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Comparison of Plankton Net and Light Trap Methodologies for Sampling Larval and Juvenile Fishes at Offshore Petroleum Platforms and a Coastal Jetty off Louisiana

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Abstract.—We sampled ichthyoplankton at artificial structures across the continental shelf (3–219-m depth) of the northern Gulf of Mexico and compared passive plankton net and light trap methodologies at three offshore petroleum platforms (shelf slope, mid-shelf, and inner shelf) and plankton push-net and light trap methodologies at a coastal jetty. Clupeiform fishes dominated collections for all gears (59–97% of the total catch). Plankton nets collected more fish than light traps at two platforms (plankton net versus light trap, minus clupeiforms: 1,404 versus 659 at slope; 3,076 versus 12,474 at mid-shelf; and 1,689 versus 1,193 at inner shelf), and jetty push nets collected more fish than light traps (33,147 versus 849). Nets collected more families than light traps at the shelf slope and mid-shelf platforms (plankton net versus light trap: 43 versus 35; 38 versus 35; and 32 versus 32) but only collected more taxa (genus level) than light traps at the shelf slope platform (plankton net versus light trap: 56 versus 47; 75 versus 78; and 50 versus 56). Jetty push nets collected more families (39 versus 19) and taxa (77 versus 34) than light traps. Kolmogorov-Smirnov length-frequency comparisons of fish collected in nets versus light traps indicated that light traps generally overlapped the net's smaller sizes, while collecting significantly larger individuals. At the jetty, greater overlap in gear size distributions were observed. There was low taxonomic similarity between gears at the two deeper platforms (Schoener's Similarity Index values = 0.32–0.38) but higher similarity (0.63) at the inner shelf platform, which was most dominated by clupeiforms. At the jetty, push-net and light trap samples had relatively high taxonomic similarity (0.61). Few significant differences were detected between Shannon-Weiner Diversity Indices for platform light trap and net samples, while jetty push nets had significantly higher diversity than light traps. When significant differences in mean total densities and mean total CPUEs were found between new versus full moon phases, four out of five instances had greater new moon catches.

Introduction

Most marine fishes, particularly structure-associated or reef-dependent fishes, have a pelagic early life history stage (Moser et al. 1984; Leis 1991). Previous studies have indicated that larval source, supply, re-

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cruitment, and settlement patterns can greatly influence the adult population dynamics of reef fish on both natural (Victor 1983, 1986; Sponaugle and Cowen 1996) and artificial reefs (Lukens 1981; Stephens et al. 1994). In response to the need for crucial information on reef fish early life history stages, several methods have been developed to collect larval and juvenile fishes in a variety of environments. Many reef fish juveniles at one time or another are associated with structurally complex habitats, either while they reside in a nursery area (e.g., mangroves, sea grass meadows, oyster reefs) or once they settle onto the reef environment itself. While towed sampling gears are effective in open waters, these methods are usually not suitable for shallow or structurally complex habitats (Brogan 1994).

Different methodologies have been developed to collect fish early life stages in complex environments, including plankton pumps (Taggart and Leggett 1984; Brander and Thompson 1989), visual censuses (Kingsford and Choat 1989), moored channel nets (Keener et al. 1988; Shenker et al. 1993), larval purse seines (Murphy and Clutter 1972; Choat et al. 1993), and diver-steered plankton tows (Marliave 1986; Brogan 1994). Other methods have used light sources to aggregate fish for collection and include lighted purse seines (Choat et al. 1993), light lift-nets (Dennis et al. 1991; Rooker et al. 1996), and light traps of various designs (Doherty 1987; Thorrold 1992; Choat et al. 1993; Brogan 1994; Sponaugle and Cowen 1996; Hernandez and Lindquist 1999; Hickford and Schiel 1999; Reyns and Sponaugle 1999). All of these methods have different biases, advantages, and disadvantages and should be chosen to best suit the environment being sampled, as well as the life history stages and questions being addressed.

To date, very few studies have investigated the ichthyoplankton assemblages associated with offshore oil and gas platforms in the northern Gulf of Mexico (Gulf) or elsewhere in the world, in part due to the difficulties of sampling within the complex, mostly vertical infrastructure of the platforms. Gallaway (1998) calculated that oil and gas platforms in the northern Gulf provided 11.7 km^2 (or <0.4%) of the total "reef" habitat. However, platforms represent vertical artificial substrate that extends from the bottom to the surface (photic zone), regardless of location and depth, which increases their significance (Parker et al. 1983). These and other artificial structures (e.g., jetties, breakwaters) could represent significant habitats for reef fish in the northern Gulf, since it is dominated by a mud/silt/sand bottom with little vertical relief or hard-bottom habitat. In an attempt to characterize the across-shelf ichthyoplankton assemblages along a transect of artificial structures (three offshore oil and gas platforms and a coastal jetty) in the northern Gulf, multiple gear types were used in an effort to sample the widest range of taxa, size-classes, and developmental stages available (Hernandez et al. 2003). This paper reports results of gear comparisons between passive plankton nets and light traps used at three, across-shelf petroleum platforms. It also includes comparisons between a bow-mounted, plankton push net and light trap (the same design) used at a coastal jetty. Previous studies have demonstrated that push nets are effective in sampling larger juveniles and small fishes, particularly in coastal areas (Herke 1969; Kriete and Loesch 1980; Raynie and Shaw 1994). In these comparisons, the taxa collected by the different gears, their similarity and diversity, as well as the size selectivities of the gears are examined. These findings will be useful to those designing similar sampling efforts for larval and juvenile fishes in the vicinity of complex structures or for those interested in collecting the full spectrum of sizes or developmental stages in their habitat surveys.

Study Sites

Data collection and analyses focused on three oil and gas platforms in the northern Gulf and at a coastal rock jetty habitat. The jetties provided a far-field, nonplatform, low-salinity end-member that was also structurally complex and represented another artificial reef-type, hard-substrate habitat. Site selection for the three study platforms (west of the Mississippi River Delta) was based upon previous work on adult fishes (Gallaway et al. 1980; Gallaway 1981; Continental Shelf Associates 1982) that reported that continental shelf nekton communities associated with natural and artificial reefs in the northern Gulf could be categorized by water depth, among other factors. Three communities were characterized: a coastal assemblage (3–20-m depth), an offshore assemblage (20–60 m), and a bluewater/tropical assemblage (water depths >60 m). The platforms selected and the jetty site encompass all three zones. Mobil's Green Canyon (GC) 18, which lies in 219 m of water on the shelf slope (27°56'37"N, 91°01'45"W), was sampled monthly during new moon phases over a 2–3-night period during July 1995–June 1996. Mobil's Grand Isle (GI) 94B, which lies in approximately 60 m of water at mid-shelf (28°30'57"N, 90°07'23"W), was sampled twice monthly during new and full moon phases over a 3-night period during April–August 1996. In addition, extra samples during the first quarter and third quarter moon phases were collected during May, but due to inclement weather, the full moon collections had to be cancelled. Exxon's South Timbalier (ST) 54G, which lies in 22 m of water on the inner shelf (28°50'01"N, 90°25'00"W), was sampled twice monthly during new and full moon periods over a 2–3-night period during April–September, 1997. The stone rubble jetties (2–3-m depth) at the terminus of Belle Pass, a major shipping channel near Fourchon, Louisiana (29°03'90"N, 90°13'80"W) were also sampled over a 2-night period in 1997 simultaneously with the sampling of ST 54.

Methods

Sampling protocols are described in detail elsewhere (Hernandez et al. 2003, this volume). In general, passive plankton nets (60-cm-diameter; 333-µm mesh dyed dark green) were used to collect ichthyoplankton at the three platform sites, both at depth (15–23 m for 10–20 min, set and retrieved closed) and near surface (1–2 m for 10–15 min) within the platform structure with the intent of sampling roughly equivalent amounts of water at both depths. Quatrefoil light traps were deployed for 10 min at depth and near surface within the platform structure. An additional light trap was floated downstream (approximately 20 m) from the platform for off-platform collections. Both the subsurface and off-platform light traps were deployed with the light off until the sampling depth/location was reached, fished with the light on, and then retrieved with the light off. Light trap samples were standardized to a catch per unit effort (CPUE) of fish per 10 min. At Belle Pass, light traps and a bow-mounted plankton push net (1 m × 1 m; 1,000-µm mesh net dyed dark green; 3–5-min samples) were fished along the jetty walls. Plankton net and push-net samples were standardized to the number of fish collected per 100 m^3 (density).

The quatrefoil light trap (Figure 1) was modified from Floyd et al. (1984) and Secor et al. (1993). The main modifications are described as follows. The acrylic tubes in the main body of the trap were enlarged to 15.24 cm (6") outer diameter. The collection assembly at the bottom of the trap was replaced with short conical plankton-net (202 mm) and cod end assembly. Four, vertical stainless steel threaded bars were added to the corners of the trap for additional support. The light source was a Brinkman Starfire II 12-V halogen fishing light (250,000 candlepower). For surface samples, power was supplied through an umbilical cord by a 12-V marine battery located on the lower deck of the platform. For subsurface collections, either the umbilical cord or a submersible battery pack was used. The battery pack was made by placing a 7.0 amp/h rechargeable sealed lead battery in a 1/4" thick PVC tube with a watertight connector on one end and a complimentary pig-tail on the end of the cable supplying power to the light.

Due to the very large numbers of clupeiform (Clupeidae and Engraulidae) fishes collected, particularly in light trap samples, statistical analyses were run without these taxa, unless otherwise noted. Clupeiform fishes are seldom the taxa of interest in studies of hard substrate habitats (e.g., artificial reefs), and their abundances tend to overwhelm the trends of other taxa (Choat et al. 1993). All analysis of variance (ANOVA), Tukey's Studentized Range Tests, and Student's *t*-tests were run with SAS version 6.12 (SAS 1989).

Studentized *t*-tests ($\alpha = 0.05$) were used to compare overall plankton net densities between locations (subsurface and surface) within the outer (GC 18), mid-(GI 94), and inner (ST 54) shelf platforms. Light trap CPUEs were compared between locations (subsurface, surface, and off-platform) within each of the platform sites using an ANOVA model with gear as a main effect. Tukey's Studentized Range tests were used to determine which light trap collections were significantly different. Before testing, plankton net densities were log transformed ($\log_{10}[x + 1]$) in an effort to conform to normality and homogeneity of variances. Analyses on light trap CPUEs were run on ranked-transformed data.

Kolmogorov-Smirnov (K-S) length-frequency analyses ($\alpha = 0.05$) were performed on selected species from GC 18, GI 94, ST 54, and Belle Pass jetties to determine if there were any significant differences between size distributions of fish collected with light traps versus plankton nets (Sokal and Rohlf 1981). Dominant taxa from each platform site and the Belle Pass jetties were chosen for these analyses if (1) the taxon comprised at least 5% of the total catch of one gear type, and (2) if at least 10 individuals of that taxon were collected by each gear type. All K-S analyses were performed using SYSTAT version 4 (SPSS, Inc. 1999).

