Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeid and Rock Shrimp Fisheries Based on Observer Data

Elizabeth Scott-Denton, Pat F. Cryer, Matt R. Duffy, Judith P. Gocke, Mike R. Harrelson, Donna Kinsella, James M. Nance, Jeff R. Pulver, Rebecca C. Smith, and Jo A. Williams

SEDAR41-RD39

28 July 2014

Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeid and Rock Shrimp Fisheries Based on Observer Data

ELIZABETH SCOTT-DENTON, PAT F. CRYER, MATT R. DUFFY, JUDITH P. GOCKE, MIKE R. HARRELSON, DONNA L. KINSELLA, JAMES M. NANCE, JEFF R. PULVER, REBECCA C. SMITH, and JO A. WILLIAMS

*ABSTRACT—In July 2007, a mandatory Federal observer program was implemented to characterize the U.S. Gulf of Mexico penaeid shrimp (*Farfantepenaeus aztecus*,* F. duorarum*, and* Litopenaeus setiferus*) fishery. In June 2008, the program expanded to include the South Atlantic penaeid and rock shrimp,* Sicyonia *spp., fisheries. Data collected from 10,206 tows during 5,197 sea days of observations were analyzed by geographical area and target species. The majority of tows (~70%) sampled were off the coasts of Texas and Louisiana. Based on total hours towed, the highest concentrated effort occurred off South Texas and southwestern Florida. Gear information, such as net characteristics, bycatch reduction devices, and turtle excluder devices were fairly consistent among areas and target species.*

By species categories, finfish comprised the majority (≥57%) of the catch composition in the Gulf of Mexico and South Atlantic penaeid shrimp fisheries, while in the South Atlantic rock shrimp fishery the largest component (41%) was rock shrimp. Bycatch to shrimp ratios were lower than reported in previous studies for the Gulf of Mexico penaeid shrimp fishery. These decreased ratios may be attributed to several factors, notably decreased shrimp effort and higher shrimp catch per unit of effort (CPUE) in recent years. CPUE density surface plots for several species of interest illustrated spatial differences in distribution. Hot Spot Analyses for shrimp (penaeid and rock) and bycatch species identified areas with significant clustering of high or low CPUE values. Spatial and temporal distribution of protected species interactions were documented.

Introduction

Bycatch in shrimp trawls is a significant source of fishery induced mortality for several state and Federally managed finfish species in the southeastern United States (Pellegrin, 1982; Alverson et al., 1994; Nichols et al.[1]; NMFS[2,3]). Significant declines in landings of several species of southeastern finfish, notably red snapper, *Lutjanus campechanus*, (Goodyear and Phares[4]), resulted in the implementation of Federal management measures to identify reasons for these declines and to expedite the necessary steps required to rebuild affected stocks.

In response to Congressional directives, NOAA's National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC), in cooperation with the Gulf and South Atlantic Fisheries Foundation, Inc. (Foundation), implemented a cooperative research plan in 1992 to identify, develop, and evaluate gear options to reduce bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries (NMFS[5]; Hoar et al.[6]). More than 150 bycatch reduction device (BRD) styles were developed by industry, scientists and gear specialists and evaluated through cooperative multi-year efforts (Scott-Denton and Nance, 1996; Nance and Scott-Denton, 1997; Watson et al., 1999; Scott-Denton, 2007; NMFS[2, 3]; Branstetter[7]; Nance et al.[8]; Foster and Scott-Denton[9]; NMFS[10]; Helies and Jamison[11]).

The two primary objectives of these evaluations were to: 1) estimate catch

[1]Nichols, S., A. Shah, G. J. Pellegrin, Jr., and K. Mullin. 1987. Estimates of annual shrimp fleet bycatch for thirteen finfish species in the offshore waters of the Gulf of Mexico. Report to the Gulf of Mexico Fisheries Management Council. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Pascagoula, Miss., 28 p.

[2]NMFS. 1995. Report to Congress: cooperative research program addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries. Natl. Mar. Fish. Serv., NOAA, Southeast Reg. Off., St. Petersburg, Fla., 68 p. (avail. at http://galveston.ssp.nmfs.gov/publications/pdf/620.pdf).

[3]NMFS. 1998. Report to Congress: southeastern United States shrimp trawl bycatch program. Natl. Mar. Fish. Serv., NOAA, Southeast Fish. Sci. Cent., Galveston Laboratory, Galveston, Tex., 155 p. (avail. at http://galveston.ssp.nmfs.gov/publications/pdf/235.pdf).

The authors are with the Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 4700 Avenue U, Galveston, TX 77551 (corresponding author: elizabeth.scott-denton@noaa.gov).

[4]Goodyear, C. P., and P. Phares. 1990. Status of red snapper stocks of the Gulf of Mexico - Report for 1990. Natl. Mar. Fish. Serv., NOAA, Southeast Fish. Sci. Cent., Miami Lab. Rep. Contrib. CRD 89/90-05, 72 p. (avail. at https://grunt.sefsc.noaa.gov/P_QryLDS/mainqry.jsp).

[5]NMFS. 1991. Shrimp trawl bycatch research requirements. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Miami, Fla., and NMFS Southeast Reg. Off., St. Petersburg, Fla., 66 p.

[6]Hoar, P., J. Hoey, J. Nance, and C. Nelson. 1992. A research plan addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries. Gulf & South Atlantic Fisheries Foundation, Inc., Suite 740, Lincoln Center, 5401 W. Kennedy Blvd. Tampa, Fla., 128 p. (avail. at http://www.gulfsouthfoundation.org/uploads/reports/45 Part 2_20091022111207.pdf).

[7]Branstetter, S. 1997. Bycatch and its reduction in the Gulf of Mexico and south Atlantic shrimp fisheries. Gulf & South Atlantic Fisheries Foundation, Inc., Suite 740, Lincoln Center, 5401 W. Kennedy Blvd. Tampa, Fla., 27 p.

[8]Nance, J., E. Scott-Denton, E. Martinez, J. Watson, A. Shah, and D. Foster. 1997. Bycatch in the southeast shrimp trawl fishery: A data summary report. NMFS, Southeast Fish. Sci. Cent., Miami, Fla., SFA Task N-10.03, 25 p. (avail. at http://galveston.ssp.nmfs.gov/publications/pdf/512.zip).

[9, 10, 11] *See next page*.

rates during commercial shrimping operations for both target and nontarget species by area, season, and depth; and 2) evaluate BRD effectiveness at eliminating or significantly reducing the capture of nontargeted species, notably red snapper.

Since the early 1990's, much progress has been made in addressing the complex issues associated with finfish bycatch reduction in the southeastern shrimp fishery (NMFS[10]). BRD's have been required in Federal waters of the South Atlantic since 1997, the western Gulf of Mexico since 1998, and the eastern Gulf of Mexico since 2004 (50 CFR 622). BRD designs currently certified (or provisionally certified) for use in Federal waters of the Gulf of Mexico and South Atlantic include: composite panel, extended funnel, fisheye, Jones-Davis, and modified Jones-Davis (NOAA, 2008a). An additional design, the expanded mesh BRD, is certified for use in the South Atlantic only. Potential BRD designs are certified based on criteria set forth in the revised and consolidated BRD testing manuals and certification requirements for the Gulf and South Atlantic shrimp fisheries (NOAA, 2008b). Once certified, observer data are used periodically to reassess the continued effectiveness of BRD designs (Foster and Scott-Denton[9]; NMFS[10]; Helies and Jamison[11]).

To improve the statistical validity of data from the voluntary observer program, including bycatch, effort, and fishery performance estimates, the GMFMC, through Amendment 13 to the Shrimp Fishery Management Plan (GMFMC[12]), mandated observer coverage of Federally permitted vessels. In 2007, the SEFSC implemented a mandatory observer program for the commercial shrimp fishery operating in the U.S. Gulf of Mexico. In June 2008, observer coverage was expanded to include the South Atlantic penaeid and rock shrimp fisheries through Amendment 6 to the Shrimp Fishery Management Plan for the South Atlantic Region (SAFMC[13]). A voluntary component of the observer program continues for the purposes of BRD development and evaluation.

Three commercially important penaeid shrimp species, brown shrimp, *Farfantepenaeus aztecus*; white shrimp, *Litopenaeus setiferus*; and pink shrimp, *Farfantepenaeus duorarum*, historically comprise the majority of shrimp landed in southeastern U.S. waters. In 2010, these three species accounted for 99.9 % of annual shrimp landed in the Gulf of Mexico (NMFS, 2003). Landings were approximately 177.0 million lb (80.3 million kg) (heads-on) valued at $335.5 million (NMFS, 2003). Penaeid shrimp landings in the South Atlantic were approximately 16.3 million lb (7.4 million kg) (heads-on) valued at $33 million. Rock shrimp, *Sicyonia* spp., also primarily targeted in the South Atlantic, accounted for a smaller percentage of landings (1.8 million lb; 816 thousand kg) valued at $2.5 million (NMFS, 2003).

The shrimp fishery operates year round in the Gulf of Mexico, with highest effort occurring May through December (Nance, 1993a). The majority of brown shrimp catch from offshore waters occurs primarily off the coasts of Texas and Louisiana in depths between 20–40 fm. White shrimp are typically caught in waters of about 10 fm in the same areas. Pink shrimp are caught in waters of about 35 fm, predominately off southwestern Florida in the winter months (NMFS, 1999). Rock shrimp are primarily targeted from waters off the east coast of Florida in depths between 10–40 fm (Anderson, 1956; Nance, 1993b).

Currently, there are 1,467 Federally permitted vessels in the Gulf of Mexico, and 534 penaeid and 106 rock shrimp Federal permit holders in the South Atlantic (SERO[14]). Observer coverage of the entire southeastern shrimp fishery is approximately 2% based on industry effort (nominal days at sea).

While finfish are the primary bycatch, several species listed under the Endangered Species Act of 1973 as amended (16 U.S.C. 1536 et seq.), or other regulatory mandates, have been encountered in the southeastern shrimp fishery. These include the following species:

Five species of sea turtles (Kemp's ridley, *Lepidochelys kempii*; leatherback, *Dermochelys coriacea*; hawksbill, *Eretmochelys imbricata*; loggerhead, *Caretta caretta*; and green, *Chelonia mydas*) occur in the Gulf of Mexico and South Atlantic and may be affected by shrimping activities (Magnuson et al., 1990; Epperly et al., 2002). All of these species are currently listed as threatened or endangered under the Endangered Species Act (ESA).

Other species that may be encountered include smalltooth sawfish, *Pristis pectinata*, listed by NMFS as endangered under the ESA in April 2003 (50 CFR 224). Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*, and Gulf sturgeon, *Acipenser oxyrinchus desotoi*, were listed by NMFS as endangered species in February 2012 (NOAA, 2012). While delisted in November 2009 under ESA, the brown pelican, *Pelecanus occidentalis*, remains protected under the Migratory Bird Treaty Act (16 U.S.C. §§ 703–712). Lastly, the Marine Mammal Protection Act (MMPA) enacted in 1972 (16 USC Chapter 31) affords protection for marine mammals. NMFS routinely prepares ESA section 7 consultations and other recommendations based on observer data to describe the effects of

[9]Foster, D. G., and E. Scott-Denton. 2004. Status of bycatch reduction device performance and research in north-central and western Gulf of Mexico. Southeast Data Assessment and Review, South Atl. Fish. Manage. Counc., Charleston, S.C., SEDAR 7-DW-38, 50 p. (avail. at http://www.sefsc.noaa.gov/sedar/).

[10]NMFS. 2006. Report to Congress: Gulf of Mexico shrimp trawl bycatch reduction. NMFS, Southeast Fish. Sci. Cent., Miami, Fla., 126 p.

[11]Helies, F., and J. Jamison. 2009. Reduction rates, species composition, and effort: assessing bycatch within the Gulf of Mexico shrimp trawl fishery. Gulf & South Atlantic Fisheries Foundation, Inc., Suite 740, Lincoln Center, 5401 W. Kennedy Blvd. Tampa, Fla., 182 p. (avail. at http://www.gulfsouthfoundation.org/uploads/reports/101_final4.pdf).

[12]GMFMC. 2005. Amendment 13 to the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico. Gulf Mex. Fish. Manage. Counc., Tampa, Fla. (avail. at http://www.gulfcouncil.org/).

[13]SAFMC. 2005. Amendment 6 to the Shrimp Fishery Management Plan for the South Atlantic Region. South Atl. Fish Manage. Counc., Charleston, S.C. (avail. at http://www.safmc.net).

[14]SERO. 2011. Fishery permits. Southeast Reg. Off., Natl. Mar. Fish Serv., NOAA, St. Petersburg, Fla. (avail. http://sero.nmfs.noaa.gov/sf/permits.htm).

Federal activities, including Federally permitted fisheries, on threatened or endangered species.

The continuing goals of the mandatory observer programs are to provide quantitative biological, vessel, and gear-selectivity information for the southeastern shrimp fishery. The primary objectives are to: 1) provide general fishery bycatch characterization and catch rates for finfish species by area and target species; and 2) provide catch rates that can be used to estimate protected species bycatch levels.

The specific objectives of this paper are to: 1) summarize trip, vessel, environmental, and gear characteristics; 2) quantify fish and protected species capture by area and target species; and 3) estimate catch per unit of effort (CPUE) trends and spatial distribution for target and nontarget species.

Methods

Methods are similar to those as described for the voluntary shrimp observer program (Scott-Denton, 2007; NMFS[3]; Foster and Scott-Denton[9]) and the mandatory reef fish observer program (Scott-Denton et al., 2011). NMFS-approved observers were placed on randomly selected shrimp vessels targeting either penaeid or rock shrimp. For the Gulf of Mexico, under the mandatory selection process, Federally permitted vessels were randomly selected based on the previous year of effort stratified by area, depth, and season. These data were derived from the NMFS shrimp landings file and cross-referenced with U.S. Coast Guard documentation records, which yielded a list of active vessels. The NMFS Southeast Regional Office (SERO) provided owner names and contact information from permit records. Shrimp effort data were not available for all areas in the South Atlantic; therefore, only landings data were used to proportionally allocate sampling effort. Once selected, permit holders were notified by certified mail at least 1 month prior to the selection period. Seasonal selection periods were as follows: January through April, May through August, and September through December.

The authority to place observers falls under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA; 16 USC 1801), ESA, and MMPA. Pursuant to MSFCMA § 303(b)(8), Federal fishery permit holders are required to carry an observer if selected for mandatory coverage. Among the several provisions promulgated under MSFCMA § 303(b)(8) is the mandate for Federal permit holders to obtain a current Commercial Fishing Vessel Safety Examination decal prior to the selection period for mandatory observer coverage. The safety decal requirement, in combination with other factors, led to low vessel compliance at the onset of the program. A continued dedicated effort by NMFS Office of Law Enforcement (OLE) has substantially increased compliance, notably in the Gulf of Mexico.

Additionally, a minimum sea day requirement by permit type was established to prevent potential early trip termination due to having an observer on board. Gulf of Mexico Federal penaeid permit holders are required to carry an observer for a minimum of 18 days during a selection period, with 11 and 6 days for South Atlantic rock and penaeid shrimp, respectively. Moreover, permit holders are required to carry an observer if selected, regardless of area fished or target species. No exemptions have been granted; however, a small percentage of vessel substitutions have been allowed (i.e., same owner, different vessel, same area).

For the Gulf of Mexico, shrimp statistical zones (Patella, 1975) were used to delineate area designations (Fig. 1). Conventionally, statistical areas 1–9 represent areas off the west coast of Florida, 10–12 delineate Alabama/Mississippi, 13–17 depict Louisiana, and 18–21 denote Texas. Depth strata seaward of the beach, or International Regulations for Preventing Collisions at Sea 1972 (COLREGS) line, were classified as nearshore (≤ 10 fm) or offshore (> 10 fm). Similarly, for the Atlantic, lat. 24°00′N–30°42.5′N denote the east coast of Florida, > lat. 30°42.5′N–32°00′N depict Georgia, > lat. 32°00′N–33°51.6′N represent South Carolina, and > lat. 33°51.6′N delineate North Carolina.

For each observed trip, vessel length, hull construction material, gross tonnage, engine horsepower, and crew size information were recorded. Gear characteristics related to BRD, turtle excluder device (TED), net type and other associated gear were recorded at the start of each trip, and updated if changes were made during the trip. Bottom time, vessel speed, and operational aspects relative to each net were documented for each tow.

Fishery-specific data were collected for each tow from the two outboard nets from vessels equipped with four nets, and one net for vessels equipped with two nets. Total catch, total shrimp, and red snapper weights were recorded for each net sampled. A subsample (one basket per net; approximately 32 kg) was processed from each net for bycatch composition by sorting for species, family, or species groupings (now referred to as species). Penaeid shrimp (and/or rock shrimp depending on the target), nonpenaeid crustaceans (crustaceans), noncrustacean invertebrates (invertebrates), and debris (e.g., rocks, logs, trash) were recorded from the subsample.

In the Gulf of Mexico, 14 other species of commercial, recreational and ecological importance were recorded. These included: Atlantic croaker, *Micropogonias undulatus*; black drum, *Pogonias cromis*; cobia, *Rachycentron canadum*; king mackerel, *Scomberomorus cavalla*; lane snapper, *Lutjanus synagris*; longspine porgy, *Stenotomus caprinus*; red drum, *Sciaenops ocellatus*; seatrout, *Cynoscion* spp.; other snapper, *Lutjanus* spp.; grouped sharks, Order Selachii; southern flounder, *Paralichthys lethostigma*; spotted seatrout, *Cynoscion nebulosus*; Spanish mackerel, *Scomberomorus maculatus*; and vermilion snapper, *Rhomboplites aurorubens*. The remaining finfish species were grouped into a finfish other category.

From 2007 through 2008, all shark species were grouped. Beginning January 2009, identification of some shark species (as well as other species) was

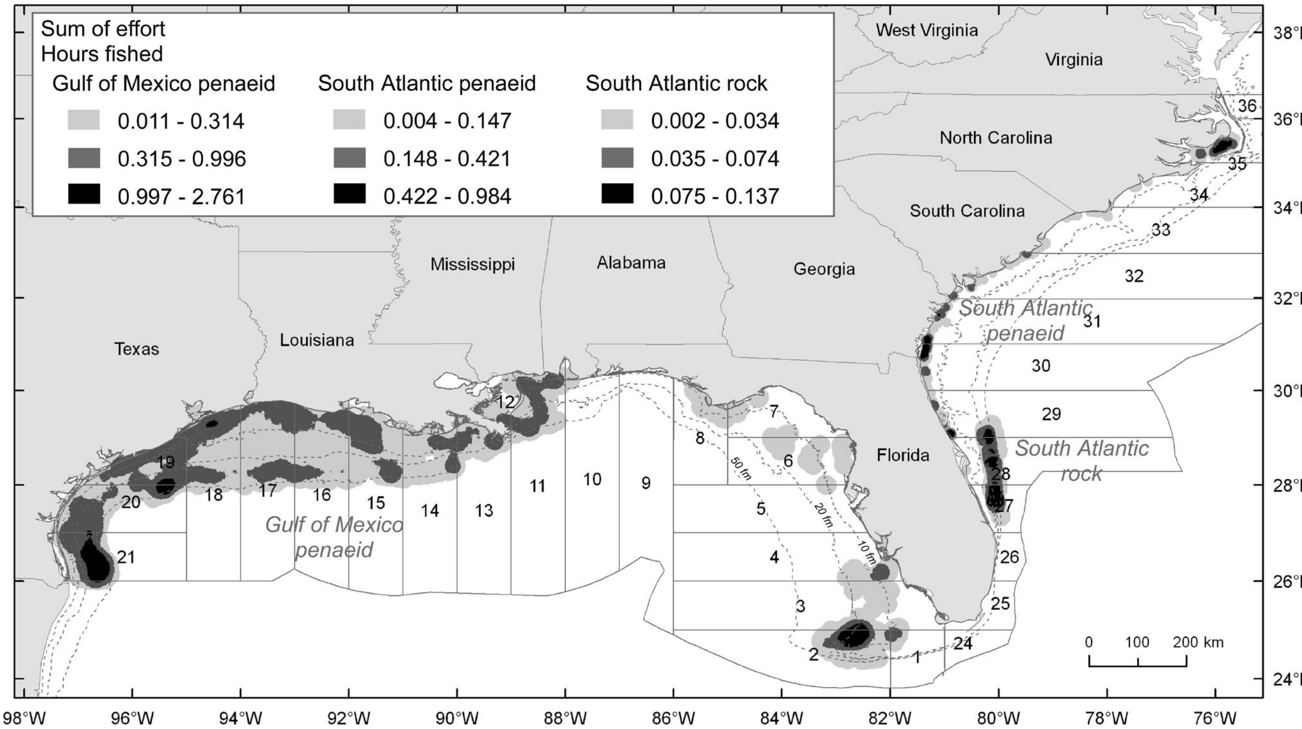

Figure 1.—Density of sampling effort (sum of tow times), based on observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

implemented; however, for the purpose of CPUE and variance analyses (2007–10), all sharks were grouped for consistency throughout the time series. Similar selection lists and methods were developed for the South Atlantic penaeid and rock shrimp fisheries. A detailed description of at-sea collection methods and data requirements are presented in the NMFS Galveston Laboratory's observer manual entitled "Characterization of the U.S. Gulf of Mexico and Southeastern Atlantic Otter Trawl and Bottom Reef Fish Fisheries" (NMFS[15]).

