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Taxonomic Composition and Relative Frequency of the Benthic Fish Community Found on Natural Sand Banks and Shoals in the Northwestern Gulf of Mexico. (A Synthesis of the Southeast Area Monitoring and Assessment Program's Groundfish Survey Database, 1982-2000)

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USGS OUTER CONTINENTAL SHELF ECOSYSTEMS STUDY PROGRAM
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MMS

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Cover page illustration:
Bonnethead shark, *Sphyrna tiburo*, collected in the center of Sabine Bank (Station Number: Sabine 2003-01-066).

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Project Cooperation

This study was undertaken to meet information needs identified by the Department of the Interior, U.S. Geological Survey (USGS), Outer Continental Shelf Ecosystem Program in concert with the Minerals Management Service (MMS).

Disclaimer

This report was prepared under the direction of, and in collaboration with, the Florida Integrated Science Center, Center for Aquatic Resource Studies, of the USGS. This report has been technically reviewed by USGS and MMS, and has been approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the USGS or MMS, nor does mention of trade names or commercial products constitute endorsement or recommendation for future use.

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INTRODUCTION

The structured environments created by ridge and shoal features on the continental shelf have been found to provide a distinctive habitat when compared to more homogeneous flat bottom (Cutler & Diaz, 2000), and are potential essential fish habitat (EFH). Sediment-based microhabitats are centered upon differences in sediment grain size, sorting, and chemistry (e.g., redox potentials). Benthic infauna and epibenthic invertebrate communities have been found to be influenced by the availability and spatial distribution of sediment types (see review in Brooks et al. 2004). Alteration of these microhabitats (e.g., meteorological disturbance, anthropogenic disturbance) could have not only a direct impact upon the resident benthic invertebrate community, but higher level trophic impacts. Many demersal fish species have sediment-based habitat preferences and rely upon the resident benthic invertebrate community as a food resource (Kaiser et al., 1999; Rijnsdorp & Vingerhoed, 2001; Rooker et al., 2004; Szedlmayer and Conti, 1999). Beach restoration projects along the Gulf coast of the United States often exploit sand deposits found in these natural offshore banks, thereby disturbing potentially important benthic habitat.

The habitat value of natural sand banks in the northwestern Gulf of Mexico may not be equal across all areas due to seascape differences in freshwater/nutrient input, depth, currents, and/or water chemistry. For example, shallow areas located off of the Mississippi River mouth are known to consistently experience hypoxic conditions (< 3.0 mg O_2/L) during parts of the year. Sedimentary environments may also differ due to variance among areas in hydrology and particle source. Thus, sandy areas of the continental shelf provide a heterogeneous landscape characterized by differences in sediments, energy regime, and water chemistry (Bergen et al., 2001; Sisson et al., 2002). A summary of the biological communities which utilize this habitat is needed in order to assess any potential long-term impacts which might result from sand mining activities.

One source of long-term information concerning demersal fish use of the Gulf of Mexico's continental shelf is the Southeast Area Monitoring and Assessment Program (SEAMAP). The SEAMAP program is a component of the National Marine Fisheries Service (NMFS), a branch of National Oceanographic and Atmospheric Adiministration (NOAA), and was created in March 1981 when NMFS and the Southeast Fisheries Science Center (SEFSC) proposed to begin a long term survey of United States waters of the Gulf of Mexico to establish a commercial and recreational fishery-independent database. The types of data which are collected as part of the program are environmental data along with plankton, shrimp, groundfish, and reef fish surveys.

Objective:

The main objective of this summary was to analyze the SEAMAP database to determine the taxonomic composition and relative frequency of the fish community collected from the following natural sand banks: Heald Bank (Texas), Sabine Bank (Texas), Tiger Shoal (Louisiana), and Trinity Shoal (Louisiana).

Specific Questions:

The database was summarized to address the following questions regarding groundfish use of natural sand bank areas:

- What commercially and non-commercially exploited species are found in these areas?
- Does a distinct fish community exploit these areas?
- Is taxonomic composition and relative frequency constant among all banks?
- Is taxonomic composition and relative frequency constant between seasons (summer vs. winter)?

METHODS

SEAMAP data was obtained from the Pascagula NMFS office for the time frame of 1982 through 2000. Specifically the groundfish survey and associated environmental data were aquired. The sampling methods for groundfish surveys have been slightly modified throughout the years from the methods described in the 1982 SEAMAP Environmental and Biological Atlas of the Gulf of Mexico (Stuntz, et al 1985). In general, the method was to trawl randomly chosen sites within shrimp statistical zones 11-20 (Figure 1) as described in the SEAMAP Environmental and Biological Atlas of the Gulf of Mexico 1998 (Rester, et al. 2000). Trawls were made in both summer (June – August) and fall (October – November). NMFS vessels from Alabama, Mississippi, and Louisiana all used a 12.2 m net, while those from Texas used a 6.1 m net. Single tows went for a minimum of 10 minutes and a maximum of 60 minutes; in some cases a series of tows was necessary to cover the entire depth stratum of a station. The method used to cover a station's entire depth stratum in the water column is shown in Table 1. Water chemistry was also monitored during trawling; bottom dissolved oxygen levels (ppm), temperature (ºC), and salinity (psu) were examined in this study.

For this study, groundfish survey data were extracted for four natural sand banks and two control areas located in federally protected waters (Table 2). Heald (29^{o} 08.047 N, 94^{o} 10.562 W) and Sabine Banks (29^{o} 26.164 N, 93^{o} 48.617 W), which are located off of Texas, and Tiger (29^{o} 23.6 N, 92^{o} 04.181 W) and Trinity Shoals (29^{o} 12.5 N, 92^{o} 10.8 W), which are located off of Louisiana, were included within the boxes (Figure 2). Additionally, two control boxes were

selected, one directly south of Trinity and Tiger Shoals (i.e., eastern control area) and one southwest of Sabine and Heald Banks (i.e., western control area). The control areas did not encompass any previously identified zones considered to contain exploitable sand resources. Fish species listed as caught in the database were classified into one of four different habitat resource categories (pelagic, benthic, pelagic with benthic food, or temporary benthic) based upon published reports of habitat use patterns. Specifically, habitat classifications were based upon species descriptions from *Peterson Field Guides: Atlantic Coast Fishes* (Robins & Ray, 1986) and *Fishes of the Gulf of Mexico, Volume 1* (McEachran & Fechhelm, 1998).

Figure 1. Shrimp statistical zones described in the SEAMAP Environmental and Biological Atlas of the Gulf of Mexico 1998.

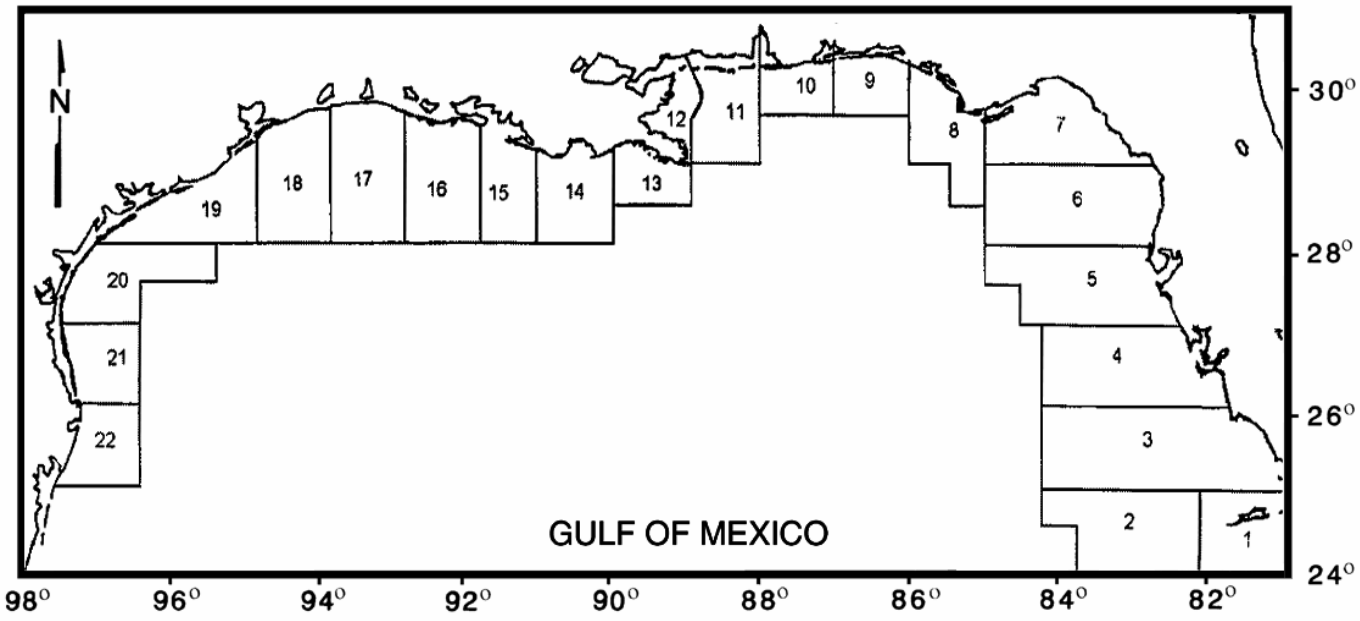


Table 1. The depth intervals used to trawl at different depth ranges.

Bottom Depth (m)	Depth Interval of Trawling
9.14-36.58	1.83
36.58-40.23	3.66
40.23-45.72	5.5
45.72-91.44	9.14
91.44-109.73	18.29

Figure 2. A map displaying the location, shape, and relative size of the four sand bank/shoal study areas.

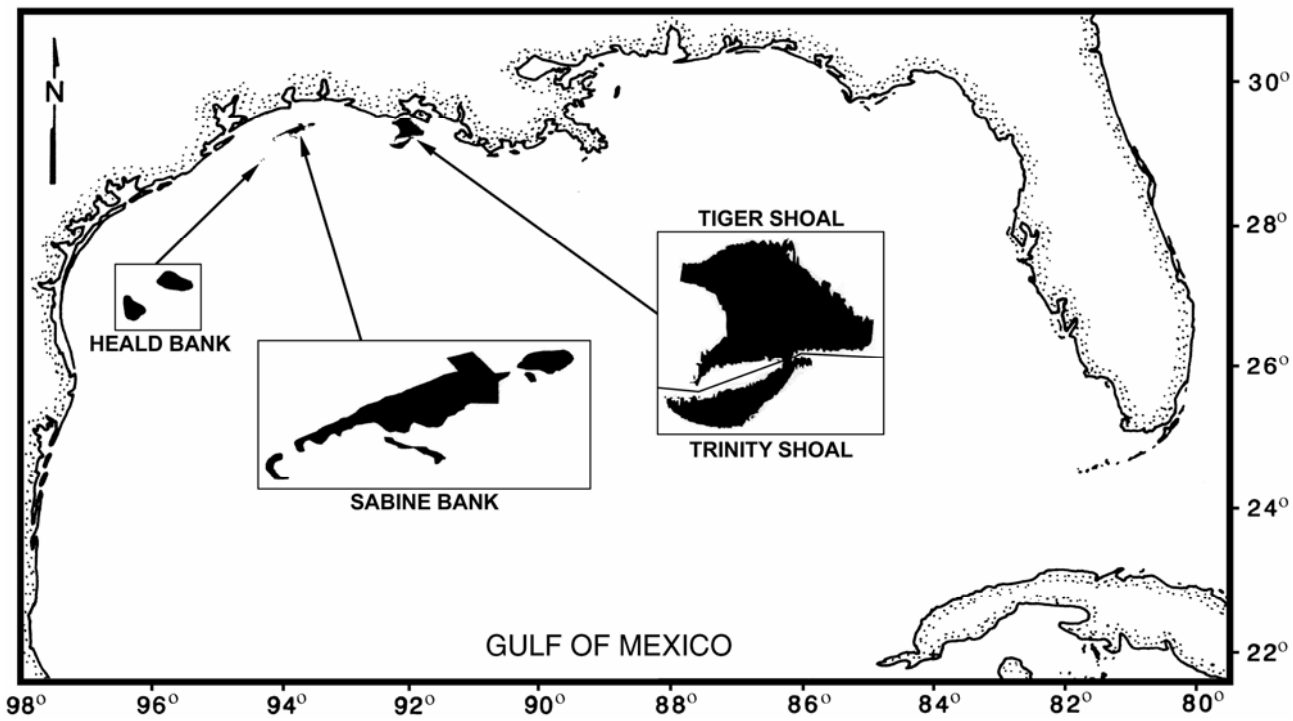


Table 2. The boxes from which the SEAMAP data was requested in relation to the bank or shoal they encompassed. Coordinates are given in WGS 1984.