Lunar periodicity (full versus new moon) was examined for plankton net and light trap samples collected at the mid- and inner shelf platforms, as well as jetties, using Student's *t*-tests ($\alpha = 0.05$). An ANOVA model and Tukey's Studentized Range tests were used

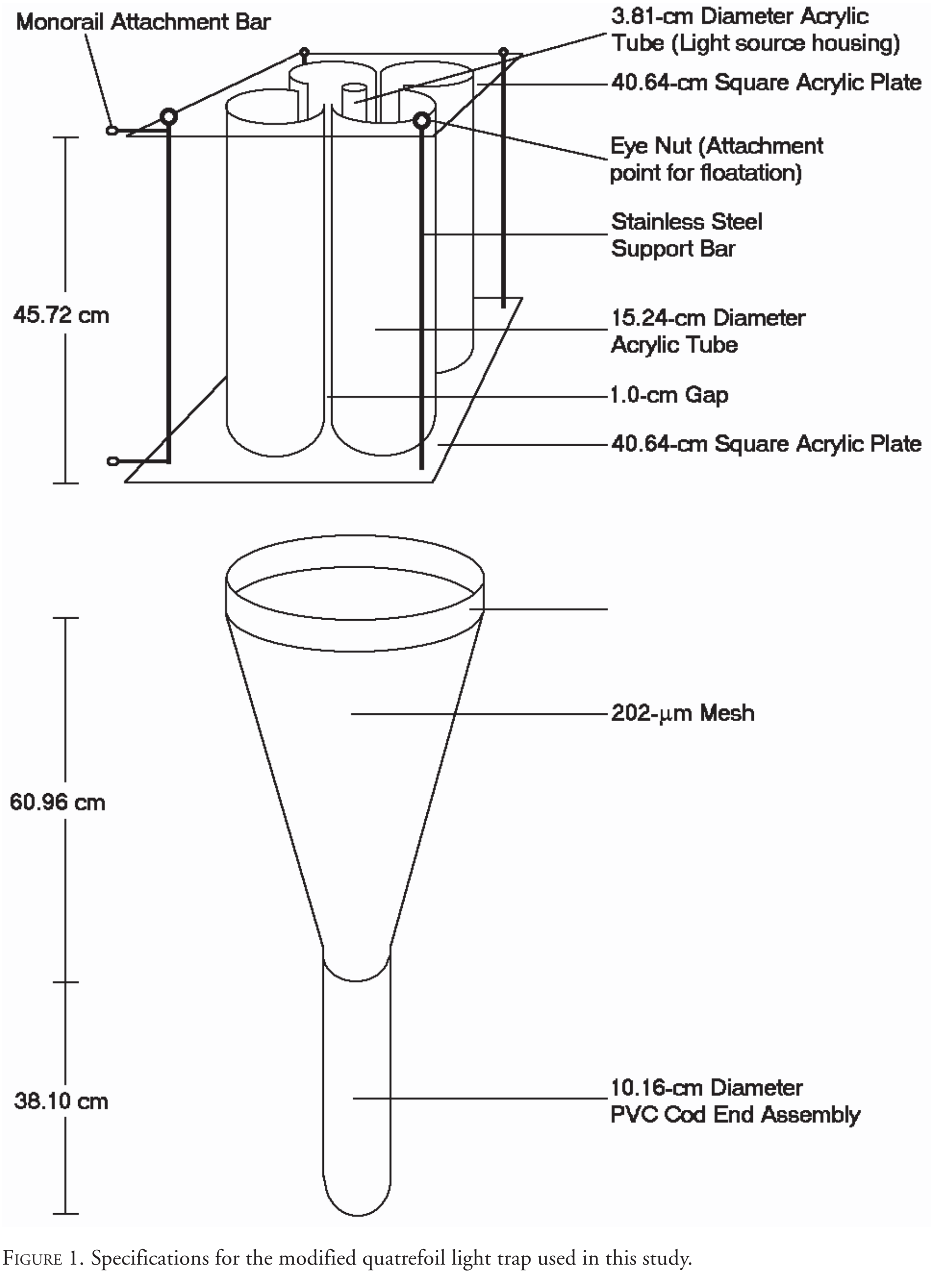


FIGURE 1. Specifications for the modified quatrefoil light trap used in this study.

to analyze the densities and CPUEs of samples collected in May 1996 at the mid-shelf platform (third quarter, new, and full moon periods).

Schoener's Index of Niche Overlap (Schoener 1970) was calculated for comparisons of ichthyoplankton collections within each platform structure (surface net and surface light trap) and far-field collections (off-platform light trap) in addition to total net versus total light trap collections. This same analysis (total net versus total light trap) was performed to compare the similarity of collections at the Belle Pass jetties. Shannon-Weiner diversity indices (Magurran 1988) were calculated for each sample collected at GC 18, GI 94, ST 54, and Belle Pass. Differences in diversity between gear types at each site were analyzed with ANOVA models using gear as a main effect. Post-ANOVA tests (Tukey's Studentized Range, $\alpha = 0.05$) were used to determine which gear types were significantly different. Only fish identified at least to the genus level were included in the similarity and diversity analyses. Because the intent of the similarity and diversity indices was to characterize the taxonomic assemblages sampled by each gear type, clupeiform fishes were included for these analyses. Taxonomic richness (either at the family, genus, or species level) is used in reference to the number of taxa collected.

Results

Overall Abundances

At the outer shelf platform (GC 18, depth = 230 m), plankton net (n = 125) and light trap (n = 319) collections captured 1,404 and 659 larval and juvenile fish, respectively (excluding clupeiforms), with a mean total density of 74.6 fish/100 m^3 (SE = 10.6) and a mean total CPUE of 2.1 fish/10 min (SE = 0.3). Plankton nets collected fish from more families (43) than light traps (35), 15 of which were exclusively from plankton nets, while light traps collected 7 unique families. Plankton nets collected fish from 56 taxa (identified at least to genus level), 25 of which were not collected with light traps; whereas light traps collected fish from 47 taxa, with 14 being unique to light trap collections. Mean plankton net densities ranged from 3.3 to 318.0 fish/100 m^3, while light trap CPUEs ranged from 0 to 12.2 fish/10 min (Figure 2). *Sciaenops ocellatus*, *Caranx hippos/latus*, and *Mugil cephalus* were among the most common nonclupeiform fishes in the plankton net collections (Table 1). Coastal pelagic taxa, such as *Auxis* spp., *Caranx crysos*, and *C. hippos/latus*, were common in the surface and off-platform light trap collections.

At the mid-shelf platform (GI 94, depth = 60 m), plankton nets (n = 329) collected 3,076 fish while light traps (n = 474) collected 12,474 fish, with a mean total density of 69.6 fish/100 m^3 (SE = 5.9) and a mean total CPUE of 26.2 fish/10 min (SE = 2.8). Plankton nets collected individuals from more families than light traps (38 versus 35, respectively). However, light traps collected more taxa (genus level) than plankton nets (78 versus 75, respectively). Twice as many unique families were collected by plankton nets (6) versus light traps (3). The number of unique taxa collected by plankton nets (26) and light traps (27) was nearly identical. Mean plankton net densities ranged from 16.6 to 201.0 fish/100 m^3, while light trap mean CPUEs ranged from 1.2 to 197.1 fish/10 min (Figure 3). Benthic taxa such as *Symphurus* spp. and *Bregmaceros cantori* were common in plankton net collections, as well as coastal pelagic species such as *Auxis* spp. and *Euthynnus alletteratus* (Table 1). Among the most common fishes collected in light traps were synodontids (primarily *Synodus foetens* and *S. poeyi*) and blenniids (primarily *Hypsoblennius invemar* and *Parablennius marmoreus*).

At the inner shelf platform (ST 54, depth = 20 m), plankton nets (n = 89) and light traps (n = 194) collected 1,689 and 1,193 fish, respectively, with a mean total density of 166.0 fish/100 m^3 (SE = 33.7) and a mean total CPUE of 0.6 fish/10 min (SE = 0.1). Due to problems with deploying the subsurface net at this site (Hernandez et al. 2003, this volume), the plankton net catch is almost exclusively from the surface. Plankton nets and light traps collected fish from an equal number of families (32), but light traps collected fish from more taxa than plankton nets (56 versus 50, respectively), including unique taxa (24 versus 16, respectively). Mean plankton net densities ranged from 15.7 to 809.7 fish/100 m^3, while mean CPUEs ranged from 0 to 18 fish/10 min (Figure 4). *Cynoscion arenarius* and *Chloroscombrus chrysurus* were the most dominant taxa in plankton net samples (Table 1). Light trap collections were dominated by *Synodus foetens* and scombrids, particularly *Euthynnus alletteratus* and *Scomberomorus maculatus*.

At the Belle Pass jetties (depth = 2–3 m), the push net (n = 149) and light trap (n = 148) collected 33,147 and 849 fish, respectively, with a mean total density of 136.7 fish/100 m^3 (SE = 12.8) and a mean total CPUE of 4.6 fish/10 min (SE = 0.6). The push net collected fish from approximately twice as many families as the light trap (39 versus 19), including 20 unique families. The push net also collected more taxa (77) than the light traps (34). No families were unique to light traps, and only three unique taxa were collected with light traps. Mean push-net densities ranged from 18.7 to 288.7 fish/100 m^3, while mean CPUEs ranged from 0 to 9.7 fish/10 min (Figure 5). Push-net samples were dominated by gobiids (primarily *Gobiosoma bosc*) and the sciaenid *Cynoscion arenarius* (Table 1). Dominant taxa in light trap collections included *Membras martinica*, *Hypsoblennius hentz/ionthas*, *Gobiosoma bosc*, and *Cynoscion arenarius*.

