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The Deep-sea Fish Fauna of the Northern Gulf of Mexico

by

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Abstract

As a part of the Deep Gulf of Mexico Benthos (DGoMB) project, fishes were sampled in May and June 2000. 46 stations were occupied using a 41' semi-balloon otter trawl along transects which ran from shallow to deep water and from northern Florida to off southern Texas. 1073 individuals in 121 demersal fish species were taken. Cluster analyses showed the fish fauna is zoned with depth. Assemblages were identified on the shelf (188-216 m), upper slope (315-785 m), mid-slope (680-1359 m), lower slope (1780-2460 m), and the rise (2248-3075 m). The most abundant species found on the shelf was the small caproid *Antigonia capros*. Deeper, the fauna is dominated by Macrouridae: *Bathygadus macrops* and *Caelorinchus caribbaeus* on the upper slope and *Nezumia cyrano* and *N. aequalis* at mid-slope. The lower slope and rise are dominated by Ophidiidae: *Dicrolene kanazawai* and *Acanthonus armatus* respectively. Species richness is highest on the upper slope (53 species) and decreases with depth; the rise has 17 species. Abundance, too, is greatest on the upper slope, especially in the Mississippi Trough and DeSoto Canyon, and declines greatly with depth. Data on fishes support DGoMB hypotheses relating to depth zonation and east-west abundance, but, because of limited samples, are inconclusive for others. There do not appear to be species of commercial interest in the deep demersal fish fauna.

Introduction

The Deep Gulf of Mexico Benthos (DGoMB) project is an ongoing study to gain a better understanding of the deep-sea areas that will be potentially impacted by current and future exploration and production of fossil fuel reserves. The deep waters which are of concern range across the slope and rise of the Northern Gulf in depths from 200 to 3000 meters. The focus is on areas most likely to be targeted for exploitation however, in order to understand the biological communities in the region, areas outside the potential target sites are also sampled. The study will describe the present condition and distribution patterns in benthic and benthopelagic communities, and will determine the biological, physical, and environmental processes that influence their structure and function. In addition to their significance in the local situation, the results of the DGoMB study will provide useful material to compare and contrast the situation in the Gulf of Mexico with that of similar ocean basins elsewhere.

The deep-sea fauna of the Gulf of Mexico is not well known. Regular biological surveys did not begin until 1950, when the U.S. Fish and Wildlife Service began exploring fishing grounds (McEachran and Fechhelm, 1998). Pequegnat et al. (1990) conducted one of the few general deep-sea biological studies of the Gulf, and prior to this the true complexity of the region was not known. Among other things, that study identified three distinct physical environments in the Gulf with respect to temperature and salinity. A shallow zone occurred at a depth of 300 m to 600 m, an intermediate zone occurred between 600 and 1000-1200 m, and a deep zone ran from this depth down to the abyssal plain.

The Gulf of Mexico has some of the most complex bathymetry in the world, with.more than 90 basins and 7 submarine canyons (including the Mississippi Trough) in the northwestern part (Rowe and Kennicutt, 2000). Along the north, south, and east coasts of the Gulf the continental shelf is broad, ranging up to a width of 170 kilometers, but along the western portion it is much narrower, extending out to less than 13 kilometers in some places (Salvador, 1991). The DeSoto Canyon, an erosional valley, cuts through the northeastern continental shelf. East of this, the bottom is dominated by carbonate sediment, and drops steeply to the deep ocean across the Florida Escarpment (McEachran and Fechhelm, 1998). To the west the continental slope is much less steep and is covered with terrigenous sediment. The Sigsbee Abyssal Plain has seamounts formed from upward movement of salt through the sediments (Rowe and Kennicutt, 2000). Salt diapirs have altered the sedimentation pattern in the Gulf, and may be responsible for much of the very complex topography observed on the slope there.

Comprehensive ecological studies are needed specifically for slope and rise regions in the northern Gulf of Mexico to identify factors that may influence the fauna, including groups of potential commercial importance such as fishes. This is important because the region is rich in fossil fuel, and exploratory wells have been drilled there in water as deep as 2292 m (Salvador, 1991). Exploitation will occur in deep water if oil fields with commercial potential are found, so studies of the deep benthic ecosystem are needed in advance to investigate the likelihood of any significant and lasting ecological impacts.

Studies of deep demersal fish communities have been conducted worldwide, mainly concentrating on the shelf and upper slope. Environmental and biological differences between shelf and slope habitats are relatively large, and their fish faunas tend to be quite different (Bergstad et al., 1999). On the slope, fish species are generally found distributed within discrete vertical ranges (Merrett and Haedrich, 1997), and there is a zonation of entire fish assemblages with depth (e.g. Farina et al., 1997; Fujita et al., 1995; Merrett et al., 1991; Bianchi, 1992; Jacob et al., 1998). Fujita et al. (1995) concluded that the environmental variable causing faunal change with depth is difficult to specify. Jacob et al. (1998) found that the distributions of fish assemblages were related to environmental gradients including light level, oxygen content, pressure, and sediment properties (Cartes and Sarda, 1993; Gomes et al., 1992; Moranta et al., 1998). All vary with depth and furthermore may affect fish assemblages in different combinations that are not yet known (Connell and Lincoln-Smith, 1999). Temperature and salinity are also thought to play an important role in determining the zonation of faunal assemblages (Fujita et al., 1995; Jacob et al., 1998). Haedrich and Krefft (1978), reported fish assemblages changed in relation to a combination of depth and temperature. Stefanescu et al, (1993) determined there is high environmental stability in the Catalan Sea below a depth of 150 to 200 meters, for both temperature and salinity, but even so the deep-sea fauna show a pattern of zonation. So, beyond the physical factors alone, biological factors are also important for influencing the distribution of different faunal assemblages.