Bank/Shoal	Top of Box (Latitude)	Bottom of Box (Latitude)	Right Side (Longitude)	Left Side (Longitude)	Depth Range (m)
Heald Bank	29º15.00 N	29º00.00 N	93º50.00 W	94º20.00 W	6-21
Sabine Bank	29º33.00 N	29º15.00 N	93º33.00 W	94º05.00 W	10-20
Tiger Shoal	29º30.00 N	29º17.50 N	91º50.25 W	92º30.00 W	4-12
Trinity Shoal	29º17.50 N	29º00.00 N	91º50.25 W	92º30.00 W	2-26
Eastern Control Area	29º00.00 N	28º30.00 N	91º59.00 W	92º45.00 W	20-52
Western Control Area	28º50.00 N	28º30.00 N	94º05.00 W	94º20.00 W	18-40

If a habitat use description was not given for an individual species, then that species was classified based upon the description given at the next higher taxonomic level, usually Family. The following guidelines were adhered to when assigning each fish species to one of the four categories:

- *Benthic* – Based on the definition, "Bottom-dwelling; occurring on the sea floor, whether shallow or deep water." (Robins & Ray, 1986).
- *Temporary Benthic* – If only part of the species lifecycle is benthic. For example, if the juveniles are pelagic but the adults are benthic.
- *Pelagic* – Defined in *Peterson Field Guides: Atlantic Coast Fishes* (Robins & Ray, 1986) as "Living in open waters away from the bottom."
- *Pelagic with Benthic Food* – A pelagic species who commonly preys upon benthic organisms. For example, filefishes (*Aluterus sp*.), are not considered to be benthic, but they feed on benthic organisms such as soft-bodied invertebrates and sponges.

For this summary, we were only interested in species that utilized the benthos either for habitat or feeding during at least some part of their lifecycle. Therefore, pelagic fish were clipped from the data set prior to analysis. Stations, where fish data were not available, were also removed as. In such cases, it was unclear whether data were unavailable due to trawl malfunction or the trawl worked but the catch was zero.

General trends in benthic fish abundance were examined using listed values of fish abundance and biomass (kg) per trawl. Individual species-specific trends were examined using the catch frequency (c.f.) for that species. Listed values of individual species abundances were not used due to inconsistency in trawl times and data entry. In some cases the same species was listed more than once for a station and there was no way to discern if this was a data entry error or if the abundance values should be lumped together. Additionally, many times abundance values were only estimates and an actual count was not made. Species-specific catch frequencies were calculated by dividing the total number of stations (i.e., trawl) a species was caught at on a bank by the total number of stations performed on the bank: [Catch Frequency (c.f.) = $N_{\text{stations caught at bank}} / N_{\text{total stations of bank}}$]. The individual catch frequencies were then classified into the following categories: never caught (c.f. = 0%), rarely caught (c.f. = > 0 but ≤ 15%), commonly caught (c.f. = >15% but ≤ 50%), or frequently caught (c.f. = > 50%). The Gulf of Mexico Fishery Management Council's *Commercial Fishing Regulations for Gulf of Mexico Federal Waters* species list and the red drum fishery and reef fish fishery sections of NOAA's draft for the *Generic Essential Fish Habitat Amendment to the following management plans of the Gulf of Mexico (GOM)* were used to determine which species are commercially exploited. Catch frequencies were first analyzed using the complete data set and then by separating the data into summer (June-August) and fall (October-November) seasons.

RESULTS

Data Summary

From 1982-2000, 434 trawls were conducted within the sand bank/shoal study areas (Table 3). Only six percent of the trawls were conducted on-bank. Within the control areas, 326 trawls (139 in the summer, 187 in the winter) were conducted in the eastern block, while sixty-eight trawls (32 in the summer, 36 in the winter) were conducted in the western control block. Overall, 157 species classified as either benthic, temporary benthic, or pelagic with benthic food resources were recorded as being caught (Appendix I - Table 1).

Table 3. A summary of the number of trawls conducted in each of the study blocks. Trawls were classified as either on-bank or off-bank based upon their position using NOAA nautical charts 11349 and 11330.

	Heald Bank Box	Sabine Bank Box	Tiger Shoal Box	Trinity Shoal Box
On-Bank	1	13	7	7
Off-Bank	57	114	41	194
Total	58	127	48	201
On-Bank Summer	1	8	7	7
Off-Bank Summer	39	50	28	92
Summer Total	40	58	35	99
On-Bank Winter	0	5	0	0
Off-Bank Winter	18	64	13	102
Winter Total	18	69	13	102

Environmental Setting

The mean depth of trawling was greater in the vicinity of Heald Bank (15.7 m $\pm$ 0.3) compared to the other bank/shoal study areas. The mean depth of trawling in the Heald Bank block was more than double that of the Tiger Shoals area (5.8 m $\pm$ 0.4, Figure 3). Mean trawling depth in the Sabine Bank and Trinity Shoal area was intermediate of the other two. The mean depth of on-bank trawls ranged from 0.4-6.8 m shallower than those conducted off-bank. Mean depth of trawling was greater in the two control areas compared to their respective sand bank/shoal study areas with a mean of 12.1 m $\pm$ 0.4 and 31.0 m $\pm$ 4.5 in the eastern and western control areas, respectively. One exception was the off-bank vicinity of Trinity Shoal which was comparable in depth to the eastern control area.

Mean bottom dissolved oxygen levels were above six parts per million for all sand bank/shoal study areas during the winter and above 5.0 ppm except for Trinity Shoal in the summer (Figure 4). Mean summer dissolved oxygen vaues in

Figure 3. The mean depth of trawling in each study area by season.

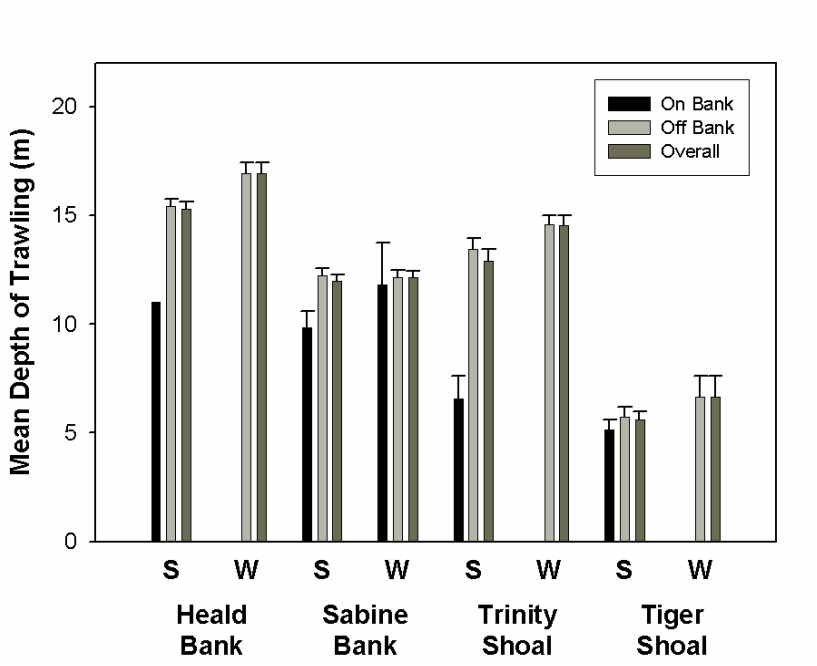
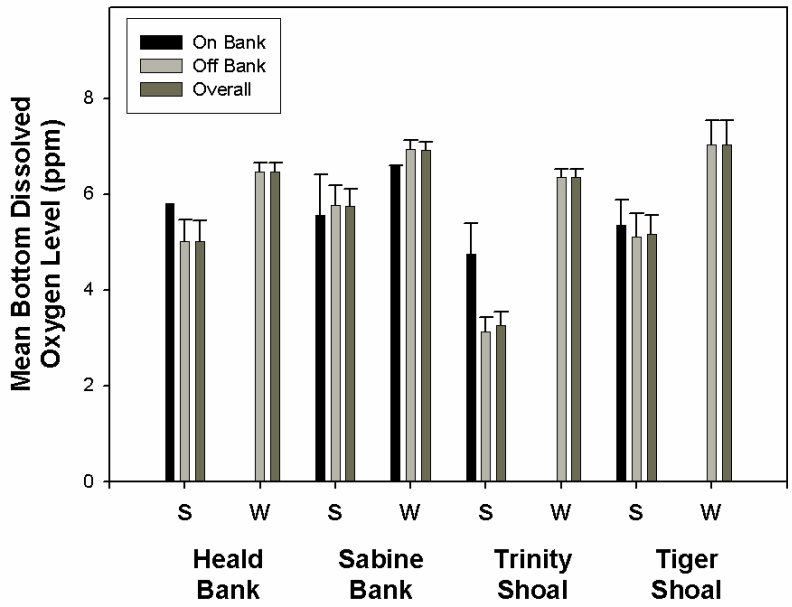


Figure 4. The mean bottom oxygen content in each study area by season.



the Trinity Shoal area were values were 4.7 ± 0.3 and 3.1 ± 0.3 ppm on versus off-bank, respectively. Approximately one-third of the summer bottom oxygen levels reported in the sand bank/shoal study areas were below 3.0 ppm. The lowest reported value was 0.0 ppm found at one station in the Trinity Shoal area (Figure 5). The frequency of low oxygen values was higher in the sand bank/shoal study areas compared to control areas. No values below 3.0 ppm were recorded in the western control area.

Mean bottom temperatures were similar across all sand bank/shoal study areas (Figure 6). Temperatures in general were 4-9 ºC cooler in the winter compared to summer. In contrast, temperatures in the two control areas were cooler (eastern control area: 24.0 ± 0.8 ºC, and western control area: 24.5 ± 0.2 ºC) than the sand bank/shoal study areas and varied by less than 1 ºC seasonally. Salinities were also similar across all study areas ranging from 28-33 psu with a reduced mean salinity in the Tiger Shoal area during the summer (21 ppt, Figure 7). Salinities in the two control areas were higher than the sand bank/shoal study areas with an overall mean of 35.6 ± 0.1 ppt.

Biomass

Mean biomass per trawl was only reported for all fish (pelagic and benthic). Biomass values were highly variable by location and displayed no seasonal pattern (Figure 8). The catch biomass appeared to be consistently lower in the Tiger Shoal box (< 25 kg trawl^{-1}) compared to the other sand bank/shoal study areas. The highest mean biomass was found on Sabine Bank in the summer (84.5 ± 8.4 kg trawl^{-1}). The mean catch biomass in the eastern control area was higher in both summer (32.7 ± 3.76 kg trawl^{-1}) and winter (80.9 ± 12.06 kg trawl^{-1}) compared to the western control area (23.2 ± 2.37 and 43.6 ± 6.02 kg trawl^{-1} in the summer and winter, respectively).

Abundance (Benthic Species)

A different pattern was found for the mean abundance of benthic fish per trawl (Figure 9). The highest mean abundance of benthic fish was found on Tiger Shoal in the summer. This was the only instance in which on versus-off bank values were different. The lowest mean benthic fish abundance was found in the Sabine Bank and Tiger Shoal boxes during the winter. Benthic fish abundance was higher in the eastern and western control blocks (285.7 ± 27.0 and 280.4 ± 28.3, respectively) compared to the sand bank/shoal study areas. Pearson Product Moment Correlation test results indicated that depth was positively correlated with catch biomass ($r=0.13$, $p=0.01$) and benthic species richness ($r=0.20$, $p=0.001$) per trawl. Catch biomass was also correlated with the total number of fish (pelagic and benthic) caught per trawl ($r=0.22$, $p=0.0005$), however the relationship was not significant when only on-bank samples were examined ($r=0.27$, $p=0.32$).

Figure 5. The cumulative percentage of stations based upon bottom oxygen levels. A) The eastern study sites of Tiger and Trinity Shoal compared to the Eastern Control Area. B) The western study sites of Heald and Sabine Bank compared to the Western Control Area.

