi-Alabama continental shelf.

Low topographic features (<2 m high)

Invertebrates - Ellisellid sea whips, antipatharians, and comatulid crinoids plus occasional mollusks, crabs, and echinoids.

Fishes - short bigeyes, yellow reeffishes, bank butterflyfishes, bank sea basses, and tattlers.

Features of intermediate size and complexity (2-6 m high)

Algae - Occasional coralline algae (above a depth of 78 m).

Invertebrates - Encrusting and upright sponges, octocorals, ahermatypic corals, and antipatharians.

Fishes - Roughtongue basses, bank sea basses, tattlers, wrasse basses, and occasional vermilion snappers, butterflyfishes, scads, drums, short bigeyes, groupers, and jacks.

Largest features (6-10 m High)
A. Reef flats (tops of flat top reefs)

Algae - Some coralline algae (above a depth of 78 m).

Invertebrates - Abundant upright sponges, gorgonians (especially sea fans), antipatharians, and comatulid crinoids. Some ahermatypic corals, bryozoans, and basket stars.

Fishes - Large schools of small sea basses and snappers, including roughtongue basses, streamer basses, vermilion snappers, and others.

B. Near vertical walls (including pinnacles)

Invertebrates - Abundant ahermatypic corals, solitary and colonial scleractinians, and comatulid crinoids. Some gorgonians, oyster clumps, sea urchins, and basket stars. Sponges and gorgonians very rare.

Fishes - Dense schools of small sea basses and snappers, particularly around the summit, including roughtongue basses, creole-fishes, vermilion snappers and others. Some scorpionfishes.

Salt dome (natural gas and brine seeps)

Bacterial colonies.

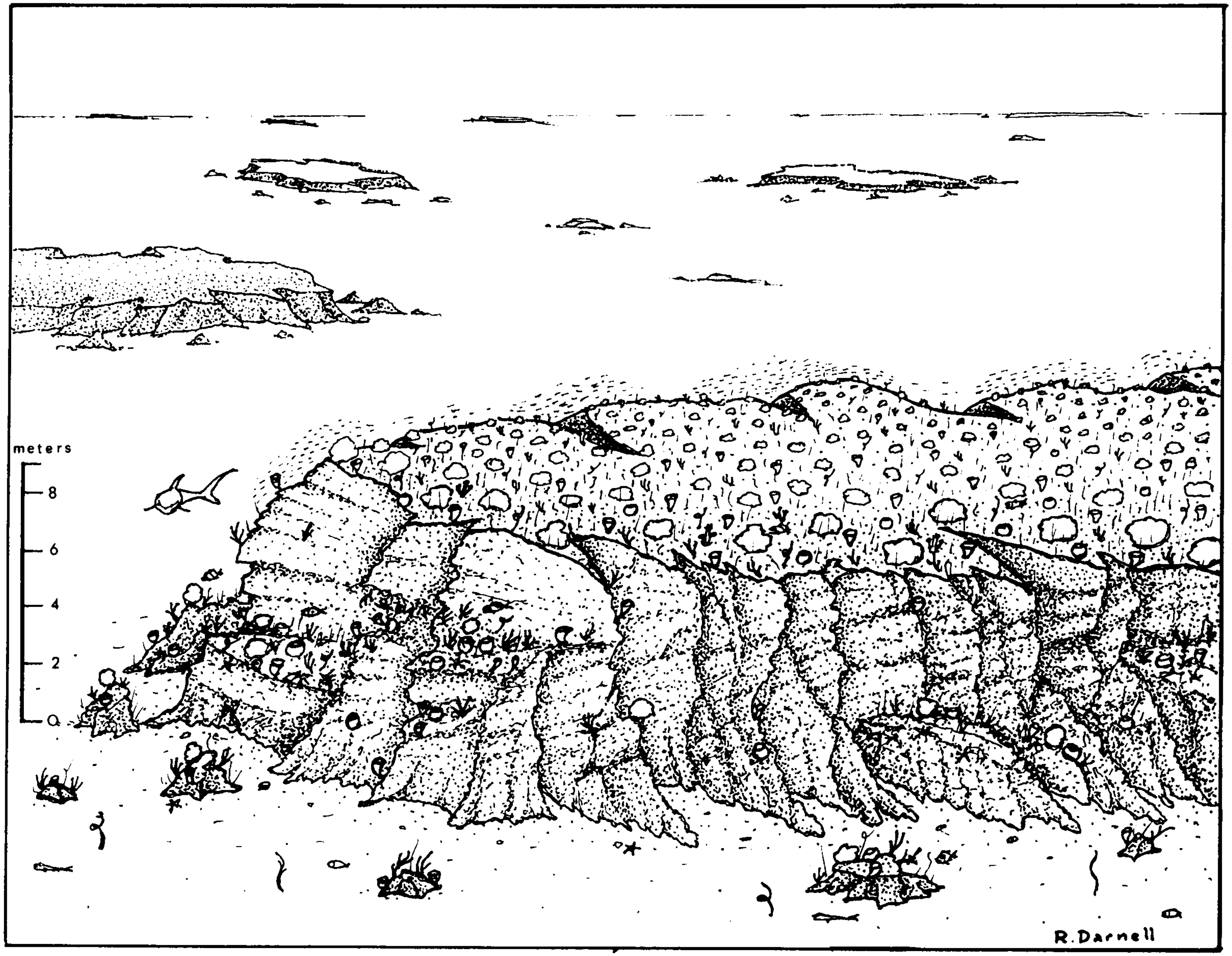


Figure 15-11. Perspective sketch of the submerged landscape of a flat-top reef province as visualized from side-scan sonar and ROV information. The biota are identified in the accompanying legend.

Legend for Figure 15-11 **and Figure 15-12.**

Invertebrates

basket sponge

vase sponge

tube sponge

sea whips (gorgonians)

antipatharian (*Cirrhipathes*)

branched gorgonian

sea fan

white bushy coral (*Madrepora, Oculina*)

black coral (*Rhizopsammia*)

soft coral

crinoid

starfish

Fishes

sea basses and snappers

short bigeye

bank butterflyfish

scorpion fish

lizardfish

flatfish

school of small serranids

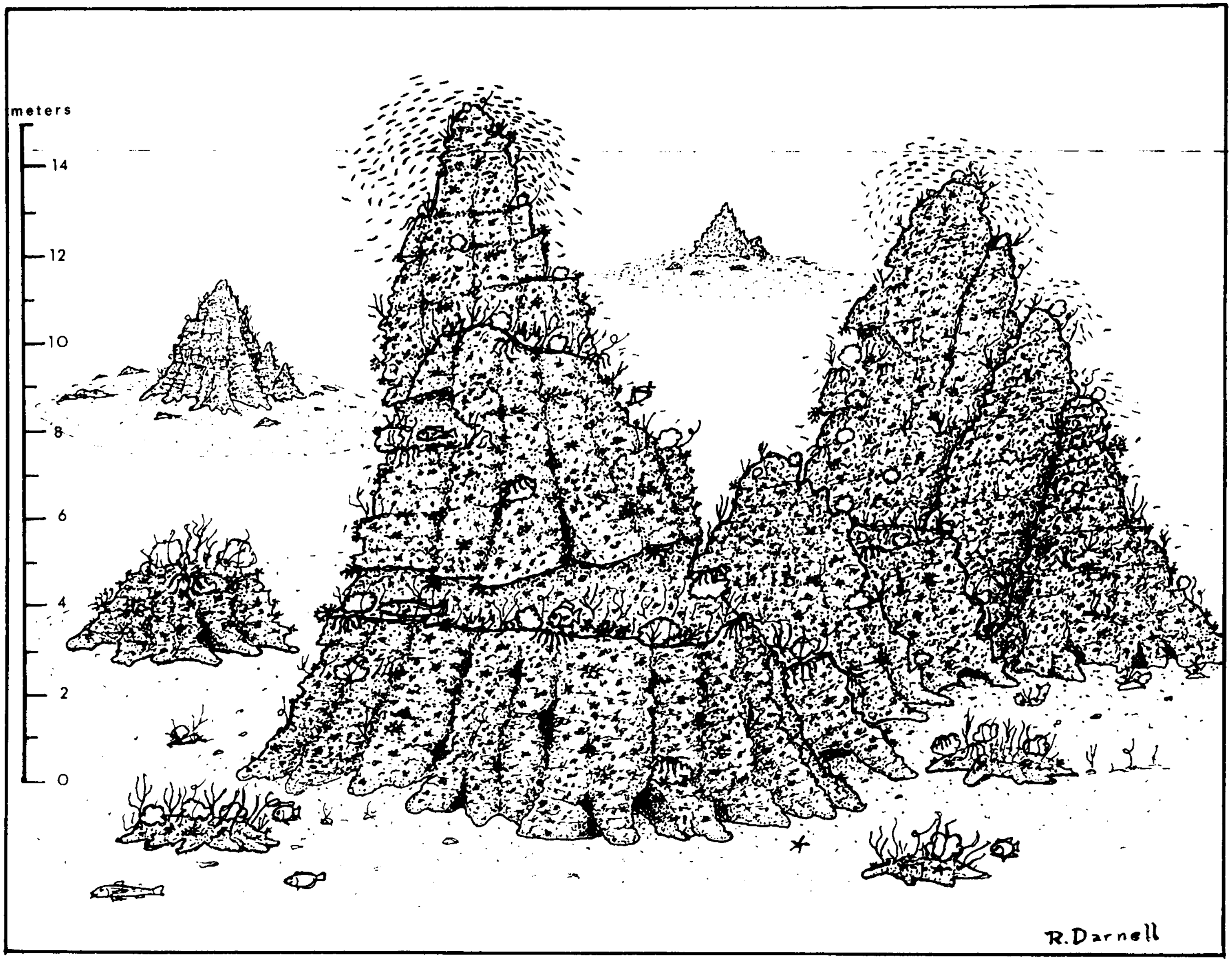


Figure 15-12. Perspective sketch of the submerged landscape of a pinnacle province as visualized from side-scan sonar and ROV information. The biota are identified in the legend accompanying Figure 15-11.

Table 15-46. Fish species recorded from the rocky outcrops which have also been recorded from soft bottoms of the Mississippi-Alabama continental shelf. Species recorded from trawl collections in the present study are indicated by an asterisk (*).

Scientific Name	Common Name
Muraenidae	Morays
Gymnothorax ocellatus*	ocellated moray
Nettastomatidae	Duckbill eels
Hoplunnis macrurus*	freckled pike-conger
Ophichthidae	Snake eels
Ophichthus ocellatus*	palespotted eel
Synodontidae	Lizard fishes
Synodus intermedius*	sand diver
Antenariidae	Frogfishes
Antennarius ocellatus*	singlespot frogfish
Ogcocephalidae	Batfishes
Ogcocephalus corniger*	
Ogcocephalus nasutus*	
Gadidae	Codfishes
Urophycis floridana*	southern hake
Ophidiidae	Cusk-eels
Lepophidium jeannae*	mottled cusk-eel
Serranidae	Sea basses
Centropristis ocyurus*	bank sea bass
Diplectrum bivittatum*	dwarf sand perch
Hemanthias aureorubens*	streamer bass
Liopropoma eukrines*	wrasse bass
Serranus phoebe*	tattler
Priacanthidae	Bigeyes
Priacanthus arenatus	bigeye
Pristigenys alta*	short bigeye
Apogonidae	Cardinalfishes
Apogon pseudomaculatus*	twospot cardinalfish
Pomatomidae	Bluefishes
Pomatomus saltatrix	bluefish

Table 15-46. Cont'd.

Scientific Name	Common Name
Rachycentridae	Cobias
Rachycentron canadum	cobia
Carangidae	Jacks
Caranx crysos	blue runner
Seriola dumerili	greater amberjack
Lutjanidae	Snappers
Lutjanus campechanus*	red snapper
Pristipomoides aquilonaris*	wenchman
Rhomboplites aurorubens*	vermilion snapper
Sparidae	Porgies
Stenotomus caprinus*	longspine porgy
Sciaenidae	Drums
Equetus umbrosus*	cubbyu
Micropogonias undulatus*	Atlantic croaker
Chaetodontidae	Butterflyfishes
Chaetodon aya*	bank butterflyfish
Trichiuridae	Cutlassfishes
Trichiurus lepturus*	Atlantic cutlassfish
Scombridae	Mackerels
Scomberomorus cavalla*	king mackerel
Stromateidae	Butterfishes
Peprilus burti*	gulf butterfish
Balistidae	Leatherjackets
Balistes capriscus	gray triggerfish
Ostraciidae	Boxfishes
Lactophrys quadricornis*	scrawled cowfish
Tetraodontidae	Puffers
Sphoeroides spengleri*	bandtail puffer
Diodontidae	Porcupinefishes
Chilomycterus schoepfi	striped burrfish

Table 15-47. Fish species recorded from the rocky outcrops which have not otherwise been recorded from the Mississippi-Alabama continental shelf.