Biological factors that may influence faunal assemblage zones include resource availability, predator-prey relationships, and interspecific competition (Moranta et al., 1998; Anderson et al., 1985). Fish composition could be related to changes in other biota in a number of studies. An important food resource for demersal fish on the upper slope is the pelagic fauna (Gordon et al., 1995; Fujita et al., 1995). McClatchie et al. (1997) discovered the size and composition of demersal fish assemblages may be determined by the mesopelagic fauna in the area. Below a depth of 1200 m in the Catalan Sea, there is a large reduction in the trophic resources that are available for use (Stefanescu et al., 1993), and this is reflected in the diets of fish species in assemblage zones there. Available resources are less due to a decrease in the mean weight of the decapod crustaceans that figure in fish diets (Cartes and Sarda, 1993). Interspecific competition can be important because demersal fish species are generally higher in the food web, and competitive interactions between groups of species are stronger at higher trophic levels (Cartes and Sarda, 1993). This could lead to competitive exclusion of some species at deeper depths where food is in lower supply.

The Gulf of Mexico is often described as a Mediterranean-type sea (Pequegnat et al., 1990), and it is worth making some comparisons. In the Catalan Sea (Western Mediterranean) a declining trend in biomass but not abundance was found over a depth range of 1000-2250 m (Farina et al., 1997; Stefanescu et al., 1993: Moranta et al., 1998). In the Algerian Basin the same trend for demersal fish species is also found below a depth of 1100 m. Species richness declined with depth (Moranta et al., 1998; Farina et al., 1997). The Mediterranean Sea has high environmental stability in both temperature and salinity (Moranta et al., 1998; Cartes and Sarda, 1993; Stefanescu et al., 1993), which is not the case in the Gulf of Mexico. As is the case in the Gulf of Mexico, the upper and middle slopes are cut by several submarine canyons (Cartes and Sarda, 1993) and th topography is complex. The number of demersal species in the Mediterranean on the lower slope and deeper is much lower than the number reported for the North Atlantic, and the fauna of the Gulf of Mexico is more typical of that found in the deep-sea of the Atlantic Basin (Pequegnat et al., 1990).

The present study presents data on Northern Gulf of Mexico deep demersal fishes identified from a DGoMB research cruise on *R/V Gyre* that took place in May and June 2000. This paper analyzes the fish data, presents a picture of distribution patterns, and uses the data to examine some of the DGoMB's core hypotheses. These hypotheses are:

H_{01}: Variation in benthic fauna is best explained by depth
H_{02}: Faunas exhibit an East-to-West gradient
H_{03}: Basin faunas are different from Non-basin faunas
H_{04}: Canyon fauna are different from Non-canyon faunas

The DGoMB cruise was designed to sample the broadest range of relevant conditions at depths from 200 m to over 3000 meters. The main hypothesis is that the fauna varies with depth, and this was examined primarily with data arranged in shallow-to-deep transects. To test the east-to-west gradient, samples were used from stations at similar depths from transects in the east, central, and western portions of the Northern Gulf. Basin fauna and non-basin fauna, and canyon and non-canyon fauna were tested in a similar manner.

Materials and Methods

The data were obtained from bottom trawl catches made on a cruise of the RV *Gyre*. 46 stations were sampled between May 4 and June 18, 2000, in two legs. The first leg took place between May 4 and May 23, 2000 and the second leg between May 30 and June 18, 2000. A letter and number are used to distinguish between the sites. Sites denoted with a C are on the central transect, M are in the Mississippi Trough, and S are in the DeSoto Canyon and along the Florida Escarpment. Sites with a B are in basins, and those with NB are not; W is the western transect, and RW is the far west transect. By sampling this far to the west, the data can be used to enforce the distinction between the fauna in the east and the west found earlier by Pequegnat et al., (1990). A chart showing station locations appears in Figure 1; see also the website: http://www.gerg.tamu.edu/GERG/dgomb.htm.

To sample the megafauna, including fishes, 40' semi-balloon otter trawls (OTSB) with 2.5-inch stretch mesh were used. The OTSB is a commercial shrimp trawl that is towed on a single warp, and is opened hydrodynamically by the spreading of two steel otter doors (Merrett and Haedrich, 1997) or by 7' x 14' wooden doors (Rowe and Kennicutt, 2000), resulting in an effective mouth opening of 9 m. These trawls are widely used in Atlantic deep-sea sampling. At each station, CTD profiles were taken with a 12-bottle rosette cast to obtain data for routine water chemistry. Five full GOMEX sediment box cores from the bottom were sub-sampled for bacteria, meiofauna, macrofauna, geochemical and geological properties, trace metals, and trace organic contaminants.

Data were analyzed using the computer program packages MS Excel, NTSys, and MapInfo Professional. MS Excel was used to organize and store the data, NTSys was used for exploratory cluster analyses (Omori and Ikeda, 1984), and MapInfo was used to map the results. The data were first displayed in Excel spreadsheets, where they were formatted for use in other programs. Cluster analyses were used to determine relationships between stations and to establish faunal patterns (Bergstad et al., 1999; Cartes and Sarda, 1993; Bianchi, 1991). A common similarity index is the Bray-Curtis Dissimilarity index (Bergstad, 1990), and this was used in our analysis. The index ranges in value from 0 to 1, with 0 indicating that the stations are completely similar and 1 they are completely different (Krebs, 1999). Statistical analyses and comparative calculations, including Shannon-Weiner diversity (Krebs, 1999), were done using Excel. Data are archived with the DGoMB project office at Texas A&M University.

Results

General patterns

A total of 119 fish species comprising 1065 individuals were sampled in 37 trawl samples. A cluster analysis utilizing the Bray-Curtis Dissimilarity Coefficient was used to divide the stations into groups consisting of similar species (Figure 2). The cluster diagram suggests that the fish are divided by depth into five discrete assemblages. A zone on the deep shelf was found between depths of 188 m to 216 m, on the upper slope between 315 m and 785 m, on the mid-slope between 686 m and 1369 m, on the lower slope from 1533 m and 2735 m, and on the rise between 2248 m and 3075 m.