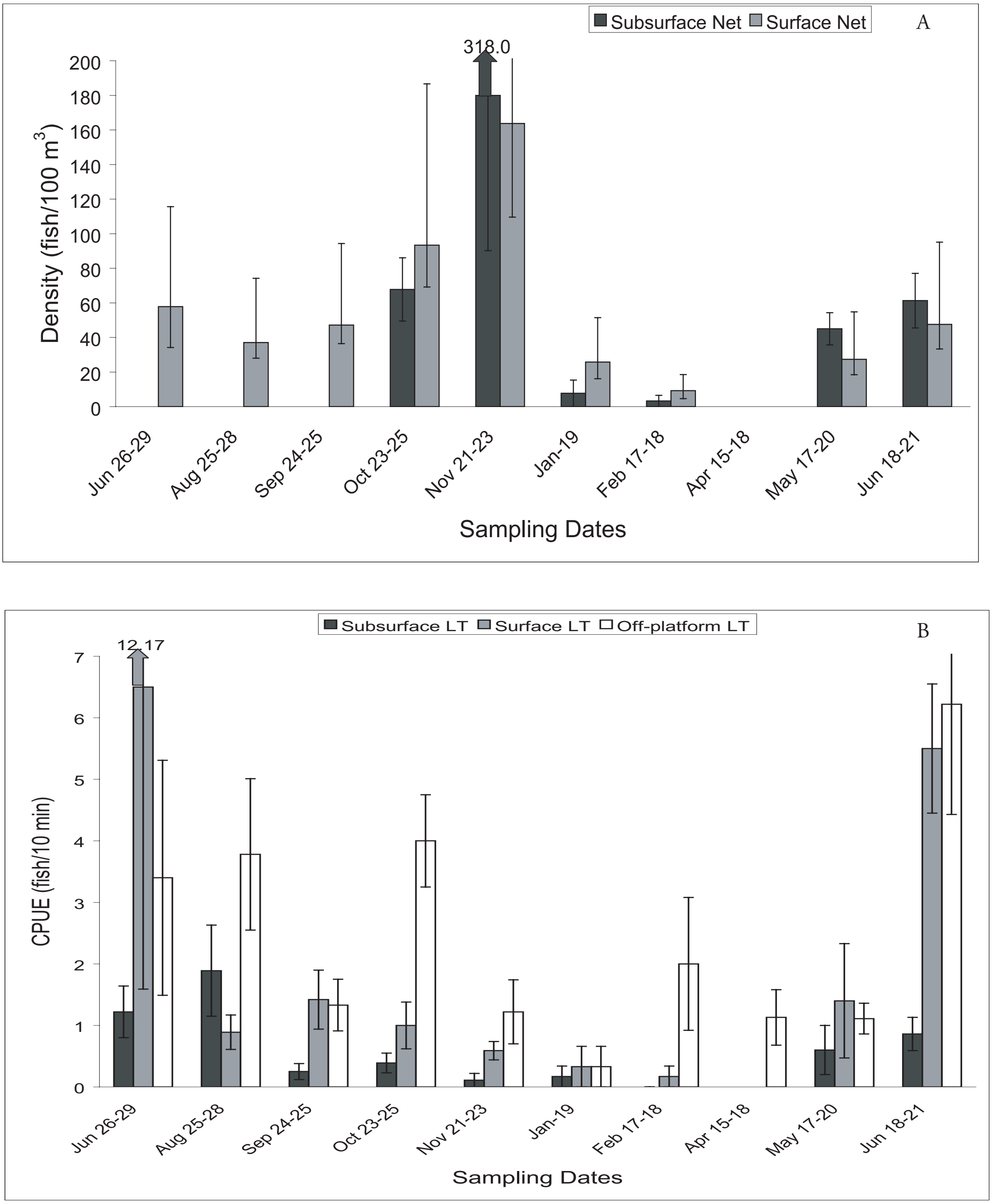


FIGURE 2. Mean total plankton net densities (A) and total light trap CPUEs (B) with standard errors for each sampling trip at Green Canyon 18 (1995–1996). Arrows above bars point toward the off-scale mean for that gear. No subsurface plankton net samples were taken during 26–29 June, 25–28 August, 24–25 September, and 15–18 April. No surface net, surface light trap, or subsurface light trap samples were taken during 15–18 April. No fish were present in subsurface light trap samples ($n = 10$) during 17–18 February.

TABLE 1. Size ranges (SL in mm) and percent of the total catch by gear for dominant taxa (>5%) collected by at least one gear type.

	Light-trap		Plankton net	
Taxon	Size range	%	Size range	%
Green Canyon 18 (July 1995–June 1996)				
Cyclothone braueri	3.2–7.2	5.8	4.0–13.0	1.8
Saurida brasiliensis	3.2–9.8	5.8		
Caranx crysos	5.0–65.0	12.0	2.5–16.5	3.3
Caranx hippos/latus	3.0–54.0	6.4	2.0–32.0	10.9
Cynoscion arenarius	2.5–4.5	1.1	2.0–4.4	6.9
Sciaenops ocellatus			1.8–3.9	12.3
Mugil cephalus	2.4–21.5	3.8	2.2–5.0	9.0
Auxis spp.	3.3–59.0	13.3	2.2–10.5	7.6
Euthynnus alletteratus	6.2–87.0	5.1	3.0–12.0	2.5
Ariomma spp.			2.1–2.5	7.8
Symphurus spp.	2.2–8.0	5.3	2.8–9.0	6.9
Grand Isle 94 (April–August 1996)				
Saurida brasiliensis	4.5–55.0	7.9	2.7–22.5	6.2
Synodus foetens	6.0–43.0	30.6	4.2–22.5	1.8
Synodus poeyi	5.3–45.0	15.6	2.0–16.5	1.2
Bregmaceros cantori	2.0–29.0	3.0	2.0–15.5	16.6
Hypsoblennius invemar	3.5–14.5	13.8		
Parablennius marmoreus	4.4–23.7	12.3		
Auxis spp.	4.0–36.0	1.4	2.5–10.3	10.3
Euthynnus alletteratus	3.1–60.0	5.3	2.7–8.7	10.7
Symphurus spp.			2.0–12.8	22.5
South Timbalier 54 (April–September 1997)				
Synodus foetens	9.0–44.5	38.9		
Chloroscombrus chrysurus	2.5–25.0	1.5	2.0–18.4	17.4
Cynoscion arenarius	2.0–7.0	7.0	1.9–7.8	53.3
Scartella/Hypleurochilus	2.0–14.3	5.0		
Euthynnus alletteratus	7.0–22.5	9.1		
Scomberomorus maculatus	2.5–40.5	6.0	1.9–10.2	4.4
Belle Pass (April–September 1997)				
Gobiesox strumosus	7.5–10.1	8.7	4.1–10.6	1.1
Membras martinica	6.1–87.0	24.1		
Cynoscion arenarius	3.2–8.2	10.8	2.5–41.0	27.5
Hypsoblennius hentz/ionthas	8.3–12.0	19.1	5.1–13.5	1.7
Gobionellus oceanicus	11.0–13.5	2.0	7.5–35.0	6.9
Gobiosoma bosc	7.7–9.6	10.9	6.5–17.0	37.3
Gobiosoma spp.	4.2–7.6	5.0	4.7–8.1	1.3
Citharichthys spp.	7.9–11.6	1.5	5.2–13.0	5.2

Within Site Comparisons of Sampling Gears

No significant differences were detected in mean total plankton net densities between surface and subsurface collections at the outer shelf (GC 18) and mid-shelf (GI 94) platforms (Tukey's Studentized Range Test, $\alpha = 0.05$), although subsurface densities were generally higher (Figure 6). At the inner shelf platform (ST 54), surface nets had significantly higher mean total densities than subsurface nets, though the sampling effort was unbalanced (Hernandez et

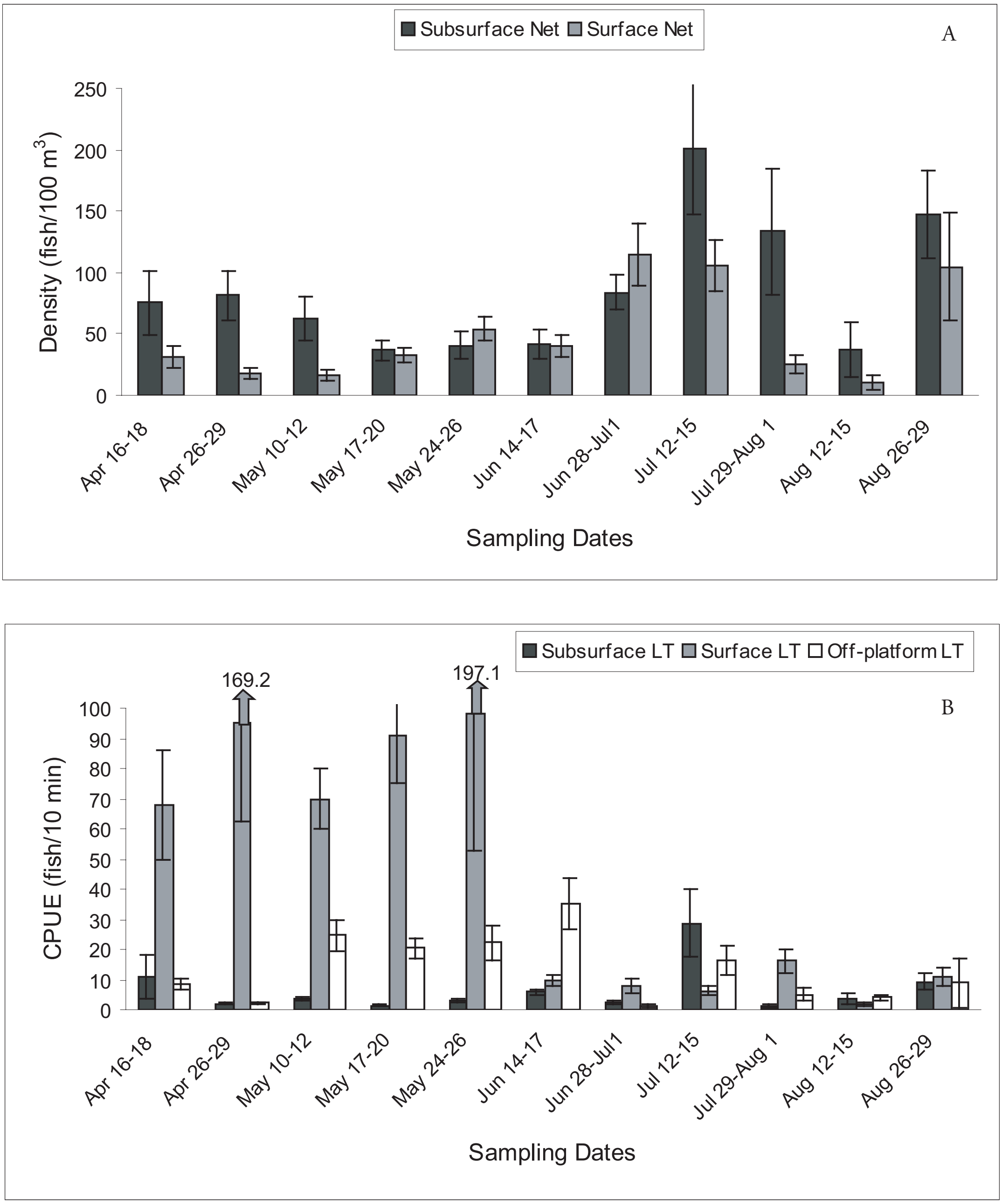
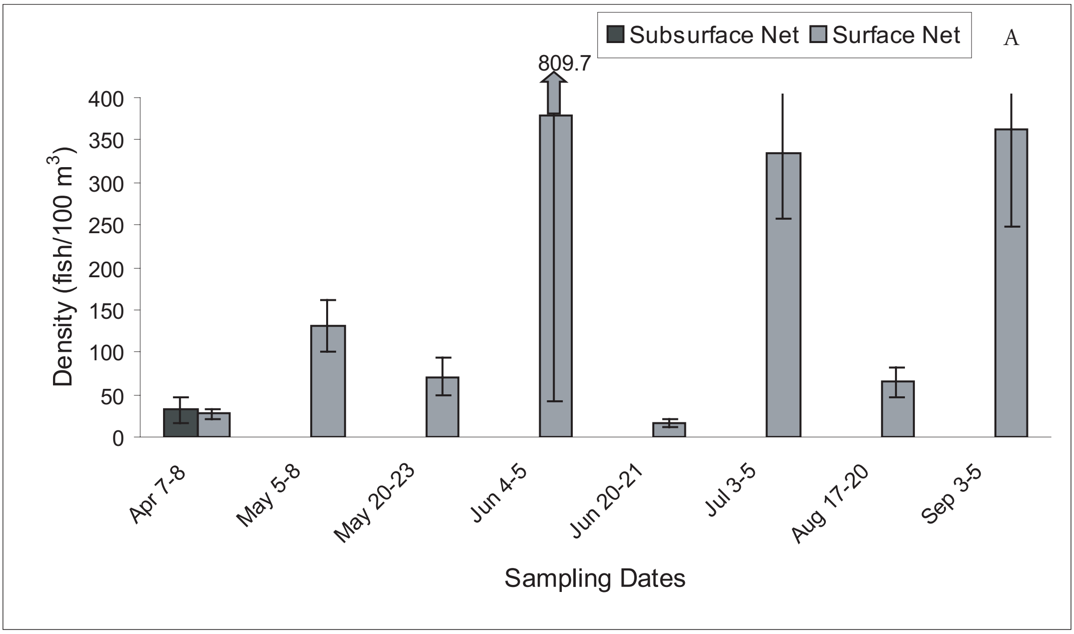


FIGURE 3. Mean total plankton net densities (A) and total light trap CPUEs (B) with standard errors for each sampling trip at Grand Isle 94 (1996). Arrows above bars point toward the offscale mean for that gear.