Scientific Name	Common Name
Muraenidae	Morays
Gymnothorax moringa	spotted moray
Muraena retifera	reticulated moray
Batrachoididae	Toadfish
Opsanus beta	gulf toadfish
Holocentridae	Squirrelfishes
Holocentrus ascensionis	squirrelfish
Holocentrus rufus	longspine squirrelfish
Aulostomidae	Trumpetfishes
Aulostoma maculatus	trumpetfish
Serranidae	Sea basses
Epinephelus nigritus	warsaw grouper
Holanthias martinicensis	roughtongue bass
Mycteroperca microlepis	gag
Mycteroperca phenax	scamp
Paranthias furcifer	creole-fish
Priacanthidae	Bigeyes
Priacanthus cruentatus	glasseye snapper
Apogonidae	Cardinalfishes
Apogon maculatus	flamefish
Apogon pillionatus	broadsaddle cardinalfish
Carangidae	Jacks
Seriola rivoliana	almaco jack
Lutjanidae	Snappers
Lutjanus cynanopterus	cubera snapper
Lobotidae	Tripletails
Lobotes surinamensis	tripletail
Gerreidae	Mojarras
Diapterus auratus	Irish pompano
Sparidae	Porgies
Calamus nodosus	knobbed porgy

Table 15-47. Cont'd.

Scientific Name	Common Name
Sciaenidae	Drums
Equetus punctatus	spotted drum
Chaetodontidae	Butterflyfishes
Chaetodon ocellatus	spotted butterflyfish
Chaetodon sedentarius	reef butterflyfish
Pomacanthidae	Angelfishes
Holacanthus bermudensis	blue angelfish
Pomacentridae	Damselfishes
Chromis enchrysurus	yellowtail reeffish
Pomacentrus planifrons	threespot damselfish
Labridae	Wrasses
Bodianus pulchellus	spotfin hogfish
Halichoeres bathyphilus	greenbaud wrasse
Halichoeres bivittatus	slippery dick
Halichoeres cyanocephalus	yellowcheek wrasse
Scombridae	Mackerels
Sarda sarda	Atlantic bonito
Thunnus thynnus	bluefin tuna
Stromateidae	Butterfishes
Peprilus triacanthus	butterfish
Scorpaenidae	Scorpionfishes
Scorpaena plumieri	spotted scorpionfish
Ostaciidae	Boxfishes
Lactophrys polygonia	honeycomb cowfish
Diodontidae	Porcupinefishes
Chilomycterus antillorum	web burrfish

disturbance, particularly to chemical pollution and to increased suspension of inorganic sediments.

15.7 Ecosystem Synthesis

The present study represents a large multi-year and multi-disciplinary effort to examine most of the components of the continental shelf ecosystem off the coasts of Mississippi and Alabama. As a total ecosystem effort the study lacks the following components:

- Parts of the ecosystem were not examined (phytoplankton, zooplankton, nekton and supra-benthic biota);
- Intimately related systems outside the area were not included in the study (marshlands, estuaries, bays, sounds and the open Gulf);
- Water current investigations were conducted for only a portion of the period of sampling;
- The number of regular sampling stations was very small in relation to the total size of the study area;
- The frequency of sampling and measurement was too low to account for many of the physical and biological changes observed; and
- The number of measurements and samples taken at each station was generally too low to permit adequate estimates of sample variability.

Nevertheless, the present investigation represents the most complete study ever conducted on the Mississippi-Alabama continental shelf and one of the most thorough investigations ever conducted on any continental shelf of the northern Gulf of Mexico. It is particularly important because it provides insight into the effects of Mississippi River outflow on this sector of the Gulf; the area supports one of the most productive fishery harvests of the nation; and it is a major multiple-use area for human commerce, resource harvest, recreation, and other activities. The present section will address broader, multi-disciplinary, ecosystem-scale issues in order to achieve environmental conclusions upon which firm management decisions may be based.

15.7.1 The Water Column

Waters of the Mississippi-Alabama shelf are influenced by major forces external to the system, and they are quite variable. Rivers as well as local storms and heavy rainfall bring fresher water from the west and north. At times these may be laden with fine clay, silt, dissolved nutrients, and particulate organic material. Input of fresher water is particularly prominent in the spring and early summer, but it may occur at any time of the year. Eddies and filaments from the Gulf Loop Current have been shown to entrap parcels of Mississippi River water and spin them eastward along the outer shelf. Storms and hurricanes as far away as Yucatan can induce strong currents, hastening the mixing processes and sweeping fine sediments to deeper water reservoirs. Intrusions of saline, nutrient poor water from the open Gulf periodically sweep the shelf, displacing a large portion of the shelf water. Figure 15-13 provides a portrait of one such intrusion event documented by satellite imagery. Current measurements reveal that near-bottom waters at mid-shelf trend toward the southwest and that at the 200 m depth throughout the year near-bottom currents prevail along the isobath toward the northeast.

Water temperature alone varies on a regular seasonal basis. It is low in the winter and high in the summer, and summer stratification of the water column appears to be a regular occurrence. The remaining characteristics are more variable and more loosely coincident with a particular season. Surface salinity is generally lower nearshore and along the Chandeleur transect, and it increases seaward and with depth. However, parcels of low salinity Mississippi River water are frequently encountered over the outer shelf. Freshwater intrusions due to local storms may occur at any season. Light transmission values were found to be highest in the summer and lowest in the winter, and this appears to reflect summer stratification and winter vertical mixing of the water column. Bottom dissolved oxygen values never approached true hypoxia during the summer, but on one winter cruise, low oxygen values were widespread over much of the area. Bottom dissolved oxygen tended to be highest in shallow water, but it was quite low at a depth of 200 m. This is an area of accumulation of organic material, but the temperature is very low, reducing the rate of decomposition, and waters

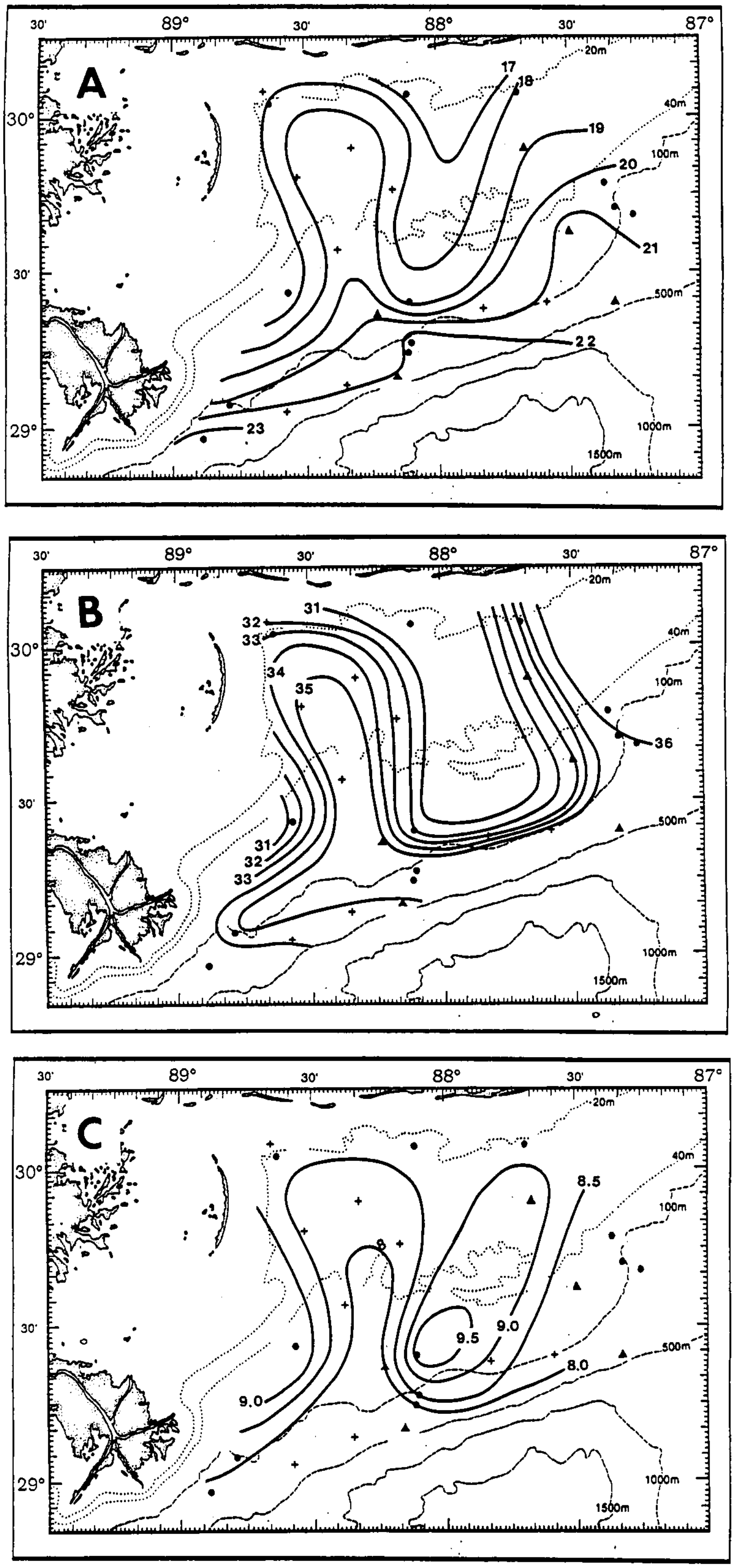


Figure 15-13. Portrait of a Gulf Loop Current intrusion event on the Mississippi-Alabama continental shelf (cruise B-4, Feb. 10-18, 1989). A = surface temperatures (°C), B = surface salinities (‰), C = surface dissolved oxygen (mg/l), D = near bottom temperatures (°C), E = near bottom salinities (‰), and F = near bottom dissolved oxygen (mg/l).

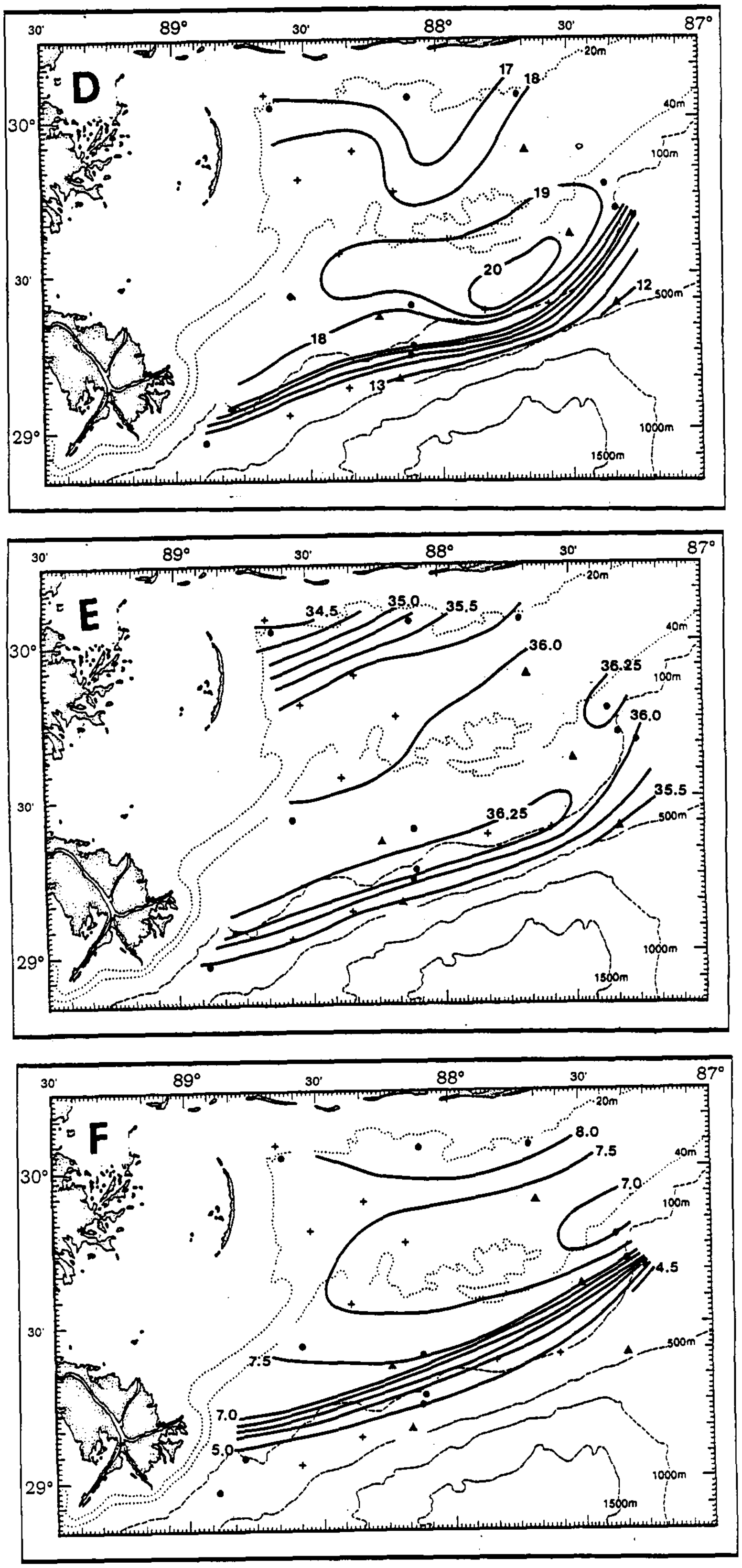


Figure 15-13. Cont'd.

at this depth represent the oxygen minimum layer which coincides with the shelf here. Dissolved phosphates were found to be low at both seasons, probably due to adsorption onto clay particles and subsequent deposition. Nitrates were low during the summer, but they were high during the winter, particularly on the Chandeleur transect and at some stations on the Mobile transect. This probably reflects the injection of new nitrates into the system as well as local regeneration and vertical mixing.

In general, water quality characteristics tended to be most variable at the nearshore station off Mobile Bay and along the entire Chandeleur transect. They were least variable on the De Soto Canyon transect. On this transect summer salinities were higher and more uniform. During the winter the temperature was more uniform, surface nitrate values were lower and less variable, and bottom oxygen values were higher. Here light transmission values were uniformly high during the winter and at most stations during the summer.

