Vertical Distribution of Ichthyoplankton in the Northern Gulf of Mexico: Relevant to LNG Intake and Discharge Depths

Richard F. Shaw

Department of Oceanography and Coastal Sciences

School of the Coast & Environment

Louisiana State University

BACKGROUND AND MOTIVATION

- On 16 February 2005, MARAD's most recent open loop decision was handed down granting Shell U.S. Gas and Power's license to operate the Gulf Landing LNG terminal in West Cameron 213 Block, 38 statute miles off Cameron, LA. Terminal will be capable of processing 1 billion cubic feet of gas per day, necessitating that more than 136 million gallons of sea water per day be pumped through its radiator-like system.

BACKGROUND AND MOTIVATION (cont.)

- Two other licenses have been granted: ChevronTexaco (Port Pelican, 36 miles off southwest LA-Vermilion Block 140, first to receive a license on March 31, 2004 for a 176 million gal/day facility); and Excelerate Energy (Gulf Gateway Energy Bridge Deepwater Port, a submersible buoy 116 miles off Cameron, LA in 91m of water which requires a ship that can regasify the LNG onboard under a license to operate at a peak volume of 76 million gal/day of seawater for 248 days/year, which is now operational (20 March 2005) and has already offloaded three shipments of LNG.

BACKGROUND AND MOTIVATION (cont.)

- Freeport MacMoRan Main Pass Energy Hub (Main Pass 299 Block, 37 miles east of Venice, LA) recently received (4 January 2007) final approval on its application which it had resubmitted proposing a closed rack system that will use very little ambient seawater.
- There are presently two (2) other LNG open loop terminals proposed for the north-central Gulf, i.e., Conoco-Phillips (Beacon Port Clean Energy Terminal, High Island Area 71, 56 miles off the LA-TX border – presently under review); and Torp Technology's Bienville LNG Offshore Energy Terminal (BOET) in Main Pass 258, 63 miles south of Mobile Point, AL.

METHODS

An on-line search was conducted of potentially-relevant databases and then pertinent literature, i.e., peer-reviewed or “grey literature” (e.g., government documents, conference proceedings, major technical reports, etc.) relevant to marine ichthyoplankton communities within Gulf of Mexico was compiled and reviewed.

METHODS (cont.)

This compilation of literature was prepared with assistance of several electronic databases subscribed to by Louisiana State University. Databases were searched electronically using Cambridge Scientific Abstracts Internet Database Service (CSA), U.S. Government Printing Office Access service (GPO), Scholarly J. Archive (JSTOR), Institute for Scientific Information (ISI), and Ovid Technologies database services. The following databases were searched:

- Academic Search Premier
- Aquaculture Abstracts (ASFA)
- Aquatic Pollution and Environmental Quality (ASFA)
- Biological Abstracts
- Biological Sciences (CSA)
- Biological Sciences and Living Resources (CSA)
- Catalog of US Government Publications
- Conference Papers Index
- Dissertation Abstracts
- Effects of Offshore Oil and Gas Development
- Electronic Collections Online (ECO)
- Energy Citations Database (Gov)
- GEOBASE
- Grey Literature
- JSTOR (Ecology)
- Marine Biotechnology Abstracts
- National Technical Information Service
- Oceanic Abstracts
- Science.gov
- Toxnet
- Zoological Record

METHODS (cont.)

- The search strategy included preparation of initial keyword and database lists. All data bases available for searching in the library at Louisiana State University and relevant to aquatic biology were queried to search article titles, abstracts, keyword lists, and any other available text in the databases using the list of key words. Nine key words or phrases, root forms, and logical operators (e.g., AND & OR) were used to develop the literature compilation. This search captured documents from 1964 to May 2006.

ichthyoplankton **OR** larval fish **OR** early life history of fish

AND

vertical **OR** depth **AND** distribution **OR** preference

AND

continental shelf **OR** across-shelf distribution

AND

Gulf of Mexico

OCS Study
MMS 2006-071

Coastal Marine Institute

Annotated Bibliography of the Potential Environmental Impacts of Chlorination and Disinfection Byproducts Relevant to Offshore Liquefied Natural Gas Port Facilities