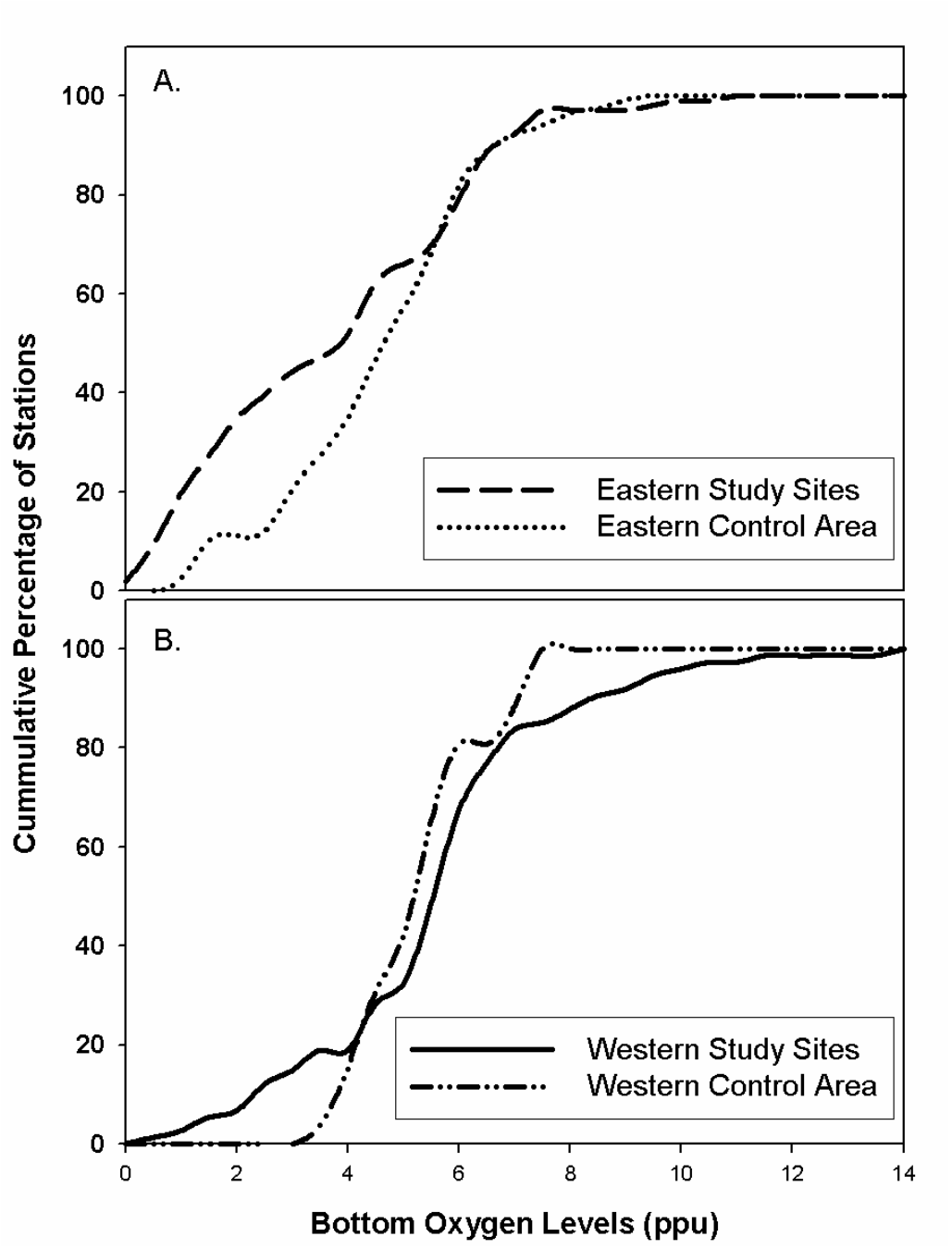


Figure 6. The mean bottom temperature in each study area by season.

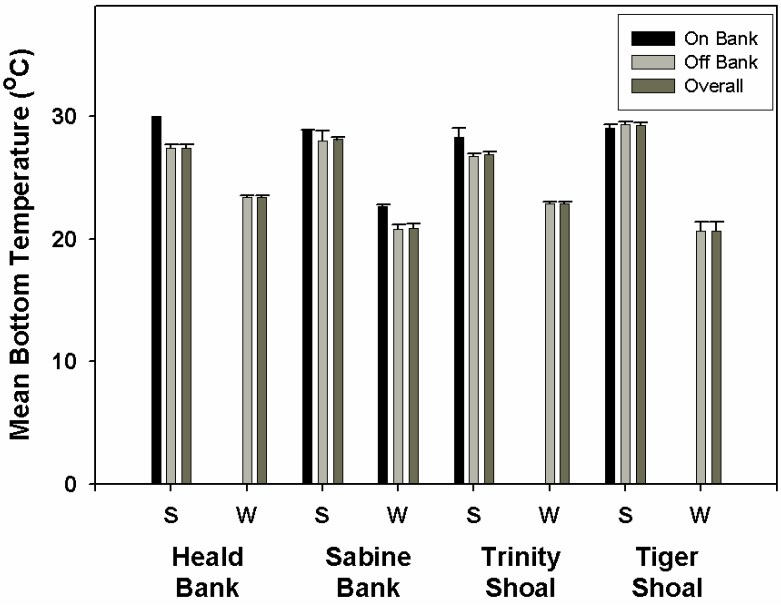


Figure 7. The mean bottom salinity in each study area by season.

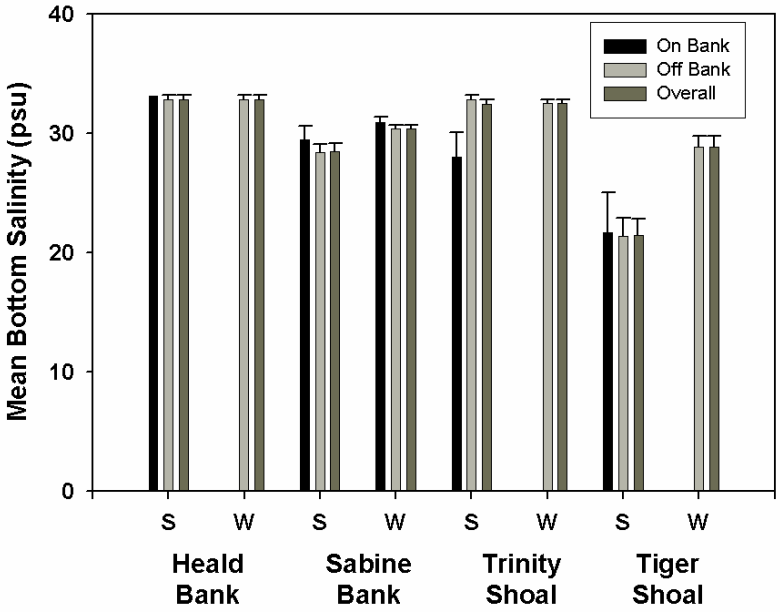


Figure 8. Mean biomass of all (pelagic and benthic) fish caught per trawl. Results are presented by bank for both seasons and overall.

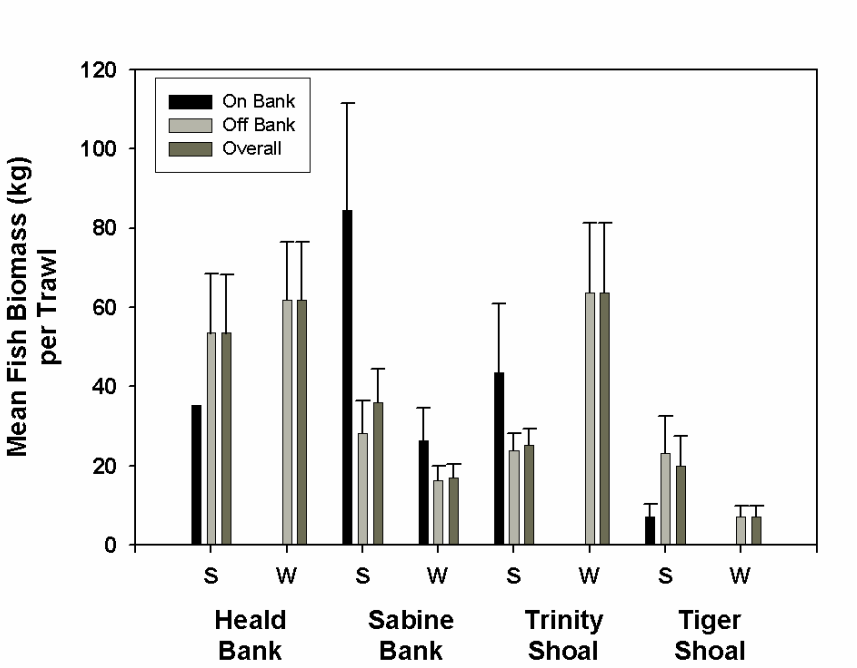


Figure 9. Mean density of all benthic fish caught per trawl. Results are presented by bank for both seasons and overall.

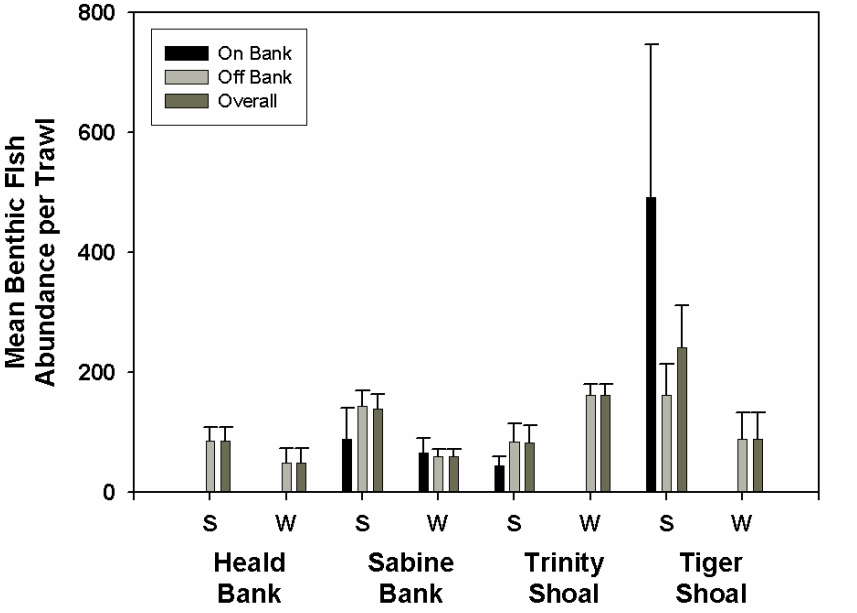


Figure 10. Mean species richness of all benthic fish caught per trawl. Results are presented by bank for both seasons and overall.

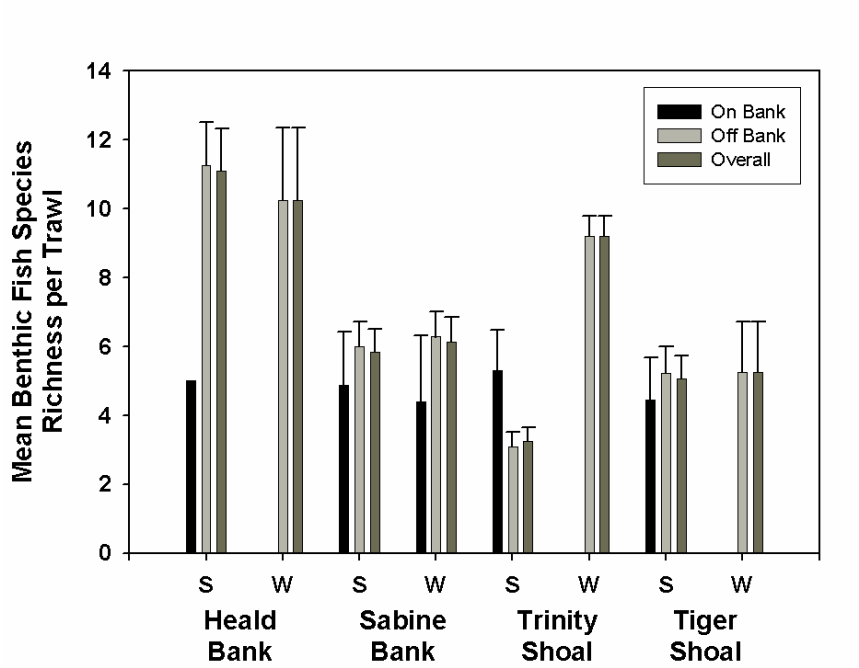
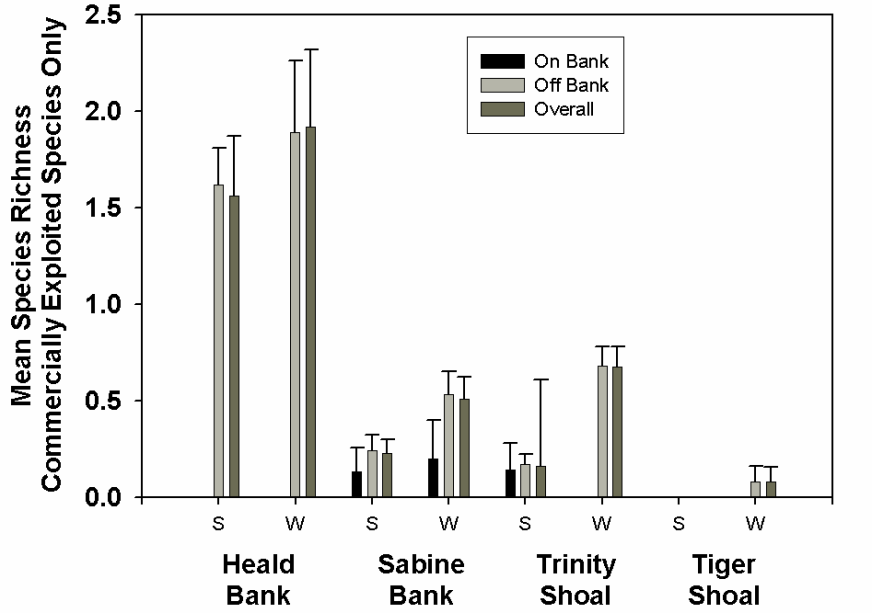


Figure 11. The mean species richness of commercially exploited species per trawl. Results are presented by bank for both seasons and overall.