Outflows of fresher water bring to the shelf species of phytoplankton and zooplankton, whereas the more saline areas are populated by true shelf species and some typical of the open Gulf. Phytoplankton standing crops (based on chlorophyll measurements) and primary productivity (based on ^{14}C uptake) are intermediate between those of the highly productive Louisiana shelf west of the Mississippi River Delta and those of the poorly productive open Gulf. Zooplankton volumes are highest nearshore and decrease with depth and distance from shore. The nektonic fauna appears to be quite diverse, but nothing is known about its density or distribution patterns.

15.7.2 The Bottoms

The bottoms of the Mississippi-Alabama shelf consist of soft sediments containing fields of rocky outcrops and higher topographic features in certain areas. In deeper water the major groups of features tend to favor certain isobaths and appear to have been formed near sea level during temporary stillstands of the Gulf during the post-glacial rise in sea level. Prominent among the features are pinnacles (ca. 105 m), patch reefs (65-70 m) and sub-parallel ridges and scarps (ca. 60 m). The soft sediments consist of particles in the size ranges of clay, silt, sand, and gravel. The surface distribution of these sediments was mapped in detail by Ludwick (1964), and the pattern appears to have changed little in subsequent years. However, since sediment patterns do vary considerably on a local scale, samples taken during the present study do not match the Ludwick map in every detail.

Most of the central and eastern shelf out to a depth of about 100 m is covered by a massive sand sheet. The western third of the shelf consists of mixtures of clay, silt, and sand in various proportions and distributed in complex patterns. All along the shelf the sediments grade seaward to finer particles, and by a depth of 200 m clay and silt account for more than 90% of the particulate material. Seasonal changes in distribution patterns of these three sediment components support the following conclusions. Sand may be moved around somewhat by the bottom currents at depths of 20 and 60 m, but only rarely are the currents strong enough to displace this material at greater depths. Silt appears to be quite mobile. Entering primarily on surface waters during the spring floods, it settles to the bottom, especially in the southwest half of the shelf where it is observed during the summer months. By the winter season most of the silt has been swept away. Clay particles, although easily carried in water column, packs tightly in the sediments and remains on the Chandeleur transect and at all the deeper stations after much of the silt has been swept away. Gravel-sized particles consist primarily of biogenic remains (of algal, molluscan and bryozoan origin), and this material was prominent only at the 60 and 100 m stations of the De Soto Canyon transect. Calcium carbonate achieved levels of over 15% in the sediments at stations M-3, D-2, D-3 and D-4. Most of this material was of biogenic origin.

During both seasons at all stations at 20 and 60 m sediments were poor in organic carbon (<1.0%), but at all deeper stations except M-3 the sediments were rich in organic carbon (>1.0%). Sediments underlying colder waters of the outer shelf serve as a repository for organic matter swept from the shallower shelf. At most stations $\delta^{13}C$ values were relatively low during the winter and high during the summer, suggesting the following scenario. Fine particulate terrestrial plant detritus brought in by the spring floods sinks from the surface waters and is deposited throughout the shelf. Mixed with marine phytoplankton debris, it persists throughout the summer. However, by the winter it has either been swept away or biodegraded, and it is replaced by a blanket of marine phytoplankton detritus.

High molecular weight hydrocarbons are present in the sediments in very low concentrations suggestive of an unpolluted shelf, but the levels are within the range of measurability permitting them to be used as tracers and revealing information about the environment. Concentrations tend to be highest on the Chandeleur transect and lowest on the De Soto Canyon transect and to increase with depth in the water column. For those hydrocarbon groups for which there is a seasonal change, summer values are about twice the winter values. These results suggest that the spring runoff brings to the shelf both natural petroleum hydrocarbons and terrestrial plant bio-waxes and that the source of this material is to the west and north, i.e., the Louisiana marshes, Mississippi River, Gulf Outlet Canal, Pearl River, Lake Pontchartrain basin, and Mobile Bay. Much of this material remains during the summer, but by the following winter it has undergone biodegradation or has been swept away. Some of the hydrocarbon data also reflect the occurrence of a major episodic event which will be discussed later.

Distribution patterns of the various trace metals in the bottom sediments are remarkably similar and differ only in minor details. For all metals and for both seasons concentrations are highest on the Chandeleur transect and at the deepest stations on all transects. The levels of most metals are so low as to suggest natural background concentrations of an unpolluted shelf. The element barium which is associated with drilling muds, is slightly elevated on the Chandeleur transect.

The accumulated information concerning characteristics of the water column and sediments provides a coherent picture of regular seasonal changes on the Mississippi-Alabama continental shelf. During the winter when the water column becomes vertically mixed, nitrogen is released from the sediments and lower column into the surface water stimulating the major annual phytoplankton bloom which occurs earlier inshore and somewhat later offshore. Fresher water sources to the west and north during the spring and early summer bring to the shelf quantities of silt, natural petroleum hydrocarbons, finely particulate terrestrial plant detritus, and plant bio-waxes. These probably arrive primarily in plumes and lenses of fresher water which remain for a time at the surface. Much of the material is precipitated near the origin (along the Chandeleur transect), but some is deposited in widespread fashion around the shelf. Traces of these materials appear in the summer sediment samples. As the spring turns to summer the surface water heats up, stratification sets in, nutrients are lost to the hypolimnion, and phytoplankton populations decrease. By the following winter bottom currents have swept most of the sedimented materials southwestward toward deeper water near the Mississippi River Delta, and there they are deposited or redistributed by deepwater currents. Since much of the organic material has been removed from the shallow and mid-depth shelf, the nitrogen released through regeneration in the bottom sediments is sufficient to support only a modest phytoplankton bloom, somewhat greater than that of the open Gulf, but considerably less than that of the Louisiana shelf west of the Mississippi River Delta where much different circumstances prevail.

15.7.3 The Benthic and Demersal Biota

For present purposes the benthic and demersal biota includes the meiofauna, macroinfauna, macroepifauna, and demersal fishes.

15.7.3.1 Faunal Characteristics

The meiofauna was not investigated during the present project, but historical information is available from a transect running southeastward from below Horn Island toward deepwater below Perdido Bay (Vittor and Associates, Inc., 1985). Densities ranged from 627 individuals/10 cm^2 at the shallowest station (<30 m) to 155 individuals/10 cm^2 at the deepest station (160 m). Free living nematodes were most abundant followed by harpacticoid copepods and polychaetes.

In the present study the macroinfauna was found to be dominated by polychaetes (60%), mollusks (ca. 15%), and crustaceans (ca 15%). A diverse array of other groups together made up only about 10% of the infauna. Polychaetes were numerically dominant in most samples. Their densities ranged from 38 to 3,014 individuals/m^2 and were highly variable. Invertebrate densities were exceptionally low on cruise B-0 and exceptionally high on cruise B-2. Infaunal densities coincided closely with sediment particle size of the samples. For total invertebrates during both seasons, high densities were encountered in the coarse sediments (sand and gravel), and this pattern also held true for the polychaetes, mollusks, and crustaceans. Densities were low in fine sediments with the exception of station C-4 where high polychaete densities on a single cruise reflected a temporary population increase by a single species. Mollusks were more strictly limited to coarse sediments than were polychaetes or crustaceans.

Over 23,000 specimens of macroepifaunal invertebrates were collected from which 310 species were recognized. Forty-three percent of the species were decapods, 30% were mollusks, 18% were echinoderms, and about 8% represented other groups. In terms of numbers of individuals, decapods made up 78%, echinoderms 10%, mollusks 8%, and the remaining groups about 5%. The numerical dominance of the decapods was due to the large numbers of shrimp taken. Considerable variability in density was observed among the different stations and cruises, and on cruise B-4 the catch for most stations was exceptionally low. Highest densities of total invertebrates were observed on the Chandeleur transect. During the summer they were high at all stations of this transect, but during the winter densities were high only at the two deeper stations. Decapod densities paralleled and largely accounted for the pattern shown by the total invertebrates. It appears that many of the decapods, particularly the shrimp, tend to concentrate in deeper water during the winter. Echinoderm densities were greatest in deeper water, and this group was generally rare on the Mobile transect. Mollusks were relatively abundant and widespread during the summer and rare during the winter.

A total of 16,182 demersal fishes was taken representing 207 identifiable species. The mean density was very low (6.22 kg/ha) apparently reflecting three sources of bias: a) very small trawl with undersized trawl doors, b) inclusion of low density deepwater (200 m) stations, and c) inclusion of data from one cruise with abnormally low catches. In general, the density would have been expected to be two or three times as great as that obtained. As in the case of the macroepifaunal invertebrates the catches at most stations on cruise B-4 were exceptionally low. During the summer months the mean density was almost a third greater than during the winter, probably reflecting the presence of many juveniles during the summer. A major shift in density occurred between the seasons. During the summer the density at 20 m was 65% greater and at 60 m it was 117% greater than winter densities at these depths. However, at 100 m the density was 17% and at 200 m it was 73% greater during the winter. The data suggest a tendency of the shelf fishes to move to deeper water during the winter months. Consistent with this hypothesis is the fact that, on average, at the 200 m station there were nearly twice as many species during the winter as during the summer (i.e., a ratio of 19 to 10). During both seasons densities were greatest on the Chandeleur transect. The Mobile transect was second in density during the winter, and the De Soto Canyon transect was second during the summer. Over half the fish species appear to change transects or depths with the seasons. Only 45% were resident at a given depth and 37% resident on a given transect during both seasons.

In general, the data reveal a demersal fish community that is highly mobile. Greatest densities occur on the Chandeleur transect with highest summer densities in the shallower waters and highest winter densities in the deeper waters. The same general pattern also applies to the mobile macroinvertebrates, particularly the shrimp. Non-mobile macroinvertebrates do not change stations with the seasons, but the mollusks which are widespread in the summer, are rare in winter collections suggesting that during the winter they burrow deeper into the substrate where they are less vulnerable to capture. The infauna are substrate limited and do not show clear seasonal patterns.

15.7.3.2 Species Assemblages

In order to determine statistical patterns of species associations all three faunal groups were examined by cluster analysis techniques. These procedures take into account both the distribution of species and their abundances at the different stations. Analyses were conducted separately by seasons as well as for the two seasons combined. Results of the combined season analyses are presented in Table 15-48. For comparison, data are also given for the mean clay contents of the sediment samples. Representative species for each of the assemblages are shown in Table 15-49.

The macroinfauna consists of three species assemblages. Assemblage A occupies those stations to the northeast characterized by coarse sediments

Table 15-48. Faunal groupings within the macroinfauna, macroepifauna, and demersal fishes based upon cluster analysis. Each faunal group is denoted by a given letter. Subgroups are distinguished by capital vs. lower case letters. For comparison with the macroinfauna, data are also presented for the mean clay content (%) of the sediment samples. Some shading has been added as an aid to visualization.

Macroinfauna

	C	M	D
1	A	A	A
2	B	A	A
3	B	B	A
4	C	C	C

Clay (%)

	C	M	D
1	22.2	11.5	4.9
2	36.7	8.6	6.8
3	63.3	27.8	17.4
4	68.1	62.6	42.0

Macroepifauna

	C	M	D
1	A	A	A
2	A	B	B
3	C	C	B
4	C	C	C

Demersal fishes

	C	M	D
1	A	A	A
2	A	a	a
3	b	b	a
4	B	B	B

Table 15-49. Species assemblages among the macroinfauna, macroepifauna, and demersal fishes. Only representative species are listed. The distribution of each assemblage is shown in Table 14-48.

MACROINFAUNA

Assemblage A (C-1, M-1, D-1, M-2, D-2, D-3)

Bivalves
- Parvilucinia multilineata
- Tellina versicolor

Polychaetes
- Aglaophamus verrilli
- Laonice cirrata
- Lumbrinereis verrilli
- Mediomastus californiensis
- Neanthes micromma
- Paraprionospio cristata
- Spiophanes bombyx

Amphipods
- Ampelisca abdita
- Ampelisca verilli

Decapods
- Euceramus praelongus
- Spinocarcinus lobatus

Assemblage B (C-2, C-3 M-3)

Bivalves
- Abra aequalis
- Abra lioica
- Nucula ageensis

Polychaetes
- Aglaophamus verrilli
- Notomastus americanus
- Notomastus hemipodus
- Tauberia reducta

Decapoda
- Alphaeus floridana
- Alpheopsis harperi
- Automate evermanni
- Raninoides louisianae

Assemblage C (C-4, M-4, D-4)

Bivalves
- Nuculana acuta
- Yoldia lohrina

Polychaetes
- Nephthys incisa
- Paralacydonia parado
- Prionospio pygmaea

Decapoda
- Micropanope nuttingi
- Porcellana sigsbeiana

MACROEPIFAUNA

Assemblage A (C-1, M-1, D-1, C-2)

Cephalopods
- Loligo plei

Decapods
- Callinectes similis
- Portunus gibbesi
- Sicyonia brevirostris
- Sicyonia dorsalis

Echinoderms
- Luidia clathrata

Table 15-49 Cont'd.