Sixty-six individuals from 16 species were caught in two stations on the deep shelf. The dominant species from this zone was *Antigonia capros*, which comprised 52% of the fish caught there. *Peristedion miniatum* comprised another 15%. The caproid *A. capros* inhabits near bottom areas between 64 m and 385 m in depth and is found in warm temperate to tropical waters (McEachran and Fechhelm, 1998). The other dominant shelf species, from the family Triglidae, is found in shallow water up to depths of 180 meters on muddy or sandy substrate (Scott and Scott, 1988). Both of the dominant deep-shelf fish are small (less than 300 mm) and feed mainly on crustaceans.

Five hundred and ninety-eight individuals belonging to 53 species were caught in 7 stations on the upper slope. The dominant species were *Bathygadus macrops*, *Caelorinchus caribbaeus*, and *Yarella blackfordi*, which comprised 9.4%, 8.9%, and 7.4% respectively of the total number of fish caught on the upper slope. Both *Bathygadus macrops* and *Caelorinchus caribbaeus* belong to the family Macrouridae. These species are generally found between depths of 200 to 750 meters in the sub-tropical to tropical Atlantic Ocean. These fish feed on invertebrates and other fish, and reach lengths of 500 and 300 mm respectively (McEachran and Fechhelm, 1998). The third dominant species on the upper slope belongs to the family Phosichthyidae. This lightfish is also found in the tropical and subtropical Atlantic Ocean and feeds on crustaceans; it reaches a length of 322 mm.

On the middle slope 38 species and 300 individuals were caught in 7 stations. The dominant species in this zone were *Nezumia cyrano* consisting of 23% of the catch, and *Nezumia aequalis*, which comprised 16%. Both of these are in the family Macrouridae. *Nezumia cyrano* is found in depths ranging from 640 m to 1324 m and feeds on invertebrates and fish. It reaches maximum lengths of 280 mm. *Nezumia aequalis* ranges from depths of 200 meters to 1000 meters and feeds on polychaetes, mysids, and amphipods (McEachran and Fechhelm, 1998). Its maximum size is 300 mm.

On the lower slope 54 individuals from 18 species were caught in 9 stations. *Dicrolene kanazawai* was the dominant species, consisting of 22% of individuals. This cusk-eel from the family Ophidiidae is found from depths of 2070 meters to 2367 meters in the Gulf of Mexico and Caribbean Sea. Its maximum length is 254 mm (McEachran and Fechhelm, 1998).

In the deepest zone, the rise, 47 organisms from 17 species were caught in 6 stations. Dominant species were *Acanthonus armatus* and *Bassozetus robustus*, comprising 19% and 15% respectively of the catch. *A. armatus* is found from depths of 1957 meters to 4417 meters, and is found in tropical seas worldwide. *B. robustus* is found in both the western Atlantic and western Pacific Oceans (McEachran and Fechhelm, 1998). Both species of fish are cusk eels (Ophidiidae), and feed on polycheates and crustaceans. They reach maximum sizes of 335 mm and 360 mm respectively.

The upper slope had the greatest abundance of fish, followed by the middle slope (Figure 3). The lower slope and the rise had the fewest fish. The geographical distribution of abundance is shown in the map of Figure 4. The greatest numbers of fish were found in the Mississippi Trough and DeSoto Canyon. Further west, the number of fish decreased and a decrease is also evident with increasing depth.

Species richness by zone is shown in Figure 5. The greatest number of species (53) was found on the upper slope. The number of species decreases with depth, with the lowest number (17) found on the rise. The highest number of species was found in the Mississippi Trough and DeSoto Canyon (Figure 6).

The diversity of species in each of the zones was calculated using the Shannon-Weiner index H'. The value of this so-called "dominance diversity" depends on how the relative abundances vary among the different species in each assemblage (Krebs, 1999). The highest diversity was found on the upper slope (Figure 7). The diversity on the middle slope, lower slope, and rise were similar. The shelf had the lowest species diversity.

Tests of DGoMB hypotheses

The fish data were used to test the hypotheses put forward for the DGoMB project. The first of these hypotheses is that *variation in benthic fauna is explained by depth*. The data, based on the results from the cluster analysis, are summarized in Table 1. The highest CPUE (number/hour) is found on the upper slope, as is the greatest number of species and species diversity. The lowest CPUE is found on the rise, but the mid-slope also has a low CPUE. To determine how depth plays a role, the percent overlap of species between zones was calculated. There was little overlap between the assemblages, indicating that these identified zones are well defined. The lowest overlap was between the shelf and upper slope, i.e. only 3.2%. The greatest overlap was between the lower slope and rise at 15.4%. These data strongly suggest that variation in the fish fauna is related to depth, and therefore support the hypothesis.

The second hypothesis stated that *fauna exhibit an east-to-west gradient*. Since the fish are zoned with depth, comparisons were made from east-to-west first in shallow water (shelf and upper slope) and second in deep water (mid-slope, lower slope, and rise). In the first analysis of the shallow areas, the Mississippi Canyon was also separated out. The results of the first analysis are summarized in Table 2. The catch was the highest in the canyon with 234 fish/hr, and lowest in the western region with 65.3 fish/hr. The number of species caught is highest in the east with 42 species and lowest in the central region with 15 species. Thus the highest species diversity is found in the east, and the lowest is found on the central transect. Diversity (H') on the western transect is higher than diversity in the canyon. The overlap between transects shows that each region is rather distinct, since these numbers are generally low. The highest degree of overlap is between the east and the canyon, with an overlap of 33.4%, and the lowest overlap is between the central and western transects, with an overlap of 9.9%. No noticeable east-west trend in the fish fauna could be detected, especially when the canyon is included, and therefore the shallow data do not support the hypothesis.

The canyon was not separated out during the examination of this hypothesis in deeper water because it cannot be readily identified at the greater depths. The results of a second east/west analysis are displayed in Table 3. From this analysis, the greatest CPUE was on the eastern transect, and the lowest was in the west. The eastern transect also had the greatest number of species, but the lowest was found in the central region. The highest diversity was also found in the eastern Gulf. Percent overlap of the three transects shows the east and west are the most similar, with 51.1% similarity. Therefore, the east and west are more similar to each other than either one is to the closer central transect. Nonetheless, values for the fish fauna in the east tend to be higher and there is a slight trend towards decline to the west, and therefore the deep data provide weak support for the hypothesis.