al. 2003, this volume). In contrast, light trap collections from surface waters (surface and off-platform light traps) had significantly greater total CPUEs than subsurface light traps at all three platforms (Figure 6). At the outer shelf site (GC 18), overall means by depth and location ranged from 0.7 to 3.2 fish/10 min, with means from surface and off-platform locations being significantly greater than the sub-



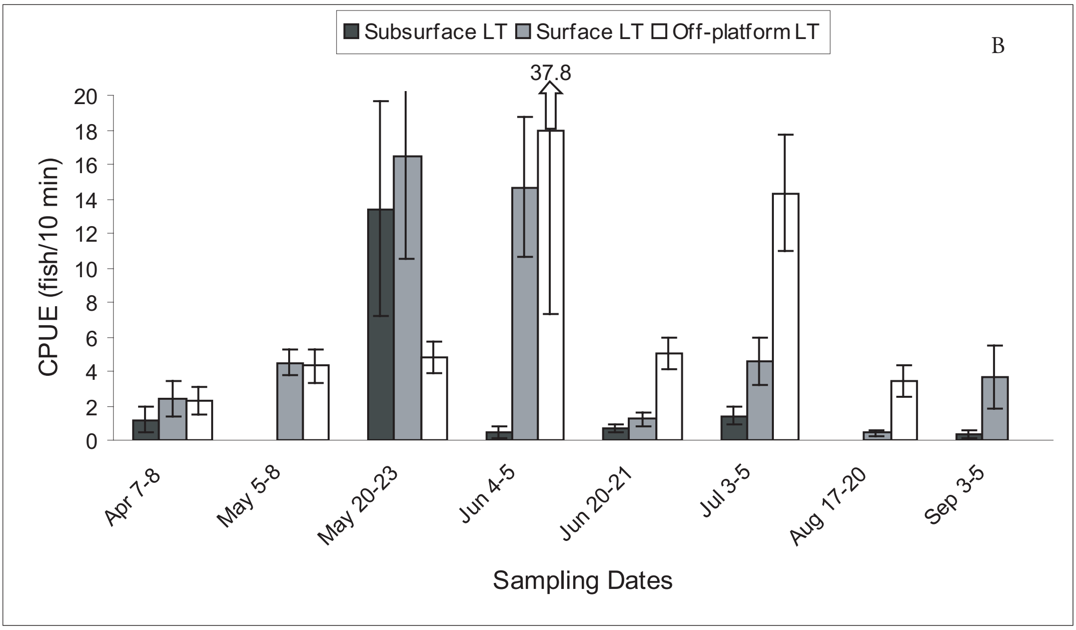


FIGURE 4. Mean total plankton net densities (A) and total light trap CPUEs (B) with standard errors for each sampling trip at South Timbalier 54 (1997). Arrows above bars point toward the off-scale mean for that gear. Subsurface net samples were only taken during 7–8 April. No subsurface light traps were taken during 5–8 May. No off-platform light trap samples were taken during 3–5 September. No fish were present in subsurface light trap samples (*n* = 4) during 17–20 August.

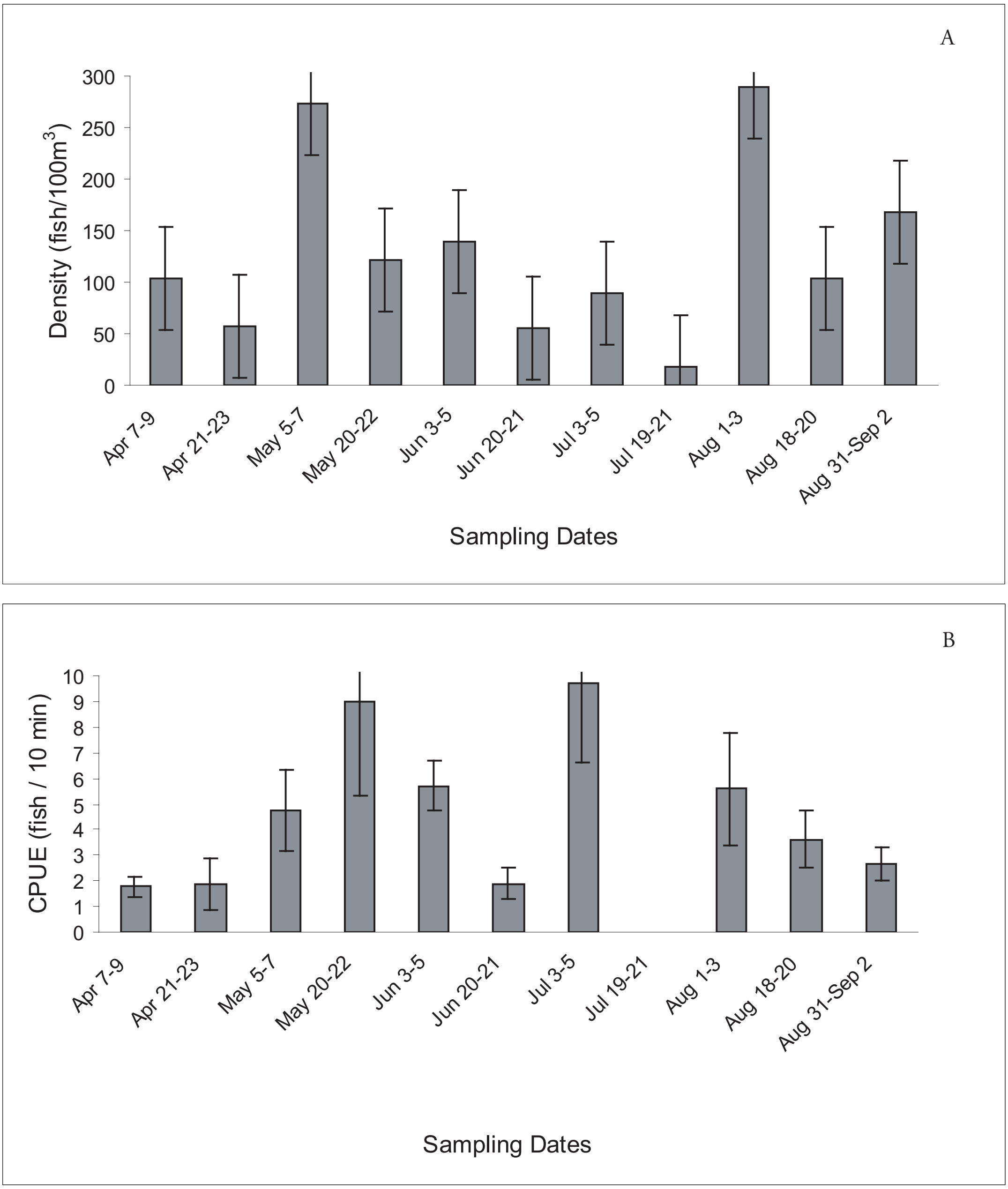
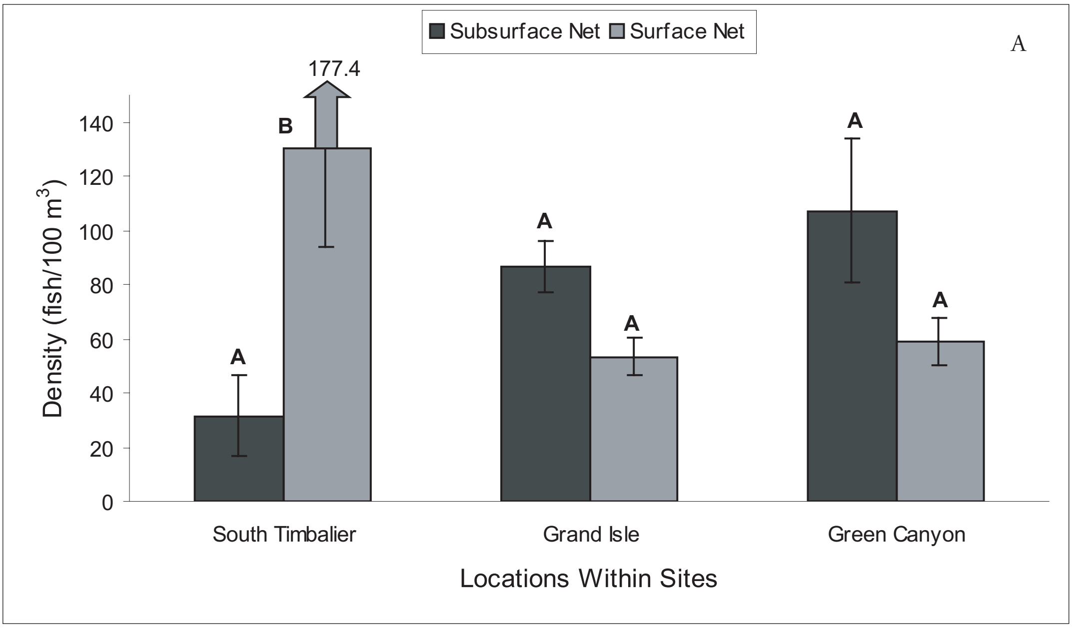


FIGURE 5. Mean total push-net densities (A) and total light trap CPUEs (B) with standard errors for each sampling trip at Belle Pass (1997). No fish were present in light trap samples during 19–21 July.

surface mean (Tukey's Studentized Range Test, α = 0.05). At the mid-shelf platform (GI 94), overall light trap CPUEs were the greatest of the three platform sites and ranged from 6.5 to 58.2 fish/10 min with significant differences detected between all light trap depths/locations. At the inner shelf platform (ST 54), overall mean CPUEs ranged from 3.8 to 7.2, and once again, all light trap depths/locations were significantly different.