R. F. Shaw and K. W. Baggett

LIST OF KEYWORDS SEARCHED FOR BIBLIOGRAPHY

- chlorination
- disinfection byproducts
- intake water
- discharge water
- cooling water
- heating water
- entrainment
- power plant
- ichthyoplankton
- zooplankton
- marine organisms

RESULTS

- Most larval fish vertical distribution data from Gulf involve studies of commercially- and recreationally-important species such as gulf menhaden, *Brevoortia patronus*, drums (Sciaenidae), and jacks (Carangidae).
  - Shaw et al. (1985) found no statistical difference in gulf menhaden densities from simultaneous surface and near-bottom tows taken across shelf off LA-TX border during either day or night. Slightly more gulf menhaden were found at surface but not consistently, and no differences were seen in their size frequency between two depths (Shaw 1982).
  - Conclusions from other vertical distributional studies on gulf menhaden differ.

RESULTS (cont.)

- Hoese (1965) reported gulf menhaden to be strictly a surface form in collections made within and offshore of Corpus Christi and Aransas Bay, TX.
- Fore (1970) observed high gulf menhaden densities at mid-depth with only a few near bottom, while using a Gulf V sampler towed horizontally at 1.5 m, 6 m, and occasionally near bottom within 32km radius of Galveston Entrance, TX.
- Based upon a comparison of horizontal tows at 4 m depth and oblique water column tows, Walker (1978) reported gulf menhaden to be more abundance above 4 m in coastal waters (3–38 m station depths) between Barataria and Timbalier Bays, LA.
- Vecchione et al. (1982, 1983) observed no significant differences between near surface, mid-depth and near bottom tows off Calcasieu Pass, LA, (12 m depth shoreward) but did indicate general trend towards higher densities in mid to upper water column.

RESULTS (cont.)

Sogard et al. (1987) and Al-Yamani (1988) reported on a series of cruises along transects off Cape Sans Blas, FL, S.W. Pass, Mississippi River Delta, and off Galveston, TX.

- Vertically stratified tows, i.e., surface (1–2m depths), in “the middle of upper mixed layer,” and “within or just above the thermocline (or mid-depth, when the water column was isothermal),” were taken at three stations along each transect at 18, 91 and 183 m station depths during dawn, midday, dusk and midnight.
- Both studies reported surface preferences for gulf menhaden at inner shelf stations at least during day, and more vertically-dispersed distributions at night.
- Both studies also reported on vertical distribution of Atl. croaker, *Micropogonias undulas*, and spot, *Leiostomus xanthurus* (Sciaenidae), which were not statistically stratified across the three station depths or the three transects. Atl. croaker were uniformly distributed across depths with only some propensity to be bottom oriented.

RESULTS (cont.)

- Cowan and Shaw (1988), using a 4-way ANOVA involving month, across-shelf station depth groups, day vs. night, and surface vs. near-bottom horizontal tow types as main effects, found Atlantic croaker, uniformly distributed.
- For spot, however, they found possible evidence for vertical migration and stratification. The interaction between day-night and horizontal tow type was statistically significant ($P < 0.05$). Mean surface density for spot larvae during the day was 0.1/100 m3, while mean near-bottom density was 1.6. Conversely, nighttime surface density was 1.0/100 m3, while at near-bottom it was 0.04. Although these are low densities, their vertical differences are an order of magnitude and their reversing pattern indicates spot larvae were stratified and could be undergoing diel vertical migration.

RESULTS (cont.)

- Sand seatrout, *Cynoscion arenarius*, were found to be somewhat surface oriented (surface densities = 9.2/100 m3 vs. near bottom = 1.9), but not significantly so (Cowan and Shaw 1988).
- Walker (1978) found spot, Atlantic croaker and star drum (*Stellifer lanceolatus*) as well as the antenna codlet, *Bregmaceros allanticus* (Bregmacerotidae) to be more abundant below 4 meters. He also reported surface preferences for the clupeid *Opisthonema oglinum* and *Anchoa mitchilli*.

RESULTS (cont.)

- A study during January and May 1981 in Dog Keys Pass, MS, found no clear vertical pattern for both gulf menhaden or spot, while also finding contrary results for sand seatrout and *Anchoa* spp. which appeared to be bottom oriented regardless of time of day (Lyczkowski-Shultz et al. 1990; Rakocinski et al. 1996).
- In a nearby study off Mississippi barrier islands (12–21 m station depths) conducted between August and November 1983–85, *Sciaenops ocellatus* (red drum) were found to be more abundant higher in water column during day, yet, deeper at night (i.e., reverse vertical migration; Lyczkowski-Shultz et al. 1988; Lyczkowski-Shultz and Steen 1991).