The third hypothesis states that *basin faunas are different from non-basin faunas*. To determine the validity of this statement stations in basins were compared to stations of similar depths that were not in basins. The results obtained from these comparisons are shown in Table 4. The number of fish caught, the number of species and the diversity is highest in the non-basin sampling areas. The overlap between the two areas is 31.3%. From the results, there is weak support for the hypothesis, since the non-basin areas have higher values. However, the number of stations used to test this hypothesis (6) is very low, and therefore the results are not definitive. Further sampling to test this hypothesis is needed.

The fourth hypothesis states that *canyon fauna is different from non-canyon fauna*. Table 5 summarizes the results of the analysis. The abundance of fish is greatest in non-canyon stations, although the number of species caught in the two areas is the same. Species diversity is very similar, 0.75 for canyon stations and 0.72 for non-canyon stations. Although these numbers are very similar, the percent overlap between the two areas is only 12.5%, indicating the taxonomic composition of the species present differs greatly. With respect to abundance and species present, the canyon fish fauna is different from the non-canyon, and therefore the hypothesis is supported. With respect to diversity however, the two places are the same, and on this basis the hypothesis is not supported. Here also the number of stations is very few (3), and the results cannot be considered definitive.

Discussion

The Northern Gulf of Mexico is characterized by five distinct demersal fish assemblages arranged according to depth. This zonation of fauna with depth has previously been found in other studies e.g. (Cartes and Sarda, 1993; Stefanescu et al., 1993; Moranta et al., 1998; Jacob et al., 1998). Cartes and Sarda (1993) found that deep-sea decapods were zoned with depth in the Catalan Sea. Moranta et al. (1998), also found fish zonation with depth on the continental slope of the Balearic Islands in the Mediterranean. Jacob et al. (1998) found the fish fauna off the coast of New Zealand was zoned with depth as it related to change in temperature. The depth zones from the current study also correspond to the depth zones found in the North Atlantic Basin (Haedrich and Merrett, 1988).

There were sixteen species caught on the deep shelf, and of these 13 (81.3%) were found only there. The reason for this high percentage on the shelf may be a artifact due to the few stations and small number of species caught. On the upper slope there were 53 species, with 36 (67.9%) endemic to this region. The highest level of endemism occurs on the rise, with 13 of 17 (76.4%) fish species found only there. On the middle slope *Nezumia cyrano* and *Nezumia aequalis* were dominant. A study by Hecker (1990) on the continental slope off the southern coast of New England also found *Nezumia* spp. dominant on the middle slope, defined as depths between 500 and 700 meters. The lower slope and rise were both dominated by species in the family Ophidiidae. Ophidiiforms are important members of demersal fish assemblages and can comprise 12% of the species found at deep depths (Merrett and Haedrich, 1997).

The abundance of fish is greatest at depths between 315 and 785 on the upper slope. In the eastern Pacific, Bianchi (1991) found the highest biomass was along the shelf- upper slope boundary. Fujita et al. (1995), found communities on the upper slope are characterized by high abundance, but low species diversity. In the current study, high abundance was also found on the upper slope, as was high species diversity. Lowest abundance was on the lower slope and rise. Decrease in fish abundance with depth is commonly reported from other study areas (e.g. Moranta et al., 1998; Farina et al., 1997; Fujita et al., 1995). Stefanescu (1993) found both the abundance of fish and available trophic resources decreased with depth. Hecker (1994) found the middle-lower slope had very low megafaunal densities overall.

The greatest fish abundance was found in the Mississippi Trough and DeSoto Canyon. These channels and troughs are typical features of areas with broad continental shelves (Bergstad, 1990), as is the case on the northern, southern, and eastern parts of the Gulf of Mexico. In the Balearic basin in the Mediterranean submarine canyons on the slope are known to exert an important influence on both the environment and megafaunal communities (Moranta et al., 1998).

Species richness is highest on the upper slope with 53 species. The mid-slope has 38 species, and this decreases at deeper depths, to 18 and 17 species on the mid-slope and lower slope respectively. The shelf has the lowest species richness, with only 16 species reported, although this is obviously too low. There is usually a maximum in species richness at mid-slope depths (Gage and Tyler, 1991). There is a general trend of fewer species at abyssal depths (Merrett et al., 1991), and this is the case in the current study. Species richness is greatest in the Mississippi Trough. The high number of species in this area may be the result of the influx of nutrients from the Mississippi River, leading to higher productivity and therefore an increase in available trophic resources. Canyons are generally productive areas and are therefore utilized by a wide range of fauna (Bergstad, 1990). Since there appears to be a higher productivity in canyon areas, there is also a greater abundance of potential food sources for demersal fish species. Although the diets of deep-sea fish are not well known, there is a lack of obvious food selection. With greater production in the canyon region, there is less competition for resources and thus a larger fish population with more species can be sustained.

The highest diversity (H') is found on the upper slope. This is in contrast to Fujita et al. (1995), who reported diversity on the upper slope off Japan to be low. The shelf has the lowest species diversity, possibly a result of limited sampling there. The mid-slope down to the rise have similar values for species diversity, ranging from 1.09 to 1.16. Diversity is reported to be higher in the deep sea than in shallow areas for benthopelagic fish (Gage and Tyler, 1991; Omori and Ikeda, 1984). The similar species diversity from mid-slope to the rise suggests that the uniformity of the environment increases with depth. The previous study of the Gulf by Pequegnat et al. (1990), found that species diversity in the northern Gulf decreased with increasing depth. Haedrich (1997) reported that in general the greatest fish diversity is founds in the depth range from 400 meters to 2000 meters.

The first DGoMB hypothesis states that faunal differences are explained by depth. The cluster analysis indicated that stations were grouped together according to depth on the basis of fish species present. The faunas in the zones identified were compared to determine how much overlap there was between them (Table 1). At all levels, the overlap was small, indicating that each zone was in fact distinct. The greatest similarity, between the lower slope and rise, was 15.4%. The least difference would be expected between these two zones, due to an increase in uniformity with depth.