Assemblage B (M-2, D-2, D-3)

Decapods
Parthenope agonis
Processa guyanae
Solenocera atlanticus

Echinoderms
Stylocardis affinis

Assemblage C (C-3, M-3, C-4, M-4, D-4)

Bivalves
Aequipecten glyptus
Yoldia solenoides

Decapoda
Parapenaeus politus
Plesionika tenuipes
Raninoides louisianae

Echinoderms
Ophiolepis paucispinosa

DEMERSAL FISHES

Assemblage Aa
Subgroup A (C-1, M-1, D-1, C-2)

Anchoa hepsetus
Arius felis
Brotula barbata
Diplectrum bivittatum
Chloroscombrus chrysurus
Polydactylus octonemus
Bollmannia communis
Prionotus martis
Prionotus rubio
Citharichthys chittendeni
Etropus crossotus
Syacium gunteri
Symphurus civitatus
Symphurus plagiusa

Subgroup a (M-2, D-2, D-3)

Raja eglanteria
Gymnothorax saxicola
Hoplunnis macrurus
Lepophidium jeannae
Centropristis ocyurus
Serraniculus pumilio
Serranus phoebe
Scorpaena brasiliensis
Scorpaena calcarata
Bellator militaris
Cyclopsetta fimbriata
Syacium papillosum

Assemblage Bb
Subgroup b (C-3, M-3)

Hoplunnis tenuis
Ogcocephalus declivirostris
Steindachneria argenteus
Bathygadus macrops
Synagrops spinosa
Hemanthias vivanus
Serranus notospilus
Caulolatilus intermedius
Equetus umbrosus
Prionotus longispinosus
Prionotus paralatus
Trichopsetta ventralis

Subgroup B (C-4, M-4, D-4)

Zalieutes mcgintyi
Bathygadus melanobranchus
Coelorinchus caribbaeus
Coelorinchus coelorhinchus
Macrorhamphosus scolopax
Synagrops bellus
Bembrops anatirostris
Poecilopsetta beani

(clay content <25.0%). Assemblage C occurs at the deepest stations of all transects. Here the clay and silt content is very high, the sediments are rich in organic carbon, year around temperatures are low, and there is little light. Assemblage B occurs at intermediate depths on the Chandeleur and Mobile transects, but the environmental correlates are not clear. All the assemblages are rich in polychaetes, but bivalves, amphipods, decapods and other groups are also prominent in some cases.

Patterns of the macroepifauna and demersal fishes bear little relationship with those of the macroinfauna, but they are quite similar to each other. For the macroepifauna three assemblages were found. Assemblage A includes all the shallow stations as well as the 60 m station on the Chandeleur transect. Assemblage B includes the 60 m station on the Mobile transect and 100 m stations on the De Soto Canyon transect. Assemblage C includes the remaining stations at 100 m as well as all the 200 m stations. The demersal fishes were found to include two major assemblages, each with two subgroups. Subgroup A of the first assemblage exactly corresponds with assemblage A of the macroepifauna. Subgroup a exactly corresponds with assemblage B of the macroepifauna. Assemblage B and b of the demersal fishes corresponds with assemblage C of the macroepifauna. This correspondence of macroepifaunal and demersal fish assemblages was totally unexpected since both groups contain highly mobile species which could be expected to respond in different ways to the various environmental factors.

In general, it would appear that assemblage A of the macroepifauna and subgroup A of the demersal fishes represent shallow water forms and some estuary related species which favor sandy bottoms and very dynamic water conditions. Macroepifaunal assemblage B and demersal fish subgroup a inhabit coarse calcareous bottoms and appear to relate more to De Soto Canyon. Macroepifaunal assemblage C and demersal fish assemblage B and b occur in deeper water on fine sediments and relate to conditions influenced by the Mississippi River and its Delta. Seasonal changes have been addressed in relation to each faunal group.

15.7.4 Major Episodic Events

It has been shown that the environment of the Mississippi-Alabama continental shelf undergoes seasonal changes to which the biota responds in statistically regular ways. The shelf is also subject to certain extreme conditions and intrusive events which may induce biological signals in terms of greatly elevated or reduced population levels. It is the purpose of the present section to examine biological signals from the three winter cruises and to seek environmental correlates which may be causally related to the observed population changes.

Table 15-50 provides physical, chemical, and biological data pertaining to the three winter cruises. The columns of this table are arranged in chronological seasonal order (i.e., cruise B-0 took place in late January and early February, B-4 occurred in Mid- February, and B-2 was conducted in mid-March). Reference to the table reveals the following information. Infaunal abundance was extremely low in late January, moderate in mid-February and high in mid-March. Organic carbon was low in late January and higher in mid-February and March. The $\delta^{13}C$ value for January was -21.45‰, but this was biased by very high values at two stations, M-1 (-25.1‰) and M-2 (-24.0‰). The average for the remainder of the January stations was -20.76‰. The $\delta^{13}C$ values for mid-February and March were -20.85‰ and -22.72‰ respectively. Thus, the low level of organic carbon in January (with the exception of stations M-1 and M-2) appears to have been due almost entirely to marine phytoplankton debris. By mid-February the organic carbon content of the sediments had increased by nearly 50%, but it was still composed largely of marine phytoplankton material. Apparently by this date the winter phytoplankton bloom was well underway. Terrestrial bio-waxes were exceptionally high, but lying in the parts per billion range, they could scarcely influence values of $\delta^{13}C$ or total organic carbon. By mid-March the organic content of the sediments was about the same as that observed during February, but the composition had changed. The $\delta^{13}C$ values were elevated, and values exceeding 23.0‰ were widespread across the shelf indicating the introduction and dispersal of terrestrial plant detritus. Surface salinity values in mid-March were reduced throughout the shelf indicating that the spring outflow from the rivers was by now influencing the shelf waters. The above scenario suggests that the

Table 15-50. Physical, chemical, and biological data for the three winter cruises. The cruises have been arranged by monthly chronology, which places cruise B-4 prior to cruise B-2.

Information category	Winter 1987	Winter 1989	Winter 1988
Cruise no.	B-0	B-4	B-2
Cruise dates	1/23 - 2/5/87	2/10-18/89	3/9-17/88
$\delta^{13}C$ $(\bar{X})$	-21.45‰	-20.85‰	-22.72‰
Biowaxes $(\bar{X})$	6.6 ppm	33.7 ppm	10.6 ppm
Organic C $(\bar{X})$	0.63%	0.95%	0.92%
Infauna $(\bar{X})$	196/m^2	741/m^2	1348/m^2
Epifauna $(\bar{X})$	229/ha	148/ha	577/ha
Demersal fishes $(\bar{X})$	470/ha	100 /ha	313/ha
Nitrates (surface)$(\bar{X})$	0.51 μM/kg	0.45 μM/kg	---
Loop Current (during cruise	No information	Intrusion (above 29.5°N)	Intrusion (above 29.5°N)
Conditions during previous fall	No major weather disturbances	Mar. - Dec. drought Aug. 1 - 1 tropical storm Sept. - 3 hurricanes Nov. - 1 tropical storm Nov. - Loop Current above 29.0°N	Dec., Jan., & Feb - Loop Current above 29.0°N

very low January infaunal density (196 individuals/m^2) was probably a normal seasonal low reflective of an exhausted food supply prior to the onset of the major winter phytoplankton bloom. There is no reason to suspect that it was a signal of some major episodic event. No major weather disturbances had taken place during the previous fall months, and both the macroepifauna and demersal fish densities were fairly high during the January cruise.

During cruise B-4, conducted in the winter of 1989, both the macroepifaunal and demersal fish populations were quite low. The mean epifaunal density was 36.7% and the demersal fish density was only 25.5% of the mean densities of the other two winter cruises. The distribution of the densities by station is shown in Table 15-51. Here the density is expressed as a percentage of the mean density for the other two winter cruises, calculated on a station by station basis. The macroinfaunal density was elevated at the nearshore stations but otherwise showed no clear pattern. The macroepifauna was higher than normal at Stations C-1 and C-2 but well below 50% of normal at all the 100 m and 200 m stations as well as at station M-1. The patterns for demersal fishes were fairly similar to that of the macroepifauna. Densities were below 50% at all the 100 m and 200 m stations except D-4, and they were also well below 50% at all shallower stations except C-1 and C-2. Clearly, such dramatic and widespread density reductions in two biological groups cannot be considered regular seasonal occurrences, and they must reflect biological responses to major external events.

Table 15-51. Density of the various faunal groups at all stations during cruises B-4 expressed as a percentage of the mean density of the other two winter cruises at corresponding stations. Values of less than 50% are shaded.

	Macroinfauna			Macroepifauna			Demersal fishes		
	C	M	D	C	M	D	C	M	D
1	110.7	116.4	249.2	347.8	21.8	57.0	50.7	9.5	10.7
2	217.6	207.6	30.1	91.6	---	172.7	58.3	10.7	29.3
3	77.5	74.8	26.6	15.2	8.4	19.9	18.6	16.6	49.9
4	16.7	98.9	150.0	8.6	1.7	41.8	12.0	18.6	75.2

Table 15-50 shows that the previous year had been marked by the worst drought in half a century. However, during late summer and fall the area was affected by a series of major weather disturbances. Tropical storm Beryl (August 8-10), which formed from a low pressure area off Louisiana, had maximum sustained winds of 50 mph. During the month of August 10.45 inches of rainfall were measured at Mobile, Alabama. In September three hurricanes visited the Gulf. Hurricane Debbie (August 31 - September 5) was confined to the southern Gulf. Hurricane Florence (September 7-11) formed in the south-central Gulf and made landfall over southeastern Louisiana. Maximum sustained winds reached 80 mph. Hurricane Gilbert, one of the strongest of the century, formed in the Atlantic and made landfall on the Yucatan peninsula. During that stormy September 14.04 inches of rainfall were recorded at Mobile, Alabama. October was a quiet month, but in November tropical storm Keith moved eastward through the Gulf below Mississippi and Alabama and made landfall on the west coast of Florida. In November, 1988, a Loop Current intrusion almost reached 29.0°N, and in February, 1989, during the period when cruise B-4 was underway, a Loop Current intrusion was sweeping the shelf well above 29.5°N (Figure 15-13). The record shows that the B-4 sampling period was preceded by a major drought, two periods of very heavy rainfall, three hurricanes, two tropical storms, and a Loop Current intrusion and that during the sampling period a major intrusion was in progress.

In the face of so many disturbances, it is little wonder that the macroepifauna and demersal fish populations were devastated. Although it is not possible to associate specific causes and effects, some clues are available. Beginning in March and continuing into August, the drought might well have reduced both recruitment and survival of estuary related species, and it could have reduced the normal outflow of nutrients and particulate matter to the shelf resulting in lower productivity there during the spring and summer. Storms and hurricanes accompanied by heavy rainfall undoubtedly brought many nutrients and much particulate matter to the shelf in the fall, but these events were accompanied by very strong shelf currents as evidenced by the current meter data. At a mooring station in 60 m of water, current speeds up to 80 cm/s were measured at a depth of 10 m, and speeds up to 35 cm/s were measured at a depth of 57 m. (Note: 51.4 cm/s

= 1 kt.) Numerous authors have pointed out that for fishes and larger invertebrates to carry out their normal seasonal migration patterns they depend upon certain environmental cues (such as minor salinity changes, subtle odors, etc.) to guide them. During exceptional years when the signals become mixed or disappear altogether, the organisms become confused, and abnormal distribution patterns may result. If a single event were to be identified as the primary cause of the faunal reduction it would have to be Hurricane Florence which headed directly across the area in September. However, all the events likely had some effect. On the basis of all the available evidence it is tentatively concluded that the major reduction in mobile fauna resulted from a coincidence of three sets of major events, each acting as follows:

- Extreme drought - reduced recruitment and survival of estuary related species;
- Major storms and hurricanes - brought heavy rainfall and induced strong currents, disrupting normal migration and distribution patterns; and
- Major Loop Current intrusions - displacing shelf waters and driving mobile species to peripheral refuges.

15.7.5 Nutrients and Trophic Relations

15.7.5.1 Nutrients

Nutrients may reach continental shelves by a number of pathways. Outflow from rivers, coastal marshes, estuaries, bays, and lagoons may transport to the shelf dissolved nutrients (nitrates, nitrites, ammonia, phosphates, and silicates) as well as particulate organic and inorganic materials (Darnell and Soniat 1979). The particulates may include living plankton. Estuary related species actively migrate back to the shelf in the late summer and fall. On the Mississippi-Alabama shelf the presence of higher $\delta^{13}C$ values and plant bio-waxes during the summer attest to the importance of these outflows associated with the spring floods. Tropical storms and hurricanes, often accompanied by heavy local rainfall are known to ravage marshes and other coastal environments and bring quantities of organic material to the shelf regardless of their season of occurrence. Filaments and eddies spun from the apex of the Loop Current have been shown to entrap parcels of nutrient rich Mississippi River water, transporting them northeastward over the outer shelf. Waters from nutrient rich deeper layers of the Gulf may intrude upon and bring nutrients to the shelf through entrainment or upwelling, and there is evidence of upwelling in the De Soto Canyon area.

Once on the shelf the nutrients are available to support phytoplankton growth so long as they are not trapped below the pycnocline in a stratified water column (which can occur during the summer). Living estuarine plankton species may flourish for awhile so long as the salinity remains low. Nonliving particulate organic material may be consumed in the water column, or it may settle to the bottom along with the inorganic particles. Regeneration in the sediments permits nutrients to return to the water column, and if vertical mixing occurs, the nutrients will be transported to the surface layer where they are again available to support phytoplankton growth.