RESULTS (cont.)

- In a shelf study conducted during 22–30 May 1994 involving 22 stations along four transects off the Grijalba-Usumacinta River system and the Del Carmen, Machona and Terminos Lagoons, Mexico (Flores-Coto et al. 1999), sciaenids (i.e., *Cynoscion arenarius*, C. *nothus*, *Micropogonias* spp., *Stellifer lancoelatus*, *Menticirchus* spp., and *Larimus fasciatus*) were mostly caught along inner shelf (18–36 m station depths).
- 16% of the total sciaenid catch taken within surface statum (0–6 m), 81% within 6–12 m stratum, and only four larvae taken within 12–18 m stratum.
- No sciaenid larvae were taken at the two other sampling strata, i.e., 45–55m or 95–105m.

RESULTS (cont.)

- During another cruise (13–22 August 1993) which occupied same four, across-shelf transects, almost all carangidae larvae (*Chloroscombrus chrysurus*, *Selar crumenophthalmus*,
- *Caranx* spp., *Selene setapinnis*, *Decapterus punctatus*, and *Hemicaranx amblyrhynchus*) were collected at mid-shelf (16–70m station depths).
- Virtually all caragid larvae were collected within the top three sampling strata (i.e., above 18 m), with only seven larvae collected from deeper strata, i.e., 45–105m (Flores-Coto et al. 2001).

RESULTS (cont.)

- A study on the Flower Garden Banks and surrounding waters (depths 100-150 m) off LA-TX border (McGowan 1985) reported on larvae of not only pelagic shelf species but also reef-associated and reef-dependent species.
  - During eight cruises from October 1980 to October 1982, three depth strata were sampled: 1) surface to the seasonal thermocline; 2) from seasonal thermocline to just above bottom nepheloid layer; and 3) within nepheloid layer.
  - Of the 85 families collected (39,674 larvae), the top 13 families accounted for over 93% of total larval density.
  - In general, densities and number of families were greater in the surface mixed layer (depth seasonally variable but < 60 m) than below. Bregmacerotidae, Myctophidae, Gonostomatidae, Ophidiidae, and Scopelarchidae, however, were more abundant below thermocline.
  - Gonostomatids actually had highest densities in bottom nepheloid layer (McGowan 1985).

RESULTS (cont.)

- In a more vertically-detailed but shorter duration study (one cruise – 26 May to 5 June 1989) along southern edge of Florida Keys (Cha et al. 1994), ichthyoplankton collections were made at eight stations (station depths = 166-237 m and a mixed surface layer < 35 m) with a 1 m2 MOCNESS at 25 m depth strata (e.g., depth strata 1 = 0-25 m; 25 m < depth strata 2 < 50 m; … depth strata 8 = 176 – 200m).
  - Only nocturnal samples were used to minimize net avoidance by larger more agile fish.
  - The top 14 families represented 87% of the total abundance, with 6.7% being allocated across remaining 51 families and 6.8% of total catch unidentified.
  - The first and second strata had 31.5% and 33.1%, respectively, of total larval fish collected (i.e., 64.6% of all larvae taken within top 50 m) and had representatives of 40 and 38 of the 65 families collected, respectively.
  - Larval fish densities and numbers of families represented continued to decrease with depth, e.g., third to eighth stratum had 27, 26, 22, 21, 14, and 2 (Myctophidae and Callionymidae) families, respectively.

RESULTS (cont.)

- These findings appear to somewhat conflict with McGowan's (1985) Flower Garden results in that four out of the five families (i.e., Bregmacerotidae, Myctophidae, Gonostomatidae, and Scopelarchidae) he found to be more abundant below the thermocline or surface mixed layer, i.e., ≤60m depth, were found mostly in depth strata 2 or above at the Florida Keys.