The second DGoMB hypothesis expected there would be faunal differences along an east-to-west gradient. Due to the depth zonation of the fauna determined earlier, two comparisons were made. The first comparison in the shallow zone showed fish abundance was highest in the canyon and lowest in the west (Table 2), a fact that was obvious in individual maps of abundance. The different regions all have low percent overlap, indicating they are distinct from one another. High abundance in the canyon appears to be related to the high trophic resources that are available in the region. For the second comparison using deeper areas, the canyon was not separated, since it is not as distinct there (Table 3). In these deeper zones the central transect had the lowest species richness and species diversity. The fewer species in the central region as compared to the east and west may be due to the influence of the river. As shown in maps of trash distribution, there is a high abundance of trash in this region compared to others. There may be large amount of pollution flowing through this area, affecting the composition of fish assemblages. The east and west transects were similar to each other, with an overlap of 51.1%.

The third hypothesis tested for faunal differences between basins and stations at similar depths that were not in basins. There was little difference between the basin and non-basin in terms of fish fauna (Table 4). The abundance is very low in both, as well as the number of species. The percent overlap between the two areas is only 33.1% however, indicating that there is some difference in faunal composition between the two areas.

The final hypothesis dealt with the difference between fauna found in and outside of canyons. Demersal fish abundance is much higher in the Mississippi Trough than elsewhere, although the species diversity is lower than either the eastern or western regions. This indicates the dominance of a few species in the canyon as compared to other areas. Rowe and Kennicutt (2000) reported that intense inputs of organic matter, such as would occur in the canyon due to the influence of the river could decrease diversity due to competitive exclusion. On the lower slope and rise, there is little difference in community patterns in and out of the canyon. The CPUE of fish was 3.6 and 5.3 individuals/hr, with the non-canyon highest. Both areas have the same number of species, so there is little difference in the species diversity values. Although these parameters are very similar, the percent overlap is low (12.5%), indicating the species composition very different between the two areas. However, this is also part of the central region, which has previously been shown to have a low number of species, which may be a factor influencing the percent overlap.

Commercial fisheries are important on the Northern Gulf of Mexico shelf, and comprise 20% of the value of all US landings. The large volume fishery is for Gulf Menhaden (*Brevoortia patronus*), and stocks are fully utilized. This species is low in the food chain, and although the catch is large in volume it is low in value and produces mainly fish meal, oil, and soluble proteins (NMFS, 1995). The Atlantic croaker (*Micropogonias undulatus*) is another important but low value species; the stock is overfished, and is now most often taken as by-catch in other fisheries (Dagg et al., 2000). The highest value fishery in the Gulf of Mexico is the shrimp fishery, which has been pursued commercially on the shelf since the late 1800's. The fishery takes many non-target species such as red snappers (*Lutjanus campechanus*), croakers, and sea trout (*Cynoscion* spp) a by-catch. In one year approximately 7.5 billion Atlantic croaker were caught and discarded by shrimp trawlers (NMFS, 1995). The by-catch are juveniles and the shrimp fishery is a major source of mortality for the species involved.

So it would seem, like shelf fisheries everywhere, that those in the Gulf of Mexico will find themselves in trouble. As traditionally harvested fish species have declined in polar and temperate seas, there has been to a shift from the shelves towards exploitation of deep-sea fish on the slopes. In Newfoundland, the fishery for cod closed in 1992 and there was an attempted compensation by building a fishery for the deep-sea Greenland halibut (Hopper, 1995; Murawski et al., 1997), a large, schooling and abundant flatfish. There have also been similar attempts to establish slope fisheries for deep-sea species such grenadiers (Macrouridae), oreos (Oreosomatidae) and others in various parts of the world (Koslow et al. 2000).

Ours is the first study that has analyzed the deep-sea fish fauna in the Gulf of Mexico. An important finding is that none of the dominant fish are now commercial species, nor are they likely to be. Unlike slope species in more northerly, cool-water areas, the deep-sea fish in the Gulf of Mexico are small, apparently not particularly schooling, and quite low in abundance. Furthermore, there is no market demand for these unfamiliar species (Hopper, 1995). As a result, deep-sea fish in the Gulf of Mexico do not have the attributes that make for viable fisheries and are not likely to be targeted for future harvesting.

Conclusion

Fish assemblages in the Gulf of Mexico are zoned with depth. Species richness is highest on the upper slope and decreases with increasing depth. Fauna in the Gulf also show an east-to-west gradient, at least to some degree. At shallow depths, fish abundance was found to be higher in canyons than non-canyons, but the data was inconclusive for deeper depths on the lower slope and rise. No difference was found between fish caught in and out of basins. These data are also inconclusive due to the limited number of samples. Therefore, more samples need to be taken in and out of basins at similar depths and in and out of canyons at similar depths to make any conclusions between the fauna in these regions in the Gulf of Mexico. The fish assemblages on the slope and rise do not appear to contain species with any commercial potential.

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Table 1. Faunal differences by depth between zones, from a total of 34 stations.

Depth Zones					Hypothesis-1
	Shelf	**Upper slope**	**Mid-slope**	**Lower slope**	**Rise**
CPUE	52.8	170.9	74.8	5.0	5.5
Species	16	53	37	18	17
H' Diversity	0.80	1.45	1.13	1.16	1.09
% overlap	3.2	9.7	8.1	15.4	

Table 2. Faunal differences from east to west at shallow depths using data from 11 stations. The last value for overlap is between east and west.

Shelf / Upper slope				Hypothesis-2
	East	**Canyon**	**Central**	**West**
CPUE	148.0	234.0	196.0	65.3
Species	42	27	15	36
H' Diversity	1.32	1.14	0.81	1.28
% overlap	33.4	13.4	9.9	16.9

Table 3. Summary of faunal differences from east to west at deep depths using data from 15 stations.