Species Richness (Benthic Species)

Mean benthic fish species richness, defined as the number of species caught, was consistently higher within the Heald Bank study area (Figure 10). The lowest species richness value was found in the Trinity Shoal study area during the summer. Mean species richness was much higher in the eastern and western control areas than in the sand bank/shoal study areas with 14.4 $\pm$ 0.4 and 18.4 $\pm$ 1.0 species per trawl, respectively. The mean number of commercially exploited species was highest in the Heald Bank study area (Figure 11) with an average of over one commercially exploited species per trawl. Only one commercially exploited species (occurring in a single trawl) was ever listed as being caught in the Tiger Shoal area. The western control block had the highest mean number of commercially exploited species caught per trawl (summer = 3.1 $\pm$ 0.2, winter = 2.8 $\pm$ 0.2). The eastern control area had a higher mean number of commercially exploited species per trawl compared to the bank/shoal study areas (summer = 1.5 $\pm$ 0.1, winter = 2.1 $\pm$ 0.1).

Species Specific Patterns - Bank/Shoal Study Areas

Non-commercially Exploited Species - The following species were frequently or commonly caught in all bank/shoal study areas: *Arius felis* (hardhead catfish), *Cynoscion arenarius* (sand seatrout), *Cynoscion nothus* (silver seatrout), *Leiostomus xanthurus* (spot), *Micropogonias undulatus* (atlantic croaker), and *Sphoeroides parvus* (least puffer) (Appendix I - Table 2). Several species-specific trends were found where the bank/shoal study areas in the east differed from those in the west. *Bagre marinus* (gafftopsail catfish), was frequently or commonly caught in the Tiger and Trinity Shoal areas but rarely or never caught in the Sabine and Heald Bank areas. The following species were frequently or commonly caught in the Heald and Sabine Bank areas but rarely or never caught in the Tiger or Trinity Shoal areas: *Menticirrhus americanus* (southern kingfish), *Orthopristis chrysoptera* (pigfish), and *Prionotus tribulus* (bighead searobin).

Several species also exhibited patterns in which they were only commonly caught in one of the bank/shoal study areas. *Citharichthys spilopterus* (bay whiff), was commonly caught only in the Tiger Shoal area. The following species were only commonly caught in the Heald Bank area but were rarely or not caught in the other areas: *Eucinostomus gula* (silver jenny), *Lagocephalus laevigatus* (smooth puffer), *Lagodon rhomboides* (pinfish), *Lepophidium brevibarbe* (blackedge cusk-eel), *Monacanthus hispidus* (planehead filefish), *Prionotus rubio* (blackwing searobin), *Syacium gunteri* (shoal flounder), and *Synodus foetens* (inshore lizardfish). *Larimus fasciatus* (banded drum) was only commonly caught in the Sabine Bank area.

A few species were found to be absent from only one bank/shoal study area. *Etropus crossotus* (fringed flounder) was not caught in the Trinity Shoal area but was commonly caught everywhere else. *Porichthys plectrodon* (Atlantic midshipman) was rarely caught in the Sabine Bank area but was commonly caught in all the other areas. *Centropristis philadelphica* (rock sea bass) was rarely caught in the Tiger Shoal area but commonly caught everywhere else.

Species-specific trends were also found when examining the northern bank/shoal study areas (Sabine Bank, Tiger Shoal) compared to the southern bank/shoal study areas (Heald Bank, Trinity Shoal). *Stellifer lanceolatus* (star drum) and *Symphurus plagiusa* (blackcheek tonguefish) were frequently or commonly caught in the northern bank/shoal study areas but rare or never caught in the southern bank/shoal study areas. In contrast, *Prionotus longispinosus* (bigeye searobin) and *S. caprinus* were frequently or commonly caught in the southern study areas but rare or never caught in the northern study areas.

Only 6.4% of all trawls were made on-bank making comparisons difficult. Three species showed a consistent trend of higher catch frequencies off-bank versus on-bank: *C. spilopterus*, *Ophidion welshi (crested cusk-eel)*, and *S. caprinus*. No species were consistently caught in a higher frequency on-bank versus off-bank (Appendix – Table 3).

Commercially Exploited Species - Six commercially exploited species were caught within the bank/shoal study areas: *Diplectrum biviattum* (dwarf sand perch), *D. formosum* (sand perch), *Lutjanus campechanus* (red snapper), *L. synagris* (lane snapper), *Sciaenops ocellata* (red drum), and *Sphyrna tiburo* (bonnethead) (Table 4). *Lutjanus campechanus* was frequently caught in the Heald Bank area while *D. bivittatum* and *L. synagris* were commonly caught there. *L. synagris* was the only commercially exploited species to be collected in all bank/shoal study areas. Except for *L. synagris* no other commercially exploited species was collected on Tiger Shoal. No consistent on-bank versus off-bank trends were found for commercially exploited species.

Species Specific Patterns – Control Areas

Non-Commercially Exploited Species –The non-commercially exploited species that were commonly or frequently caught in both control areas were; *Ancylopsetta quadrocellata* (ocellated flounder), *Centropristis philadelphica* (rock sea bass), *Cyclopsetta chittendeni* (mexican flounder), *Cynoscion arenarius* (sand seatrout), *Cynoscion nothus* (silver seatrout), *Etropus crossotus* (fringed flounder), *Eucinostomus gula* (silver jenny), *Lagocephalus laevigatus* (smooth puffer), *Lagodon rhomboides* (pinfish), *Leiostomus xanthurus* (spot), *Lepophidium brevibarbe* (blackedge cusk-eel), *Micropogonias undulatus* (Atlantic croaker), *Monacanthus hispidus* (planehead filefish), *Porichthys plectrodon* (Atlantic midshipman), *Prionotus longispinosus* (bigeye searobin), *Prionotus paralatus* (Mexican searobin), *Saurida brasiliensis* (barbfish), *Serranus atrobranchus* (blackbear sea bass), *Sphoeroides parvus* (least puffer), *Stenotomus caprinus* (longspine porgy), *Syacium gunteri* (shoal flounder), *Synodus foetens* (inshore lizardfish), and *Upeneus parvus* (dwarf goatfish) (Appendix - Table 4). There were eleven species that were commonly or frequently caught in the western control area but were rarely or never caught in the eastern control area: *Bellator militaris* (horned searobin), *Engyophrys senta* (spiny flounder), *Halieutichthys aculeatus* (pancake batfish), *Mullus auratus* (red

Table 4. A list of the commercially exploited species which were caught and their species specific catch rates within the bank/shoal study areas. For the individual catch frequencies: NC = Never Caught, RC = Rarely Caught, CC = Commonly Caught, FC = Frequently Caught.

Species	Common Name	Habitat Category	Heald Bank	Sabine Bank	Trinity Shoal	Tiger Shoal
Diplectrum bivittatum	Dwarf Sand Perch	Benthic	CC	RC	RC	NC
Diplectrum formosum	Sand Perch	Benthic	RC	RC	NC	NC
Lutjanus campechanus	Red Snapper	Benthic	FC	CC	RC	NC
Lutjanus synagris	Lane Snapper	Benthic	CC	RC	RC	RC
Sciaenops ocellata	Red Drum	Benthic	NC	RC	RC	NC
Sphyrna tiburo	Bonnethead	Pelagic with Benthic Food	RC	RC	RC	NC

goatfish), *Prionotus ophryas* (bandtail searobin), *Prionotus rubio* (blackwing searobin), *Prionotus stearnsi* (shortwing searobin), *Raja texana* (roundel skate), *Scorpaena calcarata* (smoothead scorpionfish), *Syacium papillosum* (dusky flounder), *Synodus poeyi* (offshore lizardfish). In contrast, there were only two species that were commonly or frequently caught in the eastern control area but were rarely or never caught in the western control area, *Arius felis* (hardhead catfish) and *Menticirrhus americanus* (southern kingfish). Additionally, there were 105 non-commercially exploited species which were caught during the eighteen year sampling period but were never found to be frequent or common.

Sixty-three species were recorded as being caught in the control areas but not in the bank/shoal study areas (Table 5) while only twelve species were recorded as being collected in the bank/shoal study areas but not in the control areas: *Astroscopus y-graecum (s*outhern stargazer), *Dasyatis sayi* (bluntnose stingray), *E. cyclosquamus* (shelf flounder), *Menticirrhus littoralis* (Gulf kingfish), *M. saxatilis* (northern kingfish), *Ogcocephalus corniger* (longnose batfish), *O. nasutus* (shortnose batfish), *Ophichthus gomesii* (shrimp eel), *Rhinoptera bonasus* (cownose ray), *Scorpaena brasiliensis* (barbfish), *Serraniculus pumilio* (pygmy sea bass), and *Sphoeroides nephelus* (southern puffer).

Commercially Exploited Species – There were 4 species that were frequent or common in both control areas: *Diplectrum bivittatum* (dwarf sand perch), *Lutjanus campechanus* (red snapper), *Lutjanus synagris* (lane snapper), and *Pristipomoides aquilonaris* (wenchman). All species that were commonly or frequently caught in the eastern control area were also commonly or frequently caught in the western control area (Table 6). *Diplectrum formosum* (sand perch), was commonly caught in the western control area but was rarely caught in the eastern control area.

All of the commercially exploited species collected in the bank/shoal study areas were also present in trawls from the control areas. Eight commercially exploited species were listed as being caught in the control areas but not the bank/shoal study areas: *Caulolatilus intermedius* (anchor tilefish), *Epinephelius flavolimbatus* (yellowedge grouper), *Epinephelus rigritus* (Warsaw grouper), *Epinephelus niveatus* (snowy grouper), *Lutjanus griseus* (gray snapper), *Mycteroperca microlepis* (gag), *Pristipomoides aquilonaris* (wenchman), and *Rhomboplites aurorubens* (vermilion snapper).

Seasonal Patterns - Overall

No clear seasonal pattern was observed in mean catch (pelagic and benthic) biomass (Figure 8). However, a seasonal pattern was noted for benthic fish abundance. Contrasting the general trend of higher abundances in the summer in the bank/shoal study areas, mean abundance was 29 % and 9 % greater in the winter versus summer for the eastern and western control areas, respectively (Figure 9). Species richness values varied little between seasons in the bank/shoal study areas (Figure 10). Mean species richness was higher in the summer versus winter within the western control area (summer = 20.9 $\pm$ 1.7

Table 5. A list of the species collected in the Control Areas but not present in the catch from the Bank/Shoal Study Areas.