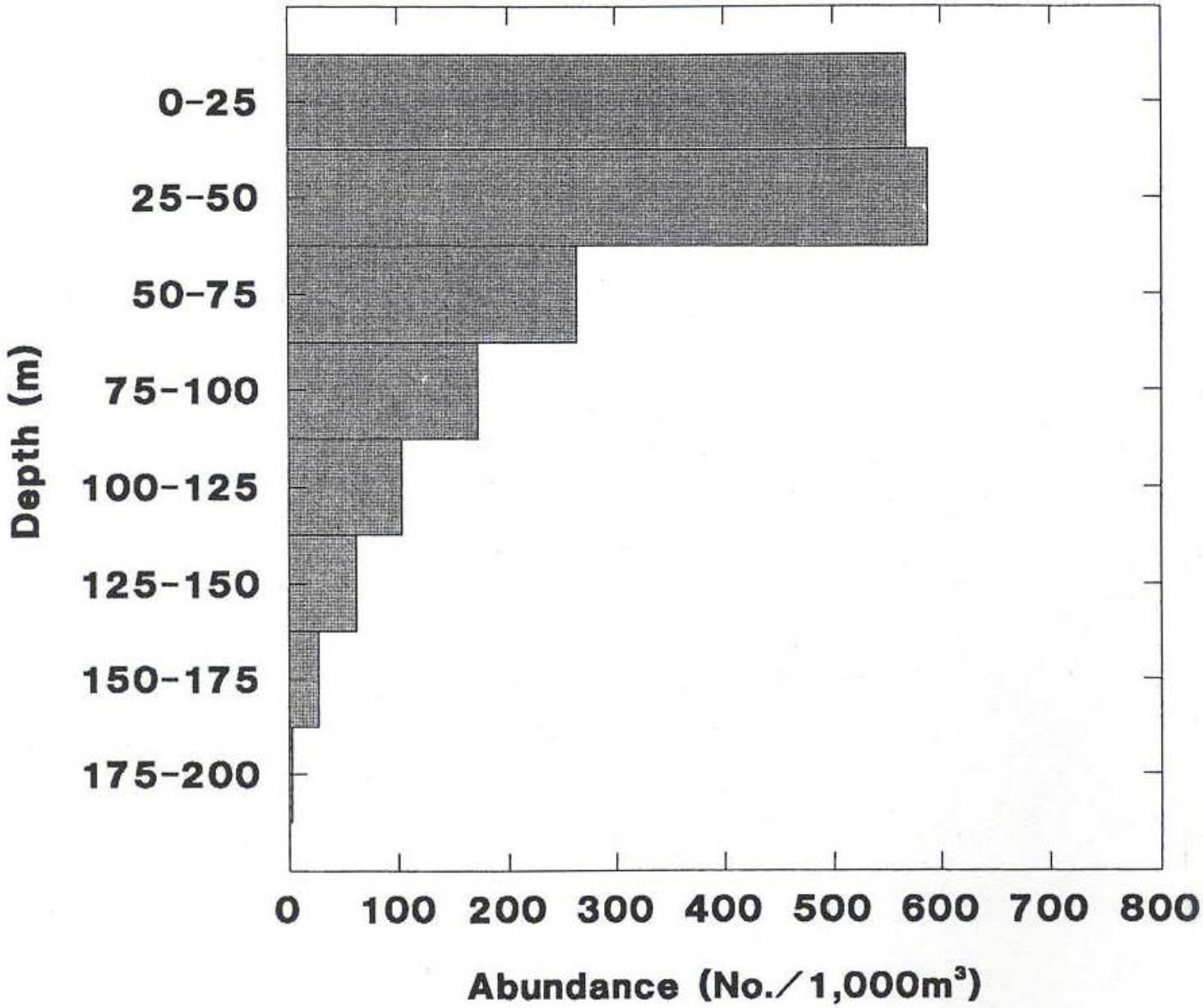

Figure 3. Vertical distribution of fish larvae; mean abundance of fish larvae at each stratum.