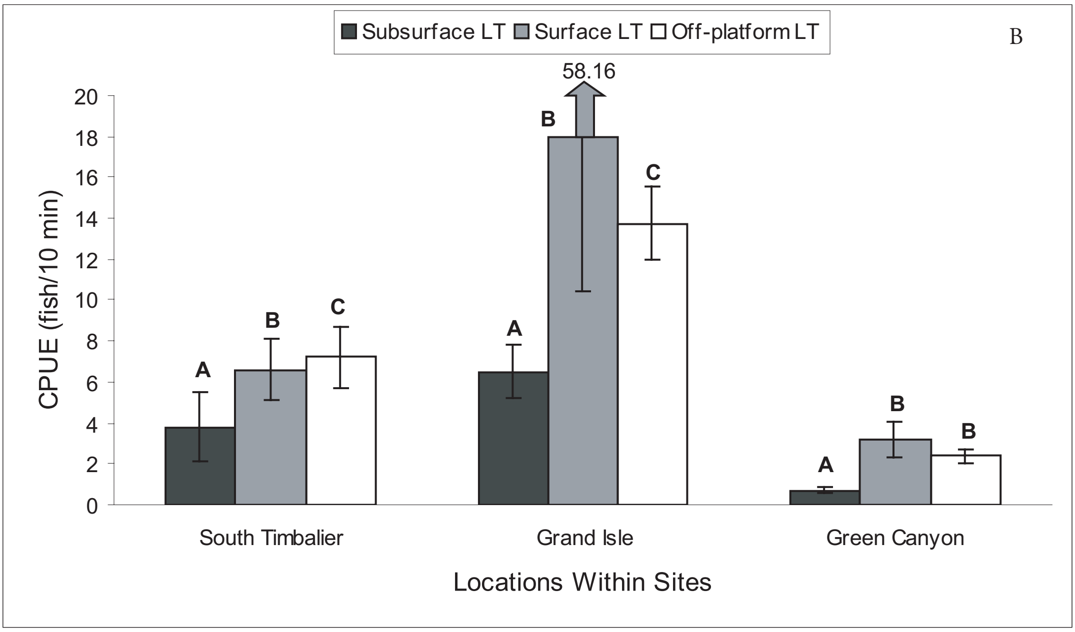


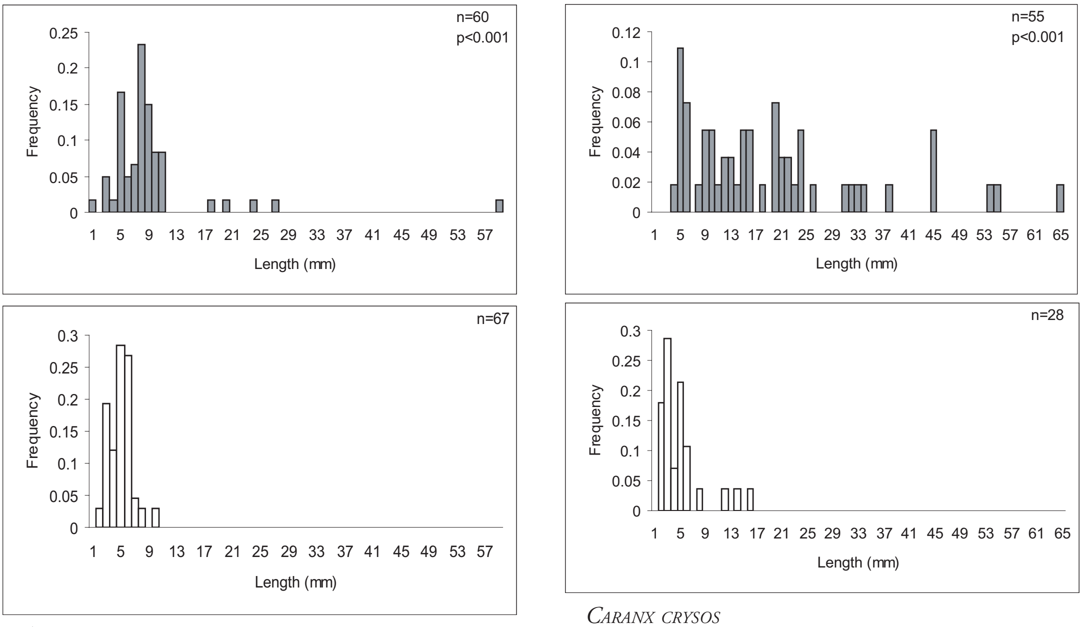
FIGURE 6. Mean total plankton net densities (A) and total light trap CPUEs (B) with standard error bars for depths/locations within each platform site. Arrows above bars point toward the off-scale mean for that gear. For mean densities within each location, the same letter above each bar indicates no significant difference between depths based on *t*-tests on log-transformed data ($\alpha = 0.05$). For mean CPUEs within each location, the same letter above each bar indicates no significant difference between depths/locations based on Tukey's Studentized Range test on ranked data ($\alpha = 0.05$). Different letters designate significant differences.

Length-Frequency Analyses

Six taxa from the outer shelf site (GC 18) met the required criteria for K-S analyses involving the differences in size-frequency distributions between sampling gears (see methods). In all instances, differences in size-frequency distributions for the two gear types were found to be statistically significant (K-S tests, $p \leq 0.05$; Figure 7). In general, there was some size overlap in all gear comparisons, although the degree of overlap and shapes of the size distributions differed among species. For *Auxis* spp., *Caranx crysos*, and *Mugil cephalus*, the plankton net samples caught predominantly smaller individuals, while the light trap samples generally encompassed these smaller sizes as well as larger larvae and juveniles. For *C. hippos/latus* and *Euthynnus alletteratus*, there was less overlap at the smaller sizes, and modal size-classes for the light trap samples were generally larger. Only for *Symphurus* spp. was the modal length of light trap samples smaller than that for net collections ($p \leq 0.05$).

At the mid-shelf site (GI 94), five of the six taxa analyzed for differences in size distributions (plankton net versus light trap) were highly significant (K-S tests, $p \leq 0.001$; Figure 8). Size distributions for *Bregmaceros cantori* appeared to substantially overlap at the smaller sizes, but the light trap samples encompassed a significantly broader range of size-classes. For *Auxis* spp., *Synodus foetens*, and *S. poeyi*, there was some overlap in size distributions, with the plankton net capturing smaller larvae, while modal sizes for light trap samples were always larger. With only one taxon (*Saurida brasiliensis*) were plankton nets not only able to better catch small sizes but also larger size-classes as well. Only one dominant taxa, *Symphurus* spp., did not exhibit a significant difference in size distribution between gears ($p = 0.385$).

At the inner shelf site (ST 54), differences between the two gear types' size distributions for two of the three taxa analyzed were highly significant (K-S tests, $p \leq 0.01$; Figure 9). In general, light trap size-frequency distributions for *Scomberomorus maculatus* encompassed that of the plankton net distributions but also included larger sizes. Little overlap in size distributions was observed for *Euthynnus alletteratus,* with light trap collections being much larger. One dominant species, *Chloroscombrus chrysurus*, did not



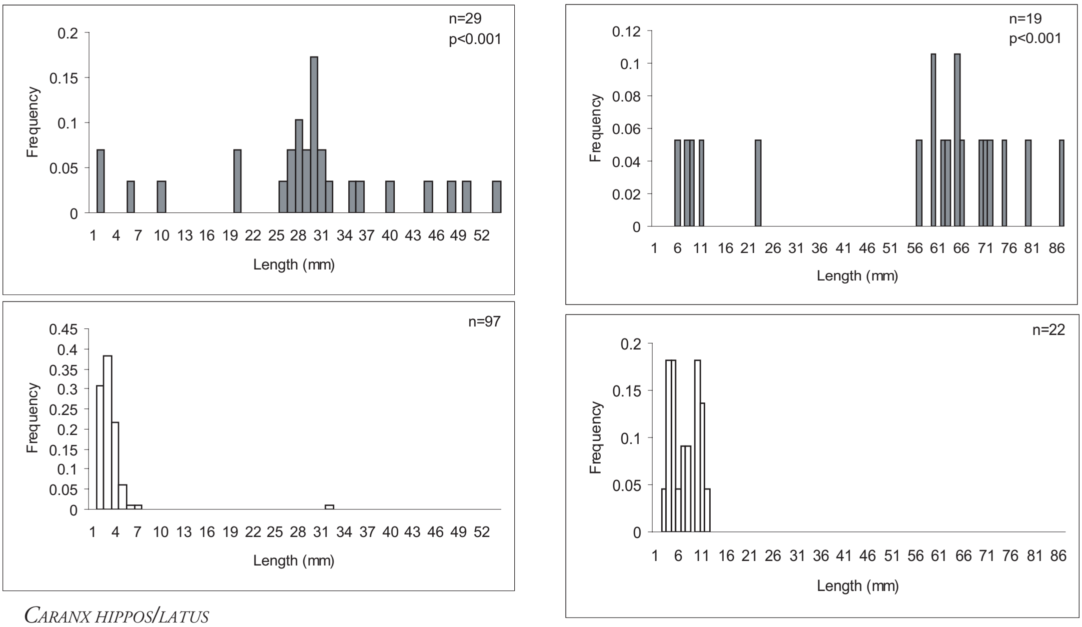
Auxis spp.

Caranx crysos

FIGURE 7. Size distributions of fish collected with light traps (shaded bars) and plankton nets (open bars) at the Green Canyon site (1995–1996). Fish length-frequency distributions were analyzed with Kolmogorov-Smirnov tests (*P*-values are represented in the upper panel of each gear pairing along with each sample size).

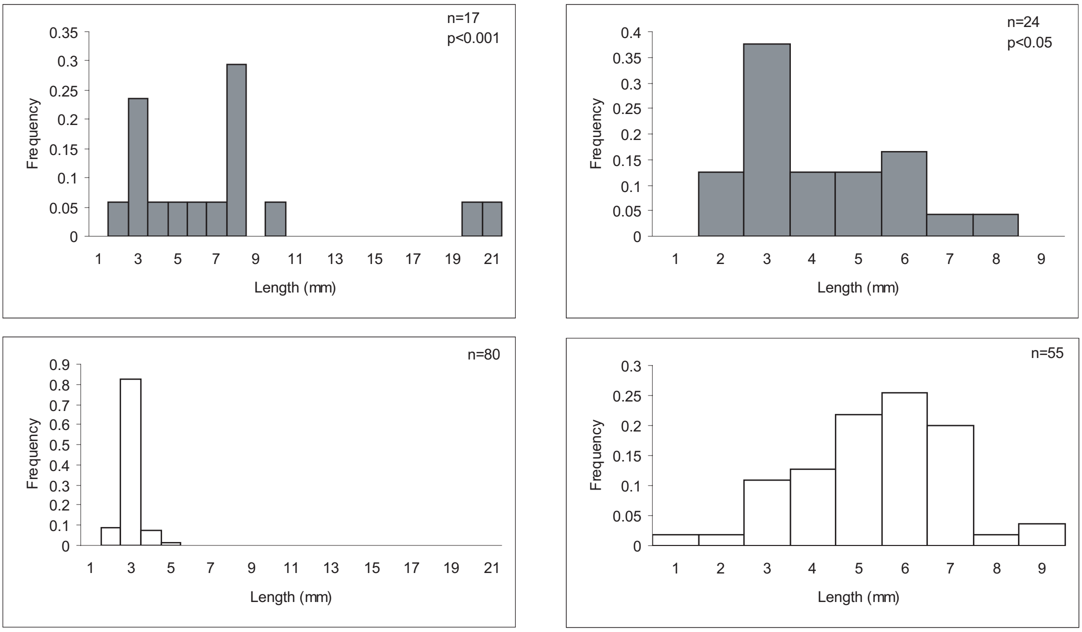
exhibit a significant difference in size distributions between the two gear types ($p = 0.133$).

In contrast to the platform sites, size distributions for push-net versus light trap collections at the Belle Pass jetties were significantly different for only three of the seven taxa analyzed (K-S tests, $p < 0.05$;



CARANX HIPPOS/LATUS

EUTHYNNUS ALLETTERATUS

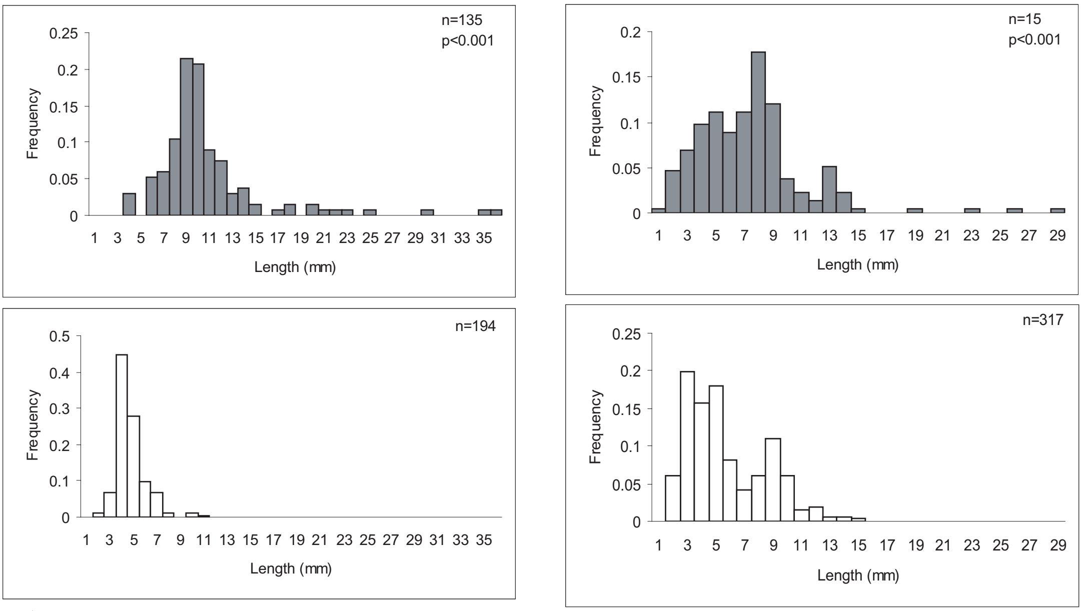


MUGIL CEPHALUS

SYMPHURUS SPP.