Aluterus heudelotti	Chascanopsetta lugubris	Lepophidium jeannae	Prionotus paralatus
Antennarius radiosus	Echiophis intertinctus	Lonchopisthus micrognathus	Prionotus stearnsi
Antennarius striatus	Echiophis punctifer	Monacanthus setifer	Pristigenys alta
Apogon affinis	Equetus acuminatus	Mulloidichthys martinicus	Pseudupeneus maculatus
Apogon aurolineatus	Equetus iwamotoi	Mullus auratus	Rypticus saponaceus
Apogon maculatus	Equetus lanceolatus	Myrophis punctatus	Saurida caribbaea
Apogon pseudomaculatus	Equetus umbrosus	Neomerinthe hemingwayi	Scorpaena dispar
Bellator brachychir	Etropus rimosus	Ogcocephalus radiatus	Serranus subligarius
Bellator militaris	Eucinostomus argenteus	Ophichthus rex	Syacium micrurum
Bollmannia communis	Gymnachirus melas	Opistognathus lonchurus	Synodus intermedius
Bothus robinsi	Gymnothorax nigromariginatus	Opsanus pardus	Trachinocephalus myops
Bregmaceros atlanticus	Gymnothorax ocellatus	Paralichthys squamilentus	Trinectes inscriptus
Calamus bajonado	Gymnothorax saxicola	Pontinus longispinis	Urophycis cirratus
Calamus leucosteus	Hemanthias aureorubens	Priacanthus arenatus	Urophycis floridanus
Calamus penna	Hippocampus erectus	Priacanthus cruentatus	Urophycis regia
Centropristis ocyurus	Kathetostoma albigutta	Prionotus martis	

Table 6. A list of the commercially exploited species which were caught and their species specific catch rates within the control areas. For the individual catch frequencies: NC = Never Caught, RC = Rarely Caught, CC = Commonly Caught, FC = Frequently Caught.

Species	Common Name	Habitat Category	Western Control Area	Eastern Control Area
Caulolatilus intermedius	Anchor Tilefish	Benthic	RC	RC
Diplectrum bivittatum	Dwarf Sand Perch	Benthic	FC	CC
Diplectrum formosum	Sand Perch	Benthic	CC	RC
Epinephelus flavolimbatus	Yellowedge Grouper	Benthic	NC	RC
Epinephelus nigritus	Warsaw Grouper	Benthic	RC	NC
Epinephelus niveatus	Snowy Grouper	Benthic	RC	NC
Lutjanus campechanus	Red Snapper	Benthic	FC	FC
Lutjanus griseus	Gray Snapper	Benthic	RC	RC
Lutjanus synagris	Lane Snapper	Benthic	FC	CC
Mycteroperca microlepis	Gag	Benthic	NC	RC
Pristipomoides aquilonaris	Wenchman	Benthic	CC	CC
Rhomboplites aurorubens	Vermilion Snapper	Benthic	RC	RC
Sciaenops ocellata	Red Drum	Benthic	RC	RC
Sphyrna tiburo	Bonnethead	Pelagic with Benthic Food	RC	RC

versus winter = 16.2 ± 1.1) but opposite in the eastern control area (summer = 13.8 ± 0.7 versus winter = 14.9 ± 0.5).

Seasonal Patterns - Bank/Shoal Areas

Non-Commercially Exploited Species - When both on and off-bank information was combined, several species demonstrated consistent seasonal trends (Appendix III - Table 5). *Larimus fasciatus* (banded drum) and *Orthopristis chrysoptera* (pigfish) were frequently/commonly caught in the summer but rarely/never caught in the winter. *Lagocephalus laevigatus* (smooth puffer), *Monacanthus hispidus* (planehead filefish), and *Serranus pumilio* (pygmy sea bass) displayed higher frequencies in the summer in the Heald Bank area, which is the only location where they were commonly found. *Leiostomus xanthurus* (spot) displayed higher frequencies in the summer but only in the Tiger Shoal and Sabine Bank areas.

Ophidion welshi (crested cusk-eel) was frequently/commonly caught in the winter but rarely or never caught in the summer. *Halieutichthys aculeatus* (pancake batfish) and *Lepophidium brevibarbe* (blackedge cusk-eel) were also found frequently/ commonly in the winter but rarely/never in the summer in the Heald Bank area which is the only location where they were commonly found. Several species were caught in higher frequencies in the winter versus summer in all areas except for Heald Bank. The species showing this pattern were *Centropristis philadelphica*, *Etropus crossotus* (fringed flounder), *Menticirrhus americanus*, *Porichthys plectrodon*, *Sphoeroides parvus*, *Synodus foetens*, and *Syacium gunteri*.

Commercially Exploited Species – Commercially exploited species did not display any consistent seasonal trends with the exception of *Scianops ocellata. Scianops ocellata* had a higher catch frequency in the winter on Trinity Shoal, which was the only location where it was commonly found.

Seasonal Patterns – Control Areas

Non-Commercially Exploited Species - Several species exhibited seasonal changes in catch frequency when information from both control areas was combined. Species that were commonly/frequently caught in the winter but rare/never caught in the summer were *Ancylopseta quadrocellata, Arius felis, Larimus fasciatus, Mullus auratus, Raja texana,* and *Rhizoprionodon terraenovae.* Seven species displayed the opposite pattern of being commonly/frequently caught in the summer but rare/never caught in the winter; *Monacanthus hispidus, Prionotus paralatus, Prionotus rubio, Prionotus stearnsi, Scorpaena calcarata, Symphurus plagiusa,* and *Synodus poeyi.* (Appendix III - Table 6). Seasonal changes in catch frequency were also observed in the western control areas for several species which were not commonly found in the eastern control area. The following species were commonly/frequently caught in the western area in the summer but rare/never caught in the winter: *Bellator*

militaris, Engyophrys senta, Prionotus ophryas, P. rubio, P. stearnsi, Raja texana, and S. poeyi.

Commercially Exploited Species - In the control areas, *Pristipomoides aquilonaris* was the only species to show a seasonal trend, being caught more frequently in the summer than in the winter.

Discussion

A diverse community of fish was found utilizing natural sandbanks in the northwestern Gulf of Mexico. However, there does not appear to be a "unique" community dependent upon these areas, but rather a suite of species which does not differ from the control areas. The benthic fish community reported in the database is also similar to inshore areas (e.g., estuaries). For example, *Cynoscion arenarius, Etropus crossotus, Leiostomus xanthurus*, and *Micropogonias undulatus* (Grothues & Able, 2003; Minello, 1998; Ross, 2003; Rozas & Zimmerman, 2000; Tsou & Matheson, 2002; Walsh et al., 1999) are all commonly found in submerged aquatic vegetative (SAV) habitat. The results of this summary differ from those of a European sandbank habitat study performed by Kaiser et al. (2004) which found a restricted number of species utilizing sand banks. Community differences were observed between "distinct" sandbanks versus extensions of inshore sediments (Kaiser et al. 2004). It is important to note that using the catch frequency as we did, without species-specific abundance information, may not accurately depict community structure. Therefore, these results should only serve as an indicator of what species are frequent components of the community. Additionally, the ability to incorporate size-frequency information into the analysis would provide a better representation of species-specific patterns in habitat use. It is possible that species are disproportionately using sand bank areas, but only within a certain size range. For example, juveniles of a specific size could be using nearshore natural sand banks as a transitiory stop in their life history between inshore and offshore habitats.

Several species were only found within the sand bank/shoal study areas however, no particular family was found exclusively there. For example, *Daysatis sayi* was not found in the control areas but *D. americana* was. Alternatively, over forty percent of the non-commercially exploited species examined in the database were found only in the control areas. Specifically, representatives of the antennariidae (frog fishes), apogonidae (cardinalfishes), bregmacerotidae (codlets), gadidae (cods), muranidae (morays), opistognathidae (jawfishes), priacanthidae (bigeyes), and syngnathidae (pipefishes) families were found solely in the control areas. It is important to note that the number of trawls was not consistent among study areas. Thus, the areas with fewer trawls have a potentially conservative estimate of the rare species which are present (i.e., the

more you sample an area the more likely you are to detect the presence of rare species, Rosenzweig 1995).

Six species which are listed as being commercially exploited by the Gulf Fisheries Council and NOAA were caught in the sand bank/shoal study areas: *Diplectrum bivittatum*, *D. formosum*, *Lutjanus campechanus*, *L. synagris*, *Sciaenops ocellata*, and *Sphyrna tiburo*. *Lutjanus campechanus* is of great concern and many research programs are now targeting this species. Efforts are in place to reduce fishing mortality rates (Workman & Foster, 1994). The focus is not only on size limits for the adult population but increasing knowledge of juvenile survival and habitat as well (Rooker et al., 2004; Workman & Foster, 1994). Early juvenile *L. campechanus* have been noted to utilize infaunal/epifuanal burrows and shells as protective developmental habitat on the upper continental shelf (Workman et al., 2002). Microtopographic differences such as depressions, burrows, and sessil invertebrates have been found to be important habitat features for juvenile groundfish (e.g., red hake, *Urophycis chuss*) in other geographic areas as well (Langton et al., 1995). It is unclear however if the juvenile *L. campechanus* preferentially utilize bank and shoal features (Rooker et al., 2004; Szedlmayer & Conti, 1999; Szedlmayer & Howe, 1997). With the exception of *L. synagris* (Franks & VanderKooy, 2000; Lindeman et al., 1998), very little research has been conducted on the habitat requirements of the other commercial species which are caught within the bank/shoal areas. Observations of *D. formosum* (Bortone, 1971) suggest that it prefers a structured sand environment with rocks when found inshore, but it is unknown if it responds in a similar way to shell ridges located on sand banks. *Diplectrum bivittatum*, *L. campechanus*, and *L. synagris* were only commonly caught in the western areas, and the only commercially exploited species to appear in the Tiger Shoal area was *L. synagris*. The western Heald Bank area on the other hand, although small in size, appears to contain a relatively high number of commercially exploited species. No east-west trend for commercial species was found when comparing the western versus eastern control area.

There were very few on-bank samples, making any conclusions concerning on-bank versus off-bank comparisons tenuous. However, for the few differences that were identified, the pattern was always for a species to be more frequently caught off-bank versus on. Sampling is needed which actually targets the bank. Additionally, the time of day during which the sampling is conducted is important (e.g., Weaver et al., 2002). Sampling during only one period of the day may be inappropriate as Diaz et al. (2003) found a diurnal shift in habitat use for juvenile fishes between Fenwick Shoal (U.S. Atlantic Coast) and the adjacent trough. In this survey highlighted differences between the bank/shoal study areas and control blocks are not likely due to daily migration patterns. The control areas were located far enough away from the bank/shoal study areas that daily movement between the two is doubtful.

The western control area hosted both the highest number of commercially exploited and non-commercial species and appears to be the most diverse area. In terms of benthic fish density and environmental setting the control areas were comparable. In contrast, benthic fish density and species richness was lower

within the bank/shoal study areas. The study areas were only half as deep, which may be partly responsible for the difference. The bank/shoal areas also had slightly reduced salinities compared to the control sites, most likely due to their proximity to freshwater outflow from Sabine Pass and the Mississippi River. It is unknown if salinity is also a contributing factor to the observed differences in fish abundance.

The Tiger and Trinity Shoal study areas may have a lower number of benthic fish present due to environmental conditions. Reduced oxygen levels on Trinity and Tiger Shoal (ranging from 0-10.7 ppm) are not surprising due to their position within the known "hypoxia zone" described by Rablais (2002). In recent years the nearshore environment off of Louisiana has experienced hypoxic conditions (< 2.0 mg l^{-1}) which impact nekton and benthos (Harper et al., 1981; Renaud, 1986; Rabalais, 2002). Less mobile demersal species may require more time to respond and may not return if an area becomes hypoxic on a regular basis. The hypoxic zone covers more than 20,000 km^2 of bottom (Rabalais et al., 2002) and can occur from late February and extend through early October. The most severe hypoxic conditions occur from June-August, the time of summer SEAMAP sampling. Although Sabine Bank is just west of the area which has been monitored annually since 1985, hypoxic areas off the Texas coast have been previously reported (Pavela et al., 1983; Rabalais et al., 2002). The reason for hypoxia is two-fold. Eutrophication from the Mississippi River results in increased water column and benthic respiration which lowers oxygen levels. The low oxygen levels are then confined when subsurface mixing is prevented by summer stratification of the water column.

It was expected that Sabine Bank, Tiger Shoal, and Trinity Shoal would have lower oxygen values in the summer leading to lower benthic fish density and species richness during that time of year. Trinity Shoal was the only area to display this seasonal pattern but overall reduced oxygen levels did correspond to lower species richness and abundance values. Additionally, roughly two-thirds of the benthic fish species, which exhibited a consistent seasonal trend in the bank/shoal study areas, were caught more frequently in the winter. This is in contrast to the control areas outside of the known hypoxia zone where sixty percent of the species were more frequently caught in the summer. The variability among demersal species appears to indicate that spawning is not synchronous in the northwestern Gulf of Mexico.