(from Cha et al. 1994)

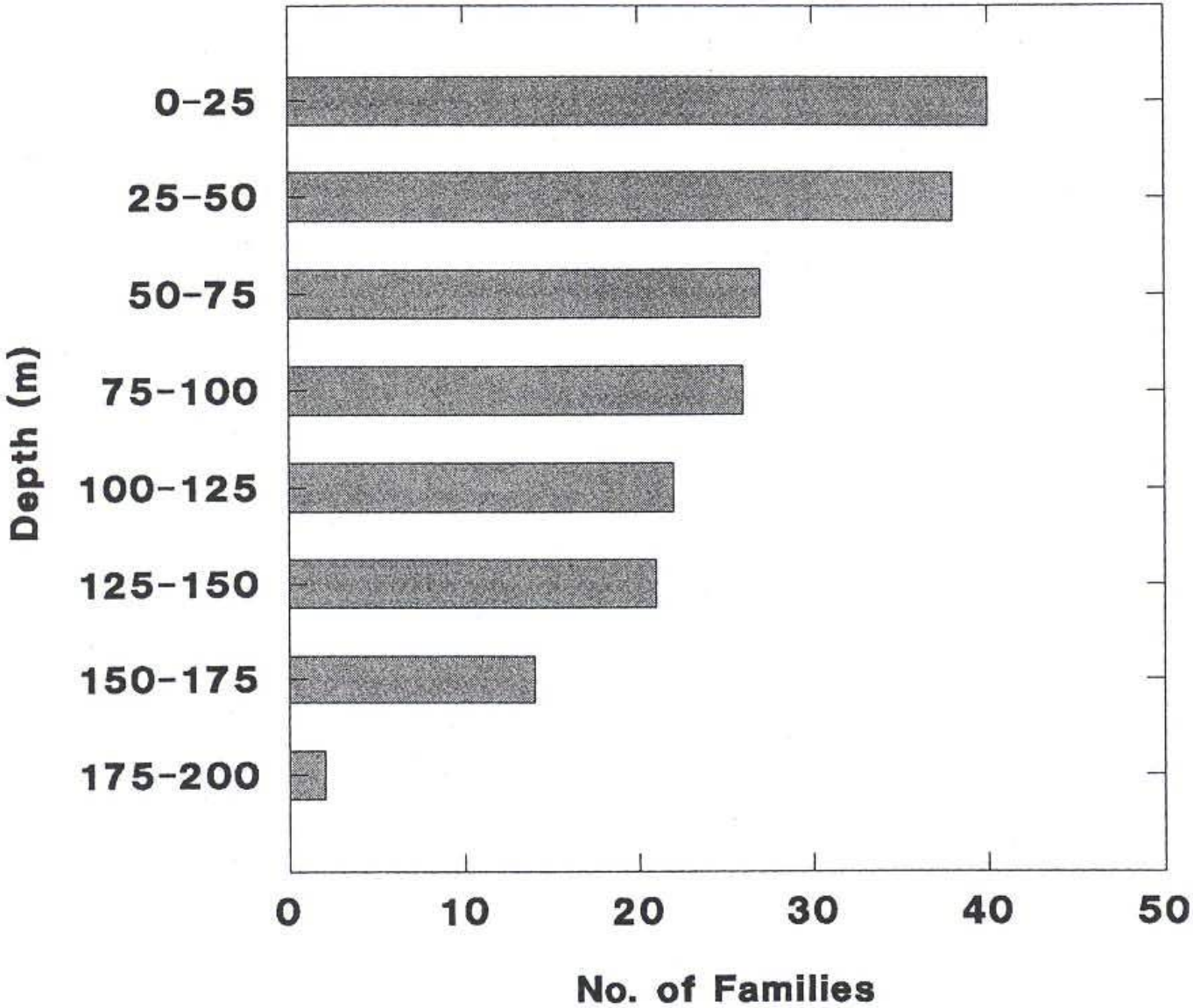

Figure 4. The number of families of fish larvae at each stratum. (from Cha et al. 1994)