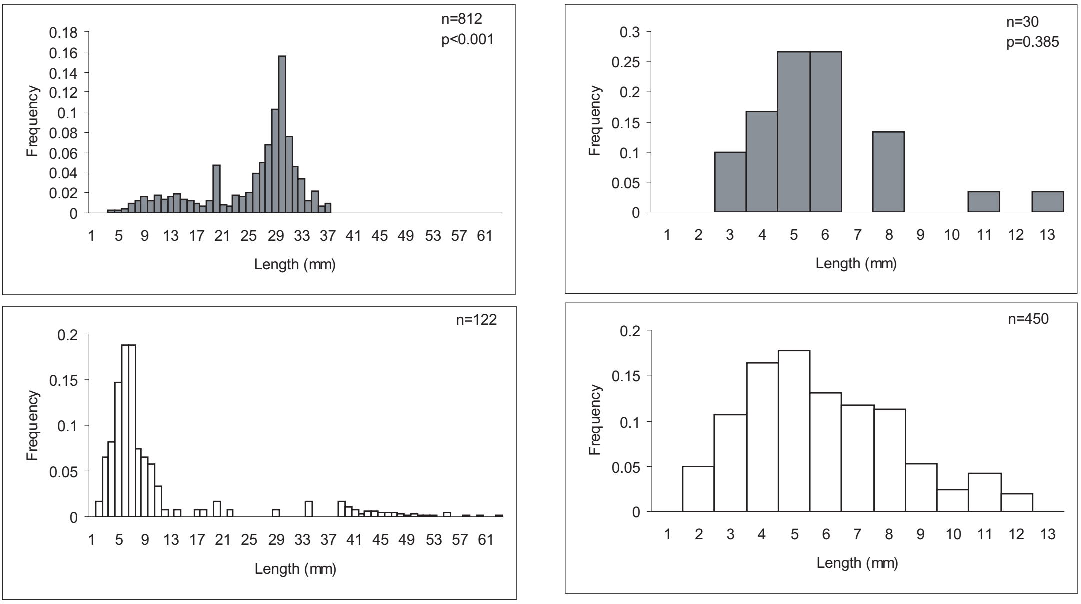
FIGURE 7. Continued.

Figure 10). There was a broad overlap in the size distributions for *Gobiosoma* spp. and *Hypsoblennius hentz/ionthas*, but in each case, the push-net samples collected larger-sized individuals with greater frequency. In contrast, the light trap size distribution for *Membras martinica* had an intermediate dominant mode. There



Auxis spp.

Bregmaceros cantori



Saurida brasiliensis

Symphurus spp.

FIGURE 8. Size distributions of fish collected with light traps (shaded bars) and plankton nets (open bars) at the Grand Isle site (1996). Fish length-frequency distributions were analyzed with Kolmogorov-Smirnov tests (*P*-values are represented in the upper panel of each gear pairing along with each sample size).

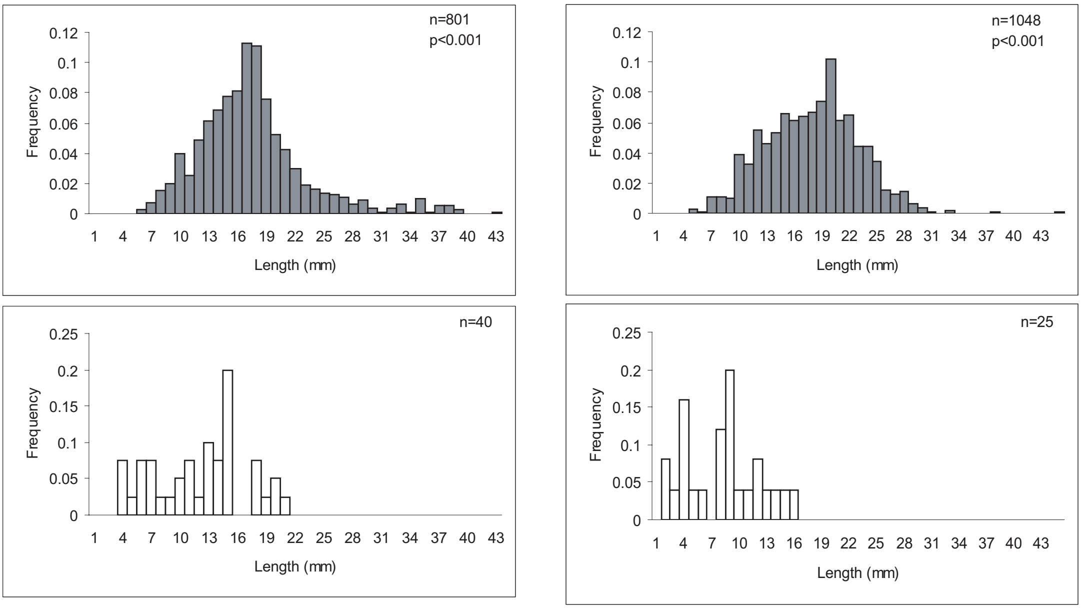
was no significant difference in the size distributions for *Gobiesox strumosus, Gobiosoma bosc, Citharichthys* spp., and *Cynoscion arenarius*.

Lunar Periodicity

At the mid-shelf platform (GI 94), mean total CPUEs for light traps were significantly higher during new moon phases (20.4 fish/10 min, SE = 2.5) than during full phases (7.3 fish/10 min, SE = 1.4; Student's *t*-test, $p < 0.0001$). The opposite trend was observed in mean plankton net densities. Mean plankton net densities were significantly higher during full moon phases (103 fish/100 m^3, SE = 13.8) than during new moon phases (61.9 fish/100 m^3, SE = 8.4; $p < 0.01$). The separate lunar study conducted at GI 94, which compared three lunar phases (first quarter, new, and third quarter moon phases sampled in May 1996), however, yielded no significant differences in mean total light trap CPUEs or mean total plankton net densities between the three phases (Tukey's Studentized Range test, $p > 0.05$). At the inner shelf platform (ST 54), there were no significant difference in total CPUEs between new (5.7 fish/10 min, SE = 1.0) and full (6.6 fish/10 min, SE = 1.5) moon phases (Student's *t*-test, $p > 0.05$). However, mean total density during new moon phases (250.5 fish/100 m^3, SE = 56.7) was significantly higher than full moons (57.6 fish/100 m^3, SE = 12.2; Student's *t*-test, $p < 0.05$). Both results are in contrast to the findings at GI 94. At the Belle Pass jetties, mean total CPUEs were significantly higher during new moon phases (5.2 fish/10 min, SE = 0.8) than during full moon phases (3.8 fish/10 min, SE = 1.1; Student's *t*-tests, $p < 0.001$). Mean plankton net densities were also significantly higher during new moon phases (181.4 fish 100 m^3, SE = 18.7) than during full moon phases (75.8 fish/100 m^3, SE = 12.8; Student's *t*-test, $p < 0.0001$). Therefore, when significant lunar differences were found in our comparisons, four out of five instances had greater new moon catches.

Similarity and Diversity of Ichthyoplankton Assemblages within Sites

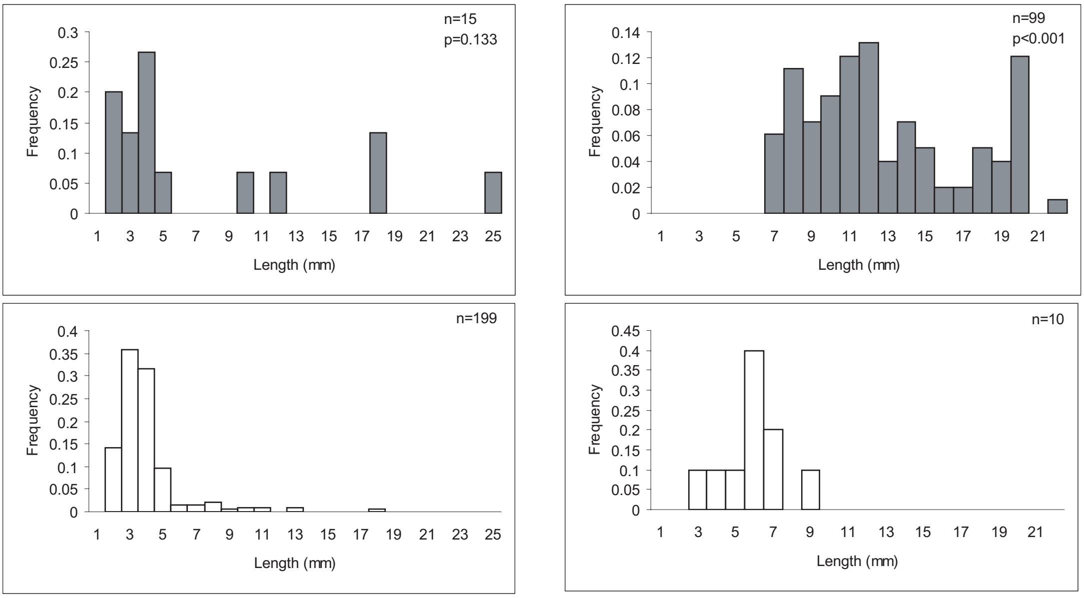
Within site comparisons of gears and surface sampling locations indicated that off-platform and surface light trap collections were more similar to each other



Synodus foetens

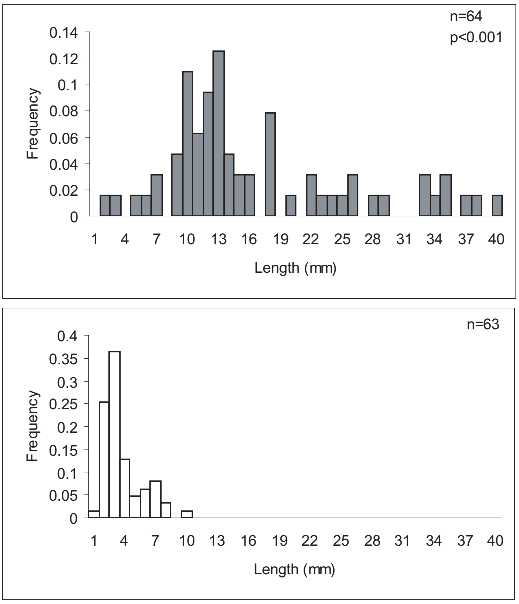
Synodus poeyi

Figure 8. Continued.