Biological measurements (weight and length) were recorded in metric units. Vessel, gear, and depth measurements followed current standards for the fisheries (U.S. system equivalents) as related to relevant regulatory mandates.

[15]NMFS. 2010. Characterization of the U.S. Gulf of Mexico and southeastern Atlantic otter trawl and bottom reef fish fisheries. Observer Training Manual. NMFS, Southeast Fish. Sci. Cent., Galveston Laboratory, Galveston, Tex. (avail. at http://galveston.ssp.nmfs.gov/research/fisherymanagement).

Catch rates are presented collectively for all years and seasons by area and target species (Gulf of Mexico penaeid; South Atlantic penaeid; and South Atlantic rock shrimp). A minimum of three vessels was required for seasonal and state-specific analyses due to confidentiality restrictions.

Protected species were documented and reported to SERO and/or SEFSC, generally within 24 h of capture. Sighting or capture of sea turtles was recorded in accordance with SEFSC protocol (NMFS, 2008). Observer data pertaining to sea turtle interactions were transmitted to SEFSC for sea turtle take level estimations.

All data were entered into the southeast regional shrimp trawl bycatch database. The database was developed in 1992 through a southeast regional program conducted by NMFS in cooperation with commercial fishing organizations and interests, state fishery management agencies, and universities. This database is housed and managed at SEFSC's Galveston Laboratory, where data sets are archived.

Statistical Analyses

Species total weights were extrapolated from subsample weight using the total catch weight, and were based on all sampled nets (sampling unit) per tow. Data from all sampled nets, regardless of operational problems (e.g., torn webbing, hangs, clogging), were included with the assumption that it represented standard commercial operations experienced by the fishery. The nets used in the analyses were consistent with current BRD regulations (required or not required). Total weight extrapolations were derived by multiplying the sample weight of the species of interest by the total weight of the sampled net, divided by the subsample weight for that net. For rare species and red snapper, all specimens were removed from the net, and no extrapolation was required. In the absence of a weight for a given species, the entire net was set aside from the analysis. Counts of individual specimens (except red snapper) were not recorded for all sampled nets, and therefore not included in the analysis.

Ratio estimation was used for analyses of species-specific catch rates. As described by Snedecor and Cochran (1967) and Watson et al. (1999), the ratio estimation (1) below was used as the sample estimate of the mean.

$$(1) \qquad R = \frac{\sum Y}{\sum X},$$

where: R = ratio estimate,
Y = extrapolated kilograms for species of interest for selected strata, and
X = hours towed for selected strata.

The estimated standard error of the estimate is given in equation 2:

$$(2) \qquad s(R) = \frac{1}{\bar{x}}\sqrt{\frac{\sum (Y - RX)^2}{n(n-1)}},$$

where: $\bar{x}$ = mean of hours towed for selected strata, and
n = number of tows occurring in selected strata.

To standardize bycatch (discard) estimates as described in "Evaluating Bycatch" (NMFS, 2004), the coefficient of variation (CV) was used as a measure of precision for bycatch estimates. CV estimates were calculated by dividing the estimated standard error by the estimate of the mean CPUE (kg per hour for selected species).

As described in Scott-Denton et al. (2011), a density surface of CPUE for commercial and recreational important species was created using Fishery Analyst.[16, 17] This is an ArcGIS extension developed to graphically present temporal and spatial trends in fishery statistics (Riolo, 2006). The search radius was based on the average minimum tow length plus the standard deviation for each fishery (20 km for Gulf penaeid and South Atlantic rock; 10 km for South Atlantic penaeid). A cell size of 1 km produced the optimal resolution. All three fisheries are depicted on the same plot because there was no overlap in fishing grounds.

Density of catch and effort values for each 1 km cell was calculated by summing those values contained within the search radius and dividing the value by the area of the circle as defined by the search radius. A summary CPUE value for all years combined was calculated for each cell by summing CPUE values for individual years and dividing by the number of years for which fishing activity occurred in that cell.

To identify patterns in CPUE for selected species in each fishery, a local spatial statistic, the Getis-Ord Gi* (Gi*), was calculated using the Hot Spot Analysis tool in ArcGIS[18] to locate clusters of features with similarly high or low values. The Gi* statistic was also calculated for all discarded species combined and shrimp (penaeid and rock) in order to assess if geographical areas of particularly high levels of bycatch occurred.

Results

Fishing Characteristics

From July 2007 through December 2010, a total of 608 trips were observed (Table 1). For the mandatory component, 10,206 tows targeting penaeid and/or rock shrimp (royal red shrimp excluded due to confidentiality) were sampled during 5,197 sea days of observations, with 9,264 tows (4,763 sea days) in the Gulf of Mexico and 942 tows (434 sea days) occurring in the South Atlantic. The highest concentration of effort was in statistical areas 2 and 21 in the Gulf, 30 and 35 in the South Atlantic penaeid, and 27 in the South Atlantic rock shrimp fishery (Fig. 1). By season, 40% of the tows occurred from September through December; 39% May through August; and 21% January through April (Table 2). The greatest percentage of tows (39%) occurred off Texas after the Texas Closure (typically in effect from May 15 through July 15 annually).

Trip and tow characteristics varied by area and target (Table 3). Trip length averaged 13.8 (± 10.7 s.d.) days in the Gulf, 2.9 (± 3.0 s.d.) days in the South Atlantic penaeid shrimp fishery, and 14.8 (± 5.9 s.d.) days for the South Atlantic rock shrimp fishery. Average tow times were longer in the Gulf (5.2 h ± 2.2 s.d.) as compared with the South Atlantic penaeid (2.8 h ± 1.1 s.d.) and rock (2.7 ± 0.8 s.d) shrimp fisheries. Try net (a small net used to intermittently test for shrimp concentrations) tow times were also longer in the Gulf (0.9 h ± 0.4 s.d) as compared with the South Atlantic (0.5 h ± 0.2 s.d). On average, South Atlantic rock shrimp vessels fished deeper depths (33.5 fm) than Gulf (16.4 fm) and South Atlantic (4.8 fm) penaeid fisheries. Average vessel speed for all areas and fisheries combined was 2.8 kn.

Vessel characteristics (Table 4) were similar for the Gulf penaeid and South Atlantic rock shrimp fisheries because they can typically target both penaeid and rock shrimp, though at different times of the year. These vessels are generally larger ($\bar{x}$>70 ft), have freezer storage capacity, and are of steel construction versus the South Atlantic penaeid fishery with smaller vessels ($\bar{x}$= 64.2 ft), ice hold storage, and wood construction.

Typical gear configurations for the southeastern shrimp fishery are depicted (Fig. 2, 3) with net characteristics by area and target species specified (Table 5). Flat nets were used more often in the Gulf (22.6%) and South Atlantic rock (56.5%) shrimp fisheries, while mongoose nets with bibs (56.0%) were used most frequently in the South Atlantic penaeid fishery. Headrope length for the primary trawls was similar among areas and target with an average from 50.5 ft to 52.5 ft. Try net headrope was also comparable in the Gulf and South Atlantic penaeid fisheries with an average of approximately 12 ft. Several trawl characteristics recorded were similar for all areas and target species including trawl body and codend material (nylon),

[16]Fishery Analyst, Mappamondo GIS, Via Rubens 3, 43100 Parma(PR) – Italy (avail. at http://www.mappamondogis.it/fisheryanalyst.htm).

[17]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[18]ArcGIS 9.3 Computer Software, 380 New York Street, Redlands, CA 92373 (avail. at http://www.esri.com/software/arcgis/index.html).

Table 1.—Trips, tows, and sea days by year and program, based on observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

		Mandatory				Voluntary			
	Year	Gulf penaeid	South Atlantic penaeid	South Atlantic rock	Deep water royal red	Bycatch characterization	BRD certification	Skimmer	Total
Trips by year and project									
	2007	31				32	5		68
	2008	107	27	3			10		147
	2009	105	68	2	1		9	15	202
	2010	104	29	1	1		1	56	192
	Grand total	348	124	6	2	32	25	71	608
Tows by year and project									
	2007	1,242				52	214		1,508
	2008	2,797	202	97			416		3,512
	2009	2,918	441	16	8		347	76	3,806
	2010	2,307	145	41	7		41	358	2,899
	Grand total	9,264	788	154	15	52	1,018	434	11,725
Sea days by year and project									
	2007	639				32	127		798
	2008	1,435	86	53			234		1,808
	2009	1,559	206	7	6		230	20	2,028
	2010	1,130	68	14	8		22	68	1,310
	Grand total	4,763	360	74	14	32	613	88	5,944

Sea days by year and region	Year	Mandatory	Voluntary	Total	Industry sea days	Industry % cover
Gulf of Mexico	2007	639	127	766	68,570*	1.1
	2008	1,435	234	1,669	62,797	2.7
	2009	1,559	250	1,809	76,508	2.4
	2010	1,138	22	1,160	62,190	1.9
	Grand total	4,771	633	5,404	270,065	2.0
South Atlantic	2007	0	32	32	15,836	0.2
	2008	139	0	139	15,473	0.9
	2009	219	0	219	15,470	1.4
	2010	82	68	150	12,081	1.2
	Grand total	440	100	540	58,860	0.9

* Partial year

door type (wood), trawl extension (none), chaffing gear (mesh), and lazy line rigging (elephant ears).

BRD type and dimensions (Table 6) were also similar among areas and target species. The dominant BRD type (fisheye), BRD position (top), and BRD location (behind elephant ears) were recorded most frequently. This was also evident with several attributes for TED's (Table 7), including TED type and design (hard/curved bar), TED opening (bottom), and TED angle ($\bar{x} \geq$ 48.6 degrees).

Catch Composition

Based on actual weight (i.e., nonextrapolated) data, 2.4 million kg of total catch was documented from 12,972 nets (towing for 69,194 h). For nets that had an effort value and an associated total catch and shrimp weight recorded, 2.3 million kg of total catch were documented from 12,415 nets (66,260 h). Penaeid and rock shrimp comprised 634 thousand kg (heads-on) or 27% of the total weight. Average shrimp CPUE was 9.6 kg/h. From 11,122 nets (62,122 h) that had effort, total catch, shrimp and red snapper counts recorded, a total of 88,058 red snapper were documented in the Gulf of Mexico, yielding an average of 1.4 fish/h.

Extrapolated Species Composition Bycatch Ratios

For the 12,403 nets that contained species characterization data, 2.3 million kg of total catch was recorded (66,164 h) for all years, areas, seasons, and depths. Based on weight extrapolations from species composition samples, bycatch to targeted shrimp (penaeid or rock) ratios by area and target species (Table 8) were 2.5 in the Gulf penaeid shrimp fishery, 4.3 for the South Atlantic penaeid, and 1.4 in the South Atlantic rock shrimp fishery. Finfish to shrimp ratios for these same fisheries were 2.0, 3.2 and 0.9, respectively.

A total of 199 species were identified (Table 9). For all areas and target species, 4 species comprised >66% of total catch: grouped finfish species (26%), Atlantic croaker (16%), brown shrimp (13%), and white shrimp (11%).

Extrapolated Species Composition Gulf of Mexico Penaeid Shrimp

Weight extrapolations from species characterization data collected from 11,322 nets (63,024 h) were placed into major categories by area and target for all years, seasons, and depths (Fig. 4). In terms of percent composition and CPUE for the Gulf of Mexico penaeid shrimp fishery, finfishes dominated the catch at 57% (19.5 kg/h), followed by penaeid shrimp at 29% (9.9 kg/h), crustaceans at 7% (2.4 kg/h), invertebrates at 5% (1.8 kg/h), and debris at 1% (0.5 kg/h).[19] Overall (total catch) CPUE was 34.3 kg/h.

At the species level, the dominant species by area and target are depicted (Fig. 5–7; Table 9). In the Gulf of Mexico penaeid shrimp fishery, 185 species were identified (Table 9). As to

[19]Percentages may not equal 100% due to rounding.

Table 2.—Percentage of tows by season and state, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

	Jan–April %	May–Aug %	Sept–Dec %	Total %
Texas				
Nearshore	3.8	4.9	5.1	13.8
Offshore	4.8	10.7	9.4	24.8
Subtotal	8.6	15.6	14.4	38.6
Louisiana				
Nearshore	1.2	7.9	7.9	17.0
Offshore	2.6	4.9	6.5	14.0
Subtotal	3.8	12.8	14.3	31.0
Alabama/Mississippi				
Nearshore	0.7	1.4	2.0	4.0
Offshore	0.5	2.3	1.1	3.9
Subtotal	1.2	3.6	3.1	8.0
Florida Gulf				
Nearshore	0.0	0.7	1.1	1.8
Offshore	0.0	0.7	0.8	1.5
Subtotal	0.0	1.4	1.9	3.3
Florida Atlantic				
Nearshore	2.0	0.9	1.1	4.0
Offshore	5.1	1.5	2.7	9.3
Subtotal	7.1	2.4	3.8	13.2
Georgia				
Nearshore	0.2	0.6	1.0	1.9
Offshore	0.0	0.0	0.0	0.0
Subtotal	0.2	0.6	1.0	1.9
South Carolina				
Nearshore	0.0	0.8	0.7	1.5
Subtotal	0.0	0.8	0.7	1.5
North Carolina				
Nearshore	0.0	1.5	0.9	2.4
Offshore	0.0	0.0	0.0	0.1
Subtotal	0.0	1.5	1.0	2.5
Grand total	21.0	38.8	40.2	100.0

Table 3.—Trip characteristics by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

Item	Gulf mandatory penaeid	South Atlantic mandatory penaeid	South Atlantic mandatory rock
Trip length (days)	$n = 4763$	$n = 360$	$n = 74$
Mean	13.8	2.9	14.8
Range	1–51.0	1–20.0	7–22.0
s.d.	10.7	3.0	5.9
Main net tow time (h)	$n = 9252$	$n = 788$	$n = 154$
Mean	5.2	2.8	2.7
Range	<0.1–16.7	<0.1–6.9	0.8–6.4
s.d.	2.2	1.1	0.8
Total hs	48534.5	2212.0	421.3
Try net towtime (h)	$n = 5565$	$n = 1121$	
Mean	0.9	0.5	
Range	0.1– 5.0	<0.1–1.5	
s.d.	0.4	0.2	
Water depth (ftm)	$n = 8959$	$n = 778$	$n = 154$
Mean	16.4	4.8	33.5
Range	0.5–65.0	1.2–16.0	5.0–90.0
s.d.	12.5	2.5	20.7
Vessel speed (kt)	$n = 9161$	$n = 788$	$n = 154$
Mean	2.8	2.5	2.6
Range	0.1–4.1	1.2–3.6	1.9–3.2
s.d.	0.3	0.3	0.3

Table 4.—Vessel characteristics by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

Item	Gulf mandatory penaeid ($n = 199$)	South Atlantic mandatory penaeid ($n = 52$)	South Atlantic mandatory rock ($n = 6$)
Vessel length (ft)	$n = 199$	$n = 52$	$n = 6$
Mean	74.0	64.2	76.7
Range	31–98	38–88	72.0–85.0
s.d.	11.9	13.5	4.8
Year built	$n = 197$	$n = 51$	$n = 6$
Mean	1987	1981	1988
Range	1951–2003	1953–2003	1977–2001
s.d.	11.0	11.8	10.3
Gross tons	$n = 190$	$n = 50$	$n = 6$
Mean	119.5	83.9	143.3
Range	12–208	10–164	107.0–167.0
s.d.	41.3	41.6	21.0
Horsepower	$n = 169$	$n = 44$	$n = 5$
Mean	559	434	573
Range	85–1234	165–1000	425–720
s.d.	223	182	138
Crew size	$n = 196$	$n = 52$	$n = 6$
Mean	2	2	3
Range	0–4	0–4	1–4
s.d.	0.7	1.0	1.0
Cold storage			
Freezer	85%	25%	100%
Ice	13%	73%	
Unknown	2%	2%	
Hull construction			
Steel	83%	31%	83%
Fiberglass	11%	25%	
Wood	5%	33%	17%
Wood/Fiber	2%	12%	

percent composition and CPUE (Fig. 5), grouped finfish accounted for 27% (9.4 kg/h) of the total catch, followed by Atlantic croaker at 16% (5.4 kg/h), brown shrimp at 14% (4.8 kg/h), white shrimp at 11% (3.7 kg/h), crustaceans at 7% (2.4 kg/h), seatrout at 6% (2.0 kg/h), invertebrates at 5% (1.8 kg/h), longspine porgy at 4% (1.4 kg/h), and pink shrimp at 4% (1.3 kg/h). All other species accounted for 6% (2.0 kg/h) of the total weight.

CPUE and variance estimates for selected species collected from all sampled nets from July 2007 through December 2010 in the Gulf of Mexico penaeid shrimp fishery depict low (<0.3) CV estimates (Table 10). The two exceptions were grouped penaeid shrimp (not taken to species level) and other snapper species (excluding red and lane snapper).

Spatial CPUE density (kg/h) plots for several of these species are depicted in Figures 8–19 for all regions and targets. For the Gulf of Mexico region, brown and white shrimp were caught and retained predominantly in the western Gulf (statistical areas ≥11), with higher density CPUE for brown shrimp occurring further offshore as compared with white shrimp (Fig. 8, 9). Pink shrimp were found throughout the Gulf, with highest density CPUE occurring off the west coast of Florida (Fig. 10). Grouped finfish were caught throughout the Gulf region with highest spatial CPUE observed in statistical areas 11–13 (Fig. 11). Several finfish species were almost exclusively restricted to the western Gulf and included Atlantic croaker (Fig. 12), trout (Fig. 13), and red snapper (Fig. 14). Spanish mackerel (Fig. 15), king mack-

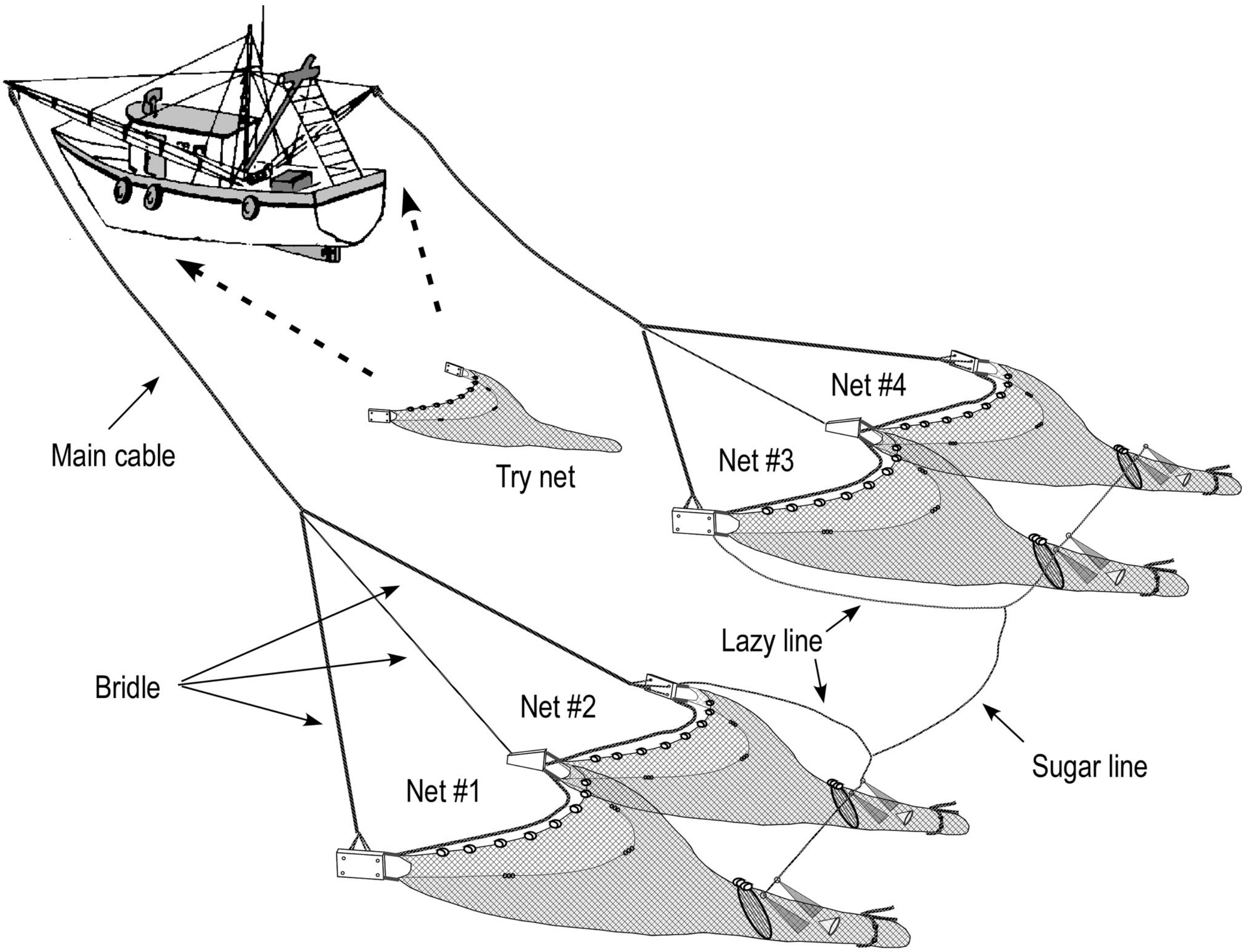

Figure 2.—Typical gear configuration for U.S. southeastern shrimp vessels equipped with four nets.

erel (Fig.16), and grouped sharks (Fig. 17), occurred primarily in the western Gulf and to a lesser extent off Florida in statistical areas 1–3. Crustaceans (Fig. 18) and invertebrates (Fig. 19) were found throughout the Gulf, with high spatial densities in several statistical areas, notably 1, 8, and 11.