Nutrients are lost from the shelf by bottom water transport into the bays and estuaries and by advective transport to the offshore waters by surface and bottom currents. A small amount may also be lost by the emigration of living organisms. Of particular importance is the fact that the Mississippi-Alabama shelf is often swept by fairly strong currents and by the intrusion of Loop Current waters. Evidence has been presented for the fact that silt and organic material deposited during the spring and early summer has disappeared by the following winter, and the presumption is that these materials are swept from the shelf to deeper Gulf water by the strong currents of the area. Such currents also transport shelf waters to the open Gulf, thereby removing much dissolved and suspended material including plankton. It has also been shown that Loop Current intrusions replace the shelf waters with nutrient poor water from the open Gulf. The general picture is one of nutrient flow from inside waters to the shelf in the spring and early summer, nutrient loss from the surface to deeper waters during the period of summer stratification, and nutrient sweeping from the shelf during the fall. Despite some backflow, the net transport is from inside waters to the shelf and from there to the open Gulf. Residence time on the shelf is considered to be a matter of a few months at the most.

A conceptual model of the nutrient dynamics of the Mississippi-Alabama shelf is presented in Figure 15-14. Included are sources, reservoirs and exchanges, and sinks. The net flow is from sources to sinks. Of particular importance are the vertical processes of deposition and resuspension which are especially active on this shelf. Significant flow also occurs between the pelagic consumers and those of the supra-benthic and benthic environments. Several recycling pathways are denoted by dashed lines. Sinks include losses to the deep Gulf as well as deep burial in the sediments.

15.7.5.2 Trophic Relations

Food studies were conducted for 49 of the most abundant species captured by the bottom trawls, but these represent a biased sampling of the total shelf ichthyofauna. Virtually unsampled were the larger fishes, faster swimmers, pelagic species, burrowing forms, and those characteristic of hard bottoms (i.e., reef related species). Nevertheless, from knowledge of the food of the species examined supplemented by historical information concerning other species known or presumed to be present (Divita *et al.* 1983; Rogers 1977; and others) it is possible to arrive at a satisfactory understanding of the trophic structure of the ecosystem as a whole.

In order to gain a perspective on major trophic patterns of the fish community, food data for all the species examined have been arranged in a trophic spectrum diagram (Figure 15-15)(after Darnell 1961). Each of the seven food categories is defined and discussed briefly below.

Unidentified Animal Matter

This material appeared to be primarily the flesh and other remains of fishes, decapod crustaceans, and polychaete worms, but the material could not be assigned with certainty to any one of these groups. Most was assumed to have been consumed alive and then digested beyond recognition, although some could have been dead and partially decomposed when eaten. Material in this category was present in most species, and it made up 22.8% of all the food consumed.

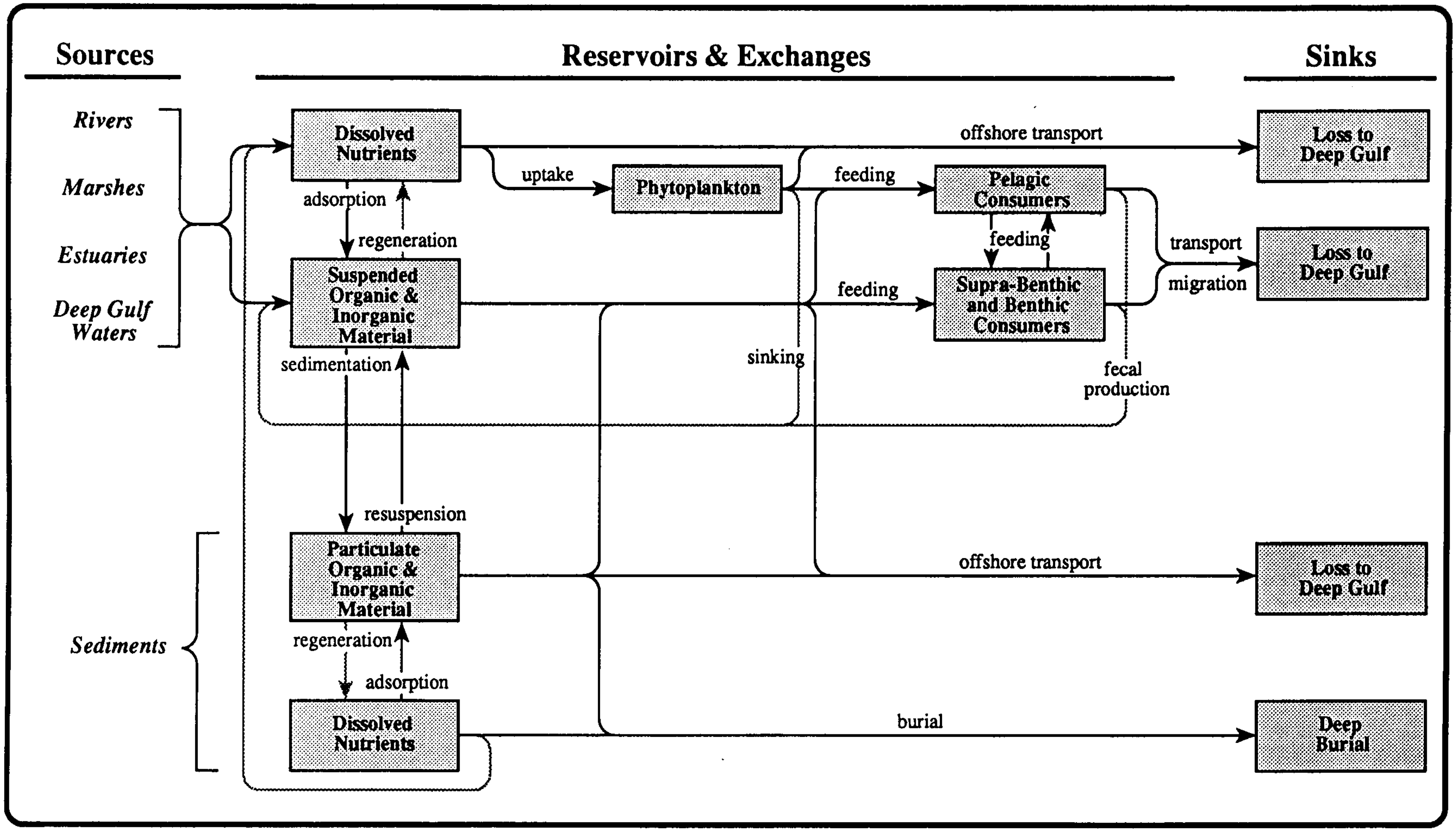


Figure 15-14. Conceptual model of nutrient dynamics on the Mississippi/Alabama continental shelf.

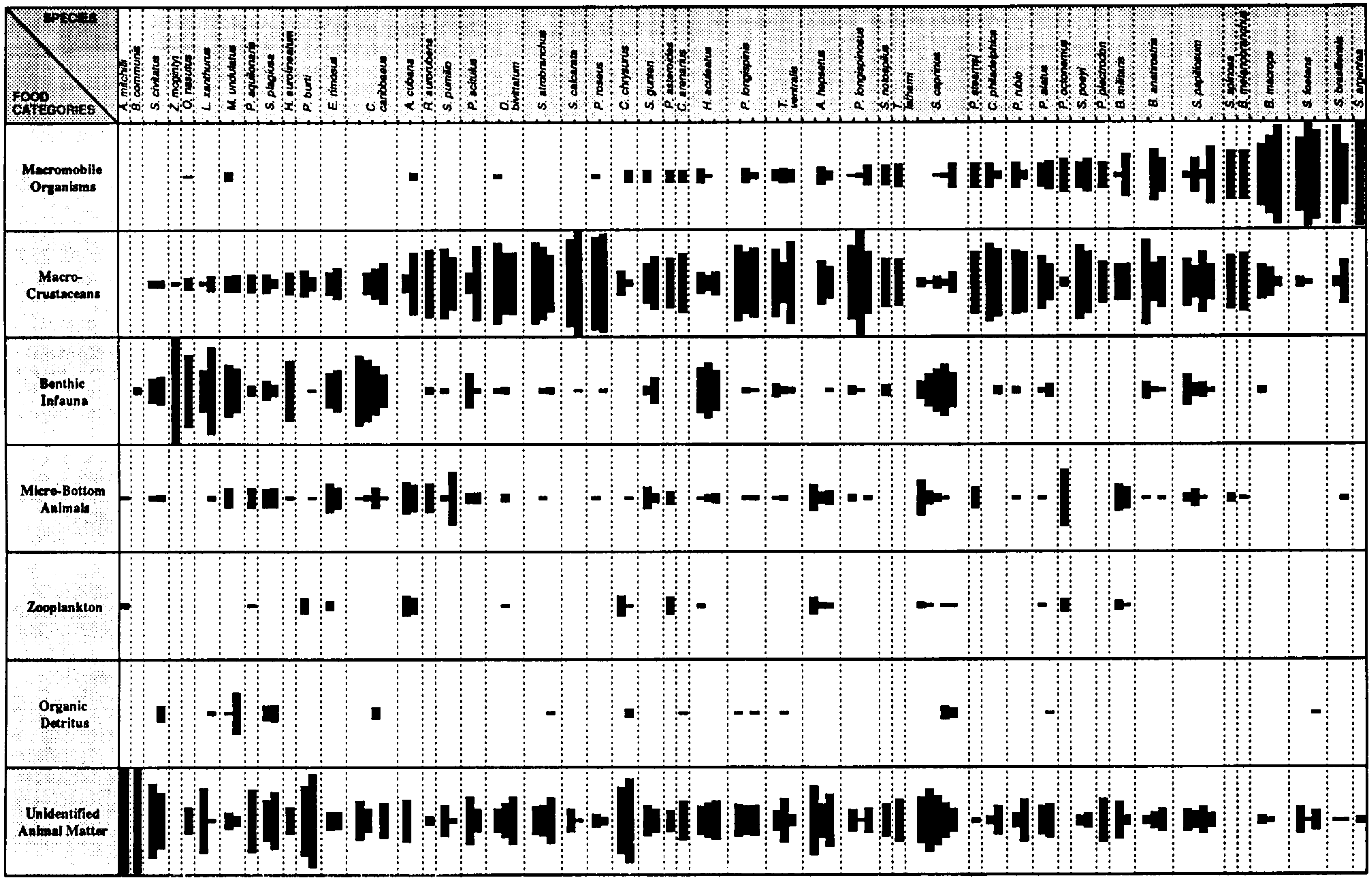


Figure 15-15. Trophic spectrum of the fish community of the Mississippi-Alabama continental shelf. Food categories are given along the left, and individual species are listed along the top. The vertical column beneath a species name provides information concerning food of the species (and size classes within a species). Dark vertical bars represent the percent volume of food observed in a particular food category. The sum of the heights of all the bars within a given spectrum equals 100%, which is also the standard height of each food category.

Organic Detritus

This was essentially vascular plant matter, generally in an advanced state of decomposition, and present as very fine particulate material. None was recognized as being *Spartina* detritus. This material constituted only 1.3% of the stomach contents and was undoubtedly ingested incidental to other feeding. Although rare in the stomachs of the fishes, organic detritus derived both from vascular plants and phytoplankton must be the chief food source for many small benthic invertebrates, and together with living phytoplankton it must be consumed in quantity by filter feeding species of the water column, as well.

Zooplankton

The zooplankton was arbitrarily defined as calanoid and cyclopoid copepods. Although recognized in over a quarter of the species examined, it was seldom important and made up only 1.5% of the total food. Despite its low representation, zooplankton is a very important link in the food chains of the shelf. Historical information clearly shows that if more very small specimens had been examined and if pelagic species had been included, the zooplankton would have stood out as one of the major food resources for the consumer species of the shelf. It would have represented the dominant food category for the larval and juvenile stages of many fish and invertebrate species and for the adults of such fishes as herrings, anchovies, silversides and some carangids and butterfishes.

Microbottom Animals

This group includes a variety of very small (≤ 1 mm) bottom invertebrates, especially small crustaceans (ostracods, harpacticoid copepods, cumaceans, tanaids, isopods, amphipods, crab megalopa, and anomurans). Although appearing in the food of three fourths of the fishes, these small invertebrates were important in the diets of only about 15% of the species. All told, micro-bottom animals made up 9.8% of the total food of the fishes examined.

Benthic Infauna

This group includes polychaetes and bivalves, the latter being rare in occurrence and never abundant in the food. Polychaetes were the dominant food of most batfishes, several flatfishes, longspine porgy and blackfin grenadier. They were also taken in quantity by the spot, Atlantic croaker, wenchman, Gulf Butterfish, leopard searobin, and duckbill flathead. Benthic infauna appeared in the food of two thirds of the species analyzed, and it was important in the diets of about one third. Altogether this group appeared to make up 13.3% of the food of the demersal species, but this is likely an underestimate. Polychaetes are digested very rapidly, and it is difficult to distinguish polychaete mucus from partially digested polychaete. Often the tube is ingested with the polychaete inside, further confounding the food analysis.

Macrocrustaceans

The macrocrustacean groups include shrimp, lobsters, crabs, and stomatopods, but small shrimp, including both larval and post-larval stages, made up by far the greatest portion of this material. Macrocrustaceans appeared in the food of all but two species, and this group was clearly the dominant food resource of the fish species examined. Thirty six percent of the food appeared in this category.

Macromobile Animals

This group included fishes and cephalopods, but the latter group was seldom present and never abundant. Macromobile organisms were observed in two thirds of the species analyzed, but they were the dominant food only in a deepwater gadid (*B. macrops*), inshore lizardfish, largescale lizardfish, and luminous hake. This group made up 15.0% of the total food. Historical studies evidence a much larger role for the macromobile species in the trophic structure of shelf communities. The poor showing in the present study relates to the fact that the larger carnivorous forms were not taken by the trawls, and this could reflect gear bias, availability or both. Nevertheless, it is certain that this group is far more important than indicated by the food analyses.