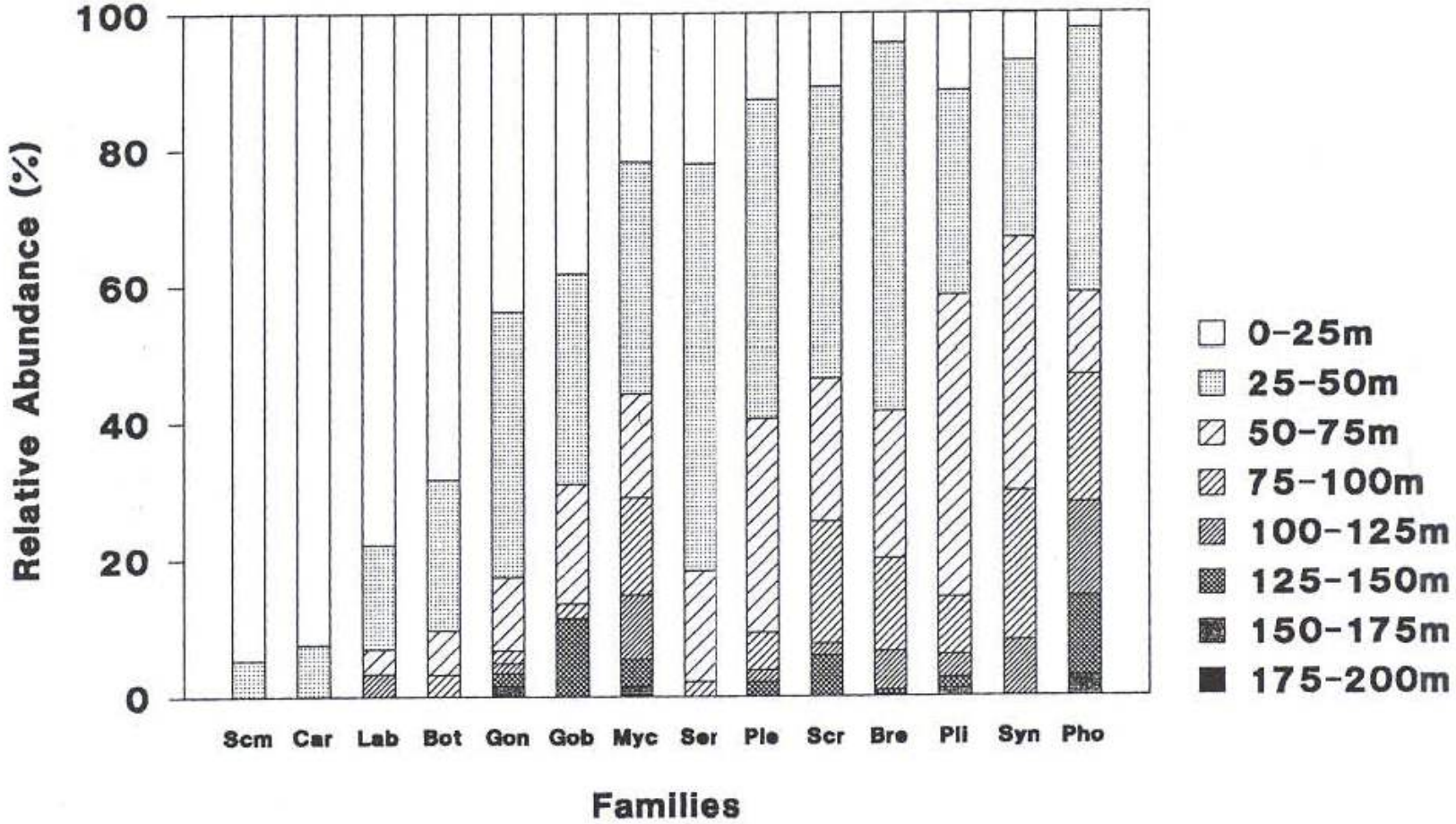

Figure 5. Relative abundance of the 14 most abundant families by depth stratum. The legends are as follows. Scm: Scombridae, Car: Carangidae, Lab: Labridae, Bot: Bothidae, Gon: Gonostomatidae, Gob: Gobiidae, Myc: Myctophidae, Ser: Serranidae, Ple: Paralepididae, Scr: Scorpaenidae, Bre: Bregmacerotidae, Pli: Paralichthyidae, Syn: Synodontidae, Pho: Phosichthyidae.

(from Cha et al. 1994)

LOOP ANALYSIS

- Only station locations (n = 92 sites) with water depth ≥7.6m (7.6 – 37m depths) included.
- Although total sampling period from Feb. 1978 to Dec. 1995, most sampling sites (n = 86) had intermittent data.
- Sampling mostly conducted during daylight and monthly but some stations only quarterly.

LOOP ANALYSIS (cont.)

- Surface plankton collections
  - 0.5 ring nets (80 and 153µm mesh)
  - 1m ring net (363µm mesh)
  - 60-cm opening and closing bongo nets (363µm) taken at surface, mid-water and near-bottom
  - At deeper stations, opening and closing bongo nets used to obliquely sample 2 halves of water column (i.e., mid-water to surface and near-bottom to mid-water).