CHLOROSCOMBRUS CHRYSURUS

EUTHYNNUS ALLETTERATUS

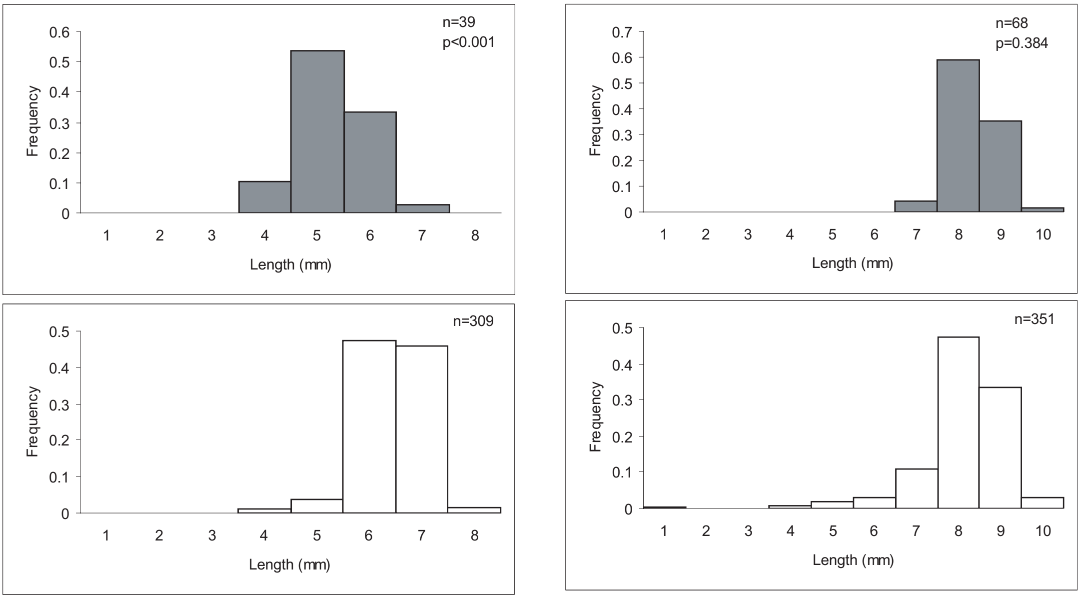


SCOMBEROMORUS MACULATUS

FIGURE 9. Size distributions of fish collected with light traps (shaded bars) and plankton nets (open bars) at the South Timbalier site (1997). Fish length-frequency distributions were analyzed with Kolmogorov-Smirnov tests (*P*-values are represented in the upper panel of each gear pairing along with each sample size).

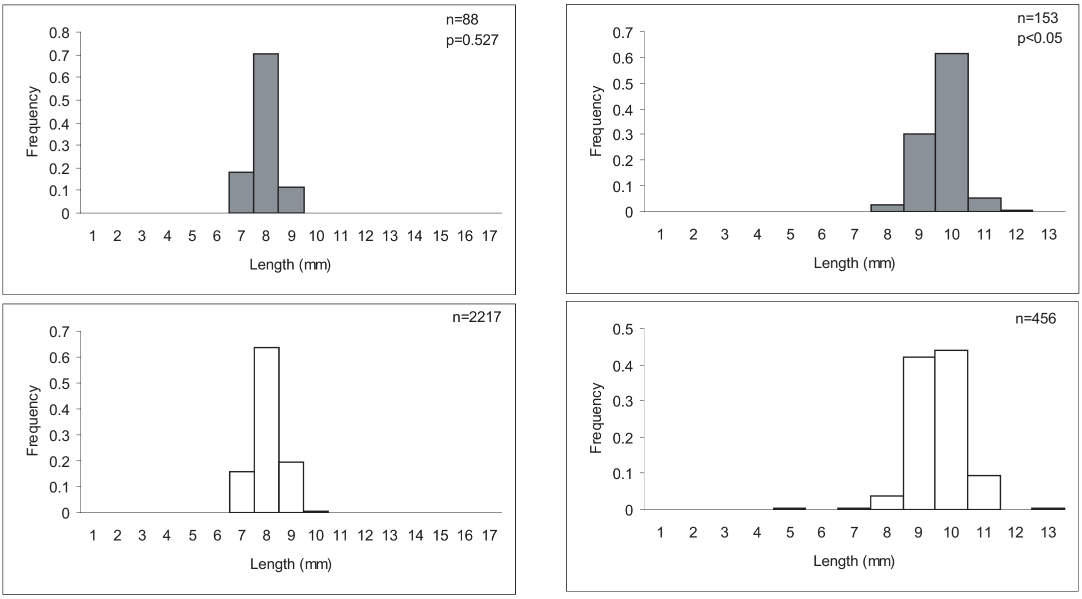
(Schoener's Index of Similarity values range from 0.45 to 0.76) than each was to surface plankton net collections (0.27–0.71), although the disparity between the index gear comparisons is smaller at ST 54 (0.59–0.71; Table 2). Overall, total light trap collections were relatively different from total plankton net samples at the outer shelf (GC 18) and mid-shelf (GI 94) platforms (0.38 and 0.32, respectively) but were much more similar at the inner shelf platform (ST 54) and Belle Pass jetties (0.63 and 0.61, respectively).

There was little difference in the Shannon-Weiner diversity index values from gear and depth/location samples collected at the outer shelf (GC 18) and inner shelf (ST 54) platforms. In both instances, only subsurface light trap samples had significantly lower diversity values (GC 18: index = 0.24, SE =



Gobiosoma spp.

Gobiesox strumosus

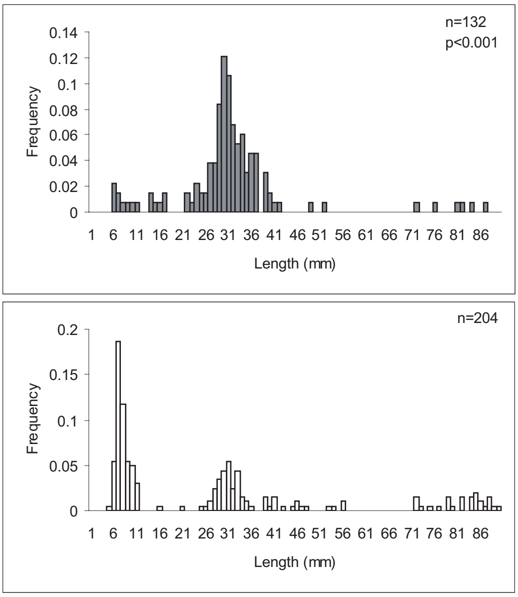


Gobiosoma bosc

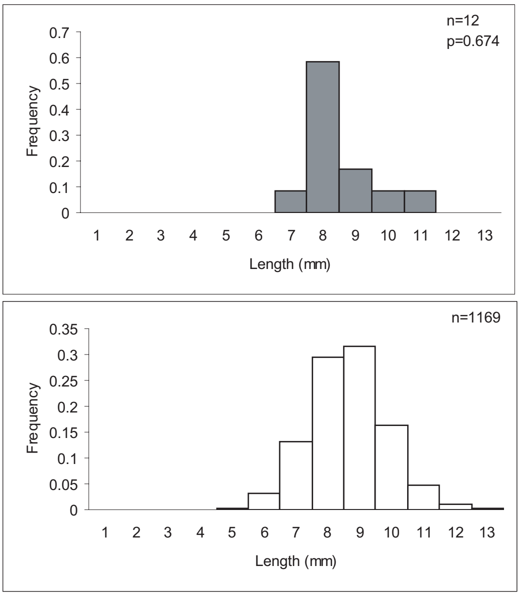
Hypsoblennius hentz/ionthas

FIGURE 10. Size distributions of fish collected with light traps (shaded bars) and a push net (open bars) at the Bell Pass site (1997). Fish length frequency distributions were analyzed with Kolmogorov-Smirnov tests (*P*-values are represented in the upper panel of each gear pairing along with each sample size).

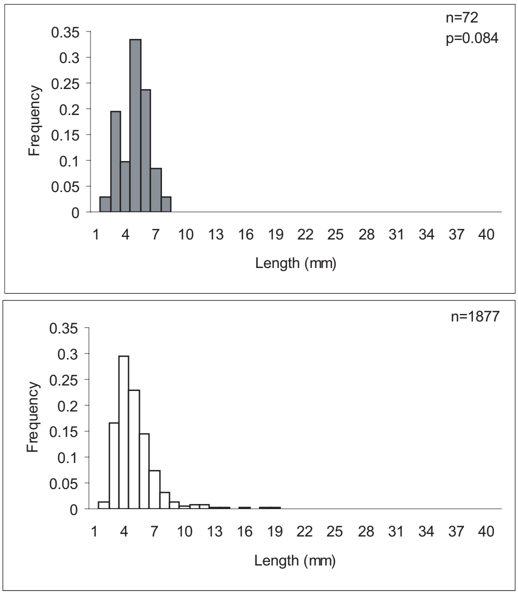
0.1; ST 54: index = 0.53, SE = 0.1) than the other gear and depth/location combinations (GC 18: index values range from 0.6 to 0.85; ST 54: values range from 0.8 to 1.7; ANOVA, $\alpha = 0.05$). No clear pattern in diversity was discernable at the mid-shelf platform (GI 94) as all index values were statistically



Membras martinica



Citharichthys spp.



Cynoscion arenarius

FIGURE 10. Continued.

similar, ranging from 0.7 to 1.06. At the Belle Pass jetties, push-net samples were significantly more diverse than the light trap samples (1.9 versus 1.0, respectively; Student's *t*-test, $\alpha = 0.05$)

Discussion

Gear Selectivity

The most obvious trend observed during this study was the overwhelming presence of engraulids and clupeids at all sites, even on the shelf slope (Hernandez et al. 2003, this volume). Light trap and plankton net collections (total catch) were dominated by clupeiform fishes at the outer (59%), mid- (66%), and inner shelf (97%) platforms and the Belle Pass jetties (74%). The dominance of these taxa is not unexpected, particularly considering the abundances of these fishes in the northern Gulf and the sampling gears utilized. Clupeiform fishes are often among the most abundant in plankton surveys of the northern Gulf and are present year-round in shelf waters (Ditty 1986; Ditty et al. 1988; Finucane et al. 1979). Light traps are selective sampling devices, and previous studies have demonstrated that often the catches are dominated by a single taxonomic group (Brogan 1994; Choat et al. 1993; Sponaugle and Cowen 1996; Thorrold 1992). Clupeiform fishes have been shown to be particularly photopositive and have dominated the total catches in several studies utilizing light-aggregating collection techniques (Brogan 1994; Choat et al. 1993; Dennis et al. 1991; Rooker et al. 1996). The push net used in this study actively collects fish and was relatively large (1 m × 1 m). It has also been shown to be an effective collector of clupeiforms in previous studies (Herke 1969; Kriete and Loesch 1980; Raynie and Shaw 1994). While the light trap collects fish based on taxon-specific, photopositive behaviors and the push net actively strains the water mass it samples, the plankton nets in the platform study collected fish passively with tidal currents. Even so, it was also very effective in sampling these fishes. This catchability was undoubtedly aided by the nocturnal sampling design.

Even with these sampling efficiency enhancements, these three sampling techniques clearly displayed gear selectivity as evident by differences in taxonomic richness between gear types. Passive plankton nets collected fish from more unique families than light traps at the outer shelf (GC 18: 15 versus 7) and mid-shelf (GI 94: 6 versus 3) platforms but not at the inner shelf platform (ST 54, eight unique families to each gear). At the Belle Pass jetties, the push net collected individuals from 20 unique families, as well as fish from all families sampled by light traps. Previous studies comparing light traps and plankton nets in marine waters have found similar results (i.e., light traps collected fewer families than plankton tows) with only a few instances where light traps collected unique families. Brogan (1994) collected 16 unique families with a diver-steered push net and only 4 unique families with light traps, and the latter 4 families, when combined, comprised a very small proportion (<0.08%) of his total light trap catch. Likewise, more unique families were collected with a neuston net (10) than with light traps (4) when fished simultaneously in Onslow Bay, North Carolina, and the unique light trap families comprised only 10% of the total light trap catch (Hernandez and Lindquist 1999). These results are similar to one aspect of this study (i.e., unique light trap families usually made up less than 1% of the total catch at each platform site). However, whereas the previously cited studies each collected only four unique families with light traps, seven (GC 18) and eight (ST 54) unique families were collected with light traps in this study. Neither Choat et al. (1993) nor Hickford and Schiel (1999) reported any families in light trap samples that were not present in plankton net samples.