Cluster locations of statistically significant high CPUE for penaeid shrimp were most pronounced in relatively small concentrated cells of statistical areas 2 and 11–20 (Fig. 20). For all discard (bycatch) species combined, clusters of significantly high CPUE were detected primarily in the western Gulf (Fig. 21) with relatively larger sections of statistical areas 11–20.

Extrapolated Species Composition South Atlantic Penaeid Shrimp

In the South Atlantic penaeid shrimp fishery, from 890 nets (2,634 h), fish species comprised 60% (31.2 kg/h) of the total catch (Fig. 4), followed by penaeid shrimp at 19% (9.9 kg/h), invertebrates at 15% (8.0 kg/h), crustaceans at 4% (2.0 kg/h), and debris at 1% (0.6 kg/h). Overall CPUE was 51.8 kg/h.

At the species level (Table 9; Fig. 6), Atlantic croaker accounted for 24% (12.5 kg/h) of the total catch, followed by grouped finfish and white shrimp each at 12% (6.4 kg/h), flat croaker, *Leiostomus xanthurus*, and jellyfish (Family Carybdeidae) each at 7% (3.8 kg/h), brown shrimp at 6% (3.3 kg/h), star drum, *Stellifer lanceolatus*, at 6% (3.0 kg/h), cannonball jellyfish, *Stomolophus meleagris*, at 4% (2.2 kg/h), and invertebrates at 4% (2.0 kg/h). All other species (54) comprised 16% (8.4 kg/h) of the total weight.

CPUE and variance estimates for species selected from all sampled nets during the monitoring period in the South Atlantic penaeid shrimp fishery are depicted (Table 11). Relatively higher (≥0.3) CV estimates were observed in the South Atlantic as compared with the Gulf for several species including, but not limited to, sciaenids (Family Sciaenidae) and sea basses (Family Serranidae).

Spatial CPUE density (kg/h) plots for several of these species are denoted in Figures 8–19. Brown and white shrimp were caught and retained predominantly in statistical areas 30, 32, 33, and 35 (Fig. 8, 9). Relatively low density CPUE was observed for pink shrimp along the southeastern Atlantic coast (Fig. 10); the one exception occurred in statistical area 35 with CPUE ranging from 1.4 kg/h to 4.2 kg/h. Grouped finfish occurred along the southeastern Atlantic coast, with highest CPUE density found in statistical areas 26, 34, and 35 (Fig. 11).

Atlantic croaker (Fig. 12) and seatrout (Fig. 13) exhibited a similar spatial pattern with high density CPUE occurring in statistical areas 29, 30, and 33–35. Density surface of CPUE was not detectable for red snapper (Fig. 14). CPUE was low for both Spanish mackerel (Fig. 15) and king mackerel (Fig. 16), with two exceptions in statistical area 31 for Spanish mackerel and in statistical area 29 for king mackerel. Grouped sharks were predominantly caught in statistical areas 30–33 (Fig. 17). Crustaceans (Fig. 18) and invertebrates (Fig. 19) exhibited a similar distribution, with high spatial densities for crustaceans detected in statistical area 35 and in statistical areas 30 and 31 for invertebrates.

Cluster locations of statistically significant high CPUE for South Atlantic penaeid shrimp were most pronounced in statistical areas 30, 31, 33, and 35 (Fig. 20). For discarded species, clusters of significantly high CPUE were detected primarily in the statistical areas 29–31, 33, and 35 (Fig. 21).

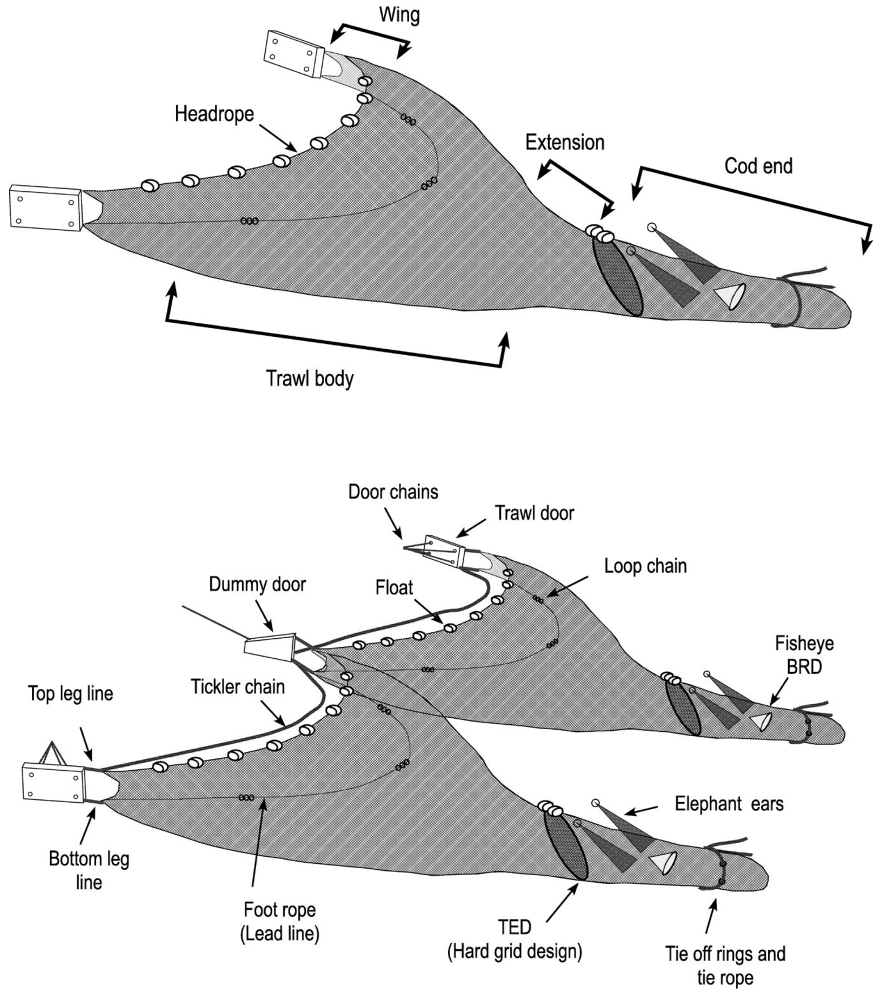

Figure 3.—Typical gear components for U.S. southeastern shrimp vessels.

Extrapolated Species Composition South Atlantic Rock Shrimp

In the South Atlantic rock shrimp fishery (191 nets; 506 h), rock shrimp accounted for 41% (29.0 kg/h) of the total catch (Fig. 4), followed by finfish at 36% (25.7 kg/h), crustaceans at 13% (9.5 kg/h), invertebrates at 6% (3.9 kg/h), debris at 2% (1.6 kg/h), and penaeid shrimp at 1% (0.7 kg/h). Total catch CPUE was 70.7 kg/h.

At the species level (Table 9; Fig. 7), rock shrimp comprised 41% (29.0 kg/h) of the total catch, followed by grouped finfish at 12% (8.8 kg/h), dusky flounder, *Syacium papillosum*, at 11% (7.5 kg/h), inshore lizardfish, *Synodus foetens,* at 9% (6.6 kg/h), iridescent swimming crab, *Portunus gibbesii*, and invertebrates each at 6% (3.9 kg/h), crustaceans at 5% (3.7 kg/h), longspine swimming crab, *Portunus spinicarpus*, at 3% (1.8 kg/h), and debris at 2% (1.6 kg/h). All other species (22) accounted for 5% (3.8 kg/h) of the total weight.

CV estimates for species selected from all sampled nets from July 2007 through December 2010 (Table 12) were higher (≥0.3), and in some instances equal to 1.0, for the majority of species in the South Atlantic rock shrimp fishery.

Highest spatial CPUE density for brown shrimp was most pronounced in statistical area 27 (Fig. 8). White shrimp had undetectable (no catch documented) spatial CPUE density (Fig. 9). Pink shrimp were found in highest spatial densities in statistical areas 27 and 28 (Fig. 10). Highest CPUE density for grouped finfish was most evident in statistical areas 27 and 29 (Fig. 11). Atlantic croaker were concentrated in statistical area 27 (Fig. 12). Several finfish species had very low or undetectable spatial CPUE densities: seatrout (Fig. 13), red snapper (Fig. 14), Spanish mackerel (Fig. 15), and king mackerel (Fig. 16). Grouped sharks were found in highest spatial densities in statistical areas 27 and 28 (Fig. 17). Crustaceans were also observed in high spatial densities in these same statistical areas (Fig. 18). Highest CPUE density for invertebrates occurred in statistical area 28 (Fig. 19).

Cluster locations of statistically significant high CPUE for penaeid and rock shrimp combined were most pronounced in statistical area 28 (Fig. 20). The highest clusters of significantly high CPUE for discarded species were also in statistical area 28 (Fig. 21).

Protected Species

From July 2007 through December 2010, 55 sea turtles (25 loggerhead, 21 Kemp's Ridley, 4 green, 4 unidentified, and 1 hawksbill) were captured in shrimp trawls with most (47%) documented from May to August (Fig. 22). By method of capture, 49% were observed in try nets, 44% in TED-equipped nets (before the TED or in codend), 4% slid out of TED-equipped nets upon retrieval, and 4% slid out of try nets upon retrieval. Most (80%) of the sea turtles were released alive and conscious.

Other protected species captured aboard shrimp trawlers (Fig. 23) included seven Atlantic sturgeon, three of which were captured at the same location, and one Gulf sturgeon. Of the eight sturgeon spp. captured, most, seven, were released alive.

Seven smalltooth sawfish have been captured in the shrimp fishery since mandatory observer coverage began. A detailed description and resulting estimates of the rate of take are reported in Carlson and Scott-Denton.[20]

One brown pelican was captured aboard a shrimp trawler. The pelican was entangled in the trawl door chains and died during release. Another unidentified seabird perished, but could not be positively identified.

Five dolphin interactions were documented in the Gulf of Mexico. Of these, three were identified as bottlenose dolphin, *Tursiops truncatus*, and two unidentified dolphins (Family Delphinidae). The condition at release included three freshly dead, two of which were entangled with the lazy line, and one in front of the TED. Of the remaining two, one was released alive (associated with the lazy line). The other, a decomposed carcass, was captured on the tickler chain.

Discussion

Bycatch remains one of the most significant and complex issues in fishery management (Hall et al., 2000; Hall and Mainprize, 2005). Many authors have defined and examined the detrimental effects of trawling, on a regional and global scale, in terms of a reduction in biodiversity, shifts in community structure, disruption of the food web, waste, profitability, user conflicts, and mortality of undersized target and nontarget species (Alverson et al., 1994; Hall, 1996; Greenstreet and Rogers, 2000; Hall et al., 2000; Murawski et al., 2000;

Table 5.—Net characteristics by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

Item	Gulf mandatory penaeid		South Atlantic mandatory penaeid		South Atlantic mandatory rock	
Net type (%)	Flat	22.6	Mongoose w/ bib	56.0	Flat	56.5
	Unknown	15.5	Mongoose	9.5	4 Seam balloon	24.0
Main net headrope length (ft)		*n*=17,735		*n*=1492		*n*=308
Mean		50.5		52.3		52.5
Range		14.0–74.5		33.4–70.0		35.0–61.0
s.d.		10.0		9.7		6.3
Main net footrope length (ft)		*n*=17,621		*n*=1492		*n*=308
Mean		56.6		55.0		56.3
Range		14.0–79.5		33.4–79.5		41.2–71.0
s.d.		10.7		10.6		6.8
Try net headrope length (ft)		*n*= 5565		*n*= 1121		
Mean		12.4		12.0		
Range		8.3–16.3		10.0–14.0		
s.d.		1.8		0.6		
Try net footrope length (ft)		*n*=5511		*n*=1121		
Mean		13.6		12.8		
Range		9.8–20.5		10.0–16.8		
s.d.		2.3		1.6		
TED		None		None		
Trawl body (%)	Nylon	65.9	Nylon	52.1	Nylon	93.5
	Sapphire	20.5	Spectra	34.4	Other	3.2
Trawl body mesh size (in)		*n*=17,467		*n*=1525		*n*=308
Mean		1.9		1.8		1.9
Range		1.0–3.0		0.9–4		1.5–2.0
s.d.		0.3		0.3		0.1
Cod end (%)	Nylon	88.5	Nylon	62.2	Nylon	100.0
	Sapphire	5.0	Poly	28.7		
Cod end mesh size (in)		*n*=17,177		*n*=1513		*n*=308
Mean		1.7		1.6		1.8
Range		0.8–2.5		0.9–4.0		1.5–2.0
s.d.		0.3		0.3		0.2
Door type (%)	Wood	61.5	Wood	82.6	Wood	100.0
	Aluminum	15.2	Aluminum	8.9		
Door length (ft)		*n*=17,843		*n*=1537		*n*=308
Mean		9.5		8.2		9.6
Range		4.0–13.0		3.0–11.0		9.0–10.0
s.d.		2.2		1.8		0.5
Door height (ft)		*n=17,843*		*n*=1537		*n*=308
Mean		3.6		3.3		3.6
Range		2.5–5.7		2.5–4.8		3.0–3.7
s.d.		0.4		0.4		0.2
Dummy door length (ft)		*n*=14,376		*n*=1183		*n*=308
Mean		7.6		6.5		7.8
Range		3.5–12.0		4.0–8.8		5.0–10.0
s.d.		1.9		1.2		1.3
Trawl extension type (%)	None	86.0	None	66.5	None	56.5
	Nylon	8.7	Nylon	12.1	Nylon	37.0
Chaffing gear type (%)	Mesh	91.8	Mesh	83.9	Mesh	69.5
	None	6.2	None	14.0	Whiskers	24.0
Lazy line rigging (%)	Elephant ears	94.9	Elephant ears	89.5	Elephant ears	100.0
	Choke	3.5	Choke	8.0		
Tickler chain length (ft)		*n*=17,478		*n*=1479		*n*=308
Mean		62.4		60.0		62.7
Range		27.0–90.0		37.0–106.8		46.6–76.5
s.d.		11.4		12.4		7.4

[20]Carlson, J., and E. Scott-Denton. 2011. Estimated incidental take of smalltooth sawfish (*Pristis pectinata*) and an assessment of observer coverage required in the South Atlantic and Gulf of Mexico shrimp trawl fishery. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Panama City, Fla., SFD Contribution PCB-11-08, 14 p.

NRC, 2002; Chuenpagdee et al., 2003; Diamond, 2004; Kumar and Deepthi, 2006). Kelleher (2005) reported tropical shrimp trawl fisheries accounted for 27% of global discards. Harrington et al. (2005) estimated 1.06 million tons of marine fish were discarded in 2002 in U.S. fisheries, making the United States one of the highest worldwide relative to discards.

Based on findings from the 2007–10 mandatory observer program, estimated overall CPUE for the shrimp fishery was comparable in some respects to earlier bycatch assessments conducted for the Gulf of Mexico, but notably different for the South Atlantic (Scott-Denton and Nance, 1996; Nance and Scott-Denton, 1997; Scott-Denton, 2007; NMFS[2,3]; Nance et al.[8]). For the 1992 through 1996 period, overall catch rates were 28.0 kg/h in the Gulf of Mexico, and 27.0 kg/h in the South Atlantic penaeid fisheries (NMFS[3]). Scott-Denton (2007) reported catch rates of 30.8 kg/h in the Gulf of Mexico and 27.7 kg/h in the South Atlantic from 1992 through 2005. In this study, overall CPUE was 34.3 kg/h for the Gulf of Mexico and 51.8 kg/h in the South Atlantic.

Early estimates by Alverson et al. (1994) calculated a discard to landing ratio of 10.30 and 8.00 for the Gulf of Mexico and South Atlantic shrimp fisheries, respectively. While estimation methods varied, more recent assessments (Harrington et al., 2005; Kelleher, 2005) revealed lower ratios. Scott-Denton (2007) estimated discards to landings ratios of 5.18 and 3.20 for the Gulf of Mexico and South Atlantic, respectively, from 1992 through 2005. These were slightly higher than estimates of 4.56 and 2.95 reported by Harrington et al. (2005) for 1992 through 1996 for the same areas. In this study, bycatch ratios were substantially lower at 2.47 in the Gulf of Mexico and higher in the South Atlantic at 4.25.

These differences can be explained, in part, for the Gulf of Mexico by examining percent composition by species categories. NMFS[3] calculated percentages of the total weight for the Gulf of Mexico of 67% for finfish and 16% for commercial shrimp species (i.e.,

Table 6.—Bycatch reduction device (BRD) characteristics by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

Item	Gulf mandatory penaeid		South Atlantic mandatory penaeid		South Atlantic mandatory rock	
BRD type (%)	Fisheye	82.0	Fisheye	97.5	Fisheye	100.0
	Composite panel	8.0	Unknown	2.2		
BRD cod end length (ft)		n=16,677		n=1460		n=308
Mean		130.3		135.7		144.7
Range		60.0–221.0		50.0–200.0		120.0–150.0
s.d.		22.2		22.2		10.8
BRD circumference (meshes)		n=17,809		n=1520		n=308
Mean		133.2		144.5		145.4
Range		89.0–195.0		80.0–200.0		120.0–150.0
s.d.		14.7		13.2		6.9
BRD distance to tie-off rings (ft)		n=17,271		n=1514		n=226
Mean		11.7		11.5		11.8
Range		6.8–21.8		8.0–20.0		7.3–14.5
s.d.		2.7		3.3		2.1
BRD fisheye (%)	Top	82.6	Top	95.3	Top	100.0
BRD escape shape (%)	Oval	54.7	Diamond	53.2	Diamond	83.8
	Half moon	18.1	Square	33.2	Oval	13.0
BRD fisheye escape height (in)		n=14,833		n=1502		n=308
Mean		6.1		6.8		5.9
Range		3.0–25.0		4.0–10.0		5.0–8.0
s.d.		2.2		1.2		0.8
BRD fisheye escape width (in)		n=15,599		n=1514		n=308
Mean		10.1		8.2		8.5
Range		5.0–27.0		4.8–13.5		6.0–13.0
s.d.		2.0		2.2		2.9
BRD location (%)	Behind	59.3	Behind	56.5	Behind	57.8
	Front	35.0	Front	37.4	Front	42.2

Table 7.—Turtle excluder device (TED) characteristics, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

Item	Gulf mandatory penaeid		South Atlantic mandatory penaeid		South Atlantic mandatory rock	
TED type (%)	Hard	96.9	Hard	97.5	Hard	100.0
TED design (%)	Curved bar	62.4	Curved bar	94.4	Curved bar	100.0
	Straight	30.7	Straight	3.1		
TED opening (%)	Bottom	65.5	Bottom	89.6	Bottom	100.0
TED funnel (%)	No	80.1	No	88.5	No	87.0
	Yes	16.2	Yes	7.9	Yes	13.0
TED flap (%)	Yes	91.4	Yes	92.2	Yes	100.0
	No	4.9	No	4.2		
TED material (%)	Aluminum	93.2	Aluminum	94.6	Aluminum	100.0
TED angle (degrees)		n=17,208		n=1496		n=308
Mean		48.6		50.6		50.4
Range		18.0–87.0		40.0–75.0		45.0–64.0
s.d.		8.7		5.5		6.3
TED length (in)		n=17,514		n=1514		n=308
Mean		46.8		44.3		49.1
Range		25.0–67.0		36.0–60.0		42.0–53.0
s.d.		5.7		5.0		2.3
TED width (in)		n=17,514		n=1514		n=308
Mean		38.9		36.6		38.6
Range		24.0–48.0		30.0–48.0		36.0–43.0
s.d.		3.4		4.0		2.6
TED PVC sponge (%)	Foam football	38.5	Foam football	62.1	Foam football	83.1
	Plastic round	30.0	Foam cylinder	10.3	Plastic football	13.0
Number of TED floats		n=17,772		n=1514		n=308
Mean		2.5		2.0		2.3
Range		0.0–6.0		1.0–3.0		2.0–4.0
s.d.		0.9		0.4		0.6

Table 8.—Bycatch ratios by area and target species, based on mandatory observer coverage of the U.S. southeatern shrimp fishery from July 2007 through December 2010.