Conclusion

The deeper control areas with less variable salinity and oxygen levels appear to host a higher diversity and abundance of benthic fishes. Temporal and spatial patterns in the occurrence of benthic fish on natural sand banks in the northern Gulf of Mexico are species-specific. A small number of commercially exploited species are found to utilize these habitats including several snapper species. No commercially exploited species however is exclusive to these areas. There is a paucity of information on the actual sand banks and shoals

themselves. While numerous trawls have been conducted within their vicinity, very few have actually transversed the bank or shoal. There is also a data gap on species specific information including standardized abundance information, individual biomass measurements, and age-length measurements. This information is vital for determining if natural sand banks and shoals are being utilized as nursery habitats.

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Appendix

Appendix - Table 1. A list of the non-commercially exploited species which were caught in the study bank/shoal areas and/or control areas.

Species	Common Name	Habitat Category
Achirus lineatus	Lined Sole	Benthic
Aluterus heudelotti	Dotterel Filefish	Pelagic with Benthic Food
Aluterus monoceros	Unicorn Filefish	Pelagic with Benthic Food
Aluterus schoepfi	Orange Filefish	Pelagic with Benthic Food
Aluterus scriptus	Scrawled Filefish	Pelagic with Benthic Food
Ancylopsetta dilecta	Three-eye Flounder	Benthic
Ancylopsetta quadrocellata	Ocellated Flounder	Benthic
Antennarius radiosus	Big-eye Frogfish	Benthic
Antennarius striatus	Striated Frogfish	Benthic
Apogon affinis	Bigtooth Cardinalfish	Benthic
Apogon aurolineatus	Bridle Cardinalfish	Benthic
Apogon maculatus	Flamefish	Benthic
Apogon pseudomaculatus	Twospot Cardinalfish	Benthic
Arius felis	Hardhead Catfish	Benthic
Astroscopus y-graecum	Southern Stargazer	Benthic
Bagre marinus	Gafftopsail Catfish	Benthic
Bairdiella chrysoura	Silver Perch	Benthic
Bellator brachychir	Shortfin Searobin	Benthic
Bellator militaris	Horned Searobin	Benthic
Bollmannia communis	Ragged Goby	Benthic
Bothus robinsi	Spottail flounder	Benthic
Bregmaceros atlanticus	Antenna Codlet	Temporary Benthic
Brotula barbata	Bearded Brotula	Benthic
Calamus bajonado	Jolthead Porgy	Benthic
Calamus leucosteus	Whitebone Porgy	Benthic
Calamus penna	Sheepshead Porgy	Benthic
Centropristis ocyurus	Bank Sea Bass	Benthic
Centropristis philadelphica	Rock Sea Bass	Benthic
Chascanopsetta lugubris	Pelican Flounder	Benthic
Chilomycterus schoepfi	Striped Burrfish	Benthic
Citharichthys macrops	Spotted Whiff	Benthic
Citharichthys spilopterus	Bay Whiff	Benthic
Cyclopsetta chittendeni	Mexican Flounder	Benthic
Cynoscion arenarius	Sand Seatrout	Pelagic with Benthic Food
Cynoscion nothus	Silver Seatrout	Pelagic with Benthic Food
Dasyatis americana	Southern Stingray	Benthic
Dasyatis sayi	Bluntnose Stingray	Benthic
Echiophis intertinctus	Spotted Spoon-nose Eel	Benthic
Echiophis punctifer	Stippled Spoon-nose Eel	Benthic
Engyophrys senta	Spiny Flounder	Benthic
Equetus acuminatus	High-hat	Benthic
Equetus iwamotoi	Blackbear Drum	Benthic

Species	Common Name	Habitat Category
Equetus lanceolatus	Jacknife Fish	Benthic
Equetus umbrosus	Cubbyu	Benthic
Etropus crossotus	Fringed Flounder	Benthic
Etropus cyclosquamus	Shelf Flounder	Benthic
Etropus microstomus	Smallmouth Flounder	Benthic
Etropus rimosus	Gray Flounder	Benthic
Eucinostomus argenteus	Spotfin Mojarra	Pelagic with Benthic Food
Eucinostomus gula	Silver Jenny	Pelagic with Benthic Food
Gobionellus hastatus	Sharptail Goby	Benthic
Gymnachirus melas	Naked Sole	Benthic
Gymnachirus texae	Fringed Sole	Benthic
Gymnothorax nigromariginatus	Blackedge Moray	Benthic
Gymnothorax ocellatus	Carribean Ocellated Moray	Benthic
Gymnothorax saxicola	Ocellated Moray	Benthic
Halieutichthys aculeatus	Pancake Batfish	Benthic
Hemanthias aureorubens	Streamer Bass	Benthic
Hildebrandia flava	Yellow Conger	Benthic
Hippocampus erectus	Lined Seahorse	Benthic
Hoplunnis macrurus	Freckled Pike-Conger	Benthic
Kathetostoma albigutta	Lancer Stargazer	Benthic
Lactophrys quadricornis	Scrawled Cowfish	Benthic
Lactophrys triqueter	Smooth Trunkfish	Benthic
Lagocephalus laevigatus	Smooth Puffer	Pelagic with Benthic Food
Lagodon rhomboides	Pinfish	Benthic
Larimus fasciatus	Banded Drum	Benthic
Leiostomus xanthurus	Spot	Benthic
Lepophidium brevibarbe	Blackedge Cusk-Eel	Benthic
Lepophidium jeannae	Mottled Cusk-Eel	Benthic
Lonchopisthus micrognathus	Swordtail Jawfish	Benthic
Menticirrhus americanus	Southern Kingfish	Benthic
Menticirrhus littoralis	Gulf Kingfish	Benthic
Menticirrhus saxatilis	Northern Kingfish	Benthic
Micropogonias undulatus	Atlantic Croaker	Benthic
Monacanthus hispidus	Planehead Filefish	Pelagic with Benthic Food
Monacanthus setifer	Pygmy Filefish	Pelagic with Benthic Food
Mulloidichthys martinicus	Yellow Goatfish	Benthic
Mullus auratus	Red Goatfish	Benthic
Mustelus canis	Smooth Dogfish	Benthic
Mustelus Norris	Florida Smoothound	Benthic
Myrophis punctatus	Speckled Worm Eel	Benthic
Neomerinthe hemingwayi	Spinycheek Scorpionfish	Benthic
Ogcocephalus corniger	Longnose Batfish	Benthic
Ogcocephalus declivirostris	Slantbrow Batfish	Benthic
Ogcocephalus nasutus	Shortnose Batfish	Benthic
Ogcocephalus pantostictus	Spotted Batfish	Benthic

Species	Common Name	Habitat Category
Ogcocephalus parvus	Roughback Batfish	Benthic
Ogcocephalus radiatus	Polka-Dot Batfish	Benthic
Ophichthus gomesii	Shrimp Eel	Benthic
Ophichthus rex	King Snake Eel	Benthic
Ophidion grayi	Blotched Cusk-Eel	Benthic
Ophidion holbrooki	Bank Cusk-Eel	Benthic
Ophidion welshi	Crested Cusk-Eel	Benthic
Opistognathus lonchurus	Moustache Jawfish	Benthic
Opsanus pardus	Leopard Toadfish	Benthic
Orthopristis chrysoptera	Pigfish	Benthic
Paraconger caudilimbatus	Margintail Conger	Benthic
Paralichthys albigutta	Gulf Flounder	Benthic
Paralichthys lethostigma	Southern Flounder	Benthic
Paralichthys squamilentus	Broad Flounder	Benthic
Pogonias cromis	Black Drum	Benthic
Pontinus longispinis	Longspine Scorpionfish	Benthic
Porichthys plectrodon	Atlantic Midshipman	Benthic
Priacanthus arenatus	Bigeye	Temporary Benthic
Priacanthus cruentatus	Glasseye Snapper	Temporary Benthic
Prionotus longispinosus	Bigeye Searobin	Benthic
Prionotus martis	Barred Searobin	Benthic
Prionotus ophryas	Bandtail Searobin	Benthic
Prionotus paralatus	Mexican Searobin	Benthic
Prionotus roseus	Bluespotted Searobin	Benthic
Prionotus rubio	Blackwing Searobin	Benthic
Prionotus scitulus	Leopard Searobin	Benthic
Prionotus stearnsi	Shortwing Searobin	Benthic
Prionotus tribulus	Bighead Searobin	Benthic
Pristigenys alta	Short Bigeye	Temporary Benthic
Pseudupeneus maculatus	Spotted Goatfish	Benthic
Raja texana	Roundel Skate	Benthic
Rhinoptera bonasus	Cownose Ray	Pelagic with Benthic Food
Rhizoprionodon terraenovae	Atlantic Sharpnose Shark	Pelagic with Benthic Food
Rypticus maculatus	Whitespotted Soapfish	Benthic
Rypticus saponaceus	Greater Soapfish	Benthic
Saurida brasiliensis	Largescale Lizardfish	Benthic
Saurida caribbaea	Smallscale Lizardfish	Benthic
Scorpaena brasiliensis	Barbfish	Benthic
Scorpaena calcarata	Smoothead Scorpionfish	Benthic
Scorpaena dispar	Hunchback Scorpionfish	Benthic
Serraniculus pumilio	Pygmy Sea Bass	Benthic
Serranus atrobranchus	Blackbear Sea Bass	Benthic
Serranus phoebe	Tattler	Benthic
Sphoeroides dorsalis	Marbled Puffer	Benthic
Sphoeroides nephelus	Southern Puffer	Benthic

Species	Common Name	Habitat Category
Sphoeroides parvus	Least Puffer	Benthic
Sphoeroides spengleri	Bandtail Puffer	Benthic
Stellifer lanceolatus	Star Drum	Benthic
Stenotomus caprinus	Longspine Porgy	Benthic
Syacium gunteri	Shoal Flounder	Benthic
Syacium micrurum	Channel Flounder	Benthic
Syacium papillosum	Dusky Flounder	Benthic
Symphurus civitatus	Offshore Tonguefish	Benthic
Symphurus diomedianus	Spotted Tonguefish	Benthic
Symphurus plagiusa	Blackcheek Tonguefish	Benthic
Synodus foetens	Inshore Lizardfish	Benthic
Synodus intermedius	Sand Diver	Benthic
Synodus poeyi	Offshore Lizardfish	Benthic
Trachinocephalus myops	Snakefish	Benthic
Trichopsetta ventralis	Sash Flounder	Benthic
Trinectes inscriptus	Scrawled Sole	Benthic
Trinectes maculatus	Hogchoker	Benthic
Upeneus parvus	Dwarf Goatfish	Benthic
Urophycis cirratus	Gulf Hake	Benthic
Urophycis floridanus	Southern Hake	Benthic
Urophycis regia	Spotted Hake	Benthic

Appendix - Table 2. A list of the non-commercially exploited species which were caught within the bank/shoal study areas and their species specific catch rates. For the individual catch frequencies: NC = Never Caught, RC = Rarely Caught, CC = Commonly Caught, FC = Freqeuently Caught.

Species	Heald Bank	Sabine Bank	Trinity Shoal	Tiger Shoal
Achirus lineatus	NC	NC	RC	RC
Aluterus monoceros	RC	NC	NC	NC
Aluterus schoepfi	NC	RC	NC	NC
Aluterus scriptus	NC	RC	RC	NC
Ancylopsetta dilecta	RC	NC	NC	NC
Ancylopsetta quadrocellata	RC	RC	RC	NC
Arius felis	FC	CC	CC	CC
Astroscopus y-graecum	NC	RC	RC	RC
Bagre marinus	NC	NC	CC	CC
Bairdiella chrysoura	NC	RC	NC	NC
Brotula barbata	RC	NC	RC	NC
Centropristis philadelphica	CC	CC	CC	RC
Chilomycterus schoepfi	RC	RC	RC	RC
Citharichthys macrops	RC	NC	RC	NC
Citharichthys spilopterus	RC	RC	RC	CC
Cyclopsetta chittendeni	NC	RC	RC	NC
Cynoscion arenarius	CC	CC	CC	FC
Cynoscion nothus	CC	CC	CC	CC
Dasyatis americana	NC	RC	RC	NC
Dasyatis sayi	NC	NC	RC	NC
Engyophrys senta	RC	RC	NC	NC
Etropus crossotus	CC	CC	NC	CC
Etropus cyclosquamus	NC	NC	RC	NC
Etropus microstomus	RC	RC	NC	NC
Eucinostomus gula	CC	RC	RC	NC
Gobionellus hastatus	NC	NC	RC	RC
Gymnachirus texae	RC	NC	NC	NC
Halieutichthys aculeatus	RC	RC	RC	NC
Hildebrandia flava	NC	NC	RC	NC
Hoplunnis macrurus	RC	NC	NC	NC
Lactophrys quadricornis	RC	RC	NC	NC
Lactophrys triqueter	RC	NC	NC	NC
Lagocephalus laevigatus	CC	RC	RC	RC
Lagodon rhomboides	CC	RC	RC	RC
Larimus fasciatus	RC	CC	RC	RC
Leiostomus xanthurus	CC	CC	CC	CC
Lepophidium brevibarbe	CC	RC	RC	RC
Menticirrhus americanus	CC	RC	CC	RC
Menticirrhus littoralis	NC	RC	RC	NC