Lower Slope/Rise			Hypothesis-2
	East	**Central**	**West**
CPUE	8.1	4.0	3.4
Species	21	10	17
H' Diversity	1.23	0.94	1.13
% overlap	30.8	24.1	51.1

Table 4. Faunal differences between basins and non-basins using six stations.

Lower slope	Hypothesis-3	
	Basin	**Non-basin**
CPUE	2.3	4.0
Species	6	8
H' Diversity	0.73	0.86
% overlap	31.3 %	

Table 5. Faunal differences between stations in and outside of canyons using data from 3 stations.

Lower Slope/Rise	Hypothesis-4	
	Canyon	**Non-Canyon**
CPUE	3.6	5.3
Species	6	6
H' Diversity	0.75	0.72
% overlap	12.5 %	

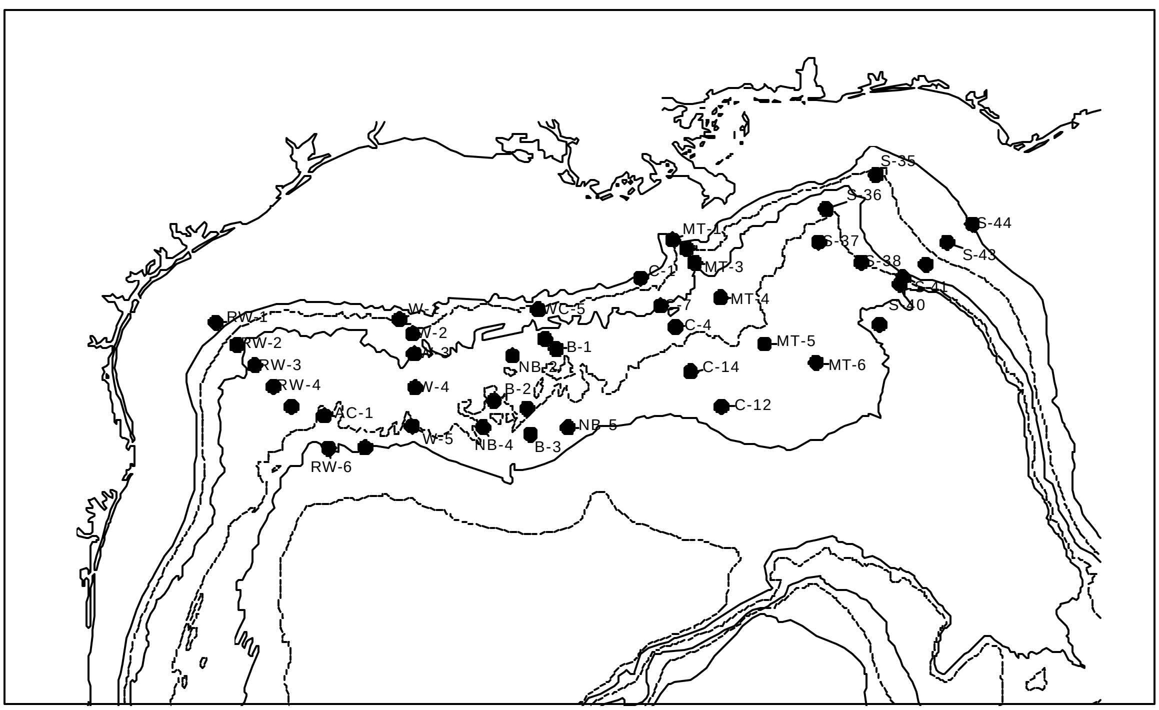

Fig. 1. DGoMB stations in the northern Gulf of Mexico, *R/V Gyre* May-June 2001.

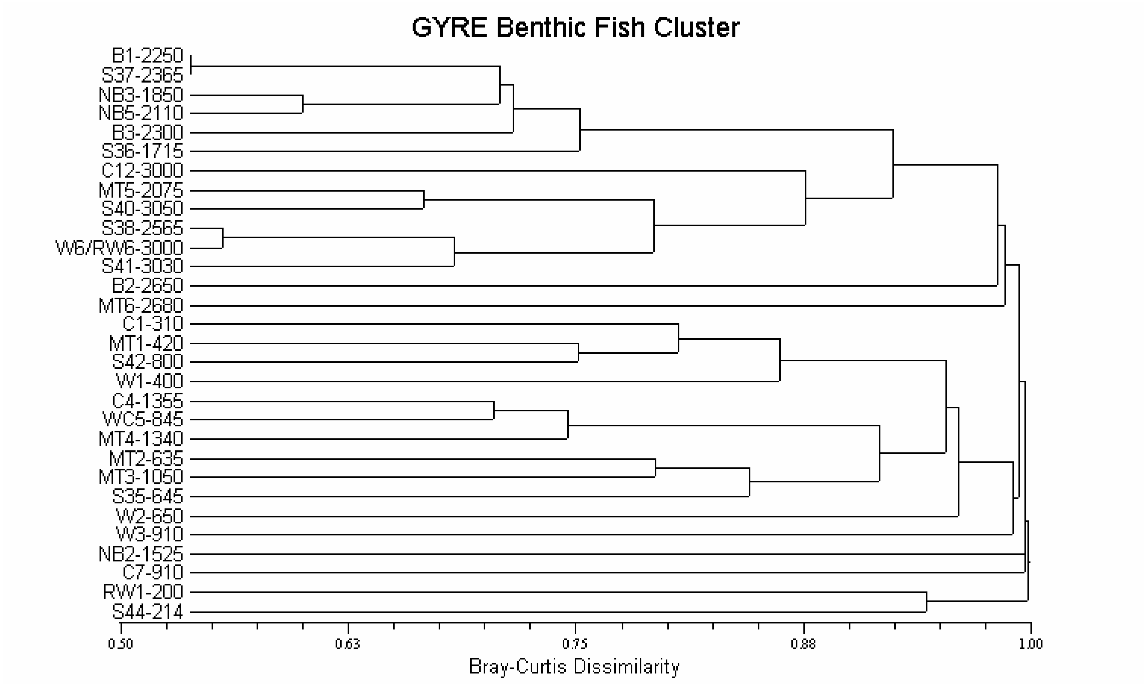

Fig. 2. Cluster analysis of DGoMB stations. Demersal fish data compared with the Bray-Curtis Dissimilarity Coefficient. Labels are station designation and mean depth.