Project	Total (kg)	All bycatch: penaeid shrimp	Fish: penaeid shrimp	All bycatch: rock shrimp	Fish: rock shrimp
Gulf mandatory penaeid	2,159,146.30	2.47	1.97		
South Atlantic mandatory penaeid	136,373.30	4.25	3.17		
South Atlantic mandatory rock	35,791.70			1.41	0.89

Table 9.—Species documented from bycatch characterization samples, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

Common name	Scientific name	Gulf Mandatory Penaeid (kg)	Gulf Mandatory Penaeid (Percent)	South Atlantic Mandatory Penaeid (kg)	South Atlantic Mandatory Penaeid (Percent)	South Atlantic Mandatory Rock (kg)	South Atlantic Mandatory Rock (Percent)	Total	Percent total
Fish (superclass)	Pisces	589,438.9	27.3	16,816.8	12.3	4,456.4	12.5	610,712.1	26.2
Atlantic croaker	*Micropogonias undulatus*	342,602.3	15.9	32,939.2	24.2	241.8	0.7	375,783.4	16.1
Brown shrimp	*Farfantepenaeus aztecus*	304,664.1	14.1	8,603.9	6.3	193.9	0.5	313,461.9	13.4
White shrimp	*Litopenaeus setiferus*	231,501.7	10.7	16,813.0	12.3	2.9	0.0	248,317.6	10.7
Crustacean	Crustacean	149,861.1	6.9	3,636.3	2.7	1,890.0	5.3	155,387.4	6.7
Seatrout (genus)	*Cynoscion* spp.	125,566.0	5.8	5,036.9	3.7			130,602.9	5.6
Invertebrate	Invertebrate	115,359.0	5.3	5,296.8	3.9	1,970.5	5.5	122,626.3	5.3
Longspine porgy	*Stenotomus caprinus*	86,452.8	4.0	0.1	0.0			86,452.9	3.7
Pink shrimp	*Farfantepenaeus duorarum*	85,055.3	3.9	546.6	0.4	164.1	0.5	85,766.0	3.7
Debris (rocks,logs,etc.)	Debris	32,257.8	1.5	1,552.3	1.1	806.2	2.3	34,616.3	1.5
Rock Shrimp (genus)	*Sicyonia* spp.	2,455.1	0.1			14,680.7	41.0	17,135.8	0.7
Spot (flat croaker)	*Leiostomus xanthurus*	972.1	0.0	10,022.1	7.3	394.0	1.1	11,388.2	0.5
Penaeid shrimp discard	*Penaeus* discard	10,664.2	0.5	373.3	0.3			11,037.6	0.5
Pinfish	*Lagodon rhomboides*	10,329.2	0.5					10,329.2	0.4
Jellyfish (family)	Carybdeidae	125.2	0.0	10,008.8	7.3			10,134.0	0.4
Star drum	*Stellifer lanceolatus*	169.1	0.0	7,911.1	5.8			8,080.2	0.3
Dusky flounder	*Syacium papillosum*	3,205.0	0.1			3,799.1	10.6	7,004.1	0.3
Cannonball jellyfish	*Stomolophus meleagris*			5,788.9	4.2			5,788.9	0.2
Red snapper	*Lutjanus campechanus*	5,675.0	0.3	0.0		0.8	0.0	5,675.8	0.2
Lane snapper	*Lutjanus synagris*	4,538.6	0.2					4,538.6	0.2
Silver jenny	*Eucinostomus gula*	4,438.4	0.2					4,438.4	0.2
Spanish mackerel	*Scomberomorus maculatus*	3,851.3	0.2	421.2	0.3	2.3	0.0	4,274.8	0.2
Drum (family)	Sciaenidae	4,168.3	0.2					4,168.3	0.2
Inshore lizardfish	*Synodus foetens*	575.8	0.0			3,364.1	9.4	3,939.9	0.2
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	3,276.2	0.2	581.4	0.4	4.4	0.0	3,862.0	0.2
Red drum	*Sciaenops ocellatus*	3,826.1	0.2					3,826.1	0.2
Sharks grouped	General sharks	3,252.3	0.2	388.3	0.3	7.9	0.0	3,648.5	
Southern flounder	*Paralichthys lethostigma*	3,031.7	0.1	243.2	0.2	21.3	0.1	3,296.3	0.1
Southern kingfish	*Menticirrhus americanus*	1,848.7	0.1	1,059.2	0.8	0.6	0.0	2,908.5	0.1
Gulf butterfish	*Peprilus burti*	2,550.6	0.1					2,550.6	0.1
Mojarra (genus)	*Eucinostomus* spp.	2,415.0	0.1					2,415.0	0.1
Northern kingfish	*Menticirrhus saxatilis*	177.8	0.0	1,888.5	1.4	6.7	0.0	2,073.0	0.1
Gafftopsail catfish	*Bagre marinus*	1,990.7	0.1					1,990.7	0.1
Irridescent swimming crab	*Portunus gibbesii*	8.7	0.0			1,979.2	5.5	1,987.9	0.1
Flounder (family)	Bothidae	1,699.4	0.1			1,699.4			0.1
Bonnethead shark	*Sphyrna tiburo*	1,252.0	0.1	396.5	0.3			1,648.6	0.1
Atlantic cutlassfish	*Trichiurus lepturus*	1,225.5	0.1	248.1	0.2			1,473.6	0.1
Black drum	*Pogonias cromis*	1,402.7	0.1	11.5	0.0			1,414.2	0.1
Blue crab	*Callinectes sapidus*			1,366.7	1.0			1,366.7	0.1
Weakfish	*Cynoscion regalis*			1,170.1	0.9			1,170.1	0.1
Atlantic bumper	*Chloroscombrus chrysurus*	1,062.8	0.0	30.6	0.0			1,093.4	0.0
Sand perch	*Diplectrum formosum*	953.4	0.0					953.4	0.0
Longspine swimming crab	*Portunus spinicarpus*	4.5	0.0			923.8	2.6	928.3	0.0
Vermillion (B-liner) snapper	*Rhomboplites aurorubens*	893.2	0.0					893.2	0.0
Left-eye flounder	*Syacium* spp.	825.0	0.0					825.0	0.0
Atlantic menhaden	*Brevoortia tyrannus*	20.1	0.0	784.2	0.6			804.2	0.0
King mackerel	*Scomberomorus cavalla*	721.6	0.0	36.0	0.0	2.1	0.0	759.7	0.0
Blacktip shark	*Carcharhinus limbatus*	667.0	0.0	49.1	0.0			716.1	0.0
Hardhead catfish	*Arius felis*	630.2	0.0					630.2	0.0
Barbfish	*Scorpaena brasiliensis*	609.7	0.0					609.7	0.0
Smooth dogfish	*Mustelus canis*	591.6	0.0	16.5	0.0			608.2	0.0
Striped anchovy	*Anchoa hepsetus*	540.8	0.0	25.1	0.0			565.9	0.0
Cownose ray	*Rhinoptera bonasus*	500.8	0.0	32.4	0.0			533.3	0.0
Summer flounder	*Paralichthys dentatus*			513.5	0.4	6.2	0.0	519.7	0.0
Pigfish	*Orthopristis chrysoptera*	509.8	0.0					509.8	0.0
Scorpionfish	*Scorpaena* spp.	507.5	0.0					507.5	0.0
Spotfin mojarra	*Eucinostomus argenteus*	465.4	0.0					465.4	0.0
Gulf menhaden	*Brevoortia patronus*	442.8	0.0					442.8	0.0
Silver seatrout	*Cynoscion nothus*	23.3	0.0	388.3	0.3	5.4	0.0	417.0	0.0
Roundel skate	*Raja texana*	411.9	0.0					411.9	0.0
Dwarf sand perch	*Diplectrum bivittatum*	362.7	0.0					362.7	0.0
Bluefish	*Pomatomus saltatrix*	56.3	0.0	227.0	0.2	33.9	0.1	317.2	0.0
Rock seabass	*Centropristis philadelphica*	55.3	0.0	1.7	0.0	230.2	0.6	287.3	0.0
Wenchman	*Pristipomoides aquilonaris*	270.5	0.0					270.5	0.0
Herring (genus)	*Alosa* spp.			258.5	0.2			258.5	0.0

Continued

Table 9.—Continued.

Common name	Scientific name	Gulf Mandatory Penaeid (kg)	Gulf Mandatory Penaeid (Percent)	South Atlantic Mandatory Penaeid (kg)	South Atlantic Mandatory Penaeid (Percent)	South Atlantic Mandatory Rock (kg)	South Atlantic Mandatory Rock (Percent)	Total	Percent total
Spotted seatrout	*Cynoscion nebulosus*	235.0	0.0	2.6	0.0			237.6	0.0
Seabass (genus)	*Diplectrum*	232.9	0.0					232.9	0.0
Tomtate	*Haemulon aurolineatum*	229.4	0.0					229.4	0.0
Orange filefish	*Aluterus schoepfi*	227.7	0.0					227.7	0.0
Spinner shark	*Carcharhinus brevipinna*	223.2	0.0					223.2	0.0
Spinycheek scorpionfish	*Neomerinthe hemingwayi*	222.5	0.0					222.5	0.0
Crab (genus)	*Callinectes*	46.8	0.0	172.7	0.1			219.5	0.0
Clearnose skate	*Raja eglanteria*	35.7	0.0	50.8	0.0	128.5	0.4	215.1	0.0
Sheepshead	*Archosargus probatocephalus*	210.3	0.0					210.3	0.0
Rock shrimp discards	*Sicyonia* discards	30.7	0.0			177.2	0.5	207.9	0.0
Scalloped hammerhead	*Sphyrna lewini*	127.4	0.0	80.2	0.1			207.5	0.0
Cobia	*Rachycentron canadum*	192.9	0.0	5.4	0.0			198.3	0.0
Twospot flounder	*Bothus robinsi*	196.2	0.0					196.2	0.0
Leopard searobin	*Prionotus scitulus*	191.6	0.0					191.6	0.0
Blacknose shark	*Carcharhinus acronotus*	174.0	0.0					174.0	0.0
Bluespotted searobin	*Prionotus roseus*	172.0	0.0					172.0	0.0
Sculptured mud crab	*Micropanope sculptipes*	171.0	0.0					171.0	0.0
Penaeid shrimp (brown,white, pink)	*Penaeus* spp.	170.6	0.0					170.6	0.0
Smooth butterfly ray	*Gymnura micrura*	45.1	0.0	115.3	0.1			160.5	0.0
Banded drum	*Larimus fasciatus*	99.4	0.0	59.6	0.0			158.9	0.0
Gulf kingfish	*Menticirrhus littoralis*	155.5	0.0					155.5	0.0
Bank sea bass	*Centropristis ocyurus*	7.2	0.0	40.1	0.0	100.0	0.3	147.3	0.0
Red goatfish	*Mullus auratus*	144.6	0.0					144.6	0.0
Paper scallop	*Amusium papyraceum*	126.7	0.0					126.7	0.0
Snapper (genus)	*Lutjanus* spp.	120.0	0.0					120.0	0.0
Bigeye (blackfin) searobin	*Prionotus longispinosus*	107.3	0.0					107.3	0.0
Flounder (genus)	*Bothus* spp.					106.0	0.3	106.0	0.0
Sash flounder	*Trichopsetta ventralis*	104.8	0.0					104.8	0.0
Polyps and Medusae (phylum)	Cnidaria	101.3	0.0					101.3	0.0
Blackbelly rosefish	*Helicolenus dactylopterus*	101.0	0.0					101.0	0.0
Black seabass	*Centropristis striata*			5.3	0.0	91.6	0.3	96.8	0.0
Grass porgy	*Calamus arctifrons*	94.6	0.0					94.6	0.0
Lizardfish (family)	Synodontidae	94.2	0.0					94.2	0.0
Herrings (family)	Clupeidae			90.3	0.1			90.3	0.0
Fringed flounder	*Etropus crossotus*	86.8	0.0					86.8	0.0
Common crevalle jack	*Caranx hippos*	82.4	0.0					82.4	0.0
Lesser electric ray	*Narcine brasiliensis*	75.0	0.0					75.0	0.0
Atlantic stingray	*Dasyatis sabina*	46.1	0.0	27.0	0.0			73.1	0.0
Southern stingray	*Dasyatis americana*	70.1	0.0					70.1	0.0
Spotted eagle ray	*Aetobatis narinari*	67.6	0.0					67.6	0.0
Dwarf goatfish	*Upeneus parvus*	67.3	0.0					67.3	0.0
Scrawled cowfish	*Lactophrys quadricornis*	66.4	0.0					66.4	0.0
Bank cusk-eel	*Ophidion holbrooki*	66.3	0.0					66.3	0.0
Harvestfish	*Peprilus alepidotus*	58.2	0.0	5.0	0.0			63.2	0.0
Atlantic angel shark	*Squatina dumeril*	60.2	0.0					60.2	0.0
Threadfin shad	*Dorosoma petenense*	0.4	0.0	58.3	0.0			58.6	0.0
Atlantic thread herring	*Opisthonema oglinum*			54.8	0.0			54.8	0.0
Planehead filefish	*Stephanolepis hispidus*	52.8	0.0					52.8	0.0
Florida smoothhound	*Mustelus norrisi*	52.7	0.0					52.7	0.0
Snakefish	*Trachinocephalus myops*	52.6	0.0					52.6	0.0
King snake eel	*Ophichthus rex*	49.1	0.0					49.1	0.0
Palmate (genus) sponge	*Isodictya* spp.	42.8	0.0					42.8	0.0
Butterfly ray	*Gymnura* spp.	7.8	0.0	34.3	0.0			42.1	0.0
Stingray (genus)	*Dasyatis* spp.	19.7	0.0	21.8	0.0			41.5	0.0
Brown rock shrimp	*Sicyonia brevirostris*	38.5	0.0					38.5	0.0
Smoothhead scorpionfish	*Scorpaena calcarata*	34.0	0.0					34.0	0.0
Seabob	*Xiphopenaeus kroyeri*	31.9	0.0					31.9	0.0
Spotted hake	*Urophycis regia*	31.2	0.0					31.2	0.0
Florida pompano	*Trachinotus carolinus*	3.5	0.0	27.2	0.0			30.6	0.0
Bull shark	*Carcharhinus leucas*	30.5	0.0					30.5	0.0
Spanish sardine	*Sardinella aurita*	29.9	0.0					29.9	0.0
Bighead searobin	*Prionotus tribulus*	28.7	0.0					28.7	0.0
Triggerfish/Filefish (family)	Balistidae	28.3	0.0					28.3	0.0
Lefteye flounder (genus)	*Paralichthys* spp.	28.1	0.0					28.1	0.0

Continued

Table 9.—Continued.

Common name	Scientific name	Gulf Mandatory Penaeid (kg)	Gulf Mandatory Penaeid (Percent)	South Atlantic Mandatory Penaeid (kg)	South Atlantic Mandatory Penaeid (Percent)	South Atlantic Mandatory Rock (kg)	South Atlantic Mandatory Rock (Percent)	Total	Percent total
Offshore lizardfish	*Synodus poeyi*	27.4	0.0					27.4	0.0
Longnose gar	*Lepisosteus osseus*	23.7	0.0					23.7	0.0
Lemon shark	*Negaprion brevirostris*	23.3	0.0					23.3	0.0
Atlantic guitarfish	*Rhinobatos lentiginosus*	23.2	0.0					23.2	0.0
Horseshoe crab	*Limulus polyphemus*	7.4	0.0	14.6	0.0			22.0	0.0
Tripletail	*Lobotes surinamensis*	21.2	0.0					21.2	0.0
Mexican flounder	*Cyclopsetta chittendeni*	20.9	0.0					20.9	0.0
Caribbean spiny lobster	*Panulirus argus*	20.3	0.0					20.3	0.0
Inverts & nonpenaeid crustaceans	Unavailable	19.3	0.0					19.3	0.0
Sharksucker	*Echeneis naucrates*	17.4	0.0					17.4	0.0
Chub mackerel	*Scomber japonicus*	12.7	0.0					12.7	0.0
Bandtail pufferfish	*Sphoeroides spengleri*	12.3	0.0					12.3	0.0
Bullnose ray	*Myliobatis freminvillei*	11.0	0.0					11.0	0.0
Stingray (family)	*Dasyatidae*			10.7	0.0			10.7	0.0
Conger eel (family)	*Congridae*	10.7	0.0					10.7	0.0
Unicorn filefish	*Aluterus monoceros*	10.5	0.0					10.5	0.0
Skate (family)	Rajidae	10.3	0.0					10.3	0.0
Bluntnose stingray	*Dasyatis say*	10.1	0.0					10.1	0.0
Yellow conger	*Hildebrandia flava*	9.9	0.0					9.9	0.0
Atlantic midshipman	*Porichthys plectrodon*	9.4	0.0					9.4	0.0
Finetooth shark	*Carcharhinus isodon*	9.0	0.0					9.0	0.0
Atlantic spadefish	*Chaetodipterus faber*	6.5	0.0	2.3	0.0			8.9	0.0
Knobbed porgy	*Calamus nodosus*	8.6	0.0					8.6	0.0
Mutton snapper	*Lutjanus analis*	7.8	0.0					7.8	0.0
Eggcockle	*Laevicardium laevigatum*	7.6	0.0					7.6	0.0
Blackedge cusk-eel	*Lepophidium brevibarbe*	7.2	0.0					7.2	0.0
Fringed filefish	*Monacanthus ciliatus*	7.0	0.0					7.0	0.0
Hogchoker	*Trinectes maculatus*	6.4	0.0					6.4	0.0
Alligator gar	*Atractosteus spatula*	6.4	0.0					6.4	0.0
Honeycomb cowfish	*Lactophrys polygonia*	6.2	0.0					6.2	0.0
Filefish (genus)	*Monacanthus* spp.	6.1	0.0					6.1	0.0
White elbow crab	*Leiolambrus nitidus*			6.1	0.0			6.1	0.0
Spotfin flounder	*Cyclopsetta fimbriata*	6.0	0.0					6.0	0.0
Ocellated flounder	*Ancylopsetta quadrocellata*	4.8	0.0					4.8	0.0
Searobin (family)	Triglidae	4.8	0.0					4.8	0.0
Gulf flounder	*Paralichthys albigutta*	4.4	0.0					4.4	0.0
Common sundial	*Architectonica nobilias*	3.9	0.0					3.9	0.0
Guaguanche	*Sphyraena guachancho*	3.3	0.0					3.3	0.0
Sand tiger shark	*Carcharias taurus*	3.2	0.0					3.2	0.0
Red porgy	*Pagrus pagrus*	2.7	0.0					2.7	0.0
Southern hake	*Urophycis floridana*	2.6	0.0					2.6	0.0
Bigeye	*Priacanthus arenatus*	2.3	0.0					2.3	0.0
Birds	Aves	2.2	0.0					2.2	0.0
Scup	*Stenotomus chrysops*			2.0	0.0			2.0	0.0
Whitebone porgy	*Calamus leucosteus*	1.9	0.0					1.9	0.0
Polka-dot batfish	*Ogcocephalus cubifrons*	1.8	0.0					1.8	0.0
Scrawled filefish	*Aluterus scriptus*	1.7	0.0					1.7	0.0
Silky shark	*Carcharhinus falciformis*	1.6	0.0					1.6	0.0
Atlantic moonfish	*Selene setapinnis*			1.6	0.0			1.6	0.0
Blackedge moray	*Gymnothorax nigromarginatus*	1.5	0.0					1.5	0.0
Silver perch	*Bairdiella chrysoura*			1.4	0.0			1.4	0.0
Red grouper	*Epinephelus morio*	1.1	0.0					1.1	0.0
Porgy (genus)	*Calamus*	0.7	0.0					0.7	0.0
Gray snapper	*Lutjanus griseus*	0.7	0.0					0.7	0.0
Mackerel (family)	Scombridae	0.7	0.0					0.7	0.0
Southern stargazer	*Astroscopus y-graecum*	0.7	0.0					0.7	0.0
Moray (genus)	*Gymnothorax* spp.	0.7	0.0					0.7	0.0
Red lionfish	*Pterois volitans*	0.5	0.0					0.5	0.0
Cubbyu	*Pareques umbrosus*	0.4	0.0					0.4	0.0
Atlantic flyingfish	*Cypselurus melanurus*	0.4	0.0					0.4	0.0
Jackknife-fish	*Equetus lanceolatus*	0.2	0.0					0.2	0.0
Shrimp flounder	*Gastropsetta frontalis*	0.2	0.0					0.2	0.0
White grunt	*Haemulon plumieri*	0.2	0.0					0.2	0.0
Yellowtail snapper	*Ocyurus chrysurus*	0.1	0.0					0.1	0.0

Continued

Table 9.—Continued.