Species	Heald Bank	Sabine Bank	Trinity Shoal	Tiger Shoal
Menticirrhus saxatilis	NC	RC	NC	NC
Micropogonias undulatus	FC	CC	FC	FC
Monacanthus hispidus	CC	RC	RC	RC
Mustelus canis	NC	NC	RC	NC
Mustelus norris	RC	NC	NC	NC
Ogcocephalus corniger	RC	NC	NC	NC
Ogcocephalus declivirostris	RC	NC	NC	NC
Ogcocephalus nasutus	RC	RC	NC	NC
Ogcocephalus pantostictus	RC	NC	NC	NC
Ogcocephalus parvus	RC	NC	RC	NC
Ophichthus gomesii	NC	NC	NC	RC
Ophidion grayi	RC	RC	RC	NC
Ophidion holbrooki	NC	RC	RC	NC
Ophidion welshi	RC	RC	RC	RC
Orthopristis chrysoptera	CC	CC	RC	NC
Paraconger caudilimbatus	NC	NC	RC	NC
Paralichthys albigutta	NC	RC	NC	NC
Paralichthys lethostigma	RC	RC	RC	RC
Pogonias cromis	NC	RC	RC	RC
Porichthys plectrodon	CC	RC	CC	CC
Prionotus longispinosus	CC	RC	CC	RC
Prionotus ophryas	RC	RC	RC	NC
Prionotus roseus	RC	NC	NC	NC
Prionotus rubio	CC	RC	RC	RC
Prionotus scitulus	RC	RC	RC	NC
Prionotus tribulus	CC	CC	RC	RC
Raja texana	NC	RC	RC	NC
Rhinoptera bonasus	RC	RC	RC	NC
Rhizoprionodon terraenovae	RC	RC	RC	RC
Rypticus maculatus	RC	NC	NC	NC
Saurida brasiliensis	RC	RC	RC	RC
Scorpaena brasiliensis	NC	RC	NC	NC
Scorpaena calcarata	RC	RC	RC	NC
Serraniculus pumilio	RC	RC	NC	NC
Serranus atrobranchus	RC	NC	NC	NC
Serranus phoebe	NC	RC	NC	NC
Sphoeroides dorsalis	NC	NC	RC	NC
Sphoeroides nephelus	NC	NC	RC	RC
Sphoeroides parvus	CC	CC	CC	CC
Sphoeroides spengleri	NC	NC	RC	NC
Stellifer lanceolatus	RC	CC	RC	CC
Stenotomus caprinus	FC	RC	CC	NC
Syacium gunteri	CC	RC	RC	RC
Syacium papillosum	RC	RC	RC	NC

Species	Heald Bank	Sabine Bank	Trinity Shoal	Tiger Shoal
Symphurus civitatus	NC	RC	RC	RC
Symphurus diomedianus	RC	NC	NC	NC
Symphurus plagiusa	RC	CC	RC	CC
Synodus foetens	CC	RC	RC	RC
Synodus poeyi	NC	RC	NC	NC
Trichopsetta ventralis	NC	NC	RC	NC
Trinectes maculatus	NC	RC	RC	RC
Upeneus parvus	RC	NC	RC	NC

Appendix I - Table 3. A list of the species which were caught and their species specific catch rates on versus off-bank for each of the Bank/Shoal Areas. Commercially exploited species are indicated with an asterisk. For the individual catch frequencies: NC = Never Caught, RC = Rarely Caught, CC = Commonly Caught, FC = Frequently Caught.

Species	Heald On-Bank	Heald Off-Bank	Sabine On-Bank	Sabine Off-Bank	Trinity On-Bank	Trinity Off-Bank	TIGER On-Bank	TIGER Off-Bank
Achirus lineatus	NC	NC	NC	NC	NC	RC	NC	RC
Aluterus monoceros	NC	RC	NC	NC	NC	NC	NC	NC
Aluterus schoepfi	NC	NC	NC	RC	NC	NC	NC	NC
Aluterus scriptus	NC	NC	NC	RC	NC	RC	NC	NC
Ancylopsetta dilecta	NC	RC	NC	NC	NC	NC	NC	NC
Ancylopsetta quadrocellata	NC	RC	NC	RC	NC	RC	NC	NC
Arius felis	FC	FC	FC	CC	FC	CC	FC	CC
Astroscopus y-graecum	NC	NC	NC	RC	NC	RC	CC	RC
Bagre marinus	NC	NC	NC	NC	NC	CC	CC	RC
Bairdiella chrysoura	NC	NC	NC	RC	NC	NC	NC	NC
Brotula barbata	NC	RC	NC	NC	NC	RC	NC	NC
Centropristis philadelphica	NC	CC	CC	CC	RC	CC	NC	RC
Chilomycterus schoepfi	NC	RC	NC	RC	NC	RC	NC	RC
Citharichthys macrops	NC	RC	NC	NC	NC	RC	NC	NC
Citharichthys spilopterus	NC	RC	NC	RC	NC	RC	NC	CC
Cyclopsetta chittendeni	NC	NC	NC	RC	NC	RC	NC	NC
Cynoscion arenarius	NC	CC	CC	CC	CC	CC	CC	FC
Cynoscion nothus	NC	CC	CC	CC	CC	CC	NC	CC
Dasyatis americana	NC	NC	NC	RC	NC	RC	NC	NC
Dasyatis sayi	NC	NC	NC	NC	NC	RC	NC	NC
*Diplectrum bivittatum**	NC	CC	NC	RC	NC	RC	NC	NC
*Diplectrum formosum**	NC	RC	NC	RC	NC	NC	NC	NC
Engyophrys senta	NC	RC	RC	NC	NC	NC	NC	NC
Etropus crossotus	NC	CC	CC	CC	NC	NC	NC	CC
Etropus cyclosquamus	NC	NC	NC	NC	NC	RC	NC	NC

Species	Heald On-Bank	Heald Off-Bank	Sabine On-Bank	Sabine Off-Bank	Trinity On-Bank	Trinity Off-Bank	TIGER On-Bank	TIGER Off-Bank
Etropus microstomus	NC	RC	NC	RC	NC	NC	NC	NC
Eucinostomus gula	NC	CC	CC	RC	NC	RC	NC	NC
Gobionellus hastatus	NC	NC	NC	NC	NC	RC	NC	RC
Gymnachirus texae	NC	RC	NC	NC	NC	NC	NC	NC
Halieutichthys aculeatus	NC	RC	NC	RC	NC	RC	NC	NC
Hildebrandia flava	NC	NC	NC	NC	NC	RC	NC	NC
Hoplunnis macrurus	NC	RC	NC	NC	NC	NC	NC	NC
Lactophrys quadricornis	NC	RC	NC	RC	NC	NC	NC	NC
Lactophrys triqueter	NC	RC	NC	NC	NC	NC	NC	NC
Lagocephalus laevigatus	NC	CC	NC	RC	NC	RC	NC	RC
Lagodon rhomboids	FC	CC	CC	RC	CC	RC	NC	RC
Larimus fasciatus	NC	RC	CC	CC	CC	RC	NC	RC
Leiostomus xanthurus	NC	CC	CC	CC	CC	CC	CC	CC
Lepophidium brevibarbe	NC	CC	NC	RC	NC	RC	NC	RC
*Lutjanus campechanus**	NC	FC	CC	CC	NC	RC	NC	NC
*Lutjanus synagris**	NC	CC	NC	RC	NC	RC	NC	RC
Menticirrhus americanus	NC	CC	CC	RC	RC	CC	NC	CC
Menticirrhus littoralis	NC	NC	NC	RC	NC	RC	NC	NC
Menticirrhus saxatilis	NC	NC	NC	RC	NC	NC	NC	NC
Micropogonias undulatus	NC	FC	CC	CC	FC	FC	FC	FC
Monacanthus hispidus	NC	CC	RC	RC	NC	RC	NC	RC
Mustelus canis	NC	NC	NC	NC	NC	RC	NC	NC
Mustelus Norris	NC	RC	NC	NC	NC	NC	NC	NC
Ogcocephalus corniger	NC	RC	NC	NC	NC	NC	NC	NC
Ogcocephalus declivirostris	NC	RC	NC	NC	NC	NC	NC	NC
Ogcocephalus nasutus	NC	RC	NC	RC	NC	NC	NC	NC
Ogcocephalus pantostictus	NC	RC	NC	NC	NC	NC	NC	NC
Ogcocephalus parvus	NC	RC	NC	NC	NC	RC	NC	NC
Ophichthus gomesii	NC	NC	NC	NC	NC	NC	NC	RC

Species	Heald On-Bank	Heald Off-Bank	Sabine On-Bank	Sabine Off-Bank	Trinity On-Bank	Trinity Off-Bank	TIGER On-Bank	TIGER Off-Bank
Ophidion grayi	NC	RC	NC	RC	NC	RC	NC	NC
Ophidion holbrooki	NC	NC	NC	RC	NC	RC	NC	NC
Ophidion welshi	NC	RC	NC	RC	NC	CC	NC	RC
Orthopristis chrysoptera	NC	CC	CC	CC	NC	RC	NC	NC
Paraconger caudilimbatus	NC	NC	NC	NC	NC	RC	NC	NC
Paralichthys albigutta	NC	NC	NC	RC	NC	NC	NC	NC
Paralichthys lethostigma	NC	RC	RC	RC	NC	RC	NC	RC
Pogonias cromis	NC	NC	RC	RC	NC	RC	NC	RC
Porichthys plectrodon	NC	CC	NC	RC	NC	CC	CC	CC
Prionotus longispinosus	NC	CC	RC	RC	CC	CC	RC	RC
Prionotus ophryas	NC	RC	NC	RC	NC	RC	NC	NC
Prionotus roseus	NC	RC	NC	NC	NC	NC	NC	NC
Prionotus rubio	NC	CC	RC	RC	NC	RC	NC	RC
Prionotus scitulus	NC	RC	NC	RC	NC	RC	NC	NC
Prionotus tribulus	NC	CC	CC	CC	CC	RC	RC	RC
Raja texana	NC	NC	NC	RC	NC	RC	NC	NC
Rhinoptera bonasus	NC	RC	NC	RC	RC	RC	NC	NC
Rhizoprionodon terraenovae	FC	RC	NC	RC	CC	RC	NC	RC
Rypticus maculatus	NC	RC	NC	NC	NC	NC	NC	NC
Saurida brasiliensis	NC	RC	NC	RC	NC	RC	NC	RC
*Sciaenops ocellata**	NC	NC	NC	RC	NC	RC	NC	NC
Scorpaena brasiliensis	NC	NC	NC	RC	NC	NC	NC	NC
Scorpaena calcarata	NC	RC	NC	RC	NC	RC	NC	NC
Serraniculus pumilio	NC	RC	RC	RC	NC	NC	NC	NC
Serranus atrobranchus	NC	RC	NC	NC	NC	NC	NC	NC
Serranus phoebe	NC	NC	NC	RC	NC	NC	NC	NC
Sphoeroides dorsalis	NC	NC	NC	NC	NC	RC	NC	NC
Sphoeroides nephelus	NC	NC	NC	NC	NC	RC	NC	RC
Sphoeroides parvus	NC	CC	CC	CC	NC	CC	NC	CC

Species	Heald On-Bank	Heald Off-Bank	Sabine On-Bank	Sabine Off-Bank	Trinity On-Bank	Trinity Off-Bank	TIGER On-Bank	TIGER Off-Bank
Sphoeroides spengleri	NC	NC	NC	NC	NC	RC	NC	NC
*Sphyrna tiburo**	NC	RC	NC	RC	RC	RC	NC	NC
Stellifer lanceolatus	NC	RC	NC	CC	CC	RC	CC	CC
Stenotomus caprinus	NC	FC	NC	RC	NC	CC	NC	NC
Syacium gunteri	FC	CC	NC	RC	NC	RC	NC	RC
Syacium papillosum	NC	RC	NC	RC	NC	RC	NC	NC
Symphurus civitatus	NC	NC	NC	RC	NC	RC	RC	RC
Symphurus diomedianus	NC	RC	NC	NC	NC	NC	NC	NC
Symphurus plagiusa	NC	RC	NC	CC	NC	RC	CC	CC
Synodus foetens	FC	CC	NC	RC	NC	RC	NC	RC
Synodus poeyi	NC	NC	NC	RC	NC	NC	NC	NC
Trichopsetta ventralis	NC	NC	NC	NC	NC	RC	NC	NC
Trinectes maculatus	NC	NC	NC	RC	NC	RC	CC	RC
Upeneus parvus	NC	RC	NC	NC	NC	RC	NC	NC

Appendix I - Table 4. A list of the non-commercially exploited species which were caught and their species specific catch rates in each control area. For the individual catch frequencies: NC = Never Caught, RC = Rarely Caught, CC = Commonly Caught, FC = Frequently Caught.