From the accumulated information it has been possible to construct a conceptual framework for food relations of the Mississippi-Alabama continental shelf (Figure 15-16). The various consumer groups appear to constitute three interrelated food chains, pelagic, supra-benthic, and

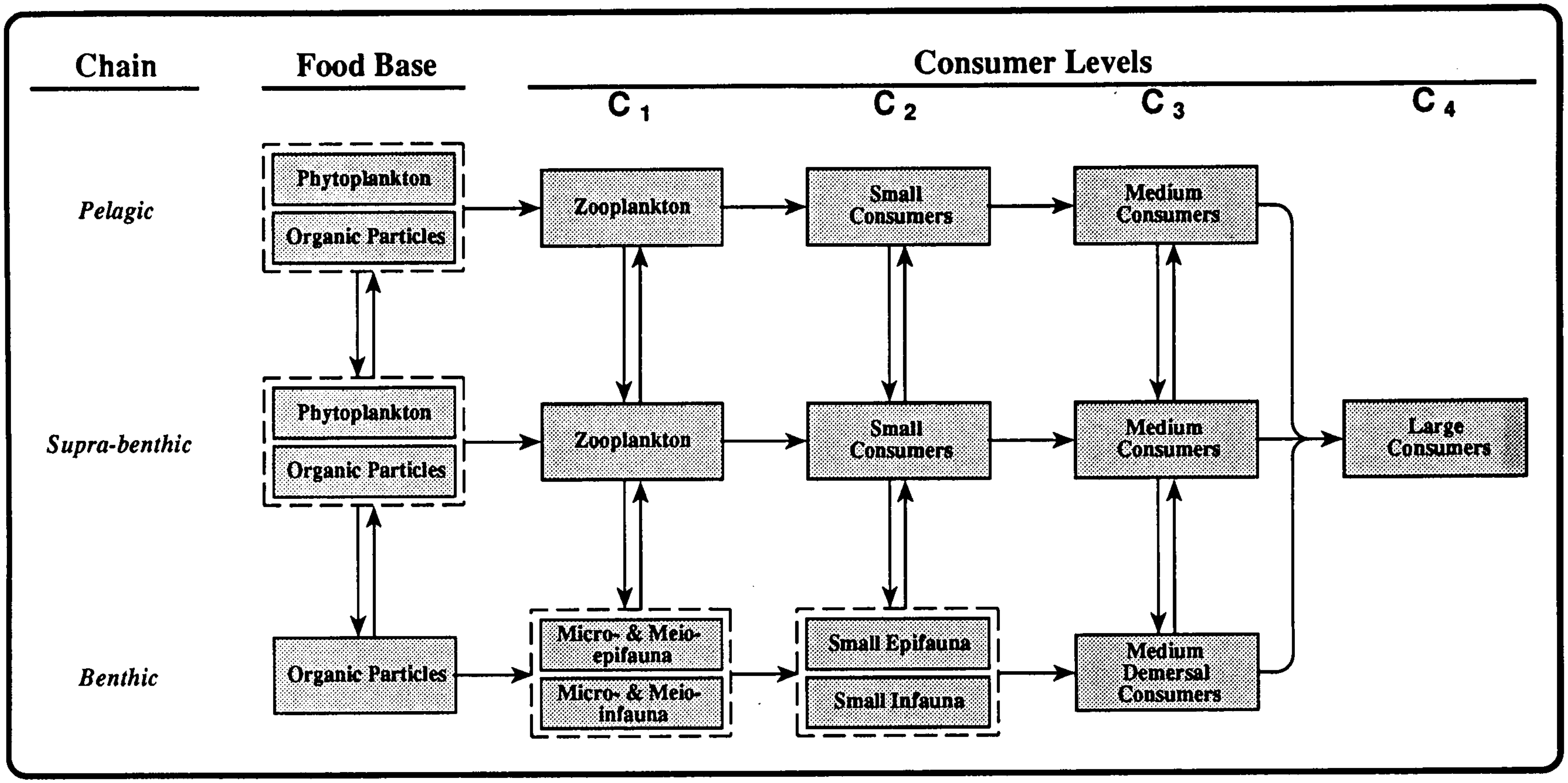


Figure 15-16. Conceptual model of the food chains of the Mississippi-Alabama continental shelf.

benthic. Traditional depictions of trophic relations in coastal waters generally show only pelagic and benthic food chains. The supra-benthic chain is added here because of the heavy dependence upon small shrimp, many of which appear to spend time above rather than on or in the bottom. Consumer species which feed upon the shrimp generally do not pick up quantities of sand and silt often observed in stomachs of the polychaete feeders.

The basic organic material which supports the consumer food chains is considered to be the phytoplankton together with fine non-living organic particles (organic detritus) derived from the phytoplankton and from terrestrial sources and coastal waters, transported to the shelf primarily during the spring and early summer. Living phytoplankton is available in the water column but only organic detritus is accessible to the bottom feeders. The first consumer level is made up of zooplankton (largely copepods) in the water column and a variety of small invertebrates (primarily small polychaetes and crustaceans) in the sediments. The second consumer level includes squids, shrimp, and young stomatopods, as well as larval and adult fishes which inhabit the upper and lower layers of the water column. Second level consumers of the benthos include larger polychaetes, crustaceans (shrimp, lobsters, small crabs, and small stomatopods), and a variety of fish species. Tertiary consumers were not well represented in the trawl samples. These include the fishes which feed upon macromobile species as well as some of the larger crabs and sea turtles. Nevertheless, there does appear to be a trophic step missing because the small fishes taken during the study are probably not the main food of the larger predatory species (sharks, snappers, groupers, jacks, mackerels, tunas, billfishes, and porpoises) which make up the top consumers of the shelf ecosystem. Thus, there appear to be four consumer levels rather than three, as is often depicted. A great deal of vertical migration takes place among the consumer species, and the three food chains are intimately connected with one another to form a three dimensional food web. Being agile swimmers, the top carnivores feed at all levels of the water column.

15.7.6 Evolutionary Considerations

The environment of the Mississippi-Alabama continental shelf undergoes regular seasonal changes which, due primarily to meteorological factors, may sometimes become extreme. In addition, major non-seasonal intrusive events, reflective of both meteorological and oceanographic factors, may occur singly or they may coincide to produce a sequence of extreme episodic conditions. Historical information has been cited demonstrating that the coastal waters which bound and provide nutrients to the shelf are also subject to seasonal and episodically extreme conditions. The question naturally arises as to how the biological species are able to cope and survive in an annually variable and unpredictably catastrophic environment.

In order to gain insight into the adaptability of the shelf species, life history data for seven fish species are presented in Table 15-52. One species, the hardhead catfish, has a short life span and does not produce pelagic eggs and larvae. The male retains the eggs in his mouth until the young can swim and fend for themselves. In this species the maximum number of eggs recorded for an adult female is only 104. The two non-estuary related species have short life histories, the eggs and larvae are pelagic, and adult females each produce up to 42,000-43,000 eggs. With the exception of the hardhead catfish, all the estuary related species are characterized by short life histories, pelagic eggs and larvae, and very large numbers of eggs per adult females, in the range of 324,000-1,075,000.

These life histories, and particularly the fecundities of the adult females, have been determined by genetic adjustment to selective pressures during past millennia, and the number of eggs per female is a rough measure of the chances of survival to adulthood of any given egg. Considering the fact that two parents are required for successful reproduction, the chances for the hardhead catfish are about one in fifty, for the non-estuary related species about one in twenty thousand and for most of the estuary related species they are roughly one in a hundred and sixty thousand to one in a half million. Except for the hardhead catfish, all the species produce pelagic eggs and larvae which are dispersed widely on the water currents. Most perish, but enough arrive in favorable habitats to keep the populations going year after year. Since the pelagic eggs and larvae may be swept along the

Table 15-52. Life history data for seven species of fishes common on the Mississippi-Alabama continental shelf. These are the only species for which egg production information is available.

Species	Max. length of life (yrs.)	Pelagic eggs/larvae	Max. number of eggs/female
Estuary related			
Atlantic croaker	3	yes	1,075,600
Spot	3	yes	514,400
Silver seatrout	1	yes	389,500
Sand seatrout	1	yes	324,900
Hardhead catfish	1	no*	104
Non-estuary related			
Longspine porgy	2	yes	43,100
Cutlassfish	2	yes	42,100

*mouth brooder

coast in the longshore currents, the species are capable of rapid recolonization of devastated areas. Fast growth rates and short life histories allow the species to reach adulthood and reproduce quickly thereby avoiding some of the ravages of predation and other vicissitudes of a hostile and capricious environment. Except for the hardhead catfish, these are in effect "weed species" with high capacity for maturation, reproduction, invasion and recolonization. These same traits characterize both the benthic infauna and most of the macro-epifauna. Such forms are what ecologists call "R-type" species as opposed to "K-type" species which inhabit stable and predictable environments. Despite the possibility of major set-backs during unfavorable years, the shelf species are quite resilient and are capable of bouncing back when favorable conditions are reestablished. Because of their life history adjustments these species have become long term survivors capable of existence under the variable physical conditions of the Mississippi-Alabama shelf environment. The remarkable thing is that so many species have made these adjustments.

15.7.7 Hard Bottoms and Topographic Features

Scattered rocky outcrops occur throughout much of the eastern half of the Mississippi-Alabama shelf, and they become more common in the vicinity of De Soto Canyon. In the depth range of 60-105 m hard bottom and topographic features are abundant and tend to occur in groups. Some are prominent features with elevations of up to 20 m above the surrounding plain, and they tend to fall along certain isobaths. These outcrops and elevations support hard bottom communities, and it is of interest to explore the ecological significance of such communities in the total biological economy of the continental shelf. Although no special studies were conducted on the functional processes and relationships of these particular hard bottom communities, from descriptive knowledge of these systems and by inference from similar systems elsewhere, a few conclusions may be reached.

In shallow water off Mobile Bay some of the hard bottoms support living algae which increase the primary productivity of the area. These particular outcrops also serve as spawning grounds for certain fishes such as the spot and Atlantic croaker. However, due to turbidity of the water and the depth factor, most of the hard bottoms of the shelf are not able to support photosynthetic plants except for some coralline algae which are virtually useless as a food supply for animals. Most of the hard bottoms support numerous suspension feeding organisms which extend a meter or more up into the water column. These structures intercept and retain much plankton and organic detritus which would otherwise be swept away. Some is consumed directly by the suspension feeders, but much more is precipitated in the relatively still waters around their bases providing habitat and a rich food supply for a variety of benthic and supra-benthic organisms. Many of these species are unique to the hard bottom communities. Thus, despite the fact that little primary productivity takes place here, the hard bottom communities greatly increase the biological productivity and species diversity of the shelf system, in general.

It has been shown that half the fish species encountered around the hard bottoms have also been taken by trawls from soft bottoms. Whether or not this ratio holds, it is likely that many invertebrates are also common to the two habitat types. This suggests that some of the smaller benthic and demersal species may move between the two areas, and it is certain that the top predatory species forage in both habitats. Thus, there is evidence for some ecological interdependence between the soft bottom and hard bottom communities of this shelf area.

Perhaps the most significant aspect of the hard bottoms and topographic features of the Mississippi-Alabama shelf lies in the fact that they form part of a chain or archipelago of such features lying at comparable water depths around the entire rim of the Gulf of Mexico and lower east coast and supporting similar biological communities. Located in a central position, they must facilitate genetic exchange between the faunas of such communities both to the east and to the west. Furthermore, lying directly in the path of Loop Current intrusions, these are likely the first hard bottom communities to be encountered by species transported from the Caribbean. Thus, they may at times serve as centers of dispersal for successful colonizers from the tropics. In these respects the hard bottoms and topographic features are of importance in terms of the larger Gulf of Mexico ecological system as a whole.

The zoogeographic significance of the Mississippi-Alabama hard banks may be illustrated by comparison of their ichthyofauna with that of the Flower Garden banks, off Texas and Louisiana, and of the Florida Middle Ground banks. As reported in Chapter 13, fishes of the Mississippi-Alabama banks have been studied for only a limited time and primarily by a single technique (underwater videocamera) supplemented by a few specimens from grabs, dredges, and hook-and-line capture. By contrast, the fauna of the other banks is much better known from longer term studies and by use of a variety of techniques. The fauna of the Flower Garden banks has been reported by Boland et al. (1983), Bright and Pequeqnat (1974), Cashman (1973), and Dennis (1985), and that of the Florida Middle Ground by Smith (1976) and Smith et al. (1975).

In any analysis of reef fish communities it is important to distinguish between primary and secondary reef species. As defined by Starck (1968) and refined by Smith (1976), primary reef species are those which are peculiar to reef environments or which appear to be attracted to such environments during at least some portion of their life history. These are the true reef inhabitants. Secondary reef species are those which appear to be only semi-resident or transient.

The primary reef fishes reported from the sets of banks are given in Table 15-53. A total of 157 species are listed, of which 125 species are known from the Flower Garden banks, 75 species from the Florida Middle Ground, and only 39 species from the Mississippi-Alabama banks. Secondary reef species are given in Table 15-54. Of the total list of 111 species, 66 were recorded from the Flower Garden banks, 53 from the Florida Middle Ground, and 31 from the Mississippi-Alabama banks.