Common name	Scientific name	Gulf Mandatory Penaeid (kg)	Gulf Mandatory Penaeid (Percent)	South Atlantic Mandatory Penaeid (kg)	South Atlantic Mandatory Penaeid (Percent)	South Atlantic Mandatory Rock (kg)	South Atlantic Mandatory Rock (Percent)	Total	Percent total
Yellowedge grouper	*Epinephelus flavolimbatus*	0.1	0.0					0.1	0.0
Snowy grouper	*Epinephelus niveatus*	0.1	0.0					0.1	0.0
Ocellated frogfish	*Antennarius ocellatus*	0.1	0.0					0.1	0.0
Bay whiff	*Citharichthys spilopterus*	0.1	0.0					0.1	0.0
Inland silverside	*Menidia beryllina*	0.1	0.0					0.1	0.0
Balloonfish	*Diodon holocanthus*	0.1	0.0					0.1	0.0
Total		2,159,146.4	100.0	136,373.3	100.0	35,791.7	100.0	2,331,311.4	100.0

penaeid; seabob, *Xiphopenaeus kroyeri;* sugar shrimp, *Trachypenaeus* spp.; and rock shrimp). Scott-Denton (2007), for the same region, reported finfish species at 65% (20.1 kg/h) and penaeid shrimp at 16% (5.0 kg/h). In this study, finfish species dominated the catch at 57% (19.5 kg/h), followed by penaeid shrimp at 29% (9.9 kg/h).

Based on Gulf of Mexico shrimp landings and effort data from 1992 through 2010 (Nance[21]), an increasing trend in CPUE (> 40 lb/h; 18.1 kg/h) has been observed since 2004, with the highest CPUE occurring in 2009 (> 85 lb/h; 38.6 kg/h). Moreover, the number of Federally permitted vessels (SERO[14]) and effort (Gallaway et al., 2003; Nance et. al, 2008) in the fishery has shown a steady decline since the mid 2000's.

Lastly, Helies and Jamison[11] suggest the lower finfish to shrimp ratios in the Gulf of Mexico may be attributed to basic weight differences between shrimp and fish taken currently in the fishery as compared with earlier years. The authors reported that nearshore sciaenids (notably Atlantic croaker) are exhibiting pronounced increases in abundance after 2002, with these increases corresponding to decreases in shrimp fishing effort, and to more effective exclusion by new BRD designs in recent years.

In the South Atlantic, NMFS[3] calculated percent catch composition for finfish species at 51%, and 18% for commercial shrimp species. Scott-Denton (2007) reported finfish species at 47% (13.0 kg/h), followed by penaeid shrimp at 24% (6.6 kg/h). In the 2007 through 2010 mandatory observer program, finfish accounted for 60% (31.2 kg/h) of the catch with penaeid shrimp at 19% (9.9 kg/h), which reveals an increase in shrimp CPUE and over a two-fold increase in finfish CPUE. In the South Atlantic rock shrimp fishery, an increase was also observed in percent composition of rock shrimp at 41% (29.0 kg/h) as compared with the 2001 to 2006 period with rock shrimp comprising 19% (8.7 kg/h) of the catch (SAFMC[22]).

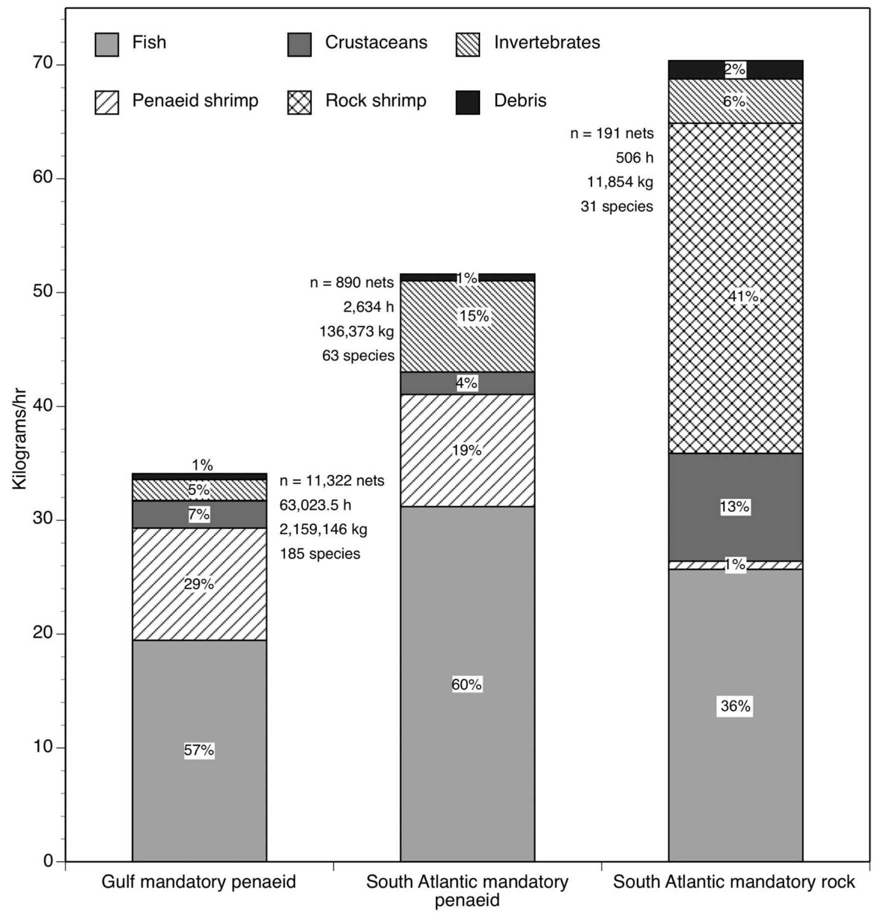

Figure 4.—Major species categories grouped by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

[21]Nance, J. 2012. Unpubl. data on file at National Marine Fisheries Service, NOAA, Galveston Laboratory, Galveston, TX 77551.

[22]SAFMC. 2008. Observer coverage of the US southeastern atlantic rock shrimp fishery, September 2001 through September 2006 Preliminary report. South Atl. Fish. Manage. Counc., Charleston, S.C., (avail. at http://www.safmc.net).

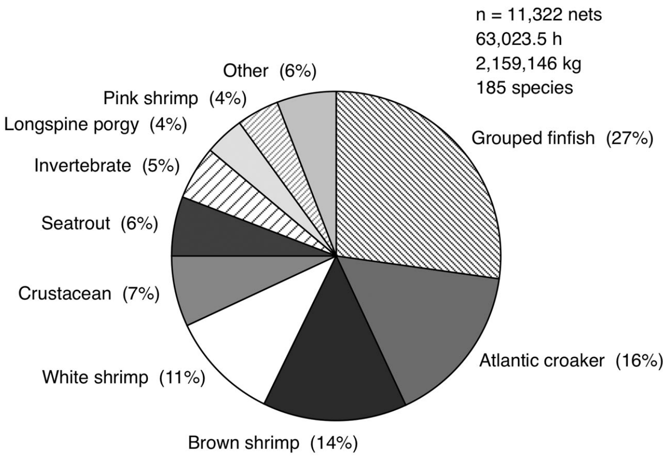

Figure 5.—Species-level characterization in the Gulf of Mexico penaeid shrimp fishery, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

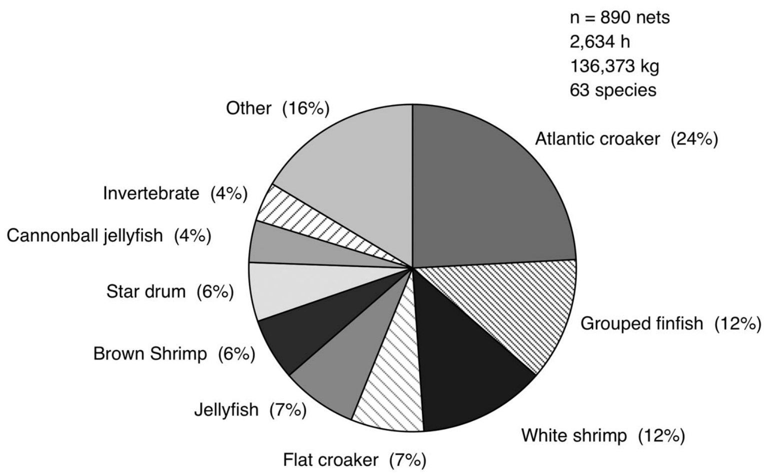

Figure 6.—Species-level characterization in the South Atlantic penaeid shrimp fishery, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

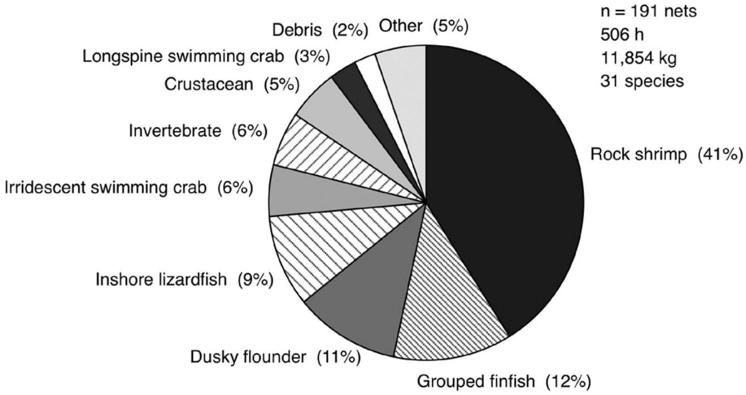

Figure 7.—Species-level characterization in the South Atlantic rock shrimp fishery, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

From 1992 through 2005, longspine porgy and Atlantic croaker comprised the largest percentage of the overall catch in the Gulf of Mexico with estimated CPUE (kg/h) at 2.8 and 2.1, respectively (Scott-Denton, 2007). In the current mandatory study, Atlantic croaker CPUE (kg/h) was 5.4 and 1.4 for longspine porgy. This shift in dominant species and rates may be attributed to the mandatory nature of vessel selection and areas fished (nearshore vs. offshore). In the 1992 to 2005 voluntary study, a large number of vessel operators who participated fished primarily in offshore waters (Scott-Denton, 2007). Similarly, with respect to the dominant species in South Atlantic during the 1992 to 2005 period, CPUE (kg/h) for Atlantic croaker was 3.6 and 3.4 for flat croaker (Scott-Denton, 2007). In this study, CPUE (kg/h) was substantially higher for Atlantic croaker at 12.5 and comparable for flat croaker at 3.8.

Several species listed as overfished or undergoing overfishing did not comprise a large percentage by weight of the total bycatch; however, the number of individuals discarded combined with the amount of annual shrimp effort exerted may be reason for considerable concern. Nichols et al.[1, 23] and Nichols and Pellegrin[24], using data from three observer programs and Federal and state resource surveys, provided annual estimates for selected species of finfish bycatch in the Gulf of Mexico commercial shrimp trawl fishery. The authors concluded that while the magnitude of species common in shrimp trawl bycatch was not unexpected, the projected estimate for the less frequently encountered species such as red snapper, king mackerel, and Spanish mackerel was similar to, or exceeded, the recreational harvest (Nichols et al.[1]). Red snapper, considered one of the most high profile species

[23]Nichols, S., A. Shah, G. J. Pellegrin, and K. Mullin. 1990. Updated estimates of shrimp fleet bycatch in the offshore waters of the U.S. Gulf of Mexico. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Pascagoula, Miss., 22 p.

[24]Nichols, S., and G. J. Pellegrin, Jr. 1992. Revision and update of estimates of shrimp fleet bycatch 1972–1991. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Pascagoula, Miss., 17 p.

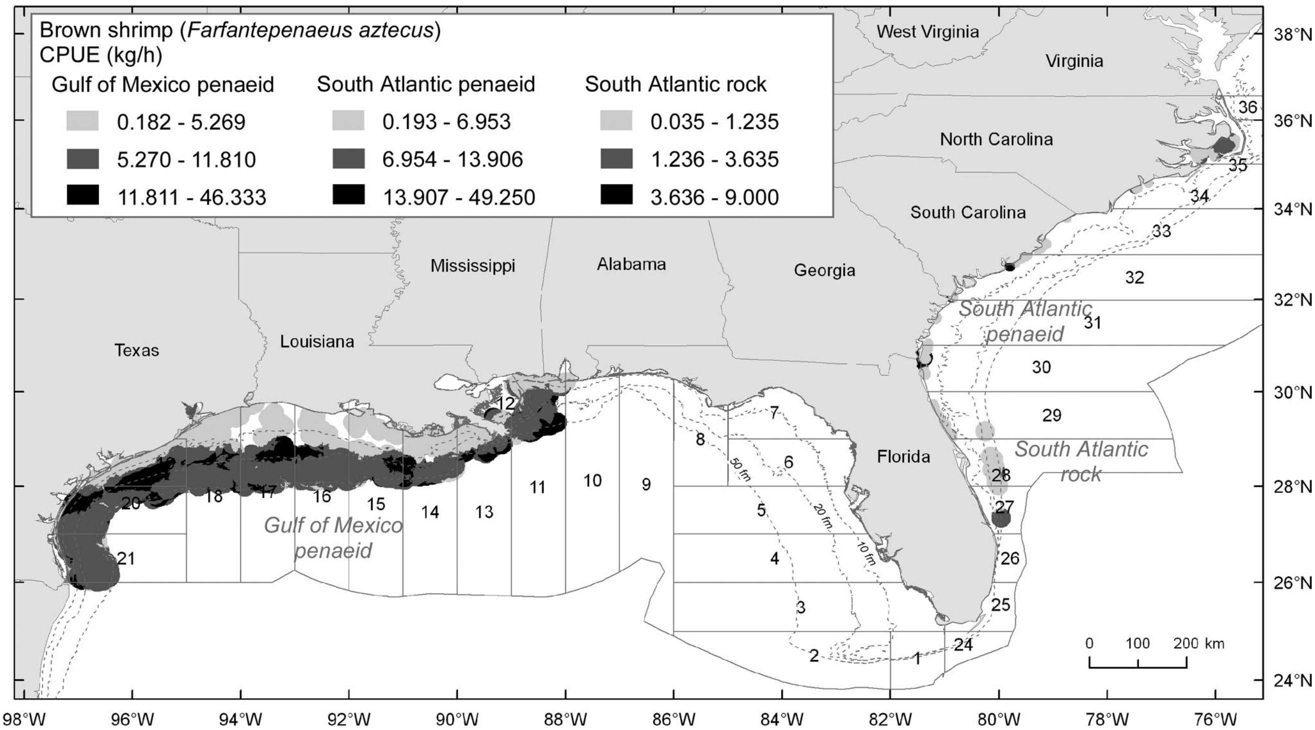

Figure 8.—CPUE density surface for brown shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

of concern, accounted for approximately 0.3% of the total catch by weight in the Gulf of Mexico in the 1992 through 2005 study (Scott-Denton, 2007). This estimate remained the same (0.3%) in this study. This is similar to findings by Helies and Jamison[11], who reported that while there have been increasing trends in the abundance of Atlantic croaker and inshore lizardfish in recent years, abundance levels for longspine porgy and juvenile red snapper have remained relatively stable.

Alverson and Hughes (1996) reported that bycatch became a major management issue resulting from the rapid growth in world fisheries, increasing competition, and the rise of environmental concerns and subsequent global efforts to limit the effects of commercial fishing operations on protected species.

Concerns initially surfaced in the southeastern United States over the incidental capture of endangered or threatened sea turtles. Using data from three shrimp trawl observer programs in the southeastern U.S. (with nets not equipped with TED's) sea turtle catch rates were estimated to be more than 10,000 sea turtles from 1973 to 1984 (Henwood and Stunz, 1987). Magnuson et al. (1990) concluded that sea turtle mortality resulting from trawling operations in the southeastern shrimp fishery was the major source of man-

Table 10.—Selected Gulf of Mexico penaeid shrimp fishery species recorded from all nets from bycatch characterization samples, based on mandatory observer coverage from July 2007 through December 2010.