LOOP ANALYSIS (cont.)

- Of the 319 taxa analyzed (312 ichthyoplankton and 7 commercially-important decapods), only 20 ichthyoplankton and 3 decapods were found to have statistically significant depth differences after Bonnferroni adjustment.

- General tendency towards higher number of taxa and higher densities associated with surface waters or surface and mid-depth depth bins combined.

- Within the horizontally-stratified sampling total taxa collected, total density and mean variability declined with depth (total surface depth bin = 68 ± 357.2 SE; total mid-water depth bin density 48 ± 6.23 and near-bottom total density = 34 ± 1.38).

LOOP ANALYSIS (cont.)

- 96 taxa collected exclusively at surface – total mean density = 2.33 (± 2.89 SE)
- 43 taxa collected exclusively at upper two layers of water column (i.e., surface, mid-depth and upper half water column oblique tows) – total mean density = 3.76 (± 5.75)
- 12 taxa collected exclusively at lower two layers (i.e., near-bottom, mid-depth and lower half water column oblique tows).
- No taxa found exclusively in the discrete mid-water or near-bottom collections (i.e., opening and closing bongo tows).

LOOP ANALYSIS (cont.)

- 141 taxa were found to have no exclusivity to any depth bin whatsoever and were therefore ubiquitous.

- Significantly higher densities at surface, mid-water or upper half water column oblique collections
  - *Anchiovella* spp. (flat anchovy?)
    Brevoortia patronus (gulf menhaden)
    Cynoscion nothus (silver seatrout)
    Paralichthyes spp. (flounder)
    Trichiurus lepturus (Atl. cutlassfish)
    **Farfantepenaeus aztecus* (brown shrimp)
    **Farfantepenaeus duorarum* (pink shrimp)
    **Litopenaeus setiferus* (white shrimp)
    - although lower oblique densities were also statistically greater than near-bottom densities.

LOOP ANALYSIS (cont.)

- Significant mid-water density differences
  - *Bairdiella chrysoura* (silver perch)
    Bregmaceros spp. (codlet)
    Brotula barbata (bearded brotula)
    Microdesmus spp. (wormfish)
    Micropogonias undulatus (Atl. croaker)
    Ophidion spp. (cusk-eel)
    Peprilus burti (gulf butterfish)
    Serranidae (sea basses)
    Sygnatus spp. (pipefish)

LOOP ANALYSIS (cont.)

- Significant near-bottom density differences
  - (*Callionymus*) *Diplogrammus paucirdiatus* (spotted dragonet)
    - although upper oblique densities were also statistically greater than lower oblique
  - *Pogonias cromis* (black drum)
  - *Sphoeroides* spp. (puffer)
  - Antennariidae (frogfishes)
  - Ophidiidae (cusk-eels)
  - Synodontidae (lizardfishes)

BACKGROUND AND MOTIVATION (cont.)

- Finally, both ExxonMobil (Pearl Crossing, 41 miles SE of Cameron) and Conoco-Phillips (Compass Point, 11 miles off Dauphin Island, AL) have withdrawn their open loop applications.

REFERENCES

Al-Yamani, F.Y. 1988. Distributional ecology of zooplankton and fish larvae (spot, croaker, menhaden) in the northern Gulf of Mexico. Ph.D. Dissertation, University of Miami, Coral Gables, FL. 421 pp. (1989. Dissertation Abstracts 49(10). 443 pp.)

Cha, S.S., M.F. McGowan, and W.J. Richards. 1994. Vertical distribution of fish larvae off the Florida Keys, 26 May–5 June 1989. Bulletin of Marine Science 54:828–842.

Cowan, J.H., Jr, and R.F. Shaw. 1988. The distribution, abundance, and transport of larval sciaenids collected during winter and early spring from the continental shelf waters off west Louisiana. Fishery Bulletin, U.S. 86:29–142.

Flores-Coto, C., P. Figueroa-Paze, and F. Zavla-Garcia. 1999. Distribution and abundance of Sciaenidae larvae in the water column of the southern Gulf of Mexico. Hidrogiologica (Izapalapa) 9:135–144 (in Spanish with English abstract).

REFERENCES (cont.)