Geographic affinities of the Mississippi-Alabama hard bank fishes are shown in Table 15-55. Among the primary reef species inhabiting the Mississippi-Alabama banks, 41.0% were shared with both the Flower Garden and Middle Ground banks, 28.2 % were in common only with the Flower Garden, and 17.9% only with the Middle Ground. Thus, 69.2% of the Mississippi-Alabama species were shared with the Flower Garden banks, and 59.9% were in common with the Middle Ground banks. Only 12.8% of the Mississippi-Alabama primary reef fishes were unique to the area. Among the secondary reef species, the percent commonality with the other banks was much lower and the percent endemicity was much higher. However, these incidental species are often much rarer, more seasonal, and more loosely associated with reef environments, and they are less likely to picked up by video cameras.

From the above analysis it is clear that in the northern Gulf of Mexico there is a pool of more than 150 species of primary reef fishes. Each bank is characterized by its own suite of species. The Flower Garden data suggest that the reef community composition varies somewhat from year to year so that only over a period of several years could observations reveal the true range of species and the dynamic nature of the reef fauna of any set of banks. The data at hand show that 87.2% of the primary reef species of the Mississippi-Alabama banks is shared with one or both of the other sets of banks, and this in turn suggests genetic exchange both westward and eastward. In the dynamic and highly variable physical environment of the northern Gulf, long term survival of the primary reef fish populations likely depends upon their ability to invade and colonize new reef habitats as conditions become more favorable elsewhere. "Island hopping" from reef to

Table 15-53. Primary reef fish species recorded from the Flower Garden banks (FGB), Mississippi-Alabama hard banks (MAB), and Florida Middle Ground (FMG). Definition of primary reef species and appropriate references are given in the text.

Scientific Name	Common name	Areas of occurrence		
		FGB	MAB	FMG
Moringuidae	Spaghetti eels			
Moringua edwardsi	spaghetti eel	X		
Xenocongridae	False morays			
Kaupichthys nuchalis	collared eel	X		
Muraenidae	Morays			
Enchelycore nigricans	viper moray	X		
Gymnothorax funebris	green moray	X		
Gymnothorax moringa	spotted moray	X	X	X
Muraena retifera	reticulate moray		X	X
Synodontidae	Lizardfishes			
Synodus synodus	red lizardfish	X		
Batrachoididae	Toadfishes			
Opsanus pardus	leopard toadfish			X
Antennariidae	Frogfishes			
Antennarius ocellatus	ocellated frogfish		X	X
Holocentridae	Squirrelfishes			
Holocentrus ascensionis	squirrelfish	X	X	X
Holocentrus bullisi	deepwater squirrelfish			X
Holocentrus marianus	longjaw squirrelfish	X		
Holocentrus poco	saddle squirrelfish	X		
Holocentrus rufus	longspine squirrelfish	X	X	
Holocentrus vexillarius	dusky squirrelfish	X		
Myripristis jacobus	blackbar soldierfish	X		X
Plectrypops retrospinis	cardinal soldierfish	X		
Aulostomidae	Trumpetfishes			
Aulostoma maculatus	trumpetfish	X	X	X
Fistulariidae	Cornetfishes			
Fistularia tabacaria	red cornetfish	X		

Table 15-53 (cont'd)

Scientific Name	Common Name	Areas of occurrence		
		FGB	MAB	FMG
Serranidae	Sea basses			
Epinephelus adscensionis	rock hind	X		X
Epinephelus cruentatus	graysby	X		X
Epinephelus drummondhayi	speckled hind			X
Epinephelus fulvus	coney	X		X
Epinephelus guttatus	red hind	X		X
Epinephelus inermis	marbled grouper	X		
Epinephelus moric	red grouper	X		X
Epinephelus nigritus	warsaw grouper	X	X	
Gonioplectrus hispanus	Spanish flag	X		
Hemanthias aureorubens	streamer bass		X	
Holanthias martinicensis	roughtongue bass	X	X	
Hypoplectrus unicolor	butter hamlet			X
Lipropoma eukrines	wrasse bass	X	X	
Liopropoma rubre	peppermint bass	X		
Mycteroperca bonaci	black grouper	X		X
Mycteroperca interstitialis	yellowmouth grouper	X		X
Mycteroperca microlepis	gag		X	X
Mycteraperca phenax	scamp	X	X	X
Mycteroperca tigris	tiger grouper	X		
Mycteroperca venonosa	yellowfin grouper	X		X
Paranthias furcifer	creole-fish	X	X	X
Serranus annularis	orangeback bass	X		
Serranus subligarius	belted sandfish			X
Serranus tabacarius	tobaccofish			X
Serranus tigrinus	harlequin bass			X
Priacanthidae	Bigeyes			
Priacanthus arenatus	bigeye	X	X	
Priacanthus cruentatus	glasseye snapper	X	X	
Pristigenys alta	short bigeye		X	X
Apogonidae	Cardinalfishes			
Apogon binotatus	barred cardinafish			X
Apogon maculatus	flamefish	X	X	X
Apogon pillionatus	broadsaddle cardinalfish		X	
Apogon pseudomaculatus	twospot cardinafish		X	X
Apogon townsendi	belted cardinalfish	X		
Phaeoptyx conklini	freckled cardinalfish	X		
Phaeoptyx xenus	sponge cardinalfish			X

Table 15-53 (cont'd)

Scientific Name	Common Name	Areas of occurrence		
		FGB	MAB	FMG
Carangidae	Jacks			
Caranx ruber	bar jack	X		X
Lutjanidae	Snappers			
Lutjanus apodus	schoolmaster	X		
Lutjanus campechanus	red snapper	X	X	X
Lutjanus cyanopterus	cubera snapper		X	X
Lutjanus griseus	gray snapper	X		X
Lutjanus jocu	dog snapper	X		X
Ocyurus chrysurus	yellowtail snapper	X		X
Pristipomoides aquilonaris	wenchman	X	X	
Rhomboplites aurorubens	vermilion snapper	X	X	X
Haemulidae	Grunts			
Haemulon aurolineatum	tomtate	X		X
Haemulon melanurum	cottonwick	X		
Haemulon plumieri	white grunt			X
Sparidae	Porgies			
Calamus bajonado	jolthead porgy			X
Calamus nodosus	knobbed porgy	X	X	X
Pagrus pagrus	red porgy	X		X
Sciaenidae	Drums			
Equetus lanceolatus	jackknife-fish	X		X
Equetus punctatus	spotted drum	X	X	
Equetus umbrosus	cubbyu	X	X	X
Mullidae	Goatfishes			
Mulloidichthys martinicus	yellow goatfish	X		
Pseudupeneus maculatus	spotted goatfish	X		
Chaetodontidae	Butterflyfishes			
Chaetodon aculeatus	longsnout butterflyfish	X		
Chaetodon aya	bank butterflyfish	X	X	
Chaetodon capistratus	foureye butterflyfish			X
Chaetodon ocellatus	spotfin butterflyfish	X	X	X
Chaetodon sedentarius	reef butterflyfish	X	X	X
Chaetodon striatus	banded butterflyfish	X		

Table 15-53 (cont'd)

Scientific Name	Common Name	Areas of occurrence		
		FGB	MAB	FMG
Pomacanthidae	Angelfishes			
Centropyge argi	cherubfish	X		X
Holacanthus bermudensis	blue angelfish	X	X	X
Holacanthus ciliaris	queen angelfish	X		X
Holacanthus tricolor	rock beauty	X		
Pomacanthus arcuatus	gray angelfish	X		X
Pomacanthus paru	French angelfish	X		X
Pomacentridae	Damselfishes			
Chromis cyaneus	blue chromis	X		X
Chromis enchrysurus	yellowtail reeffish	X	X	X
Chromis insolatus	sunshinefish	X		
Chromis multilineatus	brown chromis	X		
Chromis scotti	purple reeffish	X		X
Microspathodon chrysurus	yellowtail damselfish	X		
Pomacentrus fuscus	dusky damselfish	X		
Pomacentrus partitus	bicolor damselfish	X		X
Pomacentrus planifrons	threespot damselfish	X	X	
Pomacentrus variabilis	cocoa damselfish	X		X
Cirrhitidae	Hawkfishes			
Amblycirrhitus pinos	redspotted hawkfish	X		
Labridae	Wrasses			
Bodianus pulchellus	spotfin hogfish	X	X	
Bodianus rufus	Spanish hogfish	X		X
Clepticus parrai	creole wrasse	X		
Decodon puellaris	red hogfish	X		
Halichoeres bathyphilus	greenband wrasse		X	
Halichoeres bivittatus	slippery dick	X	X	X
Halichoeres caudalis	painted wrasse			X
Halichoeres cyanocephalus	yellowcheek wrasse		X	
Halichoeres garnoti	yellowhead wrasse	X		
Halichoeres maculipinna	clown wrasse	X		
Halichoeres radiatus	puddingwife	X		
Hemipteronotus novacula	pearly razor fish	X		X
Lachnolaimus maximus	hogfish	X		X
Thalassoma bifasciatum	bluehead	X		X

Table 15-53 (cont'd)

Scientific Name	Common Name	Areas of occurrence		
		FGB	MAB	FMG
Scaridae	Parrotfishes			
Scarus croicensis	striped parrotfish			X
Scarus taenopterus	princess parrotfish	X		
Scarus vetula	queen parrotfish	X		
Sparisoma atomarium	greenblotch parrotfish	X		
Sparisoma aurofrenatum	redband parrotfish	X		X
Sparisoma radians	bucktooth parrotfish			X
Sparisoma viride	stoplight parrotfish	X		
Sphyraenidae	Barracudas			
Sphyraena barracuda	great barracuda	X		
Opistognathidae	Jawfishes			
Opistognathus aurifrons	yellowhead jawfish	X		X
Clinidae	Clinids			
Emblemaria pandionis	sailfin blenny	X		
Labrisomus haitiensis	longfin blenny			X
Starksia ocellata	checkered blenny	X		
Blenniidae	Combtooth blennies			
Hypleurochilus bermudensis	barred blenny	X		
Ophioblennius atlanticus	redlip blenny	X		
Parablennius marmoreus	seaweed blenny			X
Gobiidae	Gobies			
Coryphopterus glaucofraenum	bridled goby			X
Coryphopterus thrix	bartail goby	X		
Gnatholepis thompsoni	goldspot goby	X		
Gobiosoma horsti	yellowline goby			X
Gobiosoma oceanops	neon goby	X		X
Lethrypnus nesiotes	island goby	X		
Lethrypnus phorellus	convict goby	X		
Lethrypnus spilus	bluegold goby	X		
Quisquilius hopoliti	rusty goby	X		
Risor ruber	tusked goby	X		
Acanthuridae	Surgeonfishes			
Acanthurus bahianus	ocean surgeon	X		
Acanthurus chirurgus	doctorfish	X		X
Acanthurus coeruleus	blue tang	X		

Table 15-53 (cont'd)

Scientific Name	Common Name	Areas of occurrence FGB	MAB	FMG
Scorpaenidae	Scorpionfishes			
Scorpaena plumieri	spotted scorpionfish		X	X
Scorpaenodes caribbaeus	reef scorpionfish	X		
Balistidae	Leatherjackets			
Aluterus scriptus	scrawled filefish	X		
Balistes capriscus	gray triggerfish	X	X	X
Balistes vetula	queen triggerfish	X		
Cantherhines macrocerus	whitespotted filefish	X		
Cantherhines pullus	orangespotted filefish	X		
Canthidermis maculatus	rough triggerfish	X		
Canthidermis sufflamen	ocean triggerfish	X		
Melichthys niger	black durgon	X		
Ostraciidae	Boxfishes			
Lactophrys polygonia	honeycomb cowfish		X	
Lactophrys triqueter	smooth trunkfish	X		
Tetraodontidae	Puffers			
Canthigaster rostrata	sharpnose puffer	X		X
Diodontidae	Porcupinefishes			
Diodon holocanthus	balloonfish	X		
Diodon hystrix	porcupinefish	X		
Total number of species		125	39	75

Table 15-54. Secondary reef fish species and occasional visitors recorded from the Flower Garden banks (FGB), Mississippi-Alabama hard banks (MAB), and Florida Middle Ground (FMG). Definition of secondary reef species and appropriate references are given in the text.