Species	Western Control Area	Eastern Control Area
Aluterus heudelotti	NC	RC
Aluterus monoceros	RC	RC
Aluterus schoepfi	RC	RC
Aluterus scriptus	RC	RC
Ancylopsetta dilecta	RC	RC
Ancylopsetta quadrocellata	CC	CC
Antennarius radiosus	NC	RC
Antennarius striatus	NC	RC
Apogon affinis	NC	RC
Apogon aurolineatus	NC	RC
Apogon maculates	NC	RC
Apogon pseudomaculatus	NC	RC
Arius felis	RC	CC
Bagre marinus	NC	RC
Bellator brachychir	RC	NC
Bellator militaris	CC	RC
Bollmannia communis	RC	RC
Bothus robinsi	RC	NC
Bregmaceros atlanticus	RC	RC
Brotula barbata	RC	RC
Calamus bajonado	RC	NC
Calamus leucosteus	RC	NC
Calamus penna	NC	RC
Centropristis ocyurus	NC	RC
Centropristis philadelphica	FC	FC
Chascanopsetta lugubris	NC	RC
Chilomycterus schoepfi	RC	NC
Citharichthys macrops	RC	RC
Citharichthys spilopterus	RC	RC
Cyclopsetta chittendeni	CC	CC
Cynoscion arenarius	CC	CC
Cynoscion nothus	CC	CC
Dasyatis americana	NC	RC
Echiophis intertinctus	RC	NC
Echiophis punctifer	NC	RC
Engyophrys senta	CC	RC
Equetus acuminatus	RC	RC
Equetus iwamotoi	RC	RC
Equetus lanceolatus	NC	RC

Species	Western Control Area	Eastern Control Area
Equetus umbrosus	RC	RC
Etropus crossotus	CC	CC
Etropus microstomus	RC	NC
Etropus rimosus	RC	NC
Eucinostomus argenteus	RC	NC
Eucinostomus gula	CC	CC
Gobionellus hastatus	NC	RC
Gymnachirus melas	RC	NC
Gymnachirus texae	RC	RC
Gymnothorax nigromariginatus	RC	RC
Gymnothorax ocellatus	NC	RC
Gymnothorax saxicola	RC	RC
Halieutichthys aculeatus	FC	RC
Hemanthias aureorubens	NC	RC
Hildebrandia flava	RC	RC
Hippocampus erectus	NC	RC
Hoplunnis macrurus	RC	RC
Kathetostoma albigutta	RC	RC
Lactophrys quadricornis	RC	NC
Lactophrys triqueter	RC	NC
Lagocephalus laevigatus	CC	CC
Lagodon rhomboides	FC	CC
Larimus fasciatus	RC	RC
Leiostomus xanthurus	CC	CC
Lepophidium brevibarbe	CC	CC
Lepophidium jeannae	RC	RC
Lonchopisthus micrognathus	RC	NC
Menticirrhus americanus	NC	CC
Micropogonias undulatus	FC	FC
Monacanthus hispidus	NC	CC
Monacanthus setifer	NC	RC
Mulloidichthys martinicus	NC	RC
Mullus auratus	CC	RC
Mustelus canis	RC	RC
Mustelus norris	RC	RC
Myrophis punctatus	NC	RC
Neomerinthe hemingwayi	NC	RC
Ogcocephalus declivirostris	RC	RC
Ogcocephalus pantostictus	RC	RC
Ogcocephalus parvus	RC	RC
Ogcocephalus radiatus	RC	RC
Ophichthus rex	NC	RC
Ophidion grayi	NC	RC
Ophidion holbrooki	NC	RC

Species	Western Control Area	Eastern Control Area
Ophidion welshi	NC	RC
Opistognathus lonchurus	NC	RC
Opsanus pardus	NC	RC
Orthopristis chrysoptera	RC	RC
Paraconger caudilimbatus	NC	RC
Paralichthys albigutta	NC	RC
Paralichthys lethostigma	RC	RC
Paralichthys squamilentus	NC	RC
Pogonias cromis	NC	RC
Pontinus longispinis	NC	RC
Porichthys plectrodon	CC	CC
Priacanthus arenatus	RC	RC
Priacanthus cruentatus	RC	NC
Prionotus longispinosus	CC	FC
Prionotus martis	NC	RC
Prionotus ophryas	CC	RC
Prionotus paralatus	CC	CC
Prionotus roseus	RC	RC
Prionotus rubio	CC	RC
Prionotus scitulus	RC	RC
Prionotus stearnsi	CC	RC
Prionotus tribulus	RC	RC
Pristigenys alta	RC	NC
Pseudupeneus maculatus	RC	RC
Raja texana	CC	RC
Rhizoprionodon terraenovae	RC	RC
Rypticus maculatus	RC	RC
Rypticus saponaceus	RC	RC
Saurida brasiliensis	CC	CC
Saurida caribbaea	RC	NC
Scorpaena calcarata	CC	RC
Scorpaena dispar	NC	RC
Serranus atrobranchus	CC	CC
Sphoeroides dorsalis	RC	RC
Sphoeroides parvus	CC	CC
Sphoeroides spengleri	RC	RC
Stellifer lanceolatus	NC	RC
Stenotomus caprinus	FC	FC
Syacium gunteri	CC	CC
Syacium micrurum	RC	RC
Syacium papillosum	CC	RC
Symphurus civitatus	NC	RC
Symphurus diomedianus	RC	RC
Symphurus plagiusa	RC	RC

Species	Western Control Area	Eastern Control Area
Synodus foetens	FC	FC
Synodus intermedius	RC	NC
Synodus poeyi	CC	RC
Trachinocephalus myops	NC	RC
Trichopsetta ventralis	RC	RC
Trinectes inscriptus	NC	RC
Trinectes maculatus	NC	RC
Upeneus parvus	FC	CC
Urophycis cirratus	NC	RC
Urophycis floridanus	RC	RC
Urophycis regia	NC	RC

Appendix - Table 5. Seasonal trends in fish catch abundances for non-commercially exploited species which were found to be common or abundant in the study bank/shoal areas. A value of "S" indicates that the species was abundant or commonly caught in the summer on that bank but not in the winter. A value of "W" indicates that the species was abundant or commonly caught in the winter on that bank but not in the summer. Blank Cells indicate that there was no seasonal variation in species catch abundance for that bank but all species in the table exhibited a seasonal change in catch frequency for at least one bank.

Scientific Name	Heald	Sabine	Tiger	Trinity
Bagre marinus			S	W
Centropristis philadelphica		W	W	W
Citharichthys spilopterus		W		
Etropus crossotus		W	W	
Eucinostomus gula	W			
Halieutichthys aculeatus	W			
Lactophrys quadricornis	W			
Lagocephalus laevigatus	S			
Lagodon rhomboides		S		
Larimus fasciatus	S	S		
Leiostomus xanthurus		S	S	
Lepophidium brevibarbe	S			
Menticirrhus americanus	S		W	W
Monacanthus hispidus	S			
Ophichthus gomesii				
Ophidion welshi	W			W
Orthopristis chrysoptera	W	W		
Pogonias cromis			W	
Porichthys plectrodon	W			W
Prionotus longispinosus		W		
Prionotus tribulus	S	S	W	
Serraniculus pumilio	S			
Sphoeroides parvus		W	W	W
Stellifer lanceolatus		S		W
Syacium gunteri		W		W
Symphurus plagiusa		W		
Synodus foetens		W		W

Appendix - Table 6. Seasonal trends in fish catch abundances for non-commercially exploited species which were found to be common or abundant in the control areas. A value of "S" indicates that the species was abundant or commonly caught in the summer on that bank but not in the winter. A value of "W" indicates that the species was abundant or commonly caught in the winter on that bank but not in the summer. Blank Cells indicate that there was no seasonal variation in species catch abundance for that bank but all species in the table exhibited a seasonal change in catch frequency for at least one bank.

Scientific Name	Western Control Area	Eastern Control Area
Ancylopsetta quadrocellata	W	W
Arius felis	W	
Bellator militaris	S	
Cynoscion arenarius	W	
Cynoscion nothus	W	
Engyophrys senta	S	
Etropus crossotus	S	
Etrumeus teres		S
Eucinostomus gula		W
Larimus fasciatus		W
Monacanthus hispidus		S
Mullus auratus		W
Orthopristis chrysoptera	W	
Paralichthys lethostigma	S	
Priacanthus arenatus	S	
Prionotus ophryas	S	
Prionotus paralatus		S
Prionotus rubio	S	S
Prionotus stearnsi	S	S
Raja texana	S	W
Rhizoprionodon terraenovae		W
Sphoeroides spengleri	S	
Symphurus plagiusa	S	S
Synodus poeyi	S	
Urophycis floridanus	S	

Chronological List of NEGOM OCS Ecosystem Studies Publications From the USGS Coastal Ecology & Conservation Research Group

Weaver, D. C., K. J. Sulak, W. Smith-Vaniz, and S. W. Ross. 1999. Community structure and trophic relationships of demersal reef fishes of the Mississippi-Alabama outer continental shelf. Pp. 286-292, In: Proceedings Seventeenth Gulf of Mexico Information Transfer Meeting, Kenner, LA, December 1997, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, OCS Study MMS 99-0042 (M. McKay and J. Nides, eds.).

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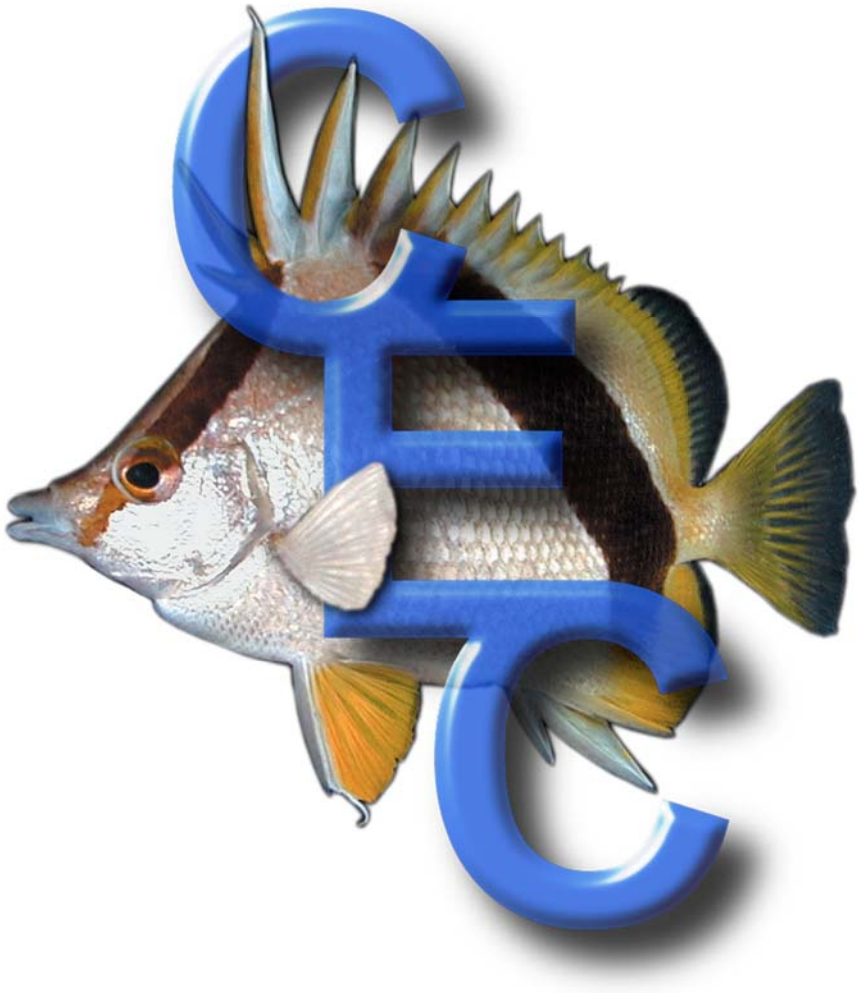

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