Flores-Coto, C., R. Rivas-Vegas, F. Zavala-Garcia, and J. Sanchez-Robles. 2001. Vertical distribution of larval carangids in the southern Gulf of Mexico. Gulf and Caribbean Research 13:1–8.

Fore, P.L. 1970. Life history of gulf menhaden Brevoortia patronus. In: Research in the Fiscal Year 1969 at the Bureau of Commercial Fisheries Biological Lab. Beaufort, NC. U.S. Fish and Wildlife Service Circular 350:12–16.

Hoese, H.D. 1965. Spawning of marine fishes in the Port Aransas, Texas area as determined by the distribution of young and larvae. Ph.D. Dissertation, University of Texas, Austin, TX. 144 pp., unpublished.

Lyczkowski-Shultz, J. and J.P. Steen, Jr. 1991. Diel vertical distribution of red drum Sciaenops ocellatus larvae in the northcentral Gulf of Mexico. Fishery Bulletin 89:631–641.

Lyczkowski-Shultz, J., D.L. Ruple, S.L. Richardson, and J.H. Cowan, Jr. 1990. Distribution of fish larvae relative to time and tide in a Gulf of Mexico barrier island pass. Bulletin of Marine Science 46(3):563–577.

REFERENCES (cont.)

Lyczkowski-Shultz, J., J.P. Steen, Jr., and B.H. Comyns. 1988. Early life history of red drum (Sciaenops ocellatus) in the northcentral Gulf of Mexico. Gulf Coast Research Lab., Ocean Springs, MS. Sea Grant Technical Report MASGP-88-013. 163 pp.

McGowan, M.F. 1985. Ichthyoplankton of the Flower Garden Banks, northwest Gulf of Mexico. Ph.D. Dissertation, University of Miami, Coral Gables, FL. 377 pp., unpublished.

Rakocinski, C.F., J. Lyczkowski-Shultz, and S.L. Richardson. 1996. Ichthyoplankton assemblage structure in Mississippi Sound as revealed by canonical correspondence analysis. Estuarine and Coastal Shelf Science 43:237–257.

Shaw, R.F., J.H. Cowan, and T.L. Tillman. 1985. Distribution and density of Brevoortia patronus (gulf menhaden) eggs and larvae in the continental shelf waters of western Louisiana. Bulletin of Marine Science 36: 96–103.

REFERENCES (cont.)

Shaw, R.F., T.L. Tillman, J.H. Cowan, Jr., and S.M. Peterson. 1982. Chapter 3: Zooplankton, fish eggs, and larvae. In: Evaluation of the brine disposal from the West Hackberry site: The regional impact on menhaden resources. Louisiana Continental Shelf System Working Group Final Report to the U.S. Dept. of Energy, Strategic Petroleum Reserve Project Management Office, New Orleans, LA. Prepared by the Center for Wetland Resources, Louisiana State University, Baton Rouge, LA. Publ. No. LSU-CEL-82-27.

Sogard, S.M., D.E. Hoss, and J.J. Govoni. 1987. Density and depth distribution of larval gulf menhaden, Brevoortia patronus, Atlantic croaker, Micropogonias undulatus, and spot, Leiostomus xanthurus, in the northern Gulf of Mexico. Fishery Bulletin, U.S. 85:601–609.

Vecchione, M., C.E. Meyer, and C.L Stubblefield. 1982. Zooplankton. In: DeRouen, L.R., R.W.Hann, D.M. Casserly, and C.Giammona, eds. West Hackberry Brine Disposal Project Pre-discharge Characterization. DOE Strategic Petroleum Reserve Project. DOE Contract No. DE-AC96-80P010228. Pp. 8-1 – 8-69.

REFERENCES (cont.)

Vecchione, M., C.M. Lascara, C.L. Stubblefield, and W.O. James. 1983. Zooplankton: The relationship between brine-diffuser operation and zooplankton distribution. In: Final Report, Vol. 3. Biological Oceanography. DOE, Strategic Petroleum Reserve Project, Management Office, New Orleans, LA. Contract # DE-AC96-80P010288. Pp. 9-1 – 9-125.

Walker, H.J. 1978. Ichthyoplankton survey of nearshore Gulf waters between Barataria Bay and Timbalier Bay, Louisiana, during July, August, and December 1973. M.S. Thesis, Louisiana State University, Baton Rouge, LA. 55 pp., unpublished.