Scientific Name	Common name	Areas of occurrence		
		FGB	MAB	FMG
Lamnidae	Mackerel sharks			
Isurus oxyrinchus	shortfin mako	X		
Orectolobidae	Carpet sharks			
Ginglymostoma cirratum	nurse shark	X		
Rhincodontidae	Whale sharks			
Rhincodon typus	whale shark	X		
Carcharhinidae	Requiem sharks			
Carcharhinus falciformis	silky shark	X		X
Carcharhinus leucas	bull shark	X		X
Galeocerdo cuvieri	tiger shark	X		X
Rhizoprionodon terraenovae	Atlantic sharpnose shark	X		
Squatinidae	Angel sharks			
Squatina dumerili	Atlantic angelshark	X		
Dasyatidae	Stingrays			
Dasyatis americana	southern stingray	X		
Myliobatidae	Eagle rays			
Aetobatos narinari	spotted eagle ray	X		
Rhinoptera bonasus	cownose ray	X		
Mobulidae	Mantas			
Manta birostris	Atlanta manta	X		X
Muraenidae	Morays			
Gymnothorax nigromarginatus	blackedge moray		X	X
Nettastomatidae	Duckbill eels			
Hoplunnis macrurus	freckled pike-conger		X	

Table 15-54 (cont'd)

Scientific Name	Common Name	Areas of occurrence		
		FGB	MAB	FMG
Congridae	Conger eels			
Paraconger caudilimbatus	margintail conger			X
Ophichthidae	Snake eels			
Ahlia egmontis	key worm eel			X
Myrichthys acuminatus	sharptail eel	X		
Myrophis punctatus	speckled worm eel			X
Ophichthus gomesi	shrimpeel			X
Ophichthus ocellatus	palespotted eel		X	
Ophichthus ophis	spotted snake eel			X
Ophichthus rex	giant snake eel	X		
Clupeidae	Herrings			
Etrumeus teres	round herring			X
Sardinella aurita	Spanish sardine			X
Engraulidae	Anchovies			
Engraulis eurystole	silver anchovy			X
Synodontidae	Lizardfishes			
Synodus foetens	inshore lizardfish	X		
Synodus intermedius	sand diver		X	X
Synodus saurus	bluestripe lizardfish			X
Batrachoididae	Toadfishes			
Opsanus beta	gulf toadfish		X	
Antennariidae	Frogfishes			
Antennarius radiosus	singlespot frogfish	X		X
Histrio histrio	sargassumfish	X		
Ogcocephalidae	Batfishes			
Halieutichthys aculeatus	pancake batfish	X		
Ogcocephalus corniger	longsnout batfish		X	
Ogcocephalus nasutus	shortnose batfish		X	
Ogcocephalus radiatus	polka-dot batfish			X
Ogcocephalus vespertilio	longnose batfish	X		
Bregmacerotidae	Codlets			
Bregmaceros atlanticus	antenna codlet			X

Table 15-54 (cont'd)

Scientific Name	Common Name	Areas of occurrence		
		FGB	MAB	FMG
Gadidae	Codfishes			
Urophycis floridana	southern hake	X	X	X
Ophidiidae	Cusk-eels			
Lepophidium jeannae	mottled cusk-eel		X	
Exocoetidae	Flyingfishes			
Cypselurus cyanopterus	margined flyingfish	X		
Cypselurus exsiliens	bandwing flyingfish			X
Cypselurus melanurus	Atlantic flyingfish	X		X
Euleptorhamphus velox	flying halfbeak	X		X
Hemirhamphus brasiliensis	ballyhoo			X
Hirundichthys rondeleti	blackwing flyingfish	X		X
Parexocoetus brachypterus	sailfin flyingfish	X		X
Belonidae	Needlefishes			
Ablenes hians	flat needlefish	X		
Platybelone argalus	keeltail needlefish	X		
Tylosurus acus	agujon	X		
Tylosurus crocodilus	houndfish			X
Serranidae	Sea basses			
Centropristis ocyurus	bank sea bass	X	X	X
Centropristis philadelphica	rock sea bass	X		
Diplectrum bivittatum	dwarf sand perch		X	
Diplectrum formosum	sand perch			X
Epinephelus itajara	jewfish			X
Serranus atrobranchus	blackear sea bass	X		
Serranus phoebe	tattler	X	X	
Pomatomidae	Bluefishes			
Pomatomus saltatrix	bluefish		X	
Rachycentridae	Cobias			
Rachycentron canadum	cobia		X	X
Malacanthidae	Tilefishes			
Caulolatilus intermedius	anchor tilefish	X		
Malacanthus plumieri	sand tilefish	X		X

Table 15-54 (cont'd)

Scientific Name	Common Name	Areas of occurrence		
		FGB	MAB	FMG
Echeneidae	Remoras			
Echeneis naucrates	sharksucker	X		
Echeneis neucratoides	whitefine sharksucker			X
Carangidae	Jacks			
Caranx bartholomaei	yellowjack	X		
Caranx crysos	blue runner	X	X	X
Caranx hippos	crevalle jack	X		
Caranx latus	horse-eye jack	X		
Caranx lugubris	black jack	X		
Decapterus punctatus	round scad			X
Elagatis bipinnulata	rainbow runner	X		
Selar crumenophthalmus	bigeye scad	X		
Seriola dumerili	greater amberjack	X	X	X
Seriola rivoliana	almaco jack	X	X	X
Seriola zonata	banded rudderfish	X		
Trachurus lathami	rough scad	X		X
Coryphaenidae	Dolphins			
Coryphaena hippurus	dolphin	X		X
Lutjanidae	Snappers			
Lutjanus synagris	lane snapper			X
Lobotidae	Tripletails			
Lobotes surinamensis	tripletail		X	
Gerreidae	Mojarras			
Diapterus auratus	Irish pompano		X	
Sparidae	Porgies			
Calamus leucosteus	whitebone porgy	X		
Calamus proridens	littlehead porgy			X
Stenotomus caprinus	longspine porgy	X	X	
Sciaenidae	Drums			
Micropogonias undulatus	Atlantic croaker		X	
Mullidae	Goatfishes			
Mullus auratus	red goatfish	X		X
Upeneus parvus	dwarf goatfish	X		

Table 15-54 (cont'd)

Scientific Name	Common Name	Areas of occurrence		
		FGB	MAB	FMG
Ephippidae	Spadefishes			
Chaetodipterus faber	Atlantic parrotfish			X
Scaridae	Parrotfishes			
Nicholsina usta	emerald parrotfish			X
Mugilidae	Mullets			
Mugil cephalus	striped mullet	X		
Mugil curema	white mullet	X		
Polynemidae	Threadfins			
Polydactylus oetonemus	Atlantic threadfin	X		
Gobiidae	Gobies			
Ioglossus calliurus	blue goby	X		X
Trichiuridae	Cutlassfishes			
Trichiurus lepturus	Atlantic cutlassfish	X	X	
Scombridae	Mackerels			
Euthynnus alleteratus	little tunny	X		
Sarda sarda	Atlantic bonito		X	
Scomberomorus cavalla	king mackerel	X	X	X
Thunnus thynnus	bluefine tuna		X	
Stromateidae	Butterfishes			
Hyperoglyphe bythites	black driftfish			X
Nomeus gronovii	man-of-war fish	X		X
Peprilus bruti	gulf butterfish		X	X
Peprilus triacanthus	butterfish		X	
Scorpaenidae	Scorpionfishes			
Scorpaena brasiliensis	barbfish			X
Triglidae	Searobins			
Prionotus stearnsi	shortwing searobin	X		
Ballistidae	Leatherjackets			
Aluterus monoceros	unicorn filefish	X		
Monacanthus hispidus	planehead filefish	X		X
Monacanthus setifer	pygmy filefish	X		X
Xanthichthys ringens	sargassum triggerfish	X		

Table 15-54. (cont'd)

Scientific Name	Common Name	Areas of Occurrence		
		FGB	MAB	FMG
Ostraciidae	Boxfishes			
Lactophrys quandricornis	scrawled cowfish	X	X	X
Tetraodontidae	Puffers			
Sphoeroides spengleri	bandtail puffer		X	X
Diodontidae	Porcupinefishes			
Chilomycterus antillarum	web burrfish		X	
Chilomycterus schoepfi	striped burrfish		X	
Molidae	Molas			
Mola mola	ocean sunfish	X		
Total number of species		66	31	53

Table 15.55. Geographic affinities of fish species observed on hard banks off Mississippi and Alabama. The abbreviations area as follows: FGB = Flower Garden banks, MAB = Mississippi-Alabama banks, and FMG = Florida Middle Ground.

Species distribution patterns	Primary reef species		Secondary reef species	
	Number of species	%	Number of species	%
MAB, FGB, and FMG	16	41.0	7	22.6
MAB and FGB only	11	28.2	3	9.7
MAB and FMG only	7	17.9	5	16.1
MAB only	5	12.8	16	51.6
Totals	39	99.9	31	100.0

community as a whole. In this regard, the presence of the Mississippi-Alabama hard banks may present the key habitat link between the reef fauna of the northwestern and northeastern Gulf of Mexico.

15.8 Management Implications

Wise management of natural resources depends upon some knowledge of the resources being managed and the broader context within which these resources exist. It rests upon general information about how the system functions and specific knowledge of some critical particulars. Of special importance are knowledge about the baseline conditions at the beginning of the management period, special areas of sensitivity, general consequences of alternative management strategies, and extremes beyond which the system cannot be stressed without incurring irrevocable damage. Based upon knowledge gained from the present study as well as historical information, the following discussion will focus upon issues relevant to the management of resources of the Mississippi-Alabama continental shelf ecological system.

Normal Variation

Although some data gaps still exist, the present study has provided a reasonable baseline picture of the composition and the physical and biological dynamics of the shelf ecosystem. Information is available concerning the physics and chemical nutrients of the water column and characteristics of the sediments. Infaunal and epifaunal invertebrate and demersal fish populations have been delineated and interpreted within both areal and seasonal contexts. Some knowledge has been provided concerning the ranges of normal variation in the above factors. Salient features include the winter phytoplankton bloom, spring influx of dissolved and particulate matter from rivers and coastal waters, summer stratification without hypoxia, and summer and fall nutrient depletion of the water column and sediments.

Episodic Intrusion and Catastrophism

The study has demonstrated that meteorological and oceanographic forces subject the area to frequent major intrusive events. These include drought, storms and hurricanes, and Loop Current intrusions. Although the specific causal connections cannot yet be made, these factors, singly or in combination, have been shown to devastate the macro-epifaunal and demersal fish populations. Such major community changes due to extreme natural causes could confound efforts to assess the effects of human intrusion.

Biological Resilience

Subject to the annually variable and episodically catastrophic environment, biological species of the Mississippi-Alabama shelf exhibit extreme population fluctuations. However, as a result of long adaptive adjustments they are quite resilient and are capable of rapid and complete recovery from devastations brought about by natural causes. They should likewise be capable of rapid recovery from major short term human-induced mortality events.

Long-term Human-induced Pressures

During the past few decades the epifaunal invertebrates and demersal fish populations have been subject to increasingly severe pressure due to estuarine habitat deterioration and commercial and recreational fishing activities on the continental shelf. The increased pressure has been accompanied by reduced population densities of shelf fishes with differentially low populations of estuary related species. What the long term effects on the biological populations may be are not yet clear, but it does appear that further reductions in populations of these species due to oil and gas activities would be difficult to distinguish from mortality due to natural factors and to the long term human intrusions.

Chemical Pollution

Despite heavy chemical pollution of neighboring bays and estuaries, the continental shelf shows no real evidence of being polluted in terms of trace metals and high molecular weight hydrocarbons. Normal circulation patterns tend to retain pollutants within the estuaries, and strong water currents appear to sweep the shelf clean every few months. Any future contamination of the continental shelf by oil and gas development activities should be immediately detectable, but due to the dynamic physical environment the contaminant signal and any effects should be very short lived.

Topographic High Features - Areas of Special Concern

Larger topographic features in the depth range of 60-105 m support extensive development of hard bottom communities characterized by high biological production, high species diversity, and the presence of many species unique to the area. Such areas are demonstrably fragile and are certainly features of special concern. This is particularly true of the tallest features called pinnacles. The hard bottom communities appear to be sensitive to the effects of suspended sediments, and areas closest to the Mississippi River Delta are those most greatly affected. This influence extends eastward for up to 70 km from the Delta. Although all the hard bottom areas are of interest, those least influenced by Mississippi River effluent support the most diverse faunas and are the systems of greatest concern. These particular systems should be afforded special protection by federal agencies.

Research Needs

Many gaps still remain in our understanding of the Mississippi-Alabama shelf ecosystem, but not all of these are of equal concern from the management perspective. Several of the more salient knowledge gaps likely to be of management interest are addressed briefly below.

- There is a need to understand the relationships between water currents, depth, and transport of sediments of different particle sizes and densities. Besides the general ecological interest, such information would permit prediction of the fate of drilling effluents and other materials associated with oil and gas development activities. It would also have a direct bearing on some engineering matters such as pipeline burial.

- There is a need to develop a more thorough understanding of the effects of tropical storms, hurricanes, and Loop Current intrusions upon all aspects of the shelf environment and the biota. These major episodic events are of interest in relation to both ecological and engineering considerations.

- Studies should be conducted on factors associated with the development and maintenance of summer stratification. Such information would aid in understanding ecological conditions on the shelf during the late spring and summer. It would also aid in predicting the dispersal of surface and bottom effluents from drilling and possible bottom water hypoxia resulting from effluent release.

- Data from the present study have shown that with respect to the sediments, chemistry, biota and probably the water masses and currents the Chandeleur transect was unique and strongly influenced by the inshore waters and marshlands to the west and north. A more detailed study of the relationships between the shelf and these inshore waters and shorelands would aid in understanding the flow of water, nutrients, sediments, and biota between the various sectors of this complex area. Such studies would also provide information concerning possible routes and transport mechanisms of oil and gas related sediments and pollutants which could potentially affect the inshore waters, marshlands, and other valuable coastal habitats.

- Relationships of De Soto Canyon with surrounding continental shelf environments are poorly understood, but enough is known to suggest that the influence is quite significant. At certain times the Canyon appears to serve as a conduit funneling deep Gulf waters to the shallow shelf, inducing upwelling (Gaul, 1967). At other times it appears to guide filaments and eddies from the Loop Current shoreward where they may affect adjacent shelves (Huh et al., 1981). The Canyon bottom may serve as a funnel for the transport of shelf sediments to the deep Gulf. As a result of these and related processes, the water masses, sediments, and biota of this area are in many respects different from those further west. Increased knowledge of the De Soto Canyon area would likely show that it is unique in the northern Gulf and that due to its physical position and configuration, it guides water masses which greatly influence the ecology of neighboring continental shelves. Because of its special fauna and its likely influence on current patterns and transport processes, the De Soto Canyon area merits special research attention.

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