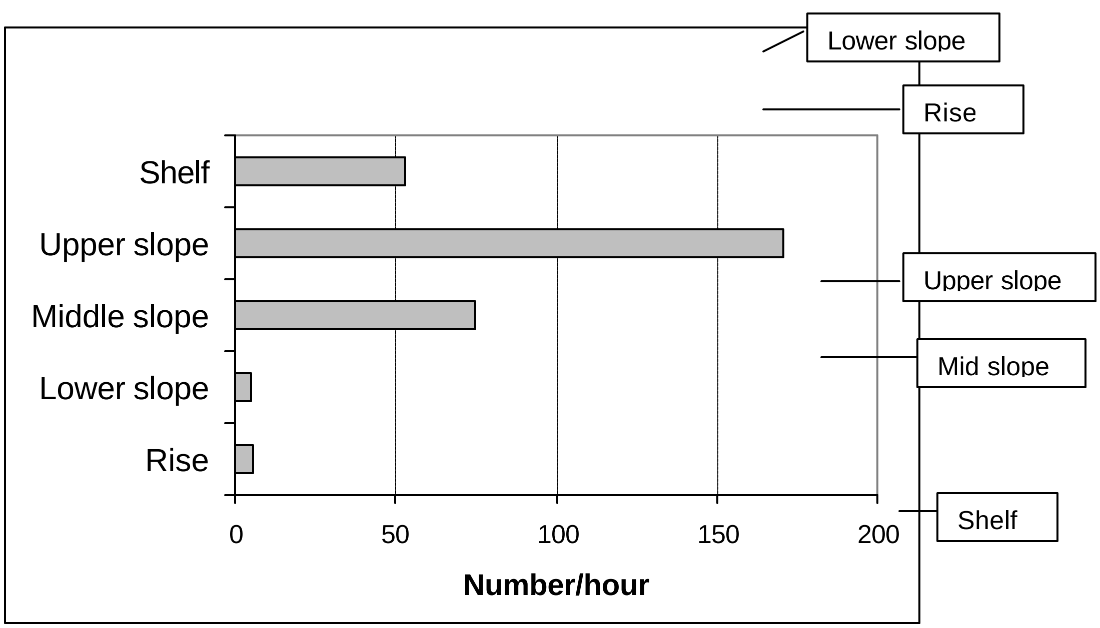

Fig. 3. Abundance (number/hr) of the fish fauna in each of the five depth zones.

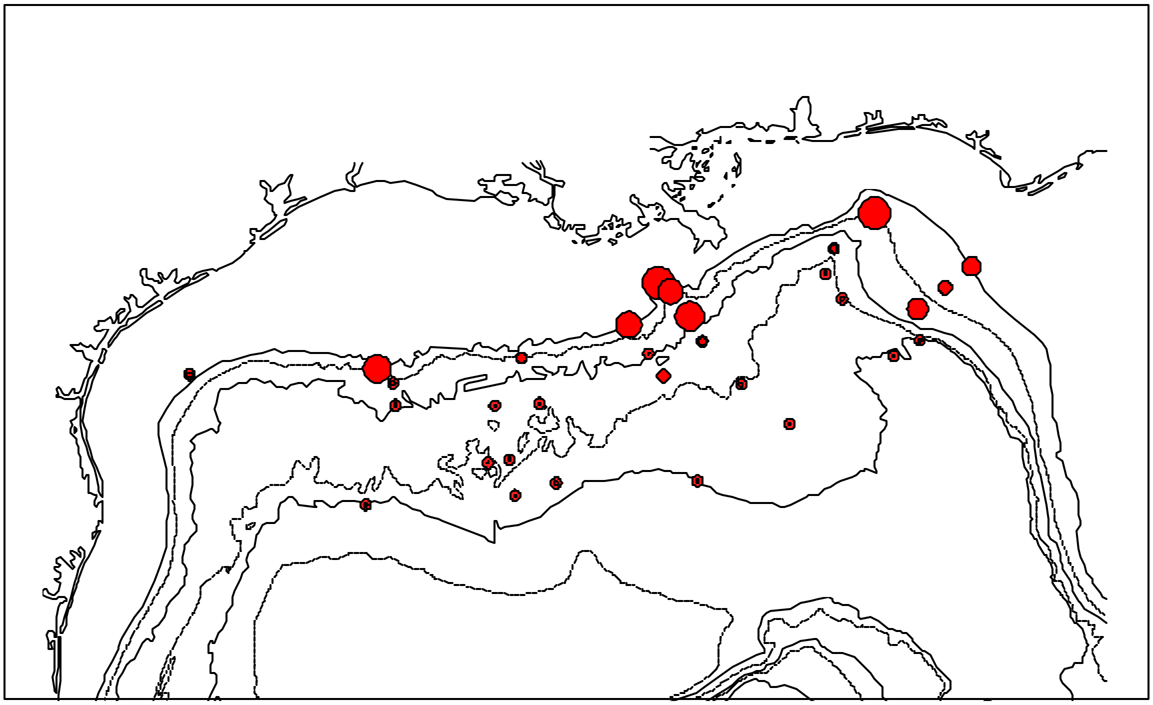

Fig. 4. The abundance of fish at each DGoMB station, scaled as the log of the number/hr. The largest dot is equivalent to a CPUE of 290 fish/hr.