Scientific name	Common name	Extrapolated weight (kg)	Kg/h	CV
Pisces	Fish (superclass)	637,493.9	10.1	<0.1
Farfantepenaeus aztecus	Brown shrimp	304,764.5	4.8	<0.1
Crustacean	Crustacean	152,676.0	2.4	<0.1
Micropogonias undulatus	Atlantic croaker	342,602.4	5.4	<0.1
Cynoscion spp.	Seatrout (genus)	125,589.3	2.0	<0.1
Litopenaeus setiferus	White shrimp	231,501.7	3.7	<0.1
Invertebrate	Invertebrate	115,778.2	1.8	<0.1
Stenotomus caprinus	Longspine porgy	86,452.8	1.4	<0.1
Farfantepenaeus duorarum	Pink shrimp	85,055.4	1.3	<0.1
Lutjanus campechanus	Red snapper	5,574.6	0.1	<0.1
Debris	Debris (rocks,logs,etc.)	32,257.8	0.5	<0.1
Penaeus discard	Penaeid shrimp discard (brown,white, pink)	10,664.2	0.2	<0.1
General sharks	Sharks grouped	9,741.1	0.2	<0.1
Lutjanus synagris	Lane snapper	4,538.6	0.1	<0.1
Scomberomorus maculatus	Spanish mackerel	3,851.3	0.1	0.1
Rhomboplites aurorubens	Vermilion snapper	893.2	0.0	0.1
Sciaenops ocellatus	Red drum	3,826.1	0.1	0.1
Scomberomorus cavalla	King mackerel	721.6	0.0	0.1
Paralichthys lethostigma	Southern flounder	3,031.7	0.0	0.1
Pogonias cromis	Black drum	1,402.7	0.0	0.1
Cynoscion nebulosus	Spotted seatrout	235.0	0.0	0.2
Rachycentron canadum	Cobia	192.9	0.0	0.2
Penaeus spp.	Penaeid shrimp (brown,white, pink)	170.6	0.0	0.5
Lutjanus spp.	Snapper (genus)	128.5	0.0	0.7

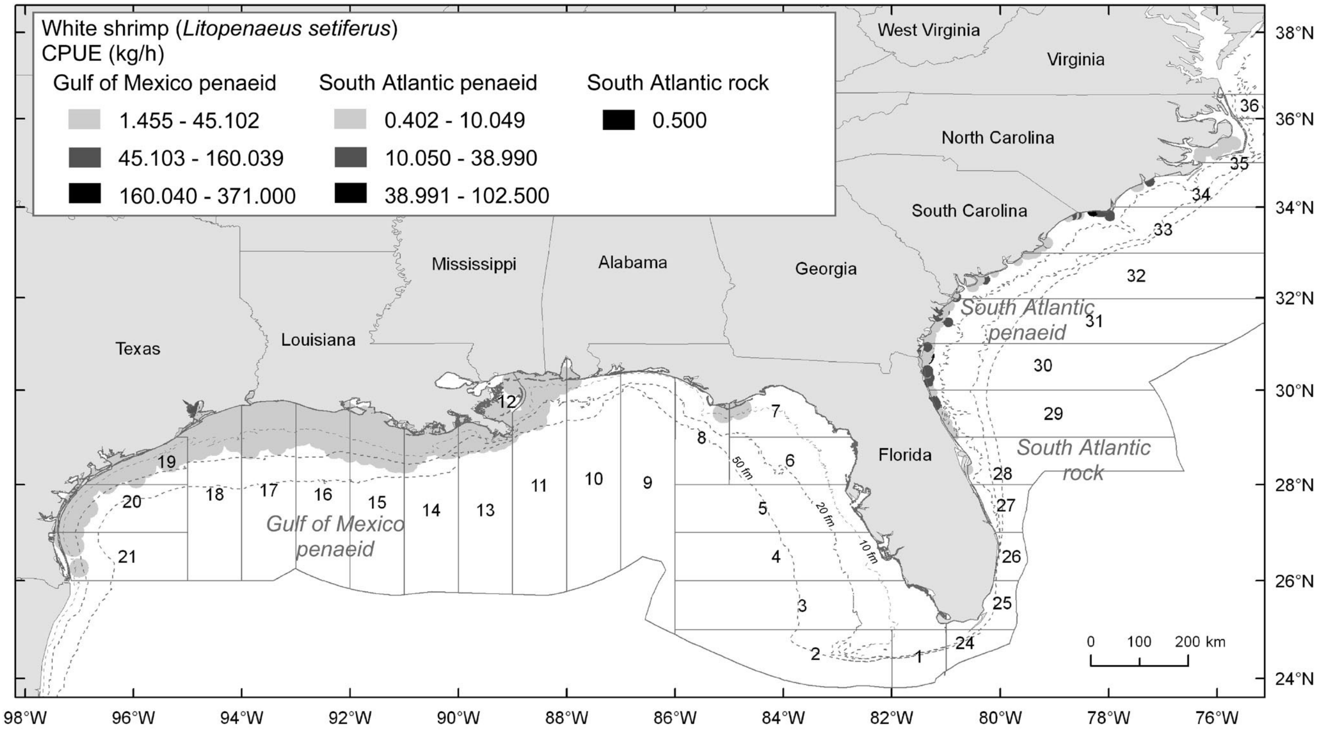

Figure 9.—CPUE density surface for white shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

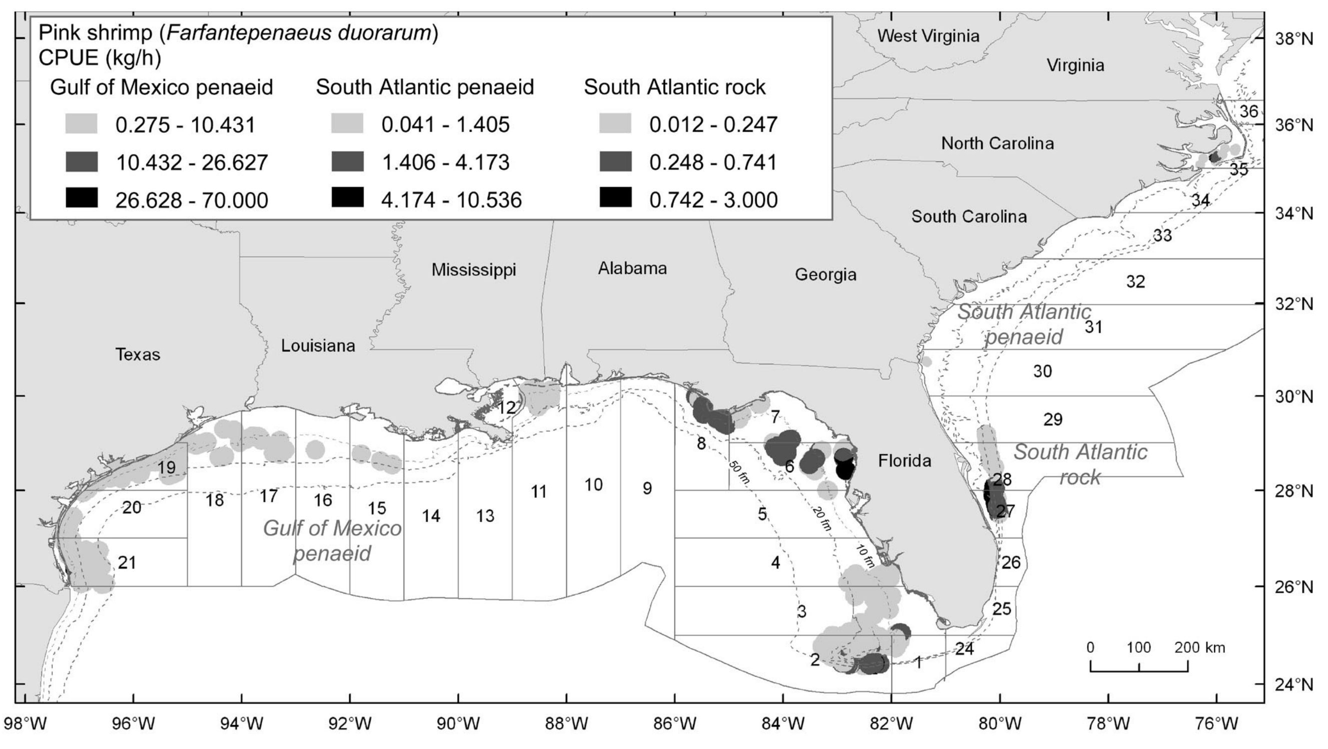

Figure 10.—CPUE density surface for pink shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

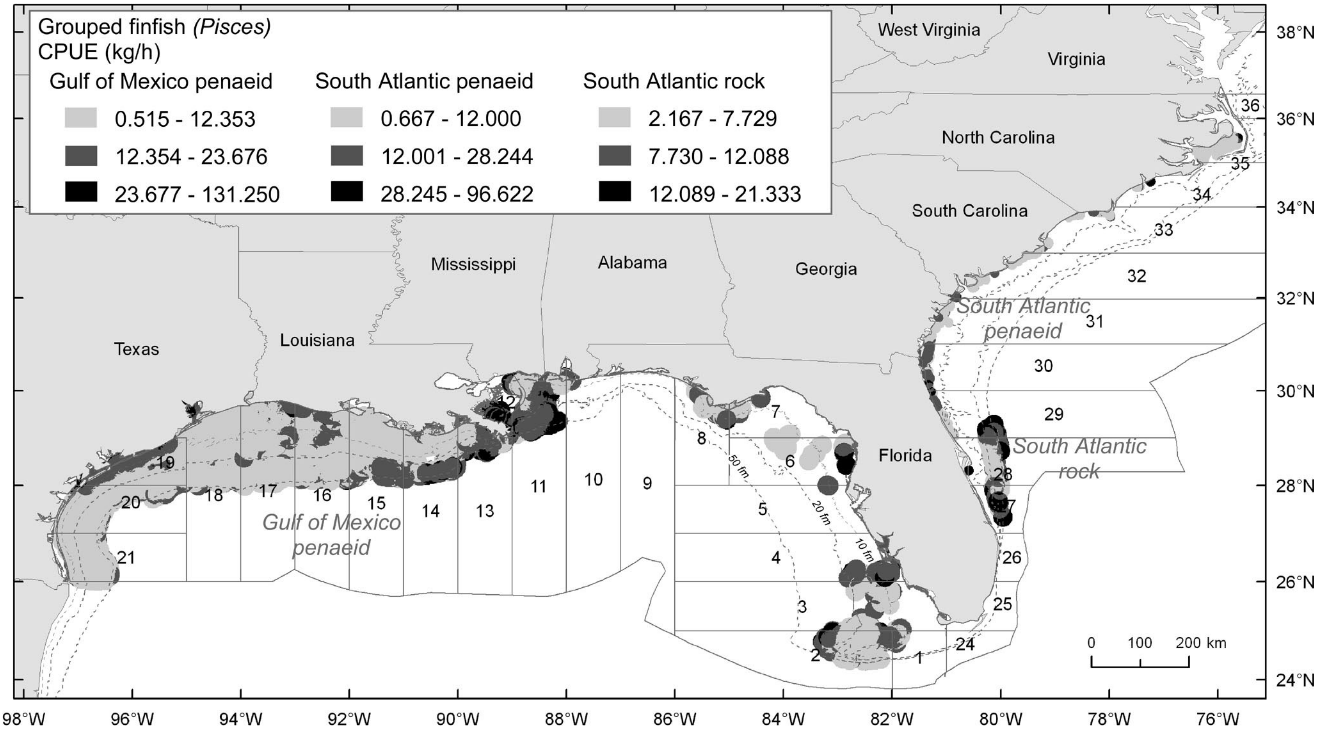

Figure 11.—CPUE density surface for grouped finfish by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

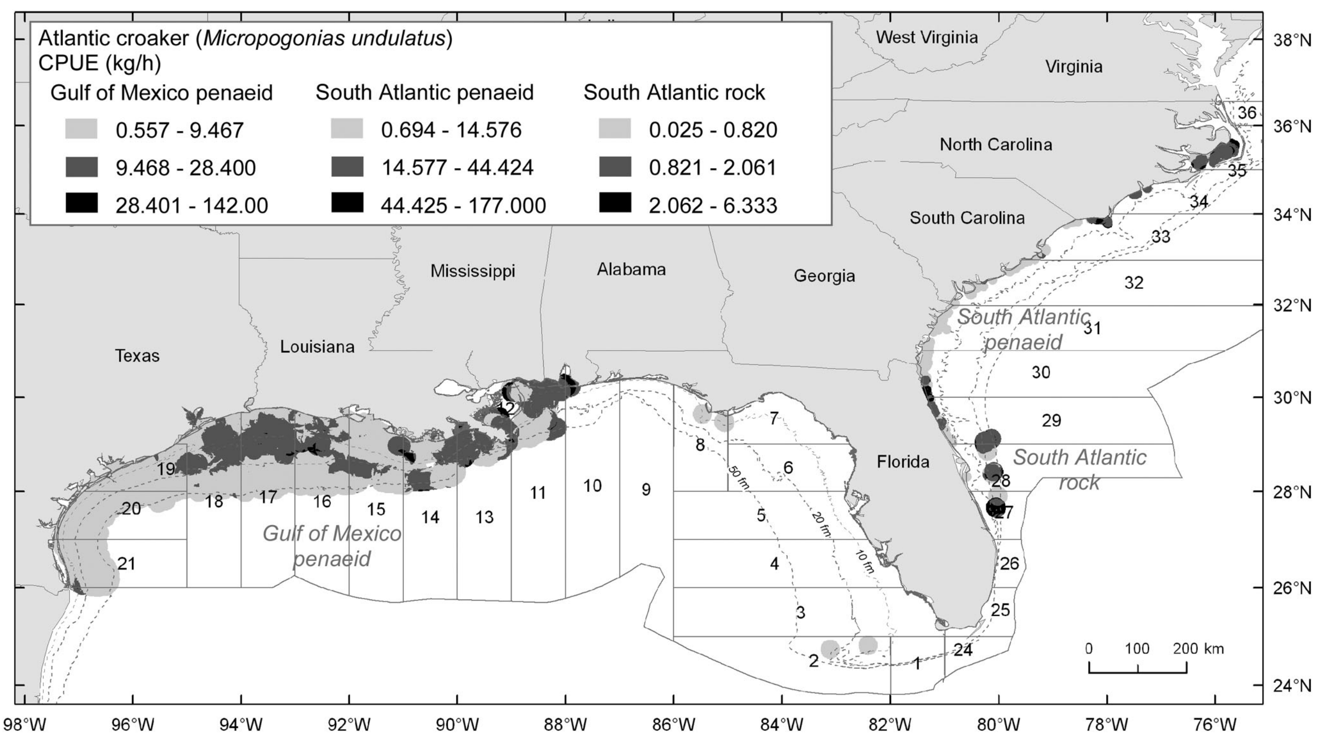

Figure 12.—CPUE density surface for Atlantic croaker by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

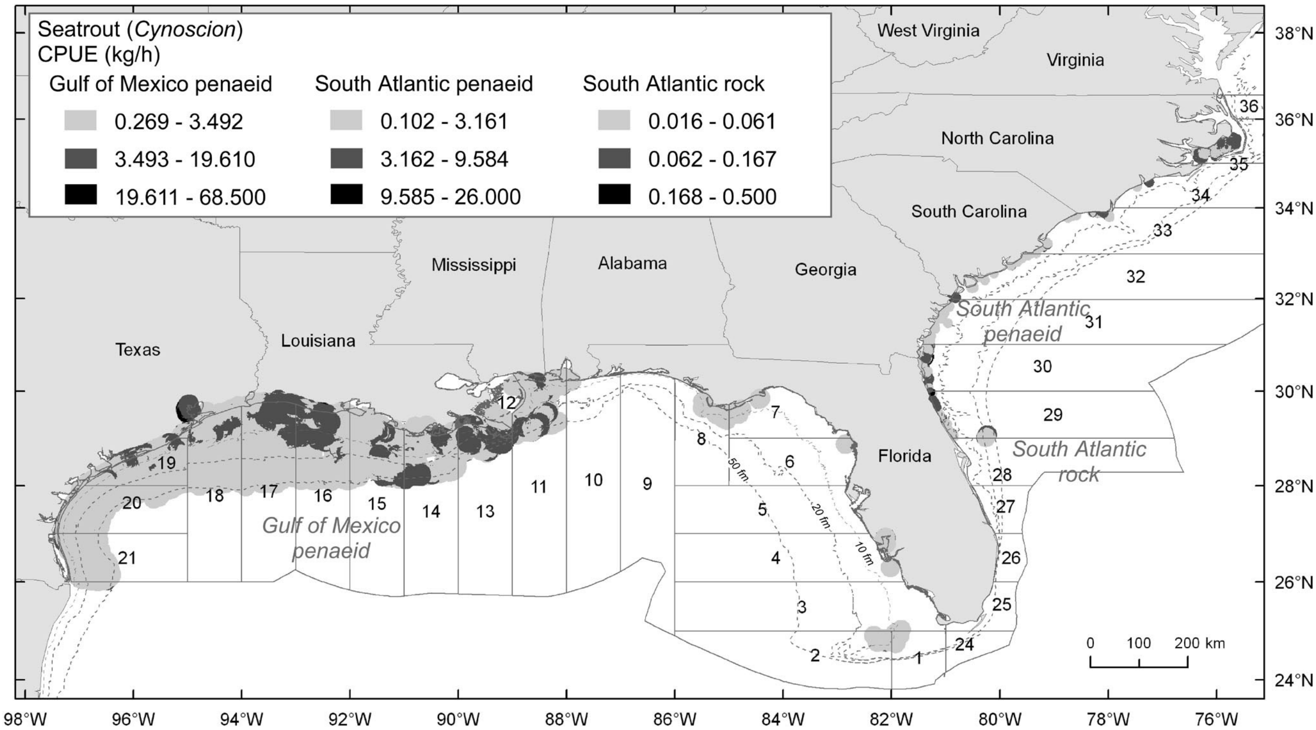

Figure 13.—CPUE density surface for seatrout by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

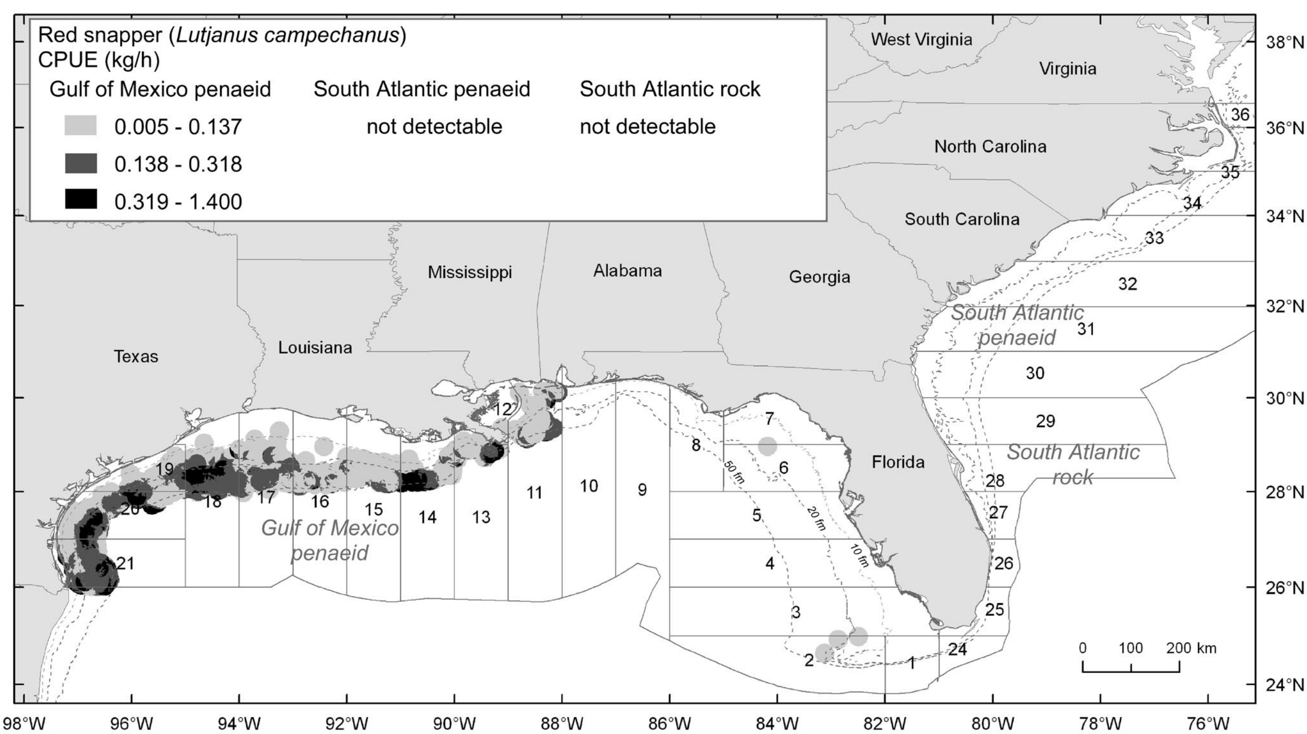

Figure 14.— CPUE density surface for red snapper by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

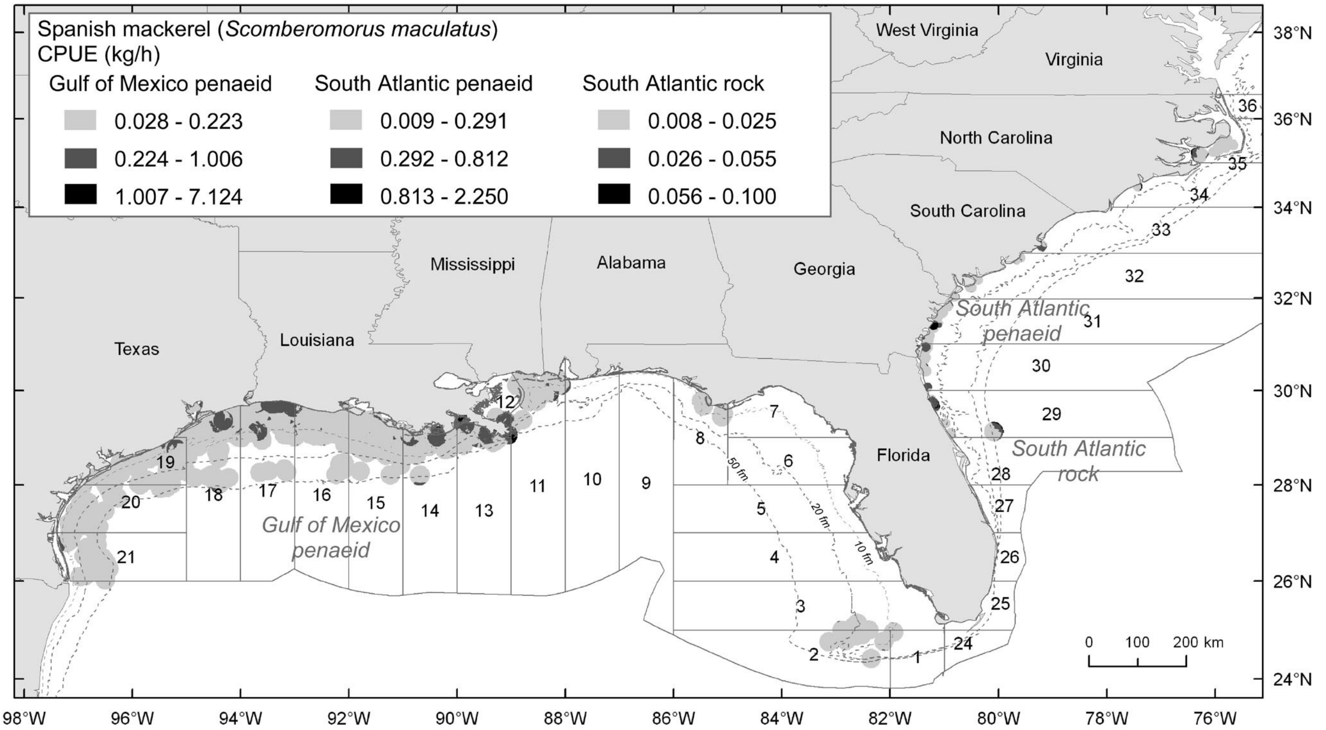

Figure 15.—CPUE density surface for Spanish mackerel by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