In addition, the large numbers of unique taxa (identified at least to genus level) collected by light traps was also surprising, since this gear is usually considered to be very taxon-specific and, therefore, limited in its sampling scope. At the genus level, light traps collected more unique taxa than plankton nets at the mid- (27 versus 26) and inner (24 versus 16) shelf platforms but not at the outer shelf platform (14 versus 25). At Belle Pass, however, the light traps collected far fewer unique taxa (3) than did the push net (44). Such large numbers of unique taxa have not been previously reported for light traps in gear comparison studies. Two studies have reported data at the genus level and found either that all taxa collected by light traps were collected by nets (Hickford and Schiel 1999) or that there were more unique taxa in the net collections than light trap collections (Hernandez and Lindquist 1999). In this study, light traps proved very useful in sampling available taxa that were not collected by plankton nets.

Trends in taxon selectivity by gear were supported in the similarity indices between the gear types within a given site (Table 2). At the outer shelf (GC 18) and mid-shelf (GI 94) platforms, there was greater similarity between the light trap samples, regardless of

TABLE 2. Schoener's Index of Niche Overlap values for different surface gear and location comparisons. (OL) off-platform light-trap, (SL) surface light-trap, (SN) surface net, (TL) total light-traps, (TN) total nets.

	OL vs SL	OL vs SN	SL vs SN	TL vs TN
Green Canyon 18	0.53	0.32	0.31	0.38
Grand Isle 94	0.45	0.37	0.27	0.32
South Timbalier 54	0.76	0.71	0.59	0.63
Belle Pass			0.61	0.61[a]

[a] Calculation is the same as with SL vs SN since only a surface pushnet and surface light-trap were used.

location, than there was between the surface light trap collections (either off platform or central location) and the surface net collections. Again, this indicates the behavioral or developmental responses of different fish taxa influence their susceptibility to different sampling gears (Hernandez and Lindquist 1999). The trend was not as evident at the inner shelf platform (ST 54), but this is not surprising as 97% of the total catch by both gears was composed of clupeiform fishes, which are very susceptible to both gear types (Schoener's Similarity Index for total light trap versus total net collections = 0.63). There was also a relatively high similarity index value (0.61) for the push net versus light trap comparison at Belle Pass, even though the push net had collected many unique taxa. Again, this site was dominated by clupeiform fishes (74% of total catch), and light traps are effective in sampling these fishes, resulting in a higher than expected similarity value. In addition, the push net's unique taxa were relatively rare and, therefore, had a limited influence in the calculation of the similarity index.

The presence of rare and unique taxa in plankton push-net collections at the jetties did increase the diversity of the assemblage, however. In contrast, few differences were observed between the passive plankton net and light trap collections at the platforms. Several studies have investigated differences in taxonomic richness between different gear types, although few, if any, have reported diversity data. Choat et al. (1993) collected individuals from more families with a bongo net (63 families), lighted-seine net (37 families), neuston net (31 families), Tucker trawl (29 families), and purse seine (25 families) than with a light trap (20 families) in a gear comparison study within Australia's Great Barrier Reef. In the Gulf of California, Brogan (1994) collected more reef fish larvae and juveniles from different families with a diver-steered plankton net (43 families) than with a light trap (31 families). Hernandez and Lindquist (1999) collected more fish larvae and juveniles from different families with a neuston net (24 families) than with either of the two light trap designs employed (18 and 21 families) in a study in Onslow Bay, North Carolina. In each of these studies, the authors concluded that the taxonomic assemblage collected in their respective studies was very method-dependent, and the same appears to be true in the present study.

The results of this study further illustrate the benefits that multiple gear types can bring to ichthyoplankton studies by sampling a more complete range of size-classes, ages, and developmental stages (Brogan 1994; Choat et al. 1993; Hernandez and Lindquist 1999). Of the 15 length-frequency comparisons between passive plankton nets and light traps, 13 exhibited statistically significant differences (Figures 7–9). In the instances where no significant differences were found, the distributions either overlapped substantially (*Symphurus* spp., Figure 8) or suffered from too few individuals in the larger size-classes for a significant statistical difference to be found (*Chloroscombrus chrysurus*, Figure 9). In general, the light trap was more effective in sampling larger size-classes of the same species at each location, depth, or site. In some cases, the light trap collections did not encompass a significant portion of the plankton net's smaller sizes but clearly excelled at capturing the larger sizes. This was the case with *Euthynnus alletteratus* (Figures 7 and 9). In other instances, the light trap collections appeared to significantly overlap the smaller sizes of the net collections but also augmented the size-frequency distribution with much larger sizes or, in some cases, even additional modes, as was the case for *Caranx crysos* (Figure 7). By using multiple gears and methodologies, the presence of a number of taxa with a full range of life history stages, ranging from recently-spawned larvae to juveniles, was confirmed. For example, at the outer shelf platform (GC 18), the plankton net collected *Euthynnus alletteratus* individuals within a smaller size range (3.0–12.0 mm) than the light trap (6.2–87.0 mm). If plankton net collections were not supplemented with light trap catches, larger juveniles at this site would have been overlooked.

The advantages of plankton push nets (see introduction) proved useful in sampling the edges of the jetty environment, which are structurally complex. The boat and push net were maneuvered very close to the shallow slope of the rock wall with relative ease. In general, net avoidance is reduced with push nets compared to towed nets because the net fishes in advance of the boat, its shadow, and its propeller wash (Raynie and Shaw 1994). The large mesh size (1,000 μm) and net opening (1 m × 1 m) minimizes the pressure wave in front of the net and minimizes net clogging, enhancing the ability to collect larger larvae and postsettlement juveniles. As a result, many of the size distributions sampled with the push net and light trap at Belle Pass overlapped considerably (Figure 10). Only 3 of the 11 species analyzed exhibited significant size differences between the gear types. In one instance, the push-net collections clearly had a larger size mode than the light trap (Figure 10, *Gobiosoma* spp.). While the same size-classes were targeted with the push net, its usefulness was in sampling different taxa. The number of families (39) and taxa identified to the genus level (77) was approximately double that of the light traps (19 and 34, respectively), which generated a taxon diversity for the push-net collections that was significantly higher than that for the light trap. Once again, multiple gear types allowed for the collection of a more complete representation of the ichthyoplankton and juvenile fish assemblages at the jetty site as well.

Lunar Periodicity

Lunar periodicities were investigated because there are many hypotheses on lunar reproductive patterns pertaining to propagule dispersal and predation rates that occur both at the beginning (spawning) and end (settlement) of the planktonic phase (Robertson 1991). Many reef fish appear to time their spawning events with different lunar cycles (Thresher 1984). Higher rates of fish settlement often occur during darker, new moon periods than full moon periods (Victor 1986; Rooker et al. 1996), presumably a response to mortality associated with visual predators. These patterns of spawning, transport, recruitment, and settlement in association with the local physical oceanographic regime, often result in variable larval supply and settlement patterns with distinct lunar periodicities. Since the sampling transect is downstream of the Mississippi River plume and extends from an outer shelf platform to a coastal jetty, baroclinic pressure gradients, wind-driven currents, and tides are important transport considerations. It should be noted, however, that in the northern Gulf of Mexico, tides are dominantly diurnal and their range in tidal height is not often in synchrony with the phase of the moon (i.e., new and full moon maximum tide ranges versus first quarter and third quarter minimums), but rather the tidal range is in synchrony with the tropical and equatorial phases of the moon's elevation (i.e., Tropic of Cancer and/or Capricorn crossing maximum tidal ranges versus equatorial crossing minimums; McLellan 1965). In addition, the effects of ambient light on gear selectivity were investigated. Since light traps rely on the illumination of the surrounding water mass to attract fish, the contrast in trap-generated illumination should be greater (and theoretically more efficient) when there is less ambient light, such as during a new moon phase (all larval and postlarval supply/availability issues being equal).

Few studies utilizing light-aggregating devices have addressed gear efficiency within the framework of lunar periodicities in fish spawning, larval supply (transport), and settlement. Gregory and Powles (1985) observed higher catches during new moon phases in a freshwater system but did not report a statistical difference. Rooker et al. (1996) used a nightlight lift-net in nearshore habitats in Puerto Rico and reported that larval fish new moon abundances were four times higher than the next most abundant phase (last quarter) during the summer months and suggested that ambient light intensities might have played a factor in gear efficiency. The competitive interaction of lunar versus light trap illumination may have played a role in the collection of fish at Belle Pass, where significantly higher CPUEs were observed during new moons. Jetty push-net collections also had significantly more fish during new moons, possibly due to decreased visual avoidance under lower ambient light conditions. It is difficult, however, to separate the effects of ambient illumination and gear performance from the supply and/or settlement patterns of the fishes, so lunar periodicity may still play a role in the occurrence of fishes at this site.

In addition, the situation at petroleum platforms may be equally difficult to discern, since platforms have many bright lights throughout the structure to illuminate the work areas at night and to aid ship navigation, which may in effect be attracting fish to the structure (i.e., fishing a light trap within a giant "light trap"). This issue was at least partially addressed by sampling away from the structure (i.e., 20 m downstream), but even these off-platform light trap collections could still be within the "halo influence" of the platform's light field. Still, when significant differences in mean total densities and mean total CPUEs were found between new versus full moon phases, four out of five instances had greater new moon catches. The analysis of the May samples at GI 94 taken over three lunar phases was disappointing, however, since it showed very little difference between the lunar phases for both gears.

Although these platform results on lunar periodicity are less than conclusive, there may be several explanations for the lack of a consistently strong pattern. First of all, the previously mentioned potential competitive interference of the platform's large ambient light-field may have partially masked any lunar effect that would otherwise be present. Second, some of the species may be responding differently to lunar cues. For example, some peak recruitment events for tropical and coastal fishes have also been linked to full moon periods (Johannes 1978; Robertson et al. 1988). Due to the rarity of reef fish taxa collected (Hernandez et al. 2003, this volume), analyses were run on total light trap and plankton net catches and not individual taxa. Multiple species responding to different lunar cues undoubtedly confounded the results. Finally, it is possible that the abundances of these fish are related to more localized factors such as water mass supply, particularly at the mid- and inner shelf sites where the coastal current regime can dynamically affect salinity, temperature, and food patchiness and where the geographical concentration of upstream platforms, which may represent potential spawning sites, is greatest when compared to the relative isolated shelf slope site.

In summary, the combination of the light trap and the passive plankton nets were effective in collecting fish larvae and juveniles within the complex infrastructure of the oil and gas platforms sampled in the north-central Gulf of Mexico. Surprisingly, the light trap collected individuals from a wide range of taxa, including many unique taxa that were not collected with the plankton net. As in previous studies, the light trap generally collected larger individuals (postflexion larvae and juveniles) than the plankton net but also performed very well at the smaller sizes. Push-net collections from the jetties were more taxonomically rich and diverse than light trap collections, and the push net was equally effective in capturing large individuals as the light trap. The use of multiple gear types in ichthyoplankton studies needs to become more common since they can provide the researcher with a more complete view of larval and juvenile fish assemblages. For example, the combination of sampling gears at the platforms allowed for the collection of a wider range of taxa, size-classes, and developmental life stages than either gear would have provided individually. This enabled us to confirm the presence of both recently-spawned larvae, larger, near-settlement size postlarvae, and juveniles at the sampling sites.

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