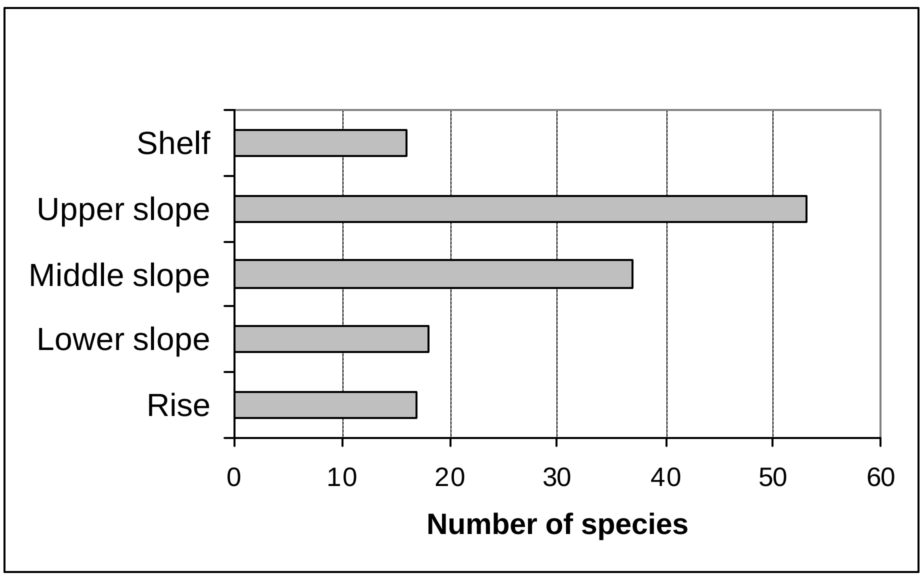

Fig. 5. Species richness of the fish fauna in each of the five depth zones.

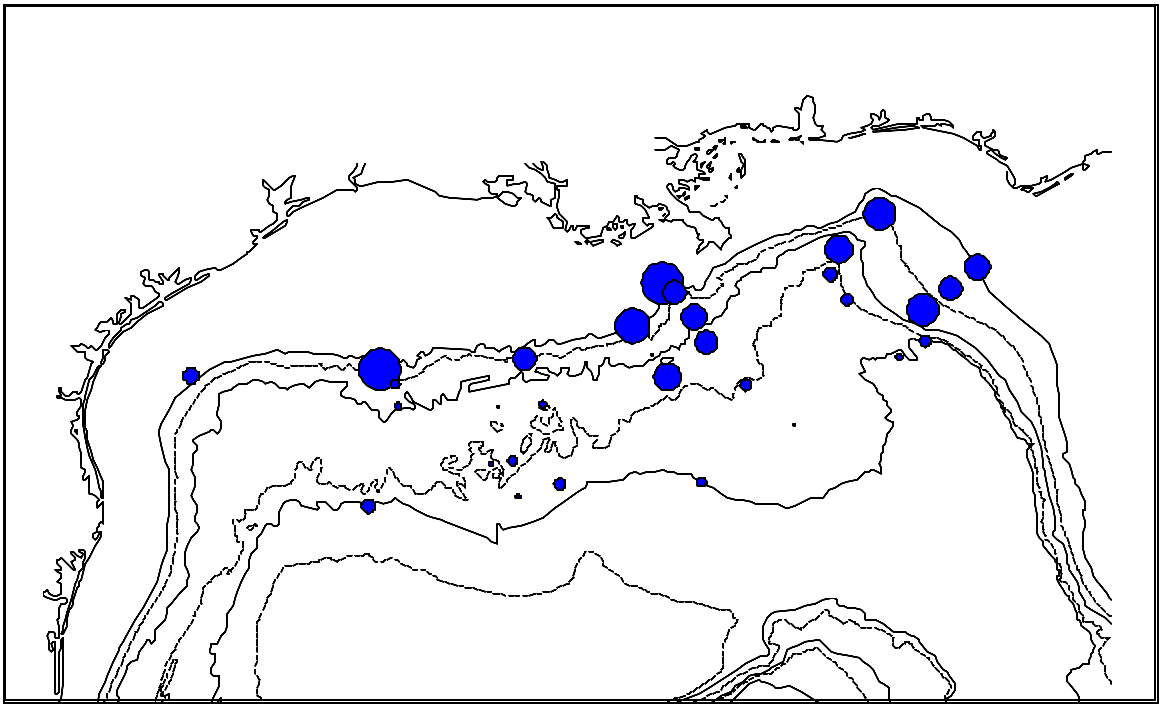

Fig. 6. Species richness of fishes at each DGoMB station, scaled directly to the number of species. The largest dot is equivalent to 18 species.

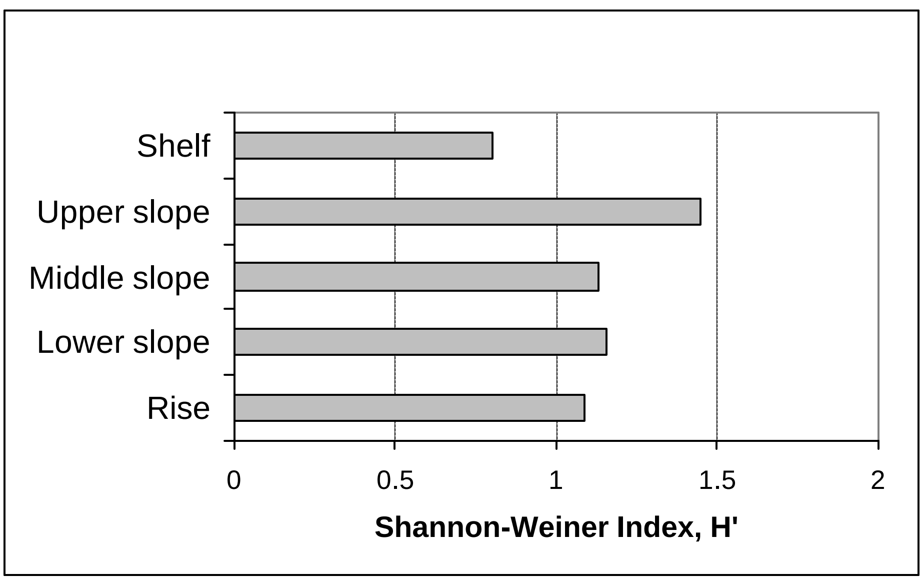

Fig. 7. Species diversity (H') of the fis h fauna in each of the five depth zones.