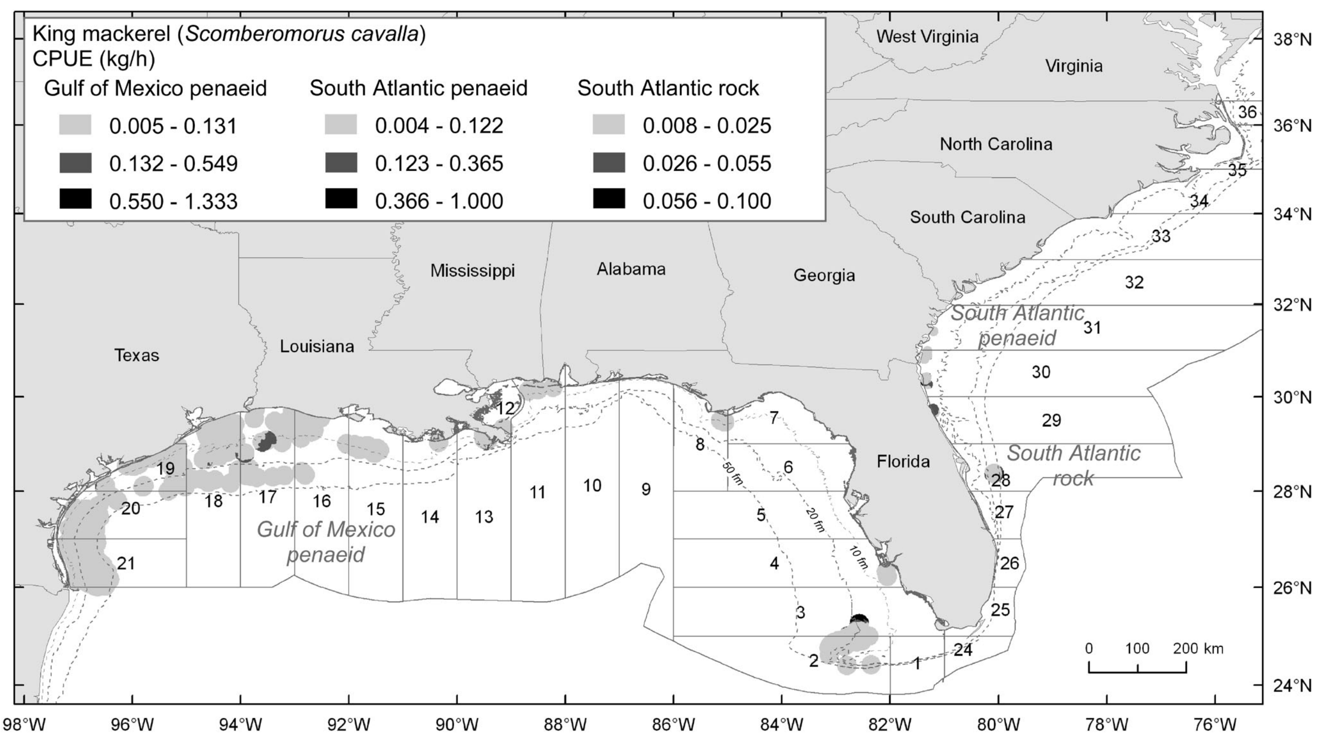

Figure 16.—CPUE density surface for king mackerel by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

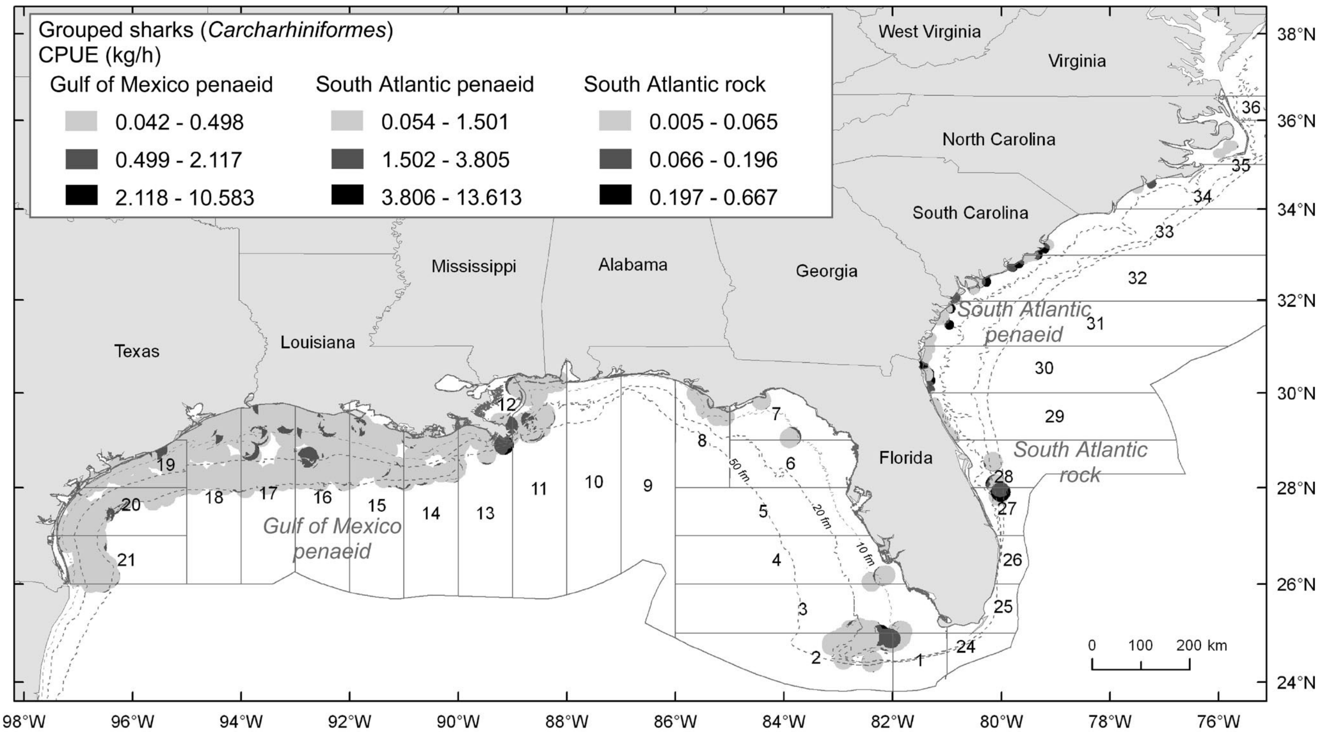

Figure 17.—CPUE density surface for grouped sharks by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

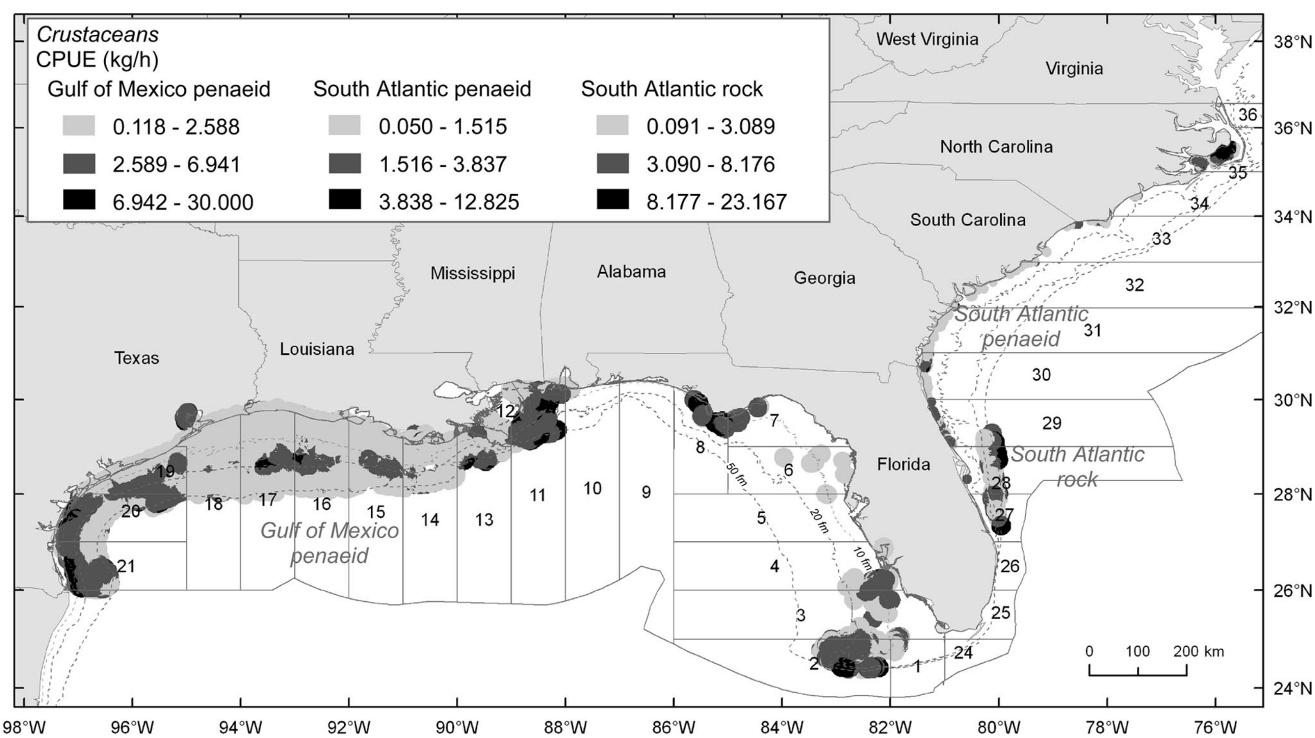

Figure 18.—CPUE density surface for crustaceans by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

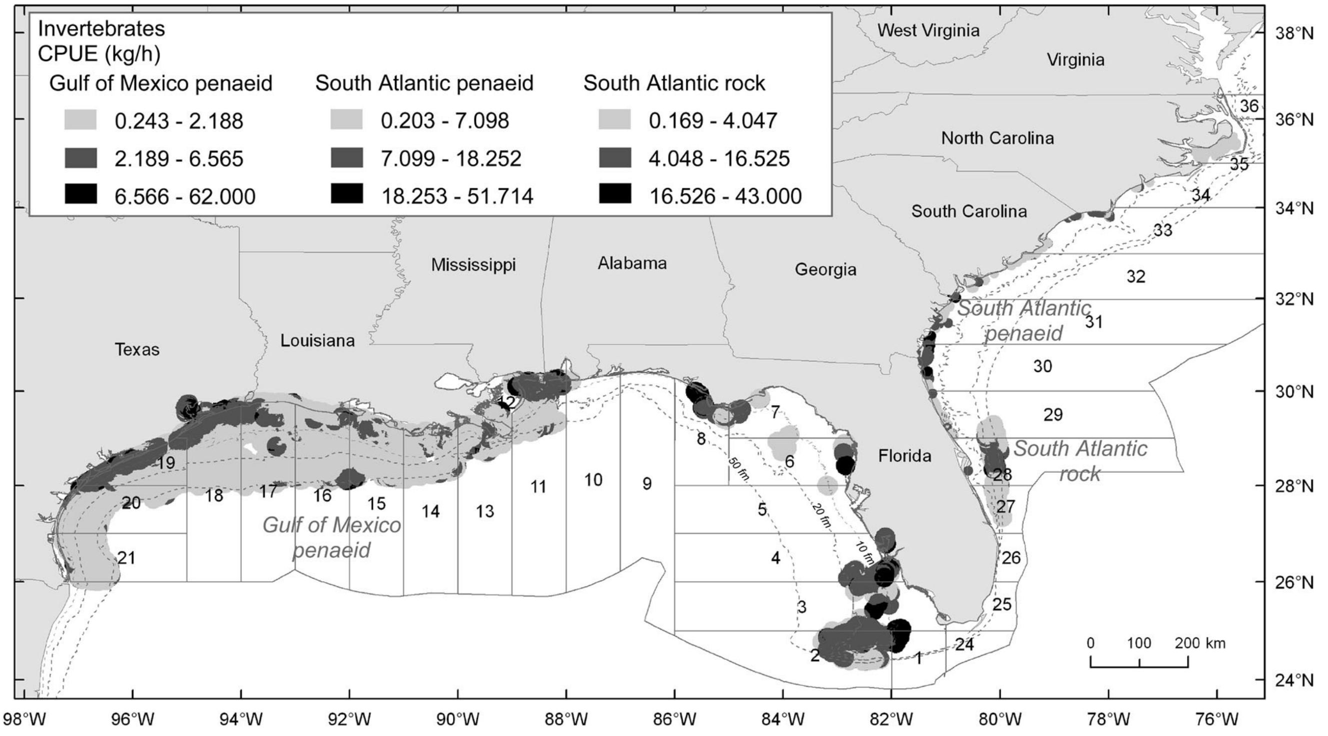

Figure 19.—CPUE density surface for invertebrates by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

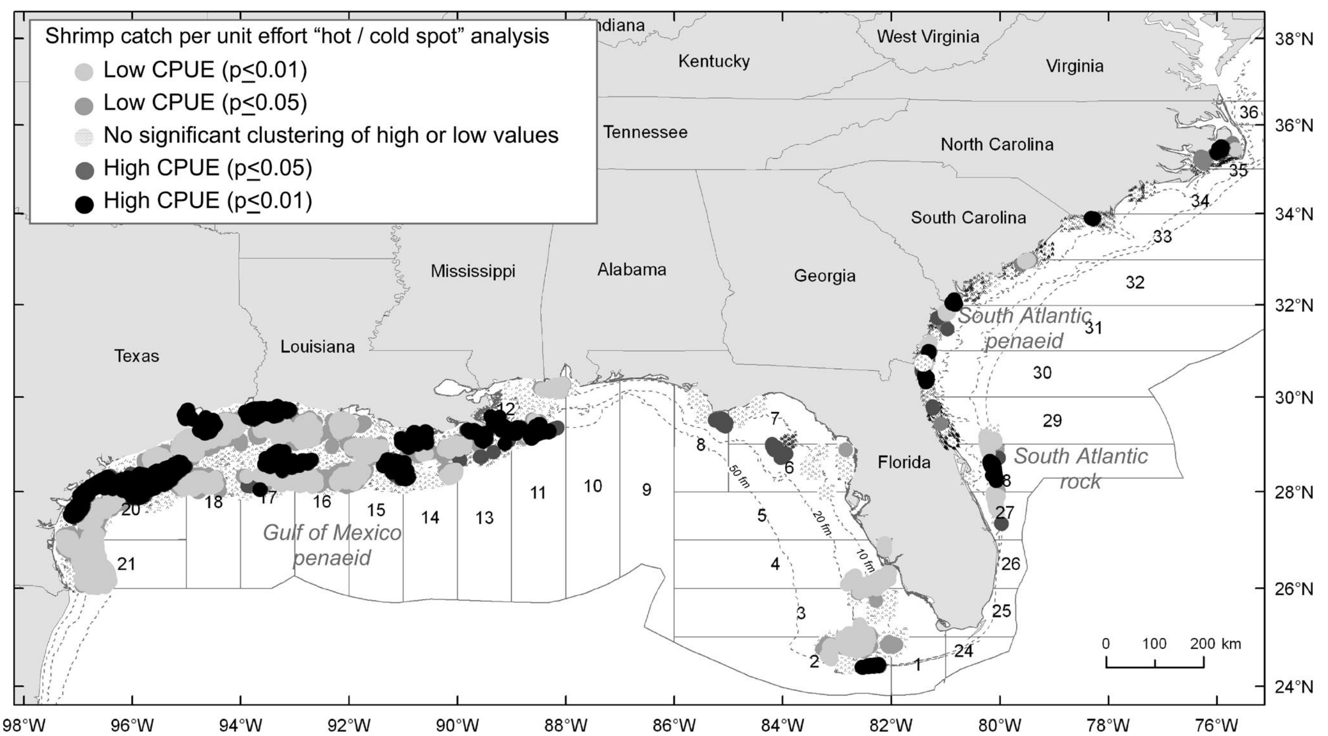

Figure 20.—Hot Spot Analysis for shrimp (penaeid or rock) by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

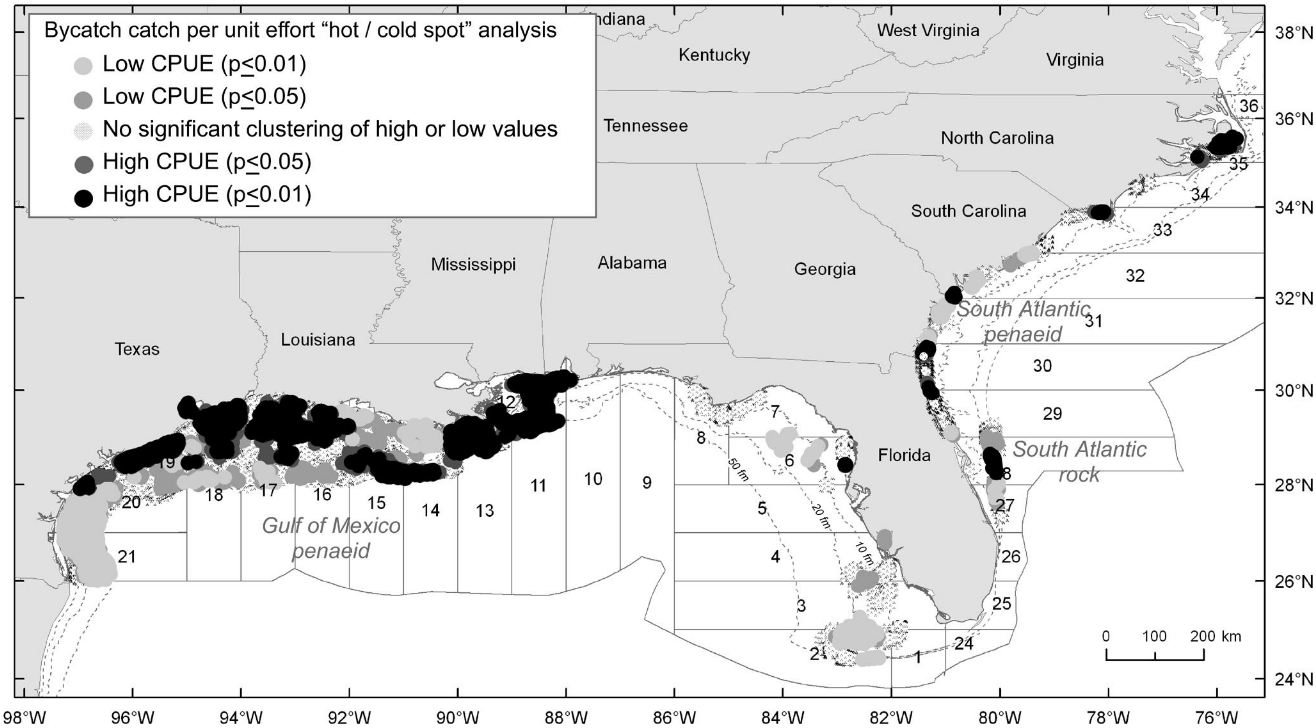

Figure 21.—Hot Spot Analysis for discard (bycatch) species by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

Table 11.—Selected South Atlantic penaeid shrimp fishery species recorded from all nets from bycatch characterization samples, based on mandatory observer coverage from July 2007 through December 2010.

Scientific name	Common name	Extrapolated weight (kg)	Kg/h	CV
Pisces	Fish (superclass)	26,381.5	10.0	<0.1
Cynoscion spp.	Seatrout (genus)	6,595.2	2.5	<0.1
Litopenaeus setiferus	White shrimp	16,813.0	6.4	<0.1
Micropogonias undulatus	Atlantic croaker	32,939.2	12.5	<0.1
Crustacean	Crustacean	5,196.5	2.0	0.1
Invertebrate	Invertebrate	21,094.5	8.0	0.1
Leiostomus xanthurus	Spot (flat croaker)	10,022.1	3.8	0.1
Farfantepenaeus aztecus	Brown shrimp	8,603.9	3.3	0.1
Menticirrhus americanus	Southern kingfish	1,059.2	0.4	0.1
Menticirrhus saxatilis	Northern kingfish	1,888.5	0.7	0.1
Paralichthys dentatus	Summer flounder	513.5	0.2	0.1
Scomberomorus maculatus	Spanish mackerel	421.2	0.2	0.1
General sharks	Sharks grouped	1,512.1	0.6	0.1
Debris	Debris (rocks,logs,etc.)	1,552.3	0.6	0.1
Pomatomus saltatrix	Bluefish	227.0	0.1	0.1
Paralichthys lethostigma	Southern flounder	243.2	0.1	0.1
Penaeus discard	Penaeid shrimp discard (brown,white, pink)	373.3	0.1	0.1
Alosa spp.	Herring (genus)	258.5	0.1	0.2
Scomberomorus cavalla	King mackerel	36.0	0.0	0.2
Centropristis ocyurus	Bank sea bass	40.1	0.0	0.2
Trachinotus carolinus	Florida pompano	27.2	0.0	0.3
Farfantepenaeus duorarum	Pink shrimp	546.6	0.2	0.3
Pogonias cromis	Black drum	11.5	0.0	0.4
Centropristis philadelphica	Rock sea bass	1.7	0.0	0.4
Stenotomus chrysops	Scup	2.0	0.0	0.5
Cynoscion nebulosus	Spotted seatrout	2.6	0.0	0.5
Centropristis striata	Black sea bass	5.3	0.0	0.6
Rachycentron canadum	Cobia	5.4	0.0	0.7
Lutjanus campechanus	Red snapper	0.0	0.0	

induced mortality on loggerhead and Kemp's ridley sea turtles, resulting in higher mortality than in all other fisheries combined. Substantial progress has been made since the 1980's to reduce sea turtle interactions, primarily through the required use of TED's (Epperly et al., 2002; Epperly and Teas, 2002). Further advances in gear refinement and development, and/or time and area management strategies should be considered for sea turtles. These considerations should be applied to other protected species and finfish stocks as well.

To date, observer programs remain the most reliable means for monitoring commercial fisheries by providing unbiased, reliable, and high-quality data. These programs provide insight on finfish and protected species CPUE, as well as life history characteristics for both target and nontarget species. Moreover, they provide a wide array of other variables of interest to fishery managers, the fishing industry, academia, and the

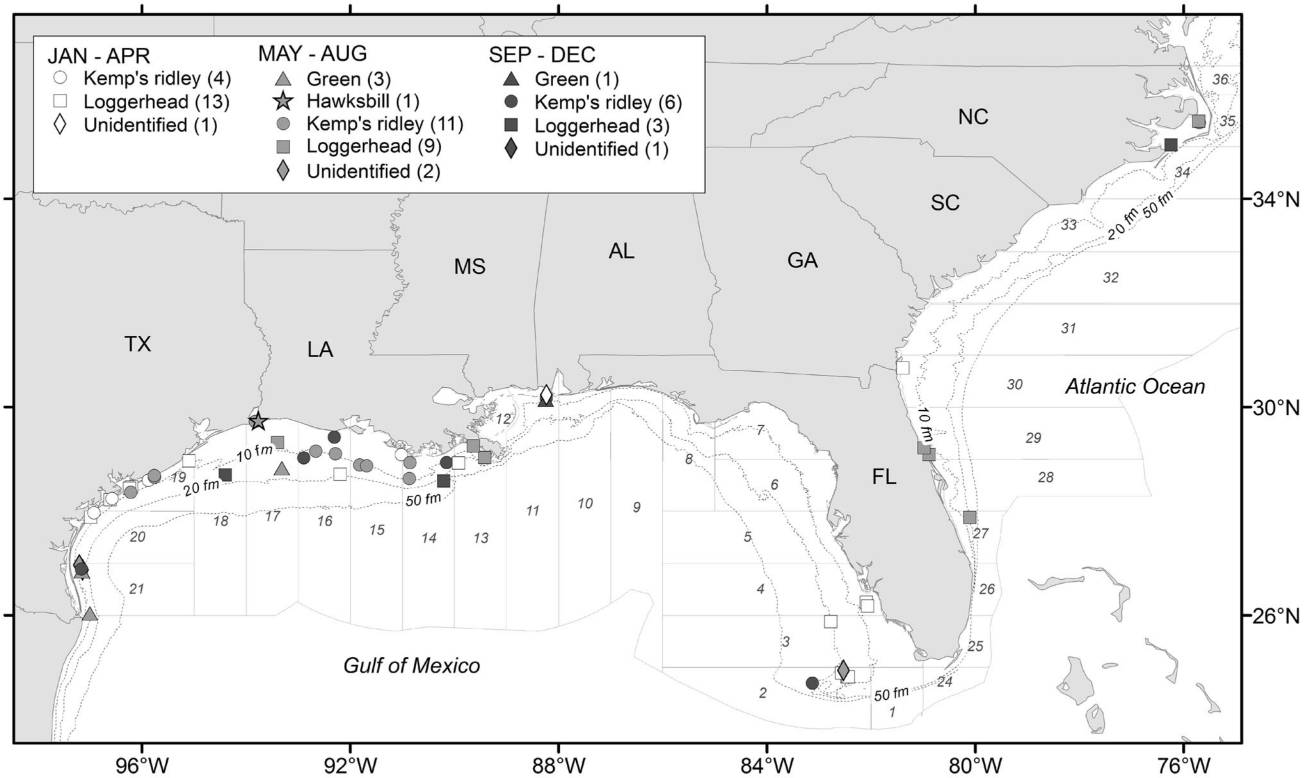

Figure 22.—Locations and dates of sea turtle captures, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

public including: discard levels, gear effectiveness, temporal and spatial shrimping patterns, socio-economic considerations as related to industry, and individual fishing quota program effectiveness.

Acknowledgments

We commend the outstanding efforts given by the fishery observers involved in this research effort and the commercial fishing industry for their continued participation.

Literature Cited

Alverson, D. L., M. H. Freeberg, S. A. Murawski, and J. G. Pope. 1994. A global assessment of fisheries bycatch and discards. FAO Fish. Tech. Pap. 339, 235 p.

________ and S. E. Hughes. 1996. Bycatch: from emotion to effective natural resource management. Rev. Fish Biol. Fish. 6(4):443–462.

Anderson, W. W. 1956. Observations upon the biology, ecology and life history of the common shrimp, *Penaeus setiferus* (Linnaeus) along the South Atlantic and Gulf Coasts of the United States. Proc. Indo-Pac. Fish. Counc. 6:399–403.

Table 12.—Selected South Atlantic rock shrimp fishery species recorded from all nets from bycatch characterization samples, based on mandatory observer coverage from July 2007 through December 2010.

Scientific name	Common name	Extrapolated weight (kg)	Kg/h	CV
Pisces	Fish (superclass)	11,854.1	23.4	<0.1
Crustacean	Crustacean	4,793.0	9.5	0.1
Sicyonia spp.	Rock shrimp (genus)	14,680.7	29.0	0.1
Invertebrate	Invertebrate	1,970.5	3.9	0.1
Centropristis philadelphica	Rock sea bass	230.2	0.5	0.1
Farfantepenaeus duorarum	Pink shrimp	164.1	0.3	0.1
Leiostomus xanthurus	Spot (flat croaker)	394.0	0.8	0.2
Debris	Debris (rocks,logs,etc.)	806.2	1.6	0.2
Farfantepenaeus aztecus	Brown shrimp	193.9	0.4	0.2
Centropristis ocyurus	Bank sea bass	100.0	0.2	0.3
Micropogonias undulatus	Atlantic croaker	241.8	0.5	0.3
Sicyonia discards	Rock shrimp (discards)	177.2	0.4	0.3
Paralichthys lethostigma	Southern flounder	21.3	0.0	0.4
Cynoscion spp.	Seatrout (genus)	5.4	0.0	0.5
General sharks	Sharks grouped	12.3	0.0	0.5
Lutjanus campechanus	Red snapper	0.8	0.0	0.6
Pomatomus saltatrix	Bluefish	33.9	0.1	0.6
Centropristis striata	Black sea bass	91.6	0.2	0.6
Menticirrhus saxatilis	Northern kingfish	6.7	0.0	0.7
Litopenaeus setiferus	White shrimp	2.9	0.0	0.7
Paralichthys dentatus	Summer flounder	6.2	0.0	1.0
Scomberomorus maculatus	Spanish mackerel	2.3	0.0	1.0
Menticirrhus americanus	Southern kingfish	0.6	0.0	1.0
Scomberomorus cavalla	King mackerel	2.1	0.0	1.0
Alosa spp.	Herring (genus)	0.0	0.0	
Cynoscion nebulosus	Spotted seatrout	0.0	0.0	
Pogonias cromis	Black drum	0.0	0.0	
Stenotomus chrysops	Scup	0.0	0.0	
Trachinotus carolinus	Florida pompano	0.0	0.0	

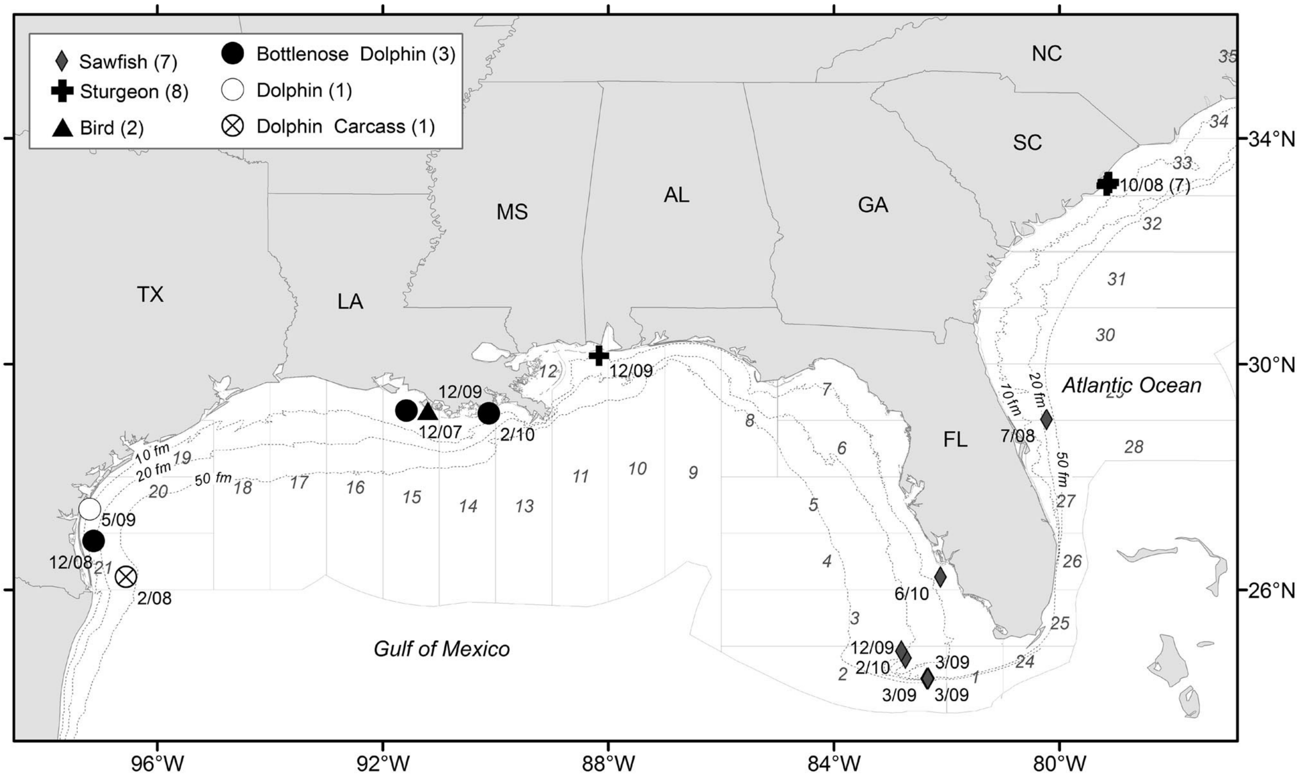

Figure 23.—Locations and dates (month/year) of protected species captures, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from July 2007 through December 2010.

Chuenpagdee, R., L. E. Morgan, S. M. Maxwell, E. A. Norse, and D. Pauly. 2003. Shifting gears: assessing collateral impacts of fishing methods in U.S. waters. Front. Ecol. Environ. 1(10):517–524.

Diamond, S. L. 2004. Bycatch quotas in the Gulf of Mexico shrimp trawl fishery: can they work? Rev. Fish Biol. Fish. 14:207–237.

Epperly, S., L. Avens, L. Garrison, T. Henwood, W. Hoggard, J. Mitchell, J. Nance, J. Poffenberger, C. Sasso, E. Scott-Denton, and C. Yeung. 2002. Analysis of sea turtle bycatch in the commercial shrimp fisheries of southeast U.S. waters and the Gulf of Mexico. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-490, 88 p.

Epperly, S. P., and W. G. Teas. 2002. Turtle excluder devices-are the escape opening large enough? Fish. Bull. 100:466–474.

Gallaway, B. J., J. G. Cole, L. R. Martin, J. M. Nance, and M. Longnecker. 2003. An evaluation of an electronic logbook as a more accurate method of estimating spatial patterns of trawling effort and bycatch in the Gulf of Mexico shrimp fishery. N. Am. J. Fish. Manage. 23:787–809.

Greenstreet, S. P. R., and S. I. Rogers. 2000. Effects of fishing on non-target fish species. *In* M. J. Kaiser and S. de Groot (Editors), Effects of fishing on non-target species and habitats: biological, conservation and socioeconomic issues, p. 217–234. Blackwell Sci., Oxford.

Hall, M. A. 1996. On bycatches. Rev. Fish Biol. Fish. 6:319–352.

________ , D. L. Alverson, and K. I. Metuzals. 2000. By-catch: problems and solutions. Mar. Pollut. Bull. 41(1–6):204–219.

Hall, S. J., and B. M. Mainprize. 2005. Managing by-catch and discards: how much progress are we making and how can we do better? Fish. Fish. 6:134–155.

Harrington, J. M., R. A. Myers, and A. A. Rosenberg. 2005. Wasted fishery resources: discarded by-catch in the USA. Fish. Fish. 6:350–361.

Henwood, T. A., and W. E. Stunz. 1987. Analysis of sea turtle captures and mortalities during commercial shrimp trawling. Fish. Bull. 85:813–817.

Kelleher, K. 2005. Discards in the world's marine fisheries: an update. FAO Fish. Tech. Pap. 470, 131 p.

Kumar, A. B., and G. R. Deepthi. 2006. Trawling and by-catch: Implications on marine ecosystem. Curr. Sci. India 90(7):992–931.

Magnuson, J. J., K. A. Bjorndal, W. D. DuPaul, G. L. Graham, D. W. Owens, C. H. Peterson, P. C. H. Pritchard, J. I. Richardson, G. E. Saul, and C. W. West. 1990. Decline of the sea turtles: causes and prevention. Natl. Acad. Press, Wash., D.C., 259 p.

Murawski, S., R. Brown, H. Lai, P. Rago, and L. Hendrickson. 2000. Large-scale closed areas as a fishery-management tool in temperate marine systems: The Georges's Bank experience. Bull. Mar. Sci. 66:775–798.

Nance, J. M. 1993a. Effort trends for the Gulf of Mexico shrimp fishery. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-SEFSC-337, 37 p.

________ . 1993b. Review of the rock shrimp fishery off the east coast of the United States. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-324, 18 p.

________ , W. Keithly, Jr., C. Caillouet, Jr., J. Cole, W. Gaidry, B. Gallaway, W. Griffin, R. Hart, and M. Travis. 2008. Estimation of effort, Maximum Sustainable Yield, and Maximum Economic Yield in the shrimp fishery of the Gulf of Mexico. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-SEFSC-570, 73 p.

________ and E. Scott-Denton. 1997. Bycatch in the Gulf of Mexico shrimp fishery. *In* D. A. Hancock, D. C. Smith, A. Grant, and J. P. Beumer (Editors), Developing and sustaining world fisheries resources: the state of science and management, p. 98–102. 2nd World Fish. Congr., CSIRO Publ., Collingwood, Victoria, Aus.

NMFS. 1999. Our living oceans: report on the status of U.S. living marine resources, 1999. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-41, 301 p.

________ . 2003. Fisheries of the United States, 2002. U.S Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Off. Sci. Tech., Fish. Stat. Econ. Div. (avail. at http://www.st.nmfs.noaa.gov/st1/commercial/index.html).

________ . 2004. Evaluating bycatch: a national approach to standardized bycatch monitoring program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-66, 108 p.

________ . 2008. Sea turtle research techniques manual. U.S. Dep. Commer., NOAA Tech.

Memo. NMFS-SEFSC-579, 92 p. [updated 1/2009].
NOAA. 2008a. Fisheries of the Caribbean, Gulf of Mexico, and South Atlantic; Shrimp fishery of the Gulf of Mexico; Revisions to bycatch reduction devices and testing protocols. 73 Fed. Regist. 30 (13 Feb. 2008), p. 68,355–68,361. Available online at http://www.gpo.gov/fdsys/pkg/FR-2008-02-13/pdf/E8-2679.pdf.
________ . 2008b. Fisheries of the Caribbean, Gulf of Mexico, and South Atlantic; Shrimp fishery of the Gulf of Mexico; Revisions to allowable bycatch reduction devices. 73 Fed. Regist. 223 (18 Nov. 2008), p. 8,219–8,228. Available online at http://www.gpo.gov/fdsys/pkg/FR-2008-11-18/pdf/E8-27351.pdf.
________ . 2012. Endangered and threatened wildlife and plants; threatened and endangered status for distinct population segments of Atlantic sturgeon in the northeast region. 77 Fed. Regist. 5879 (6 Feb. 2012), p. 5,880–5,912. Available online at https://federalregister.gov/a/2012-1946.
NRC (National Research Council). 2002. Effects of trawling and dredging on seafloor habitat. Natl. Acad. Press, Wash., D.C., 136 p.
Patella, F. 1975. Water surface area within statistical subareas used in reporting Gulf Coast shrimp data. Mar. Fish. Rev. 37(12):22–24.
Pellegrin, G., Jr. 1982. Fish discards from the southeastern United States shrimp fishery. *In* Fish-bycatch…Bonus from the sea: a report of a technical consultation on shrimp bycatch utilization held in Georgetown, Guyana, 27–30 October 1981, p. 51–54. FAO Int. Dev. Res. Cent., Ottawa, Ont.
Riolo, F. 2006. A geographic information system for fisheries management in American Samoa. Environ. Modeling Software, 21:1025–1041.
Scott-Denton, E. 2007. U.S. southeastern shrimp and reef fish resources and their management. Ph.D. Dissert., Texas A&M Univ., Coll. Stat., Tex. 400 p.
________ , P. F. Cryer, J. P. Gocke, M. R. Harrelson, D. L. Kinsella, J. R. Pulver, R. C. Smith, and J. A. Williams. 2011. Descriptions of the U.S. Gulf of Mexico reef fish bottom longline and vertical line fisheries based on observer data. Mar. Fish. Rev. 73(2):1–26.
________ and J. M. Nance. 1996. Shrimp trawl bycatch research in the U.S. Gulf of Mexico and southeastern Atlantic. *In* F. Arreguin-Sanchez, J. L. Munro, M. C. Balgos, and D. Pauly (Editors), Biology, fisheries and culture of tropical groupers and snappers, p. 360–362. Proc. EPOMEX/ICLARM Int. Workshop Trop. Snappers Groupers, Univ. Campeche, Campeche, Mex., 26–29 October 1993.
Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods, 6th ed. Iowa State Univ. Press, Ames, 593 p.
Watson, J., D. Foster, A. Shah, E. Scott-Denton, S. Nichols, and J. Nance. 1999. The development of bycatch reduction technology in the southeastern United States shrimp fishery. Mar. Technol. Soc. J. 33(2):51–56.